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ACCURACY OF MACHINE TOOLS IDEPENIDING ON THE POSITIONING MEASUREMENT SYSTEM AND THERMAL STATE

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Abstract: Temperature behaviour of machine tools is one of the main reasons for process dispersion of the modem accurate production. This paper presents a comparison of the effect of thermal expansion and positioning measuring System on the production accuracy of machine tools. In the project the positioning accuracy of pulse encoders and linear positioning measurement systems (two types) in different thermal conditions was compared and analysed. Both measuring systems were used interchangeably on each machine tool at the same time.

The test environment includes a modern sheet metal turret punch press and two horizontal machine centres, one in laboratory and one in industrial environment. The initial state of the machinery was examined in a throughout inspection using both conventional measuring equipment and a modern quick test method (doubie ball bar). All workpiece and test piece measurements were performed using a co-ordinate measuring machine in an accredited calibration laboratory.

Keywords: Thermal Expansion, Machine Tool Accuracy, Positioning Accuracy

1 THE THERMAL SEHAVIOUR OF A MACHINE TOOL

A machine tool is usually operating in a thermally non-steady state due to the heat Generation from the process itself, rotating parts, power of the drives, friction of linear motions etc. Any change in the temperatures of machine tool causes deformations like bending between different parts of the structure. All these distributions affect the accuracy of the production machinery. The thermal effects are usually divided into two groups, external and internal sources, according to the nature of the origin of the heat.

In indirect position measurement system, using lead screws and rotary encodem, the positioning error is directly to be compared with the coefficient of thermal expansion of the lead screw. When the temperature rises, the positioning error grows as a function of the temperature. The temperature dispersion does not affect only the positioning error but also the backlashes of the axes. Often the servomotor and ballscrew drives are connected with a toothed-belt transmission. This kind of structure makes the movements even more inaccurate. A position control loop includes only the servomotor and there is no actual position control of the slide.

When using a direct positioning measurement system with linear encoder the effect of coefficient of thermal expansion is theoretically smaller. The heat impact is less significant because there is no direct contact between the scale and the reading head. Therefore there is no friction either, which is normally a very remarkable heat source. The temperature of the scale itself is stable and has no offect to the backlash of the axis. A position control loop with a linear encoder includes the entire mechanical feed-drive system.

When the benefits and the problems with these two positioning systems are separately quite weil known, it seems necessary to make more research work to study how these systems will behave in similar environments. The proper way to do this is to use machine tools, which are equipped with both measurement systems. E3ecause the positioning error resulting from thermal expansion can be seen as one of the greatest problems in positioning measurements, it is obvious to make comparison as a function of temperature dispersion.

2 THF CONCEPT OF THE RESFARCH

The mentioned problems were researched in a joint project THPRMEX (The effect of THERMal EXpansion and positioning measuring system on the accuracy of machine tools) 1998 ... 99. The project had two main goals [1]:

1. to research and compare the positioning accuracy of pulse encoders and linear positioning measurement systems in different temperature conditions.
2. to achieve better production accuracy and use research results to construct new machine taols.

To reach the first goal three individual test environments was constructed. Linear position measurement encoders were added beside the normal pulse encoders for three machine tools with linear movements from 540 to 2500 mm. Two machine tools are located in a laboratory environment and represent modern technology with PC-based controllers. One machine tool is a pure industrial case. The benefits and experiences of this project will be used to construct new machine tools. For this reason the participants of THERMEX project include two remarkable Finnish machine tool manufacturers.

The most critical part of the project is accurate measuring of the temperature. It is not enough to record all possible changes and variations of the machine tool temperatures in different locations. In this case it is most important to know the absolutely correct temperatures and besides that the differences from normal temperature (20° C). For this reason the accuracy of the temperature measurement equipment should be high enough to get reliable results for positioning errors. Each machine tool will be equipped with 10 Pt-100 temperature sensors and datalogger which is able to capture and save all temperature information during and between the tests. All information of the measurements was analysed with PC-based software.

At the beginning of the project the initial state of the machinery was examined in a thorough inspection using conventional measuring equipment (i.e. laser interferometers and mechanical instruments). Control parameter changes were performed to adjust the machine tools as accurately as possible. These inspections were carried out several times during the project. The machining test procedure itself includes machining of a special test piece and normal workpiece measurements. The parts were manufactured with both linear encoder and rotary encoder positioning measurement system. All test piece and workpiece measurements were performed in a co-ordinate measuring machine. The measurement data was analysed against the information from the temperature sensors. [2, 3]

3 RESULTS

As a result from the project the following conclusions could be drawn:

1. In machining centres using an indirect measurement set up the effect of temperature is quite accurately a function of the thermal expansion coefficient.
2. Distortion of the machine tool geometry as the temperature n'ses, causes positioning errors in both systems
3. The backlash error is somewhat smaller in linear measurement systems
4. The overall accuracy of linear measurement systems is better in normal operating temperatures
5. The dispersion of the positioning data is smaller in linear measurement systems
6. The environmental temperature has a remarkable impact on the accuracy of the machine tools
7. The field test results confirm most of the findings in laboratory research

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