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BALL BAR TEST FOR MACHINE TOOLS

BALL BAR TEST PRE OBRÁBACIE STROJE

Abstract

This paper deals with a problematic of machine tools and their precision. It is talking about Ball bar test of the machine tools. Paper deals with one measurement made in company Microstep on their machine tools. In this part are also presented results of the test and at the end is made conclusion from this result.

In second part is describing measurement system from company Renishow for ball bar test. It is Measurement system QC10. It also describes the way of testing by this measuring system.

In third part it describes different mistakes in kinematics and geometrics of machine tools. It also describe the way how the look at the graphical result of the test.

Abstrakt

Tento článok sa zaoberá problematikou obrábacích strojov a ich presnosti. Zaoberá sa Ball Bar testom obrábacích strojov. V článku je jedno meranie vykonané v spoločnosti Mikrostep na nimi vyvíjanom obrábacom stroji. V tejto časti sú prezentované výsledky testu a taktiež sú vivodené dôsledky z tohto testu.

V druhej časti je popísaný merací systém od spoločnosti Renishow pre Ball Bar test. Ide o merací systém QC 10. Tiež popisuje spôsob testovania týmto systémom.

V tretej časti popisuje rôzne chyba v kinematike a geometrii zariadenia. Tiež popisuje spôsob akým sa pozerať na grafické výsledky testu.

1 INTRODUCTION

Machine tools became inseparable part of our world. In some advanced countries is production of machine tools 10 % of total machine production. These machines allowed us, reached our high living standard. In nowadays we can not thing about living without this standard. Machine tools increase possibilities of product production and also the quality of products is increased. At the other side machine tools decrease the requests on the human work. They mainly remove monotone work in places where acquiring of new workers becoming bigger and bigger problem. These machines can replace these workers in great part. The inseparable part of this machine become in nowadays numerically controlled axis.

The quality of the numerically controlled axis has great influence on quality of final products. Qualitative parameters of final product with influence of numerically controlled axis can be divided on surface quality and precision quality. On the precision quality have great influence the precision of positioning of numerically controlled axis. From this reason is precision of positioning of linear axes of the machine tool one of the most important parameters of the machine tools.

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To reach maximal precision in positioning of numerically controlled axes is necessary to implement correction program for correcting of positioning into the main program of the machine tool. The advantage of this correction is that there are no problems with bad production quality so there is no necessary for reproduction of some parts. Not less important is better positioning of numerically controlled axis.

In machine tools are many sources of positional deviation. We can say that sources are for example geometric error, static and dynamic load, temperature, mistakes in setting of parameters of feedback regulation, interpolation etc.

Geometrical error rise out at production of machine tools parts or because of static load of machine construction. This mistakes rise especially at bigger machines. There are problems especially with production of important parts with requested precision. Interpolation errors and errors in feedback regulation became from software itself. These errors depend on program quality and also from performance of processor of the machine. The thermal errors rise because of heat up of machine construction from machine engines, work instrument or from environment. Any non compensated dynamic error can be reason for vibration in machine and because of vibration also bad quality of produced parts.

One of the important tests of the machine tools is circular test describe in standard ISO 230-4. This test can find out problems at precision of the machine, kinematics error and also geometrical errors of the machine. For the test is possible use the measuring instrument from company Renishaw. The measuring machine can make a very quick test of the machine tool and also evaluate test.

2 MEASUREMENT SYSTEM QC 10

For testing is possible to use measuring system QC10 from company Renishaw.

Tab. 1 Parameters of QC10

Resolution	0.1 μm
Ballbar sensor accuracy	± 0.5 μm at 20 °C
Maximum sample rate	250 values per second
Extension Bar	50 – 150 – 300 mm
Operating range	0 – 40 °C
Calibrator accuracies	±1 μm at 100 mm bar

Measuring system is based on sensor for measuring of linear deviation. It is compossed from calibration sensor at the bar ended by ball. The ball is attaching to the central attach system.

Fig. 1 Example of bar

3 TESTING

Measuring system QC10 with included software serve for measuring of geometrical errors originate to CNC machine tools and also for detecting of uncertainties in engines and control systems of machine tools.

Measuring is performed by sending a command to the machine tool. That means command for going along the full arc or part of arc. The small deviations are measured and stored in software. These deviations are than represent in graphical form.

If the machine is perfect the result is also perfect cycle. Any deviation causes distortion in circle.

Test takes different times depended on feed rate of machine tool and also on dimensions of selected circle. Typically is from 10 to 15 minutes.

