

## **The Development of a Knowledge-based Tool for the Machining Processes**

**Ismail Fidan, Ahmed ElSawy**

**Tennessee Tech University  
920 North Peachtree Avenue  
Cookeville, TN 38505-5003**

### Abstract

Even though there are various kinds of CAD/CAM packages available on the market, there is no system developed for the basic estimations of machining processes, such as cutting time, material removal rate (MRR), feed rate, and spindle speed. Having such a system is important for a number of reasons: cost estimation, life cycle analysis, machine programming, tool and workpiece selection, production rate, and number of machining steps etc. In this paper, a knowledge-based tool (KBT), which is still under development, has been presented. The current development and its implementation are also given in the present paper.

### I. Introduction

While it is important for technology programs to educate students about the use of computer aided design (CAD) tools, they must also ensure that the students have a basic understanding of the underlying principles upon which these computer programs are based. Striking a balance between teaching the fundamentals and giving the students hands-on experience with the technology continues to be a challenge.

All technology majors are usually required to take a course in manufacturing processes and computer numerical control (CNC). The underlying philosophy of these courses is to introduce students to the basic processes that are potentially used in engineering practices. Approximately one quarter of the courses is devoted to machining processes. Besides the lectures, students use CAD/CAM simulation packages, namely GibbsCAM, EdgeCAM, CNCez, and Mastercam, before their machining practices. In this study, an intuitive knowledge-based graphical user interface program has been developed to aid the lectures and laboratory activities. The main objective of the KBT is to help students comprehend and visualize the basics of machining. A knowledge-based system refers to an intuitive computer program that can store knowledge of a particular domain and use that knowledge to solve problems from that domain in an intelligent way<sup>1</sup>.

The current version of the KBT contains Milling, Turning, Drilling, Broaching, Shaping, and Grinding processes. It has been developed using Visual Basic (VB) and will be accessed via World Wide Web (WWW) in the near future. The user enters the geometric features of the machining part and cutting tool. KBT outputs are the machining time, feed rate, spindle speed, MRR, etc. This paper reports the current development on the KBT for machining.

## II. The State of the Art

CNC is the process of manufacturing machined parts. Numerical Control (NC) is the original name given to this technology and is still often used interchangeably with CNC. NC technology has been one of manufacturing's major developments in the past fifty years. It not only resulted in the development of new manufacturing techniques and the achievement of higher production levels, but it also helped increase product quality and stabilized manufacturing costs<sup>2-3</sup>.

Since the introduction of the first NC machine, there have been many applications of NC machining technology:

- Milling
- Turning
- Grinding
- Flame and laser cutting
- Electric discharge machining, or EDM
- Punching and nibbling
- Forming and bending
- Inspection

As can be seen in Figure 1, all machine tools follow the same standard, that is EIA 267-C standard for motion nomenclature and coordinate system<sup>4</sup>. This standard defines a machine programming, coordinate system, and movements so that a programmer can describe machining operations without worrying about whether a tool approaches a workpiece or a workpiece approaches a tool.

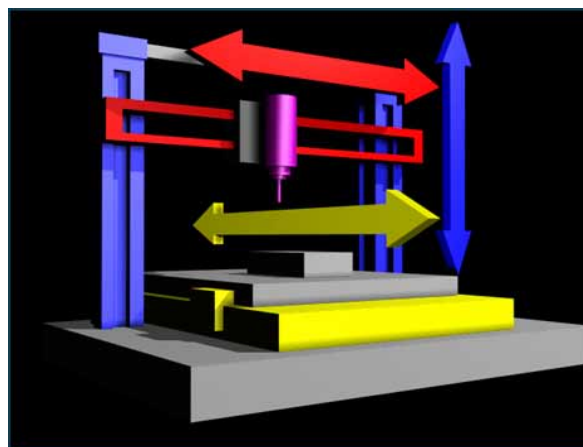


Figure 1: Coordinate System Selection in NC

It is very important to understand the correct value of NC machining parameters. For example: Too fast a speed or feedrate will result in early tool failure or poor surface finish. Too slow a speed or feedrate will lead to increased machining time and, possibly, greater part cost. In NC there are many sources and look-up tables available for picking up these correct properties<sup>3-4</sup>. For milling, the correct speeds and feedrates are determined in part by the diameter of the cutter, spindle RPM, number of teeth on the cutter, chip load per tooth, and surface feed per minute for a particular material. For turning, the diameter of the workpiece and the surface feet per minute for the material are factors in determining the proper speeds and feedrates<sup>4</sup>.

CAD/CAM based design and simulation tools are popularly used in NC machining technology<sup>5</sup>. In these programs, the user directly enters most of the process level inputs, material and tool properties as can be seen in Figure 2<sup>6-7</sup>. The current tool, which is under development, is mainly focused to fill the gap in this area. It helps the user pick up some of the NC machining properties. The current version of KBT can be used for estimating feed rates and spindle RPMs and serves as a turnkey solution for designers or engineers.

