Chapter 3.2
A Virtual Environment for Machining Operations Simulation and Machining Evaluation

Bilalis Nicolaos
Technical University of Crete, Greece

Petousis Markos
Technological Educational Institute of Crete, Greece

ABSTRACT

A virtual reality machine shop environment has been developed capable of simulating the operation of a three axis milling machine and it has been integrated with a graphical model for the calculation of quantitative data affecting the machined surface roughness. The model determines the machined surface topomorphy as a cloud of points, retrieved from the visualization system Z buffer. The current study describes the developed model for milling processes simulation in a virtual environment and the determination of the surface roughness of the processed surfaces. Also, the methodology for the verification of the quantitative data acquired by the system is presented. Results were verified with data determined in cutting experiments and by another numerical model that was integrated to the system.

INTRODUCTION

Contemporary production processes design methods employ simulation tools, like Computer Aided Manufacturing (CAM) systems and tools for determining critical quantitative data for the production processes. Most CAM systems have trivial graphics capabilities, visualizing the workpiece and a simplified geometrical model of the cutter but most importantly they have significant restrictions, such as the lack of production process

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parameters (depth of cut, feed, cutter wear, etc.) verification and quantitative data determination. These parameters affect the quality and the feasibility of the production process. Quantitative data, like the cutting forces and the surface roughness (Ko et al., 2003) are critical in the production process design (Zaman et al., 2006). Production processes quantitative data determination tools are based on analytical, numerical or experimental algorithms. These tools are posses' limited visualization capabilities.

The proposed research aims at the development of a virtual environment capable of providing complete simulation and analysis of the machining operations, thus extending CAM systems' capabilities. The system integrates CAM system functionalities with machining processes quantitative data determination models and can be used as a machining processes verification tool. A virtual environment for machining and other machine shop processes simulation was developed within a Virtual Reality platform, in order to provide higher level visualization, walk/fly through and interaction capabilities. Information about the simulated machining operations is provided in real time. In the virtual environment at the beginning a three axes milling machine is simulated. Workpiece geometry produced during the machining process is predicted and visualized in real time. For the determination of critical machining processes quantitative data, a model was developed to assess the surface roughness of the machined surface. The model exploits OpenGL functionalities. The results determined by the model are being visualized in the virtual environment.

For the verification of the quantitative data acquired by the system a two step process was employed. First surface topomorphy is verified and then the calculated surface roughness parameters are evaluated. For the verification of the model results a numerical model, experimentally verified in the past has been integrated to the system in order to compare its results and directly evaluate their accuracy. The accuracy of the model has also been verified with results determined in cutting experiments. The results were found to be in agreement with both the numerical model and the experiments. The verification process and its results are presented in the current study.

LITERATURE REVIEW

Virtual Environments for Surface Roughness Determination

Huang and Oliver (1994) developed a system for machining processes simulation in a five axes CNC machine. The system aims at the improvement of the workpiece machined surface quality by improving the cutter path. Ko et. al. (2003) developed a Virtual Manufacturing system for the determination of optimum feedrate values in 2.5 axis machining processes that provides the ability to determine cutting forces in order to improve the machined surface quality. Qui et al. (2001) and Ong et al. (2002) presented a system developed in VRML for material removal simulation. The system provides information about the required time for the completion of the machining process and quantitative data like the cutting forces, machined surface roughness, required energy and cutter wear. Bowyer et al. (1996) developed a simulation system for several types of machining operations that could be employed for design, modeling and implementation of production plans in the virtual environment, aiming at errors detection in the executed operations.

Generalized Models for Milling Process Simulation

Antoniadis et al. (2003) presented a model for surface roughness determination. In this model the workpiece is being modeled with vertical linear segments. As the cutter moves along the machin-