Krzysztof CIUPKE

Department of Fundamentals of Machine Design
Silesian Technical University, Gliwice, Poland

NUMERICAL REPRESENTATION OF FEATURES OF MACHINE ELEMENTS FOR QUALITY ASSURANCE NEEDS

Summary. ISO standards series 9000 oblige every manufacturer to guarantee quality of his products and to document the quality fulfilling according to given requirements. Numeric representation of machine elements in *object-attribute-value* form gives you possibility of its use for computer-aided quality assurance. A method of element features representation and its application in the area of quality assurance was disccused. An expert system use permits user to reach a conclusion about particular product quality and to aid making-decision prosess about the following course of given product operations.

1. Introduction

ISO Standards series 9000, defining quality assurance of service or manufactured products, oblige every manufacturer to take up necessary actions in the field of quality assurance and the way of making records concerned with quality of manufactured product in particular [1][2][7][9]. These records may be then divided according to the subsequent phases of product life.

First, they are to concerned on an agreement between a manufacturer and his client. Contents of the agreement is the part of requirements found in a proper technological documentation.

The files should also include every kind of data concerned with supply of row materials resources used in a manufacturing process of a particular product.

The very significant element is information on manufacturing process, its development and parameters.

Matching records ought to include data about devices, equipment used in this process as well as data on operators. It is recommended to register results of in- process quality control. ISO standards series 9000 pay extreme attention to *special operations* being the most substantial ones to achieve appropriate product quality [9].

The last stages of manufacturing process are control and testing. Every result of measurement and test should be documented. The contents of the files ought to be the base for particular product quality evaluation.

Such information is the source of many analyses performed so as to put the product quality on a higher level. Catching phase of manufacturing process or place where process quality is extremely low gives the possibility of planning corrective actions and increasing quality level.

1.1. Aim of the paper

The paper deals with a conception of use of numeric method to represent machine elements for the needs of computeraided quality assurance according to international standards ISO series 9000 (EN 29000).

1.2. Description of need

To fulfill product requirements found in a technological documentation determines quality of this product. Evaluation of conformity follows the results of in-process and final control. Comparison of control results with required values gives an opportunity of judgement about manufactured product quality. It can be performed only by a qualitycontroler, worker with a proper qualifications or elements of some system created for quality assurance. The last judgement is more reliable in many cases. Therefore, there came the need to create numeric method used for representing quality of machine elements. Such a method would permit to register product features as values of object attributes and to control their conformity with requirements.

2. Numeric representation of machine element features

This problem is solved with means of object approach. The author used FDL language-based frame expert system *MAS* [3][4][5] to describe the features. The author also defined classes containing description of machine elements and parts of them. The description of the features is made in *object-attribute-value* form [8]. Classes are written as frames in FDL language, attributes as slots and their values as appropriate facets.

Using numeric representation for quality assurance needs requires not only representation of geometric and material features but also describing course of manufacturing process and, as mentioned above, quality control process. The very substantial element in quality assurance process becomes also possibility of particular product and its element identification.

Using object approach, one may try to describe some abstract (abstract model of element) as a pattern for particular class of elements. In this way, manufactured product may be described as n exemplification of this class (frame). By comparing values of attributes in particular class it is possible to evaluate product accuracy and its conformity with design requirements.

Quality control includes also problems of geometric and material features representation. Representation of manufacturing process, especially representation of *special operations* is required as well [9].

2.1. Representation of geometric form

Geometric form of element is usually represented by means of assembly or workshop drawing as an abstract. It is known that achieving of completely accurate dimensions is not possible. Determining accuracy of manufacturing and appropriate tolerances gives information of acceptable dimension change in comparison with the abstract. Actual dimension is different from ideal one but it should fall into described limits. The same event takes place while recording of measurement results is performed. Describing limits makes it possible to evaluate product conformity with given requirements. Therefore, you may conclude that determining of one object attribute requires setting two boundary values used in evaluation process. Boundary values may be described in many ways by:

- determining nominal value and two deviation values,
- setting nominal value and a symbol determining accuracy group and tolerances,
- setting two boundary values.

