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Anthropometric Practices and the Complete Knitted Garment

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Abstract

There is a clear and transparent relationship between the utilisation of anthropometric data and the woven garment construction processes. Knitwear manufactured on flat bed machinery however, presents practitioners with a very different set of parameters regarding the use of body measurement data to achieve satisfactory fit. Innovative developments in knitting technology create additional complexities, as it is now possible to generate garments three dimensionally. This technology is likely to impact on the ability to size, assess fit and determine the shape of a knitted garment. An investigation was therefore prompted, which explored the potential impact of complete garment technology implementation, within the UK knitwear industry. The research employed a qualitative grounded theory strategy. Preliminary stages of the investigation generated a map of the current UK knitwear industry and identified two sampling frames for subsequent data collection. Initially semi structured interviews were conducted with key personnel from the selected machine builders, which informed case study research with two leading UK complete garment manufacturers.

It was concluded from the research that the manufacturers utilising complete garment technology had developed innovative new ranges. However, a number of inhibitors to further developments were identified, including a lack of investment in research, skills and training. Further to this, process maps generated through analysis of case study data showed how imprecise anthropometric practices contribute to unnecessary repeats within the garment development cycle. It was therefore possible to conclude that the relationship between complete garment production and body dimensions was not clearly defined during the garment development process.

1.0 Introduction

It is recognised that product development requires a matching of the physical form of the product to that of its user (Pheasant and Haslegrave, 2006). In clothing this matching must relate to the way in which the garment fits the wearer's body. The appropriation and application of correct anthropometric data within clothing production is recognised to be a primary factor in achieving satisfactory garment fit (Le Pechoux and Ghosh, 2002; Power and Otieno, 2007 and 2008). Historically clothing practitioners utilised an individual's personal measurements and applied empirically acquired knowledge to construct garments (Aldrich, 2007). Mass production of clothing, originally pioneered in America at the beginning of the 20th Century (Tamburrino, 1992) created the need for a different approach to the handling of body measurement data. It became imperative to develop sizing systems capable of accommodating whole populations. As a result the first scientific sizing survey on approximately 1500 women in America was conducted (O'Brian and Sheldon, 1941). This became the model for a UK Survey in 1953, providing measurement data for individual manufacturers to generate their own sizing systems (Kemsley, 1957). For several decades women's size charts in the UK were based on this data. During this time retailers adapted their methods creating a confusion of non-standardised sizing (Winks, 1997; Otieno et al., 2005). Retailers regard their sizing data to be confidential; a practice implying sizing is recognised as a competitive area (Otieno, 2000). In an effort to improve size charts and clothing fit in the UK, the British government in collaboration with retailers and academics undertook an anthropometric survey of 5000 women and 5000 men in 2001 (Bougourd et al.,

2000; Stylios, 2001), utilising scanning technology. Watkins (2006) however suggests that sizing surveys do not necessarily result in better sized clothing. It is unknown whether practitioners within the clothing industry have the skills to interpret and utilise the extensive and complex data made available through scanning technology. Appropriate application of anthropometric measurement within clothing construction has equal importance to the utilisation of accurate data. Pattern construction used during the initial stages of woven garment manufacture clearly identifies key body dimension utilised within the process (Moore *et al*, 2001; Aldrich, 2004; Joseph-Armstrong, 2006). There is still a lack of clarity regarding exactly how woven garment dimensions are determined to allow acceptable fit parameters, freedom of movement and comfort. Explicitly the difference between the body dimensions provided on size charts and the garment dimensions specified within the pattern making process. The result is a situation where ease amounts are not always apparent (Gill and Chadwick, 2009).

