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The role of databanks for artificial intelligence based measurement and control in computer integrated production

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Abstract

The application of computer assistance in the manufacturing field also puts sophisticated requirements on inspection methods. Therefore new demands are put to quality management using the aid of artificial intelligence. The described flexible measuring system links a local area network of personal computers to various measuring devices for accurate automated workpiece inspection. The computer system provides for design, calculation, measuring planning, simulation and evaluation. As special feature there are links to artificial intelligence based data bank systems for production, construction and quality data respectively. The application of the proposed measuring cell guarantees economical manufacturing, inspection and management of quality data and it is an example for the usefull application of artificial intelligence in production engineering.

1 Introduction

In the past twenty years we see increasing importance of computer aided measurement techniques as a means to control industrial manufacturing, to test technical products with high accuracy and to improve the quality of all kinds of products. Therefore a sophisticated measurement technique, among other things, is considered a very crucial requirement for the production of industrial goods of controlled and optimized quality.

In general workpiece accuracy can be defined as the interference of:

- deviations of size,
- surface roughness,
- deviations of form, and
- deviations of position.

The knowledge of necessary and permissible deviations from the ideal geometry of workpieces exercises great influence on the economics of manufacture if specific workpiece accuracy is demanded. References give an overview on this important aspect of modern production engineering [1, 2, 3]. Since about 1970 we see a continued increase in importance of computer aided measurement technique as a means to control industrial production. At the same time, the standards for product design and documentation have been internationally harmonized.

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Since about 1980 much work was carried out in the area of data communication in production too. Many general approaches are described in literature [4, 5, 6] but nevertheless there is still an increasing demand for flexible and accurate low budget systems in this field.

Computer aided co-ordinate measurement technique [7 to 10] has to an increasing extent assumed importance in mechanical manufacturing technology because of its universitality. Using this measurement technology it is possible to measure workpieces of any geometrically complex form accurately, quickly, and objectively. Co-ordinate measuring machines are particularly useful for the solution of special measurement problems in precision engineering.

Data communication as interaction of computer aided quality management (CAQ), design (CAD) and engineering (CAE) combines the various tasks of the interaction between inspection, evaluation and construction. Especially the set-up of workpiece geometry in respect to tolerances for dimensions, macro and micro geometry, and choosing of economic allowances are focal points of interest.

2 Production accuracy and workpiece tolerances

Competition and cost consciousness on one side and increasing demand for quality and reliability on the other side are contrary requirements in present production engineering. This must be considered also from the point of view of the international standards about quality management and quality assurance [11, 12, 13]. As an increasing important fact the protection of environment must be taken into consideration, too [14].

In the last few years, the fundamental standards governing product specification, design and manufacture have undergone basic international harmonization. Focal points of interest included surface roughness [15] and geometrical deviations of form and position [16] as well as tolerancing according to the principle of independency [17]. In most industrialized countries the mentioned international standards have been adopted on a national level too and the international harmonization is still continuing [18].

Very often it is necessary to prescribe tolerances of size, form, position and roughness if specific workpiece accuracy is demanded. The knowledge of necessary and permissible deviations from the ideal geometry of workpieces exercise great influence on the production costs and the overall economics of manufacture. Because of lack of knowledge design engineers or designers at the CAD system normally prescribe very narrow tolerances without functional relation which are the reason for unnecessary expensive production costs.

As already established by Kienzle [19] there is evidence for the existence of "inherent interrelations", as it were, among different geometrical deviations of workpieces.

Depending on whether macrogeometry or microgeometry is the focus of the analysis of workpiece surfaces, a distinction is made between form errors of different order, both in the technical literatur and in the relevant standards. It is common practice to collectively consider the more or less short-wave geometric deviations of a third or higher order as deviations in surface roughness on the basis of worldwide understood and internationally established parameters [15]. As far as geometrical deviations of form and position are concerned the increases use of co-ordinate metrology has improved common knowledge.

There exists a series of influences that must be considered in connexion with workpiece accuracy. It is general knowledge to take into account ISO tolerances [20, 21] and general tolerances [22] respectively for linear dimensions. But also geometrical deviations of form and position must lie within certain limits whereas general tolerances [23] or tables of experimental values respectively [3] can help the design technician who has to specify the allowances on drawings.

3 Proposals and rules for workpiece accuracy

In a series of publications [1, 2, 3] it was reported about the importance of workpiece accuracy. Some guidelines [24], [25], [26] worked out in the eighties in differently industrialized countries give evidence of the uptodate worldwide interest in this subject.

The basis of a nomogram published in [25] has been given in [1] whereas extensive further measurements showed the necessity to modify the originally proposed limit values.

In [2] it was demonstrated that, for workpieces with dimensions within tolerance, form deviations and roughness values measured as profile height can be allowed to have approximately equal magnitudes unless higher or smaller numerical values are specified because of functional requirements.

