Up-to-date metrology for effective quality assurance of the machine production

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ABSTRACT

Recently the main purpose of the companies is to product their products in the highest quality corresponding to the market demand. Instead of the inspection of the products more and more the increased inspection of the production process and devices is required for providing the desired quality. The reliability and the effectiveness of the measurings performed during inspections can't be provided without measuring data collecting and feedback to the manufacturing process, its rapid evaluation and documentation. These activities require advanced measuring technique devices. This article shows devices and application examples from the area of the latest measuring technique development.

Key words: quality assurance, metrological devices, intelligent measuring and diagnostic systems.

1. INTRODUCTION

The quality assurance is integrated part of the manufacturing process. The activities related to the quality assurance and among that the measuring and inspection for defining the product quality create an organical part of the company quality management system. We can make sure of achieving of the desired quality by means of the inspection performed at the right levels of the production. The quality inspection today isn't limited to only the final inspection. Beyond the procedural control of the product and parts the inspection and qualification of the manufacturing process and manufacturing devices itself is essential requirement of the gradual improvement of the reliability and the quality of the production for the sake of providing and attestation of the capabilities which necessary to achieve the desired quality [1].

In contrast with the traditional inspection concentrating to final acceptance, the procedural control qualification already plays controlling and regulating roles as it creates the possibility of feedback and through this errors repeat can be avoided in the future.

So that the measures can be built into the technological process in the last few years we can notice the following tendencies in the development of the measuring technique:

• spreading of the electronic versions of the traditional manual instrument,
• application of multipoint measuring instrument, complex measuring and qualification processes,
• application of computer controlled automatic measuring station which are able to solve different tasks by oneself,
• application of 3D coordinate measuring technique,
• on behalf of the optimalization of the features which depends on the quality of the machining tool and on the state of the manufacturing device, the supervision of state of the work - equipment - machine - tool system.

All of these raise the following increased demand in contrast with the devices of the measuring technique:

• increased measuring accuracy and reliability,
• integrability into the manufacturing process,
• obtain increasing amount of information about more and more amount of work, that is correspondence to conditions of mass production and large scale production,
• processor control, possibility of connection to computer,
• rapid work up of the measuring data,
• feedback of the resulted information to the manufacturing process.

One of the trends which lead to realization of the above requirements is the so called "mechatronics" which means the application of the electronical technologies in the field of mechanical measuring devices. Another possibility is "opto-mechatronics", which offers the latest optical processes for the production.

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The equipment manufacturing companies make great efforts on behalf of that the above mentioned latest technologies become the part of the automatic measuring and manufacturing processes in the factories. In the following part we show some of the several measuring devices and their application possibilities developed as a result of above purposes.

![Diagram of Quality Control System of Production]

**Fig. 1. Quality control system of production**

### 2. UPDATING IN THE FIELD OF LINEAR MEASURING INSTRUMENTS

#### 2.1. Application of digital instruments

Application of digital manual instruments already appeared in the beginning of 1980. At the beginning the aim was only to improve the safety of reading with numerical display. The first versions was number indicating types, the later ones have LED and LCD (liquid crystal display) display. The latter ones are the versions of the traditional manual equipment installed with odometer. For the application of the different manual instrument (micrometer, indicating gauge, calliper, altitude gauge) there are several fitting possibilities depending on the measuring tasks [2]. The so called mini processors are appropriate for store measuring data and for defining more important statistical features. Data are printed by the installed matrix printer which plots them in the form of line chart or histogram. In general one measuring device can be connected them. The multiplex interfaces allow the data of more measuring devices to be inquired and transmitted through RS 232 (or IEE 488) line. These interfaces are connected to IBM PC/XT/AT computers. In that case when in the field of the measuring there isn't available computer or there isn't time for immediate computation data collecting equipment have been developed. They are equipment of fixed program with microprocessor and relative high storage capacity. They have two interfaces to one of them can be connected the measuring instrument and later the computer or probably directly a printer can be connected to the other one.
The MITUTOYO DATA LOGGER for example allows 1000 measuring data to be surveyed and stored, and appropriate for classification of the data according to 10 features. For transmission of data aggregated by the data collecting equipment to the computer transmitters are available.