The extensive diversity of garment production methods must also be considered when applying anthropometric data to achieve fit. Pattern making processes for cut and sew knitted or jersey garments is less well documented than for woven garments (Aldrich, 1996). The majority of knitted fashion garments are constructed using a weft technique. Flatbed machinery is capable of creating shape, integral to the weft knitting process (Brackenbury, 1992; Spencer, 2001). This is achieved through a variety of methods; Changing the construction of the fabric for instance from a plain knit to a knitted rib will decrease the width. Increasing or decreasing stitch length causes incremental dimensional change. Narrowing and widening is the transference of stitches from one or more needle either outside the selvedge edge to increase width or inside the original needle to decrease width. Limitations associated with these shaping methods necessitate some cutting in order to achieve the required curvature, particularly for necklines (Walsh, 1966; Brackenbury, 1992). Knitwear practitioners responsible for creating garment fit are dealing with an entirely different set of procedures to those utilised within woven garment production. Documentation that clearly explains how anthropometric data is applied within this segment of the industry is limited. The subsequent relationship between the flatbed knitted garment and the body is therefore difficult to ascertain. There is documentation identifying a process of trial and error guided by empirical knowledge to generate garment specifications (Walsh, 1966; Eckert, 2001; Guy, 2001; Power and Otieno, 2008).

From a knitwear designer's perspective the relationships between the variables influencing the knitted structure are reported to be extremely complex (Guy, 2001). The indication is that the knitted structure presents manufacturers with a number of intricate difficulties relating to fit that are currently unresolved. The design team are expected to have the skills and knowledge to develop the fabric, shape and style of the garment at the same time (Eckert, 2001). If there is a lack of knowledge in regards to anthropometric data and its application within the knitwear industry then the ability to shape garments must surely be compromised.

In addition to the complexities caused by shaping methods there are issues related to the properties of a knitted fabric. Its multi directional extensibility enables it to mould to the three dimensional shape of a body by deformation (Brackenbury, 1992; Krzywinski *et al.*, 2001; Power, 2004; Power and Otieno, 2008). This will have an impact on how body measurement is applied. Unlike woven garments it is suggested that knitted garments can actually be constructed using smaller dimensions than those of the wearer's body (Krzywinski *et al.*, 2001; Moore *et al.*, 2001; Troynikov, 2008). This may well be correct and suggests there is a

relationship between the parameters of fabric extensibility and fit satisfaction which currently is undefined.

2.0 Technological advancement in flatbed knitting machinery

In 1995 flatbed knitting technology, capable of commercially knitting and constructing garments in one process was launched by Shima Seiki at Internationale Textilmaschinen Ausstellung (ITMA) (Gibbon, 1995b; Gibbon, 1995a; Millington, 1995). Commentators from the time reveal considerable anticipation at the prospect of the culmination of many years of research and development (Millington, 1995; Nakashima and Karasuno, 1995). However, some reservation was expressed regarding the availability of skills and knowledge to enable manufacturers to exploit the machine capabilities (Gibbons, 1995). The German company Stoll are credited with introducing important developments that enhanced commercial viability (Hunter, 2004). Shima Seiki and Stoll are acknowledged to be at the forefront of commercial application (Choi and Powell, 2005). In recent years there have been significant developments in both technology and software (Hunter 2008)

Novel technology presents further complexities for practitioners responsible for garment manufacture. Troynikov (2008), documents difficulties experienced when attempting to shape the armhole and shoulder on complete garments. Two reasons were given for this, firstly shaping restrictions and secondly a lack of templates or patterns on which to base methods. These findings support previous claims that a lack of skills and knowledge will prevent optimisation (Black, 2001; Eckert, 2001) particularly when utilising new technology. As it has been standard practice for flatbed knitwear producers to cut curved shapes that have historically been impossible to achieve, it is perhaps not entirely surprising that the shaping ability of this novel technology is under scrutiny. Producers considering investment have to trust that it can perform satisfactorily. The machine manufacturers claim the technology offers knitwear producers many advantages including: the elimination of sizing issues (Mowbray 2002) and improvement in garment fit (Stoll, 2006; Shima, 2007). The implications that knitting in tubular form has on shaping possibilities have been alluded to by the machine makers. Shima Seiki claim to have gone beyond the limitations of the simple raglan sleeve, producing garments that conform to the human body (Mowbray 2005). It has even been suggested that an entirely new type of knitted garment could emerge (Nakashima and Karasuno, 1996; Siddons, 2007). If these assertions are accurate, exploitation of this very novel machinery may help to create new niche markets (Power and Otieno, 2008) and to sustain UK heritage industries (Brownbridge, 2010). Other less optimistic appraisals however indicate that a lack of skills and knowledge are likely to inhibit producers from fully exploiting the machine capability.

