XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22–27, 2003, Dubrovnik, Croatia

AUTONOMOUS ADJUSTING OF MACHINE TOOLS IN FMS, IMPLEMENTATION AND RESULTS

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Abstract – The aim of the project (AutoComp II) was to examine the possibilities to build an autonomous measuring and compensation system for a flexible manufacturing system, FMS. This goal has been introduced in detail at the Imeko 2000 conference in the paper "Autonomous adjusting of machine tools in FMS". The focus of this paper is on the implementation and the results of the project.

Keywords: machine tool inspection, compensation

1. INTRODUCTION

The goal of the project was to develop an automated machine tool inspection and compensation system for machining centres in flexible manufacturing systems. One of the main requirements was that the system was able to follow-up and maintain the quality capability of FMS. The monitoring was carried out with measurements of machining centres and the maintaining was done by calculating new compensation parameters for the controllers and scheduling the proactive maintenance of the machine tools. In the experimental tests all the machine tools were standard 4-axis milling machines. The measuring and compensation system was implemented and examined in two separate FMS's.

The basic idea was to install the measuring equipment to an ordinary machining pallet, which is placed in the pallet storage of a FMS. The measuring pallet could then be activated to any of the machining centres of the FMS like an ordinary pallet according to a preplanned schedule and other actions wouldn't be needed. This practice will rationalize the inspection of the machine tool as a normal function of it.

2. DESIGN AND MEASUREMENTS

The design of the device was made in collaboration with Technical University of Graz, Institute of Production Engineering and Tampere University of Technology. The geometric quantities to be measured were sorted out with the representatives of the industrial partners based on the encountered problems. The test methods were selected based on the earlier research work [1], [2] and [3]. The measured quantities with corresponding methods are listed in table 1.

TABLE 1. Measured quantities and methods.

QUANTITY	METHOD
Circularity	*Double Ball Bar*
Servo response	
Scale mismatch	
Squareness error	
Straightness	
Linear positioning accuracy	*Linear encoders*
Backlash	
Spindle Run-out with load	
Rotation Error of turntable	

The circular tests were performed on three planes of a machine tool. To be accessible the double ball bar (DBB) had to be mounted to a fixed column, which was attached on the pallet (Figure 1.).

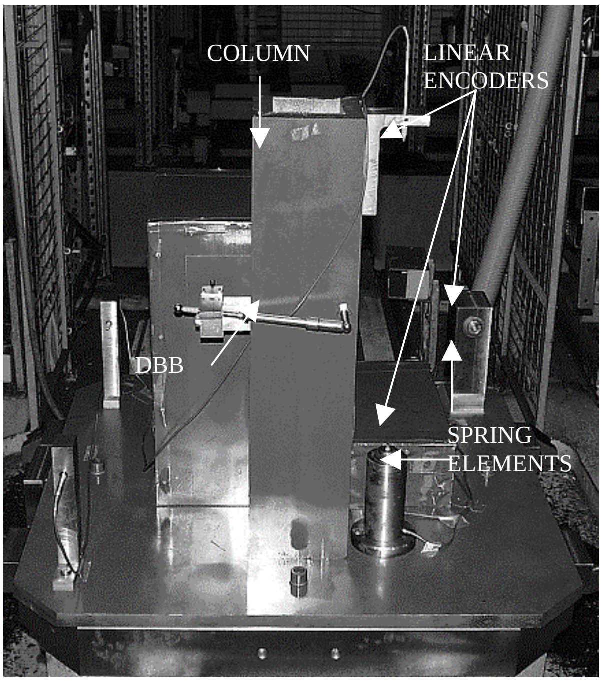

Fig. 1. Measuring pallet.

In order to keep the fixture of the DBB as simple as possible for automatic usage, the xz- and yz-planes were measured with half circle. A specific mandrel with magnetic fixture was used on a spindle to pick up the DBB. The other end of the DBB was fixed to a steel ball shown in figure 1.

The linear encoders were used to measure the positioning accuracies of the x- and y-axis. The encoders had 10 mm stroke and they were placed as shown in figures 1 and 2.

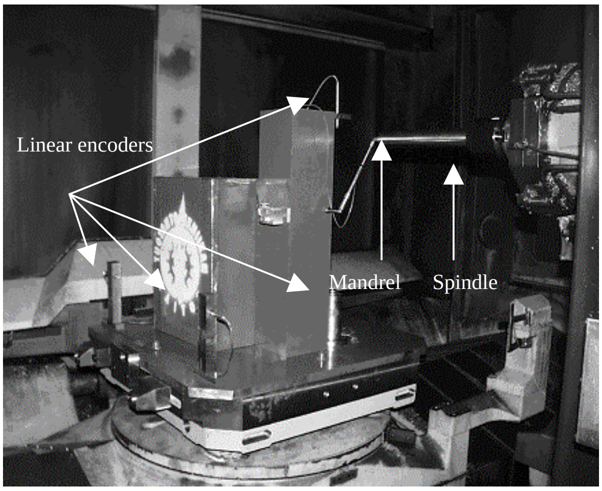

Fig. 2. Machine tool inspection.

