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EVALUATION OF MACHINE TOOL QUALITY

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Abstract: *Paper deals with aspects of quality and accuracy of machine tools. As the accuracy of machine tools has key factor for product quality, it is important to know the methods for evaluation of quality and accuracy of machine tools. Several aspects of diagnostics of machine tools are described, such as aspects of reliability.*
Keywords: *reliability, quality, machine tool.*

1. INTRODUCTION

Quality is perhaps the oldest concept by evaluating the product and identifies or describes the level of customer satisfaction with the product. Condition of a machine tool has an enormous impact on the piece quality, on which the machining process takes place. Therefore it is important to keep the machine tool in such conditions, when the machine tool will be able to produce parts that meet the demanded accuracy. Very close tolerances, or very high quality surface cause unnecessary production costs and hence high cost of the product. Positive is high reliability and long-time usability. In contrast, products with low prices have a positive impact on enterprise competitiveness.

Mechanical engineering industry as other sectors of economy, where the final product is a part, tries to increase the product quality. On the one hand stand the customer's demands and on the other hand the increasing production. Simultaneously are increasing product quality and precision instruments. At the same time are sought reserves in all the parts of the company, which would achieve good indicators of production. Future engineering enterprise will not be able to ignore the newest trends, when it will want to keep pace with other competitors on this field. While in the past, when the price was the most important point, but usually at the expense of product quality. Nowadays we can say that the quality is what counts and not the price. With the product quality we have combined superior service at a possible repair, customer complaint and quality related services.

2. MACHINE TOOL ACCURACY

Machine tool precision is characterized by the ability of the machine to produce parts of the required shape and dimensions keeping the required tolerances and to achieve the desired surface roughness. Requirements for precision of the machine tools result from the required precision of components manufactured on the machine. Because on one machine are usually manufactured different surfaces of a component of different geometric shapes, it is necessary to respect the accuracy of fundamental dimension elements of machine, such as: flatness and straightness of guide surfaces, alignment clamping surfaces, parallelism of axes with guides, the perpendicular shaper required from the spindle axis with the clamping surface of the table, etc.

Compliance with the required accuracy of manufacture and assembly of parts and machine nodes can achieve static precision of the machine tool, also called geometric precision can be achieved. Geometric accuracy of the machine tool is the precision of shape and position of its individual parts and their mutual movements. It is necessary, but not a sufficient condition for ensuring the required precision of the machine tool manufacturing.

3. INACCURACY OF MACHINING

In production of machined parts it is not practically possible to produce parts with full precision. The machined parts dimensions are always different from the nominal values mentioned in the design drawings. Relevant deviations are bound with many factors, from which the most important one would be the production process.

Total inaccuracy of machining can arise from series of factors. Among them, these are the most significant.

- inaccuracies due to elastic deformation of technology system machine - tool - workpiece from the cutting forces and resistances,
- inaccuracies caused by thermal deformations of technological system
- inaccuracies due to wear and tear of cutting tool,
- inaccuracies of machine sorting and of workpiece material composition,

- inaccuracies due to distortions in the workpiece by clamping forces,
- inaccuracies due to geometric and cinematic machine tool inaccuracies,
- inaccuracies due to geometric irregularities of the cutting tool,
- inaccuracies due to internal stresses in the workpiece material,
- inaccuracies due oscillation in the technological system,
- inaccuracies due to fluctuations of input size parameters of the workpiece and the material inhomogeneity.

From the list above we can state, that the most important factor of machining accuracy is the machine tool and its accuracy.

4. RELIABILITY AND LIFETIME PERIOD OF MACHINE TOOLS

Reliability and lifetime period are critical factors in substance, which predetermines the possibilities and the exploitation of machine tools. From a diagnostic machine tools is the more relevant issues of lifetime period and especially remaining lifetime period. Solution remaining lifetime period of machine parts is not easy. Actually represents a complex of different activities, each of them is equally important. What is actually a lifetime period? Abbreviated told that life is defined as the ability to object to fulfill required functions to achieve the ultimate state for a system of prescribed maintenance and repairs. Reliability is a general property of an object, such as the ability to perform the required functions while maintaining the values set in these performance indicators and time limits, as defined by the conditions. It is then possible to write that the reliability of output of the three mandatory factors:

- the required functions properties,
- the period during which the functional properties of watching,
- operating conditions, it is ways and circumstances of the operation of the plant.

