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QUALITY AND THE THERMAL BEHAVIOUR OF MODERN MACHINE TOOLS

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ABSTRACT
More than 50% of the modern machine tools errors are due to the thermal phenomena. The optimization of their thermal behaviour is an important part of a unitary metrology concept. The author has studied the thermal behaviour more than 25 years; he had his doctorate in this field and has carried out for the first time in Romania, the thermographical study of machine tools.
The paper presents some of the author's results carried out in Romania and at the University of Stuttgart, inclusively the project "Analysis of thermal behaviour of new types of machine tools" granted from the NATO.

1. PROBLEM STATEMENTS AND APPLICATION AREA

Some authors [1] consider the thermal errors the most important factor upon the precision of machining and measuring. In fact the errors with static, dynamic or wear, causes, have been in greater proportion obviated. Professor Bryan [2], in his Keynote Paper " International Status of Thermal Error Research " says:" Thermal effects are still the largest single source of dimensional errors and apparent non-repeatability of equipment". Today is also very important to connect the thermal errors with the quality management. The thermal stability of machine tools both in the phase of machining as in that of testing and reception, most also be connected with quality assurance and a correct concept of CAQ (Computer Aided Quality).

2. RESEARCH COURSE ANDN THE METHOD USED

The author has studied more than 20 years the optimisation of thermal behaviour of machine tools. That is an interdisciplinary study from identification of the whole concatenation of causes (size, number, extend and position of the thermal sources) up to the final effects, and the machining errors. Also, the author has carried, for the first time in Romania, the thermographical study of machine tools, and has determined on this way the isothermal field and the thermal map for machine tools [3]. The thermographic method has become today a very large extension (e.g. the determination of the thermo-elastic deformation).

The author's studies were carried in two stages: the first was performed at the Technical University of Cluj-Napoca, Romania in collaboration with a grinding machine factory, and

the second was performed with the partners from the Institute for Machine Tools, University of Stuttgart-Germany. The studies and the tests carried out in Romania were focussed on the of the design and technology of Romanian grinding machines with the scope to achieve a better quality management in the Romanian machine tools factories. The improvements carried out from the author contributed to a better quality and precision of Romanian machine tools and also to a better technological organization inside the factory. There was some first steps (in the years '70-'80) of the quality management in Romania, according to the national and international standards. Lather the studies where continued with more sophisticated instruments and tests at the University of Stuttgart, making also use of a thermostatical large-sized cabin. Other studies where carried out with the partners from Vienna University of Technology or from University of Graz, developing at a higher level the links between industrial metrology, reception of machine tools, quality management and international standards on the one side and thermal behaviour and thermal stability of machine tools and industrial robots, on the other one.

3. RESEARCH RESULTS

The studies of the Romanian grinding machines development were focused, regarding the constructive optimization, upon the basic model of the R.P.O.- R.P.V. family, namely the R.P.O.-200 machine, with adaptation posibilities to others machines.
The constructive alterations aimed the principal sub-ensembles identified through researches to be more affected by thermal stress. The achievement of these constructive improvements concerned a general view of the unit behaviour (or even the whole machine), not only it's thermal stability.
A representation of thermal behaviour of the machine, in time, until stabilization, regarding the most important zones, was elaborated as a "thermal map". Concerning the construction of precise and high precise machines, the solution with separate hydraulic basin, is preferred.
Because of constructive, geometric and functional analogies, as well as modular development of the grinding machines family R.P.O.-R.P.V., the constructive optimizations of the model 200 and 200 M, doesn´t aim only a singular case, but also the whole grinding machines family R.P.O.-R.P.V. At the machines type R.P.O.-R.P.V.- 320 and R.P.O.-R.P.V.- 500, by increasing the installed load, the optimization measures of thermal behaviour are more necessary and the development of greater entities of basic components of the family R.P.O. 200, preserves the solutions and the optimizations of the basic model.
Considering the origin and the disposing of the heat sources, it is necessary to decrease the amount of heat produced inside the machine and those provided from outside and to avoid the temperature differences among different sub-ensembles, or even inside the same element.
From the designing stage, the realization of a thermo-symmetrical machine contributes to the achievement of a stable thermal behaviour. The thermo-symmetry is a balance of geometrical elements loaded as much as possible with a uniform temperature distribution. Many grinding machine factories allow a great importance to this concept, which is linked with the notion of thermal stability of the machine tools, the working accuracy being acquired and maintained during the whole working day. These options depend to a great extent of the system structure concept and the position of the hydraulic group.
The latest research project of the author ("Analysis of thermal behaviour of new types of machine tools") was granted from NATO and carried out at the University of Stuttgart.
At the Host Institute, it was developed recently a new machine concept with preloadable gimbal-strut-kinematic and it was realized a new structure HEXACT-Parallel Kinematic Machine Tool. The new machine was presented also in some international fairs in Europe.