Every method given above has its prosandcons. The first and second methods give directly nominal value and the third one is the easiest way from numeric point of view but not from designer's. Additionally, the first way does not give accuracy group directly. The whole information may be taken from symbolic description of tolerances. Not always may the tolerances be determined in this way. Therefore, both methods of tolerance representation were used here.

Abstract as a product design was written in an abstract object form which features (attributes) were contributed to particular values appearing as dimensions in some drawing. Using mentioned method of tolerance determining one may easily compute boundary values of particular geometric features. Such a pre-defined object ("ideal" model) may be used for comparing with actual objects and drawing a conclusion about geometric shape conformity.

Existing objects are treated as instantiation of particular object class. Membership to the same class means possessing the same attributes by the abstract and exemplification. Actual object does not possess boundary values but only measured one. That's why one may compare value of every actual object attribute with values of the same abstract atribute. Similarity of all values or, in other words, establishing actual dimensions inside boundary values influences product quality. If, for example, only one value overrides the limits, then you talk about nonconformity product according to given requirements.

As an example, a numeric representation of shaft features is given (Fig.1). Each part of this shaft has its features (attributes). The attributes are (in particular): diameter (it is not an attribute of every part of a shaft), length and other characteristic features. Value of every attribute is accurately tolerated (by setting value or by default in relation to non-tolerated dimensions).

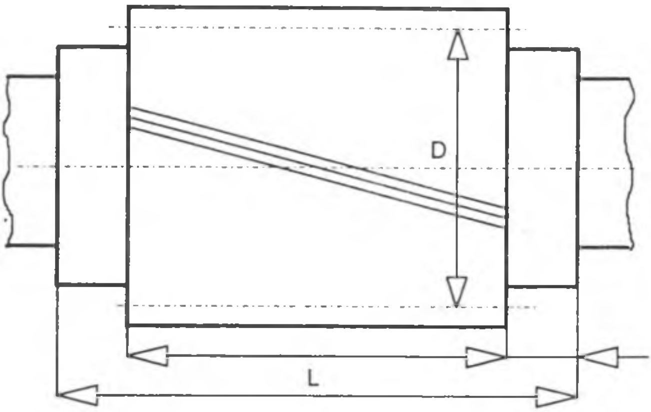

Fig.1. Shaft (part of it)

		ABSTRACT	INSTANTIATION
OBJECT	ATRIBUTE	VALUE	VALUE
Toothing	Pitch diameter (D)	$59,5^{+0,03}_{-0,01}$	59,502
	Length (L)	$60^{+0,03}_{-0,02}$	59,99
	Angle of tooth line inclination (β)	7° 22'	7° 22'
	Module (m)	3,5	3,5
	Number of teeth (z)	17	17
	Roughness of lateral surface of teeth (R_a)	0,4	0,4

2.2. Material features representation

Besides setting geometric features of machine element it's extremely important to determine material features especially for quality assurance needs. Material features are, for example :

- sort of product material,
- strength properties (A,KV,Re),
- heat treatment properties (HRC, hardened layer depth, etc.),

Values of these features may also be given as values of object attributes. In relation to a sort of material the attribute is material symbol and possible standard number defining chemical composition. If requirements from these given in the standard, then the attribute may be defined as a fraction of particular component (plus value of tolerance).

