Embellishing, engraving materials using laser technology to create innovative surfaces for recycled and sustainable materials

"How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?"

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All your encouragement, guidance and advice has helped me throughout the Process and made my research an unforgettable journey.

Thank you.

Question; ***"How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?"***

Abstract

This research originated as a budgeting issue in education and a concern for the growing abandonment of the Earth's resources through discarding materials and high energy consumption. The waste of valuable potential recyclable materials such as polymers forms the underlying body of the research. The research recognised a need for sustainable materials to be manufactured therfore experimentation of combining waste polymer products with laser re-surfacing process was investigated. Suitable materials and laser embellished products were examined through research-led experiments for sustainable use in education.

An analysis of recycling processes plus environmental impacts of polymer products that end up in a landfill informed the research of what could be reinvented into new products. This work contributes to knowledge by documenting the versatility of polymers as a remouldable material as well as the possibilities of using high powered lasers to etch complicated designs on the surface. To encourage designers to view plastic as an alternative useful material for textile design.

This thesis identifies possible existing gaps and tries to bridge the divide between students, practitioners and designers. The research identifies the need for designers to further develop technology processes as well as considering the impacts of their decisions for the Earth. It also, investigates the possibilities of mass production and limitations of the laser processes as a design tool for practitioners. The work also demonstrates the journey of the different materials through processes, moreover, how the laser interacts with each material and the constraints, hazards to both life and the environment.

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Glossary of terms

Term	**Definition**
Berm	Material build –up near the cut edges, top and bottom.
Biodegradable	Materials that are broken down into carbon dioxide, water and biomass by microorganisms within a reasonable length of time.
Bio fibre reinforced plastic	Synthetic plastic composite reinforced with natural fibres such as hemp, jute or flax
Bioplastic	Plastic-derived from biomass sources, such as rice, potato or corn and made without petrochemicals.
Bitmaps	Patterns of dots that blend to form pictures such as greyscale bitmaps used when engraving photos.
CAD	Computer aided design. General term to cover computer design.
CNC	Machining equipment operated by a computer. Known as computer numerical control.
Composite	Materials made up of multiple parts permanently bonded together such as fibre reinforced plastic made by composite laminating.
Compostable	EU standards for degrading materials in composting conditions.
Cullet	Scrap glass that mixes with raw materials to produce soda-lime glass.
Elastomer	A natural or synthetic material that deforms under load, but returns to its original shape once the load is removed.
Engraving	The process or art of a design etched into a hard surface.
3D Engraving	Making use of an engraver to create objects to appear to be three-dimensional.
Engraver Speed	The rate at which the engraving head moves, stated as inches per second (IPS).
Ferrous	Metal materials that contain iron such as steel.
Graver	A sharp engraving tool with a chisel end.
Hardwood	Wood from broad-leaved trees like birch, beech, ash and oak
Monomer	A small, simple, compound that can be joined with similar compounds to form long chains known as polymers.

Oxy-degradable plastic	Synthetic plastic that fragments into tiny particles over time due to photo-active or thermo-active ingredients.
Polymer	A natural or synthetic compound made up of long chains of repeating identical monomers that are produced by polymerization.
Raster Engraving	Old fashioned version of printing applied with a laser. The laser head acts with the style of a dot matrix and travels up one line and down the next producing series or sequences of dots.
Resin	A natural or synthetic, semi-solid substance produced by polymerization or extraction from plants. The resin used in plastics, varnishes and paints.
Resolution	Resolution is expressed in dots per inch (DPI) and depends upon the number of lines or inches that can fit in every inch of movement.
Sustainability	Conserving an ecological balance by avoiding depletion of natural resources.
Textile	A woven fabric is a type of cloth. Also a synthetic material suitable for weaving; any fibrous material, as a bonded fabric, which does not require weaving.
Thermoplastic	A polymeric material that becomes soft and pliable when heated. It can be shaped and re-shaped by a range of processes.
Thermosetting Plastic	A material formed by heating, catalysing or mixing two parts to trigger a one-way polymeric reaction.
Vector cutting	Follows an outline in a constant beam for cutting through materials such as wood or acrylic.
Virgin plastic	Plastic-derived from oil that does not contain any recycled content.

www.signwarehouse.com/engravers/info

www.engravinglaser.net/laserengravingGlossary.html

Oxford Dictionary 2012.

Abbreviations

ABS	Acrylonitrile-butadiene-styrene
BPF	British Plastics Federation
CAD	Computer Aided Design
CNC	Computer Numerical Control
HDPE	High-density Polyethylene
HIPS	High Impact Polystyrene
LASER	Light Amplification by Stimulated Emission of Radiation
LDPE	Low-Density Polyethylene
MPE	Maximum Permissible Exposure
PET	Polyethylene Terephthalate
PMMA	Poly-Methyl Methacrylate
PP	Polypropylene
PS	Polystyrene
PVA	Polyvinyl Acetate
PVC	Polyvinyl Chloride

Chapter 1

Introduction

Inspiration

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Aims and objectives

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Questions to analyse and evaluate

Reasons for research

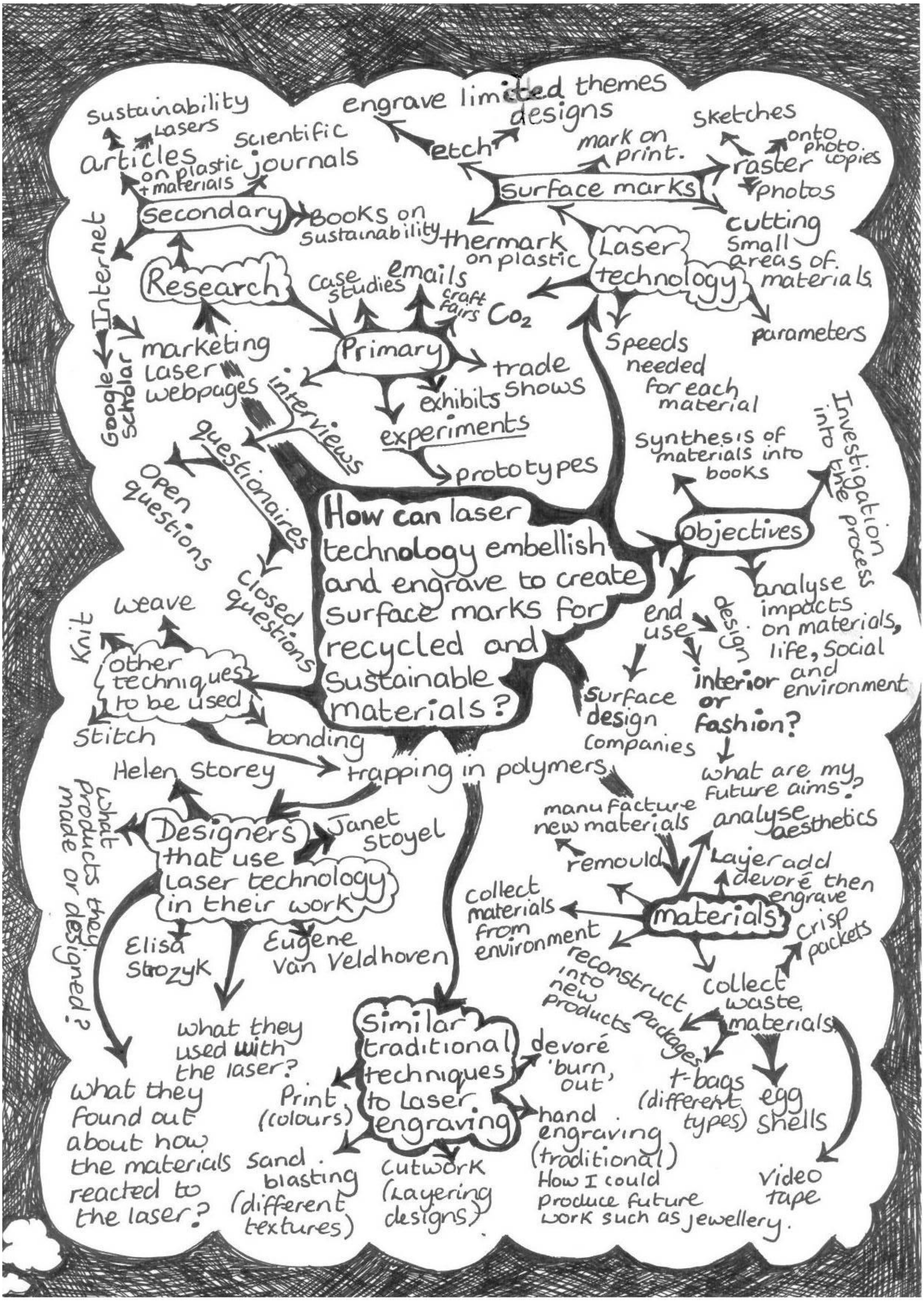


Figure 1 Mind-map of research (own work).

Inspiration

The initial concept for this research topic began whilst working as a teacher at a secondary school in the North East of England. The reason for pursuing laser marking of sustainable, recycled materials started when funding budgets in education were reduced. The curriculum demanded the need for advanced technology and sustainable materials,but funding was limited. Therefore, this research has been conducted to manufacture and develop materials that could be successfully used on the laser and kept as a library of materials to be utilised to aid the operation of the laser in Education.

Another reason the research was needed is that throughout the key stages in education teachers are expected to inform students about the 6R's, reduce, rethink, refuse, recycle, reuse and repair. Sustainability and recycling are currently "buzzwords" used in schemes of work for technology projects and exam boards such as AQA are insisting that educators inform their students of the issues, developments and processes used for core material source to end of product life. Introducing sustainability into the classroom could encourage future generations to waste less of the Earth's natural resources and energy.

As the laser process requires designs to embellish the surface of a sustainable material it was necessary to develop suitable CAD images. The inspiration for the images produced in the pratice have comparative links such as the 'New Revolution,' of laser machines as 'cyber technologies,' compared to the 'old methods,' of the 'Industrial Revolution'. However, to formulate efficient testing on the material surface a limited selection of designs were selected.

The Industrial Revolution was inspirational, changing from hand production to machine, introducing chemical manufacturing and production processes; it improved efficiency of water power, the increased use of steam power, developed machines and the rise of the factory system. Lasers, like the Industrial Revolution are now seen as being a transition move from craft methods to innovative production processes. Lasers are used extensively in modern life and this research aims to demonstrate the efficiency, benefits to the environment and overall superior performance of laser engraving to the 'Industrial Revolution,' methods (Ashton, 1948).

Ideas

Recycling materials is not a new concept, as it dates back to historical times, as far back as 400BC. Awareness through media about environmental issues such as global warming has reintroduced recycling and upcycling as a trend. Also, the improved economics of recycling laws and the introduction of recycling waste collections has made consumers think about what they are purchasing and designers to rethink what materials they are using in the manufacturing processes. This research intends to demonstrate that both consumers and designers are responsible for the product design and that recycling is not about easing a social conscious, it is more about how materials can offer a more meaningful end purpose (www.all-recycling-facts.com/history-of-recycling).

Modern designers and practitioners working with textiles appear to be discovering innovative methods to harness the abundant source of waste products and materials. Sarah Greaves (figure 2) and Kirsty Whitlock (figure 3) are textile artists that recycle waste and combine them with textile processes. Sarah describes her work as ‘embroidered graffiti’ and produces recycled textile art pieces. This inspired the research to combine recycling waste materials from the surrounding environment such as crisp packets with a process that could mark a design on the surface.

Figure 2 Image on the left demonstrates Sarah Greaves’ work “Embroidery Graffiti,” (www.mymodernmet.com)

Figure 3 Image on the right, “Bags of Aggro”, demonstrates Kirsty Whitlock’s work of mixing plastic with textile methods (www.kirstywhitlock.com).

This research aims to push the boundaries of using polymer materials and their application by using remoulded materials and laser engraving the surface. The idea of using throwaway products in practice to break the preconception of textiles being traditionally fabric based has stimulated the research. This concept also motivated an inquiry into what other unusual materials were being utilised by textile designers, practitioners and artists.

To aid in communicating the concepts of this research a poster was created and used as part of an exhibit at the ‘Surface design Show 2013’, (figure 4) . It was a useful visual form of explaining the outline of the research to visitors at the show. The information and images gave a basic overview of the topic without overloading the observers with complex information. The poster aided the creation of new ideas, concepts, build connections, formulate keywords and retain relevant information.

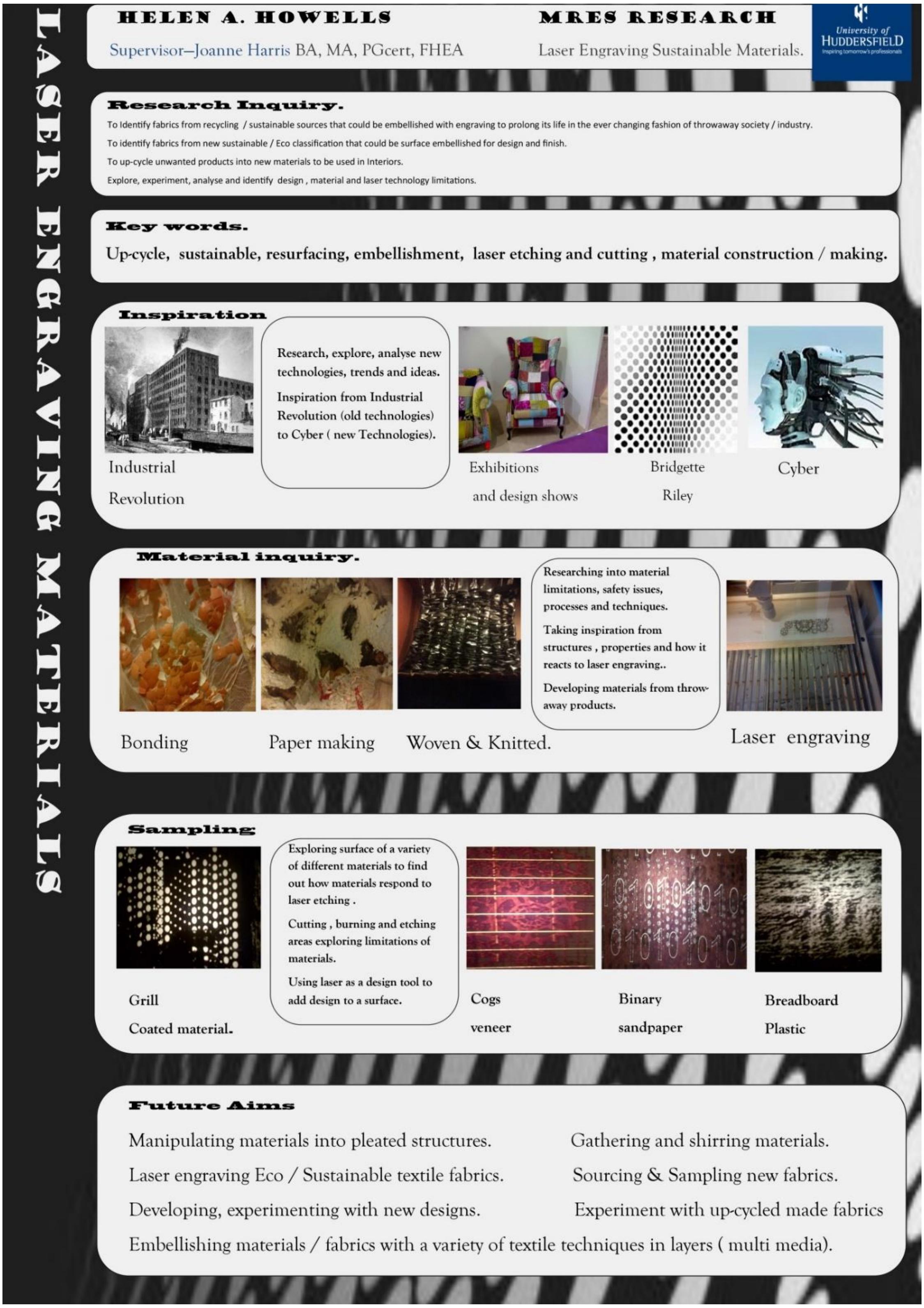


Figure 4 Poster that was displayed in the ‘Surface Pattern show London’

Rationale

The purpose of this research is to raise.' awareness of the use of unusual materials used as textiles other than fabric and cloth. Originally, the word 'textile' was termed as a fabric produced by weaving (Taylor, 1999) now textiles is an art, a combination of material and process. At the 'Surface Design Show,' Ann Goddard and Sue Stone of the '62 Group,' presented an inspirational talk on designers using wood, metal and plastics in contemporary textile installations. They debated the notions on what consumers considered to be textiles and enthused with innovative views and ideas that sparked this research to combine unconventional materials and processes to be used as a textile artefact.

The approach to this research involves exploring through creative experimentation using a variety of materials and processes. (Furlong and Oancea,2005), suggests it is, like applied research,' an area situated between academia-led theoretical pursuits and research-informed practice.' The reflection was recorded in a written format on each of the samples. Notes were taken throughout the manipulation and reaction of the materials after the laser process. Artefacts were photographed as part of the documentation of outcomes. (Groundwater-Smith and Mockler, 2006), argues that in the field of practice-based research, 'those involved in practitioner inquiry are bound to engage with both 'theoretical' and 'practical' knowledge moving seamlessly between the two.' (Campbell 2007).

This research has been supported through exploration of secondary publications from researchers' papers, articles, practitioners experimentation and engineering publications. Specific information on various aspects of the question was difficult to find through academic channels. Particular information needed to be sourced directly from practitioners via interviews, questioning, using processes, methods and trialling equipment first hand for own practice.

Aims and objectives

The purpose of this research was to understand how the laser reacts with sustainable materials. To test if it is possible to predict how a material will behave and the overall outcome of its appearance aesthetically. Prior knowledge of how materials react to the process of the laser is not readily available to practitioners without specific training, so this research will develop a range of materials with evidence documenting the effects, problems, limitations and aesthetic qualities of a range of materials

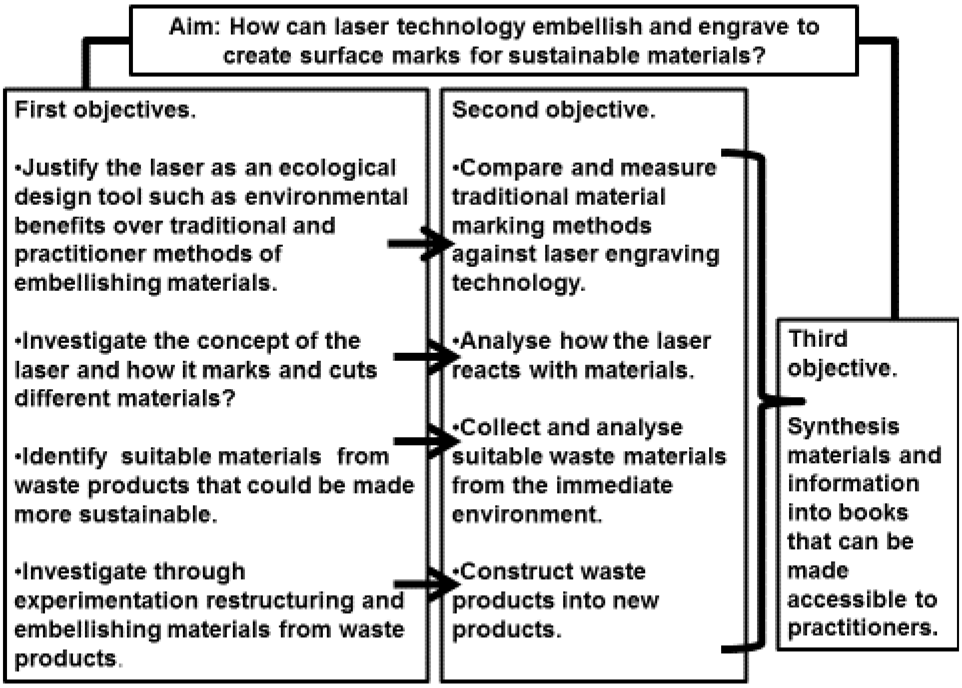


Figure 5 Outlining the aims and objectives of the research thesis own work.

The intention of this study is to understand the capabilities and limitations, gain knowledge of the physical processes that occur during laser beam interactions of vaporizing, melting and marking the surface with engraving. To regenerate polymers into new products to aid in materials becoming more sustainable and that can be laser engraved and cut safely without damaging health or the environment. Prior knowledge of how materials react to the process of the laser is not easily accessible to practitioners without specific training. The aim of this research therefore, is to research, analyse and develop a range of materials with evidence documenting the effects, problems, limitations and the aesthetic qualities of a catalogue of materials. Also, the obective is to test if it is possible to predict how a material behaves and to understand how the laser works as a design tool. The thesis will include factors such as production time, labour, economic, environmental benefits and limitations.

An exhibit of working research practice samples will be displayed at the 'London Surface Pattern Show 2013,' on the Huddersfield stand. The reason the samples will be exposed to the public in the early stages of the investigation is to gather feedback on the materials and aesthetic qualities. This opportunity to reveal the research will act as a process for knowledge dissemination as well as enabling learnt experience to be shared and reflection to take place.

Issues to be addressed

This research expectation is to critically evaluate existing knowledge of laser engraving, cutting and finishing of materials, including some background literature and relevant data. References from secondary and primary sources will be used to reflect updated knowledge of new emerging technologies, methods, material processing in the specialist area of laser engraving.

The research endeavours to document findings thus bridging the gap between practitioner and designer. To develop a body of work that can be utilised as a reference in operating the laser safely and efficiently with sustainable materials. The research also intends to recycle, utilise and restructure materials considered to be the most valuable of dwindling Earth’s resources to manufacture a material that can be classed as a new product.

Project Philosophy

Potential new design opportunities can develop for a commercial designer by transferring from the studio into a workshop environment. A practice- led approach allows the designer to explore the potential of technology and sustainable materials in manufacturing of products with aesthetic qualities**.**

This study uses a practice-led experimental approach to research and justify the use of laser technology as a feasible process in order to mark, cut and embellish onto sustainable materials. The intention of this research is to practise experimenting like the renowned artist, Walter Gropius from the Modernist Movement of Bauhaus who designed and made products from different materials. Gropius had a vision that art and craft could be combined. He proclaimed that all crafts, including art, architecture and geometric design, could be brought together and mass-produced. Bauhaus School influenced art, industry and technology. Gropius referred to the movement as a school and the program and projects as “experiments”, and the workshops “laboratories”. The Bauhaus school is considered to be the bridge between art and industry, design and functionality (www.bauhausinteriors.com).

Most modern designers seem to be withdrawing from the traditional and are using innovative new materials. They are using construction methods, without prior knowledge and are not testing whether the results meet their expectations. The aim of this research is different to the modern designers as it will be used to deepen understanding and knowledge of the use of laser engraving onto materials and the issue the materials have on the environment. The research will investigate different processes and techniques of remoulding and recycling the materials and test the laser marking process on various polymer samples.

Questions to analyse and evaluate

The main question of this research is,

"How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?"

Other topics connected to the question to be investigated are:-

- Identify materials from recycling sources that come from a man-made classification that could be embellished with engraving to prolong its life in the ever-changing textile industry.

- Investigate how sustainable materials, combinations of methods such as laser engraving with print, react to the impact of the laser beam.

- Investigate, experiment and develop materials to manufacture new products out of throwaway products as well as embellish them with laser engraved images to aesthetically appeal to design markets.

- Research, environmental impacts of materials and products as well as investigate possibilities of mass production and limitations of the process.

Reason for the research

The textile industry is causing concerns regarding current methods of textile processes being employed and damaging the environment. Scientists suggest that textile dyes and waste are toxic and are considered to be one of the worst offenders of polluting as it uses large amounts of chemicals and water. Traditionally made textiles contain residues of chemicals which are either absorbed through the skin or inhaled from the air and are considered to be harmful to the foetus as they are developing in the womb and are normally carcinogenic to life.
(Fibre 2 Fashion Article 27 2015).

This research will examine the possibility of alternative materials and processes that eliminates the need for large amounts of water and use of carcinogenic chemicals. However, the reseach will be utilising material polymer waste which is considered to be toxic to sea-life and pollute the environment. Scientists have found through their research that plastics actually break down quicker than they thought at lower temperatures and are causing harm to our food supply and in turn to humans. Therefore, polymers are considered to be harmful and should not be discarded in the oceans and seas so this research documents ways to utilise plastics and stop them ending up as waste polymer pollution by making them into a versatile material that can be re-used numerous times.

Chapter 2

Methodology

Research Methodology

Pedagogic experimental method

Action research

Research thesis structure

Research methods

Experiments

Case Study

Interviews and Questionnaires

Practice research results

Criteria and method for analysis of samples

Research Justification

To summarise

Research Methodology

The process undertaken in this research will be empirical, which tests the viability of a solution using experimental evidence. This research utilises this method to capture from contextual data, explore advanced concepts and identifies learnt experiences from others in the same field. The research will comprise of creative artwork produced on industrial equipment on a systematic basis to deepen understanding of materials, processes and equipment. Also, the inquiry will investigate through a literature review the impact the materials have at the end of their life cycle on the environment and practitioner's knowledge, research and quantitate data results will be used to reaffirm the findings.

Additionally, continuous testing will be employed in the hypothesis as a controlled approach, identifying variables, and solving new or existing issues by employing plastics as sustainable materials, which are expected to be utilised and developed into new theories to support further, future research.

The research used 'Visualising Research, a guide to the process in Art and Design,' which expresses that research is more than discovery, it is based on an open system of critical thinking and (Gray and Marlins' 2004), define academic research practice as,

"A process with explicit questions to be asked in relation to a context, a clear methodological approach, the outcome and outputs of which are open to critical review, and the research has some benefit and impact beyond the individual practitioner researcher." (Gray and Malins 2004).

Research can be considered to be objective or subjective and this research will have elements of objective approaches which are concerned with the physical characteristics such as commonly used rules and laws, tested through hypothesis, experiment and survey. The thesis will also include subjective approaches that deal with individual observation and explanations, case studies, interviews and practitioners work.

Pedagogic experimental method

One of the main styles that will be used in the thesis is the 'Pedagogic' experimental method of active experience, and reflective thoughts on that experience. The process will be used to formulate an hypothesis based on observations and theory that can be tested, proved or refuted. Another sub-style to be used is 'participate' or 'action,' research. The thesis starts with a specific question that needs investigating, monitoring and solving, through active exploration. Any new research outcomes will be implemented into the contribution of textiles through practising the research findings in education (Gray and Malins,1993).

Action research

This thesis also uses an 'Action research methodology,' to gain an understanding of the interaction of the laser to the surface of the materials used in the practice. According to (Dick, 1997), 'Action research,' is a process by which change and understanding can be pursued at the one time. It is usually described as cyclical, with action and critical reflection taking place in turn (figure 6).The reflection is used to review the previous actions plan the next one. (Dick, 1997), further mentioned the difference between action learning and action research that in action learning, each participant drew different learning from different experience. In action research, a team of people drew collective learning from a collective experience (Dick, 1997).

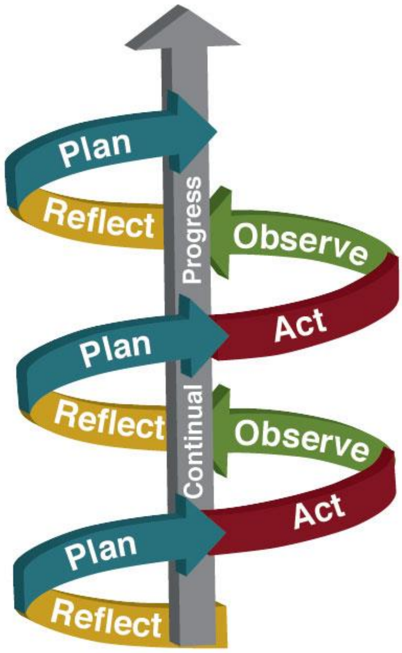


Figure 6 Action research (www.valenciacollege.edu)

Action research is a cyclonic process of three steps as shown in figure 6, 1planning that involves reconnaissance; 2 taking action; and 3 fact-finding on the results of the action. – (Kurt Lewin, 1947).

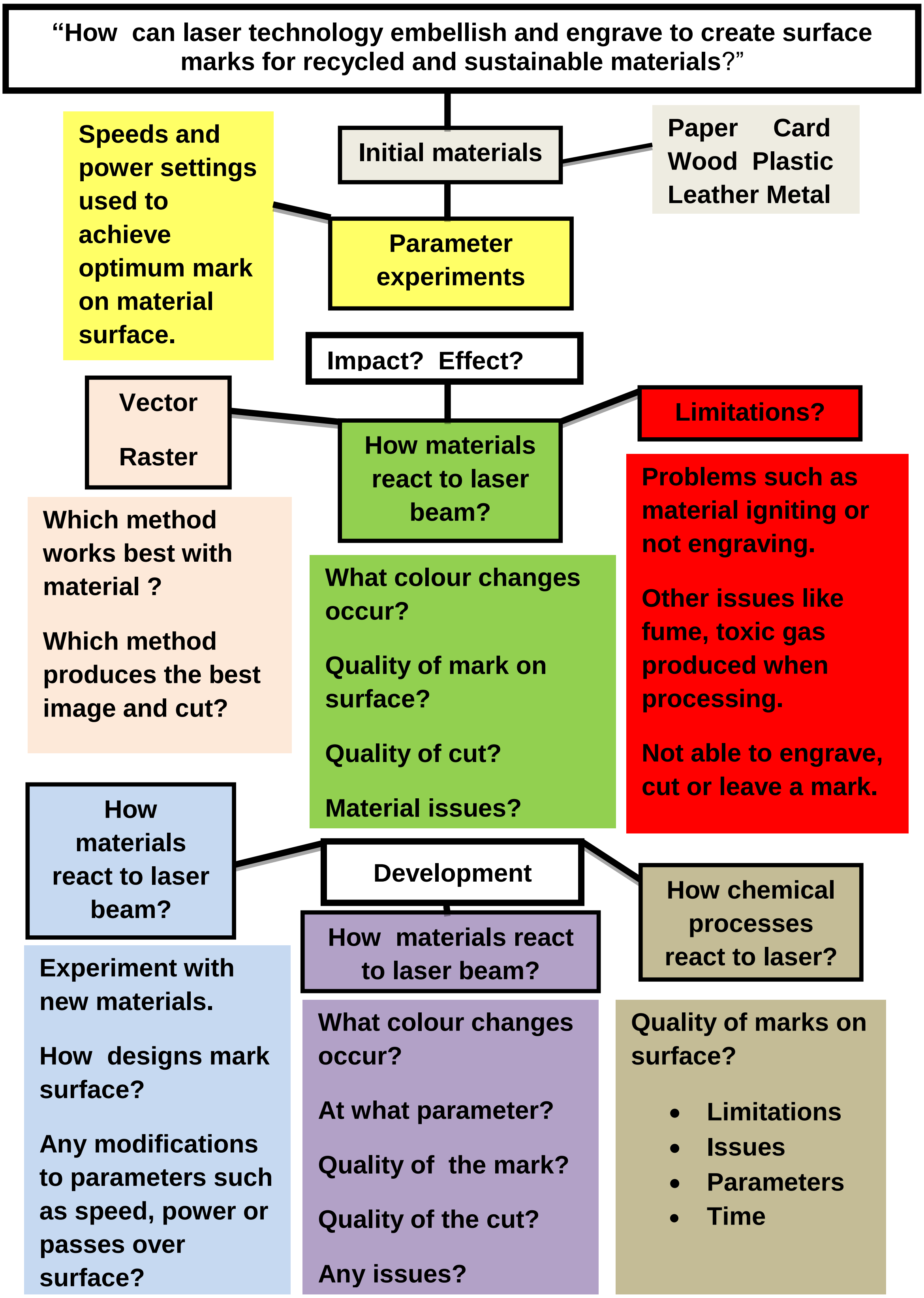


Figure 7 Overview of the action research cycle for the investigation of the material during laser beam interaction (own work).

Research thesis structure

To realise the intentions of the investigations, procedural activities were derived as shown in the diagram.

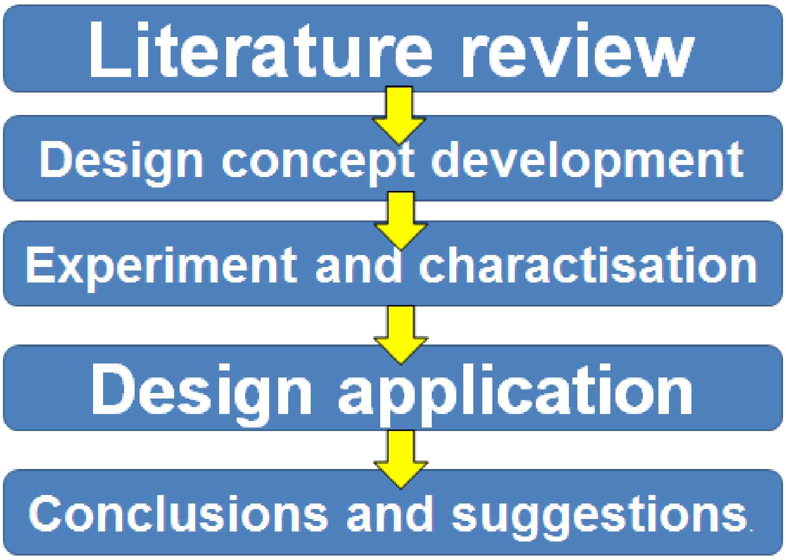


Figure 8 Diagram of procedural activities (Own work).

Chapter content will involve researching and documenting in this thesis the following;

Chapter one, introduction outlines the philosophy, inspiration, rationale, ideas, aims and objectives to be examined in this thesis.

Chapter two, is the methodology, this chapter outlines the methods to be undertaken in this research. The use of resources such as research books specifically for design subjects to aid structuring a system of methods and principles for the thesis.

The literature review consists of two major sections which considers the fundamental areas of;

1) Laser technology - chapter three.
2) Sustainability - chapter four.

Chapter Three, explores the background history of lasers such as the inventors, how a laser works, different methods of marking and joining surfaces as well as the economics, limitations and capabilities of the system. Other relevant areas connected to the topic such as, current trends, new technologies, environment issues and the future of lasers were investigated. Also, consideration into the similarities, benefits and limitations of traditional methods of marking compared to the laser such as cutwork, devore, printing, sandblasting and hand engraving was analised. Supporting research, such as other practitioners and designers that use engraving, recycled materials or laser engraving in their work has been added to the appendix.

Chapter four, examines sustainability, the impacts of various materials such as glass, wood, metal, textiles and plastics have on the environment. The research in this section narrows to one specific material where further investigation into the need to recycle and develop the material are investigated.

Chapter five is comprised of a small number of case studies connected to the topic such as hand engraving, laser engraving and recycling materials.
This section is used to aid ideas and support prior secondary research.

Chapter six develops the concept of the research by developing preliminary review of materials, techniques and processes using mould, fusing and joining methods in practitioner practice research. The laser is used to test the parameters on materials sourced from the immediate environment which would have normally finished their purpose and proceeded their way to landfill.

Further experimental development is to be conducted by using a limited selection of computer generated designs and core existing sourced materials such as paper, wood, fabric, glass and plastic with the laser set at different perimeters to change the structure and embellish the surface.

Expanded experimentation will be conducted on constructed, bonded, layered materials made in own practice from various sources such as landfill, charity shops, immediate environment and trade shows. The results will be discussed in a reflection.

The final chapter, the conclusions will be summarised and suggestions for continuing future work outlined.

Research methods

The research will include qualitative and quantitative methods which include content analysis and small-scale ethnographic studies. Furthermore, it will incorporate descriptive material, extracts from conversations at interviews and observation conclusions formed in practice. The connections between primary research and re-analysis with theoretical and empirical concerns of existing literature will be discussed in the reflection sections of this research.

Experiments

The experiments carried out will utilise the laser engraving methods to resurface materials with marks and designs. Other experimental methods such as remoulding materials are to be carried out to verify, refute, or establish the validity of re-using materials as sustainable materials. The experiments are to provide insight into cause-and-effect of the methods by demonstrating what outcome occurs when a particular aspect, such as depth, speed, power, time and heat is manipulated. The experiments must vary and be repeatable. Procedure and logical analysis of the results to be documented in the research practice in the form of tables and reflection.

Case Study

A case study is a qualitative method used to explore and is described as a main method, within it different methods are used, **interviews, observations, participant observations and questioning.** In the case studies used in this research, information needed to be gathered and considered before aspects of the subject's work and history were collated. The research was conducted in a systematic approach by collecting, analysing and reporting relevant results. The information gained from the studies was aided greater understanding of processes. The aim was to gather valuable information connected to the topics to develop knowledge and understanding not to test a hypothesis.

The informal questioning method used throughout the direct observation allowed the practitioners to be observed in their natural setting which in turn presented opportunities for photographs to be taken of physical artefacts**,** tools used, and processes demonstrated are documented in the case studies. The researcher in this thesis also became the participant and documentation through experimentation and practice aided observing the actions and outcomes of processes deployed.
(Yin, R. 1994).

Interviews and questionnaires

Interviews are a standard part of qualitative research and are one of the most important methods of gathering information on case studies. The interviews in this research were conducted to pursue in-depth information around the topic of engraving onto materials like glass and metal. An informal conversation was conducted through-out one of the interviews with no predetermined questions asked which aided the use of recording media and allowed adaptation of the questions, opportunities to observe and document any relevant information connected to the topic after the visit.

A different approach was used whilst interviewing one of the practitioners as the **questionnaire** was administered by the researcher which gave the participant, the impression that they were taking part in an interview rather than completing a questionnaire. This allowed the researcher to note any responses as the practitioner continued to demonstrate the method of engraving onto the material.

Practice research results

The practice will examine a wide variety of materials and produce a broad range of samples using polymers and textile processes. The main aim of the practice will be to judge and assess the overall effectiveness of how the laser beam impacts on the materials. The designs added to the samples are used continuously throughout the experimentation practice for analysis purposes, not for design aspect, however, their quality outcomes will be assessed. The objective of using limited designs in this way was mainly to assess and analyse the chemical reactions, heat impact and effective mark making of the laser on the different materials.

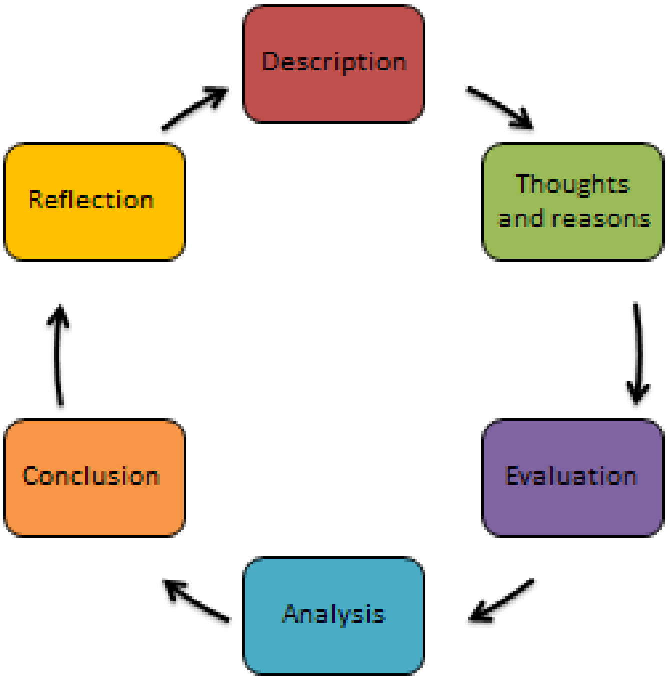


Figure 9 Practitioners own work based on Gibbs reflective cycle

(Graham Gibbs 1988).

Criteria for analysis of samples

The criteria for assessing the qualities and outcomes of how the laser will impact on the surface to be documented in the reflection and tables are as follows:

1. Aesthetic qualities.
    a. How the laser impacts on the surface.
    b. Colour changes**.**

Method

The procedure method for documentation, the evidence of the research is outlined as follows;

1. Literature reviewed examines prior experiments and work of other practitioners on topic.
    - Laser engraving
    - Sustainable materials.
    - Comparison of similar textile processes
    - Environmental impacts
    - Health impacts
2. Practice-led product experiments.
    - Sampling materials
    - Assessing outcomes of processes, reflection, records of techniques and documentation such as photographs.

Research Justification

In the experimentation of this thesis, different results and outcomes will be achieved owing to the different qualities of the materials, complexity of the design, the variation of treatment parameters and process used.

Nimkulrat states that,

"Practice in a research context can facilitate the reflection and articulation of knowledge generated from within the researcher-practitioners artistic experience, so that the knowledge becomes explicit as a written text or as a means of visual representation. Research can not only transform ways of designing or making artefacts, but also theoretically inform practice," (Nimkulrat, 2012).

Through preliminary research of publications and information derived from secondary sources, the findings suggest that lasers are able to provide a multiple of potential application opportunities in design. Practitioners and artists suggest lasers can offer an alternative method of adding images to materials which is more convenient and not as toxic as the conventional textile methods such as printing to the environment. This thesis aims to compare the sustainability of the laser to traditional textile embellishing methods and discuss the impact on the environment. Other considerations shown in the sustainability of the laser mind map (figure 10) will also be discussed and analysed.

The comparable methods in this research investigates alternative, processes to laser marking onto materials. The research includes the analysis of similarities of other burn out methods to the laser such as devore, print and traditional processes such as sandblasting and hand engraving. All processes explored in the practice and literature review will be judged for the comparisons between technology and chemical. They will also be analysed for environmental issues, energy consumption and overall aesthetics.

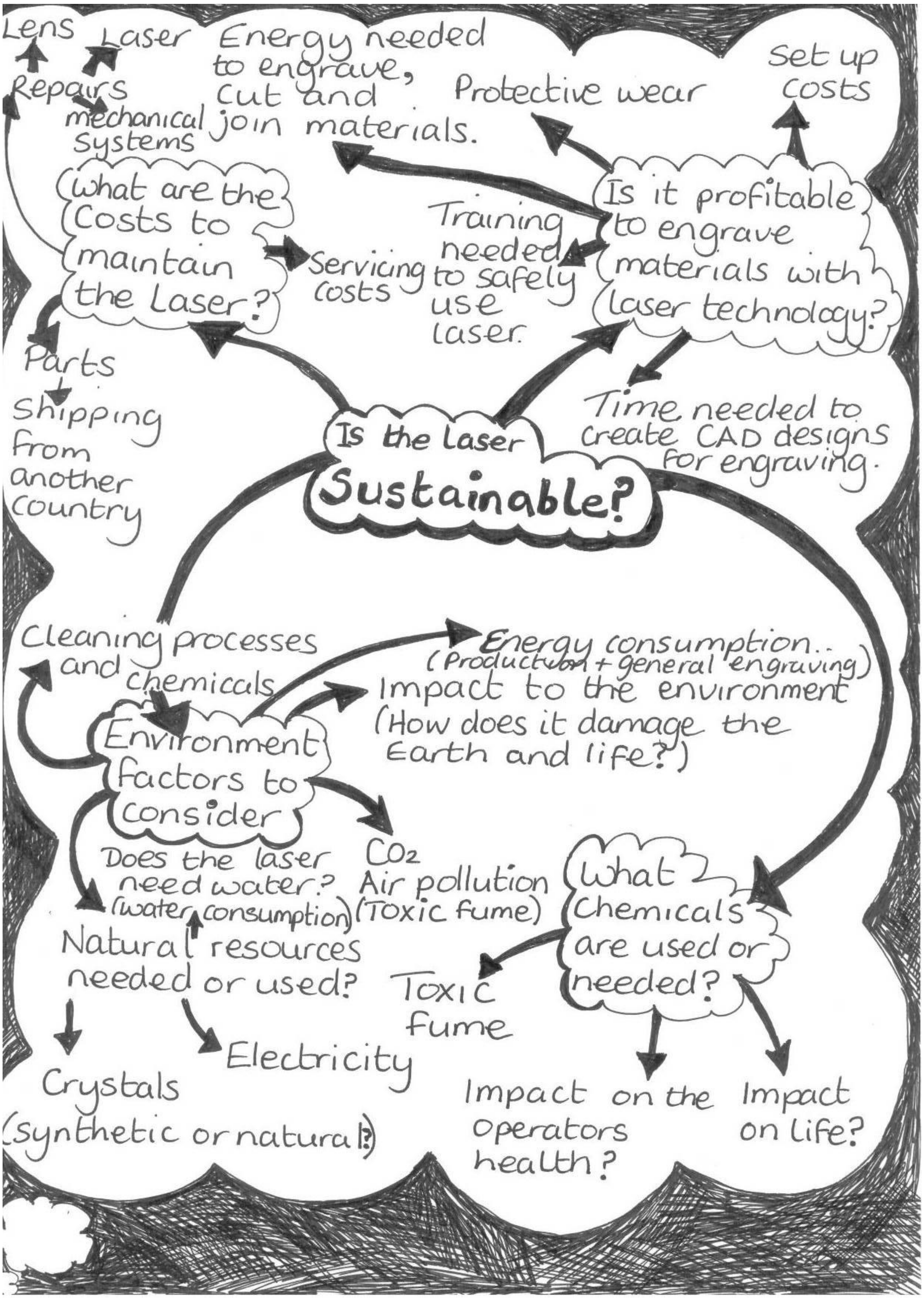


Figure 10 Mind-map of sustainability of the laser. Own work.

To summarise

The experimental, 'practice-based research', will take on the form of developing materials and creative work on the laser engraver. The scientific information will be provided where considered needed and the experimentalism contribution within this research and practice will offer a reflection on the design outcomes.

(Koskinen,2011) states a similar belief to this thesis by stating,

“It is the theoretical scaffolding that makes the difference. They position design experiments right from the outset in an academic research context: By ‘design experiment’, we refer to pieces of design carried out as a part of a research effort.”

So, in effect this work sets out to develop knowledge, advance understanding of technology capabilities, identify relations between various factors, to improve insight into cultural, social issues as well as contribute to the knowledge base of the discipline by developing new theories, methods and approaches.

The documentation of this research is to be collated and produced in the form of books in order for students to understand the technical processes; principle of the interaction between laser beams and materials. The investigation of melting, vaporisation, removal of surface and colour change will also be discussed as well as the treatment parameters such as speed and resolution. Moreover, through the practice based experimentation the research aims to develop remoulding methods achievable for creating innovative materials that can be engraved and cut as sustainable materials in education.

Chapter three

Literature review

History of lasers

What is a laser and how does it work?

Laser beam

Marking materials

Laser economics

Limitations and capabilities

Figure 11 Mind-map of literature reviewed in the research of this thesis.

*‘How can **laser technology** embellish and engrave to create surface marks for recycled and sustainable materials?’*

Literature review

The literature review is divided into two main sections as shown in the mind map (figure 11). This chapter in light blue investigates laser technology and the second part of this review in green, discusses sustainability and how sustainable the main chosen categories of paper, wood, metal and plastic materials are to re-use or recycle.

Finding literature specific to laser engraving materials was problematic due to the accessibility of the relevant information needed to answer the research question. This thesis has identified a gap in literature as there is generally only engineering books that describe the terms and technical processes in great depth. However, they do not discuss the impact lasers have on materials or suggest the parameters needed to produce clear marks on the surface. Moreover, there are some documented experimental findings produced by practitioners that have used lasers for design purposes. Also, unfortunately, they do not publish their findings through academic channels and use their research as a way of marketing the process and products on the internet. This research has used some of the practitioners’ findings to further support the research evidence found from published sources in the literature review.

Lasers serve in thousands of ways and are practically used in every major Industry. The technology has taken decades to be utilised as a tool and are now indispensable to most people’s lives. Lasers are used in many areas, such as medical research, communication, defence, industry, design and environmental care.

This chapter will be focusing on the use of laser engraving machines in design and how it is used on materials.

Laser manufacturing companies are releasing new technologies that are able to focus, produce products quicker and making machines more accurate when engraving, cutting and marking, but what the implications for traditional methods? What are the impacts on the environment in the future due to the growing demand for manufacturing of products with laser technology? Research into closely related processes such as cutwork, lace, screen printing, devoré 'burn out' method and hand engraving is compared in the literature review for similarities, differences, advantages and disadvantages between the lasers and the traditional methods.

Laser-cut materials have grown in popularity due to the benefits over hand cutting materials such as giving cleaner, accurate, high quality finishes. The main aim of this literature review was to research into how laser technology cuts, engraves and makes marks on materials. This section of the thesis also investigates the processes used by practitioners to utilise the technology in design. The review will research into current work of artists and designers. Designers like Ensuk Hur and Elsia Stozyk are just a few mentioned in the appendix in this thesis that utilise the laser process in cutting, engraving and marking their work.

Although there are many types of lasers which are grouped into six main types, gas, solid state, fibre-fibre, semiconductor, chemical and excimer**.** This research will use only one of these types of laser due to it being easily accessible in the schools used in the case studies. Industry and education widely use the CO_2 laser as it is low cost entry-level system ideally suited to cutting applications and its ability to raster fine details. Other features that make it attractive to education is that the machine is also designed to be easily transported from different rooms via large casters.

History of Lasers

Lasers have been around since the 1950's and their invention can be traced back to Einstein's theory of light emission in 1916. Before laser was invented Charles Townes and his partner Arthur Schawlow invented the "Maser", microwave, amplification by stimulated emission of radiation. The Maser was used to amplify radio signals and as an ultrasensitive detector for space research.