Due to the fact that the new machine type is also a worldwide innovation, its behaviour must be studied with the whole concatenation of implications upon the machining precision. This was possible only in Stuttgart where are available, both the machine and a very sophisticated measuring instrumentation (huge thermostatic cabin, laser intreferometer system, thermographic camera, software for images analysis, etc).
The new machine tool concept HEXACT Parallel Machine Tool has some revolutionary, technical and economical properties.

As planned, the research course has had four steps:

- The study of the new structure of Parallel Kinematic Machine, with the main components: main spindle unit (E. Fisher AG.), control and drive system (Siemens AG.), servo struts and joints (INA), welded body and hexagonal frame;

- The identification of the most important thermal sources in the machine structure (with influence on the machining precision) emphasizing some new aspects in the relation machine construction-thermal behaviour;

- Based on the former experience of the author: measurements with the thermographical camera INFRATEC, JENAOPTIK and the images saving and analysis (software IRBIS V 1.0 and CORELL DRAW 7.0);

- Solutions for thermal behaviour optimisation of Romanian machine tools with the aim of machining precision improvement.

4. CONCLUSIONS

For an optimate thermal behaviour of machine-tools, it is necessary in the first time, to decrease the inside heating and to reach in short time, stationary thermal working conditions, simultaneous with a how much uniform distribution of the temperature field, in the whole technological system.
A classification of the thermal behaviour optimization measures of machine-tools can comprehends the following aspects:

- the uniform distribution (equalization) in the whole machine-tool of the inevitable temperature increases, through a adequate distribution of the thermal sources in sub-ensembles;
- the decrease of the energy amount converted in heat, namely the intensity of thermal sources;
- the ensuring of heat transfer, the intensification of heat exchange with the outside, through the extending of the exchange surfaces and the increasing of the thermal convective coefficient;
- the cooling of the machine surfaces and the use of oil thermostatic control;
- the ensuring of climatization conditions in hall;
- the diminution of errors through compensatory systems.

As soon as these steps will be assured from the beginning of the designing- achievement cycle, both for the prototype and the serial production, it will be augmented a greater efficiency, and a better quality management [4].

This sort of studies is more necessary in Romania because of the standards absence and the need of joining to the European norms. The lather approach of the thermal behaviour, as compared to the static behaviour is resulted from the complex, interdisciplinary character of the problem, leaving from the temporal and spatial existence of a variable thermal field, and from a difficult elaboration of a mathematical model harmonious with the real physical model. The mathematical model needs considerable calculation capacities for a wide covering (using for example, the method of finite element) of the whole machine-tool structure and an accuracy introduction of boundary conditions. A new trend is to use the fuzzy- logic in the study of thermal behaviour of machine tools and robots [5].

The main conclusions of this work were: practical measurements to optimization of thermal behaviour of Romanian grinding machine tools; in the same time the increase of precision and quality of this machine tools; some quality management measures able also to optimize the technology and the organization in Romanian factories; some important steps to elaborate an integrated concept for testing and reception of machine tools and robots (static, thermal, dynamic); thermographical diagnostic, very useful for the thermal behaviour determination of machine tools, but also for industrial robots or coordinate measuring machines; some observations and improvements of the standard DIN V 8602, proposed also to the German Institute for Standardization, D.I.N.e.V.

5. REFERENCES

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