Journal of Achievements in Materials and Manufacturing Engineering

VOLUME 17
ISSUE 1-2
July-August
2006

Implementation of a tolerance model in a computer aided design and inspection system

R. Hunter [a,*] M. Guzman [a], J. Möller [a], J. Perez [b]
[a] Mechanical Engineering Department, Universidad de La Frontera,
Av. Francisco Salazar 01145, Casilla 54-D, Temuco, Chile
[b] Mechanical and Manufacturing Engineering Department,
Polytechnic University of Madrid, Jose Gutierrez Abascal 2, 28006 Madrid, Spain
* Corresponding author: E-mail address: rhunter@ufro.cl

Received 15.03.2006; accepted in revised form 30.04.2006

Manufacturing and processing

ABSTRACT

Purpose: Purpose of this paper is present a detailed framework to integrate the Computer Aided Design (CAD) and Inspection (CAI) systems through the integration of the Geometric Dimensioning and Tolerancing (GD&T) with the inspection process in coordinate measuring machines (CMMs).

Design/methodology/approach: The approach used to develop a prototype of a Knowledge Based System (KBS) applied to inspection process establishes a new methodology for integrate the geometric dimensioning and tolerancing (GD&T). The integration is achieved through the definition of the knowledge units for functional properties of GD&T, inspection resources and inspection operations in a common knowledge model. The manufacturing and processing applications are the main topics approach of this paper.

Findings: The findings are focused in modeling the features and interactions between knowledge units associated to topology, geometry and tolerances with the inspection process activities. The implementation of the product knowledge model is presented in a computer platform that extracts and represents the GD&T information in a CAI system.

Research limitations/implications: The implications are focused on the automation of the inspection process in a KBS application. The future research is focused on the use of artificial intelligent technique, such as genetic algorithms and neural networks, to optimize the time to execute the inspection process.

Practical implications: The main outcomes and implication of the KBS prototype application are focused on the reduction of the time spend to develop the inspection process. This KBS application provides the needed information to elaborate this process without the human interface.

Originality/value: The original value of this paper is the integration of the design and inspection specification in a unique prototype application. The knowledge model has been defined in a common modeling language (UML) and can be implemented in different informatics platforms.

Keywords: Automation engineering processes; Geometric Dimensioning and Tolerancing (GD&T); Knowledge based system; Inspection process

1. Introduction

The integration of computer aided design and computer aided inspection systems involve a detailed description of all functions included in design, manufacturing and inspection phases. A first input of this integration is a complete description of the different features attached to the geometry of the part. A second input is a description of the manufacturing process developed and the capabilities of the machine tool. A third input is a detailed description of the operation, parameters and resources involved in the inspection process.

The first input deals with the representation of the geometric and dimensional tolerances in a part. The research carried out in this area has been focused on the development of methodologies that use TTRS (Topological and Technological Related Surfaces) to establish models associated to the tolerances of products [1]. In this context, other research has focused on the development of information models that define the inspection process in a concurrent engineering framework and inspection process planning system [2-4], and knowledge models to automate the fixture design [5].

The modeling and representation of the information included in the GD&T is one of the most important parts in the industry due to the advances in the integration of factory technologies. In this sense, an information model associated to the GD&T should provide a generic support in a specific standard, such as STEP [6] and ASME Y14.5M [7].

Zhao [8] proposed a model for representing the geometric tolerances at different levels. This model uses the standard ASME Y14.5M as a conceptual base to obtain information associated to the geometric tolerances. Additionally, the information related to the geometric tolerances defined by DMIS and STEP is incorporated in the model to integrate the inspection processes. It is important to highlight that the information required to define the geometric tolerances, is not available in primary stages of the design process [9].

Regarding the second input, the manufacturing process, some information models have been developed to describe the manufacturing information. In this sense, Bugtai [10] proposed an information model to support the design and manufacturing decisions in an integrated framework. A first approach to develop knowledge models applied to fixture design process was proposed by Hunter [11]. Figure 1 shows the generic architecture for developing a knowledge model.