The gap between the two encoders was 350…450 mm which had to be taken into consideration on analysis and the calculation of the compensation tables. The position accuracy and reversal value of the measured axis were calculated according to ISO 230-2 standard [4]. The compensation generated is justified when the measured deviation occurred linearly, which was the case when the source of the deviations was repetitive. Thereby the compensation table could be calculated to cover the measured axis entirely when the standard deviation of the measurement was within the reasonable level.

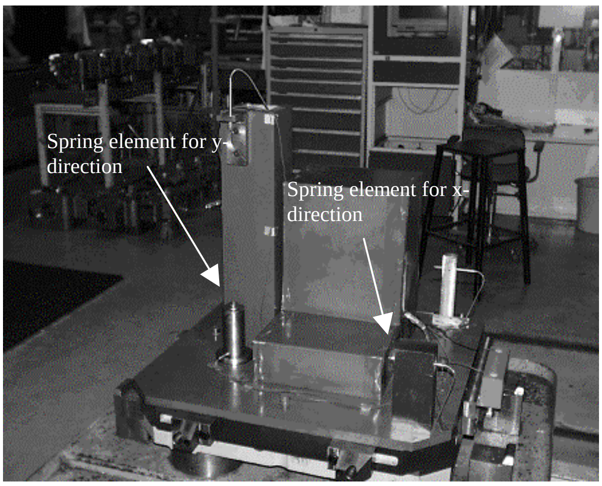

Fig. 3. The placement of the spring elements.

The run-out of the spindle was measured in x- and y-directions according to ISO 230-2. To simulate the forces occurring at the machining operation, the deflection of the loaded spindle was measured. The load of 1,5 kN was arranged with two spring elements shown in figure 3. The change of deflection was gained by comparing the result to earlier measurements and the trend line was generated. Rotation error of the B-axis was calculated from data received from diagonally mounted linear encoders (figures 2 and 3).

All data from the encoders was captured with a laptop placed on the measuring pallet. This data was saved on a text file, which was sent to the monitoring computer via wireless local area network (wlan). The startup of the laptop was arranged by separate radio signal.

The implemented software consisted of two main programs. The *Analyzer* was used as a user interface on monitoring computer, and The *DataCollector* was used to collect the data from the encoders. Different tasks of the programs are listed above on table 2.

TABLE 2. Different functions of used programs.

DataCollector	Analyzer
Error check	*Start up the measurement*
Data collection from encoders	*Allow measurement to begin after passed check*
File generation from data	*Analysis from the measurement file*
Send file to Analyzer	*Email alerts and notifications to selected addresses*
Shut down the DataCollector	*Allow DataCollector to shutdown*
	Calculate and send compensation files to NC

The main window of the *Analyzer* is shown in figure 4 where can be seen system log, status of the program and *Next events on system* –window where the timed measurements are shown. The measurement can be started manually by clicking *Run* –button and selecting the machine tool to be measured or automatically by adding the machine tools to *Automatic measurements* –list. The automatic usage of the system is implemented as follows: the start time of a measurement can be defined according to earlier measurement (days between two measurements). By this arrangement the system can be used whenever it is necessary (e.g. after compensation or collision) and the next measurement would take place after an adjusted time. A time of day can also be given so that the measurement could take place on the slack period of production.

The production cycle can be taken into consideration by giving a low priority code for the measurement pallet so that all the production pallets can be machined before the measurement. This could cause a huge waiting time before the measurement actually begins and therefore the system check will be run on the pallet for a given period of time before shut down.