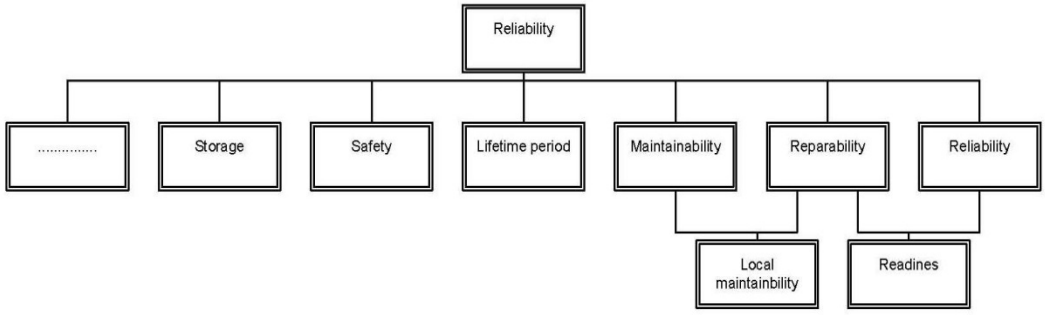

Figure 1 Properties reliability components

5. RELATIONS AMONG QUALITY, RELIABILITY AND SAFETY

In terms of quality and reliability will normally meet in everyday in life. Manufacturing highlighted in advertisements, product quality, limited reliability of products usually the owner will realize, and when the product goes wrong. There is much debate about the quality of services - both the private and public sectors. Concepts of quality and reliability are related, but are not the same thing. Product of quality or services can be defined as their ability to satisfy needs customers. However customers satisfaction with a specific product or service depends on many factors.

The standards of reliability are determined by its intended use. Reliability is necessarily implement into future products at the early stages of design, then it is necessary to ascertain the correctness of the proposed solution appropriate test. If the targets cannot consistently increased reliability of individual components, overall reliability of the devices would gradually decline. Reliability is obviously one of the most important factors that affect safety, not only is the only one. System or device can perform the required functions and yet may be both dangerous. Many serious accidents have not caused the mechanical and electronic failure, or human failure, the operators, or maintenance staff manager.

Safety of machine structure is a prerequisite for the implementation of safe operations in the technological processes in the system person – machine - environment.

Only safe and functional equipment, eventually full systems can ensure the quality and completeness of the circle that resulted in a product characterized in quality that enables its marketability. Safe machines makes the implementation of secure production process, it is create the condition that in the system person - machine - environment meet all of its constituents, the requirements follow of technological conditions.

6. EVALUATION OF QUALITY AND RELIABILITY OF MACHINE TOOLS

In the market conditions where supply exceeds demand, for the user is important to know the machine to assess the quality of the offered machines. The quality of the machine is a summary of the properties, which determines its ability to meet pre-determined or assumed to user needs. Anticipated user needs is determined everywhere where the manufacturer specifically concludes a contract with specific users (not produced according to individual orders).

