INTELLIGENT MACHINE TOOL DESIGN APPROACH AND LIMITATIONS

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Today the increasingly high operational performance of machine tools leads to much higher automation, precision, dynamics, energy saving and functional integration with the manufacturing environment, consistently with the idea of Factory 4.0.

In order to holistically meet such high demands, the machine functions and the process layout need to be managed in an optimal way. The simple control strategies and procedures must be replaced with intelligent functions based on robust mechanical, mechatronic and machining functions, requiring a highly autonomous and efficient IT software support. It is expected that the robust self-recognition of machine tool and process distortions and errors, the active reduction and compensation of errors and the active optimization of the process with regard to time, energy consumption and cost reduction will become reality. The general machine tool development components and levels are presented in Fig. 1 (Jedrzejewski and Kwasny [1]).

The figure shows how the operational efficiency of machine tools, resulting from the development of design and control, influences the levels of machine system development, with knowledge acquisition and dissemination leading towards holistic improvement. This development at present is based on modelling and numerical simulation aimed at defining intelligent and totally autonomous functions with robust monitoring. Fundamental for such intelligent machine tool design is precise tool path generation free from errors, and a digital twin for real machine tool control (see Fig. 2). Because of the complexity of the recognition of machine tool disturbances, the reduction of errors and efficient compensation they need to be supported by a holistic approach in order to define appropriate correcting functions, taking into account time-variable volumetric errors and process

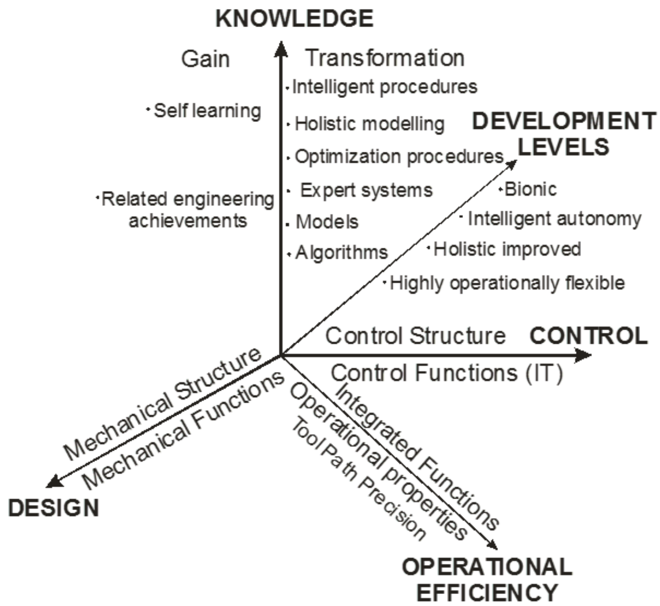

Fig. 1. Machine tool development main components and levels

parameters, to define the optimal technology for designing tool path modules and to assure high machining performance.

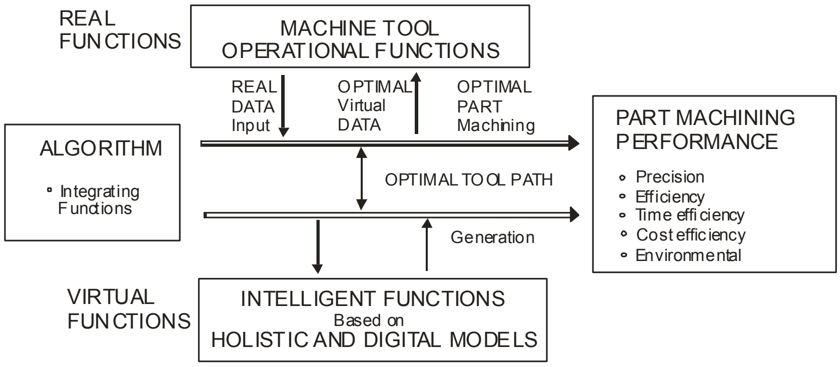

Fig. 2. Digital Twin based intelligent control of real machine tool functions.

According to the holistic approach, tool path generation must take into consideration not only static geometry errors, but also complex thermal errors caused by changes in ambient temperature and by dynamically changing (stationary and moving) internal heat sources, as well the forces affecting the positioning precision of the moving units (headstocks, tables and heads) in real-time. Errors originating from spindle shift as the speed changes, from the direct drives of motors and from the moving nut in the ball screw unit during fast work cycles and roundness errors in the turning process, which are very difficult to control, must also be taken into account and reduced. Current research is strongly focused on the generation of precise virtual tool path components and functions and on optimal design based on holistic modelling and intelligent control. Such a set of general virtual models is shown in Fig. 3.

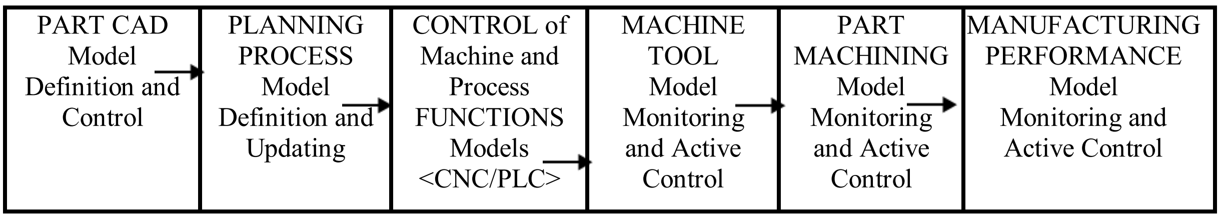

Fig. 3. Virtual tool path functions models and components.