In [3] a comprehensive proposal for appropriate geometrical tolerances of position is given. These proposed tolerances are provided as recommendations for design offices prescribing prositional tolerances for design offices prescribing various tolerances in technical drawings. The considered viewpoints are interchangeable manufacture and economical production.

The proposed numerical values of the above mentioned guidelines can be achieved in industry with high probability under uptodate conditions of manufacturing.

4 Collection system for geometrical deviation data

Having in mind the above mentioned "so to speak natural relationship" [19] among various geometrical deviations of the shape of workpieces it is necessary to reconsile measurement data with the standards for geometric dimensioning and tolerancing. In order to perform this task adequately a detailed understanding of the expected deviations from the ideal geometric form is needed when producing different features by different manufacturing processes.

Since more than ten years at the Department for Interchangeable Manufacturing and Industrial Metrology of the Vienna University of Technology measurement data of geometrical deviations of dimension, form and position gained on the basis of co-ordinate metrology and roughness data measured with precise standard stylus instruments have been collected. Nearly 50000 geometrical features of industrially machined workpieces have been measured altogether in the above mentioned period. The workpieces come from the standard production of various Austrian factories for industrial

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use. The sizes of the tested workpieces was limited by the measuring range of the used measuring device which was 500 mm x 200 mm x 300 mm. The piece numbers of series of equally shaped workpieces have been very different because of industrial conditions, lying between seven and more than 250.

The deviation data have been collected mainly in the physical form of measurement data sheets. On some experiences gained about positional deviations it has been reported in the past [3]. The now described evaluation of the collected deviation data can help to make a comparision between various guidelines and proposals and to work out an expert system in the field of geometrical deviations as help for designers and constructors.

5 Flexible measuring cell

The prototype of a measuring cell with the goal to achieve flexible automation of measuring tasks and quality management in small industrial plants was developed at the Vienna University of Technology. A local area network of personal computers is linked to a small high precision CNC co-ordinate measuring machine and to other measuring devices. The measuring cell also includes handling systems for workpiece manipulation and automatic probe exchange. As a special feature there are links to artificial intelligence based data bank systems for production, construction and quality data respectively. This item described in the next paragraph. Figure 1 shows the layout and the functional relationship of this system.

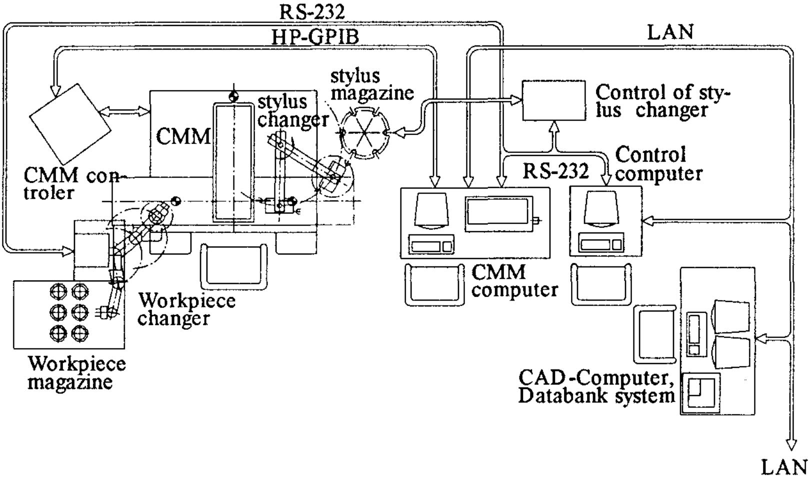

Figure 1: The used measuring system "Flexible measuring cell"

The proposed concept is an example for the useful application of artificial intelligence in production engineering and it is a principal step to achieve economical, accurate and wastefree manufacturing.

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6 Data bank and expert knowledge on geometrical deviations of workpieces

The collected geometrical deviations give the basis for the development of a data bank system using a local area network of personal computers and appropriate software [27]. Using this data bank system deviation data are stored in the computer and can be evaluated statistically. As examples the form deviations straightness, flatness, roundness and cylindricity, and orientation, location and run out deviations according to [16] are analysed.

When measured values of deviations, e.g. deviations of form (e.g. flatness) or deviations of orientation (e.g. parallelism), of comparable workpiece features are analysed a random sample Dj (with j = 1, ..., n) can be sonsidered. For analysis only sampling sizes not less than 7 are used.

Since measured values of such deviations are by experience gaussian distributed it is assumed that

$$Z_j = \log D_j \qquad j = 1,\dots,n \tag{1}$$

From sample values Z_j the according mean value $\overline{Z}$ as well as the standard deviation s are computed in the usual way. These sample parameters are used as estimates for the unknown parameters μ and σ of the distrubution.