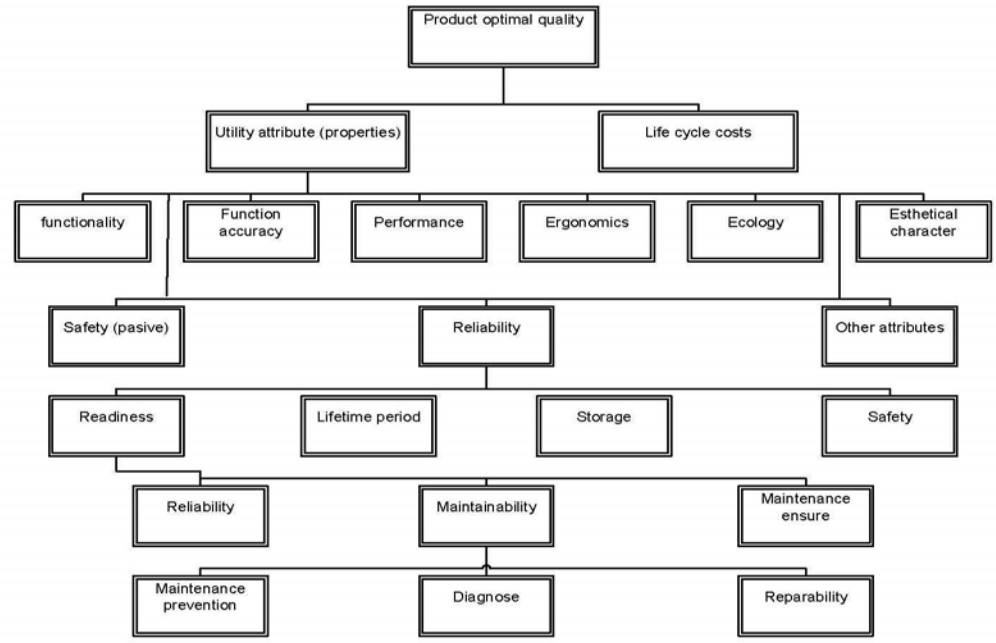

Figure 2 Criterions for evaluation of machine tool of quality and reliability

The manufacturer must in this event determine the needs based on market research, analysis of expected customer requirements, their own knowledge and knowledge of the history of its products and product development competition, using, for example for the specification of quality characteristics. An important property is the quality of reliability. Evaluation of quality and reliability is based on the principle comparison predetermined or anticipated needs of the user with truly level reached properties (product codes). Summary characteristics of the products related to reliability are shown in Fig. 2. Machine tools are to complex systems and theoretically we are able to mathematically or experimentally verify the reliability, or reliability or lifetime of each component. Practically, however, it is temporally and economically unrealistic and creative team engaged in designing and developing the machine tool must decide what parts will be verified, dimensions and materials estimated based on good engineering practice. If we realize that for example a car has several thousand components, situation look like very negatively at first sight and beyond the power of a relatively small number of its creators, in practice, however, there are several factors which enable reliability proposal of the machine tool optimized.

7. TECHNICAL DIAGNOSTICS OF MACHINE TOOLS

The technical diagnostics has the following aspects:

- very high assurance and reliability with perspective on prolongation of maintenance cycles and reduction of further damage,
- objective technical condition must be determined without dismounting and operation discontinuation,
- evaluation must be done based on reliability of whole machine system.

Diagnostics from the viewpoint of machinery is known as:

- preassembly diagnostics,
- diagnostics after final assembly - during debugging and final inspection,
- operating time diagnostics - service, inspectional or monitoring.

It is possible to meet with the following types of diagnostics:

- vibrodiagnostics,
- tribodiagnostics,
- thermography,
- acoustics,
- NC and CNC machinery diagnostics.

For NC and CNC machinery diagnostics is important especially the following:

- accuracy of CNC machinery progression monitoring,
- circular interpolation according to ISO 230-4.
- geometry measurement according to ISO 230-1.

Machine tools condition monitoring is main prerequisite for maintaining production quality as well as necessary requirement in quality control systems according to ISO 9001 standards. Observe machinery preventive geometry according to production wasters is obsolete. Current tendency is to foresee - predict machinery condition and ensure production quality accordingly. Following this it is possible to ensure satisfactory production even on machinery with worse characteristics.