3.0 Aims and Methodology

The research aims were developed, firstly to provide insight into the potential impact of complete garment technology implementation within the UK. Secondly anthropometric practices utilised by complete garment producers were investigated.

The research employed qualitative strategies of data collection. Inductive analysis generated grounded theory offering insight into the UK knitwear market. Two methods of primary data collection were utilised. (Semi structured interviews and case studies) The semi structured interviews with representatives from the machine builders explored their expectations regarding the impact of complete garment technologies, in relation to garment size, fit and shaping. Purposive sampling techniques were employed to select for the initial interviews with the machine builders. The sampling frame was created from a number of different

sources including secondary data and word of mouth. Contact was established through the UK offices and employees from the UK, Germany and Japan were selected as participants. One interview was conducted through email the other three were face to face. To determine the sampling frame for the case studies, knitwear producers utilising complete garment technology were identified through a process of cross data synthesis. (Table 1).

Table 1 Development of case study sampling frame

Knitwear manufacturers utilising complete garment technology (Case study sampling frame)	No. of sources of identification	Source of Identification
B S Attwall	3	Published literature Contact with industry expert Findings from primary data
Glenbrae high performance knitwear (Trade name, owned by Spectrum yarns)	2	Published literature Contact with industry expert
Hawick cashmere company Ltd	3	Published literature Contact with industry expert Findings from primary data
John Smedley	4	Published literature Contact with industry expert contact with trade association
James Johnston & Co. of Elgin Ltd	3	Published literature Findings from primary data Web based literature
Quantum Knitwear Ltd	5	Published literature Contact with industry expert Contact with academic expert Contact with trade association Findings from primary data
Viva knitwear	2	Web based literature Contact with industry expert

Case studies were conducted with two UK based knitwear companies. The case studies incorporated interviews with representatives from design, technical, sales and managerial practice. Observations included photographically recording complete knitted garments produced by each case study company. During the observations and interviews, data was collected in relation to the contribution of the technology to the product development. Further documentation collected included size specifications and marketing material. This additional data enhanced the assessment regarding the influence of the technology on the product. Company documentation was also scrutinised. Ethical issues concerning the use of sensitive commercial information was addressed by fully briefing both interview and case study participants of the research aims and objectives and ensured that Anonymity will be maintained. Interview questions were emailed prior to the data collection to ensure transparency and maximise data collection on the day. The participants all gave written permission for any interviews to be recorded and transcribed.

4.0 Interviews with the machine builders

The Interviews were conducted with representatives from two machine building companies (coded as MB1 and MB2) over a period of a month. Participants with experience relating to the research aims were requested when initial contact was made. Two sales managers, a

machine technician and a training manager participated in the interviews. Table 2 shows the seven categories dividing the interview questions. For the purposes of this paper findings from the first three categories listed will be discussed

Table 2 Categorisation of interview questions

Question category	No of questions per category
Utilisation of Complete garment technology in the UK	8
Size and Fit Issues	6
Shaping and garment design	14
Low labour cost.	3
Skills and training	3
Mass Customisation	3

4.1 Implementation of complete garment technology in the UK.

The first set of questions investigated the extent to which knitwear producers in the UK had invested in the technology. The participants' opinions were informed by their direct experience of marketing machinery within the UK. It was therefore possible to identify a number of issues that respondents claimed inhibited potential UK investors. The principle influencing factors for UK investment were also identified. There was variation in the responses regarding the number of UK companies utilising complete garment technology. MB1 interviewees approximated six companies, MB2 contradicted this stating there were approximately twelve. It is possible that this discrepancy might relate to an inclusion of companies utilising machinery specifically developed for accessories. The interviewees were reluctant to reveal commercially sensitive information relating to specific manufacturers utilising the machinery. It was however acknowledged by all the interviewees that only a very small percentage of the machines sold globally were complete garment.

