Paper No: 3194 – 37th MATADOR Conference

Model for a CAD-assisted designing process with focus on the definition of the surface texture specifications and quality

Q Qi[1], X Jiang[1], P J Scott[1] and W Lu[1, 2]

[1] EPSRC Centre for Innovative Manufacturing in Advanced Metrology, School of Computing and Engineering, University of Huddersfield, Huddersfield, HD1 3DH, UK

[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China

Abstract. In the early stage of engineering design, the optimal control of engineering surface is of essential importance to control the quality of products and to reduce the cost. A model for a CAD-assisted designing process with focus on the definition of the surface texture specifications and quality is presented for the purpose of assisting designers assign an optimal surface texture specification to fulfil the requirements of function, lower costs and shorter product lifecycles. The model is the basic philosophy to develop a surface texture intelligent information system which can be integrated with CAD systems.

Keywords: surface texture, Geometrical Product Specifications (GPS), CAD

1.1 Introduction

Surface texture plays a significant role in determining the function performance of a workpiece because of the sensitivity of surface texture to change in the process. It is of significance to assign an optimal surface texture specification for an engineering surface in the early stage of design. However, in current engineering practices, surface texture has been more commonly used only for compliance and not for manufacturing process monitoring or function correlation. It is also considered insufficient that for engineering drawing if only surface texture is provided without information of metrology as it is rather difficult to truly express the functional requirements. This can be seen in table 1, most current commercial CAD systems still employ old profile (2D) surface texture standards or do not completely conform to the standards. This leads to large specification uncertainty (up to 300%)[1, 2] compared with the latest surface texture specification standard ISO 1302:2002 [3]. Because of the massive GPS standards [4, 5] and intricate related knowledge on design, manufacture and measurement in the field of profile and areal (3D) surface texture, it is arduous and time consuming to finish an unambiguous surface texture specification for designers, especially when there is no surface texture specification support tool in current commercial CAD systems. The latest profile [3] and areal [6] surface texture specification standards give the tools to control the surface texture by an unambiguous specification on technical drawings. The two standards make it possible for the designers to indicate the intended surface texture with the least possible effort, also making it possible for the designer of a given surface texture specification to understand, implement or verify the requirement without mistakes. Recently, a category theory based GPS surface texture knowledge platform has been developed to facilitate fast and flexible manufacturing [4, 7]. The knowledge model in these papers is the foundation to develop a design and measurement information system in profile and areal surface texture for manufacturing industry. In this context, a model for a CAD-assisted designing process with focus on the definition of the surface texture specifications and quality is presented. The model in this paper is developed to utilize the category theory based knowledge model for the development of a surface texture intelligent information system which can be integrated with CAD systems.

1.2 Model for a CAD-assisted designing process with focus on the definition of the surface texture specifications and quality

Based on the Geometrical Product Specifications (GPS) philosophy [8], surface texture specification should be designed based on the function requirements, lower costs and shorter product lifecycles. The essential functions of the model are to help designers find a balance point between function and total costs (include design, manufacture and measurement), and to select an optimal surface texture specification elements; also to help engineers and metrologists for monitoring manufacturing

process and guiding the measurement procedure precisely.

Table 1.1. The status of surface texture specification design in commercial CAD systems

Commercial CAD Systems	Surface Texture Specification Design	Surface Texture Standards	
		Versions	Indications
AutoCAD	None	None	None
CATIA	Roughness symbol tool	ISO 1302: 1965	3.2
SolidWorks	Surface finish symbol menu	Simplified version of ISO 1302:2002	milling Ra 3.2
Pro/Engineer	Surface finish tool menu	ISO 1302: 1965	3.2
NX	Surface finish symbol Tool	ASME Y14.36M-1996	Mill 2.5/Rz 6.3