8. METHODS OF DIAGNOSTICS FOR CNC MACHINE TOOLS

CNC machine tool commonly used the following method of diagnosis:

- **Direct method:** Use of sensory organs from the maintenance personnel to observe the fault occurrence of various sound, light, taste and other anomalies, see CNC machine tool system of the various modules and circuits, with or without traces of burning and injuries to quickly narrow down the fault to a module or a printed circuit board. This is a basic and commonly used method.
- **CNC system self diagnostics:** CNC system self-diagnostic function, has become an important measure of performance indicators CNC, CNC system self-diagnostic features real-time monitoring of CNC system working state. Once the abnormal situation occurs, immediately displayed on the CRT alarm message, or by light-emitting diode indicates the causes of the fault block, which is CNC machine fault diagnosis and maintenance of the most effective and direct way.
- **Functional program testing method:** Functional program testing method is commonly used in the numerical control system functions and special features programmed by hand or automatic programming method, a functional test program compiled, into the NC system, and then let the CNC system to run the test procedures to check the tools perform these functions the accuracy and reliability, and then identify the possible fault location and cause of the malfunction.
- **Module exchange:** The so-called module exchange is generally the cause of the failure cases, the use of an alternate printed circuit board, templates, integrated circuit chip or component replacement questionable part of the functional unit of the same template or mutual exchange of metastasis observed failure to quickly determine the fault location method.
- **The principle of analysis:** CNC formed according to the principle of the work of the various components from the system theory to analyze and judge to proceed from the logic circuit fault doubt on the analysis of levels and characteristic parameters of the logic to determine the fault location method. This method is very demanding on the maintenance staff must be familiar with the whole system or each component works in order to locate the fault location.
- **PLC procedural law**: According to PLC alarm information, access to the PLC program, the corresponding alarm control module program, more related to I / O device logic state, determine the fault.

9. CNC MACHINE TOOLS DIAGNOSTICS

Machine tools condition monitoring is main prerequisite for maintaining production quality as well as necessary requirement in quality control systems according to ISO 9001 standards. Observe machinery preventive geometry according to production wasters is obsolete. Current tendency is to foresee - predict machinery condition and ensure production quality accordingly. Following this it is possible to ensure satisfactory production even on machinery with worse characteristics.

This provides monitoring by decreasing machinery service costs and at the same time maintain high production quality by means of NC and CNC machinery diagnostics. This is applied throughout our customer base especially companies working in machinery industry.

Diagnostics according to ISO 230 – 1

Geometry measurement (Schlesinger)

Machine tool basic geometry measurements (perpendicularity, straightness, flatness, circumvolution, alignment, and axis identity) according to ISO 230-1.

Measuring is always carried out on unloaded machine. Measuring period depend on machine type.

Protocol is compiled from actual measurement and contains:

- Table of measured data,
- Machine`s condition evaluation,
- Recommendations on found faults.

Supplemental measurement (machine-table flatness, machine bed lead etc.)

Flatness and true position of machine-table measurement, machine bed lead, by preparative, dial gauge, electronic water level MINILEVEL.

Measuring is always carried out on unloaded machine. Measuring period depend on machine type. Protocol is compiled from actual measurement and contains:

- Measurement schematics,
- Graphic representation of actual shape or position of machine tool,
- Machine`s condition evaluation.

Machine tools set-up (establishing of equilibrium)

Machine tools set-up (establishing of equilibrium) is important especially for lathes where it has direct connection with machine tool geometry, headstock spindle and carriage axis alignment.

Machine tool set-up is laways followed by control measurement according to ISO 230-1.

Protocol is compiled from actual measurement and contains:

- Measurement schematics,
- Table of measured data,
- Machine`s condition evaluation,
- Recommendations on found faults.

Diagnostics according to ISO 230 – 4

Geometry measurement and measurement of drive adjustment by circularity analysis.

Geometrical errors can be catched up with this measurement (perpendicularity, straightness, backlash, cross clearance…), electronical errors (drive unit delay, trailing error, gauge linear error).

Measuring is always carried out on unloaded machine. Measuring period depend on machine type and number of measured planes.

Protocol is compiled from actual measurement and contains:

- Circularity analysis according to ISO 230-4,
- Table of measured data,
- Table and diagnosis of measured errors,
- Machine`s condition evaluation,
- Recommendations on found faults - development trend of measured errors is compiled at periodical measurement

Correction into selected control systems

Up to certain levels of mechanical errors (based on dynamical measurement) is possible to input corrections into control system to achieve improvement of machine tool accuracy.