Respondents agreed that the primary deterrent to investment was the considerable cost. Chinese imports were identified as the primary cause of a decline in the UK industry, resulting in a general reluctance to spend. Additionally, UK manufacturers were deterred by the over reliance on the scarce combination of and knitting programming skills needed to operate the technology. The principle factor driving UK producers to invest was identified as the need to alleviate recruitment problems regarding knitwear construction skills. The interviewees were however reluctant to comment on whether the technology was introduced because it enabled manufacturers to reduce their workforce. Further advantages mentioned appeared to be related more to the potential benefits of the technology rather than to direct feedback from the investors themselves. The ability to respond quickly through eradication of post production processes was considered as a major advantage for UK producers. Respondents at MB2 predicted a growth in demand for UK manufactured products to satisfy ethical consumers and hoped this would increase UK interest. At the time of the interview however, this issue had not impacted on sales.

4.2 Size and fit issues

Probing the respondents' expectations regarding any potential impact the technology may have on sizing practices revealed several factors. All the respondents commented on improved production sizing consistency due to the elimination of human error, prevalent during the traditional making up process. Respondents at MB1 acknowledged that automated grading processes were not accurate and relied on trial and error to achieve the desired results. Knowledge of anthropometric data application was not demonstrated by the interviewees. Only two responded when asked to identify the key body measurements utilised within complete garments development. These related to garment dimensions not body measurement. Regarding the potential to improve fit, two key factors were raised, both of which related directly to the eradication of seams. Firstly, the elimination of seam abrasion enhances comfort, particularly important for close fitting garments. Secondly increased extensibility decreases movement restriction.

4.3 Shaping and garment design

This third set of questions explored the participants' views regarding the machinery's potential to innovate knitwear design through improved shaping capability. Interviewees agreed that manufacturers were taking influence from the experimental garments made by the machine builders. It was generally agreed however that direct copies of these were rarely made. MB2 respondents were keen to emphasize that complete garment producers in the UK were producing novel styles. The sales manager at MB1 was less optimistic, commenting on manufacturers' reluctance to adopt an experimental approach. There was no consensus of opinion regarding shaping capability. The MB1 technician claimed that complete garment machinery was not able to achieve the shaping angles attained on traditional flatbed frames. The MB1 sales manager however, stressed the availability of a multitude of new shaping possibilities. MB2 were said to be developing methods of programming to alleviate shaping restrictions. All the interviewees acknowledged that the highly specific skills necessary to exploit machine capability are not generally available in the UK. This was perceived to be a major factor regarding limitations to the potential for innovative garment design. UK companies were also said to be reluctant to invest in the necessary research and development.

5.0 Case study findings

This paper only discusses interview data from the case studies. To maintain anonymity the case study companies will not be named. Table 3 provides the coded sampling frame.

Table 3 Case study coded sampling frame

Company reference research code	Type of manufacturer	Employees interviewed
CS1	Supplier to UK high street retailers	Design manager, Designer, Technologist. Sales director, Technical director
CS2	Traditional heritage knitwear company with fashion leanings	Brand manage, Design technician

The table 4 shows the categories used to divide the case study interview questions. The findings relating to each of these points of investigation will follow.

Table 4 Case study question categories

The impact of complete garment technology on:	No. of questions
sizing practices	4
garment fit	2
shaping	3
Product development	13
Anthropometric data	3
Fitting	2

5.1 Sizing practices

The sizing processes, identified through synthesis of the collective interview responses informed the generation of a process map (figure 1). Garment dimension are initially determined by the designers, the technicians then calculate stitch density. Empirical knowledge was used to estimate any possible variant factors, such as yarn characteristics (shrinkage and extensibility). Sizing practices relied heavily on heuristic methods, causing iteration within the garment development cycle. This is illustrated in the process map as a cycle of sample production, fit assessment and sample adjustment and may be repeated a number of times until satisfaction is attained (Figure 1). There appeared to be a number of factors that contributed to this iteration; common to both case study companies was the lack of available appropriate anthropometric data (discussed more fully in the next section). Problems specific to CS1 related to their retail customers who failed to recognise the necessary specificity of knitwear production. Tolerances as low as 0.1 were being specified when 0.5cm was considered the absolute minimum amount appropriate. Complaints were voiced regarding the multitude of different size charts provided by each retailer. There was also deviance between size code preferences. Most of the garments were sized in single numeric codes, 8 to 20. Some retailers however stipulated descriptive coding, small, medium and large. Inconsistencies regarding dimensional requirements for sample sizes were also revealed. Additional modifications to achieve smaller samples for one particular retailer caused a changed to the traditional size chart.