Using the models, in order to generate an error-free tool path in real-time, an efficient error compensation procedure should be selected and applied according to:

- controller standard openness procedures for typical errors,
- process planning in real-time with adaptive error compensation,
- error compensation implementation in the tool path through an interpolator on the basis of a prognosis considering the existing limitations,
- active G-code correction,

- the holistic management of tool path generation, neglecting the-G function, and basing the postprocessing on a very fast processor.

The new possibilities for designing intelligent machine tools with optimal real-time tool path generation open the way for the application of the new STP NC standard. This standard manages complexity, especially the complexity of the tool path components from CAD to the process in real-time (Fig. 4).

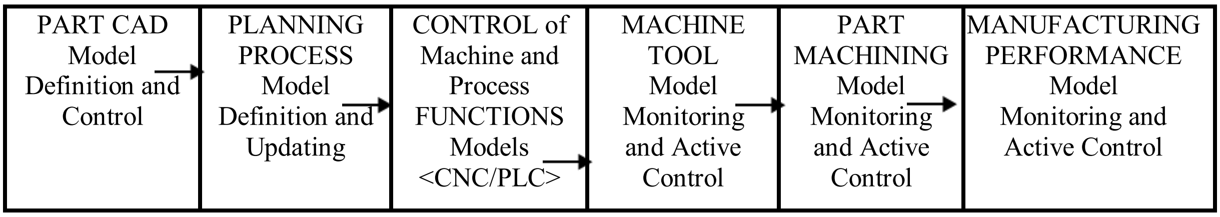

Fig. 4. Machining errors intelligent management structure and its components.

According to Hardwick [2], such a control concept opens up new possibilities for the realization of machine tool intelligence (Fig. 5). According to Languione et al. [3], the next step leads to the efficient control of the multiprocess chain in an intelligent machining/production system with total monitoring. Moreover, according to the idea proposed by Denkena et al. [4], such a total monitoring system should be based on microsensors integrated with signal processing microunits embedded in machine components. Another very interesting intelligent CNC machine tool design solution in dental prosthetics machining, based on the Digital Copy Milling concept with adaptive feed control and cutting force prediction, was developed by Nishida et al. [5] and proved effective in production conditions.

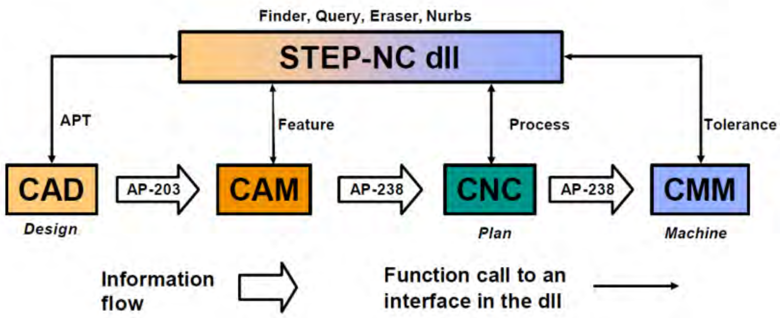

Fig. 5. Functionality of STEP-NC DLL (Hardwick 2006).

Summing up the discussion of the current development of machine tools, one can say that the design of machine tools and production processes is becoming increasingly more intelligent and autonomous.

References:

1. *Jedrzejewski, J., Kwasny, W., 2017. Development of machine tools design and operational properties. Int. J. Adv. Manuf. Technol., 93(1-4), 1051–1068.*

2. *Hardwick, M., 2006. Manufacturing Integration Using the STEP-NC DLL 1-14.*

3. *Laguionie, R., Rauch, M., Hascoet, J-Y., 2009. Simulation and optimization in a multi-process environment using STEP-NC. 2009 IEEE International Conference on Control and Automation, Christchurch, New Zealand, December, 9-11.*

4. *Denkena, B., Litwinski, M.L., Boujnah, H., 2014. Process monitoring with a force sensitive axis-slide for machine tools. Procedia Technology 15, 416–423.*

5. *Nishida, I., Tsuyama, R., Shirase, K., Onishi, M., Koarashi, K., 2019. Development of Innovative Intelligent Machine Tool Based on CAM-CNC Integration Concept – Adaptive Control Based on Predicted Cutting Force. Int. J. of Automation Technol. 13(3): 373–381.*

RESEARCH OF THE FINISHING AND STRENGTHENING TECHNOLOGICAL OPERATIONS BY USING SADT-TECHNOLOGIES

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The priority function of technological process design (TP) at the stage of technological preparation of production is the rationality of selection of process (or set of processes), which is achieved through the systematic design. The technical requirements should be providing both: for the individual elements of the technological environment in the development of new technological processes, and for the whole complex system "control system - technological environment" during the improvement of existing technologies. This allows to optimal realizing the technical and economic indicators for a given class of TP [1].

The technology is crucial in the formation of quality parameters of parts. Each technological operation in the structure of the technological process has an impact on the formation of the properties of the final product, given by technological inheritance. Each technological operation has an influence on the formation of the properties of the final product in the structure of the technological process, which is determined by technological inheritance. The design of multifactor technological operations, optimized for a large numbers of parameters of accuracy and surface quality should be carried out by means of SADT-Structured Analysis and Design Technique [2].

Technological operations for finishing and reinforcing, in particular surface-plastic deformations (PDD) for ensuring the quality of products has a priority task.