The value of tolerance is also evaluated for the remaining attributes. Comparison of corresponding value in a way mentioned above gives the possibility of quality estimation. In some circumstances required criteria needn't be so demanding. Not always does a less value of tensile strength than minimal one, for example, mean insufficient quality level. An example of such features description was given below:

		ABSTRACT	INSTANTIATION
OBJECT	ATRIBUTE	VALUE	VALUE
Toothing	Melt identifier	NULL	93-06-872
	Certificate identifier	NULL	3-7/A2-461
	Material	45H	45H
	Standard No	*PN-84/H-840*	*NULL*
	Contents of sulphur	0.030 ± 0.004 %	0.028%
	Hardness (HRC)	68 ± 2	69

As a particular object attributes of properties of such features like "certificate identifier" and "melt identifier" were considered to be necessary mentioned. They allow fulfilling ISO standards requirements in this area. Connection between this part of documentation (certificates or documentation from sub-suplier should be element of quality assurance system) gives not only information of material origin but also data about its chemical constitution and mechanical properties.

2.3. Manufacturing process representation

Description of manufacturing process should include *special processes* as elements with essential influence on quality control and product test results [7][9]. Therefore, it is necessary to inspect these processes and document their course.

Every process can be treated as a factor influencing product properties (hardened layer depth, etc.). They are, from our point of view, attributes for which you can provide value or describe process course with means of *procedural knowledge*. Course of ideal process described in this way may be compared with course of actual one. Process parameters may be recorded as single numbers or as a sequence of temporary values. Then, besides comparing corresponding process parameters, there is a possibility of a whole process course comparison (heat treatment, etc.). If any process parameter exceeds the limit, then there is a probability that the desired quality level will not be achieved.

OBJECT	ATRIBUTE	VALUE (ABSTRACT)	VALUE (INSTANTIATION)
Toothing	Hardening process course	$f_w(T)$	$f_r(T)$
	Hardened layer depth (mm)	$2^{+0,2}_{-0,2}$	2,1

2.4. Representation of final inspection and testing

Final inspection and testing are the last stage of manufacturing process. ISO standards series 9000 agree upon that obviously. They focus mainly on making necessary records concerned with tests and inspection performed. Control includes domains already mentioned above in essence. Taking assumption that when performing final inspection, you don't review the same thing previously recorded during in-process inspection, you may suppose that those records include facts concerned only with final inspection. Product tests are not taken into account here. That is why you have to consider how to manage the results of the tests.

Reliability, product life and other factors determined in tests are of the object properties (attributes). The way of performing tests is procedural knowledge. Test course and its results may be registered by description of corresponding attributes with measured values similarly to the way of manufacturing process representation. These values are results of performing certain procedures : process or some parameters registration . This way enables you to compare both process results and its course. With this knowledge, you may carry out reasoning about product quality.

For example, fundamental tests of toothed wheel are breakage, pitting, seizure and pressure tests and gear oil test. Phenomena (vibration, noise, dynamic forces, wear-out processes, etc.) accompanied by wheels when operating are also inspected. Such an inspection is performed for toothed wheel prototypes research or determined number of operating wheels. Acquired results have to be recorded as essential quality factor.

OBJECT	ATRIBUTE	VALUE (ABSTRACT)	VALUE (INSTANTIATION)
Toothing	Test course	$f_w(t)$	$f_r(t)$
	Product life (103h)	50	55
	Breakage	NULL	
	Pitting	NULL	
	Seizure	NULL	

3. Recapitulations and conclusions

Machine element representation in object-attribute-value form with use of frames and their possibilities of heritage, besides advantageous way of describing shape and product properties, is the way of enabling computer-aided estimation of a given product. Described methods of product feature quality determining show how the estimation can be done. In many cases the estimation is not a result of a direct value comparison, but it may have its origin in accompanying processes or phenomena, knowledge of a product destiny and achieving given requirements in too a small degree. This knowledge may be written and processed in expert system created for this purposes. The expert system may run decision-making process of given product destiny or quality estimation. Besides such a knowledge describing and processing, system knowledge base should include procedural knowledge of manufacturing process, for example. It is predicted to make a computer program with use of expert system *MAS* created in the Department of Fundamentals of Machine Design.

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Revised by: Janusz Dietrych