At CS2 the brand manager described the sizing process as mathematical and stressed the importance of setting correct 'knitting tension' [stitch length] on each machine. Slight variations were acknowledged to create dimensional changes in the garment. The extensibility of a knitted garment was also recognised as a consideration when sizing. The pressing process was considered important but it was stressed that it is not appropriate to try to increase or decrease garment dimension when pressing.

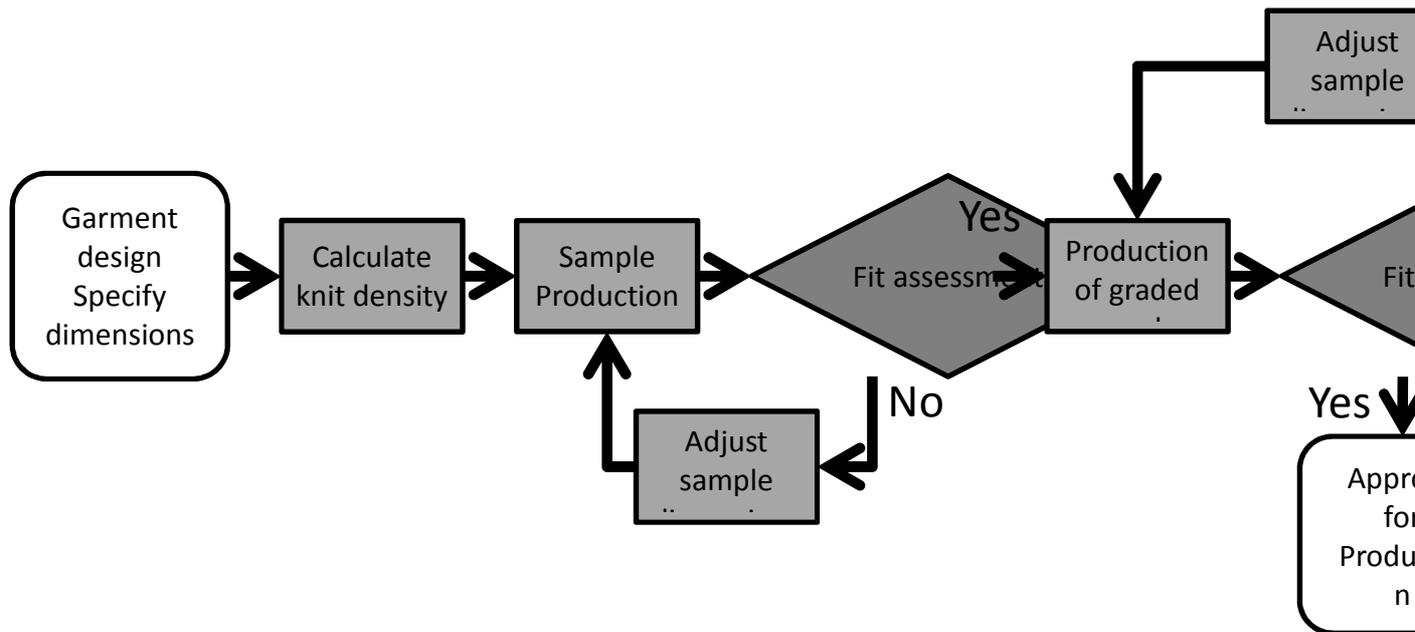


Figure 1 Process map of complete garment sizing practices

5.2 The impact of the technology on sizing practices

Findings indicate that sizing practices at CS1, who are reliant on data supplied by their retail customers, have remained unchanged. CS1's technical director stated that the available anthropometric data was limited, restrictive and inappropriate for complete garment production. Traditional methods of sizing the garment were no longer perceived to be applicable. A better understanding of anthropometric data relating to the upper body and the shoulders was identified as being critical. A limited knowledge regarding how to adopt anthropometric measurement was acknowledged.

