QUALITY OF CNC MACHINE TOOLS AND MONITORING OF THEIR ACCURACY

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ABSRACT
The paper deals with possibility of accuracy monitoring of CNC machine tools based on Renishaw equipment. The accuracy monitoring gives the good tool for machine maintenance and reduction of production cost. It is also possible to make diagnostics and to identify problems involved an inaccuracy of machine tools. Several aspects of diagnostics of machine tools are described, such as aspects of reliability.

Keywords: accuracy, quality, monitoring

1. INTRODUCTION TO QUALITY AND ACCURACY OF MACHINE TOOL

Quality is perhaps the oldest concept by which a product can be evaluated thus identifying or describes the level of customer satisfaction with the product. The state of a machine tool has an enormous impact on the quality of the piece, on which the machining process takes place. Therefore it is important to keep the machine tool in such conditions, that it will be able to produce parts that meet the demanded 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.

2. INFLUENCE ON INACCURACY OF MACHINE TOOL

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 kinematic 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 in homogeneity.

From the list above it can be stated, that the most important factor of machining accuracy is the machine tool and its accuracy.

3. DIAGNOSIS OF CNC MACHINE TOOL

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. It come to monitoring by decreasing machinery service costs and at the same time maintain high production quality by means of CNC machinery diagnostics.

3.1 Diagnostics according to ISO 230 – 1

<u>Geometry measurement (Schlesinger)</u>

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.

<u>Supplemental measurement (machine-table flatness, machine bed lead etc.)</u>

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.

3.2 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 and 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 control 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.

3.3 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.
Protocol is compiled from actual measurement and contains:

- Graphical representation of error behavior along measured axis length,
- Table of measured data,
- Machine`s condition evaluation,
- Recommendations on found faults.

Figure 1. Measurement using Laser interforometer

<u>Measurement of gauge adjustment including corrections</u>
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. Protocol is compiled from actual measurement and contains:

- Graphical representation of error behavior before corrections,
- Table of measured data before corrections,
- Graphical representation of error behavior after corrections,
- Table of measured data after corrections.

4. DIAGNOSTICS OF CNC MACHINE TOOLS BY RENISHAW BALLBAR QC-10

Renishaw's QC10 ballbar is a linear displacement sensor based tool that provides a simple, rapid check of a CNC machine tool's positioning performance to recognised internationals standards. QC10 ballbar system is a CNC machine tool diagnostic system. It consists of a calibrated sensor within a telescopic ball-ended bar, plus a unique mounting and centration system. It is not to be confused with the fixed length ballbars used for CMM (coordinate measuring machine) calibration. A ballbar test involves asking the machine to scribe a circular arc or circle. Small deviations in the radius of this movement are measured by a transducer in the ballbar and captured by the software. From the data supplied (via a PC interface) the systems software automatically detects and diagnoses a range of machine geometry, and motion errors.

Figure 2. Measurement of geometrical inaccuracy of CNC machine tool with QC10 Ballbar

Figure 3. Principle of measurement with Renishaw equipment QC10 Ballbar

The Ballbar accurately measures any deviations in the circle radius during the test. The shape of the ballbar plot indicates the major sources of machine error. Powerful software gives automatic analysis and diagnosis of specific machine error characteristics. Each error is ranked according to its significance to overall machine accuracy. Overall machine accuracy is graded with a value for circularity and positional tolerance.

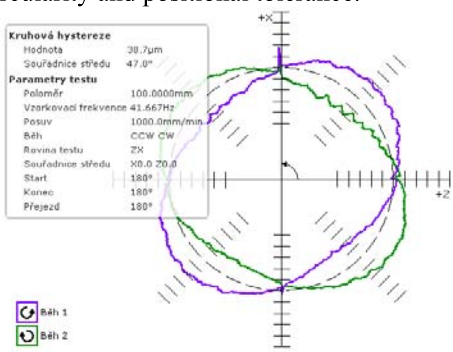

Figure 4. Output from Renishaw QC10 Ballbar software

The Renishaw QC10 Ballbar and its software are used to measure geometric errors present in a CNC machine tool and detect inaccuracies induced by its controller and servo drive systems. Errors are measured by instructing the machine tool to 'Perform a Test' which will instruct it to scribe a circular arc or circle.

Diagnostics options

- Analysis of circularity according to ISO 230-4,
- Non-circularity according to ASME B 5.57.

Furthermore, we carry out analysis of circularity deviations and quantify the proportion of possible individual causes to the total deviation. The final result of diagnostics is then given by the percentage – or possibly by the absolute value – of influence of individual errors to the total precision error. All these results can be reliably documented by printouts given at the measurement protocol which includes attachments mentioned below:

- diagnostics chart with percentage scores of individual parts,
- diagnostics chart with absolute scores of individual parts in μm.

5. CONCLUSION

Determination of inaccuracy of CNC machine tool is very complex task. There are a lot of influences in the machine tool as all components and nods have some inaccuracy.

The quality of every component produced on a CNC machine is highly dependent on the machine's performance. Many inspection procedures take place after the component is produced. This is too late. To avoid scrap it is better to check the machine before cutting any metal. Determining a machine tool's capabilities before machining, and subsequent post-process part inspection, can greatly reduce the potential for scrap, machine downtime and as a result, lower manufacturing costs.

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