The figure 2. shows the fitting possibilities of the DIGIMATIC instruments of the MITUTOYO and the possibilities of data transmission to the computer evaluation.

The instrument manufacturer companies also developed different program systems whose common feature is that it is based on process control (SPC, SQC).

Our department uses versatile data collecting and processing software named STATPAK of the MITUTOYO company developed according to the latest requirement of process control and process monitoring.

It allows versatile data transmission from all of the Mitutoyo measuring devices which have digital data output. The application possibilities range from the simple measuring device (calliper) through the projector to CNC coordinate measuring apparatus. Data analysing possibility is wide-ranging including the machine and process capability testing, measuring and classification controlling cards, defining of automatically calculated or fixed controlling and warning limits, notice of the state out of the automatically controlling, distribution and fitting tests, supporting of process supervision.

2.2. Application of electronic fiducial indicators

Considerable part of the measuring tasks of the parts can be solved with difference measuring. The measuring range of the highly sensitive - high resolution - analogue measuring instruments much more less than the length to be measured itself.

The multipoint measuring instrument which perform the complex dimension control of the parts in very short time are used in wide-range [3].

The modern multipoint measuring instrument today can't be imaged without smaller inductive fiducial indicator which totally eliminates the disadvantages of the mechanical fiducial indicator and has much higher resolution.

The most known companies dealing with linear measuring technique developed modular electronic units which can be fitted to inductive fiducial indicator for measuring instrument which can be constituted from elements. These moduls allow the tolerance limits to be displayed, the classification according to dimension and the sort merge, the measuring results to be stored, and logging with matrix printer.
2.3. Application of the measuring machines

In the industrial measuring technique practice there are many special measuring tasks such as concentricity, surface irregularity, measuring of gearwheels and the most of the profile inspection.

The gauge head of the measuring machine is usually some inductive fiducial indicator of special construction. The head or the workpiece to be measured is moved by a precision mechanism at constant velocity or rotated at constant angular velocity.

Important parts of the measuring machines are the displacement pick up and angle data transmitter which play role in defining the sampling point.

The purpose of the measuring and the signal shape analysing is to separate the individual components that is the harmonics from the total profile.

The separation of the harmonics is accomplished with filter; electrical signal shape obtained from geometrical waves that is vibration characteristic has to be filtered.

On the circular error measuring machines compared to the precisely centred locating surface certain site errors of the different surfaces of the part ( eccentricity, axial run out, obliquity) can be defined with special anvils.

The impact test of the gearwheels is performed with rolling measuring machine at which either the changing of the center distance between the tightly clamped etalon wheel and the wheel to be measured during rotation is measured or with the nominal ( and fixed ) center distance from the connected gear the fluctuation of the angular velocity of the wheel to be measured.

The dual profiled measuring process is more frequent which is applied by the department.

The profile analysers analyse the deviation of the surface macrogeometry compared to the theoretical. The resolution of both the calliper of the tractive mechanism and of the gauge head is usually 1µm. The instrument plots the surface profile in graph or in polar diagram or on the screen in the desired enlargement.

The latest type of the profile analysers is installed with two gauge heads of different measuring range, configuration and sensitivity. These measuring machines can determine the microgeometrical features of a part of the profile besides the profile analysis, and by applying for example the method of the expressive "zoom" represent it on a graph.

In the modernest gauge heads more precise laser interferometer can be found instead of inductive measuring signal converter.

For non - contact measuring direct gauge head of laser beam scanning is used such as FOCODYN gauge head matched to the feeding mechanism of PERTH - O- METER [2].

The advantage of the laser beam measuring is that the laser beam has smaller cross section than even the finest diamond point and it doesn't scratch the surface.

In the advanced digital systems measuring and computation mean two well limitable cycles. The advantage of the digital system is that the dataset in the memory for example can be registered to magnetic data carrier and from it at any time with any algorithm further features can be determined with digital filtering, Fourier analysis and different statistical methods.

At the latest generation of the surface roughness tester the installed target computer is general.