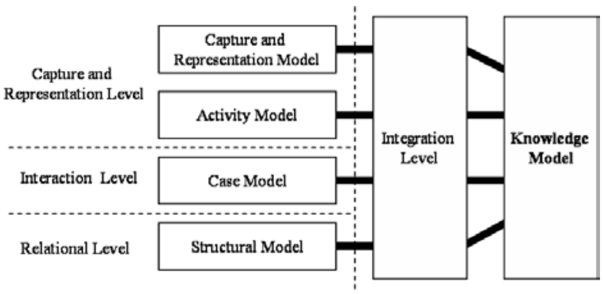

Fig. 1. Knowledge model architecture

For the third input, the inspection process, the following aspects should be considered:

- Set up: The orientation and position of the part (in respect of the elements to inspect) should be considered as well as the position of the inspection elements.
- Tolerance type to inspect. The type of tolerances to inspect (dimensional and geometric in CMMs), and finishing, usually outside CMMs.
- Accessibility of the elements to inspect. The probe heads and styli of the CMM possess a high number of possible measure orientations. Each orientation requires a previous calibration, in respect of the orientation and the characteristics of the elements to inspect.
- Path of the sensor. Geometric simplifications of the exploration tool are used (probe head, sensor and styli) to determine the interferences between probe head and the fixture or part.
- Inspection operation sequence. The structuring of the inspection operations makes it possible to minimize the changes of orientation in the part and in the sensor.

This research presents, in a detailed manner, the functional model to define and develop a knowledge based system applied to dimensional inspection process. The paper has been structured in three sections. The first section presents a detailed description of the methodologies for developing the knowledge based system. The second section presents a description of the tolerance model, i.e. the geometric dimensioning and tolerance features. And the third section shows a description of the implementation of the tolerance model in a computer application.

2. Present state of knowledge based system methodologies

A generic structure for a KBS may involve four main components: the product module, where the knowledge of the part (product) and the process is stored; external databases; input information and results generated by the product module.

Therefore, it is clear that to develop a KBS the use of advanced software techniques is necessary in order to capture and reuse the product and process it in an integrated way [12].

In this sense, it necessary to analyze the problem of how to capture and to represent knowledge in a KBS system applied to a specific area of engineering. The research and development to establish a methodology that allows knowledge to be captured and reused has been defined in recent years with great intensity.

To reuse the knowledge of knowledge based structures, so-called ontologies are employed. These have been proposed in KACTUS (Knowledge About Complex Technical systems for multiple Uses) European ESPRIT project [13]. Their objective is the development of a methodology for reusing the knowledge of technical systems during the product life cycle.

The methodology proposed in KADS (Knowledge-base system Analysis and Design Support) [14], is focused on the development of systems based on knowledge and it is used as a general guide for structuring and interacting among the different knowledge units that integrate a system with these characteristics. It proposed a methodology that covers the life cycle of KBS/KBE systems with the aim of providing a connection among the methods for developing KBS systems and other methodologies proposed for the development of this type of system.

As an evolution, CommonKADS [15] appears, which involves the whole process of KBS/KBE systems development. CommonKADS proposes the use of tools and techniques to carry out the capture and representation of knowledge. CommonKADS proposes three different stages in the process of knowledge modeling:

- Context Model: establishes three different models: organization, tasks and agents.

- Knowledge Model: establishes three submodels: domain (static view or structure of information), inference (reasoning process), task (application objectives).
- Communication Model: establishes the definition of the procedures of information exchange for transferring the knowledge among agents.

Finally, the MOKA methodology (Methodology and software tools Oriented to Knowledge based engineering Applications) [16] provides a framework for representing and storing the knowledge for KBE systems. Influenced by CommonKADS, its objective is to provide support to reduce the effort and risk associated with the development of KBE systems. The MOKA methodology defines knowledge at two levels. The first level captures knowledge in a semi-formal model classified into five types. The second level is a formal model that makes it possible to represent knowledge in a structured way, using the MML language (MOKA Modeling Language, MML).

3. Knowledge model for tolerances

The tolerance model developed has been structured in four main modules (Figure 2). The first one, the geometrical model, describes the basic features for defining the geometry of the part to inspect. This submodel is associated with the features declared in the three remaining submodels.