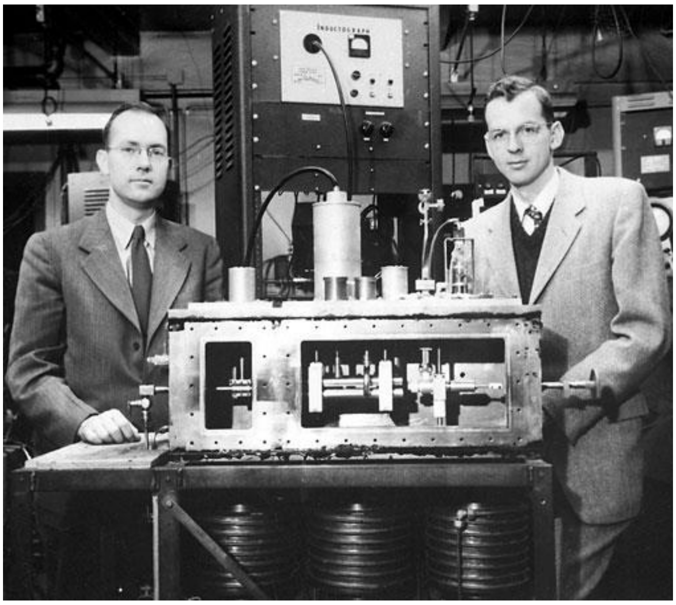


Figure 12 The first 'Maser,' Charles H. Townes (Left), winner of the 1964 Nobel Prize in Physics and associate James P. Gorden in 1955 the first Maser. (www.britannica.com)

The first laser called the Maser was invented on April 26, 1951, by Charles Hard Townes of Columbia University. He invented the laser while sitting on a park bench in Washington. Townes wrote in his autobiographical exposition on his invention,

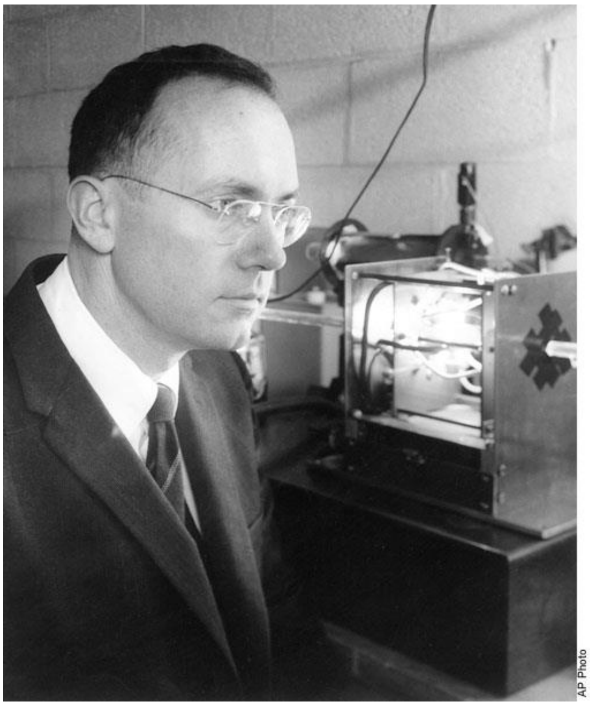


Figure 13 Charles Hard Townes 1951 (www.photonics.com).

How the laser was invented, he wrote:

"The truth is, none of us who worked on the first lasers imagined how many uses there might eventually be. This illustrates a vital point that cannot be over stressed. Many of today's practical technologies result from basic science done years to decades before. The people involved, motivated mainly by curiosity, often have little idea as to where their research will lead. Our ability to forecast the practical payoffs from fundamental exploration of the nature of things and, similarly, to know which of today's research avenues are technological dead ends is poor. This springs, from a central truth: new ideas discovered in the process of research are really new."

The actual technology was close to laser technology **light amplification** by **stimulated emission** of **radiation,** but not the same because the master used ammonia gas and microwave radiation rather than visible light. A joint paper published in Physical Review Letters 1958, by Townes, and Arthur L. Schawlow (figure 14) theoretically shows that Masers could be made to operate in the optical and infrared region. (Huff 2004).

Figure 14 Arthur L. Schawlow (www.photonics.com)

The laser was invented between 1959 and 1960. In 1957 Columbia University graduate student Gordon Gould, writes up his ideas for building a laser in his notebook. It is considered the first use of the acronym *L.A.S.E.R,* light amplification by stimulated emission of radiation. Gould leaves the university a few months later to join private research company Technical Research Group. He devised his invention in 1958 but failed to file for a patent until 1959. Gould had to fight for his patent because his application was rejected and other companies tried to exploit the technology. He did however win his patent in 1977 and became the first person to call the technology, '*Laser,*' (Huff, 2004).

Figure 15 May 16, 1960: Theodore H. Maiman, constructing the first Laser. (www.laserinventor.com/bio.html)

The first lasers were described as "a solution looking for a problem." At first they were ridiculed by other scientists, then the laser's distinctive qualities of being able to generate an intense, narrow beam of light of a single wavelength was recognised as being useful for science, technology and medicine. Theodore H. Maiman, a physicist at Hughes Research Laboratories in 1960 constructed the first laser using a cylinder of synthetic ruby and photographic flash lamps as the laser pump source. The following year lasers begin appearing on the commercial market through companies such as Trion Instruments, Perkin-Elmer and Spectra-Physics. (www.press.uchicago.edu)

Lasers have become useful and scientists experimented with ideas which eventually made the first carbon-dioxide CO_2 laser. This type of laser is the first continuous light laser on the market, which converts energy into light output. It is now one of the most used lasers on the market and is used worldwide as a cutting tool in design and industry. It has been used in many practical applications such as manufacturing, design, processing textiles and was adopted by the automotive industry in the 1980’s (www.photonics.com).

What is a laser and how does it work?

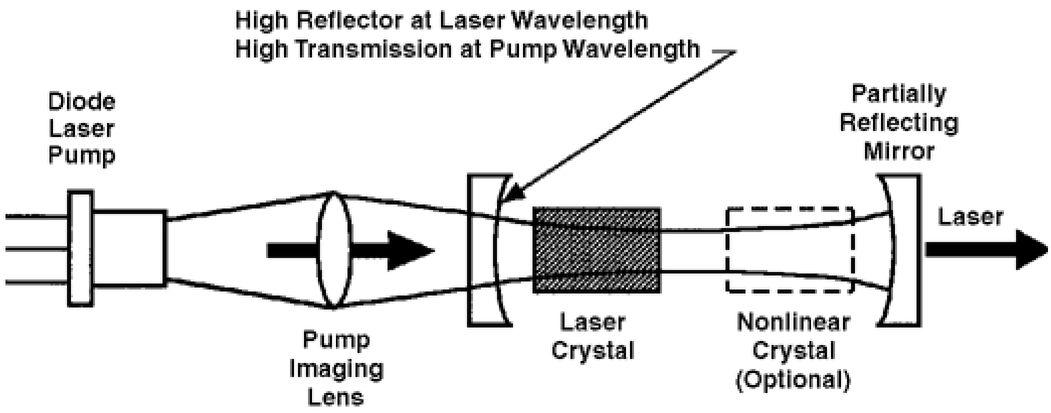


Figure 16 A diagram of a typical diode-pumped solid-state laser (www.phys.org).

A laser is basically a tube with mirrors at both ends, filled with a mixture of gases such as nitrogen, helium and carbon dioxide. When electric energy is applied to the gas-filled tube, it excites the gas molecules, which vibrate and emit light that bounces back and forth between two mirrors.to use this energy, some of the light is allowed to escape at one end of the tube, thanks to the use of a semi-trans missive mirror, which reflects most of the light toward the other mirror while permitting some light to escape. This small portion of light, then passes through a lens where it is narrowed and focused into an intense, pinpoint- sized spot of light or laser energy (Huff 2004).

A laser is a device that controls the way that energised atoms release protons. Atoms in their simplest model consist of a nucleus and orbiting electrons. There are only one hundred different kinds of atoms in the Universe, but they can form an unlimited number of combinations. They move constantly, vibrate and rotate. Solids are atoms in different states of excitation. Energy to an atom can leave what is called a ground state energy level, which becomes an excited level. The level of excitation depends on the amount of energy that is applied to the atom via heat, light or electricity. The release energy called a photon which is a particle of light. Photons are released in from everyday objects like toasters, the elements turn red, and the red colour is caused by atoms, excited by heat, releasing red photons. Another example is television screens, they release phosphor atoms which are excited by high speed electrons, emitting different colours of light, fluorescent light (Huff 2004).

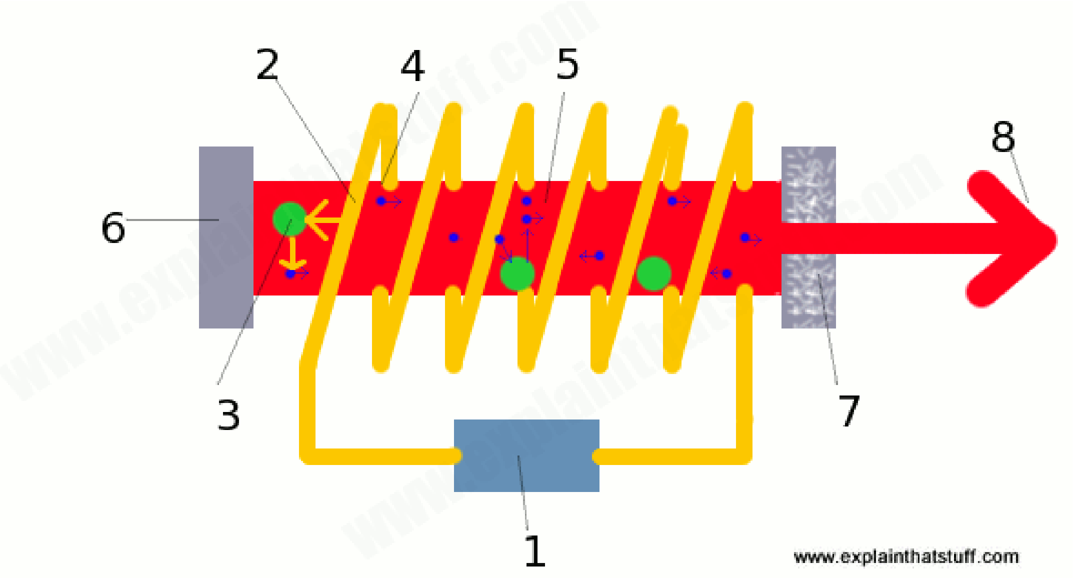


Figure 17 Explains how the flash tube and the crystal make laser light. (www.explainthatstuff.com)

A red laser contains a long crystal made of ruby,which is shown in (figure 17) as a red bar with a flash tube of yellow zig-zag lines wrapped around it. The flash tubes appearance is similar to a fluorescent strip light but the difference is it is coiled around the ruby crystal.

A high-voltage electric supply makes the tube flash on and off. (1) Each time the tube flashes, it "pumps" energy into the ruby crystal. The flashes inject energy into the crystal in the form of photons (2) Atoms in the ruby crystal absorbs the energy in a process (green circle in figure 19) called **absorption**. When an atom absorbs a photon of energy, one of its electron jumps from a low energy level to a higher one.

This puts the atom into an excited state, but makes it unstable. The excited atom can stay in the higher energy level only for a few milliseconds. It falls back to its original level, giving off the energy it absorbed as a new photon of light radiation (small blue circle in figure 19). This process is called spontaneous emission. The photons that atoms give off move up and down inside the ruby crystal, travelling at the speed of light.(4)Every so often, one of these photons hit an already excited atom. When this happens, the excited atom gives off two photons of light instead of one. This is called **stimulated emission**. Now one photon of light has produced two, so the light has been amplified (increased in strength). In other words, "**l**ight **a**mplification" an increase in the amount of light has been caused by "**s**timulated **e**mission of **r**adiation" (5) A mirror at one end of the laser tube keeps the photons bouncing back and forth inside the crystal. (6) A partial mirror at the other end of the tube bounces some photons back into the crystal. Some of the photons escape (7) The escaping photons form a very concentrated beam of powerful laser light (8) (www.explainstuff.com)

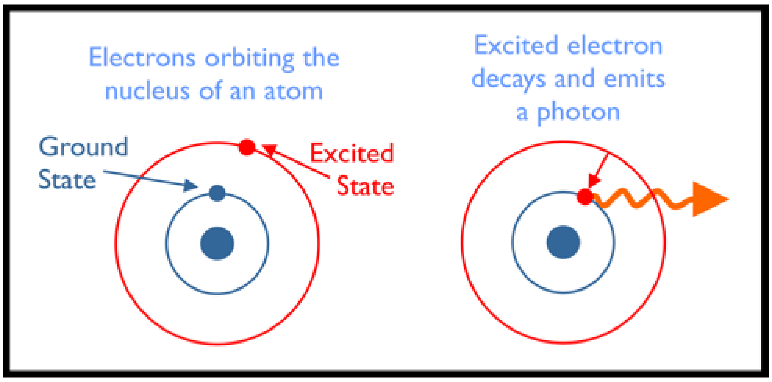


Figure 18 How the excited electron emits a photon. (www.orc.soton.ac.uk)

Laser beam

The laser produces a highly directional intense beam of light which is partially absorbed into an object which raises the temperature of the surface (figure 19). The beam is emitted from a tube which is reflected by several mirrors. The laser head has a lens that focuses the beam onto the material surface for cutting and engraving. The laser beam is radiant energy and when used on material it can cause deformities and alterations (www.cutlasercut.com).

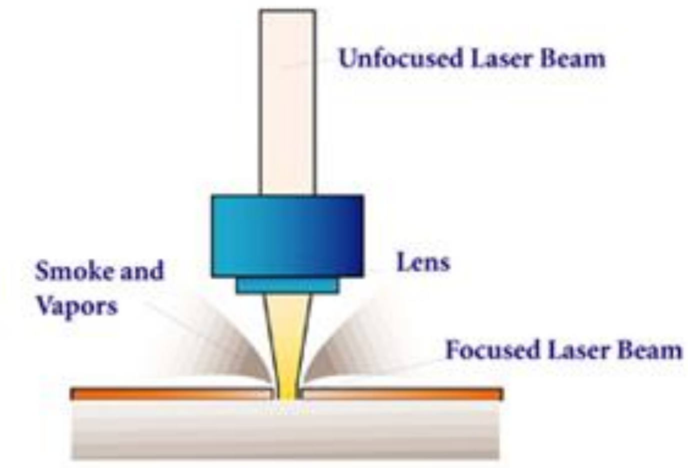


Figure 19 Laser beam operation (www.rowmark.com)

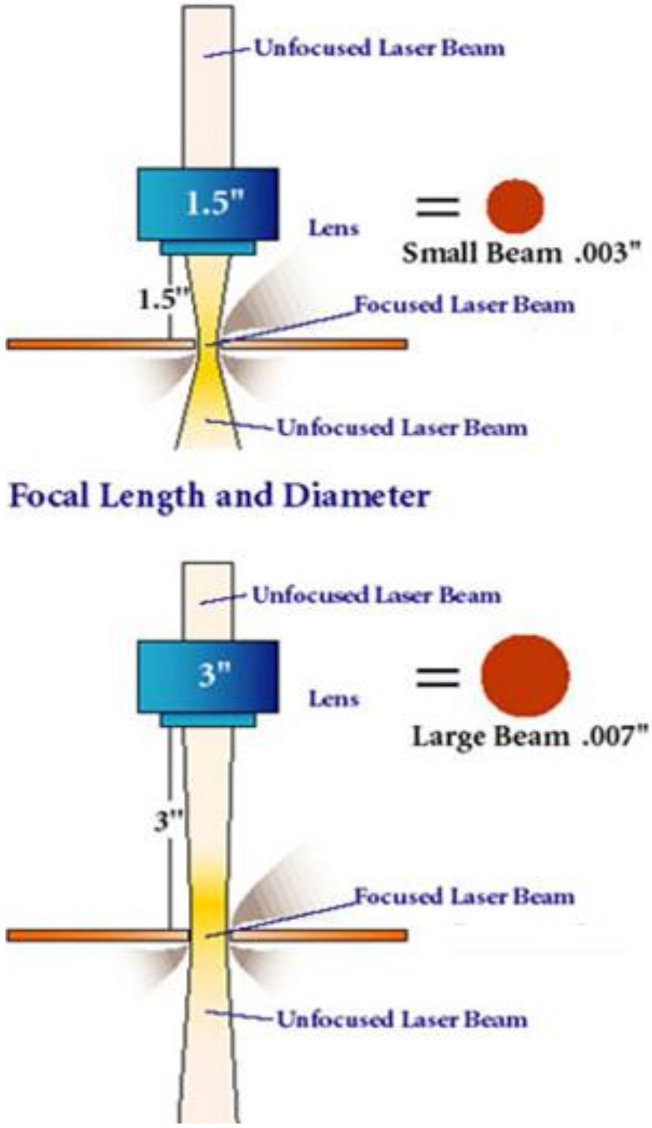


Figure 20 Diagram demonstrating the different types of beams achieved through focal heights. The laser head determines how large or small the focused beam energy is when it hits the surface of the material**.** (www.rowmark.com)

Marking materials

Laser marking is a term used to refer to different methods of adding images to a material. The laser beam modifies the optical appearance of a surface that it strikes. This can occur through a variety of methods.

Engraving

Engraving technique on a material is the fastest way of processing a mark on the surface. The material is vaporised by the laser beam through a high intensity laser beam. The interaction of the melted material and oxygen forms a colour change this makes the engraving stand out (www.troteclaser.com).

Ablation

The top layer is evaporated by laser beam, but does not interact with the base material. The cover on the material is removed so that the material is seen through the coloured surface layer (www.troteclaser.com).

Annealing

The annealing technique produces a contrasting mark without disrupting the surface finish of the metal. It makes a contrasting effect on the metallic materials and the mark is determined by the temperature attained in the metal, properties and parameters selected on the laser (www.troteclaser.com).

Colour change

Carbonisation or colour change is used for organic materials. The laser beam heats up the surface and there is a colour change from light to dark on the surface creating a branded mark (www.troteclaser.com).

Chemical marking

TherMark laser bonding technology is a chemical that creates permanent, high contrast, high resolution marks on a wide variety of surfaces. The chemical bond is able to black mark on most metals, ceramic, glass and many plastics. TherMark is easy to apply to the surface of a material, it can be sprayed or painted with a paintbrush. The coated part when the laser energy hits the compound leaving a black pattern when the excess is removed with water and a soft cloth. (www.thermark.com)

Laser economics

Efficient use of Laser Cutters is very material and application dependent. The Initial startup costs are high, but the larger cost is the gas used to expel the material out of the cut. It needs constant servicing and safety checks by a qualified technician. Parts can be also be costly and loss of production time can also be expensive for companies. However, the process creates very precise cuts with little finishing work required, which increases the productivity in the long run for a company.

Running Costs of laser engraving machines

There are many variables to consider when calculating accurate running costs of a laser machine. It is difficult to calculate the overall running cost of laser machines due to every machine will have its own cost. However, for the purpose of clarifying the use of energy and impact this research covers three points to be considered.

1. Power Consumption

All the laser machines need a PC to operate. The power required for an average PC is 800VA and all the devices supplied with the laser. An estimate 10p per kWh/HR. for electricity (www.ctrlasers.co.uk).

Machine	Power	Cost
CO_2 Engraving	2140 VA	21.4 p/Hr.
CO2 Cutting	2480 VA	24.8 p/Hr.

2.Consumables

Mirrors, lens and laser tubes vary in expected life depending on the power setting being used. Percentage of maximum power varies from company to company, usually between fifty and seventy-five per cent. The time to load, to cut and engrave also needs to be considered. Cutting is faster than engraving so loading time is a higher percentage of machine running time when cutting. As for laser usage, engraving uses lower power settings compared to cutting, so laser usage is greater when cutting. Below are the estimated consumable costs per hour of machine of time:

CO_2 Engraving	25 p/Hr.
CO_2 Cutting	51p/Hr.

3. Maintenance

Maintenance and weekly procedures for the laser machines should take an average of fifteen minutes. This is needed to make sure the machine is ready for use. The amount of contamination on these slides will vary depending on the material being processed, the mirror and the lens will occasionally require cleaning. Following a mirror cleaning, the alignment should always be checked (CLR lasers,2015).

Limitations and capabilities

There are a few drawbacks to this process such as the laser is unable to engrave or cut reflective materials, highly conductive; Producing piercing holes in materials which can make the pattern design more difficult to produce. Reflected laser light can present a safety hazard so protective glass, dust and particle filters need regular replacement for the health benefit of the operator. High uses of gasses, initial costs and which are more expensive than other cutting processes.

Laser engraving does however, have some benefits such as flexibility and precision cutting of simple or complex parts. It offers a non-contact cut, which means there are no marks or contamination on the material. It offers a high quality cut with no extra finishing required. The process also has the ability to engrave a variety of materials such as steel, titanium, paper, wood, leather and wax. Lasers additionally have the capability to cut most plastics, fabrics, and five inch stainless steel.

There are two modes of operation, vector and raster. In raster mode the head of the laser moves back and forth, ‘filling in’ the shape. In vector mode, thin lines are created; the head traces the vector path. Raster is normally the chosen method for engraving images and vector for cutting. Vector mode will only cut along thin lines of nearly zero width, whereas the raster mode will try to fill everything in.

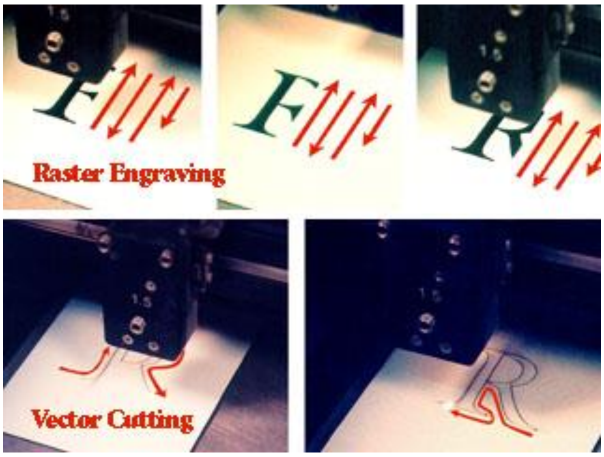


Figure 21 Examples of raster engraving and vector cutting. (www.ctrlasers.co.uk)

Cutting issues

Wavy lines that appear in vector cuts are due to the speed and power settings. Significant waves usually mean that the equipment is damaged. Any inconsistent cut quality is generally due to mechanical problems or sometimes the material is not laid flat enough. Incorrect files, geometry set outside of cutting area, laser moved from default setting of 'home' can make the laser cut along one edge only. Moving but not cutting is an indication that the beam is blocked by a physical obstruction or the electrical safety system has activated. Also, if the lens is not properly focused or dirty the laser produces thick blurred cuts. Continued use of the laser would eventually result in damage or a fire. As the lens is an expensive part of the laser it is more cost efficient to clean than replace.

Debris on the lens

Laser optics are exposed to dust and sticky fumes when the laser is engraving. The sticky fumes and dust can form 'hot spots' on the laser optic lens when engraving. This type of contamination of the laser optic can be costly as it produces poor quality engraving; time consuming cleaning of the optic lens and in some cases the lens has to be replaced as it is damaged by the 'hot spots'.

Engraving materials issues

Engraving materials are made up from all sorts of different chemical elements which are held together in complex ways. They sometimes use various bonding agents such as glues and resins. The content of the fumes which are made from an engraving laser is varied due to materials being made of different chemicals. Filtration of the chemicals from engraving lasers can also be difficult because they are used by hundreds of very different industries including - shops, schools, the military, laboratories, engineers, gift manufacturers and modellers.

Smearing

Engraving lasers use high temperatures to burn marks or cut shapes of products out of materials. Fume extractors are needed to exhume dust particles and are usually running at full capacity throughout cutting or engraving materials. Sometimes the hot material is dragged and smeared by the extractors. Product designers had to invent a new fume extractor to prevent this happening as the laser was producing costly rejects due to this flaw. The operator can now adjust the new fume extractor via a speed control system which prevents the dragging and smearing of products. (www.purex.co.uk).

Comparison of traditional embellishing and laser engraving

Laser versus traditional cutwork

Devoré

Traditional printing

Sandblasting

Hand engraving

Reflection

To further determine if laser engraving is environmentally and economically beneficial for the environment as a process, this research needed to compare other methods against laser technology. Comparative thinking is a natural operation of our minds and is essential to learning. This research uses this method to better understand how to explore the research, processes and reflect on learning experiences.

A comparative approach to the question of;

"Are the two selected processes making the same product efficiently, safely and economically taking into account environment and health considerations?

Is used to aid understanding of how the two methods of processing materials with embellishing techniques work, impact on the environment and how efficient they are compared to each other.

Traditional Cutwork versus laser

The laser process is a modern hybrid of cutwork lace and screen-printing. It also has connections to traditional processes like the 'burn out' method of devoré and hand engraving. Punto Tagliato is a traditional textile technique that cuts away the fabric, leaving a 'hole' which is reinforced with stitches around the edges to stop fraying. Examples of this type of technique are Broderie Anglaise, Carrick Macross lace and white work.

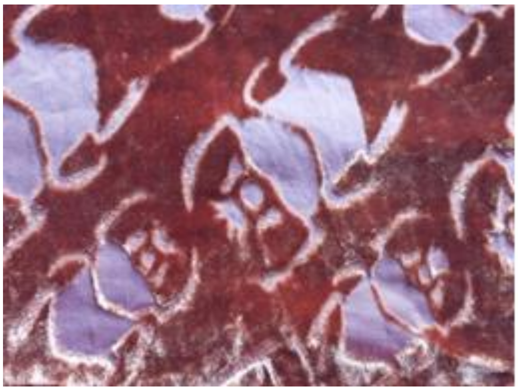
Laser Cutwork cuts out the areas of fabric like the traditional method, but uses a laser instead of a blade. The laser also seals the edges, melting as opposed to stitching re-enforcement of stitches to the material. Laser Cutwork is considered to be the modern twist of lacemaking and Punto Tagliato (Taylor, 1999).


Figure 22 on left is a Google image of a Broderie Anglais sample.
Figure 23 on the right is a laser cut dress similar to lace making from Paris Fashion week 2011 (www.bubblelondon.blogspot.co.uk)

Advantages of the laser over the traditional cut methods

Some of the advantages of the laser are, it cuts faster, it is more accurate and offers finer cleaner patterns. There is more choice of materials that can be used with the laser.It can make permanent marks and seal edges that give the fabric a better handle and more sophisticated look

Laser versus devoré



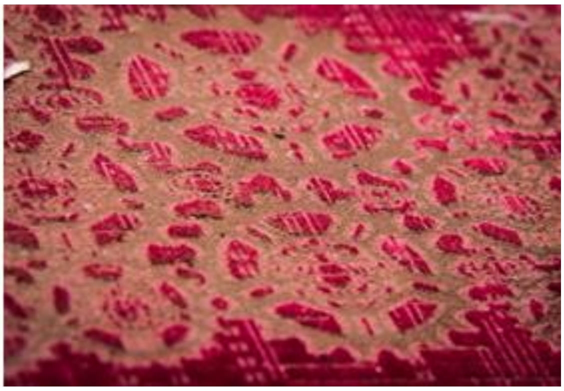


Figure 24 ‘Scarab Beetle’ image of devoré burnout technique applied to dyed velvet fabric (own work).

Figure 25 “Cogs” image Laser etched (own work).

Are Devoré and laser similar?

Devoré creates a 'burnout' pattern using chemicals and is applied to the fabric in patterns, dissolving away the cellulose-based fibres and leaving behind the protein-based fibres, which are not affected by the chemical. Whereas, the laser uses energy to create heat to burn out a pattern using a laser and design package. The benefits of marking with a laser is that it can give the same tactile burnout finish as the traditional devoré method.

What are the environmental impacts?

The devoré print process uses chemicals that generate large quantities of fibrous sludge, chemical and colour waste. The manufacture combined with the energy used to steam, dry, bake, wash off and labour makes this process of printing costly. Safe disposal of textile waste generated in the form of chemical and dyes have been an environmental concern for decades. Researchers have discovered that it is practically impossible to remove all potentially polluting substances used in devoré from the water chain. Scientists and designers have been searching for a technology which could be ecologically sound, energy efficient and create decorative sustainable products. The laser is a technology capable of producing a similar effect similar to devoré without the toxic chemicals and eco concerns.

Textile printing versus laser engraving

Textile printing is a method used to apply colour and designs to fabric. The printed design bonded to the fibre of the fabric normally goes through some chemical processes and treatment in finishing aiding the prevention of friction, wear, from the fabric surface. Whereas, laser engraving refines the surface using energy that increases the quality of the fabric. The laser etches a permanently burnt mark into the fibres and needs no chemical finishing. It can offer picture quality on a variety of fabrics and surfaces. However, it does not have the ability to produce different colours only different tones.

Laser engraving versus Sandblasting

To understand how both methods react with glass as a material a basic understanding of the manufacture of the material is needed. Glass, when heated introduces two of the most basic elements of its composition: air and water. It is a non-crystalline solid made by heating silicon sand between 1400-1600 °C and as it melts it becomes a fluid. Moreover, as the molten glass cools, it remains transparent so, metals are sometimes added to add strength and colour.

(Engravers Journal, 2005).

Laser engraving on glass

Laser engraving uses energy to mark the glass permanently instead of being blasted with an abrasive aluminium oxide under air pressure. The laser beam fractures the material at a microscopic level and vaporises the surface. The the laser also acts differently to the sandblasting method as it works similar to a pencil. The laser beam traces pre-programmed designs whereas the sandblasting method uses tools and inks as well as pressure.

(National Etching, 2015).

The glass is a problematic material for laser engraving as it reacts like a metal in sheet form. It is also challenging to mark as the laser makes the glass molten. Another problem with the laser is it will not mark an area of glass that has a concentrated amount of metal so leaded crystal will not engrave as the metal content is too concentrated. Co2 Laser marking of glass is possible as it reacts with the air and moisture trapped within the elements of silica and metal in the glass. As a laser beam strikes the glass; it heats up the air and water in the glass elements Including the silicon and metal content. Heated molecules within the solid glass expand which results is microscopic fractures in the material surface when engraved.

The laser engraved surface of the glass under the microscope (40x) shows shards of glass laying on the surface. At 100x magnification the microscopic fractures are prominent within the glass as well as on the surface.

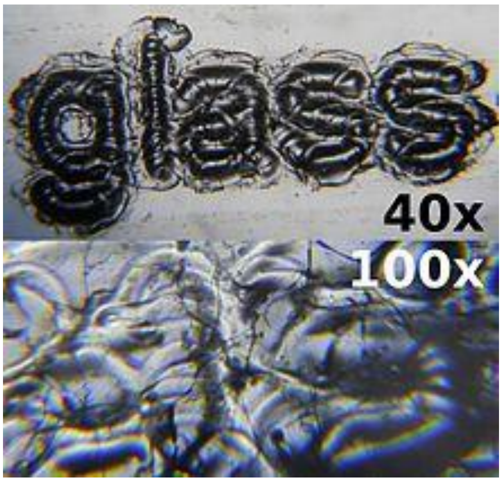


Figure 26 Laser engraved glass microscope slide with the word "glass" engraved. 3pt font. Magnified to 40x and 100x (wikipedia.org)

Satin etch and sandblasting on glass

Sandblasting achieves permanent marks and produces the best result on the glass. However, sandblasting is a labour intensive process as it need preparation of hand applied protective film masks and this method uses a lot of natural resources such as water and energy. Each step of the sandblasting method is time-consuming and complex images are difficult to produce. Stencils needed for the process can be produced on CNC machines and masks with UV exposure units in a dark room. However, sandblasting is a slower process than laser and production is one sandblasted to the equivalent of ten lasers engraved products (Spence, 2005).

Comparison of laser and sandblasting method

(Figure 29) shows a similated comparison of laser and sandblasting methods. As demonstrated in the image the sandblasted line can easily be straight and clean whereas a laser line is uneven and wavy. The difference between the two processes shown in (figure 27) and (figure 28) highlights the sandblasted process on the glass as having a smooth edge compared to the rough edge of laser marked the glass (Spence, 2005).

Benefits of laser engraving.	**Limitations of laser engraving**.	**Benefits of sandblasting**	**Limitations of sandblasting**
Permanent marking.	No colour options	Etching is permanent.	No colour option
An automated process that reduces the need for labour.	Uneven appearance.	Deep and even cuts	Expensive due to needing hand labour.
Detailed designs	The chemical composition is altered by the heat causing polycarbonate to turn yellow.	Able to produce complex designs.	

Table 1 Benefits and limitations of laser and sandblasting, (own work).

Figure 27 Left image, Laser etched glass from Bottle Glass Alley.

Figure 28 Right image, Sandblasted glass from Bottle Glass Alley.

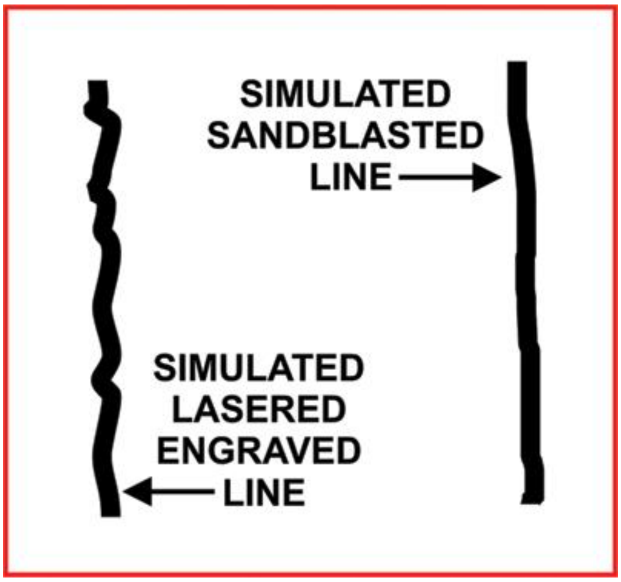


Figure 29 Simulated comparison of laser and sandblasting methods.

(www.nationaletching.com)

Hand engraving versus technology

The traditional craft of hand engraving is where the practitioner embellishes precious objects using hand tools. The traditional method is a field that requires specialist knowledge, such as the behaviour of different metals, coupled with substantial artistic and calligraphic skill. Traditional engraving, by hand tools or with the use of hand-held machines, to be practised by goldsmiths, glass engravers, gunsmiths. Modern industrial methods of mark making on metals and materials use laser engraving which has many important applications. The differences between traditional and modern methods of engraving materials are discussed in this section. (www.handengravers.co.uk)

Manual Checkering

To use this skill the engraver uses checkering tools to create an ornate pattern of small raised diamonds in the wood surfaces which are to be gripped. The checkering tools are in effect chisels, designed to leave a v-shaped groove of approximately sixty to ninety degrees in the surface of the wooden gun-stock (figure 30). Checkering consists of two parallel lines spaced between sixteen to twenty-four lines per inch. A second set of parallel grooves is then executed across the first set, at approximately a thirty degree angle, leaving the area covered with small pointed diamonds.

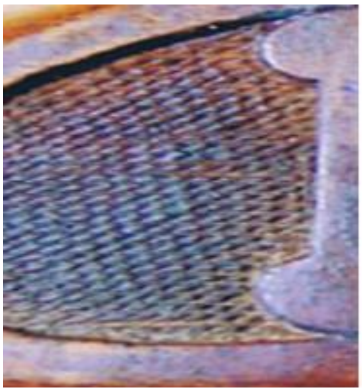
 

Figure 30 Hand Engraved checkering and Figure 31 Laser machine engraving on gun stock using gravel chisels and vice. (www.epiloglaser.com)

Figure 32 Stock positioned on the laser bed ready to be engraved. (www.epiloglaser.com)

The laser uses software and power settings of hundred percent power and thirty percent speed on a raster mode. The stock has to be secured in laser case to the engraving table. This helps secure the irregularly shaped gun stock to the table during the engraving. A spirit level is used to ensure the gun-stock is level so that engraving is even.

The position of the laser optics has to be precise to burn the image in the correct area. The laser was positioned 1.5" from the left and 1.5" from the bottom corner of the gun and they used the manual focus gauge to bring the gun stock into focus. To achieve the depth and detail on the stock the laser had to be deployed a number of times by running the same programme over the area.

Reflection, on the comparison of the processes

Laser and devoré

Laser and devoré are similar as they both burn away substrates and are capable of producing a quality tactile pattern on a material. The laser however, has some advantages over devoré, it uses low amounts of energy, works off a single-phase electric supply, uses a sealed unit, minimal cost and can burn out on many different types of substrates.

Devoré over the generations has been popular with fashion designers and resurfaces to flood the market every ten to fifteen years, however the process is potentially hazardous to the environment. Through reading various literature on government legislation the research highlighted that sustainability and environmental issues surrounding disposal of industrial wastes and effluents were enforced, but not for non-commercial establishments. Education basically, is not regulated and almost all of the effluent waste is directly released into drains and sewage systems.

Laser and traditional printing

Print and laser are similar as they both have the ability to add images to the surface of a material. Unfortunately, one of the drawbacks of laser compared to printing is that it does not have the ability to produce different colours in a design. The laser is currently only capable of producing tones such as white through to black. However, lasers do have advantages over printing such as it refines the surface and increases the quality of the fabric; is able to produce permanent marks to a picture quality; larger library of materials that can be marked without the need for chemicals.

Laser and Sandblasting

Sandblasting is a more suitable process to use on the glass and leaves a fine quality mark on the surface compared to the laser figure and figure Sandblasting can make deep and even cuts. However, both methods can leave a permanent mark and have their limitations.

Lasers find glass with high metal content difficult to engrave, but they are able to mark onto low-quality glass to a good quality. The average customer would not be able to tell the difference between the two methods. Even though laser is considered an inferior mark-making method for the surface of the glass they are ideal for adding images as they are faster, flexible and less expensive a process than sandblasting.

Both methods cannot add colour to the surface. Dyes have to be added to the etched surface as an additional process. The laser also turns polycarbonate yellow that is considered a limitation as the chemical reaction affects the quality of the finished product. Overall, both methods are good at mark making the glass. It just depends on what level of quality and how much money a business or customer wants to spend on adding an image to a product.

Reflection of laser versus hand engraving has been can be found after case studies.

Current trends and new laser technology

Current trends

Benefits of laser welding and joining materials.

Femtosecond engraving and Hydrophobic materials

New technology and advancements

The future of lasers

Reflection

Current trend in Laser processes and technologies

The usual industrial joining process for textiles is sewing, although, there is a growing number of applications in which the traditional sewing process is replaced by welding. The joining of two fabrics via laser welding is a successfully integrated textile process used in the production process of the automotive industry. Laser welding may be an alternative joining technique for airbag fabrics as it enables much higher seam strengths. Gentex has developed Laser welding materials to replace traditional methods of joining for use in commercial settings. Textile layers are fed and at the same time pressed together by rolls. Using a CO2 laser at a wavelength of 10.6 μ m, the laser radiation interacts with the interface region directly in front of the rolls. At this wavelength, all plastic materials are strong absorbers.

Benefits of laser welding and joining materials.

Gentex Corporation and TWI Ltd have patented a process that welds thermoplastic textiles Laser welding of textiles, is a comparably new technology and has only been implemented on an industrial scale in a few applications like sealing of conventional sewn seams using a thermoplastic hot melt tape as an additional material. The process was introduced to the application of highly engineered fabrics to provide a barrier to particles of liquids and gases. A few of the benefits of using laser welding as a manufacture technique is the speed, flexibility and accuracy the process offers when successfully joining polymers. The energy has to be converted into heat which produces the weld. The corresponding laser seams have a good qualitatively external appearance, as they are clean and the weld fume is minimal. Furthermore, sealed seams can be generated, which could be relevant for outer garments. (Anon, Clearweld 2005).

Benefits	**Limitations**
Automation potential- flat bed processing. Additional equipment adaptation Will allow 3D seam shapes to be made with manual / automatic fabric manipulation.	Some textiles cannot be used in this process.
External appearance retained	Seams cannot be re-worked.
Clean, aesthetical appearance of Seam appearance and good weld strength of seam.	Labour intensive procedure in garment manufacture of seams.
Strong welds can be achieved over a wide range of processing conditions Providing leak tight seams.	Difficult and time-consuming procedure to join materials in two stage joining.
Minimal weld fume	Needs variable heating in some patterned fabrics.
Fast and clean- welding speeds up to 20m/min.	Equipment is expensive.
Colours are unaffected by process	Material handle.
A wide range of synthetic materials can be used included coated and foam backed materials.	
Ability to weld all thermoplastic materials including nylon, PP and polyester.	
Multiple layers can be welded selectively.	

Table 2 Benefits and limitations of laser welding materials. (Anon, Clearweld, 2005)

New laser process (Femtosecond) engraving metals

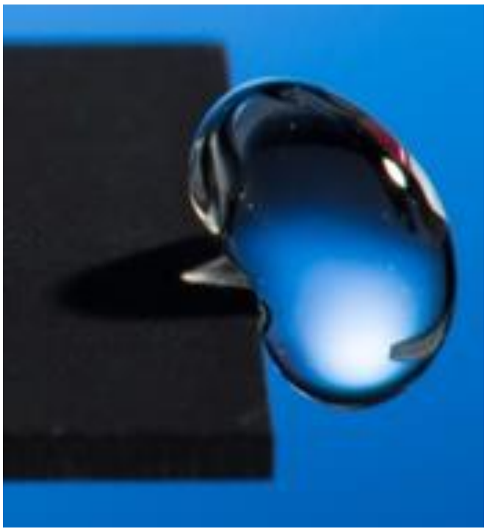


Figure   Droplets of water bouncing off a laser treated sample.

(www.rochester.edu)

Hydrophobic materials

Scientists at Rochester University have been experimenting with metals to make super- hydrophobic materials and they have discovered a new technique using the laser to etch the surface. As most current hydroponic metals rely on chemical coating, the laser patterning technique created by Chunlei Gue is a breakthrough for materials as the process eliminates the need for chemical coating. Guo states that one of the big advantages of the team's method is that "the structures created by our laser on the metals are intrinsically part of the material surface." Therfore, the marks produced by the laser aid to make the metals repel water and become hydrophobic materials. Another advantage is that it takes less than a second for the whole process. (www.rochester.edu)

Femtosecond laser energy pulses

Unlike lasers used in many industrial applications, femtosecond lasers deliver their energy in pulses and as the energy dissipates, single atoms and clusters of varying sizes evaporate off the surface; leaving nanometre-scale bumps and valleys where the laser removes differing amounts of material. Guo has found by scanning a laser beam repeatedly across samples of metal, the laser is able to cut grooves about 100 millionths of a metre wide which is the width of a human hair. Within each of the grooves, lies a structure of nanometre scale and this produces results of super hydrophobicity on platinum, brass and titanium. However, Guo admits that the method needs more experimentation to understand, but believes it will work on any metal or materials such as plastics, semiconductors and ceramics.

(www.economist.com)

New trends and laser technology

Textile dye simulation is on the increase and there is a current consumer trend for printed synthetic sportswear. There is a heightened demand for printing onto large format fabrics and dye sublimation is considered to be fast and cost effective due to decrease in price of printers and ink. However, manual cutting of the printed parts is slow, inconsistent and labour intensive as a result the laser market has added camera recognition pinpoints to be able to register marks on the fabric and speed up production.

Figure 34 Laser contour cutting sportswear on a conveyer flatbed.
(www.cct-uk.com)

Mass production laser cutting is fast becoming a reality due to the camera as the marks are easily read by the system. Large lay plans of the fabric can be continuously cut accurately and as the laser cutter is non-contact, there is no drag on the fabric, so the material is cut into the correct size and shape without any distortions.. An added advantage the system has over traditional cutting methods is that the laser is able to seal synthetic material edges.
(www.cct-uk.com).

New advancements

Figure 35 Conveyer system feeding rolls of fabric to and from the laser bed.

(www.cct-uk.com)

The new advancements of laser machines such as the conveyer, fly and shuttle systems are offering the textile industry a solution for cutting large format fabrics quickly and accurately. Motorised conveyers added to the machine aid feeding the material to the laser which eliminates the need for an operator to manually feed the machine. Advantages of the loop feed created by the system also aids to relax the material so all fabric tension is removed before cutting. Other added improvements such as loading and unloading of materials while the laser continues to cut, makes the lasers ideal for a high production environment and due to the capacity to be automatically operated (www.zund.dk/files) the operator can either collect the cut pieces or let the pieces fall off the end into a box and collect later. This means that just like in the industrial revolution an operator can supervise a number of machines at a time, which makes it less labour intensive and more cost effective. (www.cct-uk.com).


Figure 36 and 37 Duel and four head cutting and engraving heads (www.cct-uk.com)

Accessory advancements such as numerous laser heads added to the cutting machine has increased the capability to simultaneously engrave or cut identical copies of an image. This has aided the laser to have the ability to be used as a mass production tool. However, one of the drawbacks of using this accessory is that the laser power available is half the total power, so a high powered laser is needed with thicker materials. (www.ulsinc.com)

The future of lasers

Due to technological advancements of semiconductors and materials the laser market is expected to grow six per cent by 2020 (figure 38). There has been a significant growth in demand for different types of lasers used in material processing which have drastically reduced the size of the laser as well as the high wall plug efficiency, low power consumption, and cost.

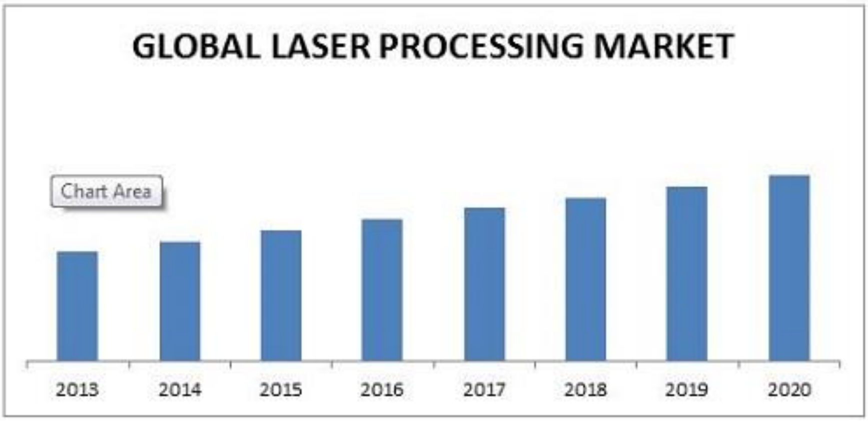


Figure 38 Bar chart of global laser processing market (www.marketsandmarkets.com)

Researchers state that in the next few decades, there will be remarkable progress with lasers, especially as there is a current trend towards mass product customisation. Professor David Hanna, Research centre for the University of Southampton, quotes,

"The laser gave a capability over previous light sources that was just so immense that you simply can't digest and exhaust all that in the matter of a few decades." Lasers are evolving and becoming powerful, their pulse rate is pushing new boundaries. Scientists have developed lasers that trace time at the femtosecond level - a thousandth of a millionth of a millionth of a second. This enables scientists to research on how matter works, to record for example the moment chemical reactions occur (www.marketsandmarkets.com)

As (Bosman, 2015) suggests, In the future, companies will need to co-operate with each other to speed the development of lasers by integrating all the elements of the process to refine the technique of engraving on materials. Laser systems will need to have the capability of delivering at least three wavelengths simultaneously, in combination with short pulse width. This will aid colour flexibility, however, without the right materials this will remain in the future.

Reflection

In summary, this research has found that through the progress of laser conveyers, machines are becoming less labour intensive, becoming more cost effective and efficient. Technological attachments of cameras and numerous heads has also aided the speedup of lasers and mass production has become a reality. Some companies are already utilising the lasers potential by batch cutting difficult materials such as streachy, synthetic sportswear.

Traditional techniques such as sewing, resurfacing, printing are starting to be replaced by the laser in joining fabrics and providing sealed edges to synthetic materials; eliminating the need to use chemicals and pastes which pollute the environment and are providing a faster alternative method of producing quality products.

The research highlights there is a need for a range of materials for engraving with the ability to provide bright colours and pure tones such as white, and black. A possible future research opportunity identified through this research is to provide a range of multi-coloured laser engraved materials employed to replace traditional print techniques. Experimentation could be conducted with a combination of pigments, dyes, additives and compounds to add colour when engraving to possibly aid colouring of materials in production and be the next new advancement in the future of laser technology.

Chapter 4

Literature review

Sustainable materials (Polymers)

What is Sustainability?

Environmental effects

Sustainability in textiles

Material impacts on the environment

Reflection

*‘How can laser technology embellish and engrave to create surface marks for recycled and **sustainable materials**?’*

This is a separate part of the literature review which will include relevant information on sustainability and sustainable materials, The main focus in this chapter will contain research mainly on polymers as the research narrows down to one specific material.

What is Sustainability?

The origins of the word sustain comes from the Latin ‘sustenare’ which means ‘to hold up,’ to support. Today the closest synonyms to the word sustain is ‘maintain’. Sustain and its derivatives sustainability, sustainable, sustaining are not new terms and have been used for hundreds of years. The use of the term was established in 1972 at UN Conference on the Human Environment held in Stockholm

“It may be true that one has to choose between ethics and aesthetics, but whichever one chooses, one will always find the other at the end of the road” (Godard 1999).

From the earliest civilisations to the present sustainability has been dominated by The human need for natural resources to maintain life. In early human history fire and desire for specific foods have changed the natural eco-systems of the plant and animal communities. The western industrial revolution of the eighteenth to nineteenth centuries excavated vast amounts of energy from the earth in the form of fossil fuels to cope with the growth potential of production. Coal was excavated to power efficient engines and generate electricity.

In the mid-twentieth century, scientists have stated that there were environmental costs connected to many of the materials being used by consumers. The damage was said to be detrimental to the sustainability of the Earth. The problems became global in scale in the late twentieth century when consumers became dependent on non-renewable energy resources.

Environment effects

In the twenty-first century there has been an increasing awareness of the threat of the greenhouse gases effect, produced by humans clearing large forests and burning fossil fuels. Increasingly, our lifestyle is placing more and more pressure on natural systems. Scientists continue to investigate how human interactions with natural systems can be maintained, improved and sustained. Sustainability is important to making sure that we will continue to have the required resources to protect human health and our environment in the future.

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (Bruntland, 1992)

Living sustainably is about living within the means of the environment and making sure that our lifestyle does not harm society and culture of other people. It is about thinking about where food, clothes, energy is sourced as well as deciding where to purchase and how products are disposed. For example, timber imported from other countries to be used in homes, what are the rules in place in other countries to prevent animals from being harmed during the timber harvesting process, or if the local indigenous people support the harvesting, or how much they earn.

Sustainability in textiles

“An increasing amount of waste is generated each year from textiles and their production. For economic and environmental reasons it is necessary that as much of this waste as possible is recycled instead of being disposed of in landfill sites. Considering the diversity of fibrous waste and structures, many technologies must work in concert in an integrated industry in order to increase the rate of recycling.” (Wang 2006).

The impact of textile waste is well documented and consumer need for new has become a problem for the environment. “volumes of clothing, purchased annually in the UK, have increased by around one third since 2000, and this embedding of ‘fast fashion’, into our consumer landscape, has resulted in a parallel emergence of ‘fast landfill’ (Allwood et al, 2006).

There are however, some existing systems in place that are enabling some synthetic materials to be recycled over numerous life-cycles such as the development of a closed loop polyester recycling scheme at Teijin or of biomaterials designed as safe nutrients for biodegradation such as Climatex lifecycle. There are some issues with these materials being recycled as they require a pure feedback in order to be properly recycled. (Allwood et al) wrote in a report in 2006 that there had been almost no technology innovation in textile recycling for over two hundred years but there was a drive by consumers for performance and functionality. (Allword et al) also stated that there was a huge increase in the percentage of mixed fibre textile waste created through blending and finishing processes.

Material impacts on the environment

Glass

Glass making goes back four to five thousand years and is simply made out of silica sand, soda ash, dolomite and sand. The ingredients are heated, until they melt and fuse together to make a malleable material this is then shaped and hardens into a form. Glass can be reshaped or re-melted as it is a fluid molecular structure and is technically more a liquid than a solid.