1.2.1 The integrated surface texture design conception

In contrast to traditional tolerance systems, the GPS based design process of the surface texture specification is mapped to and receives feedback from the manufacture and measurement. The specification of surface texture is assigned to transfer more manufacture and measurement information. Fig1.1 shows the integration between design and measurement in surface texture. In the design phase, function requirements and others such as manufacturing processes and component types should be considered for a function design of surface texture. All of the specification control elements defined in ISO 1302:2002 and ISO/CD 25178-1 (currently under development) [6] can be established according to the inputs and the inference of relationships. After the inference procedure, all the inferred specification elements can be combined into a complete surface texture specification. Then the specification, callout and related specification data can be generated and saved in CAD systems. In the measurement phase, the metrologist firstly analyzes the specification, and translates it to measurement specification which will take into account the measurement conditions. Following the measurement strategy, the metrologist carries out the measurement and obtains the measurement data. In this step, the metrologist selects different options in the form removal and filtration parts. According to the data treatment selection, the software calculates the numerical result of the specified parameter in the last step. Based on the numerical result and uncertainty estimation, the metrologist should provide conformance or non-conformance with the specified specification. Finally, the measurement result and the measurement procedure can be fed back to the design stage to compare with the desired function and estimate the measurement cost to help improve the design process.

1.2.2 Finding the balance point between function requirements and total cost of design, manufacture and measurement

After the integration of design and measurement of

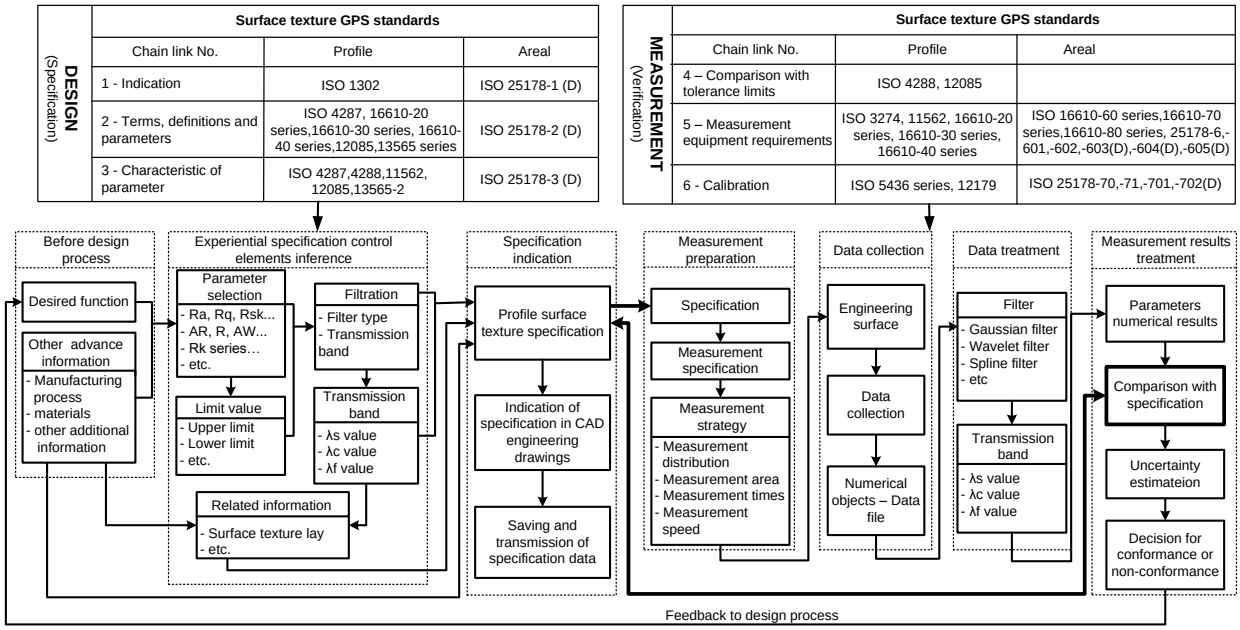

Fig. 1.1. The integration between surface texture design and measurement

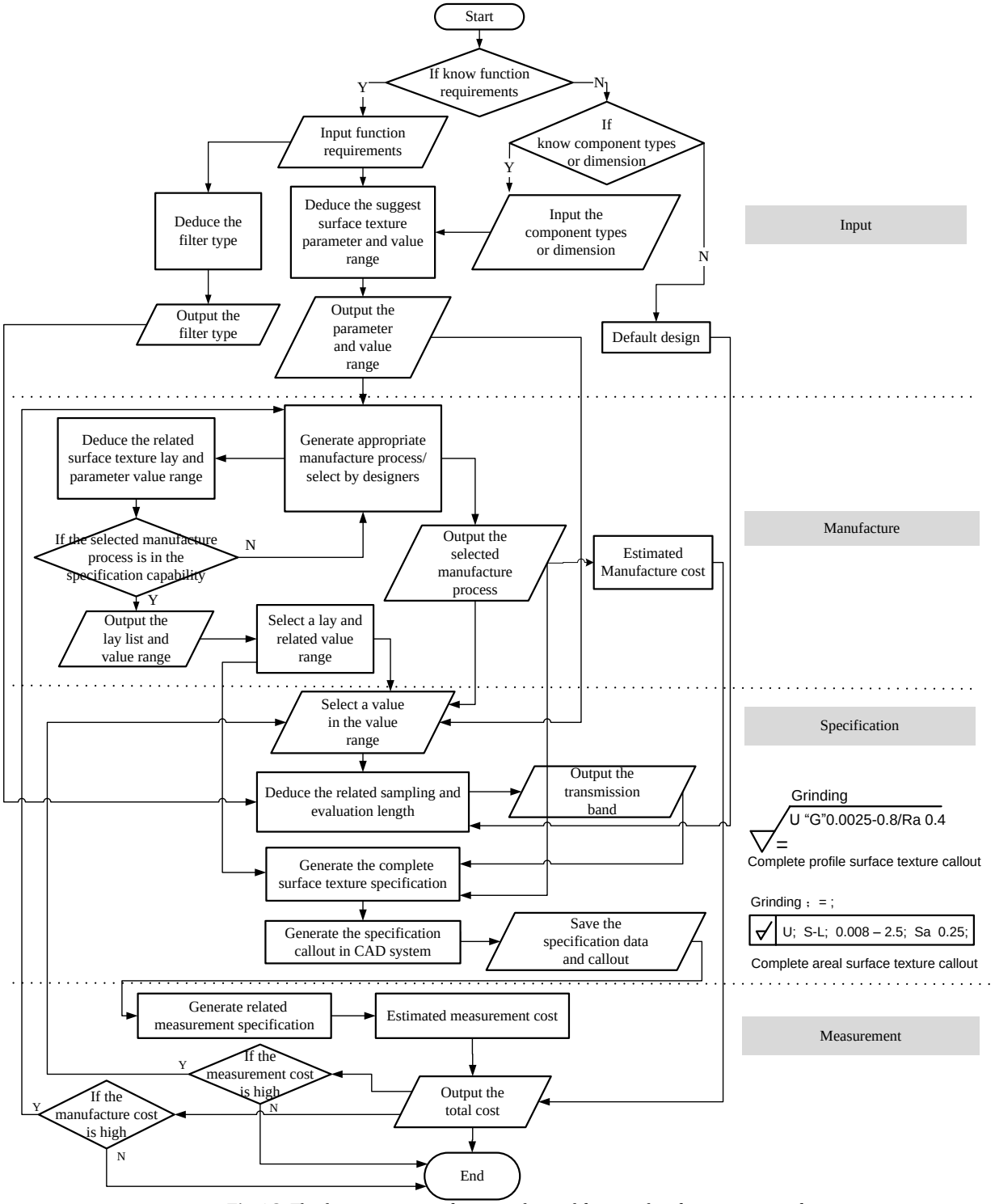

Fig. 1.2. The designing process for a complete and functional surface texture specification

surface texture, the corresponding measurement requirements for a specified surface texture specification can be determined. Within the design phase, the manufacture and measurement cost can be estimated according to the assigned surface texture specification. In figure 1.2, the flowchart of the cost optimal surface texture design process shows integration between input, manufacture, specification and measurement.

