XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

AUTONOMOUS ADJUSTING OF MACHINE TOOLS IN FMS

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Abstract: Ensuring a high quality and totally defect free production is a crucial issue in flexible manufacturing systems (FMS) because interruptions are expensive in those systems. AutoComp project examines possibilities to build an autonomous measuring and compensation system for a FMS. The system involves, besides a device itself, also analysis of measurement, calculation of compensation tables and activation of new parameters in a numerical controller (NC).
Keywords: machine tool measurement, compensation, numerical controller, FMS

1 INTRODUCTION

Automated machine tool measuring and compensation system can autonomously follow-up quality capability of a FMS and also to adjust compensation parameters of numerical controllers (NC). The primary environment where such system is intended to be used is a pallet based stacker crane FMS having horizontal 4-axis milling machines. The same measuring device can be used in all machine tools installed into the system. It is possible to organise so that the measuring run will take place at non-profit time when machine tools would otherwise idle.

The system consists of the measuring system itself, software for analysis & statistics and software for compensation. The development work is still going on at all these three areas.

2 MEASUREMENT

It is possible to achieve great savings with an automatic measuring device in time and money compared to traditional methods e.g. laser interferometer and electronic level. The most important benefit is that measurement and compensation of a machine tool can be made at non-profit time. In addition, user interventions are no longer needed and thus uncertainty of the measurement raising because of a human factor is reduced.

2.1 Requirements

Automatic measurement sets various demanding requirements to the used measuring method. Most crucial of these are:

- set up of the measurement, static and dynamic tests with the same set-up
- unambiguity of measurement results
- robust design
- reliability of results and operation
- possibility to mount measuring device firmly into a palette

All needed adjustments of the measuring device and auxiliary equipment should be able to make with long interval which supports autonomous construct.

2.2 Available equipment and alternative designs

From the available equipment those, whose set-ups are easy enough to be automated can be taken into consideration. This kind of equipment are e.g. double ball bar (DBB) [Kakino et al. 1993] and laser ball bar (LBB) [Tikka, 1992]. With these devices more geometric and parametric errors can be measured than it is possible to compensate numerically in a machine tool.

Alternative designs can be made based on these methods. Greatest potential can be seen on combination of laser ball bar and rotary encoder. This kind of device offers high accuracy to circular tests and linear positioning measurements and it agrees with stated demands.

Auxiliary equipment are needed e.g. to collect and transfer measured data to a FMS controller and further to a numerical controller. This can be carried out using battery-driven PC on a palette and wireless radio modems. The basic concept is depicted in Figure 1.

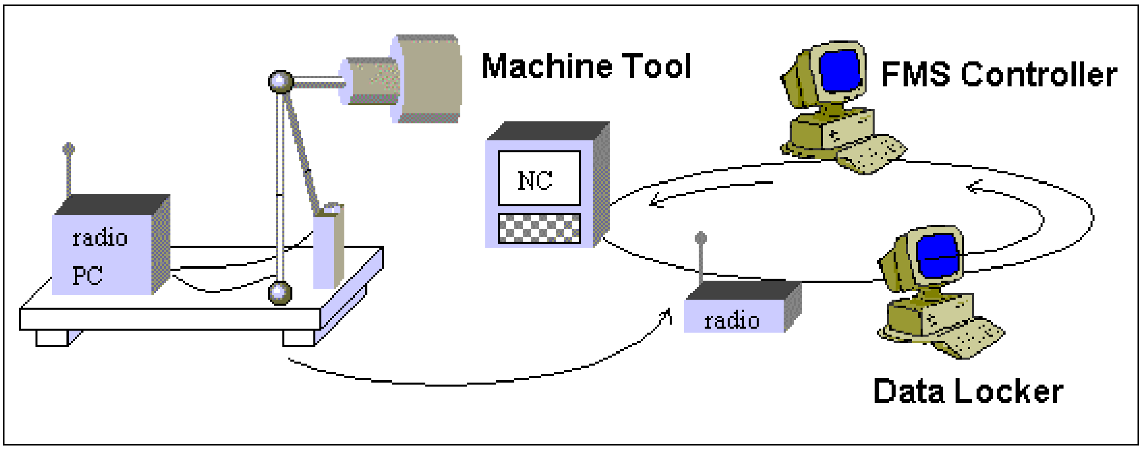

Figure 1. Basic concept of the system.