The complete garments produced at CS2 were additional to their traditional fully fashioned core product. The brand manager explained how, initially standard fully fashioned grading specifications were adopted for complete garments. However, dimensional changes between two consecutive sizes were found to be undetectable, due to the increased extensibility of the seamless structure. The grading increments for complete garments were therefore increased from 2cm to 4cm and the number of sizes in the range reduced from five to three. Measurement data utilised when constructing shaped panels was not adequate to determine complete garment dimension. however no published data had been found to be available to inform a more appropriate method. Consequently, many fit trials were necessary to achieve satisfactory results. The technician agreed with these views and described a non-scientific approach to programming, with garment fit only being achieved after at least two attempts. The automated sizing facility on the technology was not used, as it was said to hinder the management of production problems.

5.3 The impact of the technology on garment fit

At CS1 it was recognised that complete garments conform to the body differently to other types of knitwear. This was a view held by all, with the exception of the technologist who claimed not to have found significant changes. CS1's retail customers were reported to be unappreciative of manufacturing methods and any resultant improvements in garment fit. Inexperienced buyers commonly employed by retailers were thought to contribute to this lack

of awareness. Improved fit and comfort were therefore not considered to be marketable factors by CS1 respondents. These comments related directly to their core fashion product.

At CS2 utilisation of the technology was acknowledged to have had a considerable impact on garment fit. The development of experimental shaping has resulted in a garment with what was described by the brand manager as ‘a different type of fit.’ This statement was not fully explained, however it was related to shaping capability, enabling the creation of garments structured three dimensionally. An experimental approach had generated novel shaping methods, achieving fit satisfaction had however been found to be problematic and time consuming. It was also acknowledged that attempts to generate specific garment dimensions were not always successful.

5.4 The impact of the technology on shaping

Limited capability to produce shape on flatbed machinery will have a considerable impact on its eventual size and fit. The technicians interviewed commented on the need to conceptualise within the three dimensional environment, a complex skill that takes time to acquire. The ability to create a more fashionable garment through novel shaping methods was much appreciated at CS1. Particularly successful examples were listed as: integrally (the transfer or holding of stitches creating a loss or gain of width within the body of the fabric) shaped skirts and dresses and garments with unbroken pointelle pattern throughout the tubular garment form



Figure 2 Pointelle neckline from CS1

CS2 had adopted an experimental approach with varying degrees of success. Complete garment machinery was claimed to have the ability to create a greater variety of shaping than fully fashioned machinery. The most successful shaping innovations were listed as zigzag armhole fashioning, striped yokes and funnel, cowl and roll necks.



Figure 3 Striped top from CS2



Figure 4 Zigzag shaping from CS2

There was a general lack of clarity regarding the cause of shaping limitations. Factors that were acknowledged to inhibit innovative shaping included increased production costs and the lack of technical skills.

5.5 The impact of the technology on product development

Responses indicated that the technicians have increased responsibility within complete garment production processes. The designers, dissatisfied with their knowledge of the technology considered this to limit their ability to influence decisions. The product development process at both companies modified successful complete garments from

previous ranges to create new styles. Programming new styles was evidently time consuming and creatively inhibiting. Involvement in very novel product development collaborations for sports, medical and technical garments had not led to any product diversification. Participants had agreed that these markets had great potential but in the absence of research and development funding, their priority was to serve the fashion sector.

The brand manager at CS2 conceded that their position as a quality brand reflected in the price of their garments, providing flexibility regarding knit times. Experimentation during product development was also possible. CS2 use a pressing system that cannot be used to press the complete garments that are shaped three dimensionally. This was acknowledged to be a problem that had not been solved.

6.0 Discussion of findings: The potential impact of implementation

The findings from the interviews with the machine builders provided insight into the sales potential of the UK regarding complete garment technology. MB1 in particular were pessimistic about the successful uptake of complete garment technology. Respondents supported Gibbons' prediction that the skills and knowledge to exploit the machinery was a considerable deterrent for potential investors. They would not comment on the politically sensitive issue of labour reduction through implementation. However the shortage of knitting skills in the UK and the resulting recruitment problems, were suggested as the principle motive to invest. The investigation into the potential to improve garment fit revealed that these claims relate directly to the eradication of seams producing a more extensible, comfortable garment. There was some evidence to support authors who have suggested that utilisation of the machinery will generate garment innovation. However skills issues were acknowledged to be critical to the potential to innovate. This supports Troynikov's findings that a lack of knowledge contributes to the inability to achieve the desired garment shaping. There is acknowledgement by the machine builders that even their technicians' programming skills are not yet adequate to fully exploit the technology. Shaping limitations therefore may well be a skills issue rather than a machine issue