Before performing the test is necessary to input to the machine desired track and also test it. It is because of an unexpected error in track that can cause destruction of measuring system. First task is to centre the machine work instrument to the center point. Than work instrument is shifted to the radius of circle and measuring sensor is placed to the position. Now is machine prepared for the measuring. At the measuring cycle machine will made two circles one in sense of watch and one against sense of watch. Software than evaluate date from measuring and give results in graphical an also text form.

4 TEST CONDITION

Way of working of every machine tool and also of any other kind of machine is influenced by environment around the machine. Because of this is necessary to meet the conditions defined by standard or conditions agreed between supplier and customer. The environment of machine has many parameters and many of these parameters have influence on the machine. It is for example temperature of environment, air pressure, humidity and so long.

Temperature has one of the most important influences on the machine. Every material has problems with thermal expansivity. It result in different deformations of machine parts or rising of uncertainties in kinematical constrains of machine. These influences are so critical, that many works is dedicated to compensation of thermal influences of environment. Second chapter and not less important are thermal influences caused by the machine itself. These can not be included in influence of environment. In this case is it influence of working process of machine and it is up to producer to minimize these errors.

Standard require several thermal condition to be met. First condition is temperature level of environment 20 °C, if it is possible to control environment temperature in the room where machine is. If this is not possible, it is necessary to write to the results of measurement values corrected to the temperature level of 20 °C. Next condition is placing the machine inside the environment soon enough before the test. That means, that machine have time to reach the temperature level of the environment.

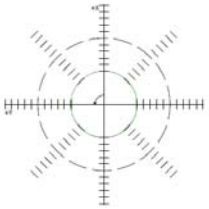
It is also very important to prevent machine from the thermal radiance (for example direct sun shine) and draught of air (moving of air along the part of machine). This can cause local over heat of machine or local temperature drop. This have consequence in deformation of some parts of machine or error in kinetic constrains of machine. This error will not be found out and there for it will not be write in measurement report and also not used at correction of results. So the result will be incorrect. More ever also small error at high precision machine can be difference between meeting or not meeting the customer request on the machine tool.

5 MACHINE TOOLS TEST

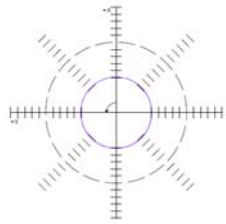
Measurement was done on the laser cutting machine of company Microstep – MicroLas, which feed rate, is up to 40 m per minute. Sensor was attached to the place of laser head. For the experiment was selected diameter of circle 100 mm and feed rate was set to 1000 mm per minute. Measurement was done in two sense of rotation. Future parameters of test are in the tables. Measuring results are evaluated according to the standard ISO 230-4 Test code for machine tools – Part 4: Circular tests for numerically controlled machine tools.

The results are divided into 3 parts:

1. Circular deviation – moving against sense of watch rotation is 50 µm/div. Circular deviation - moving in sense of watch rotation is 20 µm/div

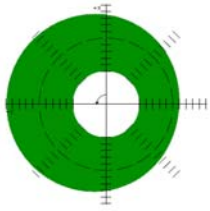


Circular Deviation (CCW)	
Value	178.9µm
Test Parameters	
Radius	100.0000mm
Sample rate	41.667Hz
Feedrate	1000.0mm/min
Run direction	CCW
Plane under test	XY
Test position	
Start angle	90°
End angle	90°
Overshoot angle	180°

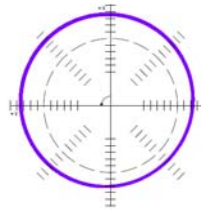


Circular Deviation (CCW)	
Value	167.3µm
Test Parameters	
Radius	100.0000mm
Sample rate	41.667Hz
Feedrate	1000.0mm/min
Run direction	CCW
Plane under test	XY
Test position	
Start angle	90°
End angle	90°
Overshoot angle	180°

2. Radial deviation – moving against sense of watch rotation is 50 µm/div. Radial deviation - moving in sense of watch rotation is 33 µm/div

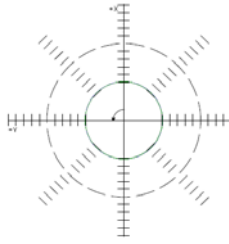


Radial Deviation (CCW)		
Maximum deviation	50.2µm	15.0°
Minimum deviation	128.7µm	89.0°
Test Parameters		
Radius	100.0000mm	
Sample rate	41.667Hz	
Feedrate	1000.0mm/min	
Run direction	CCW	
Plane under test	XY	
Test position		
Start angle	90°	
End angle	90°	
Overshoot angle	180°	



