Title:
A Feature-Enhanced Remote Machining Process Monitoring Method

Authors:
Changqing Liu, lchq0123@126.com, Nanjing University of Aeronautics and Astronautics
Yingguang Li, liyingguang@nuaa.edu.cn, Nanjing University of Aeronautics and Astronautics
Xin Gao, gaoxin@nuaa.edu.cn, Nanjing University of Aeronautics and Astronautics
Weiming Shen, Weiming.Shen@nrc-cnrc.gc.ca, National Research Council Canada

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Introduction:
The complexity and precision requirements of NC (Numerical Control) machining have become increasingly high due to the rapid changes of production capability and functionality [5]. NC machining shops are facing more and more thin-walled parts with freeform surfaces and other complex machining structures. These parts are easy to deform during machining. Besides, cutting tool wear and cutting tool breakage always exist during machining. The occurrence of these machining conditions will affect the quality of products and even cause scraps. Since production cost is crucial for enterprises in global competition environment [4], they are enforced to improve their competition capability by advanced machining techniques. Machining condition monitoring is proved to be an effective way to improve machining quality [2]. Basically, there are two different ways to monitor machining conditions: locally [3] and remotely [1]. Each of them has its advantages and disadvantages. The local monitoring is intuitive for the machine tool operators to observe the real time machining conditions and to take corresponding actions, but limited by the knowledge and experience of the operators, as complex machining conditions can only be handled by experts. The remote monitoring provides a convenient way for the production management department to monitor the performance of machine tools and the machining conditions of workpieces, and it is convenient for experts to analyze the machining conditions remotely, but more work is required to realize the remote monitoring effectively, particularly: (1) a smooth communication between remote control computers and CNC systems is required; (2) an information model to represent different application views should be developed.

Main Idea:
In order to address the issues mentioned above, a feature-enhanced and web-based machining process monitoring method is developed, which facilitates to achieve remote and real-time machining process monitoring, as well as to detect and handle abnormal machining conditions in real time. A web-based remote monitoring module (WRMM), a machining data collection module (MDCM), a signal analysis module (SAM), a NC program management module (PMM), a CNC module (CNCM), and a database management module (DBM) are contained in the system. The WRMM is located at the top level of the system, where machining information and machining condition are displayed. The DBM is an intermediate of the system, where machining information is gathered and stored.

The collaboration among different modules is established by communicating via a central database. To ensure different modules to have the same understanding of the information, the same language and protocols should be adopted by different modules. In this system, features are used as the information carrier for communication, where geometric and non-geometric information of

features are contained. Feature ID (IDentification) is used to associate information of different application views.

Machining information including geometric information, process information, NC programs, and monitoring signals is gathered into the central database from the PMM and the MDCM. And then the machining information is obtained from the central database and displayed on the webpage, such as the geometric information of the current machining feature, the spindle speed, the feedrate speed, the current coordinates of the cutting tool, the tool path movement, the real-time monitoring signals and as like. In addition, the real time loads of the machine tools are also displayed, i.e., power and torque values. The observers especially for the process planners who planned the NC program, can observe exactly how the NC program is performed without going to the machining scene. Control commands can be sent directly from the WRMM to CNC systems via the intranet. Three authority levels are defined for different roles: (1) read and real-time write, (2) read and non-real-time write, (3) read only.

Each module reads the required information from the database and writes the produced information to the database during machining. The benefit of using the database is that it can provide data support for individual modules and record the whole process of machining to manage and search the data. The hierarchical model which has three layers is utilized in the database. Three layers include the main database layer, the library layer, and the parameter layer. The data in the database are organized by features.

It should be noted that the feature-based information contains the geometric information and the non-geometric information, such as the machining precision and surface quality requirements. In terms of storage, monitoring information is associated with the feature and time so as to realize the feature-based information search and record the machining process. During machining, the feature ID of current machining feature is read from CNC system, and then the monitoring data are associated with the feature ID. Besides, the monitoring strategies of different features are determined according to the geometric and non-geometric information by the WRMM. As feature information is well structured, only the changed information is transferred in the form of feature package when communicating among different modules. Therefore, the data transferring load is significantly reduced.

Tool wear, workpiece deformation and cutting tool vibration induced by using inappropriate machining parameters are expected to be monitored and detected in this system. The current machining condition is determined by the SAM through analyzing the real-time signals from the database. In addition to real time analysis, post-machining analysis is also made in this module, which includes the evaluation of the manufacturing capacity of machine tools and the planning capacity of the process planners. Both of the capacity of machine tools and process planners can be evaluated from two aspects, i.e., overall evaluation and detailed evaluation. Detailed evaluation is performed in the view of features.

A prototype system is developed based on an open CNC system. A webpage to monitor machining processes and a database management center are developed. Real-time monitoring signals, cutting parameters, machine tool information, cutting tool information are shown on the webpage. Besides, the information of the current machining feature can also be viewed by taking advantage of feature ID, for example the geometric structure, tool path, and some other information.

Conclusions:

In order to address the issues of machining process monitoring, a feature enhanced method is proposed. The contributions of this work include:

(1) A feature-based model that can facilitate the communication among different modules in the process monitoring system and also provide support for the decision making of process monitoring;

(2) A web-based system that can monitor multiple CNC systems simultaneously and alleviate the computational load of the CNC systems;

(3) A prototype system that has been developed to validate the feasibility of the proposed approach.

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