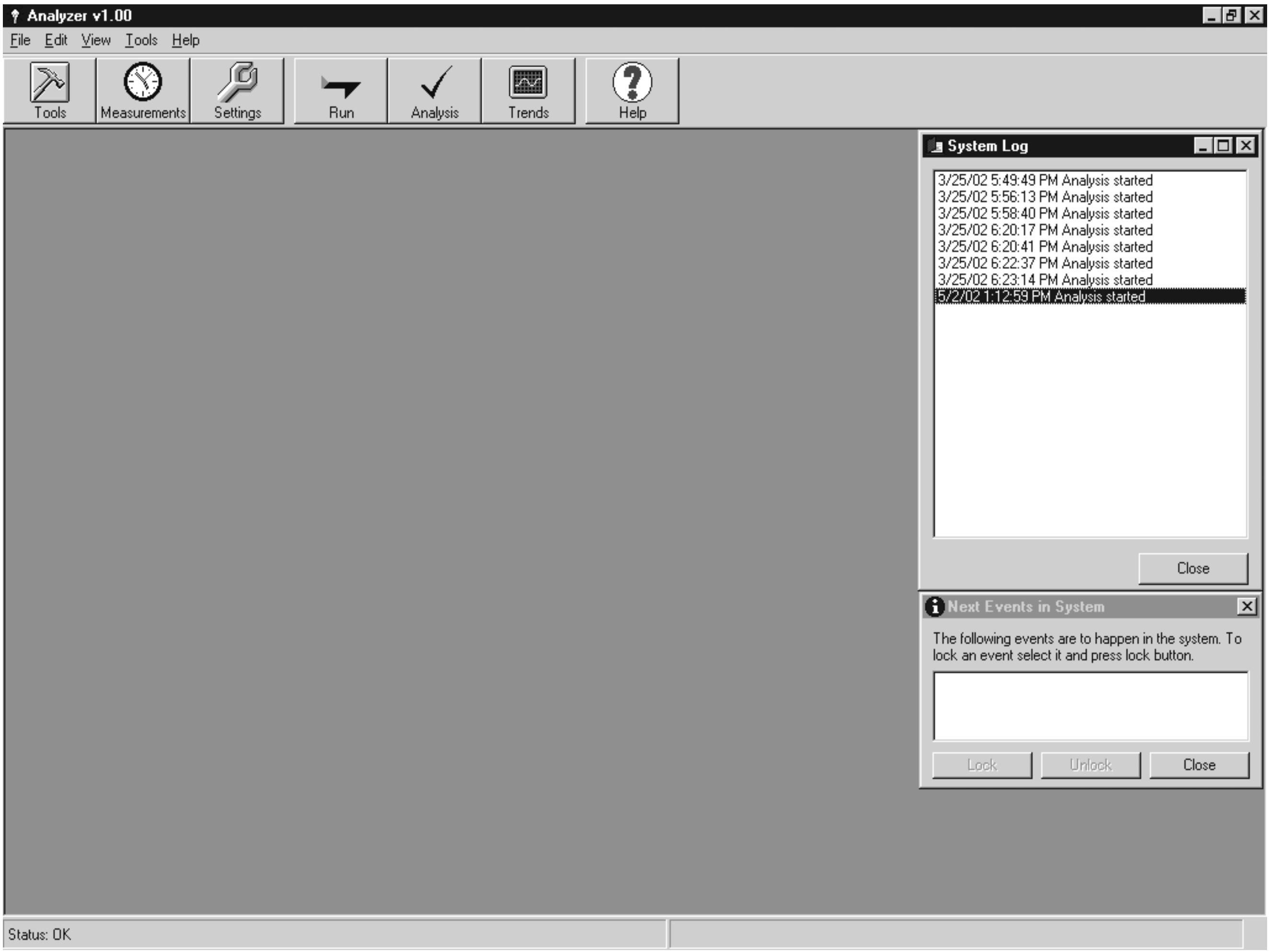

Fig. 4. The main window of *Analyzer*.

The results are given in html –format and shared across a local are network. Therefore the results can be overlooked with standard browser and other software installations are not needed.

Four kinds of emails can be sent to selected addresses. These are Measurement alarm, Measurement notification, Palette error message and Program error message. A purpose of each emails are described in table 3.

TABLE 3. Email notifications.

Measurement alarm	*Given boundaries are exceeded*
Measurement notification	*The measurement is analyzed*
Palette error message	*Faulty action of the pallet (different reasons)*
Program error message	*Faulty action of the program (different reasons)*

Tolerances or positioning accuracies, reversal and circularity values can be set. If the given tolerance is exceeded, the software proposes compensation. This was implemented to ask user intervention in prototype phase while the operation of the pallet was tested and confirmed.

3. RESULTS

The research project went on for two years. Achieved results were compared with the reference values gained by normal machine tool measurement practices like laser interferometer and DBB. About one hundred measurements from different machine tools were included to the final analysis.

The measuring pallet results with linear positioning accuracy measurements were promising. The values of were between 4...12 µm while the reference values were 5…10 µm. The respective reversal values were 0,5...2 µm measured with the pallet, and the reference values were 0,1...1 µm. Correspondingly repeatability was 5...7 µm with the pallet compared to 3...5 µm with laser interferometer.

The results from the pallet were achieved during long period of time and the comparison was made to instantaneous values. The thermal conditions were varying along the annual rhythm and the measured air temperatures were between 18…28 °C. This can be seen as a main reason for the variance of the results.

The best results from the circular tests were achieved from xy-plane where a full circle cold be used in the measurement. An example of the result is shown in figure 5. Other two planes were measured with half circles where the movement of the machine tool was restless compared to full circle. After decrement of the feed rate and increase in the trajectory's length, the results from xz- and yz-planes were much better and fully comparable with the results gained with a commercial DBB.