2.4. Application of the coordinate measuring technique

Suitability for the specification of correct shape and position of the parts can be tested reliably and economically with coordinate measuring.

The multicoordinate measuring technique have greatly developed in the last few years.

Since the positional possibilities of the universal microscope however are limited to two coordinate measuring and because of the elaborate positional process of the work with the auxiliary equipment the measuring is time - consuming and the measuring results may have some subjective errors and indefinability. With this method quick and reliable information on the dimensional stability of the product can't be provided during production.

The first step for decreasing the subjective effects and increasing the measuring speed was the installation of digital measuring systems to existing measuring systems. With the data processing units which can be connected to these systems and appropriate geometrical programs ( e.g. " 2-D Geopak" ) the reliability and capacity of the repeating and highly elaborate, two dimensional measureings performed either manually or in CNC operational mode significantly increase.

There are microscopes developed for mainly inspection to be performed during production. They can be widely used for contour and dimension measuring of miniature parts and inspection of machined surfaces. For effective inspection eye - glass of particularly high observation domain is used [2].
At several work geometries encountered in practice however the measuring task can be solved only with developing of 3D measuring technique. In the last few years there are attemption to perform also the geometrical inspection of helix - typically 3D shape - of elaborate geometry on three coordinate measuring machine. For this task measuring machines installed with CNC high precision auxiliary equipment (e.g. indexing fixture, electric gauge head) are used which can be considered purpose equipment because of their configuration. Therefore their application is practical only in large-scale production. In Hungary worm gears, tools with helical surface (e.g. hobs) and helix are manufactured in small- and medium-scale production. Therefore their geometrical inspection must be performed besides providing the inspection of other parts. So the developing of inspection of helix on universal 3D measuring machine is required. The inspection can be performed with measuring program having theoretical and geometrical bases [4]. Bevel gears and involute teeth can be measured with suitable software without application of circular table and templet on CNC 3D measuring machine. In this case surface scanning is accomplished along regular surface net formed arbitrary number of points; the results representations can be interpreted as the deviation of coordinates of the theoretical and real contact point [4],[5]. A CNC 3D measuring machine can be used for inspection reconstruction integrated into quality controlling process or CAD-CAM system as an independent measuring device in the technological series (Fig. 3.).

Digitizing softwares and interfaces worked out suitably create connection between the coordinate measuring machine and machine tool.

In the last few years several processes were worked out for rapid production of prototypes based on the information of geometrical models [6]. A common feature of these processes is that they are based on taking of the shape to layers and then building up of the prototype layer by layer on the basis of the information related to the layers. Machining is performed by peripheral equipment of the computers used for operation of engineering planning systems whose operation the planning
system is completed with interface programs. The interface program from data set of 3D geometrical model forms the files which can be directly used for controlling of the rapid prototype making equipment.

Coordinate measuring machines naturally can be used for inspection of very thin tiny soft parts or for parts with highly elaborated geometry such as integrated circuit panels and rubber parts but in certain cases their application is limited by scanning system measuring with contact method. The great instrument manufacturing companies developed 3D CNC image processing measuring systems which eliminate certain disadvantages of the scanning coordinate measuring machines and the optical measuring system by means of combining different technical solutions. These systems allow very rapid and precise CNC measuring by means of the modernest optoelectronic image processing technique. The clear and sharp representation of the image of the work and its displaying to the screen is provided by precision objective and high resolution CCD camera. The image processing with increased accuracy allows non-contact 3D measuring in case of such parts which couldn't be measured with the traditional scanning coordinate measuring machines.

In the last decade instruments used for inspection of not only the macrogeometrical but microgeometrical features and the evaluating methods have been also highly developed.

The attempts were aimed that the special surface features describe the operational state. It requires the introduction of large number of new parameters besides two dimensional parameters (surface roughness, waviness) so far registered in the normative standards. An essential step in this direction is the 3D surface analysing. However the traditional two dimensional profile measuring combined with visual observation on microscope is enough in some application areas, but the 3D surface topography provides device in more and more application area for quantitative description of the surface features according to different aspects. Special software packages help the data processing including 3D surface filtering and computer determination of 3D parameters. Recently this technology is available for industrial application of increasing number and some measuring systems may be purchased in the market [7], [8].