This includes constrol systems: Heidenhain TNC 307 to 530i, MEFI, Sinumerik 810D, 840D, GE FANUC series 0,5,6,16,18,20,21,16i,18i,20i,21i.

Corrections input into control system follows machine tool control dynamical measurement according to ISO230-4. Protocol is compiled from this measurement (see geometry measurement).

Supplementary static measurement of repeatability

This measurement is suitable for production in large series when repeatability of tool or workpiece impositioning into position is emphasised.

Measuring is always carried out on unloaded machine. Measuring period depend on machine type and number of measured planes.

Protocol is compiled from actual measurement and contains:

- Graphical representation of tool impositionig into position,
- Table of measured static repeatability data,
- Table of measured maximal repeatability data,
- Machine`s condition evaluation.

Diagnostics according to ISO 230 – 2

Laser (interferometric) geometric measurement

This is so far the most accurate machinery diagnostics.

Machine geometry can be catched up with this measurement (perpendicularity, straightness, flatness, cross clearance, backlash, gauge adjustment).

Measuring is always carried out on unloaded machine. Measuring period depend on machine type and number of measured planes.

Figure. 3 Measurement using Laser interforometer

Measurement of gauge adjustment including corrections

This measurement can adjust gauge (non-linear) which means that measured axis is divided into given number of smaller positions (2 000 mm min. for 5 measured positions) which are compensated according to actual measured error.

Measuring is always carried out on unloaded machine. Measuring period depends on number and length of measured axis.Machine is measured before corrections first. Corrections are inputed and control measurement is carried out.

10. ECONOMICS ASPECTS OF TECHNICAL DIAGNOSTICS OF MACHINE TOOLS

There are different opinions on the expected economic benefits due to technical diagnostics which will increase the reliability of machine tools. Manufacturers of measurement devices show various parameters percentage cost savings, which is only difficult to navigate what is real. So what search of a economic benefits of introducing technical diagnostic methods in the control of inspection activities, machine tools:

- reduction in maintenance costs by using internal reserves,
- reduction machine shutdown due to an effective technical knowledge state,
- the lifetime period extensions and operational capability of objectification repair cycles,
- improvement in the care of the machine tool,
- the reduction of accident danger,
- savings in material resources planning objectification cost of replacement parts,
- reduction in investment in new equipment.

Figure 4 Measurement of geometrical inaccuracy of CNC machine tool

Greatest benefits may be looking for as well:

- improving the quality, speed and extension of the control examinations,
- increasing objectification and standardization of examinations in the optimal and reproducible cycles.
- simplification of service activities in connection with diagnostic results forecast.

Individual issue to assess the economic benefits of technical diagnostics is certainly solvable by commonly used methods, but you will certainly specificity of activity of technical diagnostics, which is given by that way, although it is does not create new benefits in terms of innovative use of technology, but operating at a higher applicability technique is used, leading to some purposeful methodical way.

11. CONCLUSION

The interaction of operator and supplier of machinery lies in the fact, that the knowledgeable to a contractor already emphasize, that supplied the machine has to be protected.

New machines now come to the customer with some minimal equipment, while a slight imbalance is in the protection of the machine that is acceptable to a greater extent than diagnostics, which is seen as a luxury addition. Inspection and maintenance of machine tools in good condition is a key prerequisite for maintaining the production quality. The current trend is determined to predict the state of the machine tool, and consequently to ensure the quality of production. It follows, that even on the machine tool with worse parameters is possible to ensure satisfactory production.

Planned diagnostics can reduce production costs and keep high quality production using diagnostic devices used to machine inspection, whose skills are mainly applied in engineering production. In the article we focus on reliability as an essential parameter of machine tools, where we divided it into several parts. Reliability of machine tools as one of the factors is essential for the correct operation of a manufacturing enterprise.

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