

## **THE DEVELOPMENT OF AN ALGORITHM FOR CNC MACHINING QUALITY IMPROVEMENT**

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### **ABSTRACT**

The production of parts on CNC machines is one of the most common techniques used in modern manufacturing processes. CAM software generates NC programs that are mathematically exact and usually contain constant cutting parameters for a particular tool path and does not simulate the expected machined part quality (accuracy of machining and the machined surfaces quality), and also does not take into account parameters that affect process errors. The aim of the paper is to develop an algorithm for improving the quality and accuracy of processing and its implementation on CNC machines. Based on the input parameters, from the existing knowledge and processing error database, the algorithm will recognize the expected error and regenerate the NC code (obtained by appropriate CAD/CAM software based on technological and geometric processing parameters) and create new NC code that will enable better processing. The algorithm obtained at this stage would be further applied under laboratory conditions to a particular CNC machine in order to verify its application.

**Keywords:** CNC, Machining, Algorithm, Quality improvement.

### **INTRODUCTION**

An advanced version of the third industrial revolution that aims on taking over the computers and automation of the former revolution and strengthening it with smart systems equipped with machine learning and artificial intelligence has come to the surface by the name, Industry 4.0 (Ved, & Kamta, 2020). Artificial Intelligence, Machine Learning, and Data Analytics seem to be promising tools to achieve the total independence of CAPP systems on the experience of the process planners in the era of Industry 4.0 and smart manufacturing systems. The ideal intelligent CAPP systems will be able to collect the experience and knowledge of the technology experts in addition to being adaptive and self-learning according to the machining process real-time data and work history (Besharati-Foumania, Lohtander, & Juha, 2019). Over five decades ago, manufacturing industries have been looking for more efficient processes to manufacture products through Computer Numerical Control (CNC) machines. CNC manufacturing has since relied on data and product modeling and therefore technologies related to Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Process Planning (CAPP) and Computer Aided Manufacturing (CAM) are primarily important. The development of a product modeling consists of three elements which are firstly a problem definition, secondly a product modeling involving synthesis, a rough physical implementation of the product model as well as evaluation of the model functional behavior and finally, the selection of the best product model (Ibrahim et al., 2016).

Computer aided process planning (CAPP) is a means to automatically develop the process plan from the geometric image of the component. The key of the development of such CAPP

System is to structure the data concerning part design, manufacturing facilities and capabilities into categories and logical relationships. CAPP thus appears to fully integrate CAD and CAM (Sonesale, 2016).

CAPP systems need to receive or recognize various types of data related to the designed part to be able to provide suitable instructions for its manufacturing processes. The required input data for CAPP systems comprises geometric characteristics such as dimensions, tolerances, surface finishing quality in addition to the information about the material, hardness and data about the machining facilities and their capabilities (Kang, Han, & Moon, 2003). The output of CAPP system needs to include the optimum manufacturing processes, the sequence of processes, cutting tools, machining conditions, jigs and fixtures specifications, and the tool path for roughing and finishing processes. Also, it is requested by industries to include cost and time reduction, and quality checking capabilities into CAPP systems (Al-Wswasi, Ivanov, & Makatsoris, 2018). Various technologies and approaches are used to develop CAPP systems such as feature-based methods, knowledgebased systems, fuzzy logic, agent-based systems, STEP standard compliant data, artificial neural network (ANN), genetic algorithms (GA), and so on (Xu, Wang, & Newman, 2011). The techniques used by CAPP systems can be classified as one of the following (Besharati-Foumani et al., 2019).

Feature representation and recognition technology. An effective approach for generating the 3D models of parts is feature-based modeling (FBM). Features are defined as a region of a part with a specific geometrical characteristic. In computer-aided design (CAD) software, form feature which contains parametric information in addition to shape information is commonly used. A section of a part that encompasses some specific manufacturing elements can also be referred as a feature. Part entities such holes, ribs, pockets, slots, bosses and so on which are produced by manufacturing operations are typical feature representations (Khan et al., 2018). CAD systems store the geometrical feature data with various structures and no unified standard is developed as a reference for all of them. CAPP systems use different part description structure which is based on the manufacturing feature definition (Abouel, & Kamrani, 2006). CAPP systems cannot directly utilize CAD data and need interpreted information either by human interference or automated means.