Radial Deviation (CCW)		
Maximum deviation	33.5µm	167.0°
Minimum deviation	133.8µm	94.0°
Test Parameters		
Radius	100.0000mm	
Sample rate	41.667Hz	
Feedrate	1000.0mm/min	
Run direction	CCW	
Plane under test	XY	
Test position		
Start angle	90°	
End angle	90°	
Overshoot angle	180°	

3. Circular hysteresis



Circular Hysteresis	
Value	72.6µm
Location	193.0°
Test Parameters	
Radius	100.0000mm
Sample rate	41.667Hz
Feedrate	1000.0mm/min
Run direction	CCW
Plane under test	XY
Test position	
Start angle	90°
End angle	90°
Overshoot angle	180°

According to the technological process of cutting by laser the result precision is good enough. That means errors of cutting process are bigger, then uncertainty of positioning.

6 ERROR DISPLAYED BY THE TEST

By the circular test is possible to reveal many kinds of different mistakes of the machine. Some of them is possible to compensate immediately and other have to be added to the compensation program and used at the correction. To the most common errors belongs:

1. Axes reversal spikes

When the axes is shifting in one direction and after that have to shift in opposite direction, it is possible that instead of smooth change of direction there will be pause in moving. This has consequence in short spikes that appear on either axes reversal point.

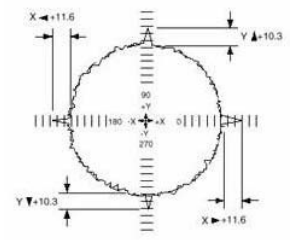


Fig. 2 Axes reversal spikes

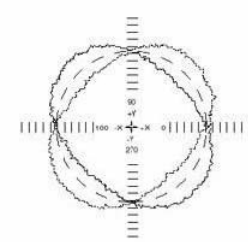


Fig. 3 Scale mismatch

2. Scale mismatch

It is shown as an oval plot. This plot is extended along one axis. One axis is faster or slower as second one.

3. Backslash

If backslash is positive it is possible some error in guide way. If backslash is negative it is possible, that parameters of machine are overcompensated.

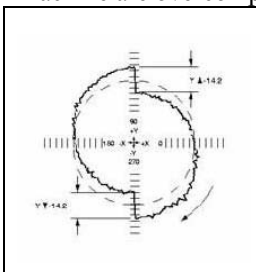


Fig. 4 Backslash

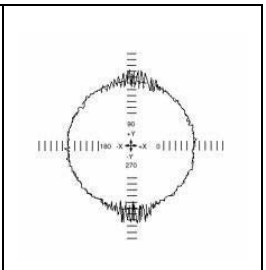


Fig. 5 Stick-slip

4. Stick-slip

It rises because of friction at low speed. Friction causes stick one of axis. This error can be reasons of problems at surface finishing.

5. Squareness error

It rises if normally orthogonal axes have not longer 90 ° angel between them.

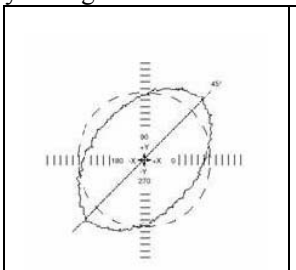


Fig. 6 Squareness Error

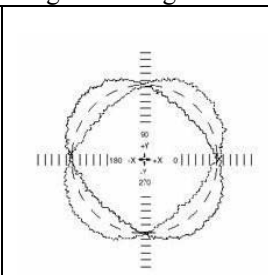


Fig. 7 Servo mismatch

6. Servo mismatch

Error displays as oval plot tilted 45 ° from the axes. In this way bad intensifying of servo is shown. This have as result impossibility of circular interpolation.

7. Cyclical error

It is shown as a plot with waviness that varies in amplitude. It reaches maximum amplitude at axis reversal points.

8. Master/slave change over error

It is often error of CNC machines, which can interpolate only one axis at the same time. While speed of one axis is changing the second only stay in it's moving along the arc. This can make precise positioning impossible.

9. Lateral play

It is caused by looseness in the guide ways.

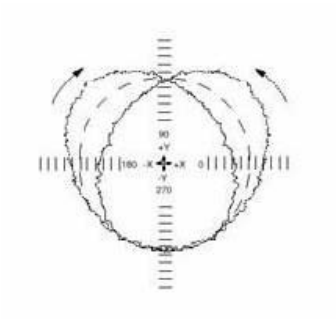


Fig. 8 Lateral play

These are some of errors, which is possible to find out by circular test. As shown it is very useful way of finding many kinds of errors and imperfections in the construction of the machine tools.

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