2.3 Empirical results

Empirical studies from Unitest equipment (Figure 2) [Meitz, 1999] has shown that the aim to measure all six degrees of freedom (6 DOF) with one set-up as a fully automated device is hard to achieve. The accuracy requirements for automated follow-up of 3 and 4 axis milling machines are high. When we are seeking for a complete 6 DOF measurement, there are required a number of joints in the device. This complicates the optimisation of stiffness and sensitivity. Empirical results have shown that positioning accuracy, mean reversal value, circularity and backlash of machine tools can be measured reliably with this device. But currently accuracy of squareness error, servo mismatch and linear scale error measurements are not suitable for automated measurement and compensation as such.

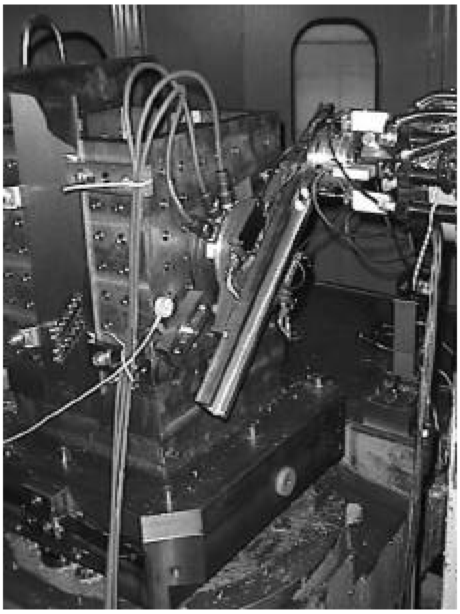

Figure 2. Unitest measurement

3 COMPENSATION

The compensation means here numerical correction of geometrical errors. We are not working with tool length or radius corrections nor with thermal compensations. Common numerical controllers (NC) support at least linear error compensation. Most of these NC's also support automatic or semi-automatic transfer of compensation tables. This paper studies three common NC's, Siemens 840D, Heidenhain TNC 426/430 and Fanuc 16. An automatic compensation program has been built at TUT and tested for Siemens 840D. So far only positioning errors have been practically used but the program also supports straightness error compensation.

3.1 Requirements

Automatic compensation requires a computer for user interface, a way to transfer data from the measuring-machine used to test the machine-tool and a program to translate the results to be used for creating the compensation tables which can then be transferred to the NC. Fully automatic system also requires means to activate the new compensation tables automatically. Here is one of the main problems because usually NC's need some sort of start-up, which either cannot be automatized or the start-up disturbs badly automatic operation of FMS.

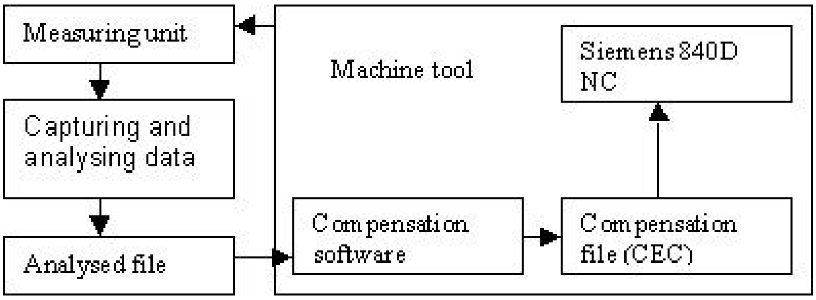

Figure 3. Data flow example of Compensation system

Figure 3 shows the principal way the data is transferred from the measuring machine to the numerical controller. The results of measurement are first analysed and stored as an analysis file, which is saved for the compensation software. The software then translates them to the correct format (here i.e. CEC-table) that the NC can understand. For a system to fully operate under FMS computer, also the measuring device should be equipped with wireless communication link.