The advantages of glass are that the materials are cheap, easy to obtain, resistant to water, corrosion and attack by chemicals. Their durability makes them suitable for re-use and recyclable indefinably. However, the contaminants that come with glass such as bits of paper, plastic, cork, metal create air lumps and bubbles in when it is being recycled which diminishes the quality of the glass.

In the UK, each person consumes on average three hundred and thirty glass containers of bottles and jars per year. That is not taking into consideration other consumables like electronic devices and windows. Over one point six billion wine bottles are imported into the UK each year. Overall the UK recycles around sixty percent of glass and the landfill takes the majority of the rest. An enormous amount of this glass is imported green glass ‘recyclate.’ Even though the UK has a large bottle bank, manufacture clear glass ‘flint’ for exports still has to be done. WRAP, a government agency has been set up to encourage bulk importation of wine in flexi-tanks made of plastic so that the imported green bottles to the UK can be re-used. Just one tank saves over thirty-two thousand wine bottles being shipped to the UK each year (Hill, 2011).

Metal

There are seventy ‘naturally occurring metals used for many applications and gold, silver and platinum are becoming less available due to the developed, the ‘Industrial Revolution’, and current consumer demands.

Most of the impact of today’s mining comes from ‘subsistence mining’ which has high health costs for its workers as they mine toxic materials like mercury. Mining also creates different types of waste like slurry which contains chemicals and water. Rocks left to the elements can cause problems too such as when exposed to rain they can produce sulphuric acid which causes water pollution. Metals can be indefinitely re-melted and recycled and like glass they use much less energy than excavation from source. A good example is aluminium which saves about ninety five percent on energy by recycling. In the U.K. alone nine-hundred thousand tonnes of aluminium is being consumed. Globally thirty percent of aluminium production is recovered. In Britain forty-two percent of aluminium packaging and fifty-five percent of aluminium cans are recovered and the rest make their way to the landfills.
(Hill, 2005)

Wood

From 1100 to 2050 three quarters of the forests of England will have disappeared due to fuel consumption, populations growing and manufacturing of products such as paper, buildings, and furniture. In the UK most of the wood is softwood such as spruce, pine and birch which grow fast. However, exotic woods grown in other continents such as mahogany and teak take decades sometimes centuries to grow to maturity in natural forests. Trees are important as they make an environmental contribution to the environment by collecting and filtering our fresh water. They maintain the planets overall hydrological cycle by moderating floods and droughts; maintain soil health by keeping the nutrient topsoil in place. Also a lot of medicines are harvested from these trees such as ipecac and quinine (Leonard, 2011).

However, wood is not easy to re-use and recycle as it tends to rot, or be heavily treated with chemicals. The main way to recycle wood is to chip it or turn it into pulp. Unfortunately, this process is energy demanding and difficult to do because of the prior treatments and therefore is considered un-recyclable and is incinerated for energy (Hill, 2011).

Paper

Paper is mostly made from trees such as wood fibres because of the high quality and strength. Chemicals are used in pulping to separate the fibres which has an impact on the environment as it also uses a lot of water in the process. Paper can be recycled and uses less energy than processing virgin pulp. Unfortunately, it can only be recycled seven times as the fibres weaken and become impractical. Even though there is a move towards electronic media, the world still increases its demand for paper. An estimated seventy-seven percent increase is expected by 2020. A high proportion of media, promotional paper ends up in the landfill without even being purchased by customers. An estimated thirteen million tonnes of this media was sent to landfill in the UK in one year.

Plastics

In Britain house-holders are offered the service of curbside recycling which aids to collect plastics that would normally end up in landfill such as PET. This type of polymer contains substances and is covered with synthetic dyes and chemicals. PET is recycled into materials like fleece but at the end of its product life it cannot go back into the soil safely.

The Chinese buy most of our mixed plastics as they have a shortage of polymers and can afford the labour to sort out the different polymer types. The UK are not short of polymers and are wasteful as only specific plastics are recycled. The UK market for reproducing plastics is gradually developing and solutions for reforming plastics are being sort. Mixed plastics and contaminated materials are difficult to separate into their constituent polymers. To recycle successfully, reproducing facilities need clean specific polymers such as PET so that they can be cut up and chemically purified back into polymers. Mixed polymers are considered closed loop and less valuable or useful (Hill, 2011).

Polymers are expensive and cost more than most metals, however,they are relatively cheap to turn into products because of their natural qualities- strength and adaptability. They are able to mould very easily into product shapes, they are light and a tonne of polymer can make a numerous amount of products (Hill,2011).

Reflection

Education on the implications surrounding materials for products need to be available to customers, manufacturers and designers. Designers and manufacturers needs to take in to consideration the impact their sourced material has on the environment, communities and life.

Resource strategies like reducing packaging, redesigning products to contain fewer materials or use recycled materials. Other strategies that could be used in design such as repairing, recycling, adapting or even making them more durable at production. There are considerable amounts of materials are being wasted every year that could be recycled or at least reused. As the materials have already been extracted and processed the most sensible idea would be to keep them in use rather than discard them in the landfills. However, some toxic compounds like PVC or metals such as lead should be replaced with non-toxic materials and not used at all.

Glass- Sand even though plentiful requires digging up which has environmental and human impacts. Recycling glass makes sense as it saves energy as it takes a lot of energy to make virgin glass. Fifty per cent of recycled cullet and new glass uses fifteen per cent less energy and less water compared to using just virgin materials.

Metal- It is better to re-use the materials already in use due to all the impacts on the Earth and life. Even though a good proportion of metals are being recovered, mining is still happening due to greed. Metal has value even scrap metal can be recovered, recycled and re-melted to make new products indefinitely. However, a shift to recovery needs to happen as more countries are undergoing technological industrial revolution.

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Wood and Paper- cannot have a closed loop system as after recycling the fibres in several processes as they become too weak and useless. This means that paper cannot be continuously turned back into paper and trees have to be continued to be harvested. Also land is difficult to keep for wood and paper harvesting due to the high demand for building houses and food crops for the ever growing population. However, there are several million tonnes of paper that could be utilised that ends up in the landfill because people do not put paper in the re-cycle bins.

Plastic- There are many arguments against the sustainability of plastic and the scale in which the material impacts environment. As plastic is a derivative of fossil fuels which are dwindling and getting more difficult to extract, the damage caused by greenhouse gas emissions which are connected to fossil fuel. Plastics have waste issues and the public are more aware of the impact as they pay duty on plastic bags used in shops and stores. There is also a lot of media coverage of the issues of waste such as the Pacific Ocean's 'garbage patch.'

Further research into polymers as a sustainable material

Origins of plastic

Polymer Molecules

Thermoplastics and Thermosetting plastics

Polymer types

Melting points of plastics

Polymers, background research of the origins of plastics, dangers to life and environment.

The main aim of this research was to find a sustainable material to use in education with demanding projects and laser technology. Although polymers are not considered a closed loop material the possibilities plastics offered as a remoulded material was worth investigating, Another reason to research waste polymers in depth and remould is, the current main use of plastics is used as single-use items that end up in a landfill within a year. Plastics products are lightweight, inexpensive materials that potentially could provide more service than they do at present.

Natural raw resources such as fossil fuel that make plastics can be reused or recycled and are an important commodity. Unfortunately, instead of a majority of fossil fuel being utilised as a plastic it is used as energy. Using this resource as heat and power means that when it is burned it is gone and cannot be replenished.

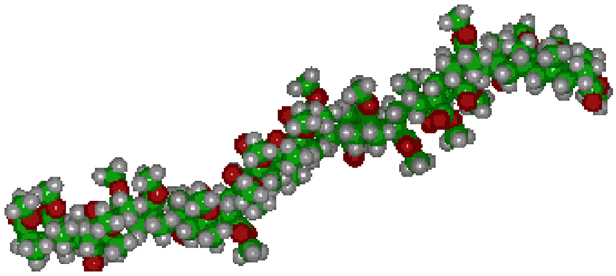


Figure 65 Polymer Chain (www.engineershandbook.com)

Origins of plastic

The name plastic comes from the Greek verb ‘plassein,’ which means ‘to mould or shape.’ Plastics are also referred to as polymers, meaning “many parts” in Greek and are substances made up of long chains of thousands of atomic units called monomers, Greek for “one part”.

The plastics associated with oil were first introduced in 1907 and was classed as the first ‘true’ plastic. A Belgian chemist, Leo Baekeland made the first plastic to be made entirely from synthetic materials. Baekeland mixed together phenol, known as carbolic acid and formaldehyde methanol and used heat with pressure to mould into a hard material called Bakelite (Hill,2005).

After Bakelite, chemists experimented and produced other plastics such as PVC and Vinyl which was made proportionately from oil and chlorine in salt. Scientists eventually developed a range of materials such as polyester, polystyrene and polys with different properties to suit industrial needs and a good example is DuPont, who developed Kevlar a polymer that can be made into fibres and woven into a textile capable of stopping a bullet (Bond, 2013).

Polymer Molecules

Polymer molecules are larger than other substances such as water and can contain tens of thousands of monomers which form chain links. The length and arrangement of the chain aid to determine a polymers properties; strength, durability, clarity, flexibility and elasticity. Chains crowded close together can make for a tough, rigid plastic bottle such as detergent containers. Whereas, chains, more widely spaced can be used to make a flexible bottle like a squeezable ketchup bottle (Freinkel, 2008). These polymer chains of plastic have been created to last, and plastic products such as the ketchup bottle and crisp packet are currently littering the streets; clogging waterways, ending up as detritus on the Ocean floor, choking marine life and becoming an ever growing plastic mountain in landfill.

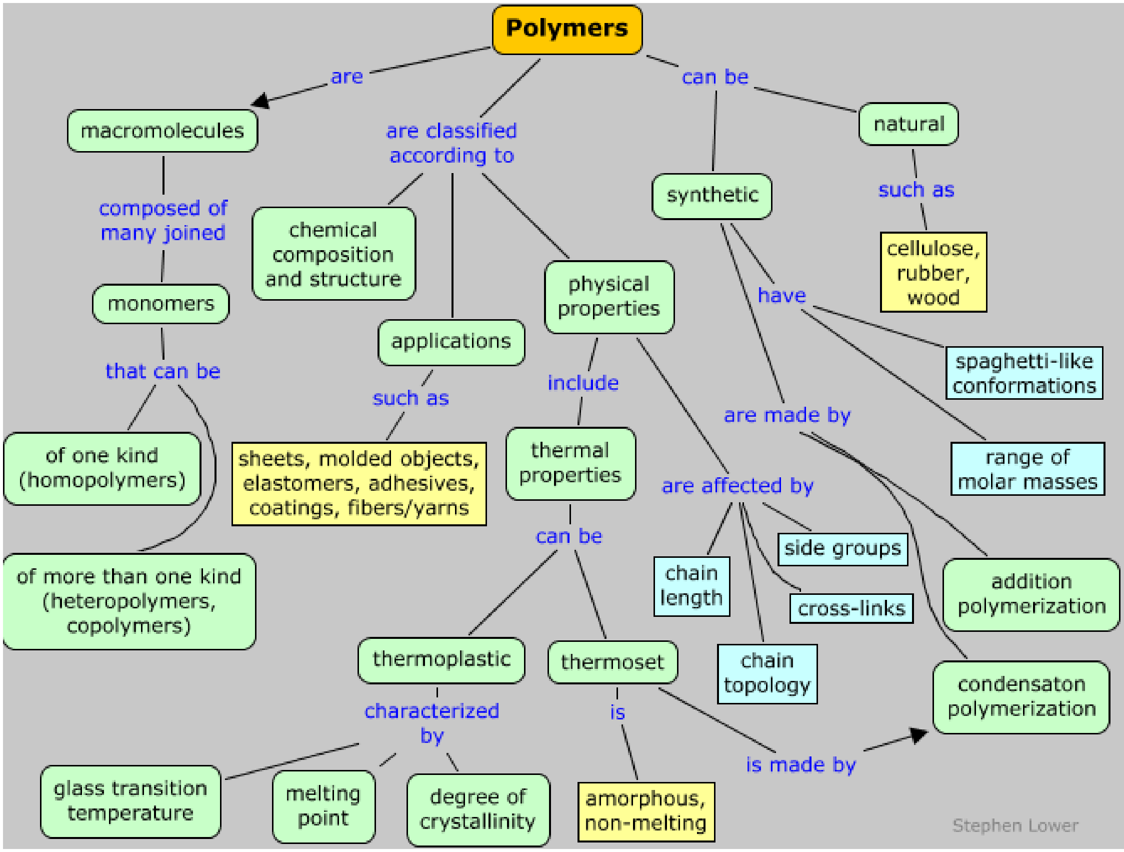


Figure 39 Classification of polymers mind-map (www.chem1.com).

Thermoplastics and Thermosetting plastics

Plastics fit into two categories – Thermoplastics and Thermosetting plastics. These two have different properties and therefore the type of plastic used depends on the use and product.

The main thermosetting plastics are epoxy resin, melamine formaldehyde, polyester resin and urea formaldehyde.Thermosetting plastics can only be heated or shaped once due to the polymer chains being interlinked. Separate polymers are joined in order to form a huge polymer.

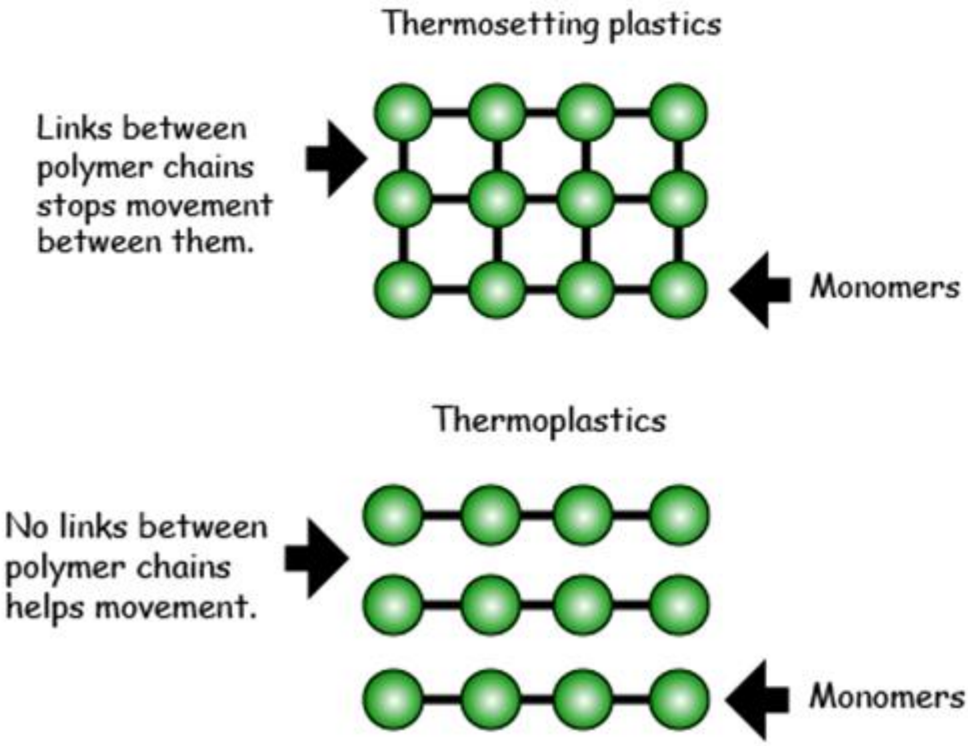


Figure 40 Diagram explaining thermosetting plastic chain.

Figure 41 Diagram explaining the polymer chain of thermoplastics

(https://sites.google.com/a/tamaki.ac.nz/mrs-smallwood-s-science)

Thermoplastics are ABS, acrylonitrile butadienestyrene, Nylon polyamide, acrylic polymethyl methacrylate, uPVC polyvinyl chloride, polystyrene, polypropylene and cellulose acetate.Thermoplastics will soften when heated and shaped when hot repeatedly. The plastic hardens when cooled and can be reshaped as there is no links between the polymer chains.

Thermosets	Thermoplastics
Solidifies or sets when heated	Softens when exposed to heat and reverts back to its original state at room temperature.
The molecules of these plastics are cross linked in three dimensions that is why they cannot be recycled or remoulded.	Do not undergo significant chemical change
They are useful for their durability and strength	Weak bond, which becomes even weaker on reheating
Used predominantly in automobiles and construction applications. Other uses include adhesives, inks, and coatings.	Thermoplastics can easily be shaped and modelled into products such as floor coverings, credit cards and carpet fibres

Table 3 Differences between thermosets and thermoplastics (Pathak et al. 2014)

Polymer type	Classification and products	Polymer type	Classification and products
Polyethylene Terephthalate		Low Density Polyethylene	
High Density Polyethylene		Polypropylene	
Polyvinyl Chloride		Polystyrene	
		Unallocated References	

Table 4 Classification of plastics in table own work (Images from Google).

Polymer types

Type 1 Polyethylene terephthalate

PET plastic is one of the most common plastics used for single use. It is a lightweight material that is easy to recycle. Recycling rates are around twenty percent and the material is in high demand by remanufacturers.

Researchers in Italy discovered that water in PET bottles releases a chemical called 'Bis' 2ethychexyl phthalate, Dehp slowly after a bottle has been used for nine months. Dehp has been reported by scientists to have potential to trigger cancer and have negative effects on testicles. It has also been suggested that it damages the DNA in sperm.

Type 2 Plastic – High Density Polyethylene (HDPE)

The acronym HDPE (high density polyethylene). HDPE plastic can withstand heat up to 120°C, good for chemical resistance, tough and permeable from gas. HDPE is often used to make bottles with short shelf life or holding chemicals, such as milk and juice.

Type 3 Plastic, PVC- Polyvinyl chloride / vinyl.

PVC is rarely recycled due to the high cost of processing the material.The acronym PVC, Polyvinyl Chloride or Vinyl is used to refer to type three plastic. There are two types of PVC plastic – polyvinyl chloride and vinyl. Polyvinyl Chloride contains toxins called Chloride and Phthalates, which can cause hormone imbalance and some of the wrap plastics contain a chemical called DEHA which is considered a carcinogen. Scientists suggest avoiding prolonged skin contact and careful disposal of PVC as it releases dioxin, which is a poisonous cancer-linked chemical.

Plastics type 4 – Polyethylene (LDPE)

Low-density Polyethylene, LDPE is rarely used in products that would affect human health. This plastic is considered safe, but not very environmentally eco-friendly.

Type 5 Plastic – Polypropylene (PP)

Polypropylene is a thermoplastic polymer and was first polymerised in 1954. It went into full-scale production in 1957. It is reasonably economical to be produced and is translucent when uncoloured. Polypropylene is a robust plastic that is heat resistant considered highly safe for human use. Due to its high heat tolerance, Polypropylene is unlikely to leach even when exposed to warm or hot water. It has good resistance to most common chemical solvents and acids. This plastic is approved by the FDA for use with food and beverage storage. Polypropylene plastics can be re-used safely and with hot beverages. This is the safest plastic to use and can sustain heat up to 135 degrees Celsius. It is considered tough and flexible with a good level of durability. Polypropylene basically can retain its shape when subjected to short term pressure.

Polypropylene is commonly recycled, but not all of this plastic is recovered in recycling. Without the addition of UV- absorbing additives and anti-oxidants, the plastic cracks and degradation occurs.

Type 6 plastic- Polystyrene PS.

Polystyrene in it pure state is a colourless hard thermoplastic material. It was discovered in 1839 as an organic substance distilled from the resin of the ‘ Liquidambar orientalis ‘ tree which naturally polymerised on distillation. Polystyrene started to be produced in 1939 with the development of a reactor vessel that helped to produce pellets. Polystyrene (PS) contains the toxic Styrene, a possible human carcinogen. This material can pose environmental problems in manufacture and disposal and also becomes structural unstable when introduced to high temperatures or oil.

Type 7 Plastic – Polycarbonate / ABS.

Polycarbonate has negative health effects, it is made with Bis phenol A, a chemical invented in the 1930’s in search for synthetic estrogen. Polycarbonates trade name LEXAN, is a hormone disrupter which stimulates the action of estrogen. This plastic can leach into food products after six months and can leach into hot beverages.

LEXAN -Bisphenol A may also be a potential carcinogen.
Currently polycarbonate is recycled by the material being re-ground and made into pellets for re-use. However, most of this material ends up in landfill sites where it degrades at a very slow rate. It is relatively difficult to recycle this material because it involves de-polymerising the resin with hazardous materials which can contaminate the recovered materials.

Nylon

Nylon is a synthetic polymer. It is classified as a polyamide. First produced in 1935 by Du Pont and is one of the most common forms of plastics used. The polymer is produced in two forms, as fibres or as a solid plastic and has many applications, from textiles, rope, to the strings of a musical instrument.

Melting points of plastics

All plastics are polymers but not all polymers are plastic. Different polymers have different melting points like thermoset plastics do not melt, but suffer decomposition at high temperatures because their molecular structure will not let them melt, instead they change colour and char.

Many plastics are shaped by heating them until they are soft and they are then moulded. It is a problematic process to do in a domestic environment because plastics are poor conductors of heat, a whole sample is difficult to melt without burning the outside surface and it is necessary to carefully control the temperature of plastics. Most plastics need higher temperatures and this can cause a significant risk if melting the plastic in a saucepan. What is needed is a plastic welding set up which melts the plastic with a stream of heated nitrogen gas. Other plastics need a controlled low temperature, which can be difficult to achieve over a stove. If the plastic has a melting point less than the boiling point of water a double boiler should be used. The temperature will change for a common plastic like polyethylene depending on the grade of polyethylene such as LDPE will melt at about 105-115 °C, and is used in many plastic bags and is already soft. Another common plastic is PVC or uPVC, which melts at 100-260 °C and is used in wire insulation PVC, pipes and window frames uPVC. It gets softer above about 80°C, which is uPVC's glass transition temperature.

Plastic polymer	Melting point
HDPE (High Density Polyethylene)	130 ºC
LDPE (Low Density Polyethylene)	105-115 °C,
PET (Polyethylene terephthalate)	250- 260 ºC
PP (Polypropylene)	160-170 ºC
PS (Polystyrene)	70—115 ºC
PVC (polyvinyl chloride)	100-260 °C
PTFE (Polytetrafluoroethene) (Teflon®)	327 °C
POM (Polyoxymethylene)	162-173 °C.
PLA (Polylactic acid)	Softens at 50 °C
ABS (Acrylonitrile butadiene styrene)	Softens at 90 °C

Table 5 Various melting points of different types of plastic

(WWW. plastictroubleshooter.com)

Biopolymers

Green plastic

The effect on the Environment and health

Pros and cons of bioplastic

The future of bioplastic

Bio-based polymers have been used for thousands of years, and are documented to be used in the bible as rushes pitch and slime which might be called a fibre-reinforced bio plastic. PLA bio plastic was discovered around 1890 but was replaced by plastics made from synthetic polymers The history of plastics has changed since the early 1900s due to the discovery of crude oil. However there was a revival in the development of artificial bio-based plastics from the mid-19th century until the early 1940's, (Stevens, 1938). The rising cost of oil, regulation and mounting concern over climate change has necessitated a move towards renewable sources of polymer feedstock.

Green plastic

Designers excavate natural substances created over millions of years and develop them into products designed for " a few minutes of use," and then return them to the Earth as litter to never deteriorate. We use plastic based technologies to save lives but do not consider the threats to life. Humans bury in landfills the energy rich molecules that were excavated from deep in the earth. Countless countries send plastic waste overseas to become raw materials for finished products that are sold back. Plastic is a versatile material, it is in our cars, toys, packaging, clothing, home goods, food utensils and medical devices. Plastic is a valuable material which consumes large amounts of non-renewable fossil fuels to make however it can be recycled or remoulded into new products.

For a material to described as sustainable it must have the three pillars of sustainability; environmental, economic and social. Plastics are an important part of the UK economy and are said to make a positive contribution to these three pillars according to BPF . Plastics have a good environmental profile as when they complete their phase as a car bumper or a bottle they can be recycled or incinerated for energy. Plastics provide an important source of power. They can be viewed as 'borrowing' the oil rather than using it (BPF,2015).

Plastic originate from a non-renewable source. Some plastics are very toxic, both in the production process and additives used. Five million tonnes of plastic is made every year and the UK uses half of this plastic for applications like teacups, carrier bags, mobile phones and wrappers. Plastics Europe has suggested that plastic has grown by one point five million tonnes over the last sixty years and the UK recovers less than a quarter of the plastics used every year, even though most of them are recyclable.

As plastics are light this poses a problem for local authorities who have to recycle household waste by weight as they have to collect more plastic than paper to meet their targets. Only four percent of the world's oil production is used for plastics yet plastics use much less energy to produce than other materials, they are lightweight and durable which makes them the best choice for packaging, pipework, cars and aircraft.

The effect on the environment and health

Scientists have learnt through tests and research that plastic is dangerous to life and hazardous beyond the landfills. Chemical added to plastic are absorbed by humans and have an adverse effect on health and vast amounts of discarded plastic have made the oceans a dangerous toxic soup. Marine animals are choking and being killed by the waste. Ingested plastic debris by marine animals and plankton are feeding on plastic fragments that have polluted the oceans, and this means that eventually humans are consuming plastic.

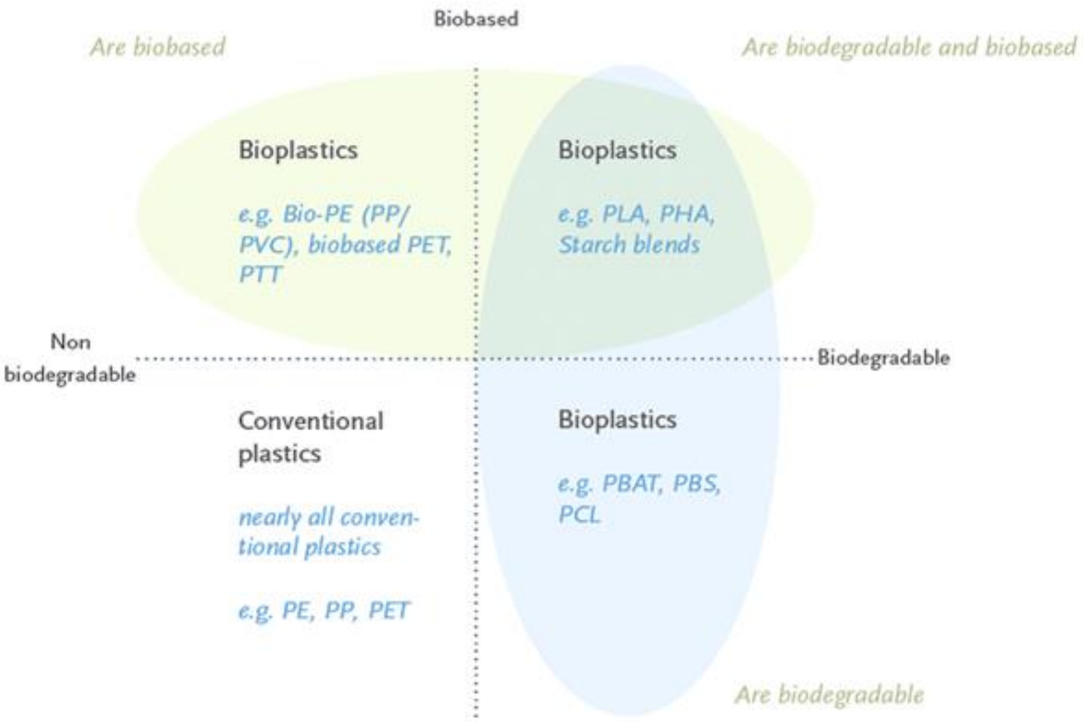


Figure 42 Bioplastics: Its Timeline Based Scenario & Challenges (Pathak et al 2014).

Bio-plastics are made from renewable raw materials and help preserve non-renewable resources, petroleum, natural gas and coal. Bio-plastics are biopolymers which are polymers that occur in nature. Bio-plastics require less energy to manufacture than petroleum- derived plastics and are compostable (www.bpf.co.uk).

Bio-mass plastics are plastics made using polymers that are produced using plant materials instead of petroleum products. Plants or trees can be used to obtain sugars that are linked into polymer chains during fermentation. One of the many benefits to biomass plastics are that they are considered carbon-neutral. Although they are incinerated at the end of their lifecycle, the amount of carbon dioxide that is produced is no more than the amount taken up by plants required to make the plastics in the first place. Another benefit to biomass plastics is they do not require the use of non-renewable resources, petroleum products. Biomass plastics can be made from wastes of the food industry, which means they do not have to detract from the use of food crops for feeding people. These plastics are used in food biotech to make packaging. They are also used in many other industries, for example for making car parts. A downside to the use of biomass plastics is that they are made from similar polymers to petroleum-based polymers and the same toxic plasticizing chemicals such as Bisphhenol A and phthalates are added. These toxic chemicals have been linked to health problems such as cancer, diabetes and obesity (Phillips, 2014).

Figure 43 Bio products – life cycle (http://earthware.in/images/concept.gif)

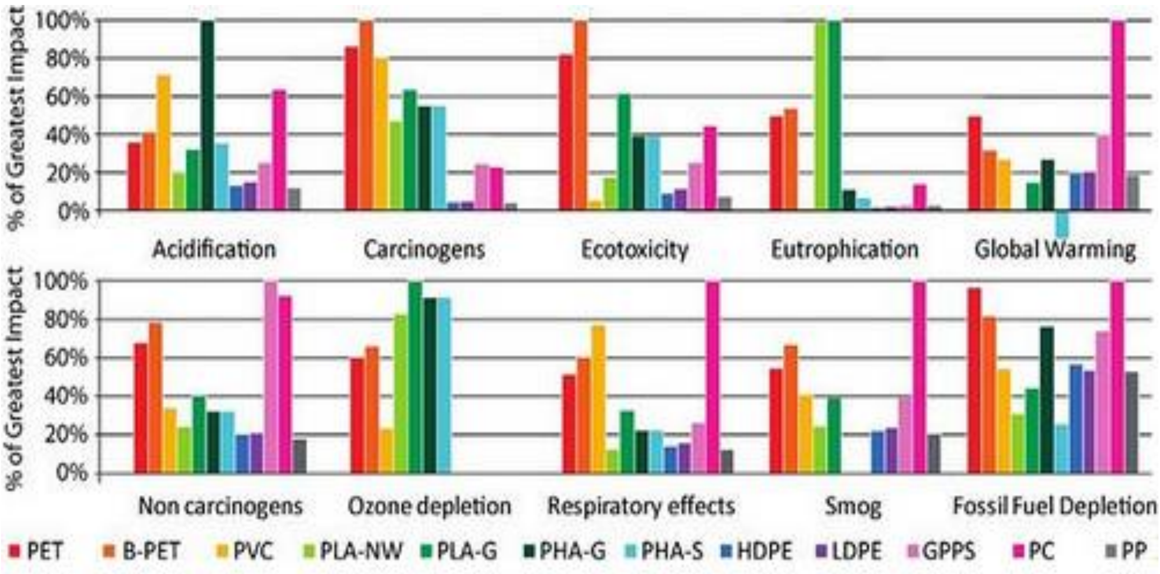


Figure 44 Impact on the environment (www.green-talk.com)

Pros and cons of bioplastic

PLA plastics can be incinerated and do not emit toxic fumes like their oil based counterparts. They come from renewable natural sources such as plants. They are carbon neutral and have many uses such as medical, food packaging, packaging and industrial products.

However, corn plastic has its issues as it only composts in the hot moist setting of a commercial composting facility. This green plastic can take as much time as fossil plastics to biodegrade in a backyard composting heap or landfill. Its Chemical composition is different to fossil plastics and can contaminate plastic when recycling.

PLA plastics are also not good for the environment as they produce the greenhouse gas methane when they decompose. They need large fields to grow the crops that could be used to grow food for an ever-rising global population. Scientists have also genetically modified the corn which could have an impact on human health and the environment.

The future of bioplastic

Demand for materials like plastics is continually growing and, the plastics industry is becoming a cause for concern. The pressures of increasing waste and diminishing resources have led many to try to re-discover natural polymers and put them to use as materials for manufacture and industry. Over the last five years there has been a expansion of products made from bio plastic such as PLA from lactic acid, PHA's from fermentation platforms and polyethylene from bioethanol. Polymers derived from renewable resources offer the opportunity to benefit society and the environment by reducing demands on fossil resources. Sugars, oils and other compounds in renewable feed-stocks can be converted into platform chemicals and polymers using conversion processes similar to those employed by the petrochemical industry today (www.bpf.co.uk).

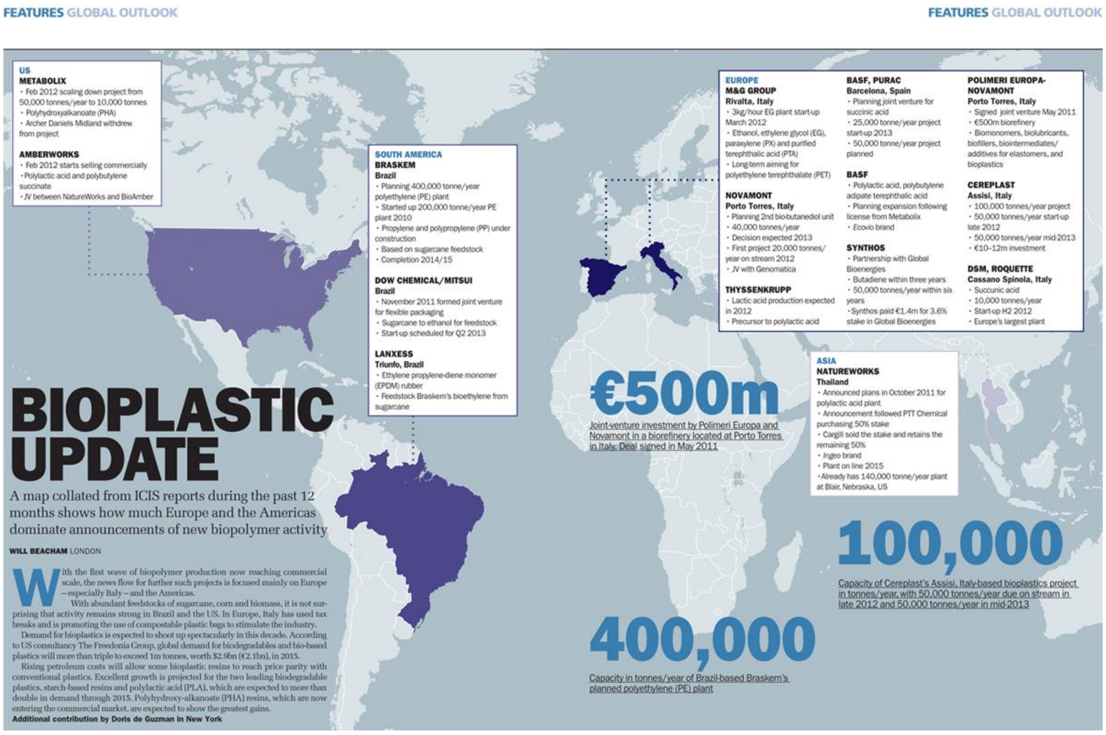


Figure 45 Bio plastic update article (www.pakbec.blogspot.co.uk/2012).

The cheapest and easiest biopolymer is starch due to its abundance and low price it has found numerous applications in the non-food sector, which includes its use in renewable plastics. The current rise of the oil and natural gas prices is reflected in the plastics market, and is making renewable plastics more competitive. As a consequence of the development of new markets energy consumption and waste production is increasing at a fast rate. The amount of goods produced and packed is also growing, making waste disposal a big issue. These problems are stimulating the growth of renewable plastics and continuous development of renewable plastics. This opens up the opportunity to close the loop from raw material to end of life disposal than is possible with fossil derived materials. (www.greenprophet.com)

Bio-plastics are being produced by 200,000 tons in 2006 and are set to grow to about five million tons by 2016, bio-plastics is growing fast observes the Germany-based Helmut Kaiser Consultancy. Currently, bio-plastics production is concentrated in the U.S, Europe and Japan, with the largest market being Western Europe, which accounts for about forty percent of the world's demand for bio-plastics. The total plastics market is recorded a fast-paced growth of about eight to ten percent per year and the renewable polymers market will increase rapidly in the next two decades (figure 47) (www.nnfcc.co.uk).

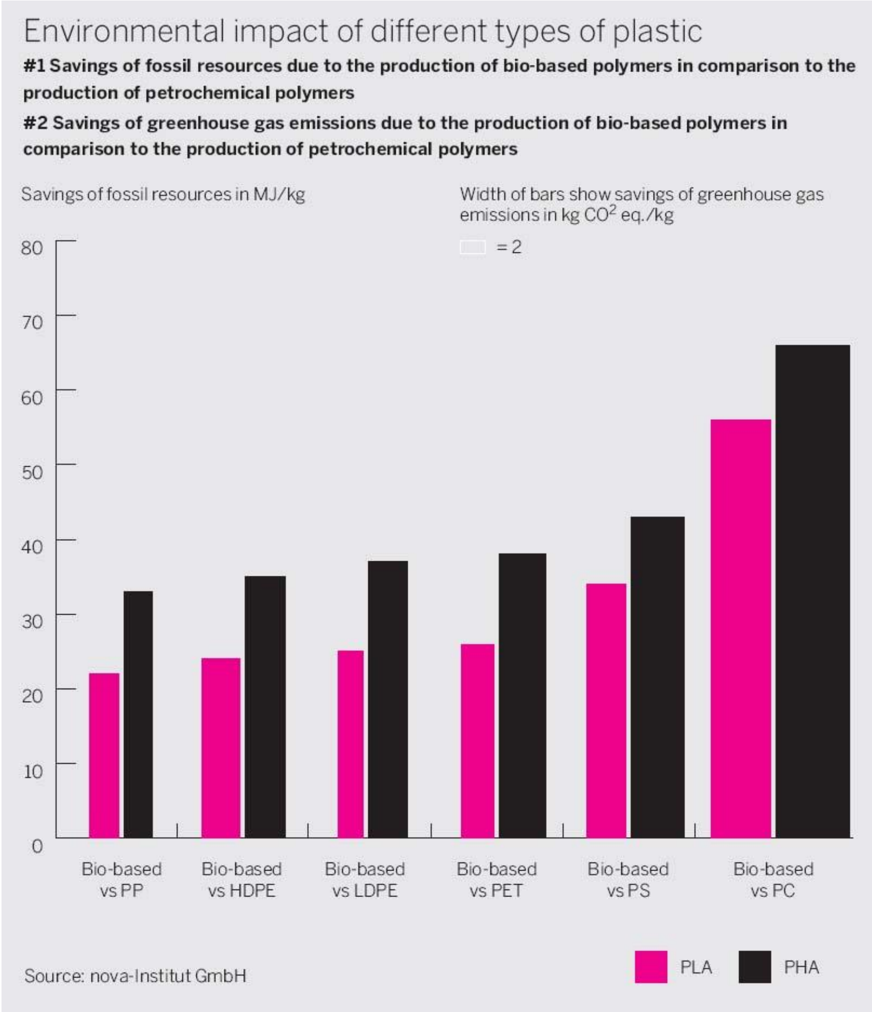


Figure 46 Bar chart of environmental impacts of plastic.

(www.pubs.sciepub.com/)

Figure 47 Evolution of PLA Production Capacities (www.bioplasticsmagazine.com)

Reflection

It should also not be forgotten that reuse and recycle equally applies to renewable plastics as it does to fossil derived polymers The advances in science and the rapid development of technology has put a strain on current natural resources of the planet. The energy needed to sustain society at present is unsustainable and plastics have become an important commodity in the modern lifestyle. The search for a sustainable material that is derived from renewable resources has been on-going. Scientists are looking to address unsustainable practices and develop efficient methods of conversion of natural resources into sustainable materials and fuels.

The research highlighted that If properly designed, biodegradable plastics have the potential to become a preferred alternative to conventional plastics.
However, biodegradable plastics will probably remain less superior than petrochemical plastics as more effort and work is needed to develop these plastics efficiently into daily life. Bio based materials however are more superior in terms of sustainability and environmental protection. Even with a new generation of bio-plastics, manufacturing single-use disposable products will ultimately not be sustainable as the planet has almost seven billion plastic consumers. The throwaway culture addicted to disposable plastics is likely to continue harming our environment, whether it is made out of oil or plants.

Case Studies

Practitioner or company	Subject
Design technology department Headlands School Bridlington	Laser engraving onto various materials.
Design Technology Department South Holderness School Hull	Recycling plastic
Bottle Alley Glass Cross Green Approach Leeds	Glass recycling, laser and sandblasting material.
Paul Dyer Engraver Blackwood Gwent South Wales	Traditional hand engraving.

Overall reflection of the case studies.

Case studies

The case studies in this section are conducted as primary research. The focus of the studies was mainly on education and practitioners that utilised waste to remould into new products or used embellishing techniques to mark materials. This empirical method of research aids in a practical context to gain information for the wider question. It also allowed for focusing specifically on areas covered in this research, such as laser engraving and remoulding materials.The case studies are conducted in an Illustrative format and are primarily descriptive studies that utilise the information to familiarise with common language about the topic in question. The case studies form a qualitative descriptive research that is used to look at individuals and collect data about the participants using direct observations, interviews and questions.

Case study 1 Headlands School

Figure 48 Left image of Bridlington shown within the East Riding

(https://en.wikipedia.org/wiki/Bridlington)

Figure 49 Right image of Headlands School Bridlington.

(http://www.hulldailymail.co.uk)

Background

Headlands School is a co-educational comprehensive school situated near the coast in Bridlington, East Riding of Yorkshire, England. Headlands School became a specialist school in Science in 2002 and has a free-standing observatory on the school grounds.

Technology department.

Headlands school Design and Technology department believe that

“Design and Technology is vital to the future success of our students as they both live and work in the modern World that is evolving at an exponential rate. We want to ensure that our students can both interact with and be part of creating the future. Design and Technology is not just about manufacturing aesthetically pleasing products but relates to all aspects of how we live and is linked to our intellectual, emotional and physical needs”. (www.headlandsschool.co.uk)

Figure 50 Laser engraving and cutting machine Headlands Technology department. (Own Work).

Observations

Laser systems are being introduced into technology departments to promote academic growth. Incorporating laser technology into an interdisciplinary curriculum as a tool is aiding students to prepare for tomorrows jobs. Trends in education due to the estimation of jobs in science, mathematics, engineering and technology are seeking to implement rigorous, relevant and engaging curriculums to inspire imagination and improve student achievement through science, technology, engineering, mathematics (STEM) and Art (STEAM). Primary and secondary schools are offering STEM curriculums by engaging students in problem based project learning.

Schools need to keep abreast with industry and the challenge has always been what technology to incorporate into the school curriculum. Laser engraving and cutting systems have been rapidly making their way into educational institutions. These highly functional systems are being introduced into design technology departments because of their versatility and ease-of use. In keeping with their department mission of keeping up with Industrial practices, Headlands School saw the need to acquire a new piece of high-tech equipment that could be incorporated into the schools classes. "The piece had to be some kind of updated CNC type machine or similar technology," said Mr Coupland, technology technician for the school "The problem was that most of the CNC type machinery that was available in the departments price range weren't functional for producing shop quality pieces so we decided to invest in a laser," he said.

The laser engraving systems are having a positive impact on the schools and the students using them in their design work. “The laser engraver was an invaluable tool during this project,” Mr Coupland, “We used it to cut out the prototype, as well as numerous complex components for the kids work.”

As technology continues advance, educators need to keep up on the latest developments and decide how to implement them into the curriculum. Lasers are being utilised in classrooms, extra-curricular activities and enterprise marketing opportunities. Schools have realised that having a laser engraving machine is a useful tool to develop student’s skills, creativity and critical thinking.

Laser machines offer a lot of cross curricular opportunities such as art, textiles, resistant materials and science. It can also be economic for a school by using it to produce signage or perhaps raising funds through ‘business enterprise’ activities such as designing, creating and selling personalised products.

Case study 2   South Holderness Technology School.

Background

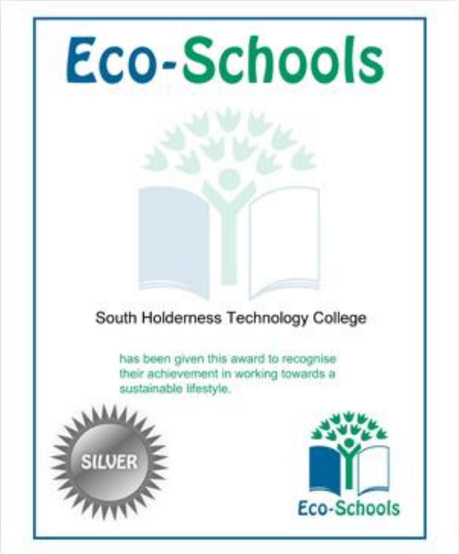


Figure 51 South Holderness school http://www.shtc.org.uk/

Background

South Holderness Technology College is a Community School located in Hull, East Yorkshire, teaching Secondary students aged between eleven and eighteen years of age. One thousand and seven hundred pupils attend the school which far exceeds the country average. The school is a mixed school, having fifty-one per cent girls and forty-nine per cent boys. The school operates under the East Riding of Yorkshire local authority and is known as SHTC. It receives extra funding due to its high curricular activity in technology, I.C.T. and science.
(http://self.gutenberg.org)

Technology department

The technology department encourage pupils to be able to design and make products with creativity and originality, using a range of materials and techniques. They create and develop products which can be evaluated for their commercial viability. Students learn about a range of materials, manufacturing processes, techniques and technologies, The department introduced recycling plastic bottles and other plastic products by chipping and remolding them into new sheets of plastics which the pupils use in the design and make process. The teachers guide and aid pupils to understand the underlying influence of their projects. The use of recycled and up-cycled materials in the projects throughout the design process used by the pupils have to be suitable for commercial production

Observations

The Government in England wants every school to be a sustainable school by 2020. The Department for Children, Schools and Families (DCSF) launched their Sustainable Schools Framework in 2006 when the Secretary of State for Education set out challenging long-term aspirations for schools to mainstream learning about sustainable development issues and sustainable practices into everyday school life.

Eco-Schools is an international award programme that guides schools on their sustainable journey, providing a framework to help embed these principles into the heart of school life. learning about sustainable development issues and sustainable practices in everyday school life.

Case study 3   Visit to Bottle Alley Glass

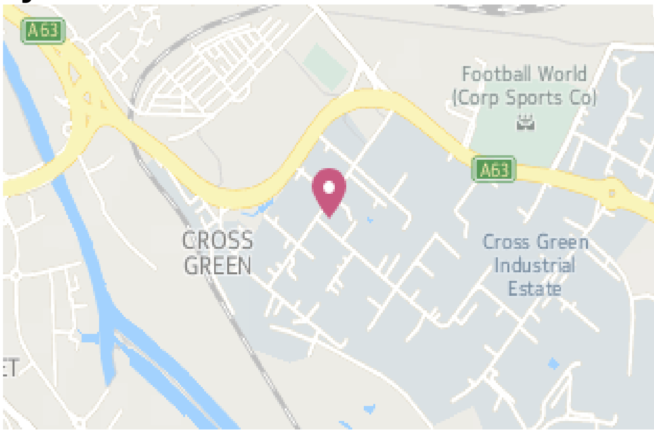


Figure 52 Alan Ash bee and daughter Phillipa. Figure 53 Map of where Bottle Alley Glass is situated. (www.bottlealleyglass.co.uk)

Background

Bottle Alley Glass LTD was set up in 2007 and started making products from recycled glass in 2012. The Yorkshire company is situated in Unit 5 Anneal Business Centre Cross Green Approach Leeds LS9 0S. Alan Ashbee and his daughter Phillipa run the small family business that take unwanted & recycled glass bottles and fuses them into glass panels suitable as worktops, splash-backs and fitted furniture. (www.bottlealleyglass.co.uk)

Alan found a niche in the market for a sustainable product. The individual solid surfaces made from hundred per cent recycled glass bottles making them fully recyclable end of life for use in commercial projects has made them marketable. Bottle Alley glasses also are energy conscious and use fused glass in energy efficient kilns (figure 57) to produce an eco-friendly products which makes their products attractive to the interior industry.

Observations.

For every tonne of recycled glass melted in the reproduction process saves approximately 315kg of Carbon Dioxide, which reduces emissions overall. Recycling of glass also reduces the demand for raw materials, as they do not have to be quarried from the landscapes, which is a huge advantage of recovering and recycling glass. It is believed that for every tonne of recycled glass used preserves 1.3 tonnes of raw materials, causing a reduction in quarrying in the UK. (www.glassrecycle.co.uk)

Figure 54 Picture of recycled glass product showing how Perfect for fabrication the counter is using traditional and modern stone masonry skills. The sustainable material enhances cradle to cradle without compromising quality. (www.bottlealleyglass.co.uk)

The UK Government's Low Carbon Action Plan named “SKA rating” is an environmental assessment method, benchmark and standard for non-domestic fit-outs SKA rating aids to assess fit-out projects against a set of sustainability good practice criteria. The SKA scheme consists of 'good practice' measures covering energy , CO_2 emissions, waste, water, materials and pollution. (www.rics.org)

Bottle Alley Glass manufacture their sheets of fused art glass to fit within the SKA scheme outlined below.

1. They make products made from 100% recycled glass.
2. The products are 100% recyclable after use. The glass can be melted down and remade into new glass products.
3. They fuse waste glass producing zero C02 emissions.
4. Their products qualify as a 'Quick Fix' under the SKA scheme.
5. Alley glass are currently working with charities and social enterprises such as Bottle Rescue in Keighley and St Nicholas Fields in York, at Bottle Alley Glass, they believe in improving the social as well as environmental impact.

On average, in the UK each household uses three hundred and thirty glass bottles per year therefore recycling rather than disposing of them would save energy . Bottle Alley Glass collect discarded waste glass bottles that normally end up in landfill from various suppliers. Some of the glass comes from bottling factories, landfill and other sources. The glass is washed, sorted into colours then de-labelled and finally crushed into cullets. The cullets are graded to size, (figure 55) and laid out on flat in trays creating patterns and designs. As cullets are all different the designs are also unique. The trays are then baked in the kilns to create sheet slabs of tough glass. Alan has experimented with weight of glass up to 260 kilos and there was no evidence of stress, making the glass a robust product.

Figure 55 Recycled Bottles and cullets of various sizes. (www.bottlealleyglass.co.uk)

Figure 56 Machine used for crushing the glass. Picture taken at interview.

Figure 57 Kiln for remoulding the glass into new products. Picture taken at interview.

Figure 58 Band saw used to cut the cooled glass into required sizes.