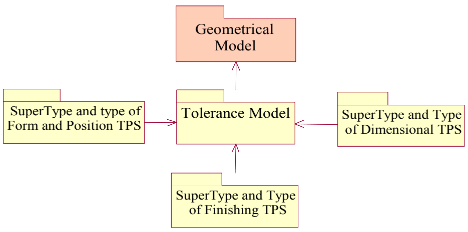

Fig. 2. The tolerance model

Table 1.
Features of the tolerance model

Submodel	Super type and type of feature
Supertype and type of form and position TPS	▪ CATITPSGeometricTolerances
	▪ CATITPSForm
	▪ CATITPSPosition
	▪ CATITPDOrientation
Supertype and type of dimensional TPS	▪ CATITPSDimensionalTolerances
	▪ CATITPSLinearDimension
	▪ CATITPSAngularDimension
	▪ CATITPSBasicDim
Supertype and type of finishing TPS	▪ CATITPSRoughness
	▪ CATITPSFinishingProcess
	▪ CATITPSMachiningProcess

The supertype and type of form and position TPS submodel describes the main features for specify the tolerance type, only if necessary to ensure the initial requirement of the part. The graphics representation of these tolerances has been developed in a three dimensional system. The supertype and type of dimensional TPS submodel represent the main features of dimensions of the part. These features are associated with the geometrical features of the part. Each of the dimensional features is linked to a line, circle and curve of the part. The supertype and type of finished TPS submodel describes the finishing parameters and values of specific surfaces of the part. These finishing features are linked to the features of the part geometry submodel, such as, surfaces of the part to inspect. The main features of the GD&T model are presented in Table 1.

4. Implementation of the tolerance model

In the next section, the implementation of Geometric Dimensioning and Tolerancing in a computer application system is presented. This implementation has been carried out in two phases.

The first phase establishes the relationship between the geometric features of the part to inspect and the tolerance model. This relationship is defined through three basic entities: cells, domains and bodies. A Cell, is an basic topology entity; Domain, set of cell with n-dimensions linked with cell n-1 dimensions; and Body, a group of n-domains. The geometry features also makes it possible to define a group of primitive entities, such as, surfaces, splines and points. These basic entities are linked to the features defined in Table 1, in a three dimensional graphics system.

The right part of the Figure 3 shows the definition of the geometric and dimensional tolerances in a three dimensional system. The importation of the geometrical dimensioning and tolerancing is carried out through the program realized in Visual Basic in CATIA V5. The result of the application of this program is a STEP file that contains the GD&T information associated with the part geometry.

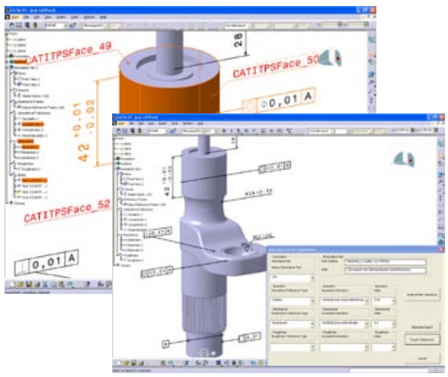

Fig. 3. Definition and importation of GD&T from CAD to CAI system

The second phase is the definition of the knowledge based system structure. This structure involves the definition of two modules. The first module, extracts the topological and geometric information associated to the part to inspect. In this module, a group of identifiers is defined for each feature of the geometry, such as surfaces, faces and lines. These identifiers are linked to a single GD&T marker. These markers contain a set of attributes that define all the properties of the tolerances to inspect. The left part of the Figure 3 shows the identifier associated to cylindrical surface.

The second module uses the information extracted in the first module to develop the inspection process in an integrated framework. The information for geometric dimensioning and tolerances is exported from CAD to CAI system through the STEP AP 203 protocol. The structure of the knowledge based system is shown in Figure 4.