3.2 Available compensation means

For the three NC's studied it is possible to compensate errors presented in table 1. Some additional means not mentioned here are also available. All the three have their own style of compensation table. Newer versions of Fanuc (160i etc.) have also compensations additional to linear axis errors. The following table shows possible compensations for the NC's studied. Some of these compensations are offered as an option by the manufacturer.

Table 1. Available compensations

	Siemens 840D	Heidenhain TNC	Fanuc 16
Linear positioning error	Yes	Yes	Yes
Positioning error (stepwise)	Yes	Yes	Yes
Constant backlash	Yes	Yes	Yes
Variable backlash	Yes	No	No
Straightness error	Yes	Yes	No
Linear temperature error	Yes	Yes	No

The compensation software developed in this research calculates compensation step according to old compensation tables. This is because the maximum number of points cannot be changed automatically. This value must determined at the configuration phase of the system. If the compensation software is activated for a new machine, there should be space reserved for all possible compensations. One axis requires at least six tables, 2 for positioning error and 2 for both other two straightness errors.

3.3 Possibilities and restrictions

Errors like pitch, yaw and roll cannot be easily compensated, because the machine tools in the scope of this research have only 3 or 4 axes. Therefore the measuring equipment needs to be capable only to measure positioning error and straightness. The development of such device is under study at our institute.

Saving the old compensation values gives us valuable information we can use to analyse the machines condition in a longer period. That way we can forecast the need for larger machine maintenance.

3.4 Compensation software

The compensation software includes program for generating compensation tables. The main screen of compensation program is in Figure 4.

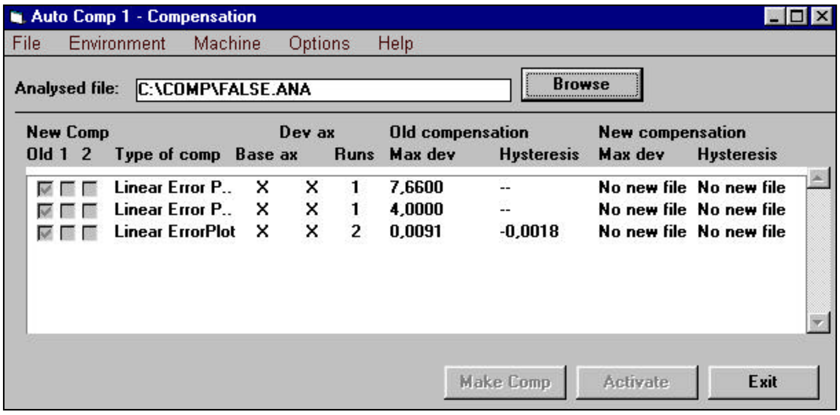

Figure 4. Compensation software

The compensation software can currently do the following. Software shows current compensation statistics on screen: Current compensation types for selected machine tool, backlash and maximum deviation values of each type are shown.

1. Software allows user to load analysed measurement file from which it
   - finds measured compensation types.
   - shows new compensation types on the screen on the same line as current active compensation of this type. If this deviation type is new for the selected machine tool, it is shown on a new line below current active compensations
   - allows user to select compensation types for which to make new tables. It’s possible to select one or two tables for compensation types which have been measured in both directions. It’s also possible to save current compensation table.
   - generates new compensation tables for selected compensations.
   - activates them at NC.
2. Software knows current compensation and compensation history of all installed machine tools.
3. Software allows user to add new machine tools and different compensation style components.

4 CONCLUSIONS

Autonomous adjusting of machine tools in FMS offers a great potential. Research work has been done at the Institute of Production Engineering to develop tools that support such system. The system utilises standard compensation tables that are already available at modern numerical controllers. However, there is still a lot of development work to do with the measuring itself. This is the main subject of the continuing research project.

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