In the design input phase, the most crucial part is the selection of the right surface texture parameter and limit value according to the function requirements and other inputs. As in many applications surface texture is

closely allied to function, for instance where two surfaces are in close moving contact with each other their surface textures will affect their sealing or wear properties. This might suggest that it is a case of "the smoother the better", but this is not always true as other factors may be involved. The financial aspect has to be considered: it costs a lot of money to produce very smooth surfaces and the expense of this exercise can considerably add to the bill without gaining a great deal of performance. However, identifying very specific parameters of the surface texture with function is fraught with problems, usually because of time and expense. One point to notice is that it is rarely the individual parameter *Ra* or *Rq* for example which is important but often the type of parameter. It is a fact that often combinations of different parameter types are needed to get the best correlation between parameter and function [9].

The manufacturing process of the specified surface can be determined by the function requirements and/or the component type of the surface. Whether the manufacturing process is assigned by the designer or deduced by the system automatically, the manufacture cost, related surface texture lay and parameter value range can be estimated accordingly.

In the specification phase, all other specification elements can be deduced according to the inputs and generated specification elements. For example, the sampling and evaluation length can be determined according to the assigned parameter and value. Then a series of complete ten/eleven specification elements for profile and areal surface texture can be generated. In the CAD system, an integrated application program will be developed to analyze the generated specification; a surface texture indication will be generated and related specification data will be saved.

In this model, the designer can gain the measurement information. The related measurement requirements for the assigned specification can be inferred and the measurement cost can be estimated. The measurement cost then will be added to the total cost which can be used to balance the design and measurement details. As the complete specification can be generated by the category model, the design cost will be decreased. If the manufacture cost is high, the designer is required to choose lower cost manufacturing process which is still fulfilling the function performance. If the measurement cost is high when the suggested measurement instrument is expensive; or the procedure requires multiple measurement ($\geq$12), the designer is required to modify the specification with a larger limit value which is sufficient to convey the design intent.

1.3 Discussion and Conclusion

A model for a CAD-assisted designing process with focus on the definition of the surface texture specifications and quality is presented. The model is the basic philosophy to utilize the category theory based knowledge model for the development of a surface texture intelligent information system which can be integrated with CAD systems. In the model, although the utilized latest profile and areal standards still have a certain specification uncertainty, the specification elements of them are considered to provide enough information for manufacturers and metrologists. When all elements are specified in one surface texture specification, the symbol may appear much longer than traditional ones. Then more drawing space is needed. A simplified version or reference symbol can be applied but should be without any significant information loss.

1.4 Acknowledgements

The authors are grateful for support from project ERC-2008-AdG 228117-Surfund and NSFC 51005089.

1.5 References

[1] ISO/TS 17450-2:2002 Geometrical product specification (GPS) - General concepts - Part 2: Basic tenets, specifications, operators and uncertainties. International Standardization Organization, Geneva, Switzerland

[2] Bennich P, Nielsen H, (2005) An overview of GPS, A Cost Saving Tool. http://www.ifgps.com

[3] ISO 1302:2002 Geometrical product specification (GPS) - Indication of Surface Texture in Technical Product Documentation. International Standardization Organization, Geneva, Switzerland

[4] Qi Q, Jiang X, Liu X, et al, (2010) An unambiguous expression method of the surface texture. Measurement 43:1398-403

[5] Qi Q, Jiang X, Blunt L, Scott PJ, (2010) Modeling of the concepts in ISO standards for profile surface texture. Future Technologies in Computing and Engineering: Proceedings of Computing and Engineering Annual Researchers' Conference 2010: CEARC'10. University of Huddersfield, Huddersfield, 172-176

[6] ISO/CD 25178-1 Geometrical product specifications (GPS) – Surface texture: Areal – Part 1: Indication of surface texture. International Standardization Organization, Geneva, Switzerland

[7] Qi Q, Jiang X, Scott PJ, (2012) Knowledge modeling for specifications and verification in areal surface texture. Precision Engineering 36:322-333

[8] ISO/TR 14638:1995 Geometrical product specification (GPS) – Masterplan. International Standardization Organization, Geneva, Switzerland

[9] Whitehouse DJ, (2001) Function maps and the role of surfaces. International Journal of Machine Tools & Manufacture 41:1847-1961