(www.bottlealleyglass.co.uk)

Case study 4 Paul Dyer the hand engraver

Figure 59 Image of Paul Burton Dyer photographed taken at Workshop

(Anon, 2015)

Figure 60 Map of Newport area (images@yahoo.com)

Background

Paul Dyer's workshop is based in Gwent South Wales. He attended the Central School of Arts London where he studied etching, engraving and printmaking methods. After becoming redundant from lecturing in art at Merthyr College he pursued the art of restoration engraving onto firearms for the American market. As a trade, gunsmith and hand engraver Paul Dyer specialises in repairs, modifies, designs, or rebuilds sports guns. He basically does factory level repairs, renovation such as applying metal finishes, and makes modifications and alterations for special uses. As an engraver he applies carvings, engravings and embellishments to an otherwise finished guns, jewellery and fashion accessories.

Observation

In the interview with Paul he stated that Sporting guns are costly and Purdey's or Holland and Holland can cost as much as an average house to purchase. This is not surprising as gun makers only turn out a dozen of master engraved guns each year, each one taking seven hundred to eight hundred man hours, spread over two years. Paul states in his interview "A new gun is lovely and soft to engrave, after engraving it is usually hardened unless its alloy. Old guns must be annealed in a furnace, taking steps to avoid scaling build up. It is then polished and re-cut," which suggests that not only is the process labour intensive, time consuming it has also implications for the environment.

Research on Lasers has suggested that they have become more sophisticated over the last five years producing products that are photo quality produced. The technology is becoming more affordable and some of the 3D work with animal composition and design are aesthetically worth considering lasers for engraving. Laser technology is taking hold in the engraving market as now some of the best custom made guns in the world are machine engraved. However, the best firearms and bespoke products still rely on hand engraving and traditional methods for a quality custom presentation.

Reflection

Engraving is expensive and prices can vary in both methods. An engraved item can become a work of art, valued far more for the engraving than the material beneath it. Hand engraving is traditional and uses no chemicals which is good for environment and energy consumption. However it is not hundred per cent accurate and designs have some flaws.

Laser engraving is very accurate but uses energy and chemicals to achieve an image on the surface of the metal. They are soulless and artificial looking. Hand engravers apply detail with skill and dexterity whereas the machine offers production, ensures accuracy and consistency.

So, simple economics tells us that when there is a demand for products in a quick turnover and the need becomes too great the demand will cause industry to invest in tooling to eliminate hand work and the hand worker. This is the history of the industrial revolution all over again. However the bigger the mass produced market, the more niche markets seem to thrive

The goal of the analysis of the subject in each case study provides opportunities to examine issues from multiple perspectives and then synthesize solutions. The triangulation method used aided the research and learning experience, because they involved and encouraged immediate use of newly acquired skills.

The case study of Headlands School aided the question of how the laser was utilised as a tool in schools as well as industry. The technician clarified key facts to be considered and aided the research by offering alternative ideas and aided problem solving. The technician aided by practical demonstration of complex procedures to achieve the outcomes on the sustainable materials which extended into the practice.

South Holderness aided the research by offering alternative methods of constructing a new material to what had been investigated. The experimentation of materials and processes aided the problem solving of moulding some of the materials. The technician, Alan was able to offer his practical knowledge on how materials reacted to the machinery. He was aided with recycling trends of the school and how they utilise the materials they remould into the products needed to fulfil the curriculum needs.

Bottle Glass Alley case study provided an insight into the impact of waste materials to the environment. The study also provided information on how they produced products without too much impact on the environment through government schemes and local business contributing waste materials. Ideas for new research into comparing laser engraving and sandblasting were considered after the informal interview with Alan.

Paul dyer the practitioner was able to offer a comparison of lasers and had engraving. The questions of which process offered the best outcome had its pros and cons. Paul did however suggest that hand engraving was an art that was dying due to the industrial methods and that laser produced products were substandard to the work he was producing as it had no unique qualities. He also stated that time, money and duplication factors have also played a role in the demise of the hand engraving craft as consumers want products that are mass produced quickly and cheaply. He did nevertheless feel that there was still a market for bespoke items. All the case studies aided the research by strengthen ideas and information found through prior reading of literature on each of the subjects covered in the studies. Ideas such as moulding the materials from chips rather than large waste materials and laser engraving using the faster speeds at lower power.

Chapter 6
Practice

Selection of materials

“How can **laser technology embellish** and **engrave** to create **surface marks** for recycled and sustainable materials?”

This chapter focuses on the processes of remoulding, recycling materials and embellishing the surface with laser technology. A series of experimental samples of remoulded polymers will be manufactured and then engraved, cut and marked. The first step was to use commercial manufactured and natural materials to trial the process in order to understand how to set up the machine and use the software to produce a design. Experimenting in this way aids the process of understanding the way the machine marks the surface. Manipulation of the materials and processes will be explored through practitioner experimentation and detailed documentation of all the samples will be recorded using a simple table.

A continuous action research process of reflection throughout the experimental practice of the methods used on the samples manufactured, marked, and cut will be recorded at each stage, (Dick 1997, Kurt Lewin 1947). All findings will be analysed and inserted into a table of criteria referencing the aesthetic qualities, limitations and successes.

Selection of materials

An extensive range of materials selected (figure 61) and used in this section of the research. The choice of materials for this research required consideration of aesthetic appeal, the cost to remould, life cycle assessment considerations such as material performance, availability and impact on the environment and the ability to reuse, recycle or dispose of the material at the end of its life.

The materials must be used sustainably; this means the way the material will be used in the experimentation must not compromise future use by harming the environment through processing and engraving.

Materials were sourced from the immediate environment and selected from:

1. Recycled materials
2. Materials that are in plentiful supply.

The selected materials life cycle assessment consideration was the performance and waste disposal, recycling, reuse before they impact on the environment.

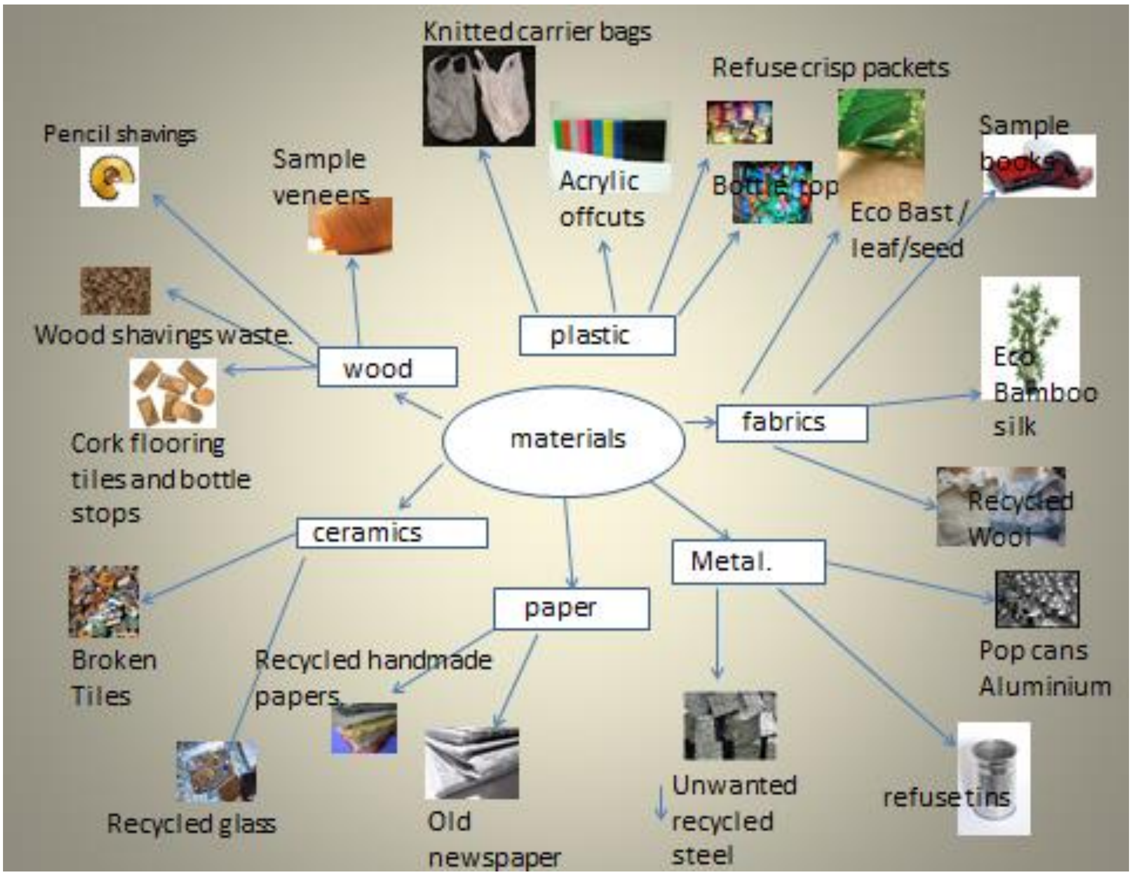


Figure 61 Mind-map of selected materials from the immediate environment to be considered for recycling, remoulding and laser processing by cutting and engraving. (Own work)

Experimentation with polymers

Handmade paper

Reconstructing, recycling fibres and polymers

Handmade paper

After experimenting on commercially made paper with the laser, the next step of the investigation was to develop surface qualities with recycled papers. The idea of processing old newspapers and other household materials into a new material came from other artists using throwaway products. At first the experimentation was simply using papers from surrounding environments such as tissue and kitchen paper. A mixture of PVA and water made into a smooth watery consistency was used to bond materials together and trap organic waste in layers.

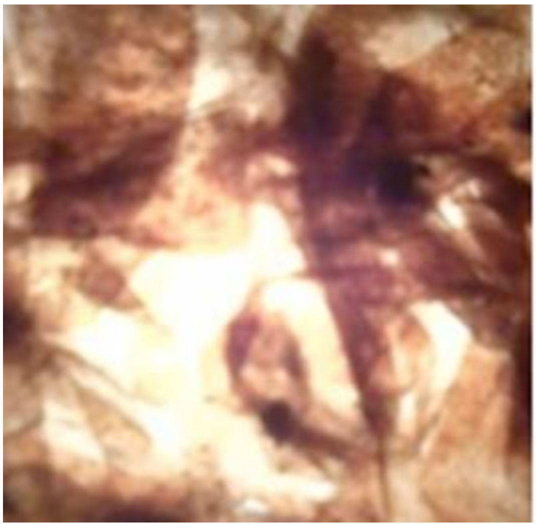
The main reason the handmade paper was produced as part of the experimentation process was to explore how the laser would react with the uneven surface. Many materials were mixed into the pulp from the surrounding environment for example bark, wood, leaves, orange peel, tea leaves and tea bags. The aim of the experimentation was to explore different surfaces using recycled fibres. The objectives of the trialling were to use a variety of materials to:

- Produce some samples with uneven surfaces.
- Experiment with a variety of materials.
- Develop ideas for further investigation.

Method 1

Organic materials and polymers

Method 1 Organic materials and polymers



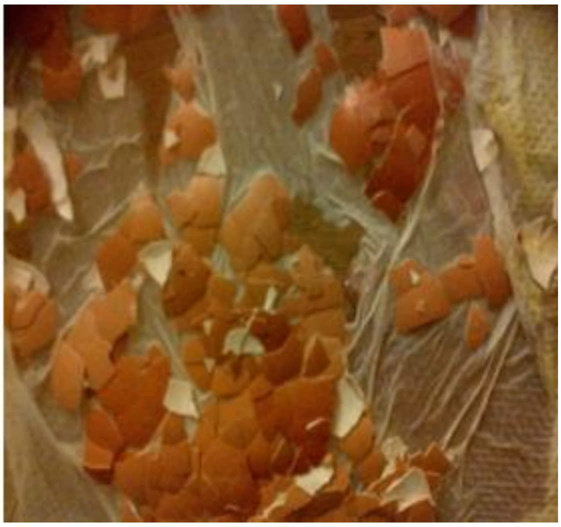


Figure 62 Left image Tea bag paper trapped between two layers of kitchen roll.

Figure 63 Right image, egg shell trapped between plastic and fibre.

Description

Figure 62 is made of a variety of different branded tea-bag paper which is a thin version of a coffee filter that comes from abaca hemp and is the strongest papermaking fibre. The plastic part of a tea bag inside aids, to seal the edges and is made from Polypropylene.

Figure 99 is constructed from budget kitchen paper brushed with a PVA and water solution over the surface. Organic waste such as broken eggshell was trapped between the sheets and a small amount of shell was added to the surface with the PVA paste to give the structure of the material an uneven surface.The kitchen towels used in this experiment were made from recycled paper pulp and is extracted from wood and fibre crops.

Thoughts and reason

The paper waste experiments were a mixture of paper and plastic as tea bags are made from paper and plastic. The bonding agent used was PVA, Polyvinyl acetate, a polymer which made it an ideal bonding agent to use with the laser as it is not combustible and has a neutral PH level. When the PVA dried, it gave a flexible and clear surface which made it an ideal choice as it gave a permanent bond and was only toxic if consumed.

The thought process behind laser engraving the organic and polymer samples was to observe how the different textures and materials react to the laser. The use of waste materials thrown away on a daily basis were incorporated to up-cycle waste to make it useful as a new product.

Analysis

The experiments used a variety of different branded tea-bags to analyse how they would produce a new material. Their original function made them a suitable choice for the experiments as the paper fibres could be easily made into a new material. As The tea-bags were collected from the waste they cost nothing and were easy to collect. Other interesting features of the tea bags such as they had plastic in their structure, were abundant and difficult to biodegrade and they had individual crushed patterns in varying shades of brown making the tea-bag an obvious choice for a restructuring material.

Evaluation

As PVA is a water-soluble polymer it was easy to use and purchase from supermarkets and art shops. The experiments found that the polymer when mixed with the water created a thin paste which could be spread thinly over surfaces. The amount of water added and how much of the solution was added to a surface determined the depth of the sample. The polymer and water solution was easy to peel off the surface when dry and had an interesting translucent quality.

A variety of different branded and shaped tea-bags were collected and dried out. The tea-bags were cut and the tea-leaves were dried and kept to be used in the manufacture of the handmade paper. The process of utilising the tea-bag paper started by ironing it flat between two sheets of grease-proof paper. The main reason for making sure the paper was flat was to make it easier to store. The paper towels had good wet strength and was able to be manipulated without tearing. The experiments with the paper towels surpassed expectations as the translucent quality made an interesting canvas for the intended laser design. This could have been due to the PVA as the water-soluble polymer becomes a translucent paste when dry.

The tea bags were difficult to bond together in their ordinary state and the more PVA added, the more the material began to lose its soft handle. It became more like a plastic product than a paper material. A strong seal was achieved when glued pieces were clamped together in the (figure 62) sample material. The clamping process trapped kitchen paper and egg shell between two steel plates covered in cling film. It was quick drying, and had very high bond strength.

Conclusion

The PVA was a useful bonding agent that could be used on the laser. As the adhesive was made up of non- combustible polymers and water, there were no issues with using it with the laser as it did not give off fume or ignite under the beam energy.

The samples produced from these experiments were strong and had interesting qualities such as translucent and textured areas. The waste eggshell did not bond well and some of the waste dislodged when handled, however the samples did produce distinct laser patterns of white over their natural colour.

However, the paper towel section surpassed expectations as the translucent quality of the material would make an interesting canvas for laser engraving of designs. The surfaces adopted from the areas they were applied to such as; patterned or smooth surfaces gave the materials a textured surface which would make an interesting experiment with the laser.The paper towels were strong and easy to manipulate and could be manufactured in batches, however the whole process was labour intensive and time consuming.

Method 2

Traditional Paper

Traditional Paper

Figure 64 Left image is a sample of organic materials with mixed paper fibre.

Figure 65 Right image is a sample of organic materials mixed with toilet paper.

Description

(Figure 64) is constructed from selected paper from recycled newspapers. The samplepaper is made from a combination of recycled matter,wood pulp, organic materials and PVA. The pulp was trapped between cling film and flattened using a rolling pin.

(Figure 65) Is manufactured from toilet tissue from 'virgin' paper and organic waste. The texture of the surface has troughs and rises with hard and soft wool like areas. The material has a delicate structure and tears when handled.

Thoughts and reasons

As consumers throw away copious amounts of organic waste which ends up in landfill and undergoes anaerobic decomposition. When the waste breaks down it releases methane gas, which causes more harmful to the environment than CO_2. This experiment aimed to restructure the waste and fibres into restructured materials that could be aesthetically appreciated as textile products.

The reason to use tissue paper and dried organic materals to restructure into a new material was that some of the original material not only producing gasses; it was using extensive amounts of resources such as water, chemicals and bleaches. Also, recycled toilet paper has its issues as it uses sodium hydroxide, (www.madehow.com) The thought was that as the materials already exist maybe they could be combined and utilised further as a product for use before having to end up in the landfill.

Analysis

The experiments intend to utilise fibres and organic materials and bond them into new materials. The products function needs to be suitable for its structure therefore making the waste into recycled paper that could have an aesthetic purpose and be further recycled aids the waste from ending up in the landfill before it is exhausted.

Handmade papers vary considerably even when processes are the same. The weight, thickness, strength, and stiffness can change the material into a different paper. During the process of making the paper, close examination of the physical characteristics needed monitoring to attempt to achieve a good quality material.

Evaluation

The paper produced was difficult to manufacture as a batch. Each paper had its own physical and aesthetic quality. Some of the papers exhibited good qualities such as stability, tear strength, weight, thickness and stiffness whereas other materials were fragile, and easy to tear. Prior chemical processing and the nature of the raw materials also contributed to the different results of the paper.

Conclusion

All of the papers produced had interesting aesthetic qualities such as colour, opacity, translucency and texture. The surfaces were uneven and some had a cotton wool like texture such as (figure 65) which was not stable and was very fragile. The mixing of organic materials with the paper pulp added texture and colour to the surface of the structured paper. Natural felts and fibres also added aesthetic qualities and bled into the materials.

As the eggshell sample did not bond well a coffee grinder was introduced to the experimental stage and the samples produced has sharp,dense grit surfaces. The sample still had same bonding issues, however, the material made with the PVA and kitchen towel had interesting aspects and further experiments were documented before laser engraving. Moreover all the pva solution experiments were found to be time consuming.

Remoulding polymers

Material collection

Material collection

The specific type of plastic for experimentation, mainly crisp packets and carrier bags were collected from the immediate environment. The crisp packets were sorted into the different types as although the inside of the packet is shiny and looks like foil, it is in fact a metallised plastic film. Whilst the film can be recycled, the difficulty lies in separating the food debris from the surface and also separating the various components of the film, before it can be recycled. This type of material is not currently recycled at the curb side as there is little environmental gain due to the energy required to recycle the material.

Figure 66 left image is a plastic chipsticks packet

Figure 67 and 68 is an image of metallised plastic film crisp packet (https://uk.images.search.yahoo.com)

When collecting and sourcing materials a sorting exercise of determining if the crisp packet was foil or metallised plastic film had to be performed. The process of crumpling the packet, and observing if a metallised plastic film will revert back to its original form. This type of plastic is not easy to recycle. However, it can be recycled into other products by being mixed and melted together into low grade blended polymer. The plastic is suitable for making pallets and roadside markers. As a hydro carbon material it is useful as a fuel to generate useful energy (http://uk.answers.yahoo.com)

Method 1

Cooking plastics using a iron, toaster and press

Method 1 Cooking plastics using a iron, toaster or press

Figure 69 Texile singer press Figure 70 Breville flat plate toaster

(Own images)

Initial experiments

The initial experiments were basic and used a domestic iron with grease-proof paper was used on a flat board. The crisps melted and shrank with an uneven bubbled surface (figure 71). The plastic bags fused well and produced a thin lace-like material which was aesthetically appealing (figure 72).

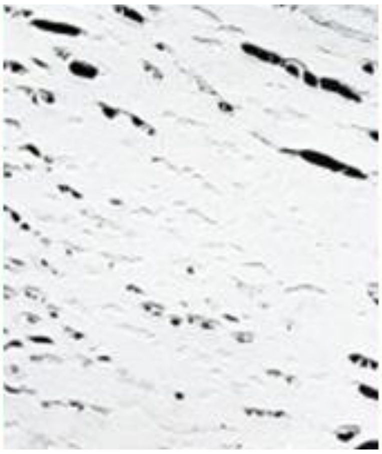


Figure 71 metallised plastic Figure 72 shopping bags. Figure 73 Oven liner

(own work, 2014)

Fume

Ventilation was important when experimenting with the plastic due to the high volume of fumes from the crisp packets and plastic bags. The odour was a mixture of residue food and melting plastic. Later in the research a textile pressing machine was used to try to minimise the fume and increase the quality of fusing the material. Experiments still had to be conducted in the open air for health and safety reasons. The issue of fume and maximising of aesthetic qualities was still a problem needing solving.

Structure

Knitted and woven structures were introduced to develop the fusing of the material together. Experimentation of different shop carriers was used and different samples were produced. The material fused well and produced a solid block of material (figure 75) The samples produced by the knitted structures were superior to the flat layered plastic fusing. One of the reasons for this could be the thickness of the plastic produced by the interlocked structures of the knitting. The quality of the material used to manufacture the bags also determined the strength, thickness and quality of the remoulded plastics. The block remoulded plastics had interesting qualities as the colours merged and blended in a pattern.

Figure 74 knitted structures. Figure 75 Melted knitted structures.(Own work, 2014)

Further Development

The crisp packets needed further development and after researching how other practitioners remoulded plastics the sandwich toaster was introduced as a process. The crisp packets still went through the initial process as previously explained. The fused packets were then shredded, cut into small chips, placed onto an oven liner and finally into a sandwich toaster to heat and cook. The temperature was set at 190° C which combined with the containment of the plastic aided to reduce the fumes in the immediate environment. The fumes were drastically reduced and the samples produced were thick, but the aesthetic qualities were good and could be used for experimenting with the laser.

Method two

Industrial Oven

Method 2 Industrial Oven

Figure 76 Industrial oven used in schools to soften and remould plastics**.**

(Own image, 2014)**.**

Experimentation with oven

This practice research found that melting plastic in an oven aids to contain the fumes of the material. This process makes it safer to be in close proximity to the material. Chipped bottle caps from milk and carbonated drink bottles melt well and range in a variety of colours. The plastic does not melt into a liquid, it basically becomes a soft malleable material which can be manipulated to form into sheets or 3D products.

Fume dangers

The fume released from crisp packets is mainly a mixture of paraffin waxes. The mixture includes very low molecular weight paraffin which releases as fume and the heavier paraffin content appears as a viscous liquid and solid. As PP is mainly paraffin, they are not as dangerous as products manufactured from PVC (www.quora.com)

Process method

The method involved the recyclable plastic being chipped with an industrial chipper and placed onto two stainless steel metal plates which were placed into a hot oven. The plastic melted between the plates and was taken out after a period of time and pressed by a mechanical, industrial press. The samples were documented and put in table form and attached in appendix 7

The process method was simple and similar to the toaster method as it simply melted chip plastic between two plates. The advantage this method had over the toaster was that it was able to manufacture larger samples and totally contain the fumes. The oven was also able to achieve higher control temperatures. The samples produced from the oven method were aesthetically the best samples produced. The surface was smooth and glass like.

Conclusion

Through experimenting with specific plastics the research has highlighted an area where melting, fusing and baking techniques to remould waste plastic could offer a greener alternative to waste plastics and the environment. It could also be a new cottage industry opportunity that could manufacture bespoke recycling products However, care would have to be taken not to overheat the plastic and cause more fumes than it would take to recover by just throwing the plastic away.

Through experimenting with plastic crisp packets the research found that the polymer chains when heated up started to get more energy and began curling. The wrapper shrinks because the polymer chains cross over each other. Ventilation through containment in an oven was possible, but care needed to be taken when using plastics that formed gasses as the build-up could become a potential hazard.

Reflection

The sample results of fusing, melting methods of processing the waste polymer demonstrates the technical feasibility of a closed loop in recycling crisp packets. The results indicated that the main physical character of the plastics is preserved showing limited material degradation during the remoulding recycling processes.

Regarding the aesthetics of the remoulded plastic, further investigation could be performed to understand the visual defects of specific manufactured crisp packets when remoulded. Further experimentation using different melting and moulding methods could be utilised such as injection moulding to make shaped products with the recycled waste materials.

This research has been limited to experimenting with specific plastics, future work could assess the economic viability, which would depend on the design industry markets williness to use and pay a reasonable price for the recycled, remoulded material and products.

Laser Experiments

Parameter experiments

Laser engraved paper and polymer

Laser engraving wood and polymer

Laser engraving plastics

Bioplastic

Parameter experiments with laser

Preliminary testing was conducted on the selected materials before engraving designs to investigate how the materials reacted under the thermal heat of the laser whilst engraving or cutting. The power and time was decreased until the structure of the material vaporised and reached its fastest time and power as shown in (figure 77) The initial parameters were selected by the lowest energy delivered at the fastest speed whilst the material is being engraved.

The materials were placed flat on the lasers work bed and secured with masking tape to ensure that there was no movement during the process. The laser head was focused set each time to the correct height for each material.

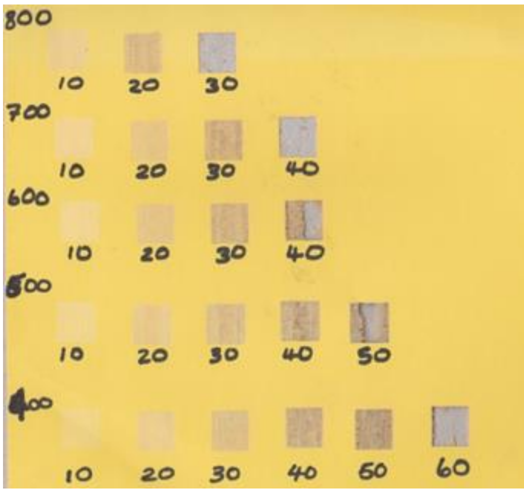


Figure 77 Initial laser engraving experimentation on commercial paper scanned used as parameter setting (own work, 2014)

Parameters were incrementally set by 10 percent, increasing each square until a visible mark was etched onto the surface of the material. A test sample as shown in (figure 77) demonstrates the range of parameter settings to cut or mark the material being engraved successfully.

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	400	10	5000	1
ENGRAVE	400	20	5000	1
ENGRAVE	400	30	5000	1
ENGRAVE	400	40	5000	1
ENGRAVE	400	50	5000	1
ENGRAVE	400	60	5000	1

FEED	POWER	PULSE	PASSES
700	10	5000	1
700	20	5000	1
700	30	5000	1
700	40	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	500	10	5000	1
ENGRAVE	500	20	5000	1
ENGRAVE	500	30	5000	1
ENGRAVE	500	40	5000	1
ENGRAVE	500	50	5000	1

FEED	POWER	PULSE	PASSES
800	10	5000	1
800	20	5000	1
800	30	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	600	10	5000	1
ENGRAVE	600	20	5000	1
ENGRAVE	600	30	5000	1
ENGRAVE	600	40	5000	1

Figure 78 Documented findings in the form of a table (own work,2014).

Through the initial experimentation, the research found that each material reacted differently to the energy impact of the laser. Therefore, before adding any marks to new materials, experimentation is needed with high speed and low power parameters so that there is less energy applied to the material (figure 78) as too much energy applied to a material can cause it to ignite.

Results obtained through the testing of the laser on the materials will be used as the basis in this research practice. Modification of process parameters (figure 78) will be needed on wood or handmade materials as they usually have different thicknesses and qualities.

Figure 79 Initial experimentation onto different surfaces documented in a scrapbook as evidence of practice. To be utilised as a visual reference to how materials react to the impact of laser engraving and cutting (Own work 2015)

Experimenting with materials and laser technology

Organic materials, engraving and cutting

Figure 80 Laser engraved suede side of the leather.

Figure 81 Laser branded image on chamois leather.

Description

(Figure 80) is a natural organic material on animal skin. Both sides of the material are suitable for engraving. On this sample the suede side of the leather has been CO2 laser marked with a bold design.

(Figure 81) sample is chamois leather which has been commercially dyed and an Image of clocks added to the surface.

Thoughts and reason

Leather is a tough material to add designs to the surface and fix permanently. It is also considered to be difficult for hand engravers as it causes early wear and tear on tools that come into direct contact with it.

The design used in (figure 80) was to observe how a solid branded mark could be achieved on the surface. (Figure 81) illustrates a fine detailed design in comparison to (figure 80) and observes how the laser reacted on the material.

Analysis

The dark area of the material is achieved by the contrast levels between the leather skin and the branding. One issue of leather is the quality of the hide meaning the lower the quality of leather the higher the levels of oil content is used in the tanning process. This means that the laser could cause a flare up during the marking process. Flare ups only lasts moments but the flame will have damaged the material and stained the material. Staining on the fabric is not very easy to remove and especially on textured organic surfaces like suede. It is important that extraction is set on high settings so that any flare up is pulled high and away from the materials to reduce or eliminate and staining of the material.

Evaluation

As the laser has a long focal setting on the delivery optics means that engraving onto large surface is possible. This ensures that the engraved mark is consistent across all the area. Leathers were easy to laser engrave and can look very similar to hot-branding. However reconstituted leather is not safe to laser engrave due to resins, glue and finishing treatments.

Although the laser does mark the skin side quite well. The energy from the laser vaporises the surface which results in the image being branded, permanent and distinctive. (Figure 81) on the chamois leather was not as successful as (figure 80) sample of leather with solid branded design. The chamois leather had burnt areas and cut through areas that needed constant parameter setting changes.

Conclusion

The experimental practice found that the laser cut edge is darker in tone than the leather surface. Deeper engraving required slower process speeds and higher power settings which caused the leather to warp. It also produced a variation in the engraving. When the laser machine extraction pulled the fumes over the top surface it created a scorched edge to the appearance of the engraving.

Variations of tone in the engraved finish did occur in different areas of the same hide. The tone, density and non-uniformed flatness of the hide had an impact on the tone. It was difficult to predict how each hide would react to the laser and every piece needed to be tested with standardised settings and modified to get the desired results. However the laser did produce a "sealed" edge.

Results

Table of results is added to appendix 9.

Reflection

Leather is a tough material to engrave by hand; however, laser-engraving and laser-cutting seemed to be able to mark, perforate, and brand a permanent design on this material easily. The laser is a good alternative to traditional methods as it does not use tools that come into contact with the material and therefore is less abrasive and problematic as it does not need to constantly employ new tools to engrave the surface.

As suede and leather are natural materials. This research found that they tend to cut with burnt marks and can ignite if the setting is too high. Therefore, this means the material needs to be tested each time a new hide is used which wastes materials, energy and is time consuming The material has other drawbacks too, as it can shrink or warp during the engraving process caused by the heat of the laser. This affects the aesthetics of the engraving and the handle of the material.

Lexmark marking on stainless steel

Figure 82 ID wizard black marking method onto waste stainless steel material. Figure 83 on the right is an aerosol can of ID Wizard used in the experiments on metal.

Description

Unknown what "type" and "grade" of stainless steel was used in (figure 82). The waste metal is in a thin sheet form. ID wizard compound added to the surface and laser engraved a simple block design.

Thoughts

CO2 laser machines cannot naturally mark onto plain metals, as the type of laser power bounces back from the metal surface. To mark on plain metals such as stainless steel, a CO2 laser machine will require a metal marking spray, tape or paste. (Figure 83) used ID Wizard marking compound to investigate how metal is marked in industry.

Analysis

The laser will not mark stainless steel in its raw state and it is not possible to achieve any depth beyond a surface marking. All metal is difficult to engrave because it is such a hard material, however there are chemical marking solutions designed to create a dark mark on the metal surface. This is a semi-permanent mark which is scratch resistant, and can give excellent results for embellishing products. Lexmark and Cermark are leading companies producing chemical compounds that can be used on metals.

Evaluation

To engrave using ID wizard, a marking compound the images needed to be converted into hundred percent black and white bitmaps with no grayscale shades. The image had to be a solid shape to make a clear black mark onto the surface of the material as the compound is not capable of recognising grayscales or tones.

The aerosol spray had some issues as the compound kept blocking the small spray hole. Careful washing of the spay mechanism needed to be done at intervals to ensure the compound sprayed onto the surface evenly. The sheet metal was sprayed at forty-five degrees with the chemical, allowed to dry and then engraved using a fifty watt unit. The power setting was approximately twenty watts and the speed was set at four hundred for a smooth finish to the design. The raster marking was the preferred method of marking bold images and vector marking on finer images.

The compound, when applied to the surface was off-beige in colour. The laser had to be set to the optimized power settings to engrave over the compound whilst marking the steel with permanent black marks. The heat and energy on the compound surface oxidised and made engraving marks, referred to as annealing.

Conclusion

As there were problems adding the compound to the surface In the experimentation the ID wizard chemical compound did not fuse correctly with the steel surface resulting in a variation in tone. Therefore, to achieve a clear image a smooth consistent application of the chemical is needed. Also the parameter setting needs to be set high and the laser needs to pass over the compound in a few passes to develop clean lines. This process can provide a very high quality finish.

Through the experiment on thin stainless steel the research found that heat from the energy of the beam can make the corners of the metal curve up making the laser loose its focus. This is because of the intense heat penetrating a thin metal. The best thickness to use is at least two millimetres.

The process of black marking on metal is labour intensive and the chemical compound has to be carefully washed off after the engraving as it is considered to be toxic. PPE of safety masks and gloves had to be worn throughout the process of applying and washing off the chemical from the metal.

Results

The results are added to appendix 9.

Reflection

The whole process is time consuming and black marking relies on the surface being cleaned of oil and debris by wire carding the metal before adding the chemical compound. Also the images need to be processed so there is no tone which means the operator has to change settings of designs in the process.

Careful handling of the compound had to be taken to ensure no chemicals were inhaled or sprayed onto operator’s hands. Plenty of ventilation was needed throughout the process and protective gloves and masks were needed. Also the extractor fan had to be on full power to take away any excess fumes.

Another drawback of the process was that the frequency of a CO2 laser was unable to cut through the stainless steel, as metal needs a very high wattage to penetrate.

Laser engraved paper and polymer

Laser engraved paper

Laser engraved paper

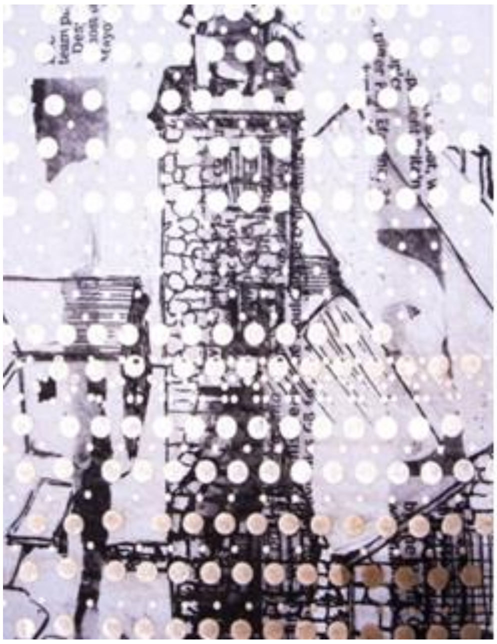


Figure 84 Photocopied drawn sketch

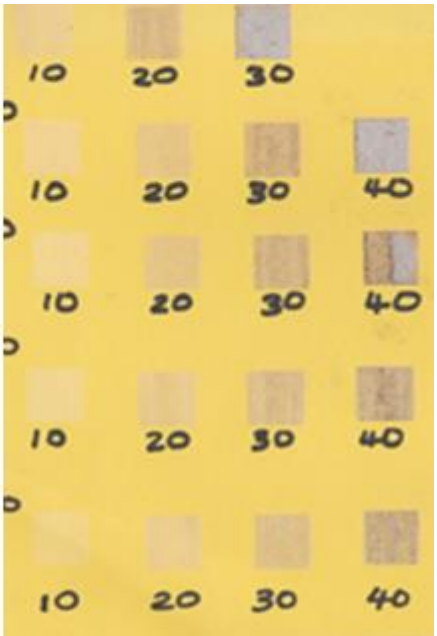


Figure 85 parameter experiment

Description

(Figure 84) is a photocopied drawn image of industrial factories onto 80g white bleached paper. The laser etched a simple dot matrix image over the surface to achieve a gold tint over the black print.

(Figure 85) demonstrates the experimentation of different power and time over the surface of coloured paper.

(Figure 89) is a commercial sandpaper coated with an abrasive to the face. In this research the sandpaper, “aluminium oxide paper", came from various sources.

(Figure 91) was sourced from Headlands school technology department sanding machine. The surface of the sanding disk paper had wood residue from pupils resistant materials projects.

(Figure 90) is a heavy paper pulp corrugated cardboard. The material consists of a fluted corrugated sheet and two flat linerboards. The corrugated medium and linerboard board both are usually over 0.01 inches, 0.25 mm thick. The surface is laser engraved with three different designs

Thoughts and reasons

Currently, there is a greater interest in the laser process as manufacturers of consumer goods are looking for new techniques and finishes to provide product differentiation. Manufacturers are looking for a machine that can do a set of applications at once; they want processes that are cost effective, efficient, reliable and fast. The idea behind these samples was to experiment with engraving techniques on different types of commercial papers in order to achieve different tones and colours that could be manipulated to imitate a printed design.

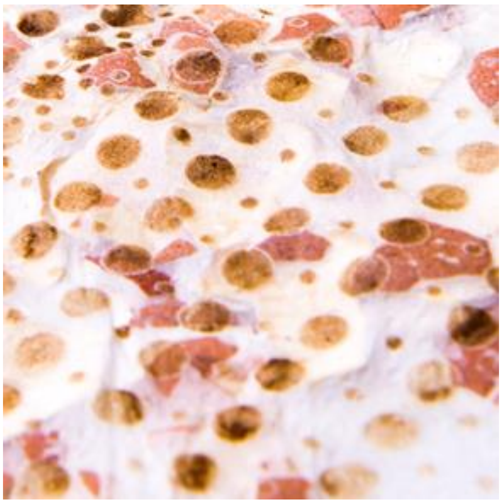


Figure 86 and 87 Laser engraving uneven surfaces.

Analysis

Paper engraves in a similar way to wood, which has a similar chemical composition so care with engraving needed to be taken with parameter settings. The mount-board has three main layers which would give the design depth, contrast and different tones due to the different materials used to make the board. However, the laser would need to be configured to only remove the top layer of paper in varying, calculated depths without damaging the reverse side of the material. Also,with the **organic samples** the laser would need to be set to the highest peak so that it did not move the material or damage the nozzle of the laser as surfaces had peaks and troughs.


Figure 88 left image of black mount board laser engraved and cut.

Figure 89 right image of two laser engraved designs on sandpaper

Evaluation

Paper and card are easy to cut due to them being relatively thin compared to other materials, even very low laser power can be used to cut paper perfectly. Varying thicknesses can also be engraved to produce interesting effects. Some colour pigments can change when laser engraves tinted paper, as the heat affects the molecules of the pigments as shown in (figure 84 and 85).

When engraving the paper is evaporated and escapes in a gaseous form, which is visible in the form of fume smoke. Paper when cut at low power and speed gives off little or no fume smoke. The residue is non-existent with no burnt edges which means the thermal load on the material is low. Configuration of the machine can be calculated to only remove the top layer of the paper in varying depths as shown in (figure 88) without damaging the reverse side of the material. Through experimenting with various depths of engraving the investigations found that it is possible to engrave deeper into the card surface, but it can make the engraving inconsistant in appearance. It also starts to compromise the board structure and make it unstable.

On standard raster engraving setting the design produced a shallow surface mark. After increasing the settings the black mount board engraved with a gold tone in contrast to the black card surface. However, vector engraving on the black mount board is very subtle in appearance to raster engraving and the result is darker and only really visible when viewed in certain lights.

A technique used to improve the contrast when laser marking was paint-fill. After engraving the design the next step would be to apply the paint with a roller to add texture to the surfaces randomly. Using a spray paint is usually the easiest method of application for paint fill and provides many colour options.

Conclusion

As shown in (figure 86 and 87) laser engraving changes the material from its original state. The laser colours the paper a subtle brown in contrast to the clean white. The laser adds a delicate relief mark on the surface as it is being scorched by the heat. The laser setting can be adjusted and the frequency to make cutting burn marks almost non-existent ensuring immaculate typography detail. Over the photocopy section the colour was a gold hue which could mean that the pigments in the dye of the print has reacted to the energy and produced a gold colour. Also the experimentation has found that variation in tone can be affected by the power distribution in engraving artwork that varies in size, this can make the engraved surface seem uneven on large surface areas.

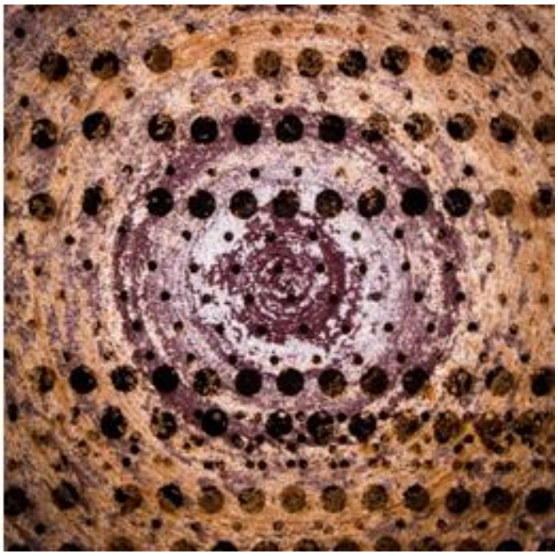


Figure 90 on left laser engraving corrugated card (own work)

Figure 91 On the right laser engraved industrial sandpaper (own work)

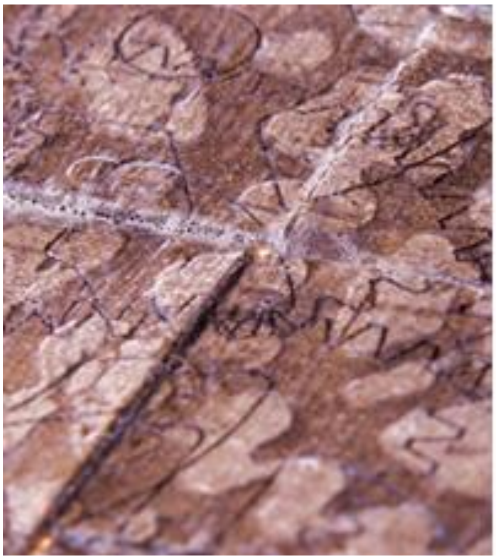
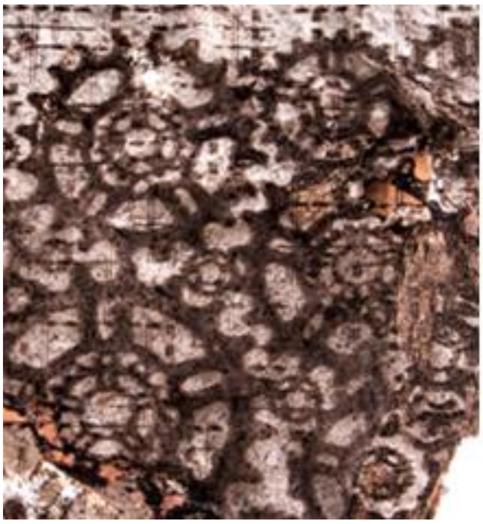
 

Figure 92 on left woven recycled grey card with vector and raster engraving.

Figure 93 on right Laser cut and engraved veneer, trapped between two layers of teabag paper (Own work)

Reflection

Careful manipulation of the parameters is needed on layered materials such as corrugated cardboard (figure 90) as the material structure could ignite if the laser beam went too slow. Power had to be set to a minimum with two passes in areas. On the recycled grey card (figure 92) laser etching was achieved by setting up, a simple step and repeat. The laser cutting systems demonstrate the precision to cut cardboard material in a manner suitable for mass production and being able to combine processes such as marking and cutting makes this material versatile. Also the process of cutting, engraving and marking of cardboards on the laser produces top quality edges with none of the deformations that occur during punching.



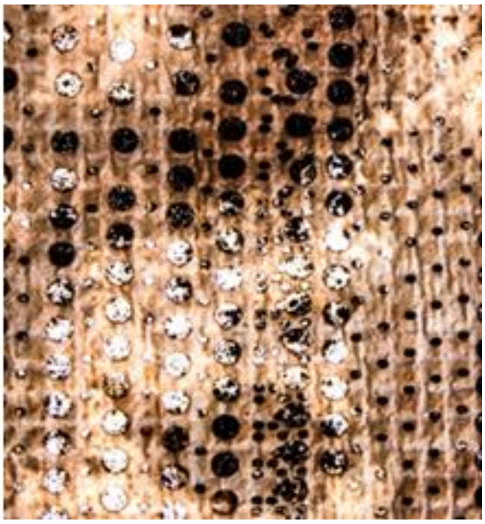
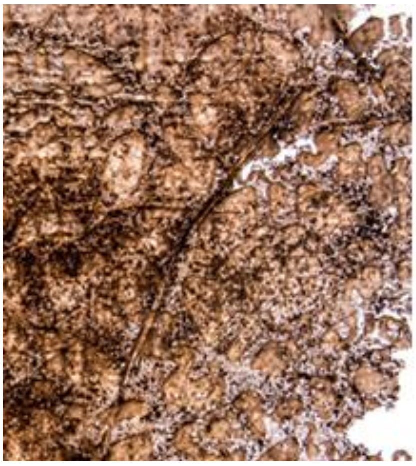


Figure 94 Traditional handmade paper with organic materials. Laser engraved with 'Cog design' (Own work).

Figure 95 Traditional handmade paper with organic materials. Laser engraved with a simple circle design (Own work).

(Figure 96) Organic materials and recycled pulp made from mixed paper such as newspaper and old reading books. Laser engraved at different speeds and power with various laser focus heights. Own work



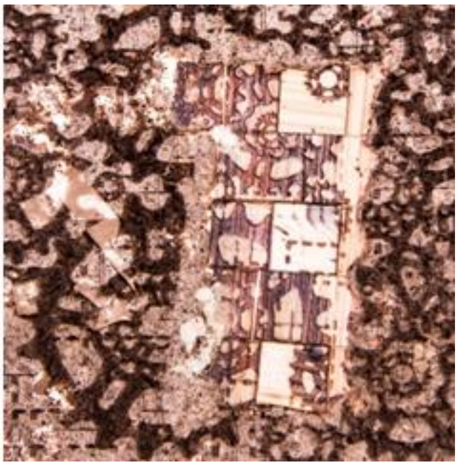


Figure 97 Layered Kitchen roll and PVA laser engraved with ‘Cog design’.

Figure 98 Veneer trapped in handmade paper engraved with ‘Cog design’

Some of the papers that were experimented on produced higher quality marks and cuts to other materials, such as recycled paper,seemed to produce less marking but higher definition than commercial papers. On a few of the papers the laser hardly marked the surface.

An issue with using commercially produced papers was that the added chemicals and dyes in papers produced fumes and the heat produced scorch marks that damaged the top surface of paper and card.

Other issues that occur when using the laser, were that marks were made on the reverse side of the paper where the laser came into contact with the honeycomb cells. Heat from the laser causes residues on the honeycomb to transfer back onto the material. To minimise this happening a lower power setting is needed, however sometimes the marks still occur on the paper.

Further developments could have been investigated with different glues and papers. The use of homemade glues and handmade paper rather than manufactured adhesives could improve results.

Laser engraving wood and polymers

Recycled veneer

Laser engraved veneers

Description

(Figure 100) reconstituted recycled wood made into a three millimetre veneer. The veneer had been dyed prior to the manufacturer cutting it for a purpose. The veneer was laser cut into two centimetre width strips by fifteen centimetres and woven into a wooden structure. The surface was laser engraved with symmetrical clock designs. The finish added at the final stage was varnish painted on with a thick brush.

(Figure 99) uses an adhesive backed vinyl plastic added to the surface and laser engraved with simple design of 'Cogs'. Raw veneer cut into strips of two centimetres by sixteen centimetres and woven into a wooden structure. Vinyl burnt into the surface in areas made an abstract design image. Varnish being applied to the surface to add protection and finish.

(Figure 101) Raw veneer 3mm in diameter woven into a wooden structure after laser engraving. Trapped in resin to protect the fragile structure.

(Figure 102) Recycled pencil shavings collected from classroom activities. Shavings was added to a solution of PVA and water in the ratio of two to one. Surface remained uneven and PVA solution dried clear. Laser engraved with clock design and cut with co2 laser successfully.

Figure 99 right image woven strips of veneer with laser engraved clocks.

Figure 100 left image of woven veneer with red vinyl plastic and laser engraved

Figure 101 left image of a woven laser etched veneer trapped in resin (Own work)

Figure 102 right image picture of PVA and wood shavings, laser etched with ‘Cog design’ (Own work)

Thoughts and reasons

After using perimeter tests laser engraving and cutting MDF using an engineered wood product, the idea was to try to utilise the wood shavings and produce an interesting surface to laser engrave onto. The fibres in MDF are combined with wax and a resin binder forming panels by applying high temperature and pressure whereas this sample was made by fusing wood shavings together with PVA and pressure.

Analysis

All wood types are excellent absorbers of CO_2 laser energy wavelength=10.6 µm. When wood absorbs the laser energy, it rapidly converts optical energy into molecular vibrations causing heat. Sufficient heat leads to rapid decomposition and combustion. Material directly in the laser path is ablated away into vapour and fine particles. The material just outside of the laser's spot or path will conduct some heat, but not enough for complete and thorough combustion and ablation. The surface quality will vary from dark, sticky to black and sooty. Some of these combustion products are water soluble, meaning the dark residue can be partially removed with water and a washcloth or plastic brush.

(www.ulsinc.com/laser-processes)

MDF is ideal for laser cutting and engraving due to its constant density and heat tolerance. However, as MDF is manufactured from natural soft wood fibres the tone, and density can vary. MDF can mark when the laser first pierces the material at the start of a closed vector shape. Another issue is that the laser produces a burnt edge which transfers onto hands when handling. MDF engraves to a pale orange to brown tone. Variation in an engraved finish and tone of wood depends on the density of softwood fibres, moisture content and by power distribution.

Cork has a fine closed cell structure and is made from the bark of the cork oak tree. The cork particles are compressed with steam with a resin binder. These binders can be flammable, so caution is needed when cutting and engraving the material. It is a non-absorbent elastic material to liquids dust or dirt.

Evaluation

As the material was uneven the laser head had to be re-adjusted throughout the laser engraving process. On uneven materials the focus height of the beam needs to be modified to ensure an even accurate engraved mark on the surface. The laser power required for wood is low. Hardwoods like walnut, oak, mahogany and maple produce good results but softwoods tend to vaporize at less-consistent depths. When laser engraving, the beam is removing or vaporizing the substrate and exposing what is underneath. Beneath the surface of solid wood products is an endless quantity of tiny veins and canal ‘Burning’, softwood with a fan blowing on it requires lowest power, quickest speed of cut, and enough airflow to extinguish what is trying to ignite. Thin specialist woods like bark weave are very difficult to engrave and constant monitoring is needed.