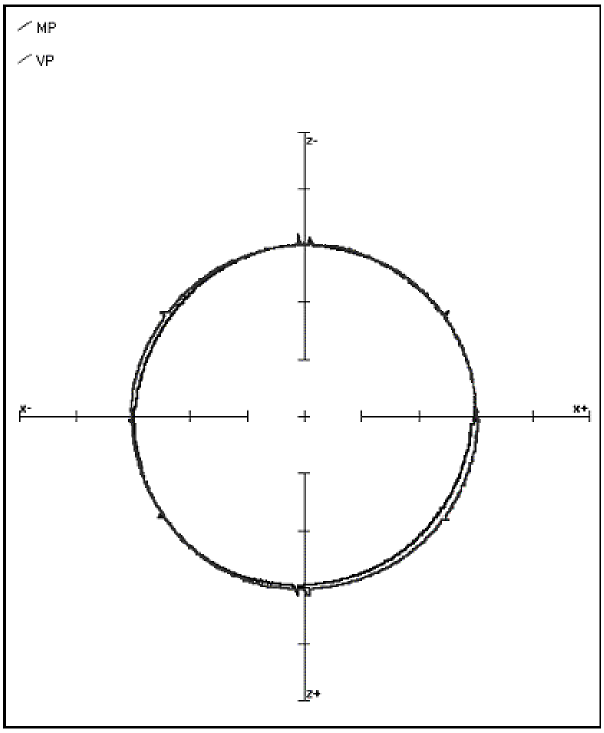

Fig. 5. A graph from circular test with 50 µm scale.

4. CONCLUSIONS

Some problems with the touching measurement were encountered during the automatic procedure. The prevailing circumstances in workshops lay claim on regular maintenance to keep the system reliability in needed level. Different kinds of covers for encoders have to be used to prevent fouling of the equipment. All contact areas and fixtures have to be cleaned periodically to ensure the appropriate functioning of the pallet and reliability of the results. The calibration of the measuring pallet was done with laserinterferometer equipment, but easier way to do this must be found.

The effect of metal chips in the magnetic fixture of the DBB can be seen in figure 6. After this measurement the magnets were cleaned and the measuring mandrel was covered with plastic cote, which was used while the mandrel was in tool store.

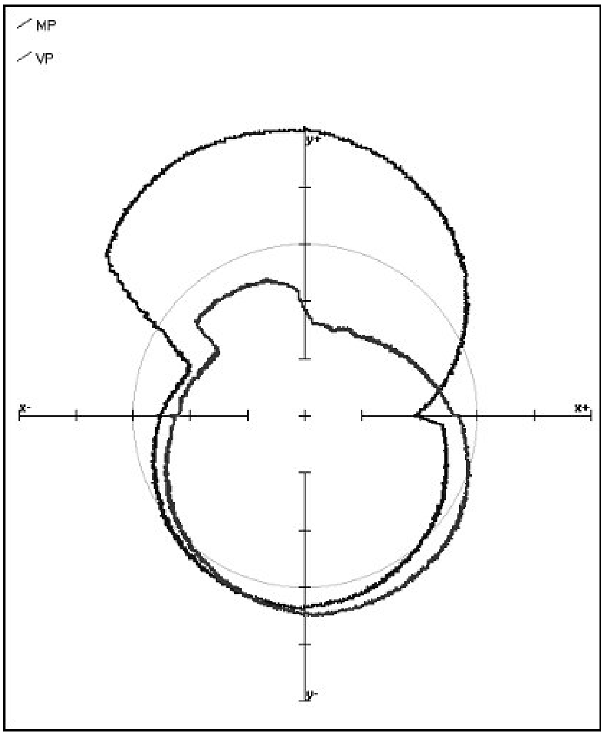

Fig. 6. Dirty magnet ruined the measurement.

Because of the age of the numerical controllers, some reductions to automation had to be made. The transfer of the compensation parameters needs user actions, as the controller has to be turned to read/write mode and reboot after changes. An open architecture PC-based controller could be turned into read or write mode on the fly, but the actual NC controllers in the industry are somewhat more traditional.

The usage of the laptop on the pallet was too complicated because of the additional batteries, charging, and starting up the computer. All the needed accessories had to be covered, thus the need of space was increasing. The laptop and the operating system need extra care. To get rid of this, a radio modem was tested. The idea was to put the radio modem to the pallet to RS 232 interface of the encoders, and the data was sent to computer within the range of the modem. The measuring software (*DataCollector*) could have been run in monitoring computer and only a little battery would have been necessary on a pallet.

The method itself has shown a great potential to be used as an inspection method and a part of the quality assurance. Next goal on this research area is to develop a non-contacting method to cover the workspace entirely. This kind of measuring method could be used widely on machine tool inspection in FMS environment.

5. REFERENCES

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