Knowledge-based system approach and expert systems. Expert systems are software that solve problems using stored knowledge and expertise in the form of coded facts, rules, procedures, and logic which are collected and transferred from expert human to the computer to empower its decision-making capability. Knowledge-based system (KBS) is a subcategory of Artificial Intelligence (AI) which includes three factors such as database, knowledge base, and the inference engine (Leo-Kumar, 2017).

Artificial intelligence and evolutionary techniques in the intelligent process planning systems. Artificial intelligence has a significant role in developing automated decision-making or intelligent systems for different application areas. It has been widely used to increase the functionality of automated process planning systems for manufacturing during past decades. Evolutionary approaches such as GA, ANN, PSO, SA, and so on are implemented in recent efforts to extend the AI capabilities to deliver more efficient solutions (Deb, Ghosh, & Paul, 2006).

This paper presents and describes a hybrid model for improving the quality of machining that integrates knowledge-based system approach, expert systems and artificial intelligence and intelligent process planning systems. The model contains a database of process error model, influential parameters on the machining error, information from the CAD/CAM system with design requirements (SAT), technological parameters, tool geometry, etc. Based on existing knowledge, which is constantly supported by the database, in advance can assume the expected processing error and correct it by regenerating the NC code.

## THE DEVELOPMENT OF AN ALGORITHM FOR CNC MACHINING QUALITY IMPROVEMENT

The machining accuracy depends on the deviation of the position of the cutting edge of the tool from the theoretically required value, the deviation of the actual tool path from the expected tool path. The accuracy of machining is conditioned by the existence of geometric errors, non-uniform thermal expansion of the elements of the machine structure and static/dynamic loading of the elements of the production process: tool - part - accessories - machine. As a consequence of these factors, a resultant error is created which occurs as an error between the cutting tool and the workpiece and which can be affected by the regeneration of the NC code. The quality of the generated surface can be improved by regenerating the NC code through tool path compensation procedures as well as by optimizing process parameters by different methods.

### MODEL ELEMENTS

The basic elements of the model for regenerating NC code (Figure 1) are the CAD/CAM system into which the input information needed to generate NC code is imported.

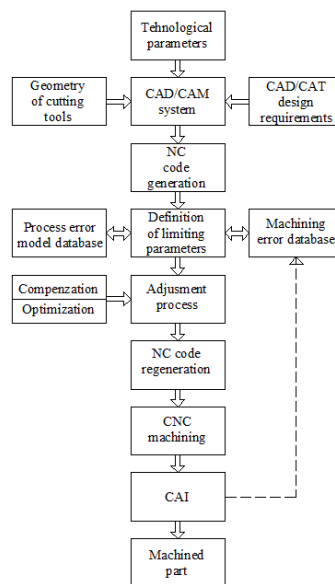


Figure 1. Model for regeneration of NC code.

Data related to technological parameters, geometry of the cutting tool, as well as design requirements set through the CAD/CAT model of the part are imported. Based on the input parameters, the CAM system generates a standard NC code. Then the initial part, with the input information and the generated NC code, passes to the phase of defining the limiting parameters of the process. Defining constraint parameters represents the relationship between the process error model database and the machining error database. The process error model database is a database of existing "knowledge" on the basis of which the existing dependency model is selected in order to eliminate the machining error. If the system recognizes the error model from the process error database, the adjustment process is applied and performed. In the adjustment process, the debugging procedure is selected. Machining error correction can be performed by the process of compensation or optimization of machining parameters. After the adjustment process, the procedure of regenerating the NC code is performed, and then the machining on the CNC machine tool. The processed part is then measured by some measuring devices (coordinate measuring machine or non-contact device) and the measurement results are analyzed by computer-aided measurement (CAI) procedures. The measurement results are sent to the machining error database, and part, if it meets the design requirements, exits the machining process or, if it does not meet the

design requirements (technical drawing), and it is estimated that finishing is possible, it is returned for machining.

### DATABASE OF PROCESS ERROR MODEL

The database of process error model is the link between the input and output data and the database processing error (Figure 2).