6.2 The utilisation of anthropometric data

Findings from this study support Watkins' (2006) assertion that sizing surveys alone will not improve fit satisfaction and size provision. The case study practitioners were clearly not influenced by SizeUK and did not appear to have access to the data. This also supports Power and Otieno's (2008) previous research regarding UK knitwear manufacturers whose sizing practices were not informed by British Standards. Utilisation of new knitting technology was acknowledged by case study participants to necessitate a more detailed set of anthropometric data in order to achieve satisfactory garment fit. Currently sizing specification in both companies were informed by data developed to knit shaped panels. Whilst these respondents were able to identify the limitations of the available data, they were not able to determine what additional information was needed. The technical manager at CS1 did however identify the upper and underarm body regions as being particularly problematic. These findings reveal that there are additional complexities in relation to the utilisation of anthropometric data within complete garment production. Findings also support previous research identifying the use of trial and error within the production of knitwear. Further to this, failure to apply anthropometric data during sizing processes is identified as a contributing factor to unsatisfactory heuristic practice. Although direct questions were asked of all the participants, no clear insight was gained into how garment dimension relates to body measurement. It is therefore still unknown how the extensibility of the knitted fabric changes the application of anthropometric data compared to its application during woven garments development.

Within complete garment production there appears to be no recognition of the distinction between anthropometric data and garment dimension. Therefore the potential to define the relationship between the garment and the body is lost. Case study interviews revealed that size specifications were determined through modifications during fit trials (Figure 1). The relationship between the garment and the body is therefore only acknowledged after the development process has been conducted.

6.3 Sizing practices

Findings imply that the extensible property of a knitted fabric appeared to influence a greater margin for error than that used for woven garments. Measurement tolerances of 0.1cm specified by CS1's retailer customers were patently inappropriate for knitwear. This evidence suggests that retailers do not acknowledge that knitted garments which are recognised to be unstable structures are different from those of a woven garments. Sizing tolerances should be specific to knitwear and relate directly to complete garment manufacture.

The change in sizing practice at CS2 positively demonstrates that complete garments have different fit parameters to knitted garments with seams. The changes were however based on subjective assessment methods and therefore may not accurately reflect what these differences are. The practice of sizing through the use of previously established garment measurement relies heavily on modification during fit trials. Findings again support previous research (Eckert 2001; Power and Otieno 2008) that knitwear sample production is based on unsatisfactory processes of trial and error resulting in costly iteration. Additional evidence that these heuristic methods continue through the production cycle has also been found. Illustrated at CS2 where knitting tension [stitch length] was reported to influence garment dimension. These comments indicated that a system of trial and error was used before satisfaction was achieved. On such sophisticated machinery (Nakashima and Karasuno 1995) it is surprising that this type of experimental approach is necessary and is again indicative of a lack of skills and knowledge.

6.4 The product development process

The heuristic methods discussed in the previous paragraphs have a direct impact on the product development cycle. The development of new programmes for complete garments was found to be time consuming and expensive. The designers therefore aimed to modify existing styles in order to avoid the need to create new programmes. It was also found that the designers received less training than the technicians. The process of creating products starts with the designers. It is therefore advantageous that they fully understand the design implications presented by the utilisation of new technology. This study also supports the suggestion that complete garment production demands high levels of skills from its users (Siddons 2007; Troynikov 2008). There was also evidence to support previous research which identifies communication problems between knitwear technicians and designers (Black 2001; Eckert 2001; Eckert and Stacey 2003). The implementation of new technology appears to intensify the need to address the communication gap. This was demonstrated within CS2 when the Japanese designers' specifications caused technical problems. This situation suggests not just a communication gap, but a skills gap between designers and technicians and supports the recommendation that complete garment designers and technicians work together in teams (Power and Otieno 2008). There was however clear indication that the case study companies were producing innovative products. CS2 have utilised the technology to introduce novel product ranges that are marketed in addition to their traditional classic knitwear. This finding supports the opinion that implementation of the technology has the potential to facilitate the exploitation of new niche markets. Case study participants

particularly at CS1 acknowledged a lack of investment in research and development. There was clear indication however that the most innovative garments had been developed for medical and technical market sectors. This provides further evidence to suggest the technology has the potential to create novel niche markets for UK manufacturers, prepared to invest in technological developments.