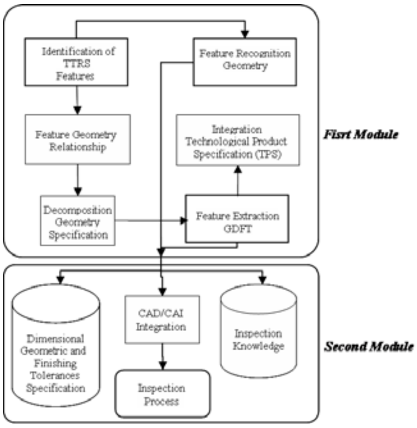

Fig. 4. Structure of the KBS inspection system

5. Conclusions

An integrated approach for developing and implementing a tolerance model in a computer aided design and inspection system has been proposed. The basic aim was to develop a tolerance model in the integration of the geometric dimensioning and tolerancing in two environments: the design and inspection process (and in manufacturing if such scope were contemplated).

The use of methodologies for developing a knowledge based system provides the support needed to define and structure the knowledge involved in design and inspection processes. This approach makes it possible to integrate the early stages of design (definition of the geometric and dimensional tolerances) and inspection process, providing a reduction in the time spent on developing and executing the dimensional inspection.

Finally a new approach for associating the geometric and dimensional tolerances with the geometry to inspect is presented. In this case, a set of identifiers are defined to link the GD&T and the different levels of the part geometry.

Acknowledgements

This research has been carried out thanks to the support of Universidad de La Frontera – Mechanical Engineering Department through the project DIUFRO IN 110504, Knowledge based engineering systems applied to high speed machining fixture design, and the Polytechnic University of Madrid-ETSII-UPM - Mechanical and Manufacturing Department.

References

[1] H. Toulorge, A. Riviere, A. Bellacicco, R. Sellakh, Towards a digital functional assistance process for tolerancing, Journal of Computing and Information Science in Engineering 3 (2003) 39-44.

[2] J. Barreiro, J. Labarga, A. Vizán and J. Ríos, Information model for the integration of inspection activity in a concurrent engineering framework, International Journal of Machine Tools & Manufacturing 43 (2003) 797-809.

[3] S. Zhang, A. Ajmal, J. Wootton, A. Chisholm, A feature-based inspection process planning system for co-ordinate measuring machine (CMM), Journal of Materials Processing Technology 107 (2000) 111-118.

[4] C. Yuen, S. Wong, K.P. Venuvinod, Development of a generic computer aided process planning support system, Journal of Materials Processing Technology 139 (2003) 394-401.

[5] R. Hunter, A. Vizán, J. Pérez and J. Ríos, Knowledge models as an integral way to reuse the knowledge for fixture design process, International Conference on Advances in Materials and Processing Technology, AMPT'2005, Gliwice-Wisla, 2003, 254-257.

[6] ISO-10303, Product data representation and exchange Part 1: Overview and fundamental principles. ISO 10303 Part 1, 1993.

[7] ASME Y14.5M-1994, Dimensioning and Tolerancing. American Society of Mechanical Engineers, 1994.

[8] X. Zhao, T. Kethara, R. Wilhelm, Modeling and representation of geometric tolerances information in integrated measurement process, Computers In Industry, Article in Press, 2005.

[9] K. Rennels, Current methodology for geometric dimensioning and tolerancing, Technical Paper, IEEE, 2003.

[10] N. Bugtai, R. Young, Information models in an integrated fixture decision support tool, Journal of Materials Processing Technology 76 (1998) 29-35.

[11] R. Hunter, A. Vizán, J. Pérez and J. Ríos, Knowledge models as an integral way to reuse the knowledge for fixture design process, Journal of Materials Processing Technology 164-165 (2005) 1510-1518.

[12] R. Hunter, Definition and integration of requirements and manufacturing functions in a KBE system applied to machining fixture design. PhD Thesis, Polytechnic University of Madrid, 2004.

[13] G. Schreiber, B. Wielinga, W. Jansweijer, The KACTUS view on the "O" word. University of Amsterdam, 1995.

[14] B. Wielinga, A. Schereiber, J. Breuker, KADS: a modeling approach to knowledge engineering, Knowledge Acquisition 4 (1992) 5-53.

[15] G. Schreiber, H. Akkermans, A. Anjewierden, R. de Hoog, N. Shadbolt, W. Van de Velde, B. Wielinga, Knowledge engineering and management. The commonKADS methodology. The MIT Press, 2001.

[16] M. Stokes, Managing engineering knowledge: MOKA methodology for knowledge based engineering applications. ASME Press, 2001.