Whilst laser engraving some of the wood materials, there was noticeable black marks produced which soiled the surface of the materials. As part of an experiment these areas were masked out with paper masking tape as an overcoat especially on finished and resin woods so that cleanup was a matter of picking the tape off the un-engraved areas, which is easier than removing the sticky and smoky surround "halos" and requires no varnish-removing chemicals.

Cork can be a problem when engraving or cutting as it scorches and chars on the surface due to the structure and resin. This can result in brown marks surrounding the cut or engraved lines. Particularly when the laser beam first pierces the material surface at the beginning of the vector line. Deep engraving on this material can produce black fume marks which soil the surface of the material and cannot be removed. Cork absorbs light and converts it into heat, chemically vaporising the organic material. Power and speed needs to be adjusted to minimise material removal. (www.sciencedirect.com)

Laser cutting completely removes and separates material from the top surface to the bottom surface along a designated path. The edges that result from laser cutting may be darkened or charred. In general, charring and edge discoloration are proportional to material density. Thin sections of wood cut with higher power, may exhibit a brown, sticky residue which is natural from wood that can be removed or reduced with water and a soft brush. Dense sections of wood cut slowly and tend to char and cannot be cleaned easily.

Results

Results are in appendix 9.

Reflection

Through experimenting on different woods the results concluded that most wood types are easy to cut using laser technology however some present a challenge such as bark weave as it tends to smoulder and ignite due to its thin depth and the structure of its surface. Some woods have very dense and uneven grains and the result was the laser beam charred the surrounding material and did not fully cut out. Faster processing speeds are needed on thin woods and lower power setting as high power setting and low processing speeds caused the oils from the wood to be released and mark the surface. The extraction pulls the oils and fume over the surface creating a scorched edge to the appearance of the engraving.

Laser engraving plastics

Direct laser engraving on remoulded plastic

Blackmarking on plastics

Acrylic laser engraving

Bioplastics

Reflection

Direct laser engraving on remoulded polymers.

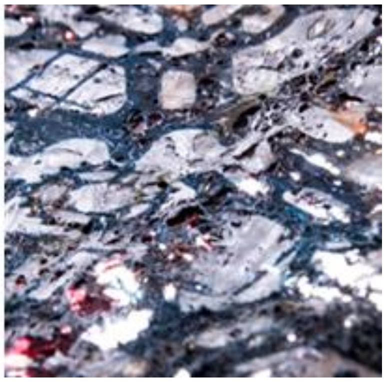
  

Figure 103 left image is plain crisp packets remoulded and laser engraved**.**

Figure 104 middle image is a variety pack remoulded and laser engraved.

Figure 105 right image is a close up of the variety pack remoulded and laser engraved.

Description.

The three samples of remoulded plastic (figure 103, figure 104) and (figure105) are remoulded plastic laser engraved at low power and high speed with a simple ‘Cogs’ design. The samples was originally waste crisp packets. The process used to remould these plastics was a long process involving an iron and steam press

Black marks on plastics

Figure 106 Fused crisp packets with plastic compound. Chemical black marked.

Figure 107 HDPE remoulded plastic parameter test

Description of the sample

(Figure 106) is a tile remoulded from plastic and aluminium foil coated with plastic film. The tile has been coated with LMC12 and clock image marked using CO2 laser. Laser cut and engraved with a clock design.

Thoughts and reason

(Figure 109) shows a black marking process used in industry on thermoplastics. The reason this research had to investigate using a chemical was for the reason of adding permanent marks onto plastic. The process of adding marks can be difficult and traditional methods like printing can easily be removed using solvents. Direct laser engraving can mark the surface with a burnt, but not a permanent black mark. Some plastics, even have to be moulded with an expensive additive to facilitate a direct mark. TherMark can offer a marking method which can produce black marks on a range of thermoplastics.

Analysis

The LMC12 TherMark process uses lasers and marking materials scientifically formulated to permanently fuse black marks onto plastics. It was originally formulated for marking glass and ceramics. Thermark the trade name offers black marks with high-contrast and high-resolution through the chemistry involved in its laser marking process.

Plastics have a lower melting point than most materials, so the pigment in the liquid is typically embedded just below the surface of the plastic rather than on top. The mark is visible on the surface. Due to the way the process works. it is also protected from damage and removal, making the mark permanent (www.thermark.com).

Figure 108 Thermark compound. Own work.

Figure 109 Thermark Compound coating on sample to be laser engraved with a fine design. Own work.

Description of the method

LMC12 is very expensive and comes as a liquid that can either be foam brushed or sprayed through an airbrush. The best method is airbrush as it generates a homogeneous coating over the substrate. The application method is more suitable for manual or batch processing. However, due to the extremely wide variety of plastic materials,laser marking materials is not consistent. Thermark have tested and found that thermoplastics were more successful at marking (www.thermark.com)

The main plastics tested with this method in this research has been HDPE and PP and both had marking to the materials. The PP marked well and gave an attractive outcome. HDPE marks were satisfactory, but the material experimented on had been re-moulded into a new shape. The surface on HDPE was pitted and uneven, the PP was smooth and flat which gave it an advantage as the laser works consistently over a flat surface.

Acrylic laser engraving

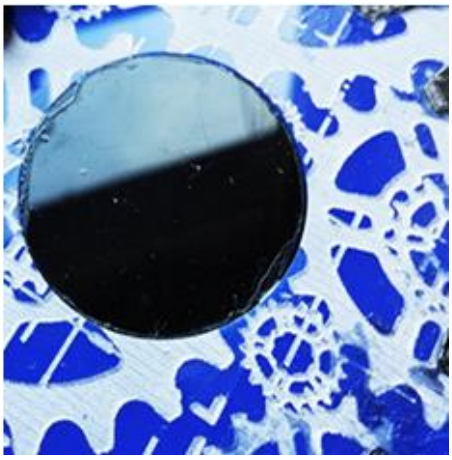


Figure 110 left image coloured cast acrylic, laser engraved and block printed with laser engraved block. Own work.

Figure 111 right image coloured cast acrylic laser cut and engraved. Polymer glue used to fuse the acrylic together. Own work.

Description

Coloured cast acrylic pieces cut and interlocked together. The surface is laser engraved with a variety of designs. Block print embellishment added as a second layer with a blue form laser engraved block. The final layer was a varnish which was applied with a thick brush. This was added to protect the printed design.

Thoughts and reasons

Standard cast acrylic plastic generally laser cut and engraves well. In fact. most schools stock acrylic as one of their preferred materials for product design on the laser because of its qualities such as durability and shiny surfaces. Experimented with laser cutting on acrylic three millimetres thick from a stockpile that would have ended up in a landfill. The process used a multiple of passes to engrave and cut through the material, allowing the power to be set low enough not to create burn marks during the process.

Analysis

Laser cutting acrylic is extremely fast, with the 'Cog' design being cut in just a few seconds**.** This resulted in a round-bottomed groove about 0.5mm deep to instantly vaporise the material, leaving hardly any burr however, there was a problem with fumes being drawn across the surface The Laser leaves a smooth, flame polished edge on which does not require any further processing. Laser cutting can also produce extremely intricate patterns due to the small diameter of the laser beam. Parameters need testing, when engraving new pieces of acrylic so that the system practices the optimum combination of depth, clarity, minimum recast and engraving speed for the material. Coloured cast acrylic also produces a nice satin white image when engraved and contrasts effectively with clear acrylic.

Evaluation

The laser was able to engrave to a deeper depth, but the edges of the large marked areas were not crisp. To correct this the laser power had to be reduced and the speed increased. It is very important to adjust only one parameter at a time when you are resetting the machine to improve the quality of your engraving. In this way, there is more control of the engraving and this aids the quality of the burn. It also aids the documentation of the changes of the settings with the experimentation. Once the optimum setting for laser engraving acrylic was achieved, the colour of the acrylic and outcome was documented in a scrapbook for future reference.

Bio-plastic

Figure 112 Bio-plastic laser engraved

Description

Figure 148 material made from a formula of corn starch, glycerine, water and vinegar with a hob method. The bio-plastic has elastic qualities and is translucent. The laser marked the surface with an opaque design.

Thoughts and reason

Fossil plastics can be marked with the laser using a chemical compound. The experiment on bio-plastic was a question of “Can the laser mark an organic material?”

Analysis

None of the materials used to manufacture the product were recycled. Consideration about the formula of the material had to be considered as there is no prior information on how bio-plastics react with heat, energy of a laser beam. The material ingredients was not combustible and natural which meant it was relatively safe to engrave and cut with laser. The only issue perceived was that a residue could possibly be produced through vaporisation of the material.

Evaluation

The material produced no visible odour or fume whilst being engraved or cut with the laser. The surface etched well and produced a clear image in white. The bubbles trapped in the material was not an issue as the laser did not mark below the surface. The laser cut through the material and left a neat edge.

Reflection

The experimentation and practice found that acrylic is easy to cut and engrave. The material is versatile, comes in a variety of colours and is relatively inexpensive. The acrylic has interesting qualities when engraved and cut such as the edges have a smooth finish when cut and the suface gains a white image.

Acrylic reacts differently to each design so testing was needed on waste material. The method needs to start from a starting point of fifty percent speed and fifty percent power with dpi set at four hundred. The laser needs to be scrutinised to make sure the design has a combination of burnt engraved areas as well as fine detail. This practice will aid the process of finding the optimum settings. Manipulation of the settings is needed if the engraved image is not satisfactory. Also, when producing a laser engraving it was found beneficial to remove the paper or plastic masking before engraving, as it is time consuming and difficult to remove the masking from an engraved piece.

This research has been searching for sustainable, recyclable materials that can be laser engraved without impacting heavily on the environment. This research has led to bio and organic materials. (Figure 112) demonstrates the possibilities of laser engraving onto bioplastics and the aesthetic qualities and characteristics that could be developed in future work. This material has similar qualities to tracing paper and through experimentation of the depth, the material has many possibilities. It could be utilised in making a material that could be joined in stitch.

The laser worked well on the surface and produced a clear image on the surface. Future experiments on coloured bioplastics can be investigated using the laser and its interaction on surfaces.

Chapter 7

Conclusion

Review of research

Identified materials

Environmental impacts of materials and products

The research has demonstrated

The gap in research

The future of Laser technology

Personal Practice research

Future work

Conclusion

The main question of the research was to investigate,

'How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?'

This research explored the concept of laser engraving and marking of sustainable materials and identified polymers as a sustainable material, that could be employed and extended further in the cradle to cradle loop. The key aspect reviewed in the literature, demonstrated that laser engraving and manufacturing of recycled polymer materials could effectively reduce the use of energy and aid reduction to the damage of the environment and life.

The purpose of this research was to understand how the laser reacted to materials, to test if it is possible to predict how a material would behave and the overall outcome of its appearance aesthetically. Knowledge of the opportunities and limitations of the laser process were gained by thoroughly investigating how the materials reacted in practice led experimentation. This led to the development of the manufacture of laser embellished waste polymers which have application for fashion and interiors.

Topic; Research, environmental impacts of materials and products as well as

investigate possibilities of mass production and limitations of the process.

During the practice experimentation with polymers some sample results demonstrated the technical feasibility of recycling the polymers by fusing and remoulding them into new sample products. The results indicated that the main physical characters of the plastics are preserved showing limited material degradation during the remoulding and recycling processes. The experimentation practice aided the development of materials with evidence documenting the effects, issues, limitations and aesthetic qualities. Images of laser cut and embellished samples were catalogued with information on processes as a reference library of materials.

Review of research

A review of historical lasers, was included which demonstrated how scientific developments had progressed over the last couple of decades. The literature also demonstrated that laser technology is the future regarding engraving, cutting and joining materials. Due to new advancements. it has possibilities for the mass production of products for fashion and textiles.

Throughout the research, there was a difficulty in sourcing specific books and papers published on sustainable materials used for product design and even less literature on laser engraving and marking organic materials. All relevant laser engraving literature was aimed at engineering. The general literature, specifically in the context of laser engraving was difficult to source and several vital questions needed answering. There are however plenty of designers and artists who have uploaded on the internet their work to share with other practitioners Practitioner findings sourced from marketing on lasers, provided an overview on how to proceed when applying embellishment to the material surface.

The research demonstrated that laser embellishment and cutting could be utilised as an alternative to devore and offered an innovative, ecological development in comparison to the traditional chemical method of ‘burn out’. Also the laser process of cutting is able to create designs similar in appearance to broderie anglaise.
Designs are easily manipulated in CAD which allows flexibility and ease of design development. The laser process allows the design to be positioned or re-positioned

at any stage of the application. Through experimentation and literature review the research found that parameters can be altered while the material is being engraved. Workload is reduced compared to traditional methods as the laser is able to cut as well as embellish in one production. The laser can etch a photo image in gradient tones, selectively remove parts of a layer to improve handling and produce a quality finish.

The case studies aided the research by strengthening ideas and information found from the prior reading of the literature on each of the subjects covered in the studies. Ideas such as remoulding the materials from chips rather than large waste materials and laser engraving using the faster speeds at lower power. The case studies aided the question of how the laser was utilised as a tool in schools as well as industry. Key facts about the impact of waste materials to the environment were clarified through the case study research by the technicians and practitioners. They also offered a comparison of similar methods and practical alternative ideas that aided problem solving.

Identified materials

Topic; ***'Identify materials from recycling sources that come from a man-made classification that could be embellished with engraving to prolong its life in the ever-changing textile industry****.'*

This research has discovered that designers need to research and source the implications surrounding their choice of materials for products; additionally take into consideration the impacts of the excavation of the material, processing and where the product ends its cycle. There is a need for designers to redesign their production systems to use fewer resources which would decrease the need for extraction. There is a realisation in design for materials to be recycled, made ecologically sustainable and developed further into new products.

The research discovered that plastic is a versatile material and that various plastics can be recycled or remade into new products. As, plastics are an important part of the UK economy and are said to make a positive contribution to the environmental profile as when they complete their phase as a product they can be recycled or incinerated for energy. Polymers, therefore, provide an important source of power and can be viewed as ‘borrowing’ the oil rather than wasting the Earth’s resources.

*Topic; ‘**Investigate, experiment and develop materials to manufacture new products out of throwaway products as well as embellish them with laser engraved images to aesthetically appeal to design markets.’***

Through personal practice and experimentation with polymers some sample results demonstrated the technical feasibility of a closed loop in recycling. The waste polymers used methods of fusing and melting to be remoulded into a new sample products. The results indicated that the main physical characters of the plastics are preserved showing limited material degradation during the remoulding and recycling processes.

Environmental impacts of materials and products

*Topi**c; Research, environmental impacts of materials** and products as well as investigate possibilities of mass production and limitations of the process*.

The advances in science and the rapid development of technology has put a strain on current natural resources of the planet. The energy needed to sustain society at the present is unsustainable, and plastics have become an important commodity in the modern lifestyle. The throwaway culture addicted to disposable plastics is likely to continue harming our environment, whether it is made out of oil or plants. The search for a sustainable material that is derived from renewable resources is on-going.

It has been shown that if properly designed, biodegradable plastics have the potential to become a preferred alternative to conventional plastics. However, biodegradable plastics will probably remain less superior than petrochemical plastics as more effort and work is needed to develop these plastics efficiently.

The research has demonstrated

The interest the laser engraving samples received at the Surface Design Show 2013 supports the trend of laser technology used on textiles. Research gathered from other practitioners, artisans, artists and designers supported using engraving for decoration, embellishment and simple production sampling. This evidence was gathered through research of fashion designers who use laser technology to cut, engrave and finish products.

The Co2 engravers through recent developments are capable of cutting material for mass production. It can cut and engrave almost any material and is a capable process that offers flexibility, precision and a high-quality non-contact cut. The laser cuts faster, is more accurate and offers finer cleaner patterns. It can make permanent marks and seal edges that give the fabric a better handle and more sophisticated look The process can also engrave a variety of materials such as steel, titanium, paper, wood, leather, wax fabrics and most plastics. It is also less destructive to the environment as it does not need chemical finishing or disposal of print pastes. However, there are a few drawbacks to this process such as the laser is unable to engrave or cut reflective materials, it is highly conductive moreover it is unable to cut through the stainless steel.

Topic; Research, *environmental impacts of materials and products as well as* ***investigate possibilities of mass production and limitations of the process.***

The limitations of the materials used in this research practice have been due to the materials having different depths and uneven qualities. Speeds and power parameters had to be constantly modified throughout the laser engraving of the materials and some of the materials needed chemical compounds to black mark on the surface.

The research also discovered that laser engraving material such as low quality glass with metal is considered difficult, nevertheless it is still considered ideal for adding images to the surface as it is faster, less expensive and more flexible than methods such as sandblasting.

The gap in research

One development made through this research was the remoulding and marking of plastics with laser technology. The marking of plastics that are currently not recycled at the curbside were remoulded through an oven and press method to produce a new product. This has opened up possible opportunities for re-using and recycling crisp packets instead of them being a single use they could be utilised as part of the recycling loop.

There were limitations with remoulding the polymers and there were difficulties engraving the surfaces. A compound for black marking had to be used to add an engraved mark to the surface. Power settings needed constant modifying when engraving due to the varying material qualities. This made engraving very time consuming. The materials also were too deep in depth to cut and the plastic melted under the energy beam which meant it was unsafe to cut as it was leaving a sticky residue on the lens.

The future of laser technology

Due to technological advancements, the laser market is expected to increase with a significant growth in demand for different types of lasers used in material laser processing. Lasers have changed drastically since the first Maser, they have reduced laser size, high wall plug efficiency, low power consumption, cost less to buy and maintain. However, (Bosman, 2015) suggests that companies need to co-operate with each other to speed the development towards mass product customisation and for laser decoration to replace other techniques in textiles. The laser systems for future decorative applications need to have the capability of delivering three wavelengths simultaneously, in combination with short pulse widths to aid colour flexibility.

Personal practice research

Topic; Investigate how sustainable materials, combinations of methods such as laser engraving with print, react to the impact of the laser beam.

This practice aimed to push the boundaries of materials and application, by using remoulded materials and laser engraving to mark the surface to break further the preconception of textiles in the traditional approach. Textile processes such as knitting, weaving, stitch and print were combined with a variety of materials not normally associated with textiles. Embellishment through laser engraving was explored as a decorative method to the surface of the combined, constructed structures.

The methods of the laser technology that were used in the practice to create engraved and black marked, sample products. Exploring research through practice has given the research opportunities to develop ideas and allow time for greater analysis of design decisions. Reflection through this approach permitted design development to be thorough and aided instrumental planning of the delivery of future research and delivery. Also relevant feedback from entering exhibits of working research practice samples at the London Surface Pattern Show on the Huddersfield stand acted as a process for knowledge dissemination, an opportunity to question possible customers on the materials as well as enable learnt experiences to be shared and reflection to take place.

Future work

This research expectation is to aid the teaching of the findings and methods to art and design students in the technology curriculum in schools. This would aid students to understand laser processing and material behaviour before becoming undergraduates. Future research could take place at colleges, secondary schools as topic days where laser demonstrations and organised exhibitions of the documentation and artefacts could be displayed and discussed.

Also for future development this research and practice has identified a need for a range of materials for engraving that give pure and bright colours, real white, and black. This gap in colouring designs with the laser could be researched into further by experimenting with dyes, compounds and a range of multi-coloured laser engraved and finished plastic recycled and organic materials as a the product could be manufactured to take the place of print techniques. Also, research into combination of pigments, dyes, additives and compounds which give a certain normal colour with laser engraving could be explored

As a designer, practitioner, educator, I realise the need to consider sustainability and the three R's- reduce, reuse, recycle, in my work. It has become more of a focus since completing this research. In future research I will need to create products with aesthetic qualities such as bioplastics and organic materials and polymers that have the capability to be recycled with the laser. So the next step in the research hopes to build on the gathered information on how plastics function and planning will involve adapting and moulding the materials into 3D engraved products for fashion using textile techniques and product design processes.

Regarding the aesthetics of the remoulded plastic, further investigation could be performed to understand the visual defects of specific manufactured crisp packets when remoulded. Further experimentation using different melting and moulding methods could be utilised such as injection moulding to make shaped products with the recycled waste materials. This research has been limited to experimenting with specific plastics, the future investigation, could assess the economic viability, which would depend on the design industry markets willingness to use and pay a reasonable price for the recycled remoulded material and products.

Furthermore, developments could extend the range of designs added to the moulded, fused and shaped products. Experimentation with scale in relation to the application and end use. Thin polymer structures could be made into lace-like jewellery and other polymers could be moulded into bracelets and attachments to adorn dresses. Also, research through consulting with businesses, material companies and fashion designers about aesthetics of materials and trends could be further investigated.

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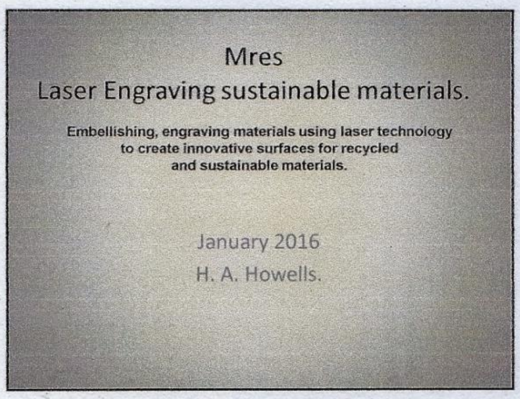
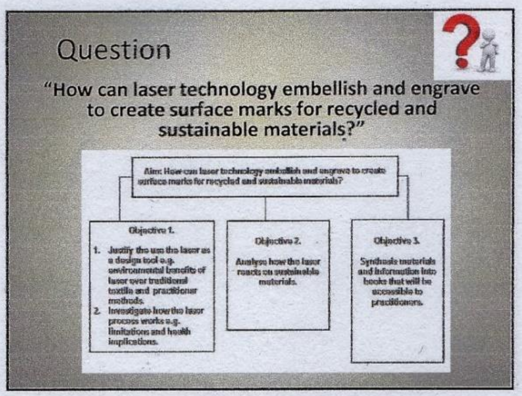
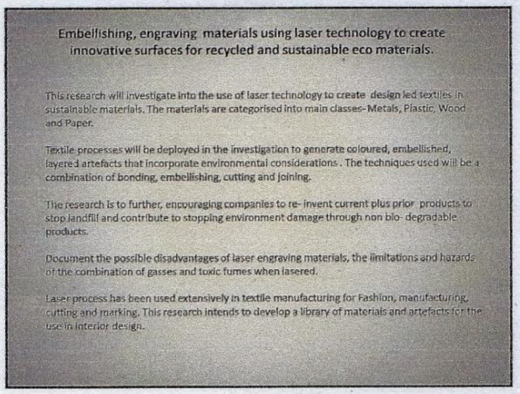
Appendix

Appendix 1

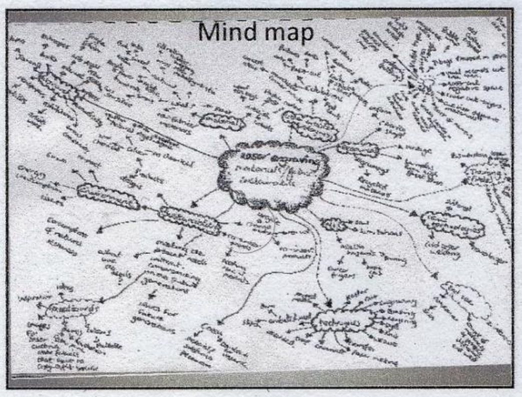
Power-point

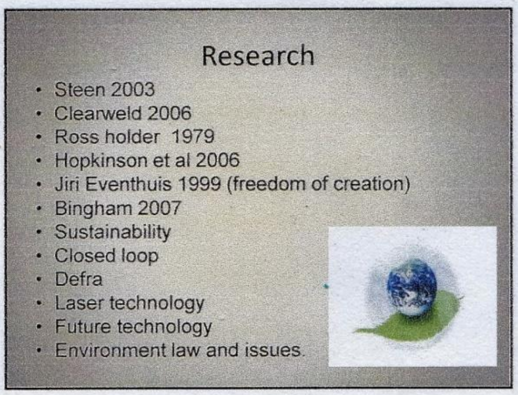

Mres
Laser Engraving sustainable materials.
Embellishing, engraving materials using laser technology to create innovative surfaces for recycled and sustainable materials.
January 2016
H. A. Howells.

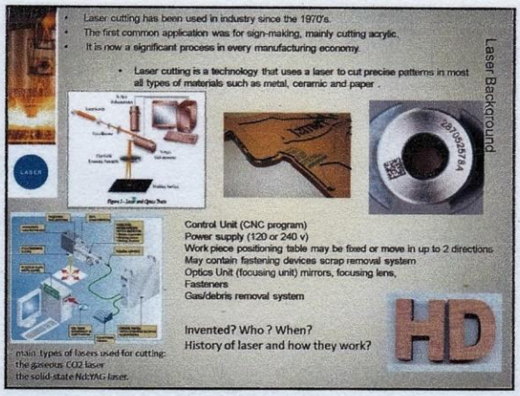

Question
"How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?"
Aim: How can laser technology embellish and engrave to create surface marks for recycled and sustainable materials?
Objective 1.
1. Justify the use the laser as a design tool e.g. environmental benefits of laser over traditional textile and practitioner methods.
2. Investigate how the laser process works e.g. limitations and health implications.
Objective 2.
Analyse how the laser reacts on sustainable materials.
Objective 3.
Synthesis materials and information into books that will be accessible to practitioners.

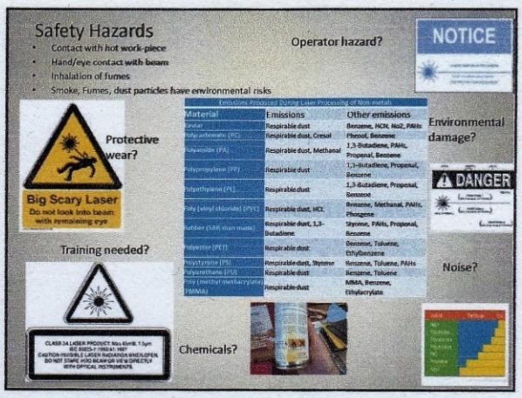

Embellishing, engraving materials using laser technology to create innovative surfaces for recycled and sustainable eco materials.
This research will investigate into the use of laser technology to create design led textiles in sustainable materials. The materials are categorised into main classes- Metals, Plastic, Wood and Paper.
Textile processes will be deployed in the investigation to generate coloured, embellished, layered artefacts that incorporate environmental considerations . The techniques used will be a combination of bonding, embellishing, cutting and joining.
The research is to further, encouraging companies to re- invent current plus prior products to stop landfill and contribute to stopping environment damage through non bio- degradable products.
Document the possible disadvantages of laser engraving materials, the limitations and hazards of the combination of gasses and toxic fumes when lasered.
Laser process has been used extensively in textile manufacturing for Fashion, manufacturing, cutting and marking. This research intends to develop a library of materials and artefacts for the use in interior design.

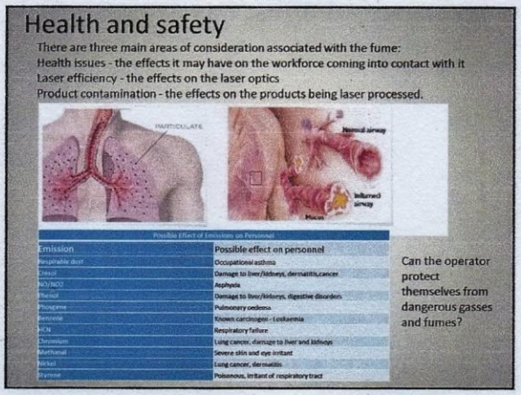

Key Words
• Sustainability
• Engraving
• Trapping / layering
• Reform / redesign
• Bonding
• Laser cut/ raster/ etch.
• Surface re-structure
• Embellishment
• Up-cycle.
ECO FRIENDLY
Reduce – Reuse – Recycle

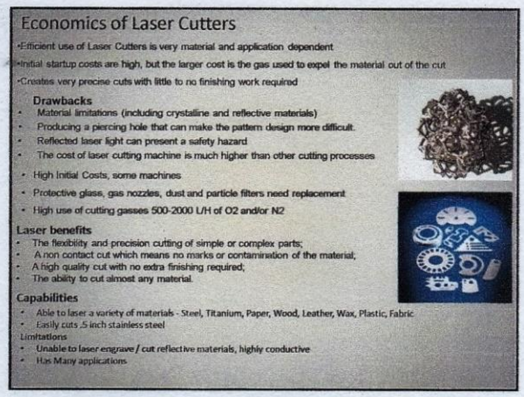

Mind map

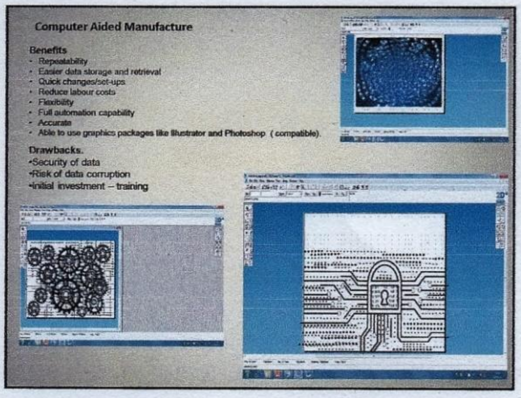

Research
• Steen 2003
• Clearweld 2006
• Ross holder 1979
• Hopkinson et al 2006
• Jiri Eventhuis 1999 (freedom of creation)
• Bingham 2007
• Sustainability
• Closed loop
• Defra
• Laser technology
• Future technology
• Environment law and issues.

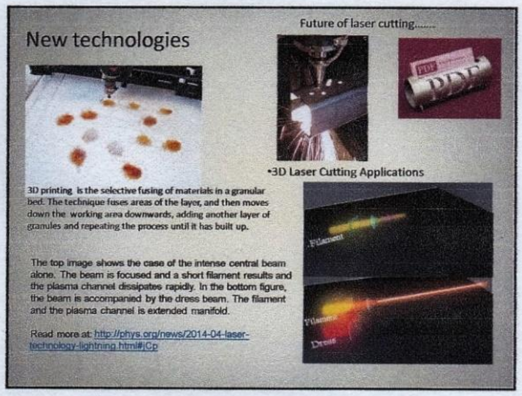

Laser cutting has been used in industry since the 1970's.
The first common application was for sign-making, mainly cutting acrylic.
It is now a significant process in every manufacturing economy.
Laser cutting is a technology that uses a laser to cut precise patterns in most all types of materials such as metal, ceramic and paper .
Laser Background
LASER
287052578A
Control Unit (CNC program)
Power supply (120 or 240 v)
Work piece positioning table may be fixed or move in up to 2 directions
May contain fastening devices scrap removal system
Optics Unit (focusing unit) mirrors, focusing lens,
Fasteners
Gas/debris removal system
Invented? Who ? When?
History of laser and how they work?
HD
main types of lasers used for cutting:
the gaseous CO2 laser
the solid-state Nd:YAG laser.

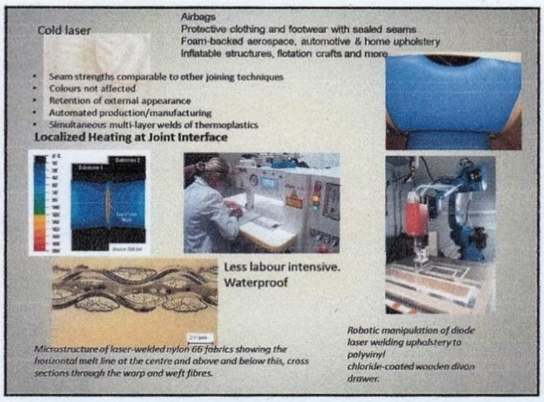

Safety Hazards
Contact with hot work-piece
Hand/eye contact with beam
Inhalation of fumes
Smoke, Fumes, dust particles have environmental risks
Operator hazard?
NOTICE
Protective wear?
Big Scary Laser
Do not look into beam with remaining eye
Training needed?
Material
Emissions
Other emissions
Respirable dust
Benzene, HCN, No2, PAHs
Respirable dust, Cresol
Phenol, Benzene
Respirable dust, Methanal
1,3-Butadiene, PAHs, Propenal, Benzene
Respirable dust
1,3-Butadiene, Propenal, Benzene
Respirable dust
1,3-Butadiene, Propenal, Benzene
Respirable dust, HCL
Benzene, Methanal, PAHs, Phosgene
Respirable dust, 1,3-Butadiene
Styrene, PAHs, Propenal, Benzene
Respirable dust
Benzene, Toluene, Ethylbenzene
Respirable dust, Styrene
Benzene, Toluene, PAHs
Respirable dust
Benzene, Toluene
Respirable dust
MMA, Benzene, Ethylacrylate
Environmental damage?
DANGER
Noise?
Chemicals?

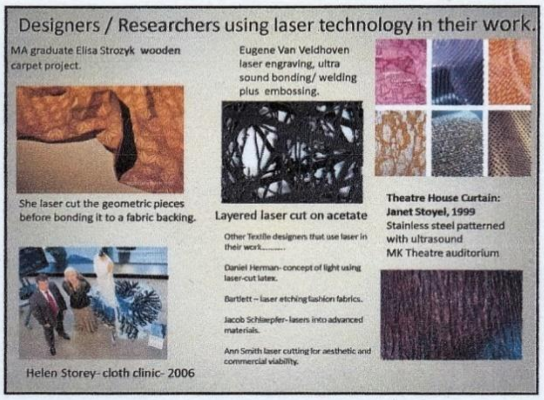

Health and safety
There are three main areas of consideration associated with the fume:
Health issues - the effects it may have on the workforce coming into contact with it
Laser efficiency - the effects on the laser optics
Product contamination - the effects on the products being laser processed.
PARTICULATE
Inflamed airway
Mucus
Emission
Possible effect on personnel
Occupational asthma
Damage to liver/kidneys, dermatitis,cancer
Asphyxia
Damage to liver/kidneys, digestive disorders
Pulmonary oedema
Known carcinogen - Leukaemia
Respiratory failure
Lung cancer, damage to liver and kidneys
Severe skin and eye irritant
Lung cancer, dermatitis
Poisonous, irritant of respiratory tract
Can the operator protect themselves from dangerous gasses and fumes?


Economics of Laser Cutters
•Efficient use of Laser Cutters is very material and application dependent
•Initial startup costs are high, but the larger cost is the gas used to expel the material out of the cut
•Creates very precise cuts with little to no finishing work required
Drawbacks
Material limitations (including crystalline and reflective materials)
Producing a piercing hole that can make the pattern design more difficult.
Reflected laser light can present a safety hazard
The cost of laser cutting machine is much higher than other cutting processes
High Initial Costs, some machines
Protective glass, gas nozzles, dust and particle filters need replacement
High use of cutting gasses 500-2000 L/H of O2 and/or N2
Laser benefits
The flexibility and precision cutting of simple or complex parts;
A non contact cut which means no marks or contamination of the material;
A high quality cut with no extra finishing required;
The ability to cut almost any material.
Capabilities
Able to laser a variety of materials - Steel, Titanium, Paper, Wood, Leather, Wax, Plastic, Fabric
Easily cuts .5 inch stainless steel
Limitations
Unable to laser engrave / cut reflective materials, highly conductive
Has Many applications


Computer Aided Manufacture
Benefits
Repeatability
Easier data storage and retrieval
Quick changes/set-ups
Reduce labour costs
Flexibility
Full automation capability
Accurate
Able to use graphics packages like Illustrator and Photoshop (compatible).
Drawbacks.
•Security of data
•Risk of data corruption
•initial investment – training

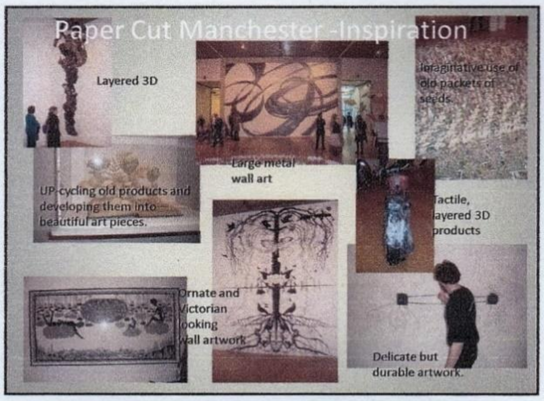

New technologies
Future of laser cutting.......
PDF
•3D Laser Cutting Applications
3D printing is the selective fusing of materials in a granular bed. The technique fuses areas of the layer, and then moves down the working area downwards, adding another layer of granules and repeating the process until it has built up.
The top image shows the case of the intense central beam alone. The beam is focused and a short filament results and the plasma channel dissipates rapidly. In the bottom figure, the beam is accompanied by the dress beam. The filament and the plasma channel is extended manifold.
Read more at: http://phys.org/news/2014-04-laser-technology-lightning.html#jCp
Filament
Filament
Dress


Cold laser
Airbags
Protective clothing and footwear with sealed seams
Foam-backed aerospace, automotive & home upholstery
Inflatable structures, flotation crafts and more
Seam strengths comparable to other joining techniques
Colours not affected
Retention of external appearance
Automated production/manufacturing
Simultaneous multi-layer welds of thermoplastics
Localized Heating at Joint Interface
Less labour intensive.
Waterproof
Microstructure of laser-welded nylon 66 fabrics showing the horizontal melt line at the centre and above and below this, cross sections through the warp and weft fibres.
Robotic manipulation of diode laser welding upholstery to polyvinyl
chloride-coated wooden divan drawer.

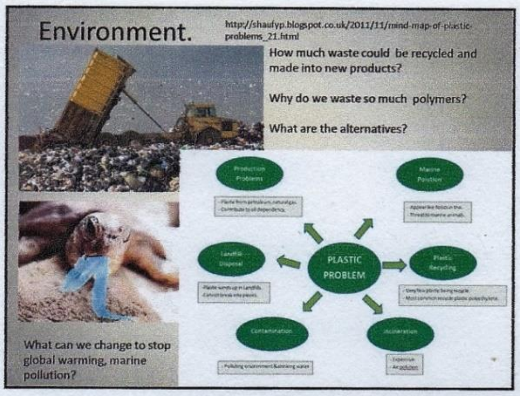

Designers / Researchers using laser technology in their work.
MA graduate Elisa Strozyk wooden carpet project.
Eugene Van Veldhoven laser engraving, ultra sound bonding/ welding plus embossing.
She laser cut the geometric pieces before bonding it to a fabric backing.
Layered laser cut on acetate
Theatre House Curtain:
Janet Stoyel, 1999
Stainless steel patterned with ultrasound
MK Theatre auditorium
Other Textile designers that use laser in their work.........
Daniel Herman- concept of light using laser-cut latex.
Bartlett – laser etching fashion fabrics.
Jacob Schlaepfer- lasers into advanced materials.
Ann Smith laser cutting for aesthetic and commercial viability.
Helen Storey- cloth clinic- 2006


Setting the scene
Industrial Revolution
Old - New technologies
Recycle
Techno and Cyber-punks
Steam Punk
Techno
Wall tiles- interior design

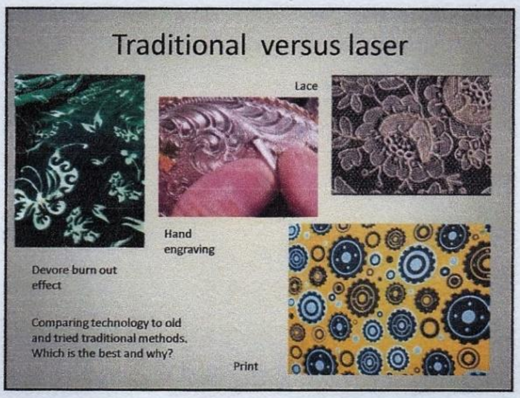

Shows and Exhibitions
Interior Trade show
Patchwork devore
Up-cycling old uniforms and hats to make a new product.
Ideal homes Exhibition
Recycling and up cycling project.
Homeless project in your pocket?
Re-using old artwork, techniques as artwork.
Knit and Stitch Show
Glass images
Tactile , layered imagery
Up-cycling products to become art pieces.
Using every day products.
Alex May Gallery

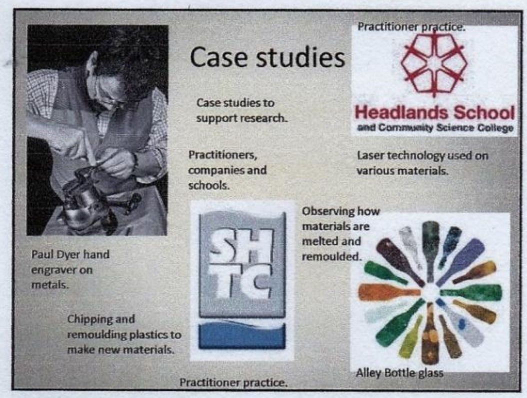

Paper Cut Manchester -Inspiration
Layered 3D
Imaginative use of old packets of seeds
Large metal wall art
UP-cycling old products and developing them into beautiful art pieces.
Tactile, layered 3D products
Ornate and Victorian looking wall artwork
Delicate but durable artwork.


SURFACE DESIGN SHOW
BUSINESS DESIGN CENTRE
LONDON — 4-6 FEB 2014
www.surfacedesignshow.com
Is there a need for my research?
What products are the customers buying and what is already on the market?
Visits to various trade shows for inspiration and research.
Future Thinking

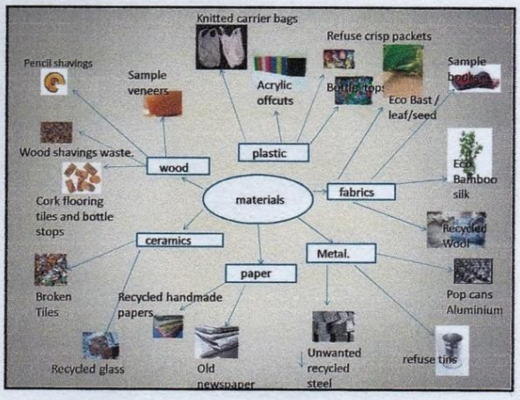

Environment.
http://shaufyp.blogspot.co.uk/2011/11/mind-map-of-plastic-problems_21.html
How much waste could be recycled and made into new products?
Why do we waste so much polymers?
What are the alternatives?
PLASTIC PROBLEM
What can we change to stop global warming, marine pollution?


Up-cycling
Taking old and discarded materials and transforming them into one-of-a-kind designs. This up-cycled outfit by Janet Lee & Lorraine Kwan is a brilliant example. It's called Candy Carousel and it's made out of plastic food lids.
In 2004 Veronika Richterová discovered that plastic bottles could be manipulated by heat. She decided to create a plastic bottle sculpture and call it PET art. She has up-cycled thousands of plastic bottles and created hundreds of plastic bottle sculptures.
http://www.upcyclethat.com/


Traditional versus laser
Lace
Hand engraving
Devore burn out effect
Comparing technology to old and tried traditional methods. Which is the best and why?
Print

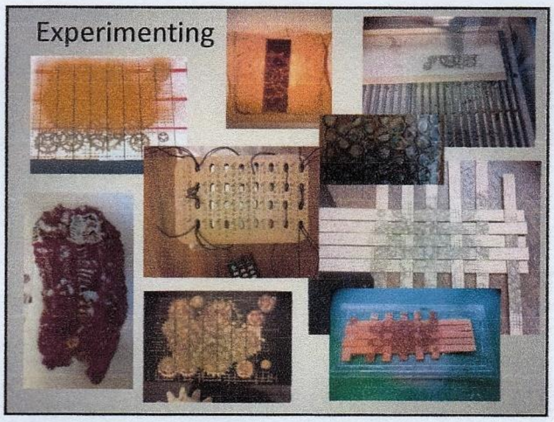

Case studies
Practitioner practice.
Headlands School
and Community Science College
Case studies to support research.
Practitioners, companies and schools.
Laser technology used on various materials.
Observing how materials are melted and remoulded.
Paul Dyer hand engraver on metals.
Chipping and remoulding plastics to make new materials.
Practitioner practice.
Alley Bottle glass

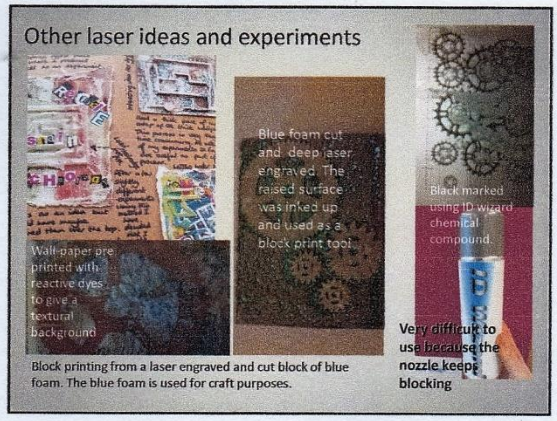

Ideas
Paper - Tea bags- corn based, paper and plastic coated. Different shapes, sizes , flavours.
Handmade Paper- trapping wood, tea-bags, twigs, leaves
Shells- egg shells trapped in paper
Crisp bags / plastic bags - plastics
Video tape- knitted / woven, melted and transfer printed on.
Cassette tape knitted, woven, printed on.
New materials – organics – bamboo silk
Recycled glass- Leeds company.

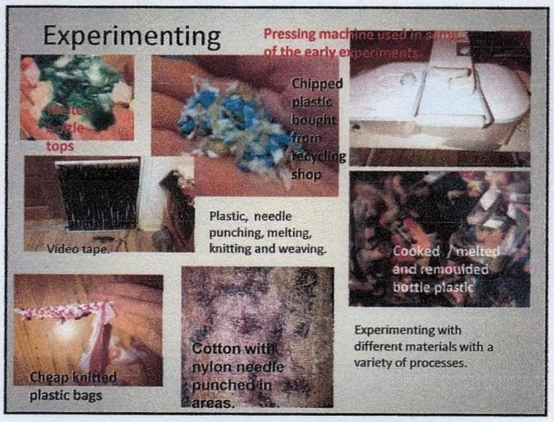

Knitted carrier bags
Refuse crisp packets
Pencil shavings
Sample veneers
Acrylic offcuts
Bottle tops
Eco Bast / leaf/seed
Wood shavings waste.
wood
plastic
materials
fabrics
Eco Bamboo silk
Cork flooring tiles and bottle stops
ceramics
Metal.
paper
Recycled Wool
Broken Tiles
Recycled handmade papers
Pop cans Aluminium
Recycled glass
Old newspaper
Unwanted recycled steel
refuse tins


Sample materials from waste.
Egg shells trapped in kitchen paper . Pva glue produced a transparent material.
Trapped cut up tea-bag edges in kitchen paper with PVA glue.
Egg shells, flower petals etc. trapped in handmade paper.
Handmade paper with orange peel. Orange peel made discoloured areas.
Trapped garden waste. Leaves, seeds, flower tops etc. They were trapped in layers of handmade paper made from old bill statements

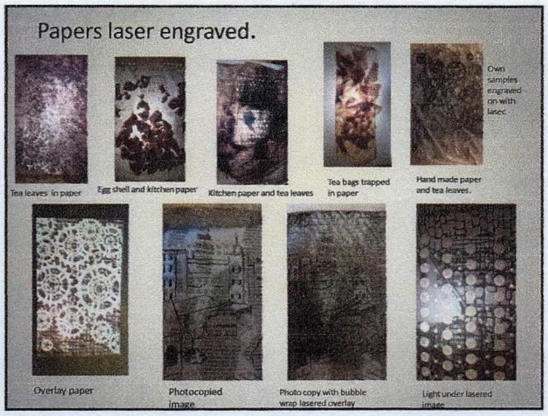

Plastic sample materials
Bubble wrap
Knitted, melted, heated , chopped into chips and ironed.
Crisp packets
Melted plastic bags
Bottle tops chipped and remoulded together.
Plastic packaging
Various classes of plastics processed, remoulded and manipulated to produce new materials for use with the laser.

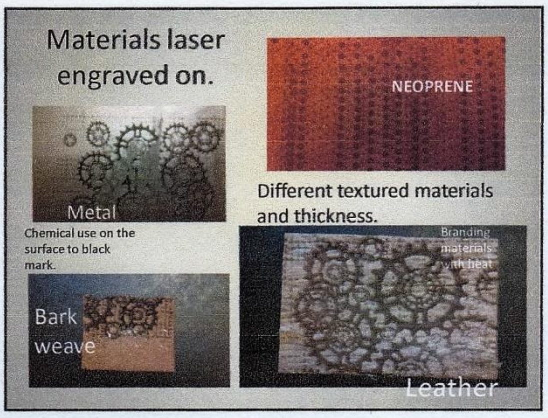

Experimenting

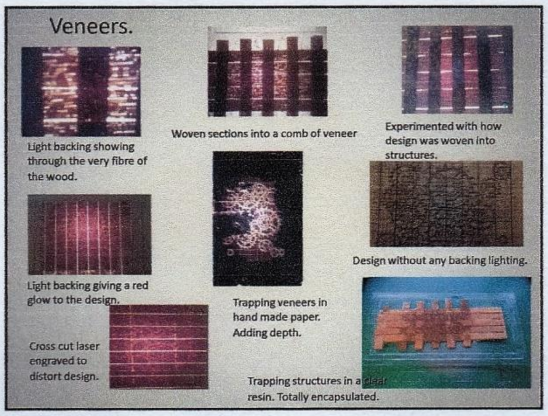

Other laser ideas and experiments
Blue foam cut and deep laser engraved. The raised surface was inked up and used as a block print tool.
Black marked using ID wizard chemical compound.
Wall-paper pre printed with reactive dyes to give a textural background
Block printing from a laser engraved and cut block of blue foam. The blue foam is used for craft purposes.
Very difficult to use because the nozzle keeps blocking

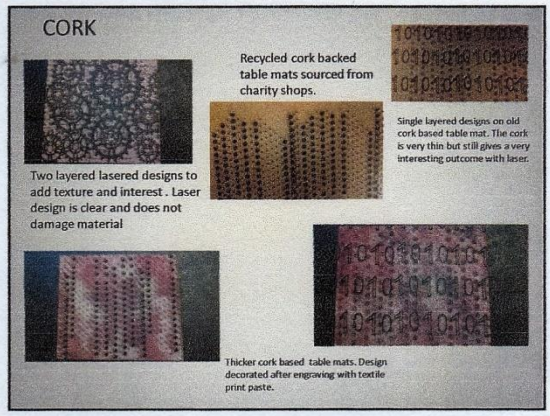

Experimenting
Chipped plastic bought from recycling shop
Video tape.
Plastic, needle punching, melting, knitting and weaving.
Cooked / melted and remoulded bottle plastic
Cheap knitted plastic bags
Cotton with nylon needle punched in areas.
Experimenting with different materials with a variety of processes.