6.4 The impact on garment fit

The findings reveal evidence to suggest that complete garments fit the body differently. CS2 in particular have noted this and changed their methods of sizing accordingly. This change was influenced by the fact that the seamless garment structure was more extensible than a knitted garment with seams. In relation to the claim that complete garment technology influences the ability to improve garment fit (Stoll 2006; Shima 2007), findings are more ambiguous. The interview participants from the machine builders and the case studies regarded the seamless structure of the garment to provide improved fit. There was however no real indication that this was recognised by either the retail customers or the consumers. The brand manager's comment at CS2 relating improved shaping capabilities to the creation of 'a different type of fit' may further support the claims for improved fit. The findings however indicate that heuristic methods of trial and error used to achieve the shaping had not generated adequate knowledge. The statement about different fit could not be adequately explained and the process used to achieve it was not understood. This raised doubts as to the relationship between shaping and fit as the results appeared to rely on approximations and chance

7.0 Conclusion

The conclusions related to the first aim are based on interviews conducted with representatives from two knitting machine builders. These international companies were selected for their specialist knowledge regarding the implementation of complete garment machinery in the UK. The interviews provided indication that only a small number of manufacturers in the UK had invested in the technology. This supported the findings from the variety of sources utilised to identify the sample frame shown in table 1. The primary reason for investment was reported to be the ability to maintain production of shaped garments without having to rely on skilled labour. This was claimed to be more influenced by recruitment problems than a drive to reduce the labour force. Knitwear producers in the UK were not generally investing in new machinery and the cost of complete garment is considerable and a major deterrent. Manufacturers were also concerned about being able to recruit personnel with adequate programming skills combined with knitting experience. Explanation relating to the claimed improvements in the ability to size complete garments revealed that this relates to elimination of human error formally found in the production process. The claims regarding fit improvements related directly to the eradication of seams which provided two benefits: Firstly additional comfort when worn next to the skin, secondly increased extensibility and the ability to conform to the body. The increased shaping capability available to complete garment producers was reported to be exploited by UK producers who are producing novel garment designs.

Case study interviews were conducted with personnel with differing perspectives on anthropometric practice. Conclusions therefore relate to a variety of experiences within companies that are representative of the small sample of complete garment manufacturers currently operating in the UK. Findings clearly indicate that the implementation of complete garment technology has revealed a considerable gap in knowledge regarding anthropometric

data. Practitioners responsible for sizing do not know how to access current data. They do not appear to know which key body measurements are appropriate when specifying and programming complete garment dimension. It was recognised that the methods currently used were outdated and adequate only for generating knitted shaped panels. There is no satisfactory documentation available that clearly outlines the process that translates body measurement data into three dimensional knitted garments. This research concludes that complete garment manufacturers in the UK need to be more clearly informed and there appears to be scope for new methods to be formulated. Currently this gap in knowledge and skills is contributing to an iterative process of trial and error which inhibits innovation and the creation of novel design.

A number of other factors that contribute to problems within the sizing processes have been identified. Retailers, who provided their complete garment supplier with sizing data, failed to recognise that knitwear manufacture needs specific information. There was also a notable lack of standardisation regarding the retailers demand for size coding and garment dimension. The retailers' failure to recognise manufacturing processes has led to inflexibility within working practices. In addition opportunities to improve sizing practice or acknowledge potential improvements regarding garment fit have been overlooked. Changes have been noted in the way the complete garments conform to the body which has directly impacted on some of the sizing practices. Some indication that the relationship between shaping innovation and garment fit was found, however it is difficult to draw any conclusion regarding this relationship as no details had been clarified. It is possible to attribute this inability to properly understand how shaping had affected garment fit to the heuristic methods used to develop complete garments.

Whilst it is possible to conclude that manufacturers in the UK have developed innovative garments through exploiting complete garment machine capability. A lack of skills and knowledge can be seen to limit the ability to fully exploit the potential to create three dimensional garments. It is therefore recommended that further investigation is needed in order to generate a theoretical framework informing anthropometrical practices for complete garment manufacture.

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