3. DEVICES HELPING THE STATE MONITORING OF A MACHINING SYSTEM

We can make sure of the reliability of the production process mostly by means of the inspection of the tool’s state (wear). Tool wearing influences not only the dimensions and the surface quality of the work but the load and the power consumption of the machine tool. The continuous observation of the cutting edge facilitates resharpening if we notice the wearing time thereby the failure of the tool and work can be avoided. Tool monitoring can be performed with direct and indirect methods. At the application of indirect measuring methods the effect of the different parameters on the wearing is analysed without the observation of the tool itself. Different sensors are applied for sensing of the variables characterising the process. Most of them are large enough to operate reliably among ambient conditions in the working space of the machine or the tool. The most frequently noticed signals are the acoustical emission of the cutting force, the power consumption and temperature change. The increase of the tool wearing usually causes increasing signal level. In case of turning and milling it occurs mainly because of the temperature change in the contact zone of the work and the tool while in case of drilling it occurs because of the increase of the dynamics of the process [9], [10].

A limit of the practical application of the indirect detection methods is the necessity of the calibration processes. The direct monitoring methods provide precise signals eliminating theoretically the necessity of the calibration. They directly show the changes in the environment, the quality and the geometry of the cutting edge. The application of visual system for tool state monitoring requires highly reliable data collecting and evaluation systems with which tool state is diagnosable with adequate accuracy.

The application of an optical sensor with visual system allows excellent optical observation of worn tool surfaces [11]. Such sensors must be placed in the working space to accomplish measuring during the process (Fig. 4.).
The work with digital visual system requires conversion of the image into electrical signals which can be evaluated by the computer. The collaboration between the camera and the lighting has influence on the image quality consequently on the measuring results. Infrared light source facilitates to feed out the surrounding light with the aid of a band filter. Tougness as well as small size and available TV-standards are features of CCD cameras. In this way high resolution of the object to be measured can be achieved.

The rapid developing of the computer image processing opened a wide range of application areas for the use CCD cameras and the image processing evaluating softwares. One of the active measurings with CCD cameras is for example the measuring of wear of the wheel grinding worm [12]. A CNC wheel controlling equipment [13] is available for the controlling of the profile of the wheel which is able to control continuously the wheel during machining but for the determination of the controlling necessity we should measure the deviation from the desired profile. A rapidly rotating grinding wheel can be measured only with non-contact method so for the observation of the change of the wheel profile the CCD camera measuring seems to be the most suitable. We should carefully align the optical axis of the camera in case of the different profile grinding wheels. Figure 5. illustrates the change of the magnitude of the measuring error depending on the position of the camera.
4. FUNCTIONAL INSPECTION METHODS AND DEVICES OF THE PRODUCTS

For the inspection of the technical data and operating parameters advised in instruction manual the electrical measuring methods and devices of the nonelectrical quantities are suitable in production of traditional system. The analysing of displacement, angular rotation, angular acceleration, force, torque, pressure, vibration amplitude, velocity, acceleration, conducted and airbone sound and their spectrum provides for this purpose the following specially developed measuring chain: electrical signal converter, carrier frequency measuring amplifier, analoge and digital display, recorder, measuring magnetophon, transient recorder, FFT Fourier analyser, data processing and measuring systems [14].

The devices of the electrical linear measurement technique of the production of traditional system passed development of two generations in the last few years. The increase of the accuracy of the reading, data registering and measuring information, the decrease of the measuring time allowed the rapid transmission, systematization and feedback of data in the quality assurance system.

The analysis performed on the bases of measuring and the objective qualification processes facilitates the finding of the criterias which determine the machine capacities and accuracy and geometrical, kinematic, statical, dynamical, thermal and acoustical features.

In the last few years significant development were carried out in the field of measurement technique and intelligent measuring instruments which sense, measure and document the different parameters and facilitate the feedback of the results to the manufacturing process.

In the future developments sensor technology integrated into manufacturing process should play a more important role with which an opportunity of the signalling in time of not only the manufacturing errors but the environmently harmful effects and thereby their prevention and elimination will be provided.

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