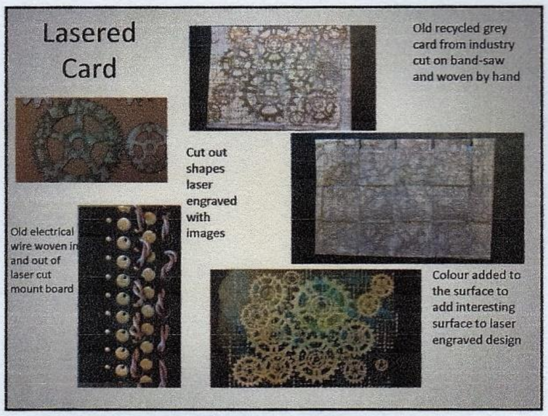

Accidents / problems and limitations
Any issues or problems encountered with processes.

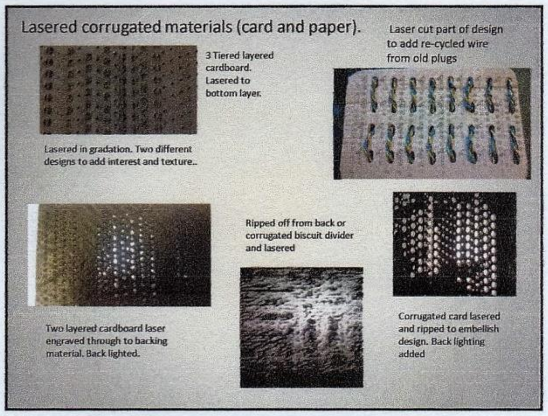

Papers laser engraved.
Own samples engraved on with laser.
Tea leaves in paper
Egg shell and kitchen paper
Kitchen paper and tea leaves
Tea bags trapped in paper
Hand made paper and tea leaves.
Overlay paper
Photocopied image
Photo copy with bubble wrap lasered overlay
Light under lasered image


Materials laser engraved on.
NEOPRENE
Metal
Chemical use on the surface to black mark.
Different textured materials and thickness.
Branding materials with heat
Bark weave
Leather


Veneers.
Light backing showing through the very fibre of the wood.
Woven sections into a comb of veneer
Experimented with how design was woven into structures.
Design without any backing lighting.
Light backing giving a red glow to the design.
Trapping veneers in hand made paper. Adding depth.
Cross cut laser engraved to distort design.
Trapping structures in a clear resin. Totally encapsulated.


CORK
Recycled cork backed table mats sourced from charity shops.
Single layered designs on old cork based table mat. The cork is very thin but still gives a very interesting outcome with laser.
Two layered lasered designs to add texture and interest . Laser design is clear and does not damage material
Thicker cork based table mats. Design decorated after engraving with textile print paste.


Lasered Card
Old recycled grey card from industry cut on band-saw and woven by hand
Cut out shapes laser engraved with images
Old electrical wire woven in and out of laser cut mount board
Colour added to the surface to add interesting surface to laser engraved design


Lasered corrugated materials (card and paper).
3 Tiered layered cardboard. Lasered to bottom layer.
Laser cut part of design to add re-cycled wire from old plugs
Lasered in gradation. Two different designs to add interest and texture..
Ripped off from back or corrugated biscuit divider and lasered
Two layered cardboard laser engraved through to backing material. Back lighted.
Corrugated card lasered and ripped to embellish design. Back lighting added

Appendix 2

How to operate the Laserite L10060

How to operate the Laserite L10060.

Open the lid and place material in cutter, firmly against the upper right hand side at 90- degree reference stop (home). Set the laser head to correct depth e.g. so that the laser comfortable glides over the top of the material without touching it.

Image taken in practice of the laser bed.

The laser head should be in its HOME position (as shown) before cutting or engraving takes place. This is mainly for good practice.

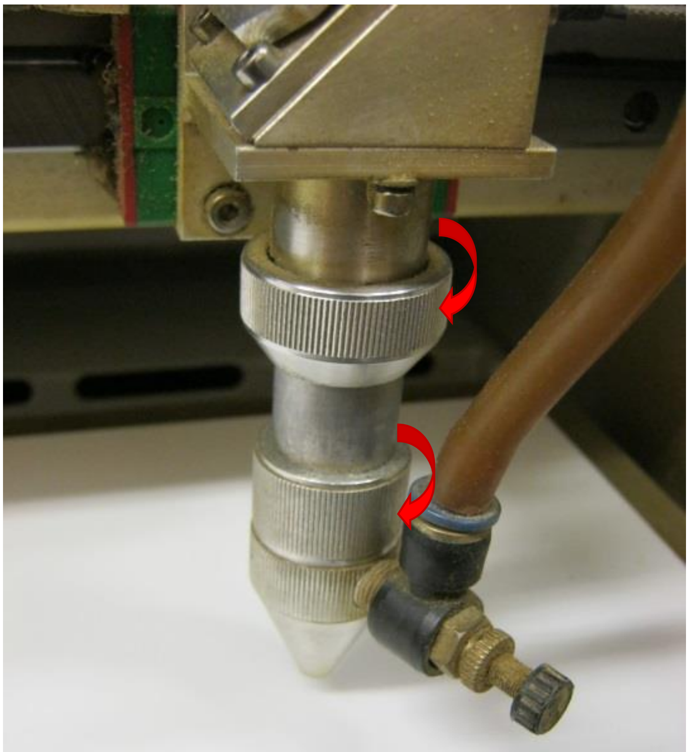
At this stage you add the material intended to be laser engraved or cut.

The material has to be placed flat on the laser bed, any creases will mean that the beam will cut or engrave differently. It could also catch on the laser head, causing the material to move or even ignite.

A good note to remember at this stage is to ensure it is placed as close to the top right corner as possible. Also that all of the bars are in correctly, for example flat.

Image of laser head being moved manually.

When moving the laser head hold the body of the laser head and gently pull the head over the top of the material. You have to be very careful when handling the laser as it is very delicate and the mechanism can be broken with rough treatment which incurs costs and time.

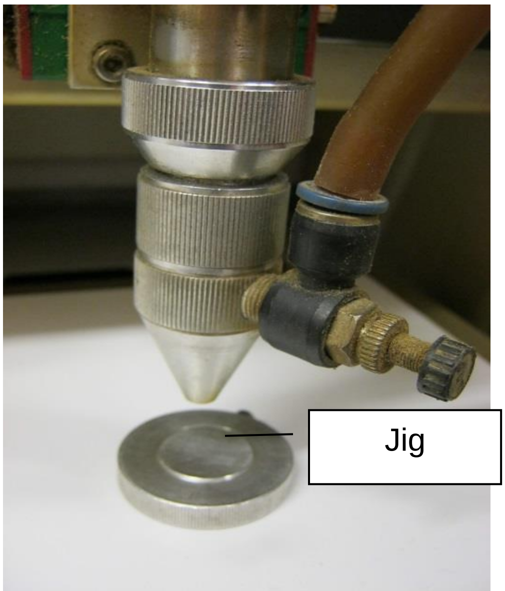


WARNING: The collar is a screw mechanism and wears quite quickly. Over tightening causes damage to the collar.

Image illustrating how to change the focal point and twist the collar to tighten.

Careful movement to lift the base of the laser head is needed. The head is telescopic and is therefore adjustable so force is not needed and can cause damage.

A round metal disc called a JIG is required to set the distance from the material. The JIG disc is placed underneath the laser head and the laser head positioned comfortably above.



QUALITY ASSURANCE: The use of the JIG enables the correct height to be set and therefore the finest cut possible

The head of the laser is then lowered until it gently touches the top of the JIG

The collar is then tightened. There is a danger at this stage to over-tighten the collar which over time wears the collar away which incurs costs, damage and can be dangerous to use.

Once the collar has been tightened to nip the laser head, the jig needs to be removed by sliding it from its position.

The laser should now be set to the correct height and there is no need to move the laser head manually. In fact the machine will be asked to move the head into its home position before it starts to engrave or cut.

Once the collar has been tightened to nip the laser head, the jig needs to be removed by sliding it from its position.

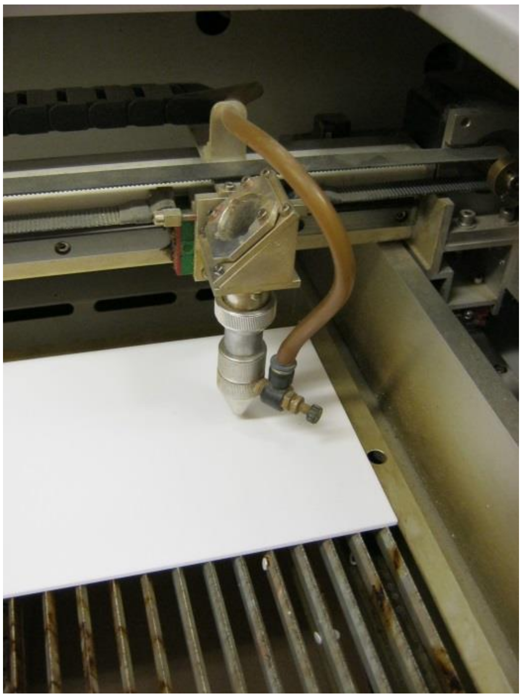


Image of laser head in cutting position.

The laser should now be set to the correct height and there is no need to move the laser head manually. In fact the machine will be asked to move the head into its home position before it starts to engrave or cut

Software

Laser systems process designs in the form of data files. These files can be from other systems e.g Techsoft 2D design. The advantage of this is that the designer can work at home or in the office and then send files for processing reducing the time they would need to be on a laser processing system EZECAD.

There are two important types of file formats that are used in laser processing;

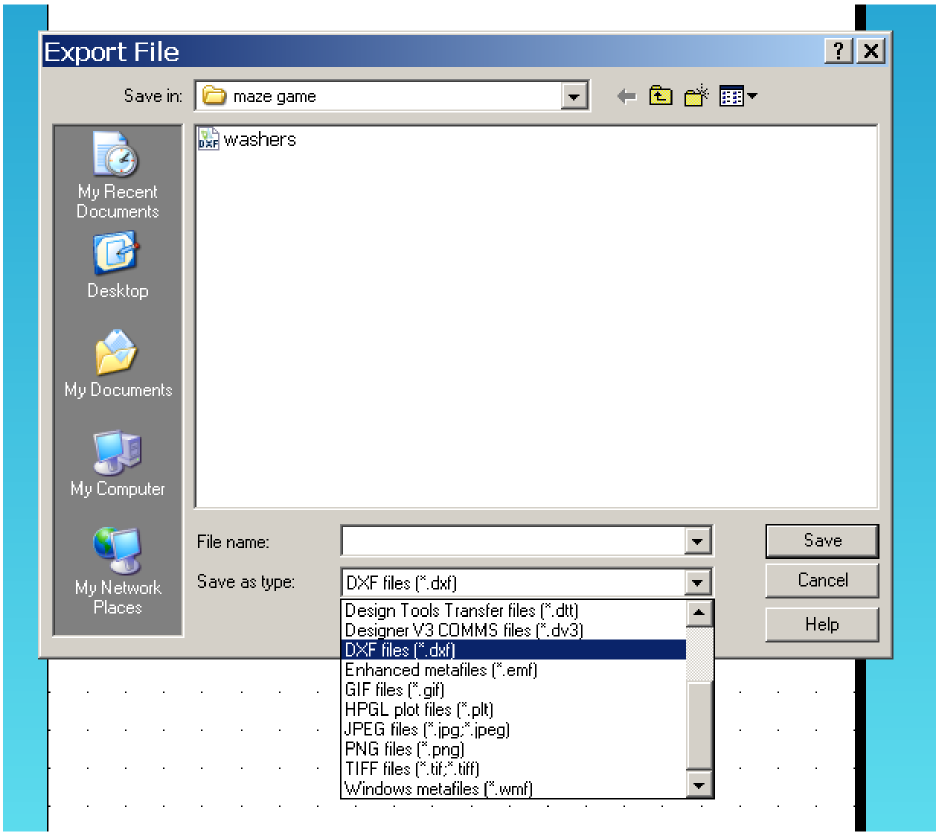
Vector files- Vector images are made of hundreds of thousands of tiny lines and curves (or paths) to create an image. They describe lines to be cut or marked by the laser. The energy parameters assigned to the line determine the width and length of the line.

Raster images are composed of pixels and are called 'Bitmaps'. The greyscale image is broken down into thin strips by the laser processing software. The greyscale becomes energy; dark areas are given more energy than the lighter areas.

With Raster images the laser head engraves by moving from left to right slowly down the material. Bitmaps are not good for cutting purposes. These operations normally require a vector line for the cutter head to follow.

Downloading your design.

Open the software- Techsoft 2D-Design and EZCAD

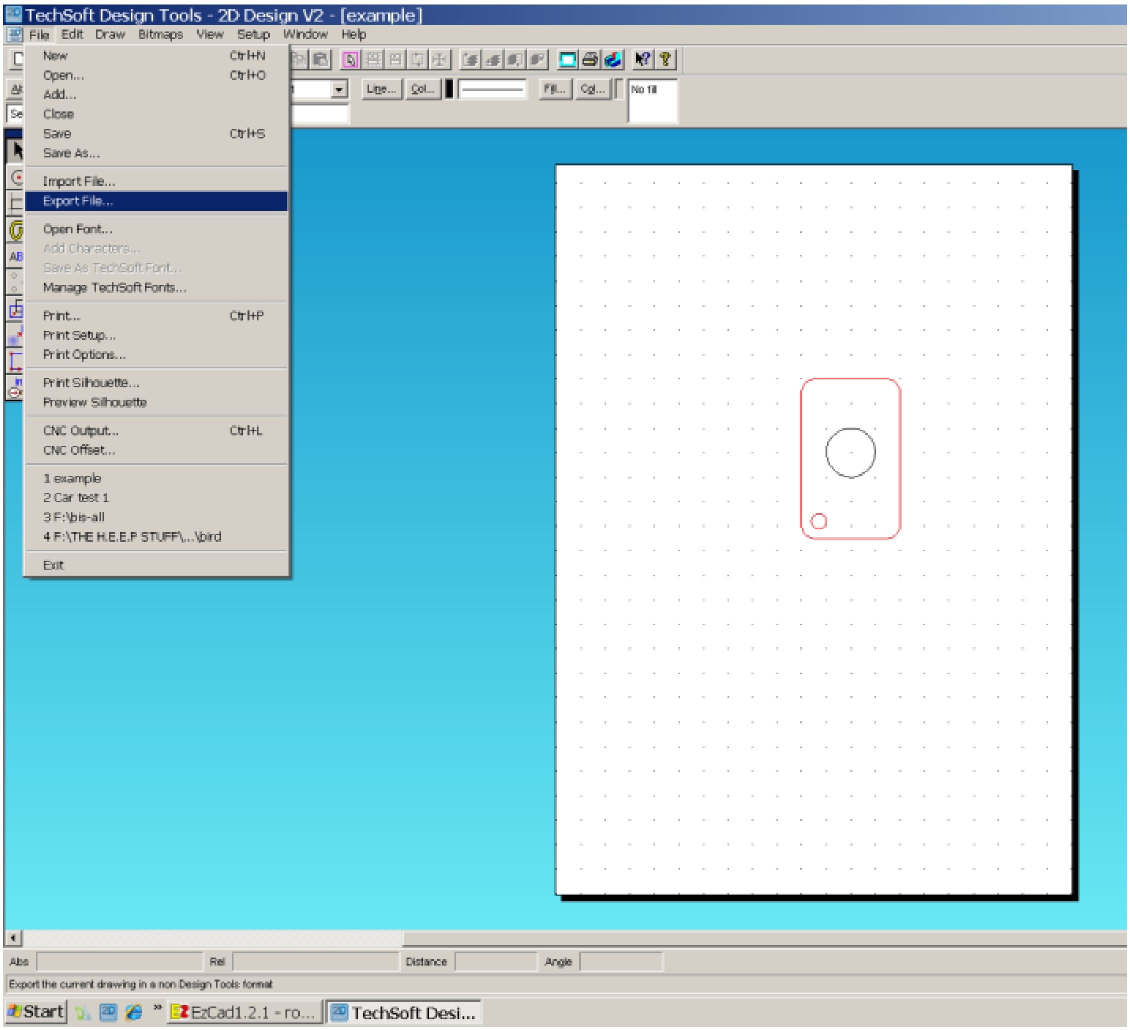


EXPORT YOUR FILE AS ??.dxf FILE

Using 2D-Design, to create design and coloured the lines accordingly

(i.e. RED = cut, BLACK = score/engrave)

QUALITY ASSURANCE: Check design to ensure the colours are correct.

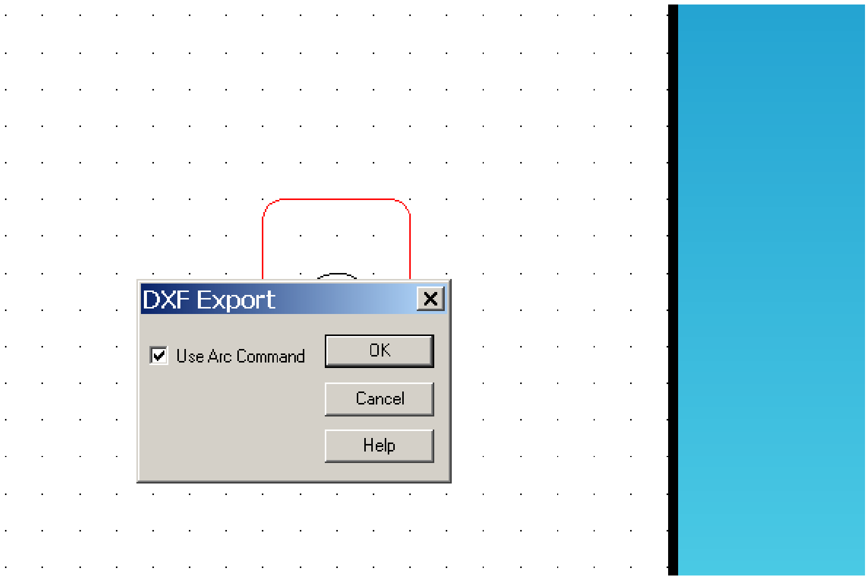


Go to **FILE** then choose **EXPORT FILE.**

Select a drive to save the design, as with all computer packages this is a sensible way to ensure designs are saved.

If using the PC connected to the laser you can save it to 'My Documents' on the hard drive. Use a designated area so that other operators did not use the artwork. If using a PC anywhere else, the design needs to be saved onto a USB stick to transfer it to the stand-alone PC with the laser.

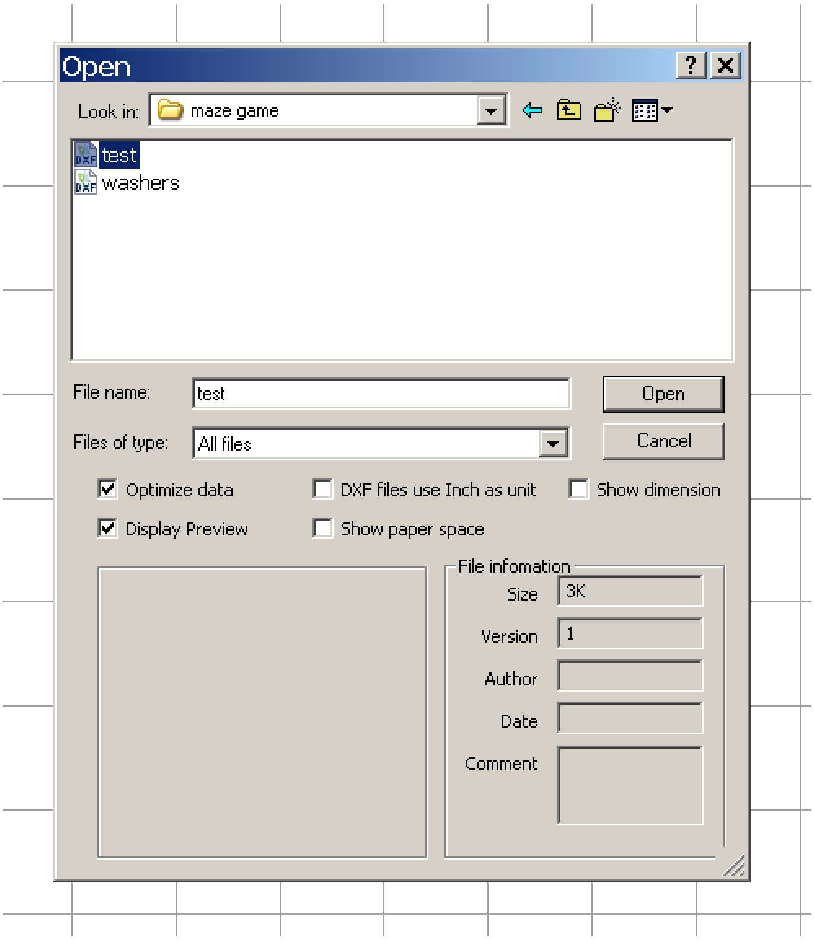
The program requires **DXF FILEs** so to save work it needs to be saved in the 'Save as type' drop-down menu



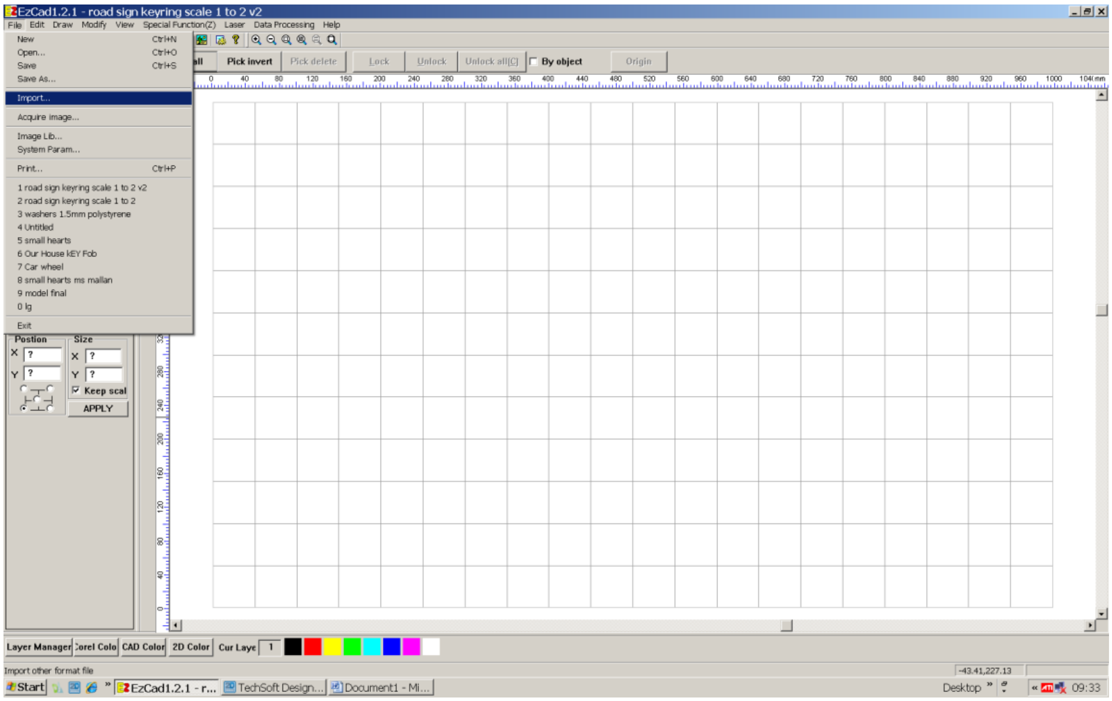
Select **OK when export box shows on screen.**

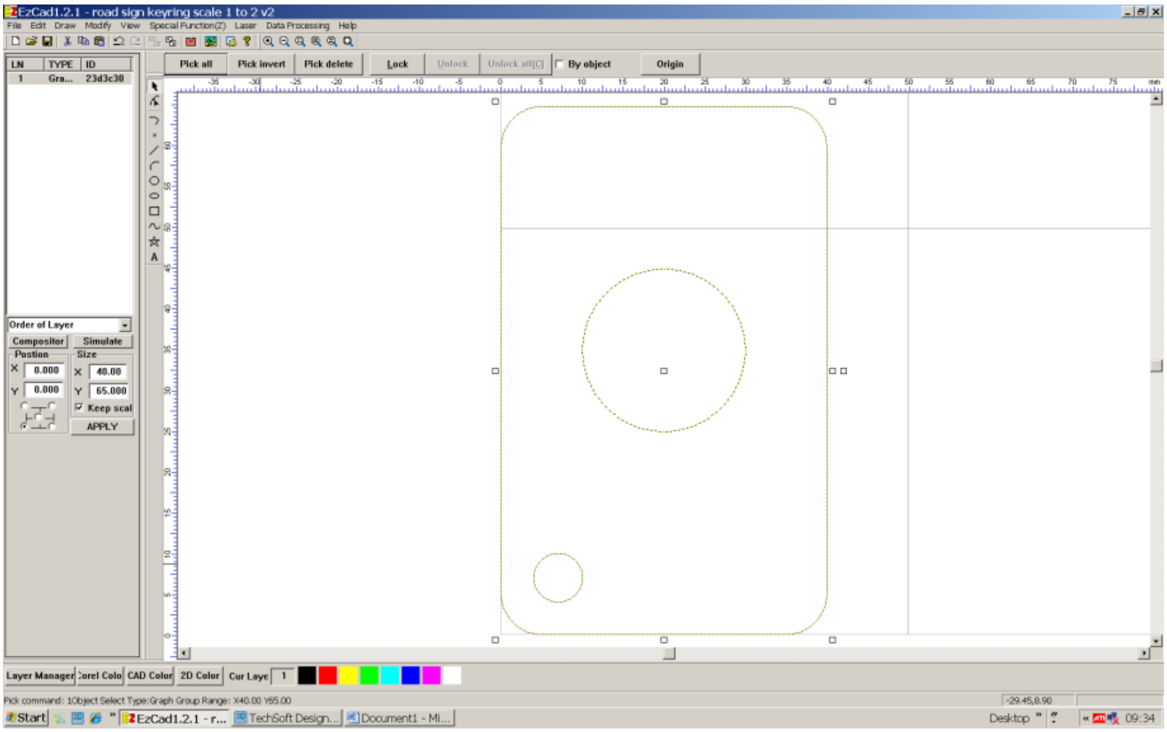
Minimise 2D-Design software and open the EZCad software from the main bar.

I then need to select my FILE then IMPORT which is executed by selecting a file from ‘My Documents’ or from a USB stick. As with any other computer package you select your file then **ok** the file.



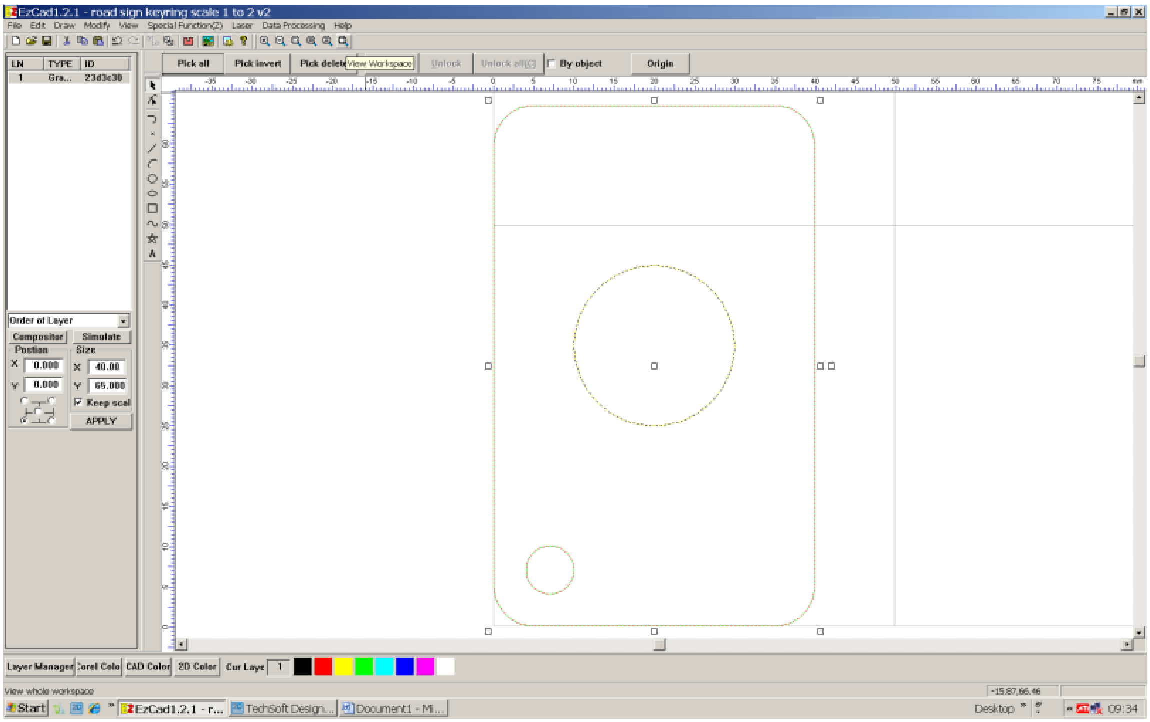
NOTE: Ensure the file type setting is set to **.DXF**

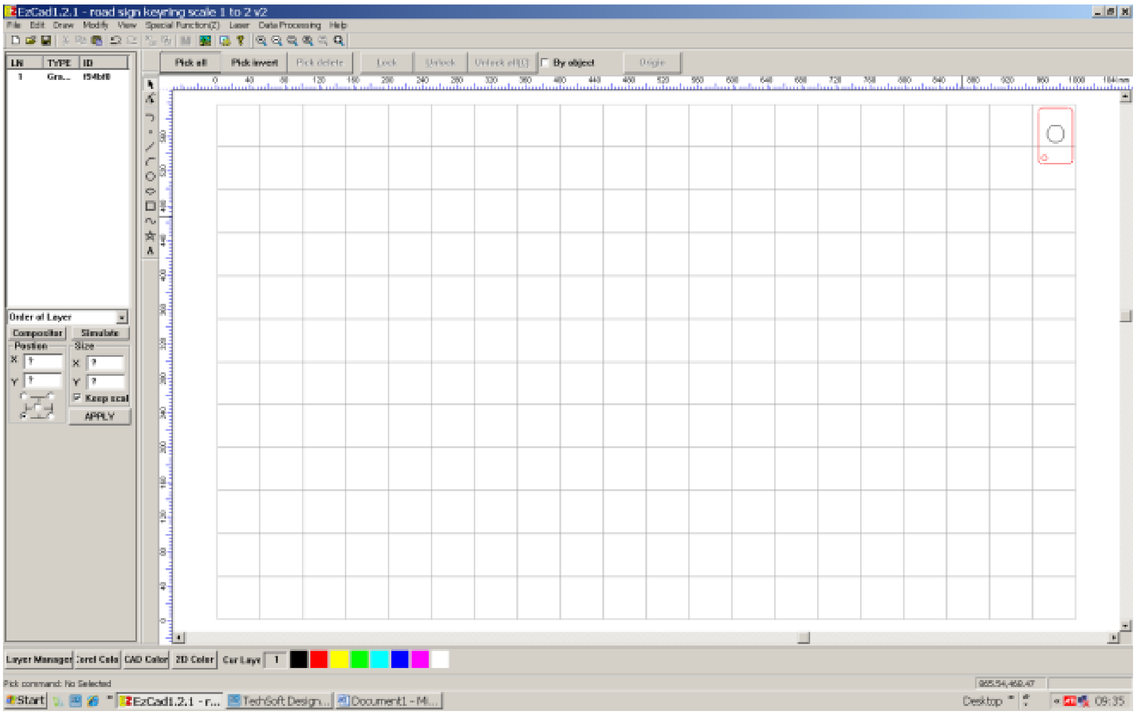




The file opens and a similar screen is displayed to the one above

To access the view workspace there is a magnifying glass image which needs clicking on.





The design will be shown on a grid representing the full size of the bed.

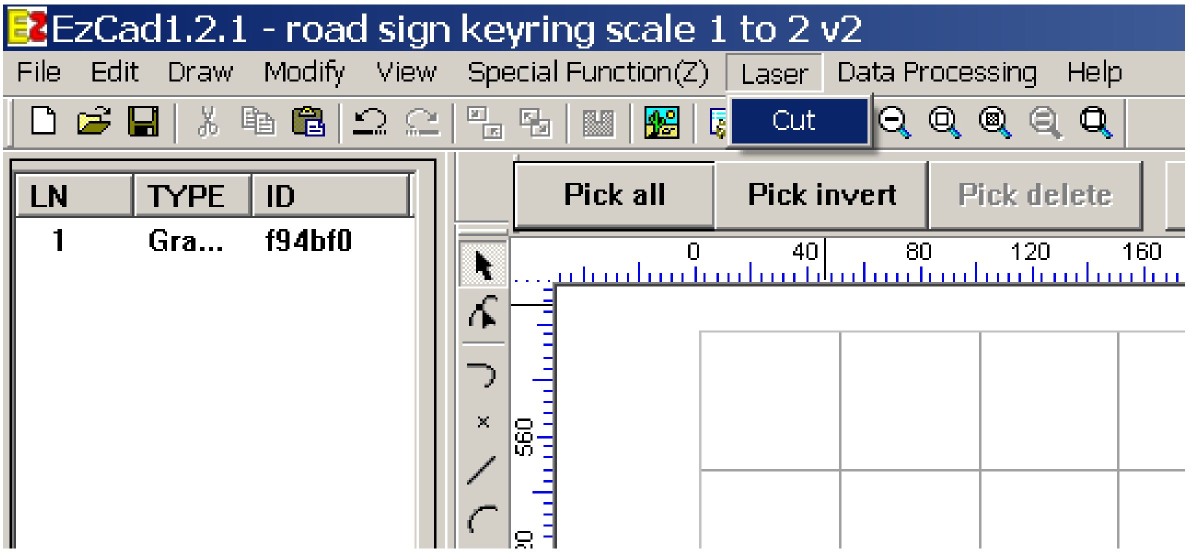
Designs should be positioned in the TOP RIGHT CORNER of the grid.

This is where you have placed your material on the bed and is also where the laser beam will be its strongest and it will enable the shortest production time as the laser is closest to its HOME.

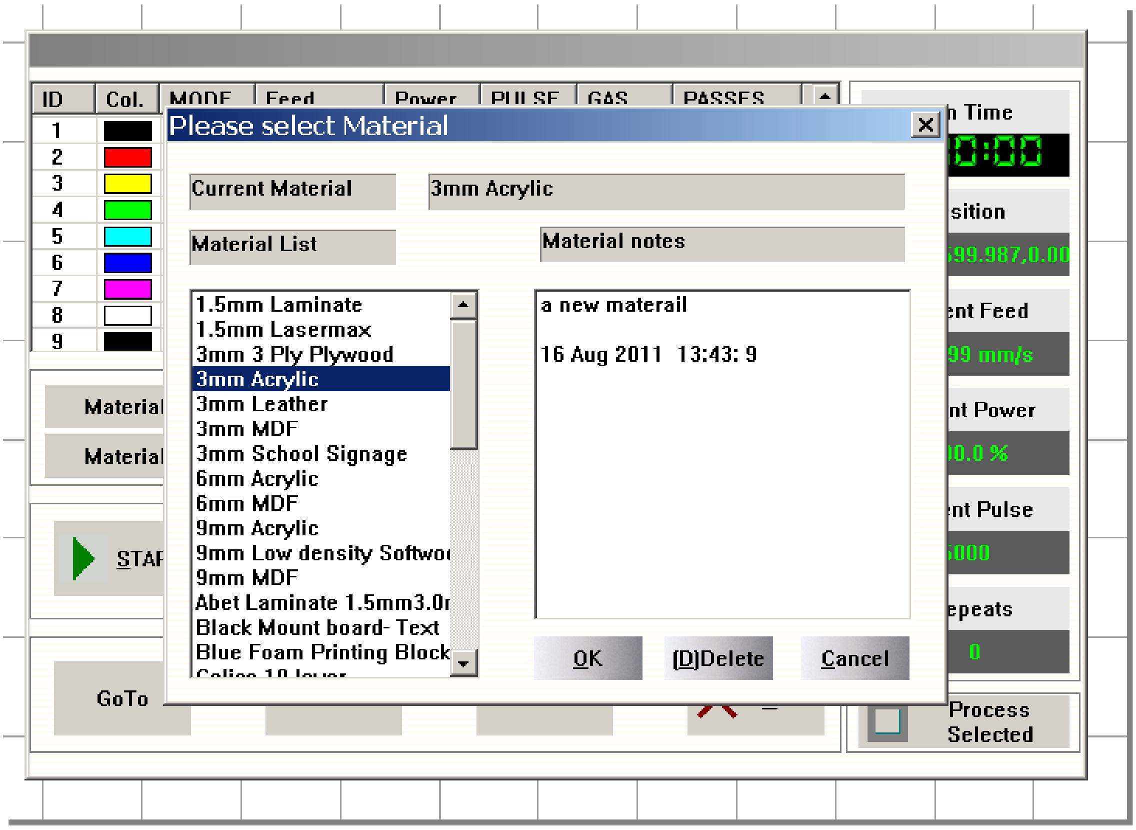
Note: The image must not be over the edge of the grid. It must be enclosed just inside.

QUALITY ASSURANCE: Check the colours of your design. Sometimes they can be altered during the import process.

To laser engrave or cut out on materials select **LASER** on the bar and then dropdown and select **CUT.**

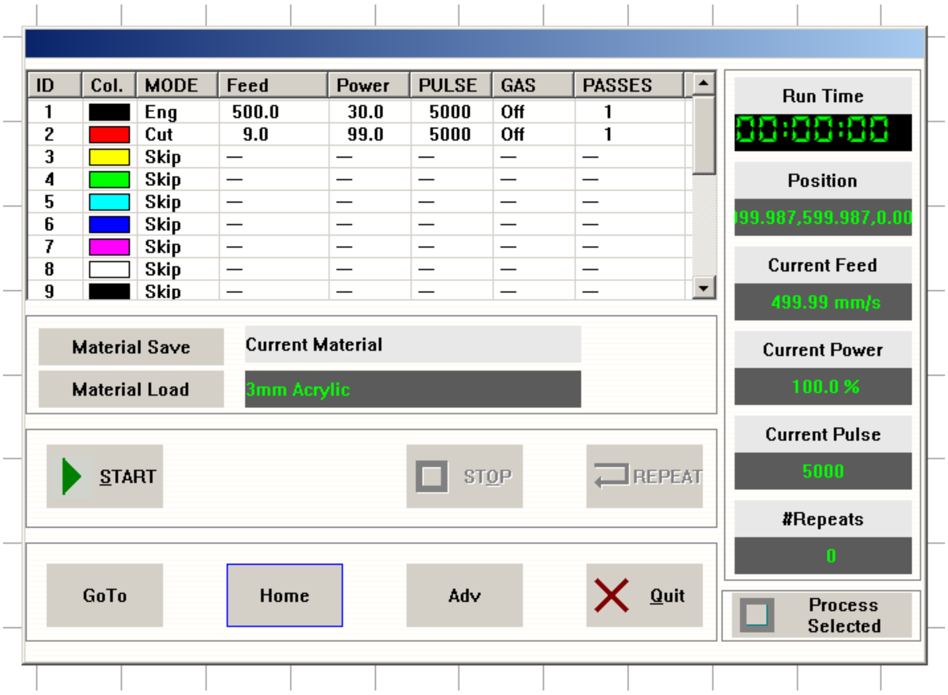


Click on **MATERIAL LOAD** and select the name of the material that has been placed on the bed. This is usually programed in by the technician to save time and hassle. There are a few notes that need to be followed at this stage e.g. the material selected is also the same thickness i.e. Select 3MM ACRYLIC



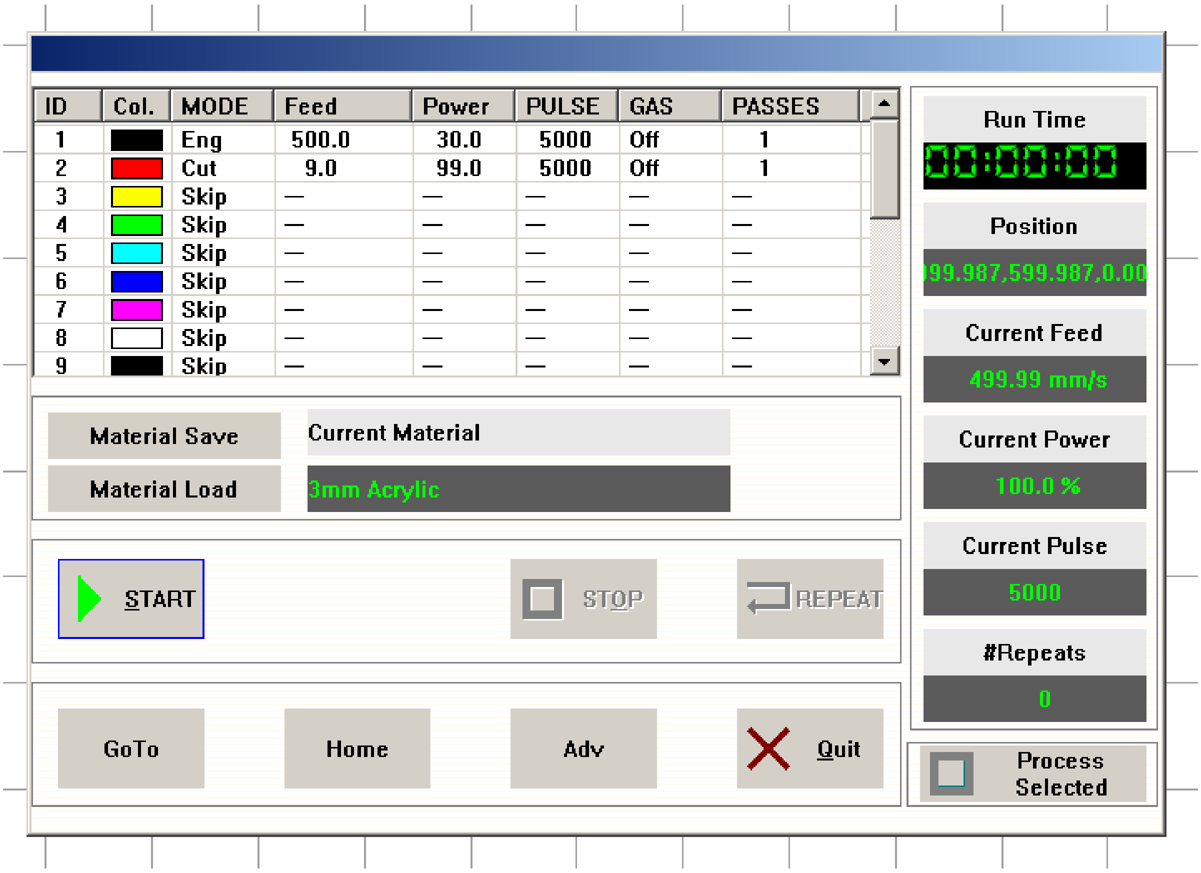
This screen shows the settings used for each material.

(For the experienced user, you can alter these settings by clicking on each number)



WARNING: It is vital that AIR ASSIST is ON to ensure that the lens stays cool and waste material is blown away from the intense heat of the laser beam.

Click on HOME, this will reset the laser head to its home position



QUALITY ASSURANCE: Complete one final check to ensure that everything is correct before committing to cutting

Click on START the laser should now cut the design.

Appendix 3

Artists research

Louise Baldwin

Wim Delvoye

Su Blackwell

Crystal McFarlane

Ensuk Hur

Jo Angell

Eugène Van Veldhoven

Louise Baldwin

‘the mundane waste of domestic packaging‘. Louise Baldwin (www.62group.org.uk/artist/louise-baldwin)

Louise Baldwin is a textile artist who combines hand and machine embroidery to create collage wall hangings constructed from recycled materials. She uses a variety of recycled papers, packaging and fabric scraps to create decorative collages. Her work inspires this research as she uses materials that she feels connected to and in her environment. She uses a variety of recycled papers, packaging, fabric scraps, items from around the home, including card form toys, medication boxes, biscuit wrappers and layers them, building up collages randomly with the sewing machine to create decorative wall art. (www.62group.org.uk/artist/louise-baldwin)

Louise exclaims,

'I am interested in how we absorb knowledge and life’s experiences; selecting out the bits that resonate for us, sometimes carefully, other times by accident. It's what makes us who we are.

Connections are made between the most seemingly random things, cell structures, pattern, text and mark. Fabric and stitch seem to be the most obvious materials to use as we are bound to cloth in so many ways. Life is strange and difficult and funny.' (www.62group.org.uk/artist/louise-baldwin)

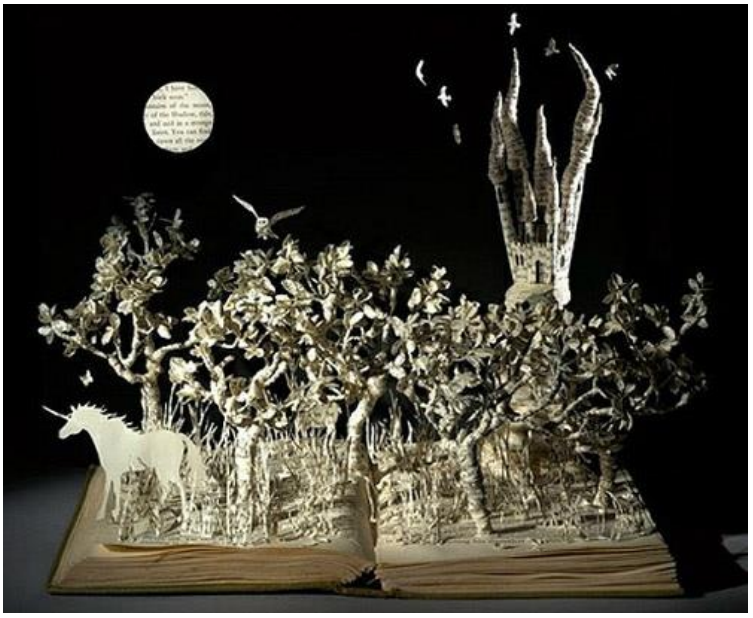
Artist that up-cycle using cutwork.

Wim Delvoye

Hand carved tires (www.happy-pixels.com/2012/10/14/wim-delvoye)

Wim Delvoye Belgian artist creates art with used tires and no mechanical devices. His work inspired the practice part to this research as he uses tough tires from tractors and uses a cut method to create his work. This thesis hopes to use a variety of unusual everyday discarded items to recycle rather than up-cycle into new artefacts. (https://wimdelvoye.be/work)

Su Blackwell



Su Blackwell is a British artist who constructs delicate sculptures from the pages of old books (www.sublackwell.co.uk).

Su Blackwell states;

"My background is in textiles, and embroidery was my medium. I tried to push the boundaries of embroidery, electroplating it to make it sculptural and using fine wire. I began to develop more sculptural work, and to encompass other medium in my work, that I felt communicated my messages. I began to incorporate paper. Which has both a fragility and strength that drew me in and still fascinates me to this day. it is a readily available, cheap material that has gone through a cyclical process from wood to paper."

This cutwork from every-day objects e.g. clothes and books into three-dimensional forms using a scalpel and glue was one of the first inspirational ideas that inspired this work. The pages of books create miniature scenes in her work and it stimulated ideas in the surface of the work produced at the start of the research practice (www.sublackwell.co.uk)

Crystal McFarlane.

Silk laser cutting detail.

(www.cutlasercut.com/showcase/crystal-mcfarlane-textile-laser-cutting)

Using lasers to cut and add surface decoration to materials in fashion is not new and is utilised by designers like Crystal McFarlane. They use the laser to cut delicate fabrics that normally would be damaged by hand cutting. The uses of low power when cutting the silk textiles seals the delicate pattern edges and prevent them from fraying (www.cutlasercut.com/showcase/crystal-mcfarlane-textile-laser-cutting)

Ensuk HUR

Laser cut felt (www.cutlasercut.com/showcase/ensuk-hur-laser-cutting-felt)

Another interesting designer called Ensuk, likes to push boundaries, and explore different materials and textile processes. She motivated this research to combine laser cutting with different materials, processes and recycling to develop a product that could be used for fashion and interior design.

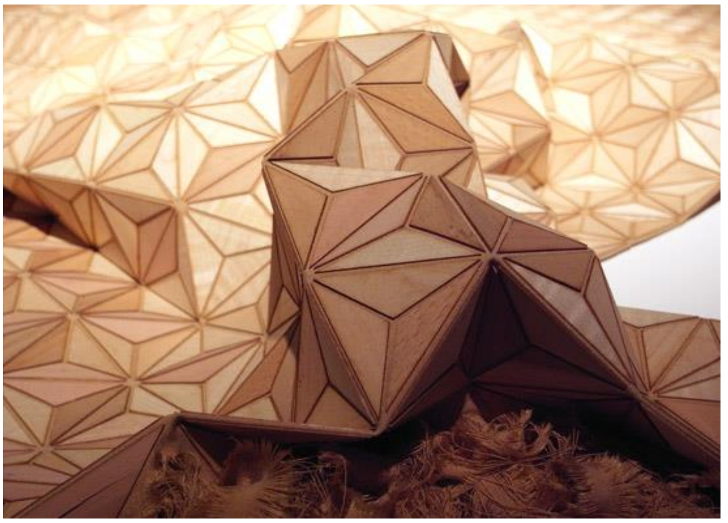
Her work uses laser cut components in natural wool felt and creates a product where the design can be altered over and over. This process of altering and reusing stimulated ideas to use a material that could be remoulded and reconstructed in a sustainable procedure. http://www.cutlasercut.com/showcase/ensuk-hur-laser-cutting-felt

Jo Angell

Laser cut plastic, layered to show light. (www.joangell.com)

Jo is a textile designer whose work explores the effects of light through laser cutting and layering materials. Jo's work uses a variety of materials and her work showed that there was a market for products that used laser technology in interior lighting This was an interesting concept that was explored in her research practice and then taken to the London Surface design show for feedback from visitors. These laser cut plastics inspired this research in using light through recycled and remoulded plastics. The practice was also taken to the Surface design show in London. (http://joangell.typepad.com/joangell/2009/05/whilst-studying.html)

Elisa Strozyk



ECO Mortimer Wooden Carpet Design

(www.brwnpaperbag.com/elisa-strozyk-wooden-textiles)

Elsia Stozyk is a German textile designer who showcased her wooden textile carpet at the London trade show. The product on show was made from teak veneer offcuts that had been laser cut and bonded to a backing fabric made of linen.