In this way it is possible to compute estimations for form or positional deviations D (of a special type according to [16] for a selected nominal feature size and selected workpiece accuracy, both according to [20]) an upper limit D_{lim} which the deviations that occur do not exceed with a certain probability P if a sufficiently large number of observations are presupposed so that

$$D \leq D_{lim}$$

is satisfied.

The probability that a gaussian stochastic variable takes a value

$$Z \leq Y$$

is in accordance to general knowledge

$$P(Z \leq Y) = F(Y) = \Phi\left(\frac{Y-\mu}{\sigma}\right)$$

with

$$Y = \log D_{lim} \tag{2}$$

where Φ is the distribution function of the gaussian distribution with mean value 0 and variance 1.

In particular,

$$P(Z \leq \mu + 2{,}326\sigma) = 99\ \%$$

and thus

$$Y = \overline{Z} + 2{,}326s$$

can be derived as an estimate, from which D_{lim} is computed according to equation (2).

A great variety of workpieces produced in different industrial plants produced with different manufacturing methods for different purposes and tasks have been measured in the course of the data evaluation as described in Section 4. To illustrate the good agreement with the above described presuppositions in relation to the distribution of the measured deviation values of form (Figure 2-a) and position (Figure 2-b). The figures give presentations as histograms where frequency ratios are plotted as function of measured deviations for selected samples of the deviation data bank.

To give an idea of the numerical values that stand behind the graphics in Figure 2-a a sample of 451 elements and the flatness deviations occured is considered. The maximum extension of the measured planes is 50 mm manufactured by turning. The range of flatness deviations is 0,1 to 281 mikrons whereas more than 99 % of the measured values are less than thirty mikrons.

Figure 2-b gives an analog example for parallelism deviations. The sample size in this case is 87. It shows also the appropriate D_{lim}- value of fifteen mikrons according to equation (2) for the evaluated sample.

So in the databank system geometrical deviations of the various types and the production methods and manufacturing conditions respectively are collected. The evaluation of these data allow the development of appropriate guidelines.

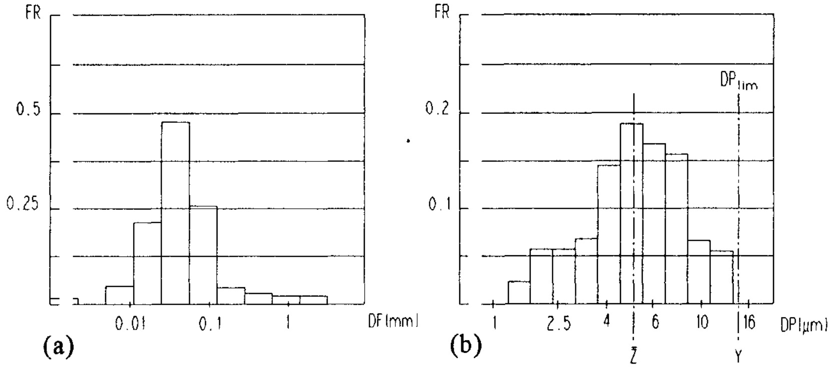

Figure 2: Histogram of form (a) and positional (b) deviations

This system also makes it possible to compare various existing guidelines, e.g. [2, 25, 26]. In general these guidelines show good accordance. In the range of small nominal sizes and ISO tolerance grades less than IT10 but also low values of form deviations and roughness peak parameters up to one hundred mikrons there are very small differencies of less than ten percent. As to speak about the bigger values of permissible deviations in [2] and [25] the proposed values are in contradiction to working conditions and manufacturing accuracy of modern production equipment. But it is the opinion of the present authors that informations about

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the size of the permissible allowances are allways important. The workpieces can be produced with cheap machine tools and chip dimensions can be chosen bigger. Therefore there is an effect on the economy of production if the necessary informations are forwarded to production planning.

7 Conclusions

The problem of workpiece accuracy is of still growing importance in the present time of competition, cost consciousness and computer integration on one side and increasing demands for quality, reliability and environmental protection on the other side. In many instances these are contrary requirements in modern production engineering especially in the industrial application field. Nevertheless it is necessary to find an economic solution.

The present authors pointed out that there exist various guidelines for geometrical deviations of workpieces. These guidelines have been developped in various countries if different level of industrialization. The proposed artificial intelligence based system allows the evaluation of new guidelines derived from measured values and a comparision of the already existing guidelines. Proposed values depend first of all of the industrial branch. The influence of the state of industrialization exists only to a much lower extent.

So expert knowledge and guidelines for permissible allowances for the various geometrical deviations as there are roughness and deviations of form and position in correlation to workpiece dimensions and tolerance grades can help to reduce production costs by reducing working stages and decreasing the necessary manufacturing time. Therefore artificial intelligence based evaluation of measurement data can help to rationalize production without neglecting the increasing demand for quality in modern industry.

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