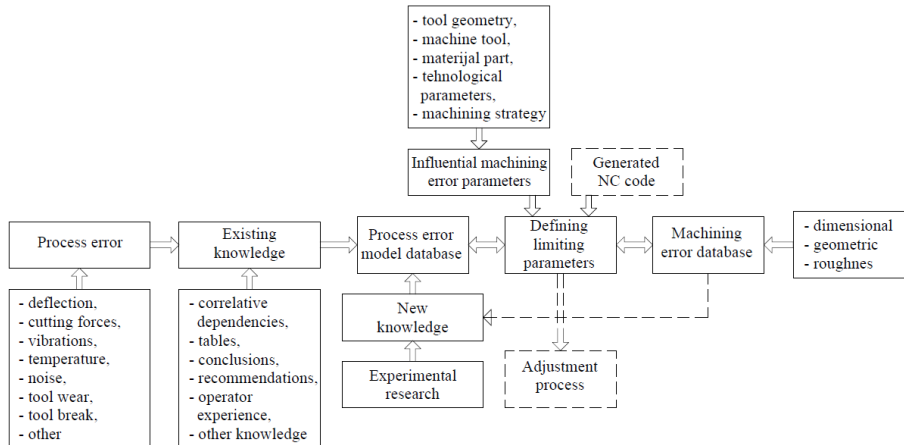


Figure 2. Database of process error model.

The database of process error model contains all previous knowledge, ie experience, and it is constantly supported by new knowledge obtained by experimental research and those resulting from machining in production conditions. Existing knowledge represents correlative and other dependencies obtained through continuous testing, existing tables, conclusions, recommendations, and if there is no appropriate knowledge in the database, the experience of the operator will be used. Correlative dependencies represent the relationship between processing quality, influencing factors on processing errors and process errors. Influential factors are related to known (measured) error parameters related to tool geometry and clamping, machine tool, workpiece material, machining strategy as well as technological parameters. Thanks to the database of process error model, and considering the influential parameters on machining error, information from CAD/CAM system with design requirements, technological parameters and tool geometry, the expected machining error can be assumed in advance and corrected by regenerating NC code.

### MACHINING ERROR DATABASE

From the machining error database, the expected error can be determined (predicted) based on the input machining parameters and the process error model. The machining error database is the database of existing experimental test results. Machining errors define the quality of workpiece machining and contain information on dimensional and geometric deviations, as well as information on the quality of the treated surface, that is roughness. This database is supported by constant interrogation and depends on the process error model. Error information is compliant with standards on dimensional and geometric tolerances as well as regulations related to surface roughness. Data obtained by computer aided measurement (CAI) of the processed part are imported into the database, by measuring the deviation of results (point clouds) obtained on the measuring (contact or contactless) device and CAD/CAT model in accordance with the design requirements.

### CONCLUSION

Thanks to the process error model database, and considering the influential parameters on the machining error, information from CAD / CAM systems with design requirements, technological

parameters and tool geometry, the expected machining error can be assumed in advance and corrected by regenerating NC code.

The mentioned model generates a standard NC code using the CAM system, which contains the expected quality of the treated surface. By comparing this information with the data contained in the database with the results of experimental research, information was obtained on the adequacy of the proposed processing conditions generated in the NC code. If there is a non-compliance, if it is determined that in the proposed machining conditions, the experimental tests have obtained a surface quality that does not meet the requirements, it is necessary to correct the proposed machining conditions, and enter the corrected data in the NC code. The presented model should enable the correction of NC code based on process errors (tool wear, deflection, stability, stiffness of the tool-part-machine system, etc.). The part is processed in the new processing conditions, and the data on the final quality of the treated area are stored in the database of machining errors. This model has the ability to enter a large number of influential parameters on machining errors and process error model, which can be controlled by correcting the NC code. A CAD model with assigned tolerances, computer-assisted tolerance can also be entered into the database and thus the obtained dimensional and geometric deviations can be compared with the allowed ones. The proposed model takes all existing models and all influential parameters on the quality of the generated surface, whether it is roughness, dimensional accuracy or geometric accuracy of the work. Also, the model can apply any existing approach of tool path compensation or optimization of technological parameters.

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