Elisa laser cutting teak veneer wood into geometric shapes.

(www.brwnpaperbag.com/elisa-strozyk-wooden-textiles)

The wooden carpet she made is extremely flexible and can be positioned in different ways. It is considered to be interesting and re-evaluates the way we look at hard materials as textiles.

Wooden dress by Lea Peckre and Elisa

(www.brwnpaperbag.com/elisa-strozyk-wooden-textiles)

"We know the feeling of walking across wooden floors, to touch a wooden table top or to feel the bark of a tree. But we usually don't experience a wooden surface which can be manipulated by touch" says Elisa.

She created the flexible wooden surface, by deconstructing the wood into many small pieces through laser cutting and then attached them back together in mosaic-like patterning on top of a textile base using a glue to bond them to the fabric. Elisa explains that she is interested in finding new "ways to provide wood with textile properties in testing methods to make wood flexible and soft, or interweave textile elements".

Bonding the laser cut veneer to linen.

Elisa sees wood in textiles as a sustainable product and states that "Wooden Textiles is an approach to responsible thinking concerning lifecycles of products. The outcome is a material that is half wood-half textile, between hard and soft, challenging what can be expected from a material or category. It looks and smells familiar but feels strange, as it can move and form in unexpected ways." Elisa also states that she likes the natural raw state of the wood, "I love how wood ages without losing its beauty. Somehow it just grows old in a nice way."

(www.elisastrozyk.de/seite/collaborations.html)

Practitioner of ultrasonic welding and laser technology.

Eugène Van Veldhoven specialises in coatings, print techniques and other surface treatments. Some of the techniques he uses include laser cutting and engraving which is interesting. He has also experimented with ultrasonic welding which he manipulated to develop some interesting results of the surface of materials.

His unique combinations of using textile, laser and other technical techniques has given him an edge and aided him to give a very specific input to industry. Most of his clients are in the higher end of interior textiles, fashion, automotive, ceramics, plastics and paper industry markets.

Ultrasonic testing in an Industrial laboratory in the Netherland. (www.tumblr.com)

For this technique Eugène Van Veldhoven states;

"A generator generates a vibration that is a 'hand gun' is connected to the generator and a Sonotronic is screwed on top of the gun. The intensity of the vibration can be adjusted, as every material reacts differently to the sound. Synthetic materials heat up and melt together due to the vibration causing the molecules in the textile to heat up. When the Sonotronic has a sharp edge, the material cuts, with a smooth edge that does not fray. When the Sonotronic has a blunt edge, or a relief, the material can be embossed. The materials can be glued together, just by sound and pressure,no chemicals are needed, which is better for environment and easier for recycling the material at the end of its life cycle." (www.tumblr.com)

Appendix 4

Interview with Paul Burton Dyer Hand Engraver

Q. Could you begin by telling me a little about how you got started with engraving? What made you decide to start Hand Engraving? How did you make the transition into Hand Engraving guns?

A. Having trained at the London University of Arts (Central School) in Printmaking including Etching and Engraving; and being made redundant from my lecturing job at Merthyr Tydfil College, where I taught Art &Design. The interest in repairing, renovating and engraving sporting guns took off.

Q. Did you train at an engraving school to learn your art, or are you self-taught?

A. As I stated in your last question I studied printmaking techniques including wood engraving and metal etching. These learnt skills lent themselves to metal engraving. I did however have a few pointers from a world famous gun engraver.

Q. What country or countries impress you with their highly skilled engravers? Can you name some Engravers that inspire you?

A. It has to be Italy, as they produce some of the finest engraving in the world. However a local Engraver has inspired me. Phil Coggan a largely self-taught world renowned gun engraver. He was made redundant from his job too. He was very interested in antique guns, and taught himself how to make them, each gun had a certain amount of engraving on it which he tried to copy, and gradually the engraving took over from making the guns. He attended an engraving school in Italy, and polished his skills.

Q. What were your first projects when you first started in the engraving industry?

A. Annealing old gun actions. Re-cutting the worn engraving and re-colour hardening.

Q. what tools do you use when you are working on your projects? Are they expensive and easy to purchase? Do you need to maintain any of your tools? How much on average do you spend on your tools and how long do they last?

A. I use mainly gravers. They are ground from square section 3/16 high speed steel or 'cobalt' blanks. They are not very expensive, but specialist Swiss tools like liners or round scorpers are a little more expensive. Other tools like hammers and vices are easy to get hold of and last a long time.

Q. Could you tell me more about some of your more interesting or challenging projects?

A.I'm currently working on a project for a friend which I am finding challenging because

of the material I am working with not the subject I am engraving. It is made of stainless steel which is very difficult to hand engrave because the metal is hard and difficult to scratch.

I found working with Celtic designs very interesting and I enjoyed the soft metals and outcomes of the designs. I have some examples on my website.

Q. Can you tell me about some of the people you have done work for? Specific models? Projects?

A. At one time I did a lot of work on antique English guns and big named guns like Purdey and Holland for American Clients. Unfortunately the bottom fell out of this this market and I no longer engrave for Americans. Now, I would do work for anyone. I currently work for British clients who want jewellery, accessories and odd items engraved. I still engrave guns but usually it’s just re-cuts.

Q. What part of engraving do you find most challenging or difficult?

A. Perfect scrollwork. The larger less quality work stands out if it’s not perfect.

Q. What part of an engraving job do you dislike the most and why?

Lettering because it’s boring and repetitive.

Q. Are any of the pieces you make in a series of production? Is there a particular gun that proved particularly challenging? Can you describe a piece of engraving you’ve done in the past that you are most proud of?

A. Pairs of guns need to be engraved the same. The exception being the game scene which contains different animals on each action. However the scroll is always identical. When I first started ,I had to re-engrave a pair of Dickson’s round actions. They had a lot of scroll work. Other than the guns I am very proud of a brass horse buckle I engraved with Celtic dragons.

Q. How long, on average does it take to engrave a gun? Can you explain to me the steps that are involved in preparing for engraving, and the engraving steps themselves?

A. A new gun is lovely and soft to engrave, after engraving it is usually hardened unless its alloy. Old guns must be annealed in a furnace, taking steps to avoid scaling build up. It is then polished and re-cut. Time scale can be anything from twenty four hours to three hundred hours.

Q. Are you limited by the size of the plate, or are there other limitations? What materials are the most difficult to work with?

A. No, I ‘have engraved metal guitar bits, rings etc. The hardest material I found to cut is stainless steel. It limits how fine the detail can be because the metal is so hard.

Q. What is the worst engraving mistake you ever made and how did you fix it?

A. Ummm.. I can’t think of any major mistakes. You see you can’t really make a mistake it is like being a tattoo artist but in metal.

Q. What is the difference between hand engraving and laser engraving in your opinion? Which do you think is value for money? Which is the most cost effective?

A. Hand engraving has a sort of character, something about it whereas laser engraved guns look mechanical and lack character.

There are some guns being produced with laser e.g. Boxall and Edmiston at twelve to fifteen thousand pound. Hand engraved guns are a lot more expensive. A new Purdey would cost about one hundred thousand plus depending on who engraved on the gun. You basically pay for quality.

The problem with laser is that although the scroll pattern looks o.k. the game scene design looks poor and at the end of the day everything looks mechanical.

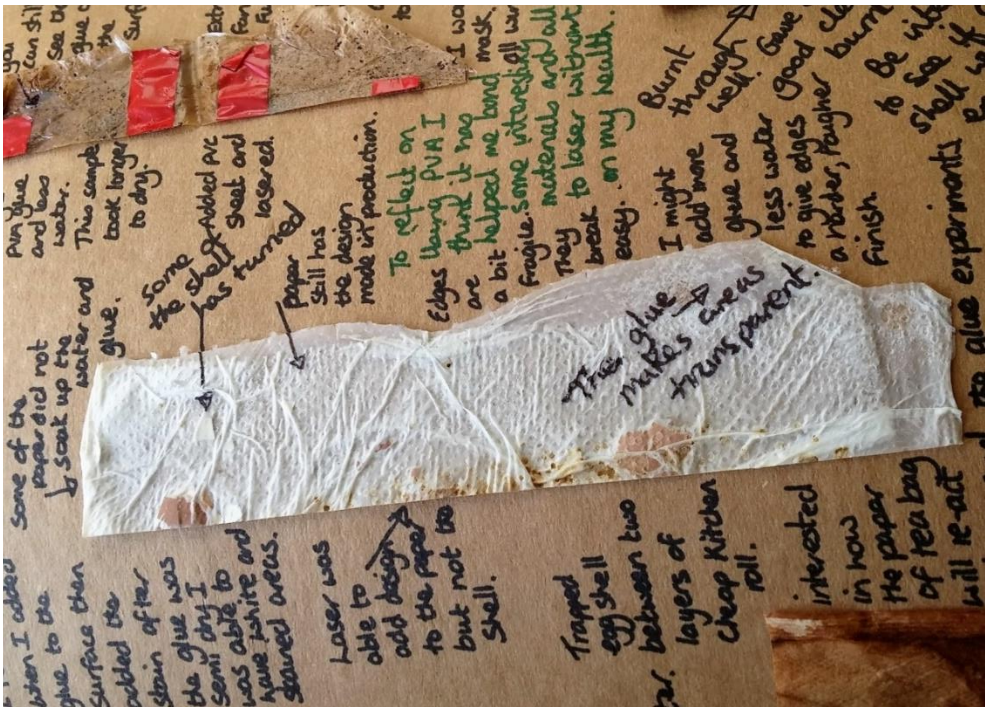
Q. Would you use a laser engraver for any of your projects? Can you explain why?

A. No, I personally would not use a laser engraver for my work I am an artist.

Appendix 5

Experiment Scrapbook


Used toilet tissue, orange peel combined. PVA used to bond all materials together.
Paper has uneven texture.
my own papers from toilet paper and Kitchen roll are much more exciting than the crude types I started off with.
Experimented with Kitchen paper and waste plastic. Used PVA Glue to bond the materials together to form a recycled material from waste.
All these papers were experiments. I decided to make my own papers so that I could laser uneven and textured surfaces. I wanted to see how the laser burnt away the surfaces.
orange peel shows natural
Laser cut a square Sample out of the hand made paper. The paper was made out of mushed pulp from tissue paper. I added tea leaves, orange and small pieces of wood.
Reflection
Kitchen roll, PVA
I added tea leaves
paper and add extra
the paper on a
plastic which
The paper
grid while it
an even surface.
Bit rough, but


Some of the paper did not soak up the water and glue.
PVA glue and less water. This sample took longer to dry.
Some of the shell has turned
Added PVA Shell and lasered.
Paper still has the design made in production.
To reflect on using PVA I think it has helped me bond some interesting materials and allowed me to laser without on my health.
Edges are a bit fragile. They break too easy.
The glue makes areas transparent.
I might add more glue and less water to give edges a harder, tougher finish.
Burnt through well.
Laser was able to add design to the paper but not the shell.
Trapped egg shell between two layers of cheap Kitchen roll.
interested in how the paper of tea bag will re-act


All those ideas could be used to develop work in textiles.
Paint has ran under stencil and has still formed lines so design is not spoilt.
Added embroidery but was careful in spacing the stitches so that I did not tare the paper.
I also feel they would laser well and give interesting results.
Added a layer of paper over the top
design to distort
so that the design
more interesting.
use this as a
fabric.
I have decided
the laser has
interesting
design tool.
After deciding I quite liked the layering of the design. I decided to try to distort the image further and scrunch the wet glue
Made some
large and
I decided
pattern


they are successful.
This is a successful design as the middle has not fallen out.
I found this work interesting and wanted to use the idea in my work.
I experimented with the card and printed onto paper the design (using the laser
used in this experiment to make stencils for me to use
exercise.
from some of the artists in my research. Adding textile processes to different materials. Different
Printed onto scrap paper using the laser stencil.
I liked the outcome as a design idea.
It is a useful way to develop designs.
I would use this idea to develop children's work
Good way to develop a textile design.
Layered design could be improved by adding more layers
used card cut with
or printed design.

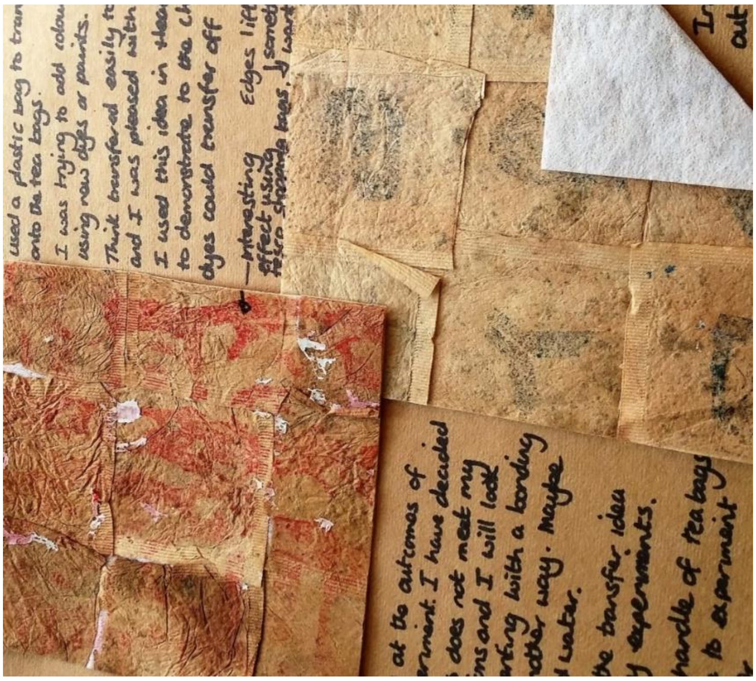

used modpodge not PVA.
After a few slightly different experiments using this method I have decided that I
process.

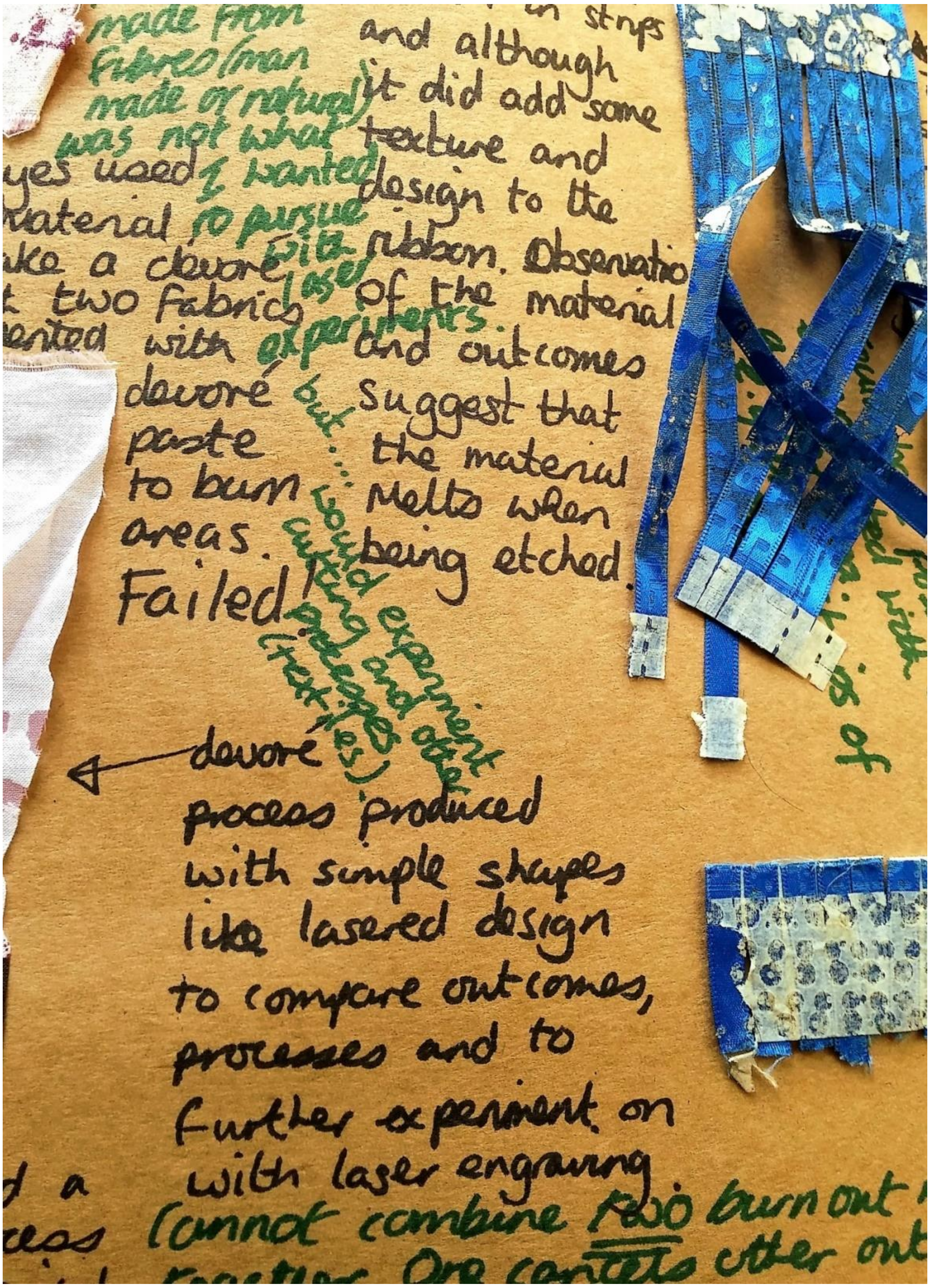

There is dust and smoke residue on the surface.
Lines have lasered better than the cog images.
maybe this is because the lazer works intermittently on the lines.
very difficult to cut on laser.
Build up Gives this piece a more artistic look.
image took a long time to laser even though I had the laser working at fast speeds. This has however impacted on the quality of the design outcome.
variation of colour and texture due to use on the sander.
Did not engrave as well on the

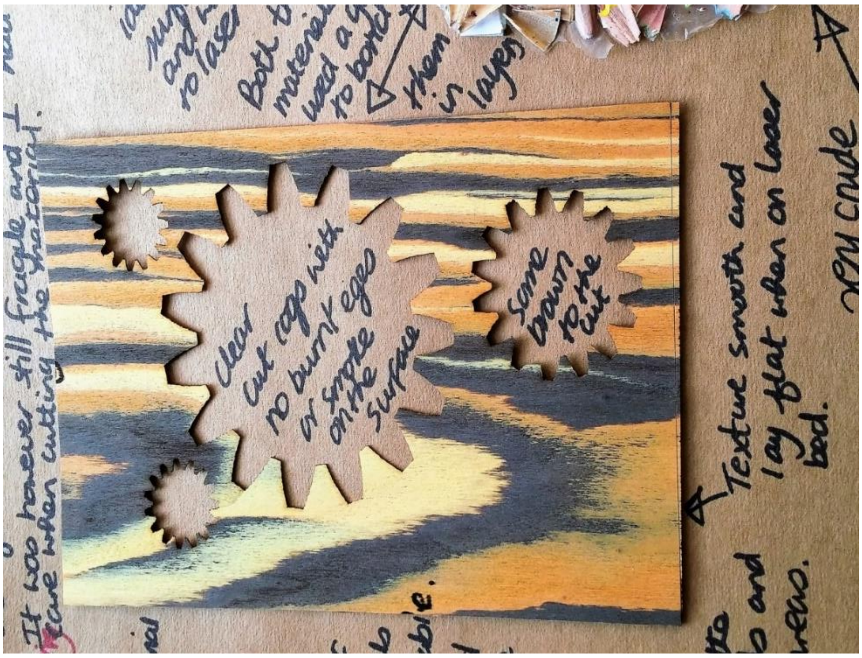

wallpaper I bought from Grumpys in Manchester
I added a textile print process of reactive dyes + pigment dyes.
Block print, paint, dye and laser engraving. I added a thin layer of paint over the top to preserve the idea
Combined print.


Laser engraved well
Card is a good material for cutting and laser engraving would be useful for scrapbooking, craft or even to decorate books.
Divider of a box.
I might laser engrave card for my business shows and exhibitions.
Like the layered idea of the corrugated card.
Used masking


recycled paper
and cloth.
very thick
and has
not been
bleached
or coloured
You can feel the indent of the laser on this card.
would make lovely buttons in fashion
Different
was made out of recycled card.
The laser cut out of the card easily. The shape fell out of the cut area.




made from
Fibres (man
made or natural)
was not what
I wanted
so pursue
with
laser
experiments
but...
would experiment
cutting and other
processes
(textiles)
and although
it did add some
texture and
design to the
ribbon. Observatio
of the material
and outcomes
suggest that
the material
Melts when
being etched.
two Fabrics
with
devoré
paste
to burn
areas.
Failed!
devoré
process produced
with simple shapes
like lasered design
to compare outcomes,
processes and to
further experiment on
with laser engraving
(cannot combine two burn out
other out


Clear cut caps with no burnt edges or smoke on the surface
Some brown to the cut
Texture smooth and I lay flat when on laser bed.

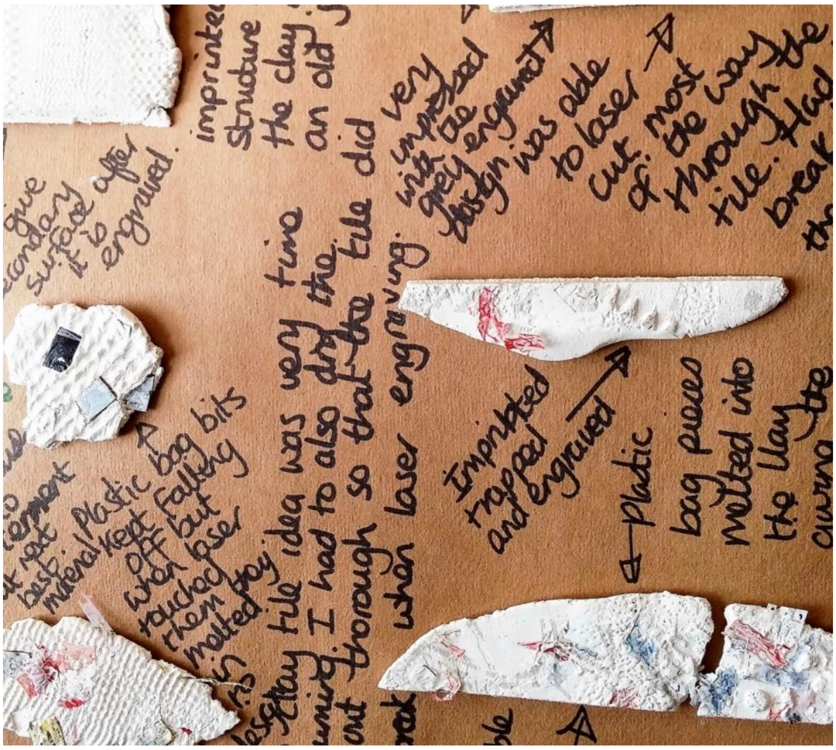

Reflection.
Strips were made 2cms in width
Different veneers used. Both recycled
coloured and bleached wood


This makes it easy to manipulate into a new form.
Thin bubblewrap
It is one of the main landfill materials.
Bubble wrap with printed images was transferred off wallpaper by accident.
Layered sweet wrappers over plastic bubble wrap to make a bonded structure.


Used some of my degree fabrics and layered them.
Zig zag stitch in areas to further re-enforce structure.
Used as simple running stitch randomly.


Lace like effect.
Realised that lasering over plastic in this thin sheeting would just make bigger holes.
memories of 'shrinkies
this experiment with a
rapper from noodles.
Started to experimen
layering and bondin
different plastics


many large h
Knitted plastic bags.
Ironed under
Grease proof paper.


Imprinted
trapped
and engraved
plastic
bag pieces
melted into
the clay


The weave I intended to
do on this piece would have
broken the warps as I cut
the veneer on the wrong
direction.
Trapped veneer
could add
some more
design to
this piece.

Appendix 6

Recipes

Appendix six

Bio- plastic Recipes

Recipe 1

1tsp of corn starch

½ tsp. of salt

25 cups of 1% glycerol solution.

Recipe 2

1 tsp. of corn starch

½ tsp. salt

¼ tsp. of sorbitol

26 cups of water

Recipe 3

1 tsp. of starch

50mls of white vinegar

40mls of water

150mls of 1% glycerol solution.

Recipe 4

1 tbs of corn-starch

½ tsp. of corn oil

27 tbs of water

1 tsb of white vinegar

Recipe 5

1 tbs corn starch

1tsp of cider vinegar

4tbs of water

1tsp liquid glycerine

1 drop of food colouring.

Appendix 7

Experiments using the oven method

Material	Other equipment	Temperature	Time	Pressing time	Results
Acrylic	Tin tray	250 °C	15 mins	5 mins	Plastic did not fuse together properly.
Acrylic	Bacofoil tray	300 °C	25 mins	5 mins	Fused. Tin foil difficult to remove from acrylic.
Acrylic	Baco foil tray smeared with detergent	400°C	15 mins	5 mins	Gasses from the acrylic caused a chemical reaction which resulted with the oven door been damaged. (Dangerous).

Table of results from method 3 experiments.

Material	Equipment	Temperature	Time	Pressing time	Results
HIPS	Metal sheet	250°C	10 x 2 mins	5 x 2 mins	Added extra chips and put back in oven. Good result.
HIPS	Metal sheet	250°C	15 mins	5 mins	Did not fuse around edges.
HIPS	Two metal sheets	250°C	9 mins	4 mins	Sample has a flat surface.
HIPS	Two metal sheets	250°C	6 mins	3 mins	Tried with fewer chips. Sample was thinner but it made a cracking noise as it was cooling in press. Sample cracked.
Hips	Two sheets of metal	250°C	8 mins increased to 10 mins	5 mins	Sample flat and smooth.
Hips	Hollow bar	180°C	25mins	10mins	Good sample. Fused well and has a smooth surface.

Table of results from method 3 experiments

Material	Equipment	Temperature	Time	Pressing time	Results
PET	Tray	250°C dropped to 190°C then back to 250°C	20mins	10mins	Fragmented when cold. High fume.
PET recycled bottles	Tray	250 °C	35mins	5mins	Did not fuse. Stayed in chip form.
PET bottle tops	Tray	250°C	10 mins	2mins	Good Sample. Fused and flat.
PET Drink bottles	Tray	200°C	35mins	5mins	Will not fuse together. Stayed in chip form.
PET Bottle tops and unknown plastic	Tray	200°C	10mins	2mins	Sample fused but has a twist.

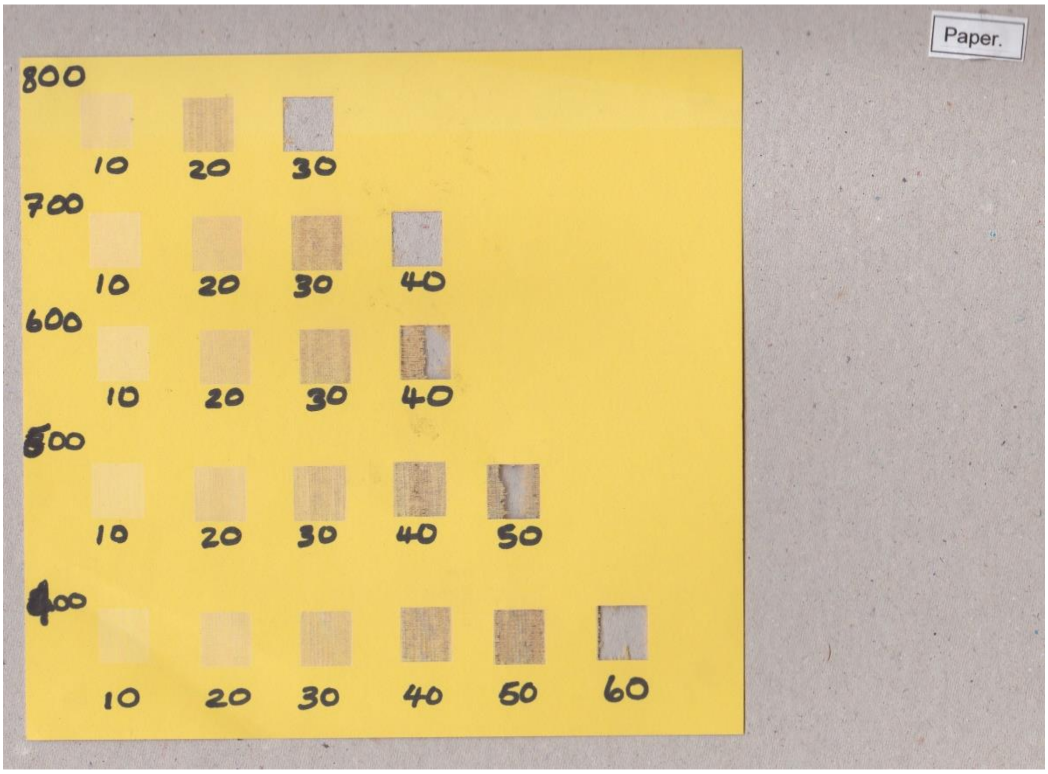
Table of results from method 3 experiments

Material	Equipment	Temperature	Time	Pressing time	Results
HDPE	Two metal sheets	125°C	35 mins	10 mins	Sample did not fuse.
HDPE	Two metal sheets	250°C	10mins	5 mins	Sample did not fuse
HDPE	Two metal sheets	250°C	13 mins	5 mins	Sample did not fuse. High Fume.
HDPE	One thin press plate and silicone sheet	180°C	20mins	10mins	Pressed and fused well. Warped after 30mins.
HDPE	Hollow bar	180°C	25mins	10 mins	Fused together well on outer area but not fused in middle.
HDPE	Hollow bar	180°C	35mins	15mins	Fused together well. Cooled quickly in water and released from mould easily.

Table of results from method 3 experiments

Appendix 8

Documentation of laser parameter experiments



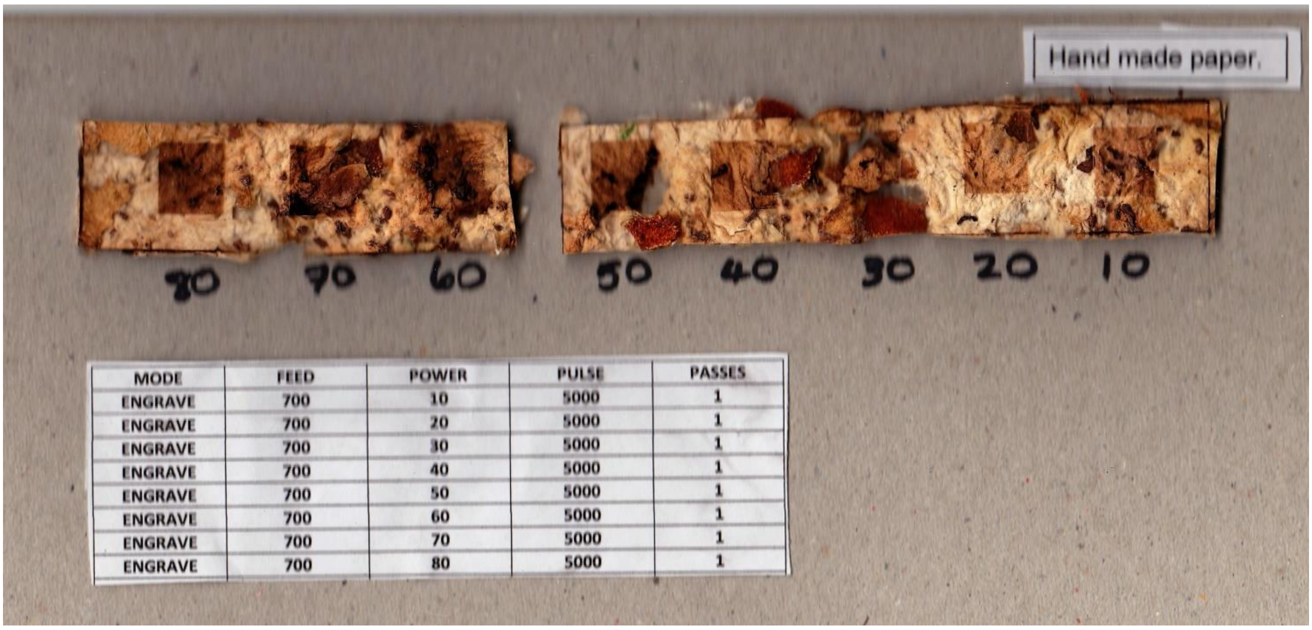
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	400	10	5000	1
ENGRAVE	400	20	5000	1
ENGRAVE	400	30	5000	1
ENGRAVE	400	40	5000	1
ENGRAVE	400	50	5000	1
ENGRAVE	400	60	5000	1

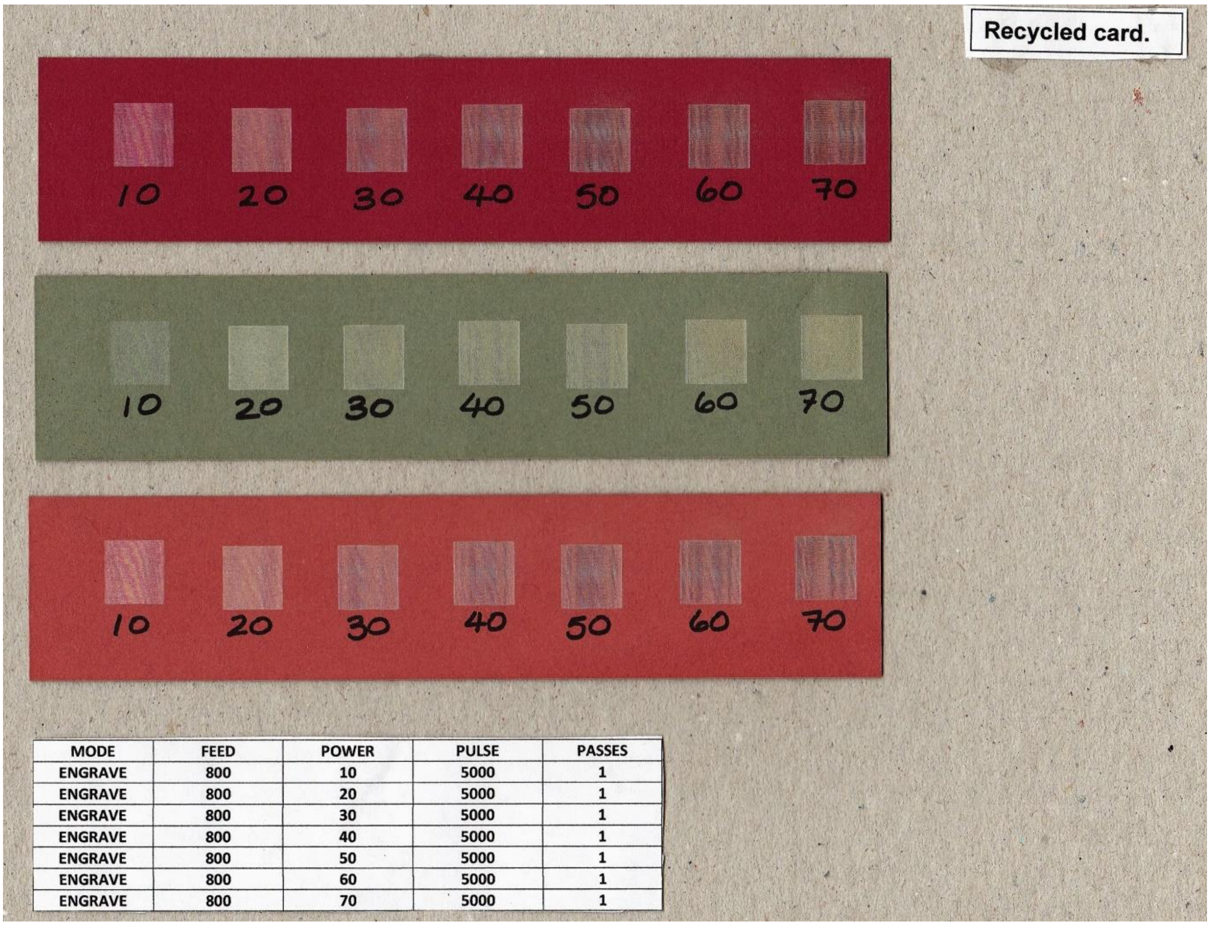
FEED	POWER	PULSE	PASSES
700	10	5000	1
700	20	5000	1
700	30	5000	1
700	40	5000	1

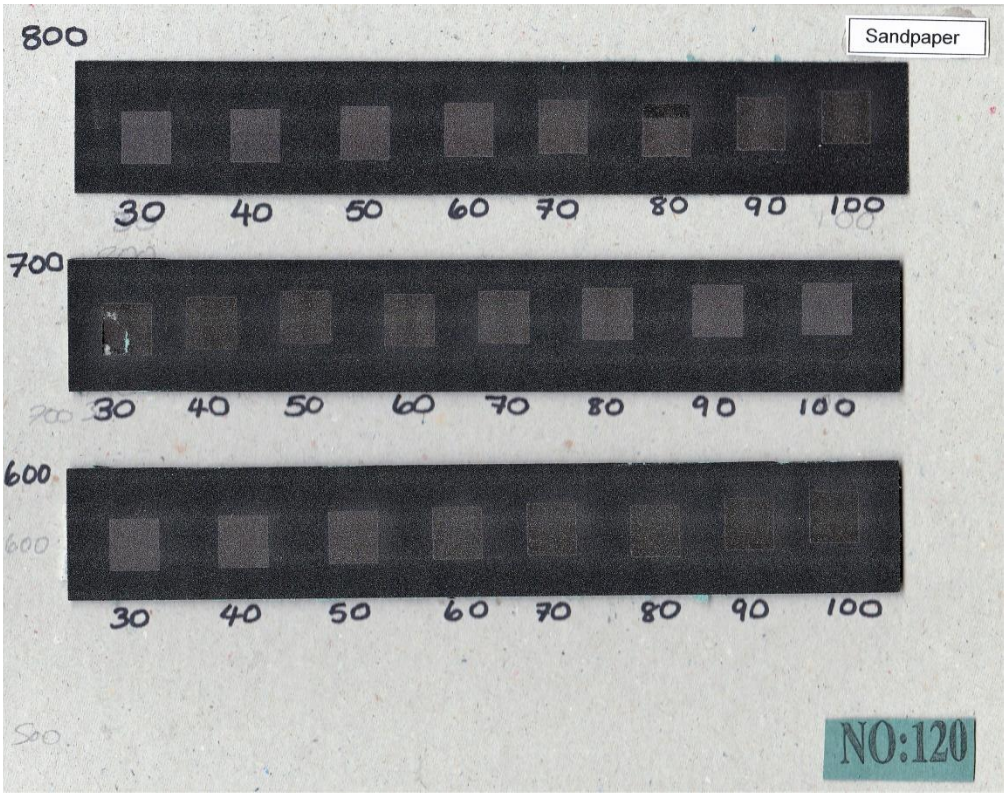
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	500	10	5000	1
ENGRAVE	500	20	5000	1
ENGRAVE	500	30	5000	1
ENGRAVE	500	40	5000	1
ENGRAVE	500	50	5000	1

FEED	POWER	PULSE	PASSES
800	10	5000	1
800	20	5000	1
800	30	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	600	10	5000	1
ENGRAVE	600	20	5000	1
ENGRAVE	600	30	5000	1
ENGRAVE	600	40	5000	1


Hand made paper.
80 70 60 50 40 30 20 10
MODE FEED POWER PULSE PASSES
ENGRAVE 700 10 5000 1
ENGRAVE 700 20 5000 1
ENGRAVE 700 30 5000 1
ENGRAVE 700 40 5000 1
ENGRAVE 700 50 5000 1
ENGRAVE 700 60 5000 1
ENGRAVE 700 70 5000 1
ENGRAVE 700 80 5000 1

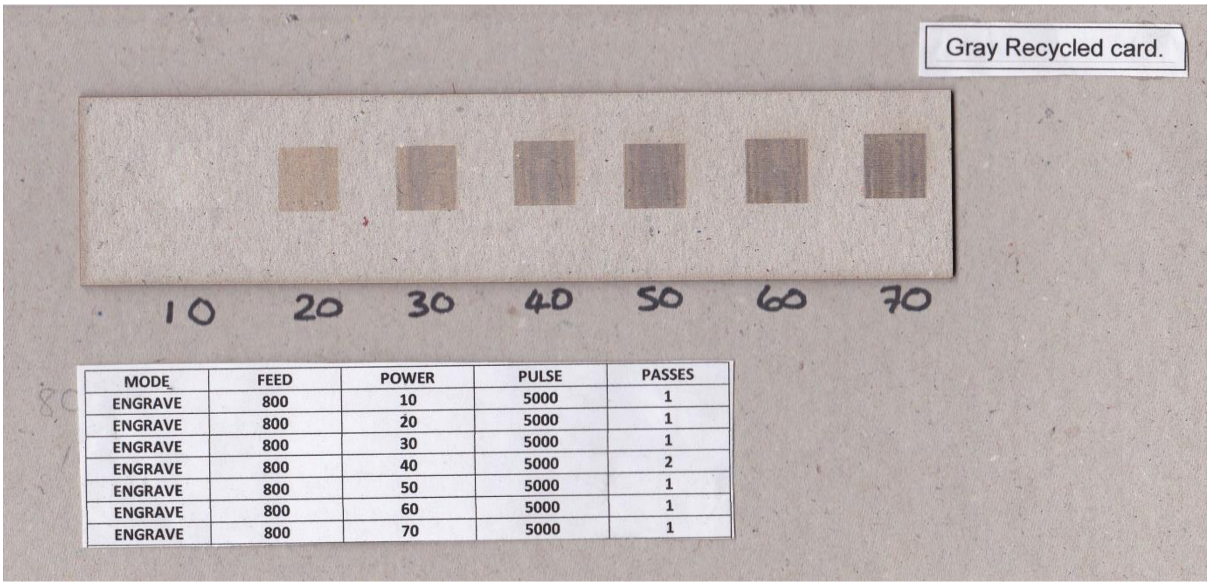

Recycled card.
10 20 30 40 50 60 70
10 20 30 40 50 60 70
10 20 30 40 50 60 70
MODE FEED POWER PULSE PASSES
ENGRAVE 800 10 5000 1
ENGRAVE 800 20 5000 1
ENGRAVE 800 30 5000 1
ENGRAVE 800 40 5000 1
ENGRAVE 800 50 5000 1
ENGRAVE 800 60 5000 1
ENGRAVE 800 70 5000 1



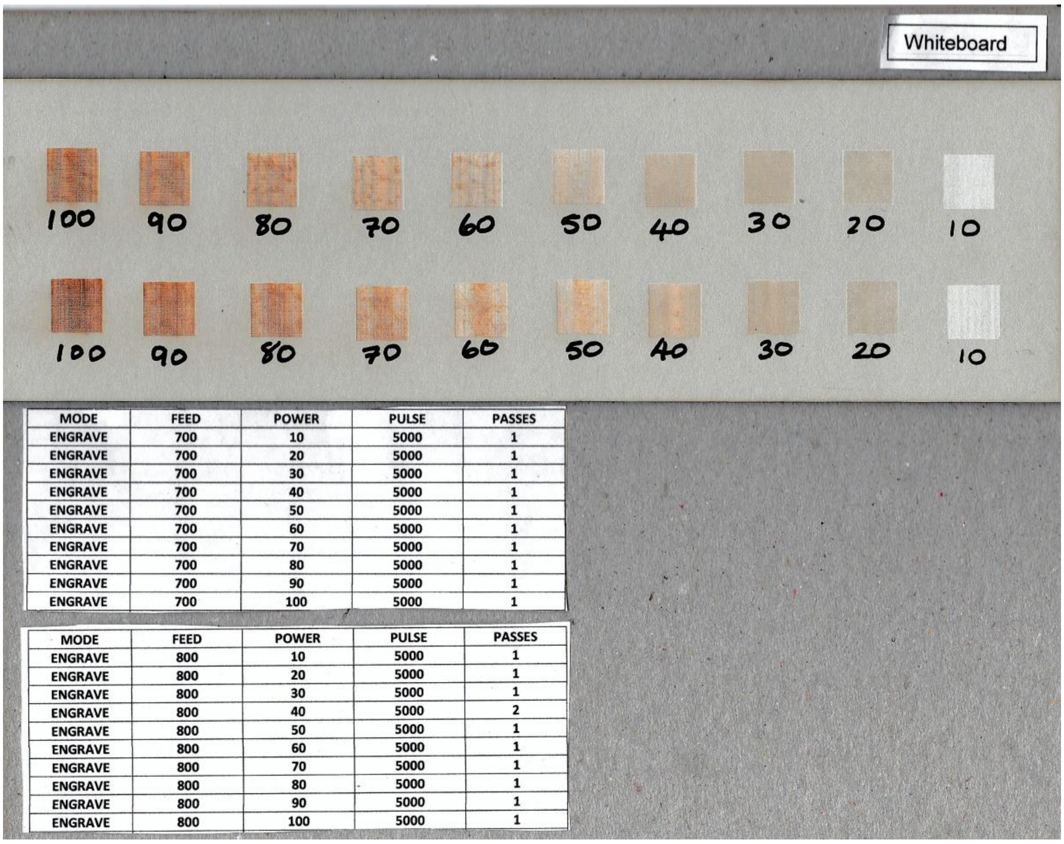
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	600	10	5000	1
ENGRAVE	600	20	5000	1
ENGRAVE	600	30	5000	1
ENGRAVE	600	40	5000	1
ENGRAVE	600	50	5000	1
ENGRAVE	600	60	5000	1
ENGRAVE	600	70	5000	1
ENGRAVE	600	80	5000	1
ENGRAVE	600	90	5000	1
ENGRAVE	600	100	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1
ENGRAVE	700	80	5000	1
ENGRAVE	700	90	5000	1
ENGRAVE	700	100	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	2
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1
ENGRAVE	800	90	5000	1
ENGRAVE	800	100	5000	1

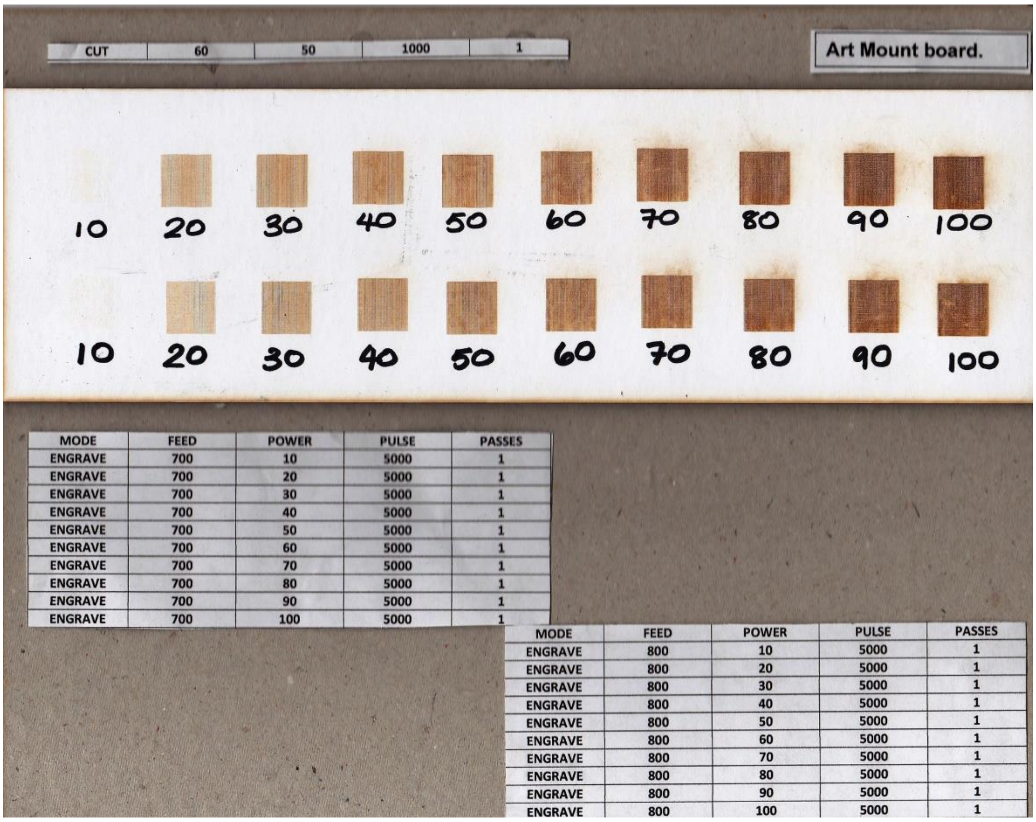


MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	2
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1



MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1
ENGRAVE	700	80	5000	1
ENGRAVE	700	90	5000	1
ENGRAVE	700	100	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	2
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1
ENGRAVE	800	90	5000	1
ENGRAVE	800	100	5000	1

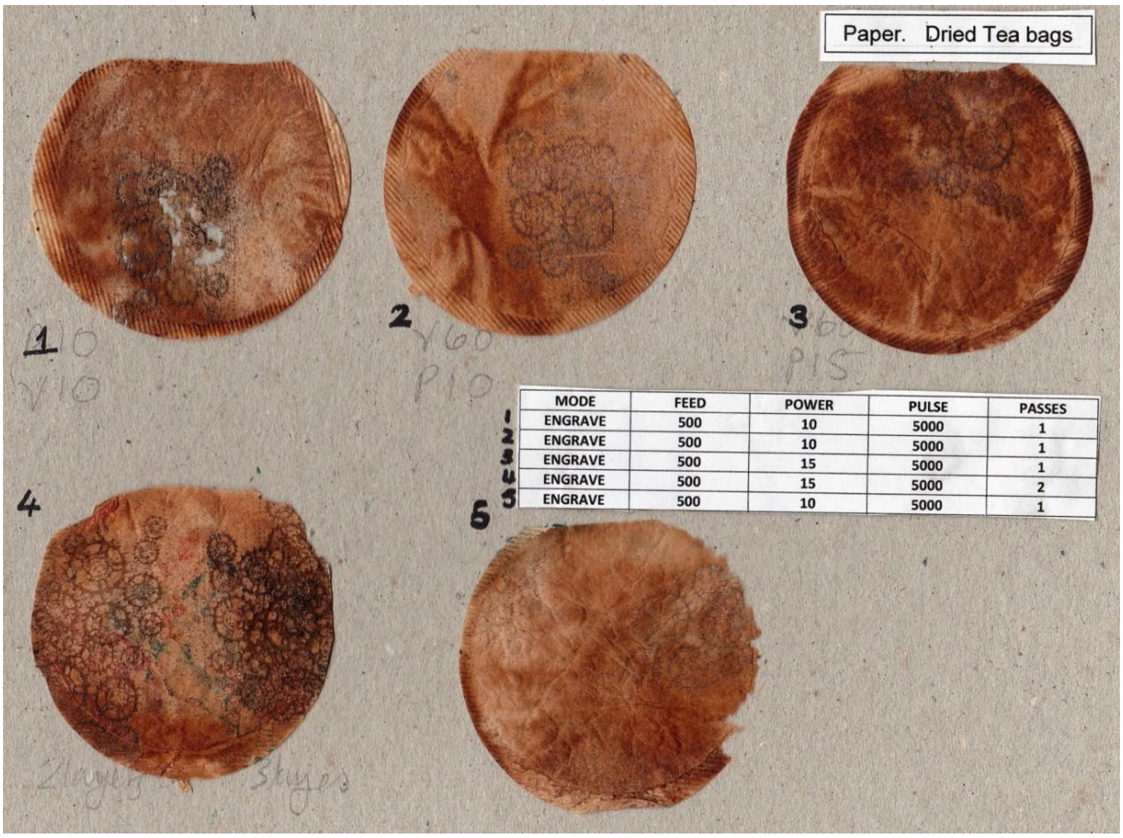


CUT	60	50	1000	1

Art Mount board.
10 20 30 40 50 60 70 80 90 100
10 20 30 40 50 60 70 80 90 100

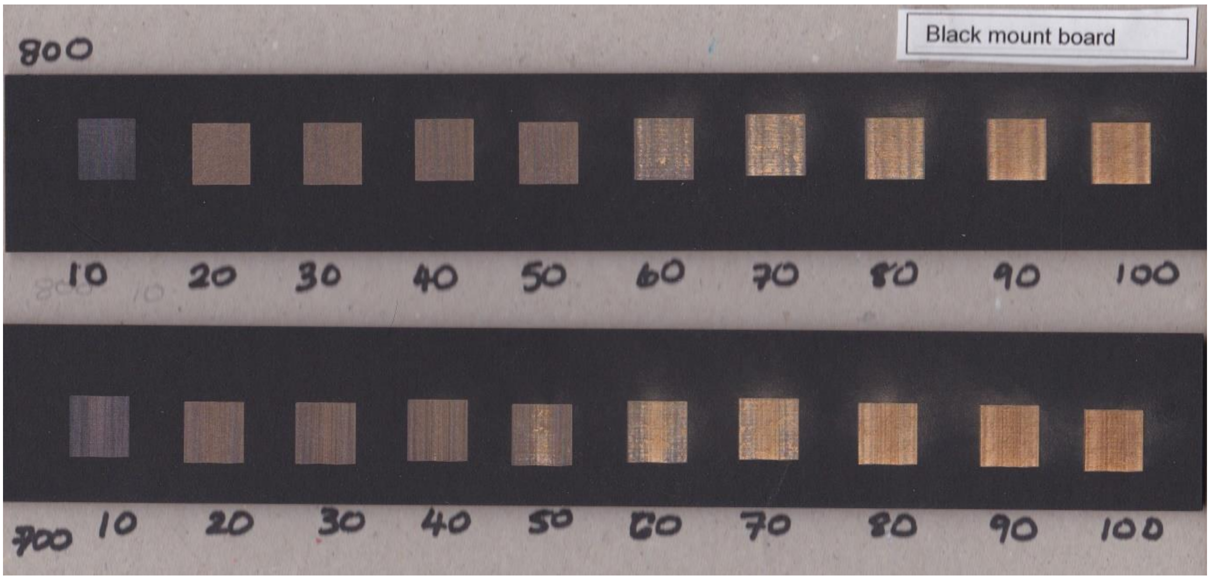
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1
ENGRAVE	700	80	5000	1
ENGRAVE	700	90	5000	1
ENGRAVE	700	100	5000	1

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	1
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1
ENGRAVE	800	90	5000	1
ENGRAVE	800	100	5000	1



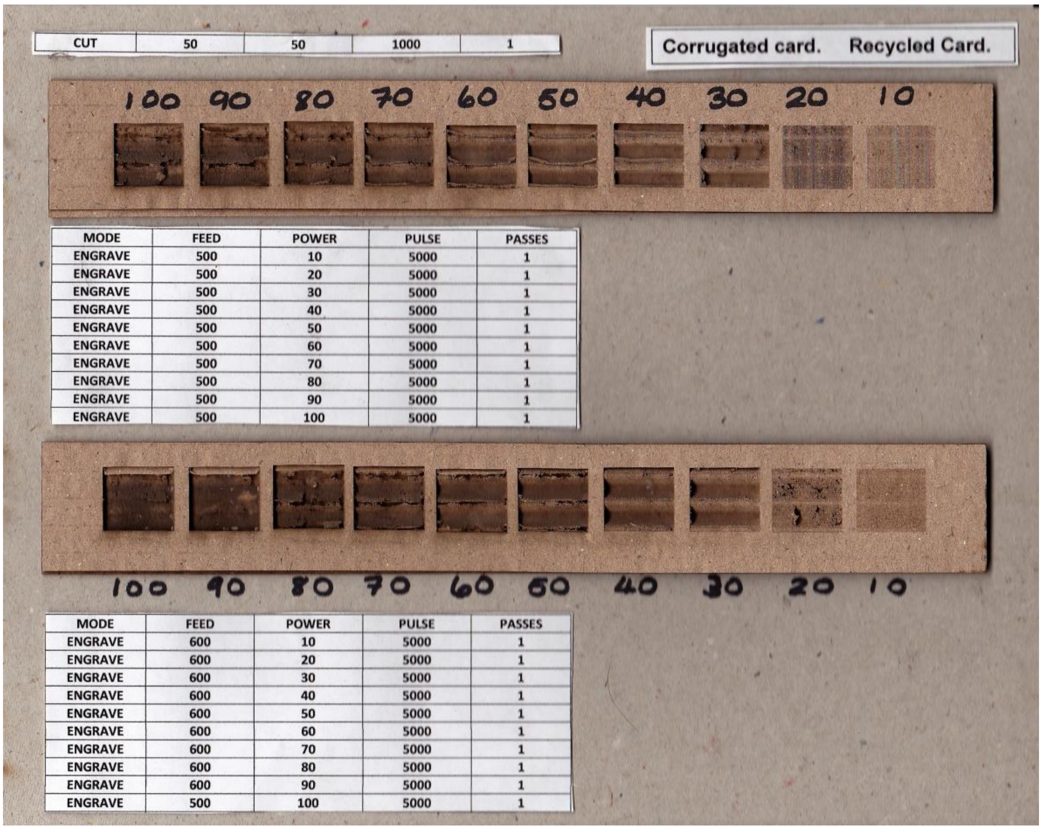
Paper. Dried Tea bags
1
2
3
4
5

	MODE	FEED	POWER	PULSE	PASSES
1	ENGRAVE	500	10	5000	1
2	ENGRAVE	500	10	5000	1
3	ENGRAVE	500	15	5000	1
4	ENGRAVE	500	15	5000	2
5	ENGRAVE	500	10	5000	1



MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1
ENGRAVE	700	80	5000	1
ENGRAVE	700	90	5000	1
ENGRAVE	700	100	5000	1

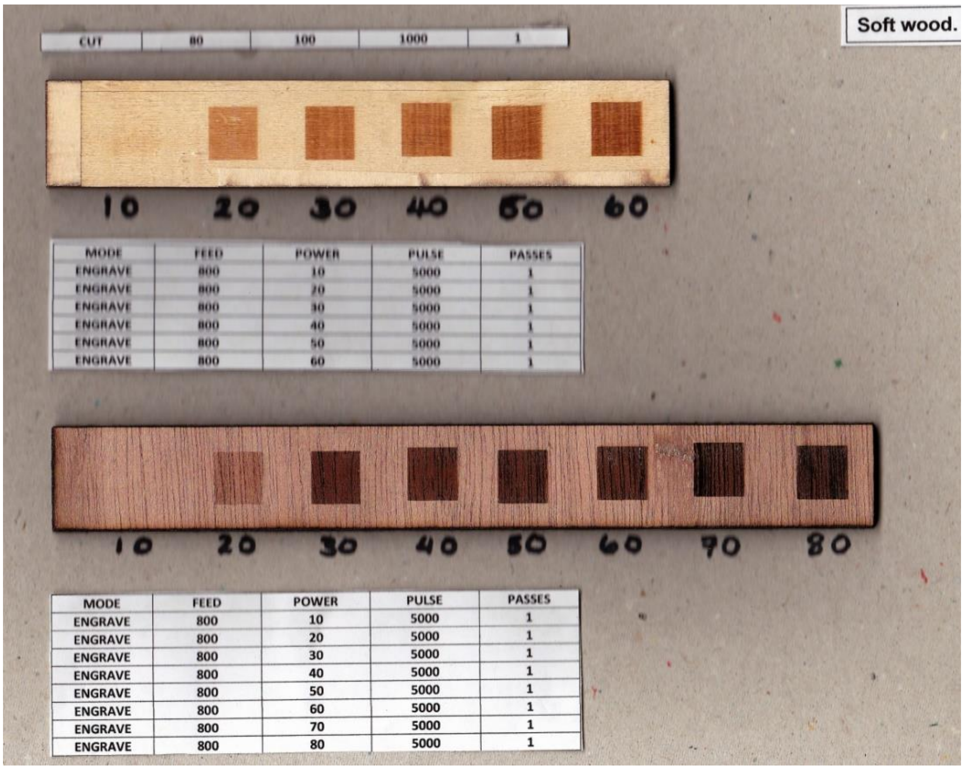
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	2
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1
ENGRAVE	800	90	5000	1
ENGRAVE	800	100	5000	1


CUT | 50 | 50 | 1000 | 1
Corrugated card. Recycled Card.
100 90 80 70 60 50 40 30 20 10

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	500	10	5000	1
ENGRAVE	500	20	5000	1
ENGRAVE	500	30	5000	1
ENGRAVE	500	40	5000	1
ENGRAVE	500	50	5000	1
ENGRAVE	500	60	5000	1
ENGRAVE	500	70	5000	1
ENGRAVE	500	80	5000	1
ENGRAVE	500	90	5000	1
ENGRAVE	500	100	5000	1

100 90 80 70 60 50 40 30 20 10

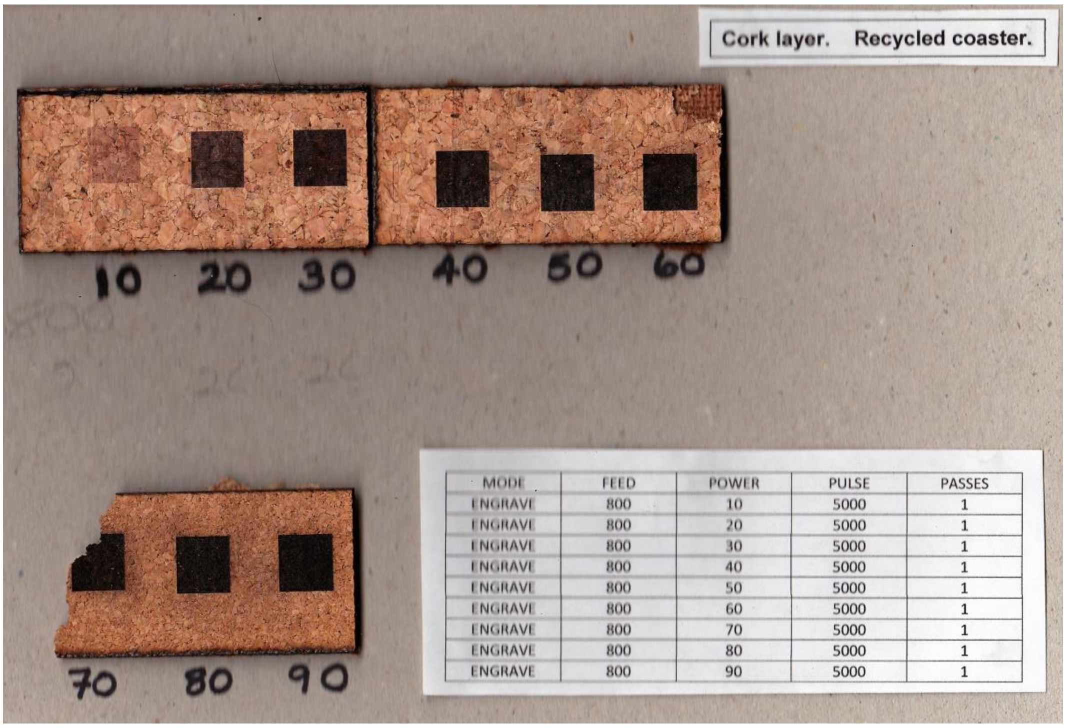
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	600	10	5000	1
ENGRAVE	600	20	5000	1
ENGRAVE	600	30	5000	1
ENGRAVE	600	40	5000	1
ENGRAVE	600	50	5000	1
ENGRAVE	600	60	5000	1
ENGRAVE	600	70	5000	1
ENGRAVE	600	80	5000	1
ENGRAVE	600	90	5000	1
ENGRAVE	500	100	5000	1


CUT | 80 | 100 | 1000 | 1
Soft wood.
10 20 30 40 50 60

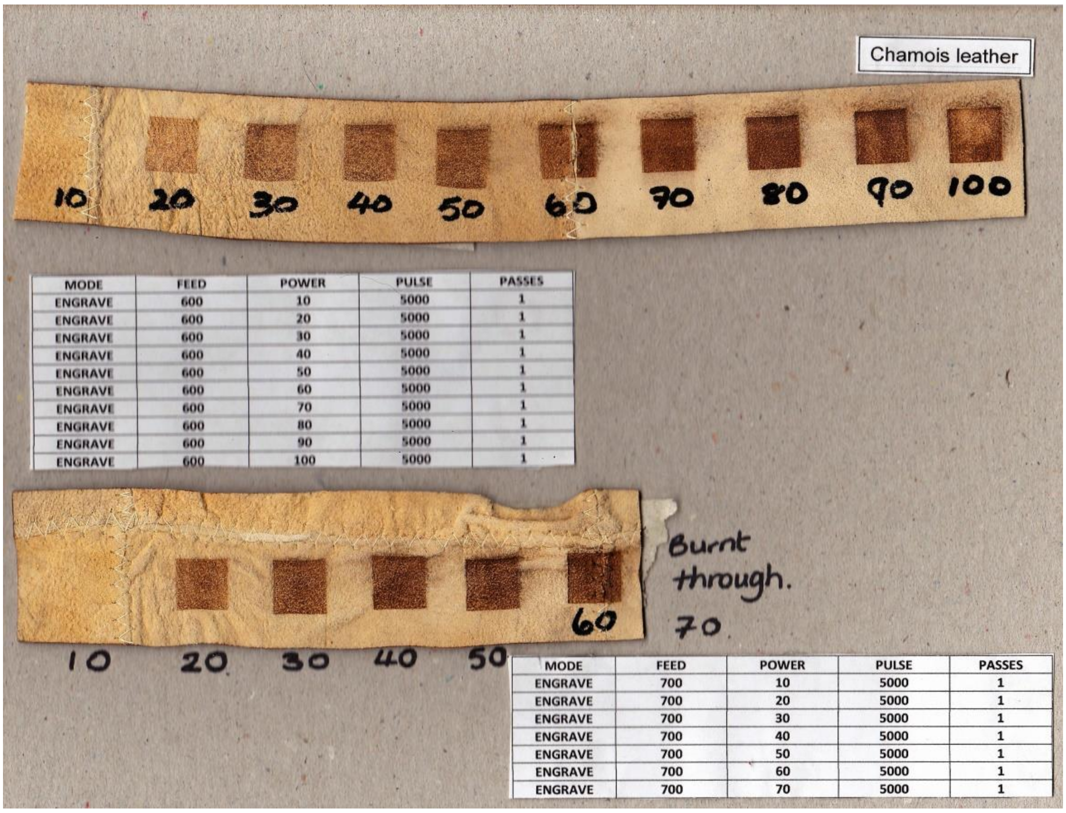
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	1
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1

10 20 30 40 50 60 70 80

MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	1
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1

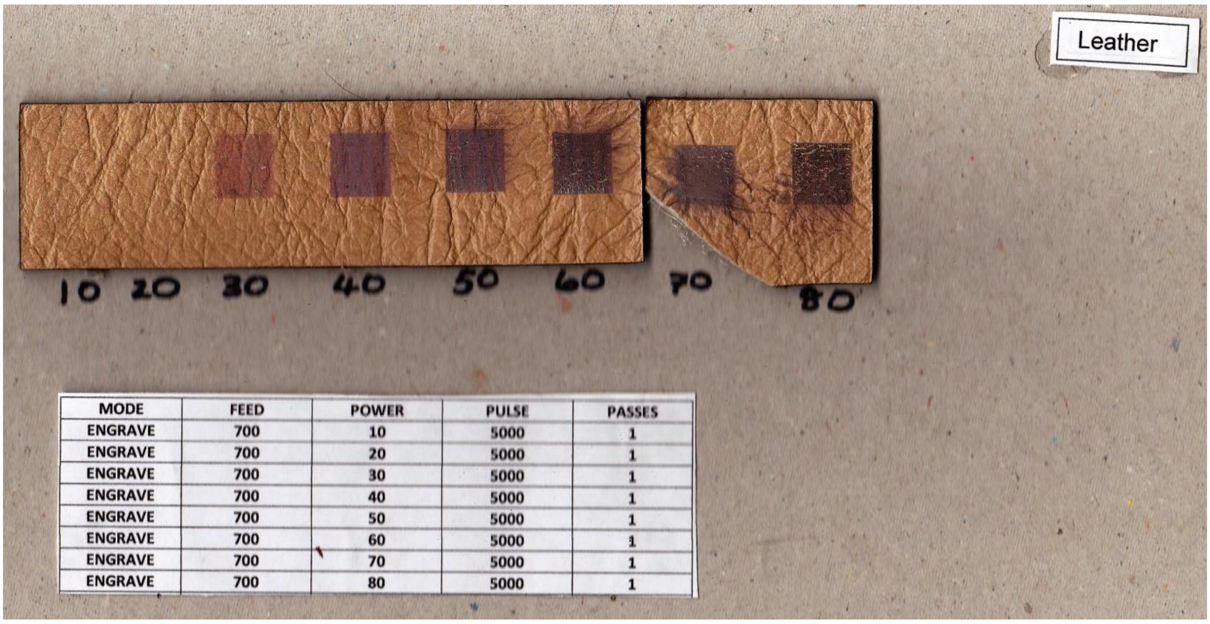


MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	800	10	5000	1
ENGRAVE	800	20	5000	1
ENGRAVE	800	30	5000	1
ENGRAVE	800	40	5000	1
ENGRAVE	800	50	5000	1
ENGRAVE	800	60	5000	1
ENGRAVE	800	70	5000	1
ENGRAVE	800	80	5000	1
ENGRAVE	800	90	5000	1

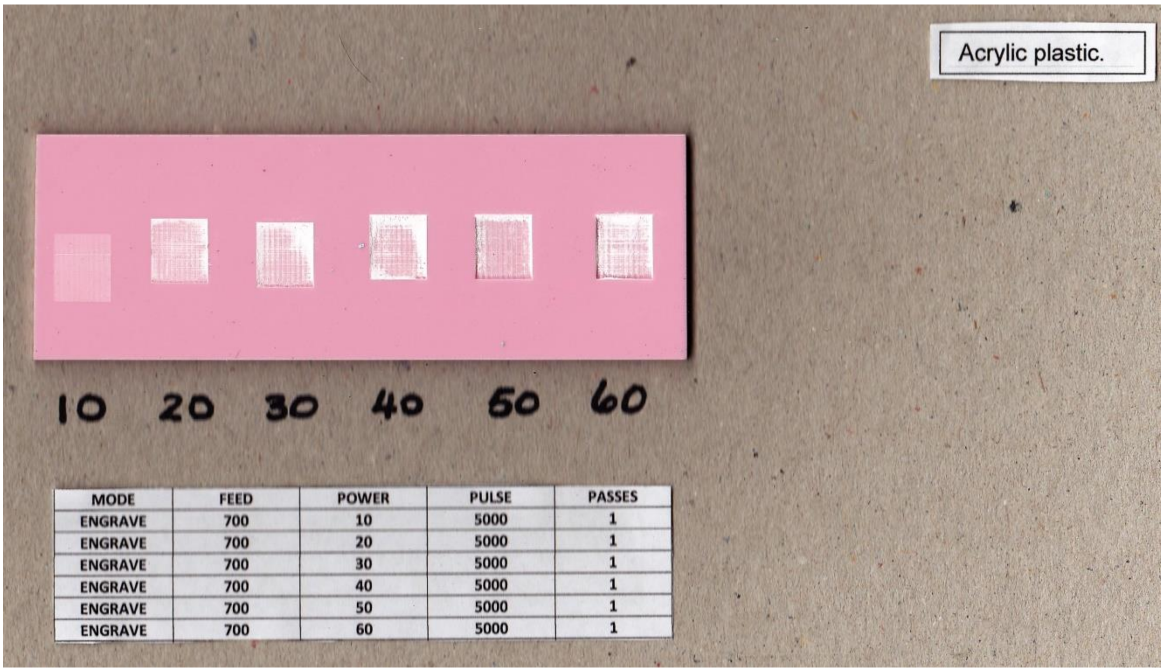


MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	600	10	5000	1
ENGRAVE	600	20	5000	1
ENGRAVE	600	30	5000	1
ENGRAVE	600	40	5000	1
ENGRAVE	600	50	5000	1
ENGRAVE	600	60	5000	1
ENGRAVE	600	70	5000	1
ENGRAVE	600	80	5000	1
ENGRAVE	600	90	5000	1
ENGRAVE	600	100	5000	1

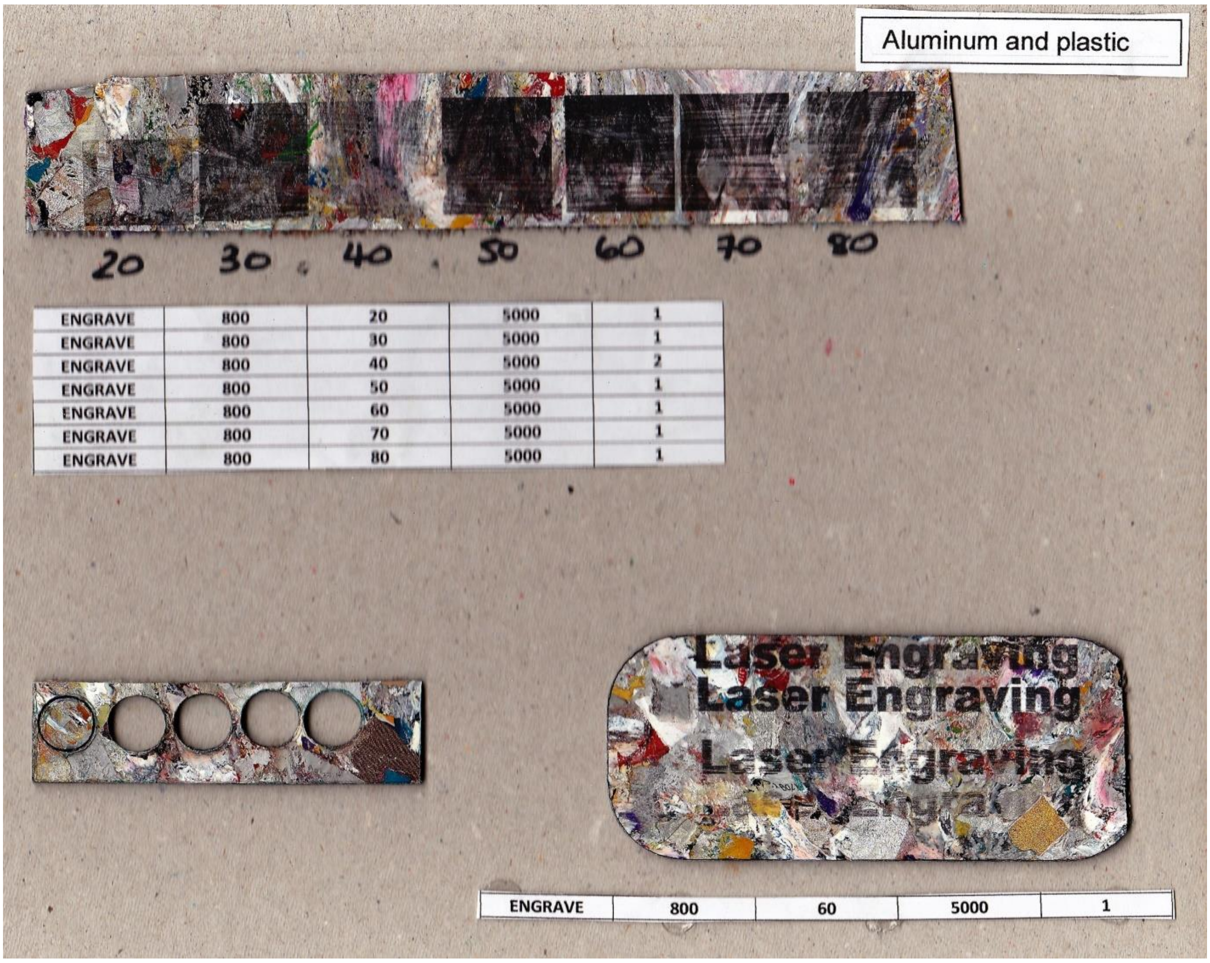
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1



MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1
ENGRAVE	700	70	5000	1
ENGRAVE	700	80	5000	1

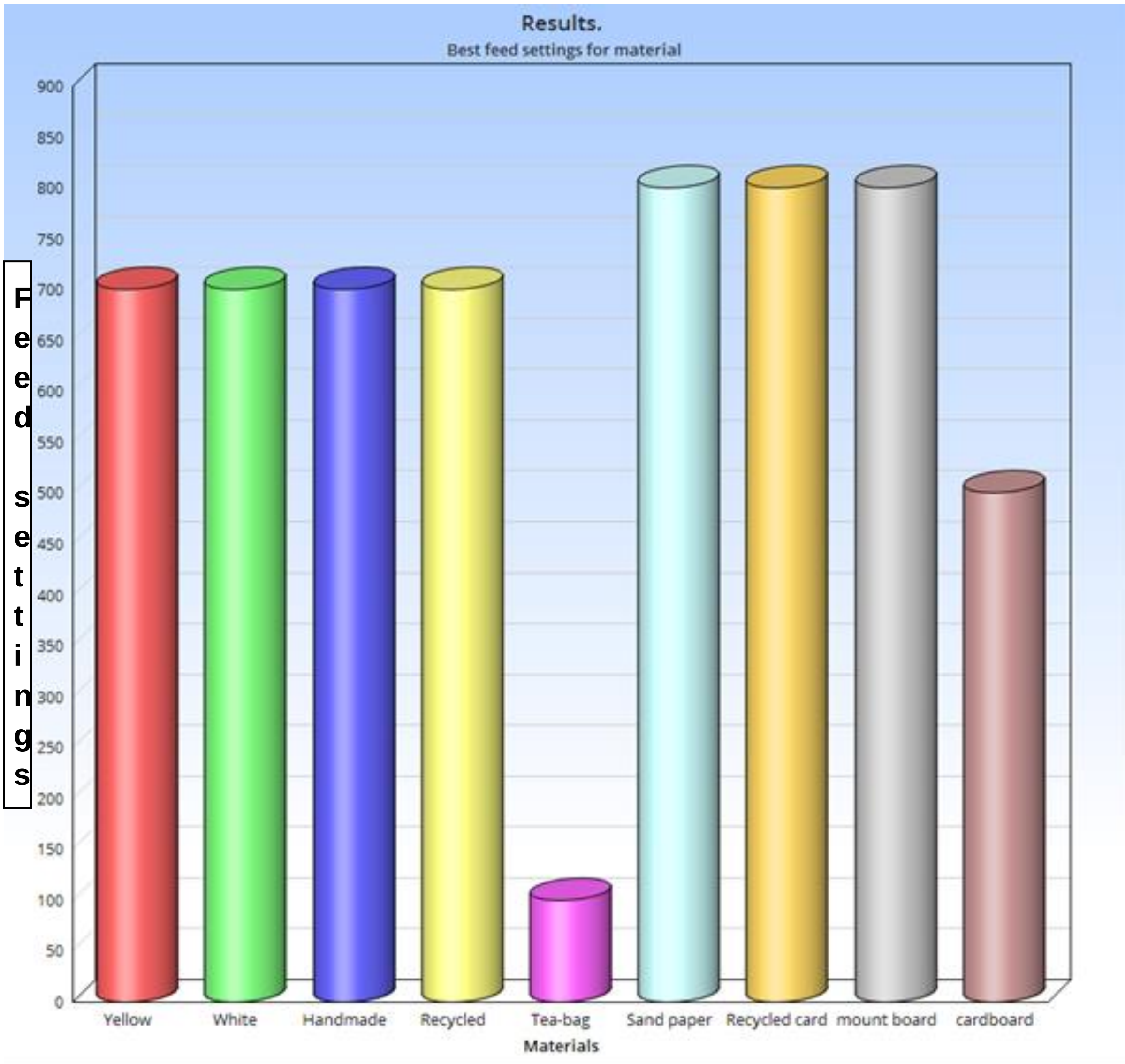


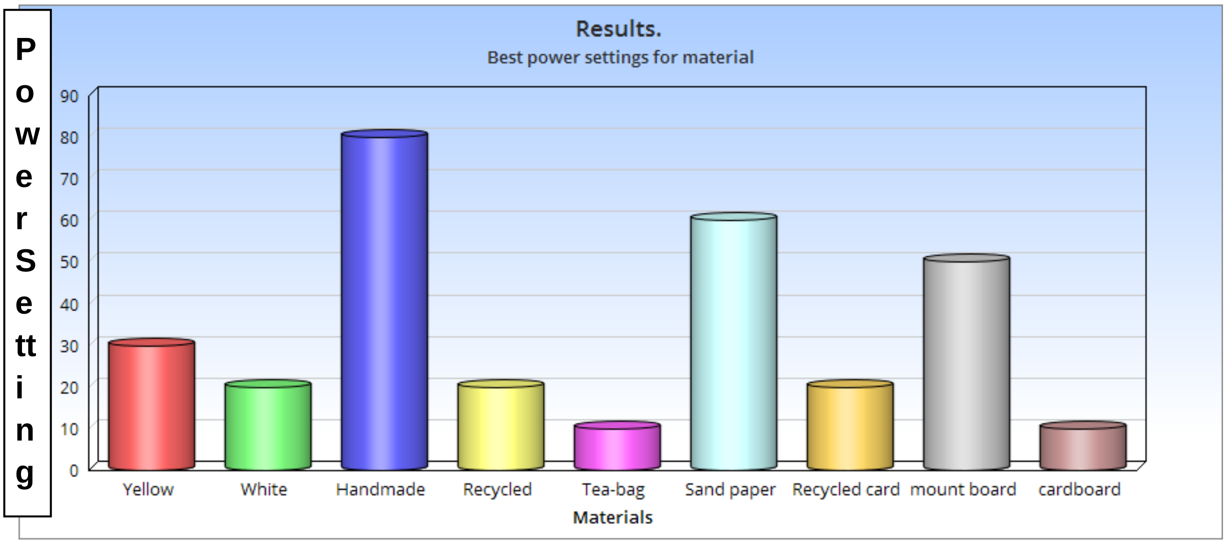
MODE	FEED	POWER	PULSE	PASSES
ENGRAVE	700	10	5000	1
ENGRAVE	700	20	5000	1
ENGRAVE	700	30	5000	1
ENGRAVE	700	40	5000	1
ENGRAVE	700	50	5000	1
ENGRAVE	700	60	5000	1


Aluminum and plastic
20
30
40
50
60
70
80
ENGRAVE 800 20 5000 1
ENGRAVE 800 30 5000 1
ENGRAVE 800 40 5000 2
ENGRAVE 800 50 5000 1
ENGRAVE 800 60 5000 1
ENGRAVE 800 70 5000 1
ENGRAVE 800 80 5000 1
Laser Engraving
Laser Engraving
ENGRAVE 800 60 5000 1

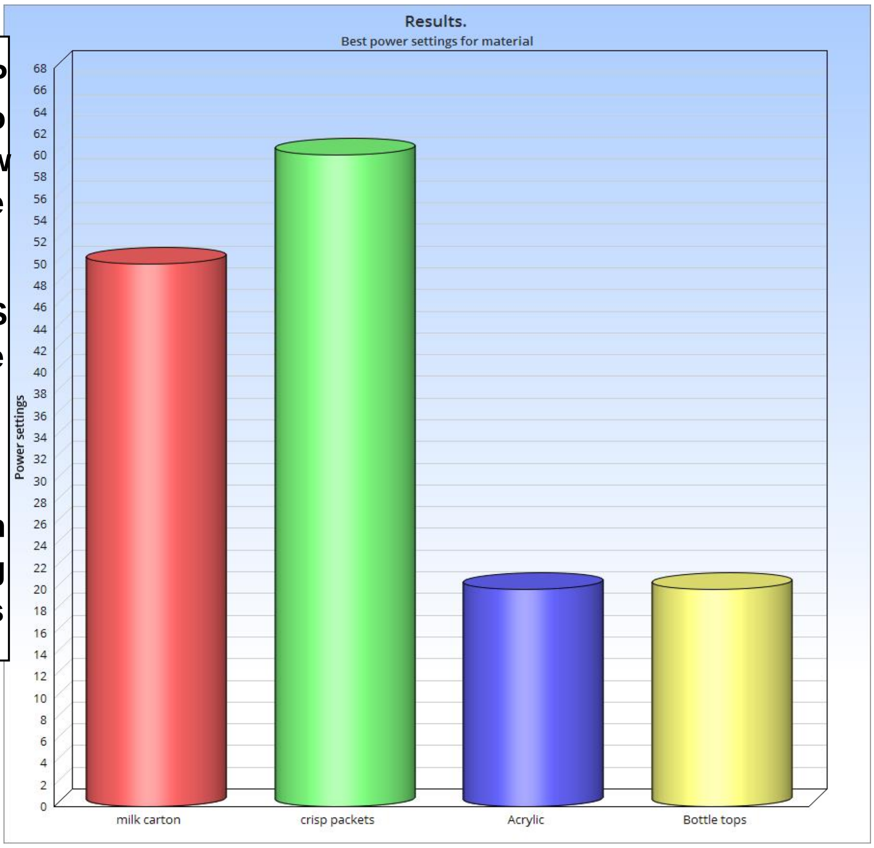
Appendix 9

Results

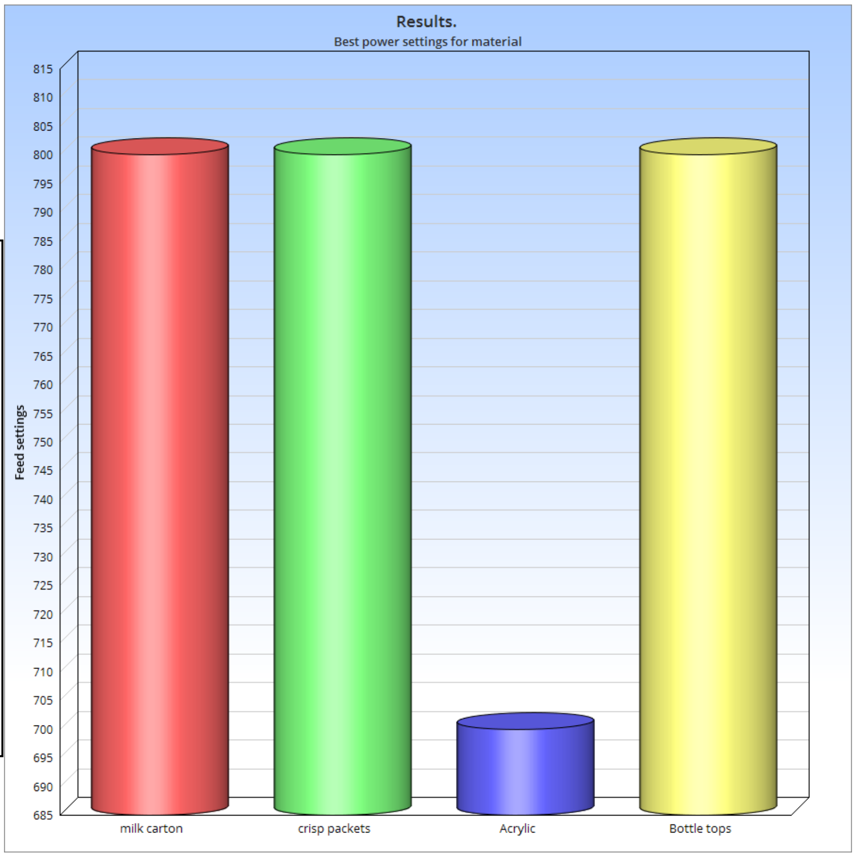

Results.
Best feed settings for material
Feed settings
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Yellow
White
Handmade
Recycled
Tea-bag
Sand paper
Recycled card
mount board
cardboard
Materials

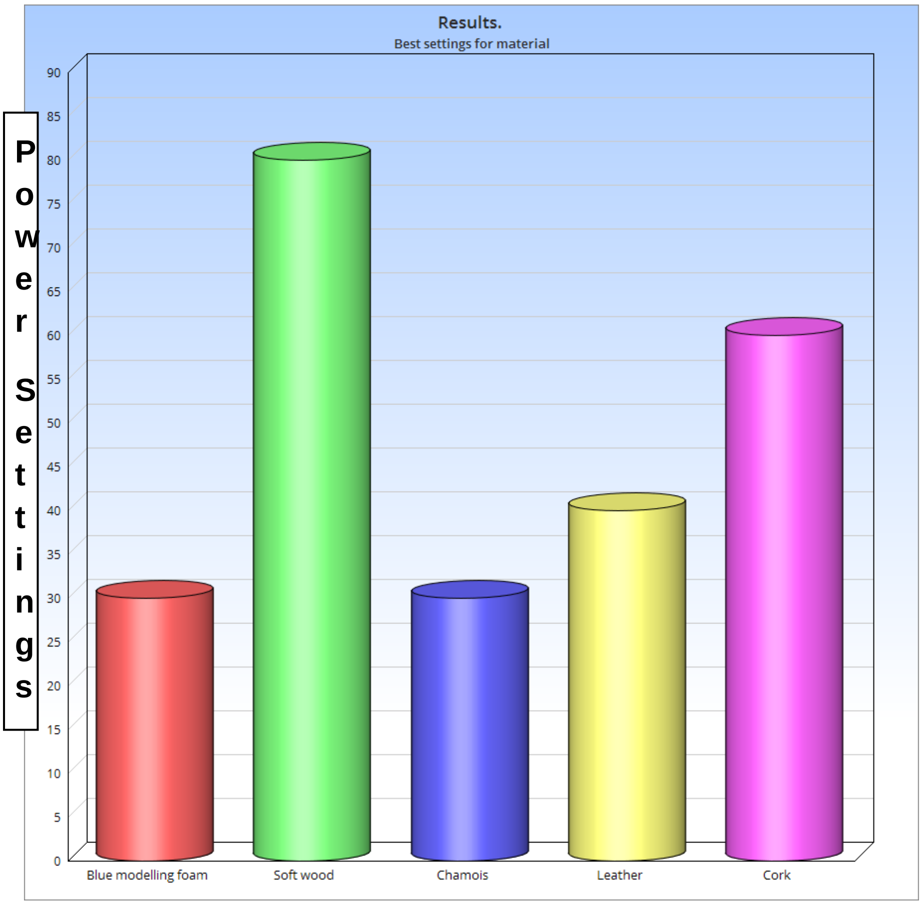

Results.
Best power settings for material
PowerSetting
90
80
70
60
50
40
30
20
10
0
Yellow
White
Handmade
Recycled
Tea-bag
Sand paper
Recycled card
mount board
cardboard
Materials

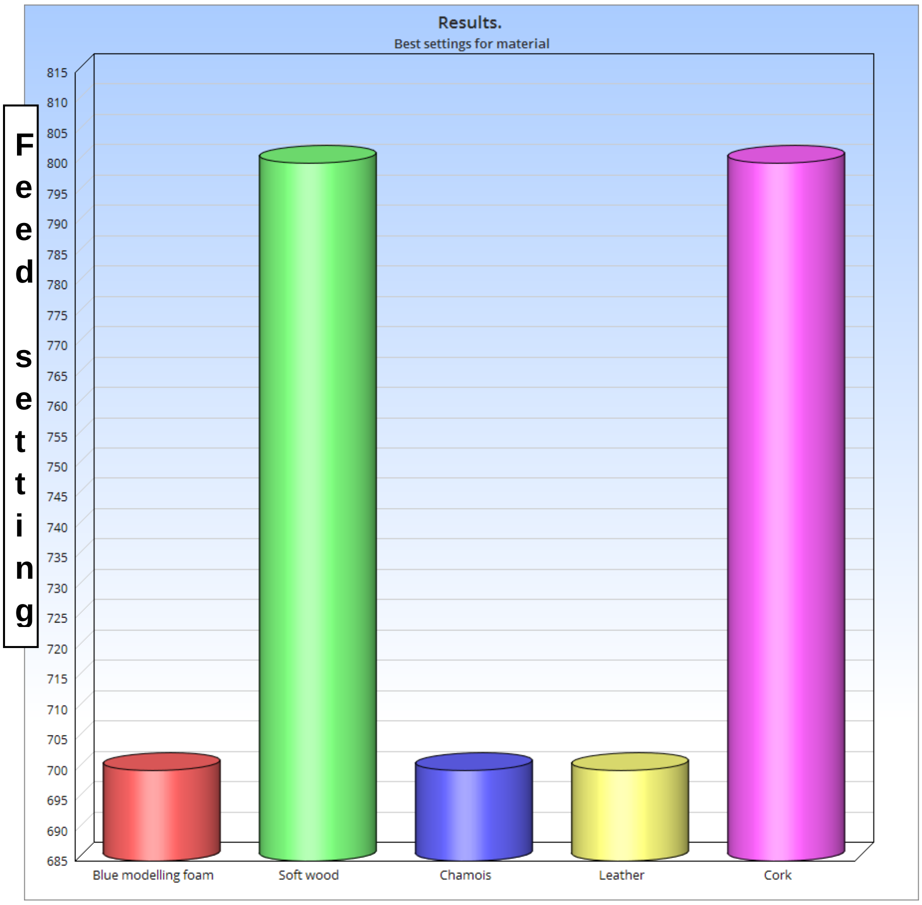
Power Settings



Feed settings




Power Settings
Results.
Best settings for material
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Blue modelling foam
Soft wood
Chamois
Leather
Cork


Feed setting
Results.
Best settings for material
815
810
805
800
795
790
785
780
775
770
765
760
755
750
745
740
735
730
725
720
715
710
705
700
695
690
685
Blue modelling foam
Soft wood
Chamois
Leather
Cork

Results

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
100										
200										
300										
400				m						
500						m				
600										
700				m						
800						c				

Table of results for figure 80 own work

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
00										
200										
300										
400				m						
500						m				
600										
700				m						
800						c				

Table of results for figure 81 own work

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
100										
200										
300										
400										
500										
600										
700										
800					m		m	m		c

Table of results for figure 88 (own work)

Results

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
100										
200										
300										
400										
500										
600										
700										
800			**m**			**c**				

Table of results for figure 90 (own work)

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
00										
200										
300										
400										
500	**m**		**m**				**m**			
600										
700										
800						**c**				

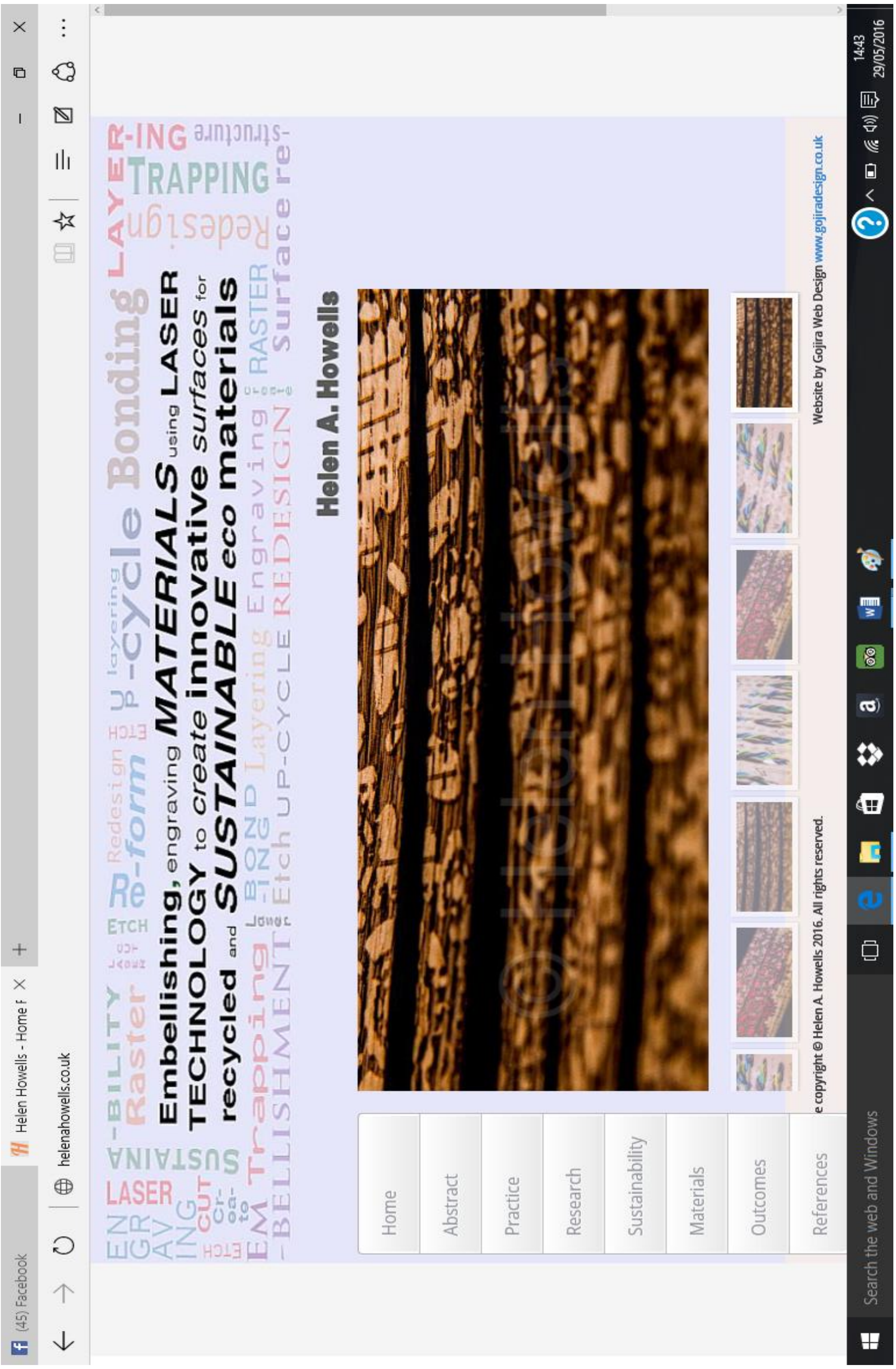
Table of results for figure 91 (own work)

							Power %			
Feed	10	20	30	40	50	60	70	80	90	100
100										
200										
300										
400										
500										
600										
700				**m**						
800						**m**				**c**

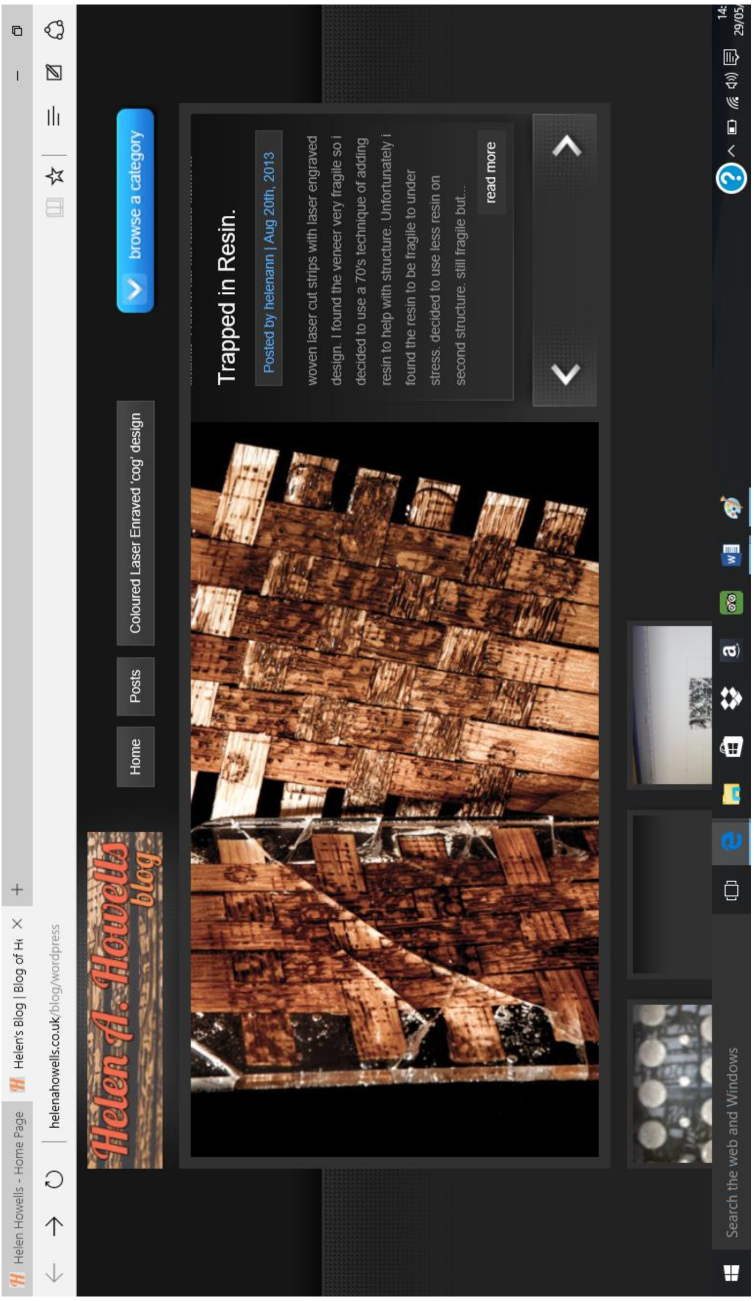
Table of results for figure 92 (own work)

Appendix 10

Webpage and blog



(http://www.helenahowells.co.uk/)



(http://helenahowells.co.uk/blog/wordpress/?cat=1)