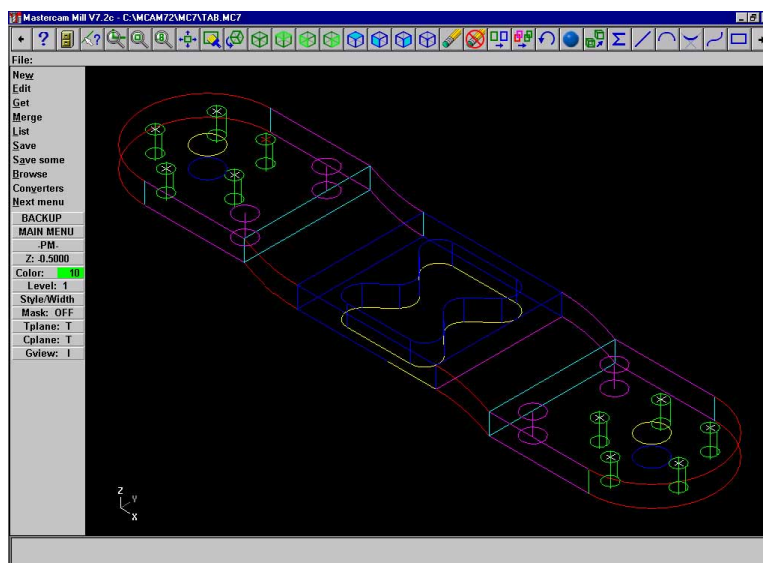


Figure 2: Mastercam7.2 is one of the most popular CAD/CAM tools

### III. KBT System Structure and Data Acquisition

The current KBT is based on a database for six different machining processes, which are namely Turning, Drilling, Milling, Broaching, Shaping, and Grinding. The kind of data input in this system depends on the type of the activity involved. If the activity is a milling process, then the selection is divided into two separate subsections; Peripheral milling and face milling.

The interfacing is realized through an interactive menu-driven technique<sup>8</sup>. Once all the necessary data are fed to the tool a message is presented to the user in the *Calculated*

*Results.* Depending on the selected machining process, different processing outputs are taken from the KBT.

Some of the process input parameters are taken from the part engineering drawing; initial billet diameter, final part diameter, and length of cut etc. The system is pretty user friendly and easy-to-update. Some extra machining processes and parameters can also be added into the current KBT easily. The machining processing data, formulas, and parameters available in the system are gathered from different manufacturing process books and manuals<sup>2-4</sup>.

Some process level constraints will be added into the KBT in the near future. With this addition, any message appeared on the *Calculated Results* will inform the user about the nature of the process reliability. Some examples are '*Estimated RPM is high for the current material picked. Select a different workpiece material!*'.

KBT has been developed using VB 5.0 and will be accessed through WWW in the near future.

#### IV. How to Run

The type of the process is selected through the tapped buttons, each of which has specific knowledge panel collected for the process conditions. A separate radio button option is sometimes used to detail the tapped button. For example, milling can be considered as peripheral or face as can be seen in Figure 3. The machining inputs are entered into the blank blocks, and then any block left unfilled is informed to user. Finally, the calculated machining processing outputs were shown at the bottom of the tool in a separate *Calculated Results* frame as soon as *Calculate* is hit. A new set of values is entered via *Clear All* option, and *Quit* is used to log out the tool. Depending on the part and cutter material, calculated RPM, cycle time, and MRR are evaluated. The RPM and feedrate information received from the KBT is plugged into the workpiece G&M coding.

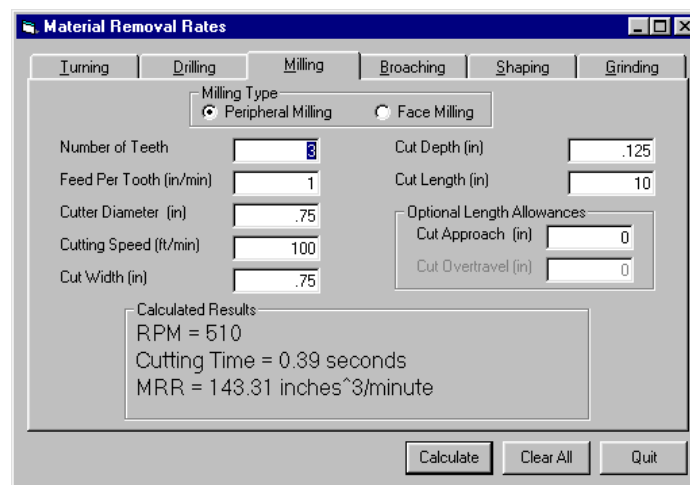


Figure 3: Milling portion of the current KBT

## V. Implementation of KBT

The current tool has been implemented in *IT-306:01 CNC Machining Practices* course in Fall Semester 2000. The implementation was to create a machined aluminum alarm clock. The finished part details have been given in AutoCAD 14. Students estimated the required RPM level and feed rates by using the current KBT, and then used CNCez as a CAD/CAM simulation package. Figure 4a shows the alarm clock in CNCez 2.0.

Estimated spindle speed and feed rates are highlighted at the bottom of the figure. Figure 4b presents the NC G&M code written for the Alarm Clock. Finally the real milling operation was performed on a FADAL88 Vertical Machining Center.

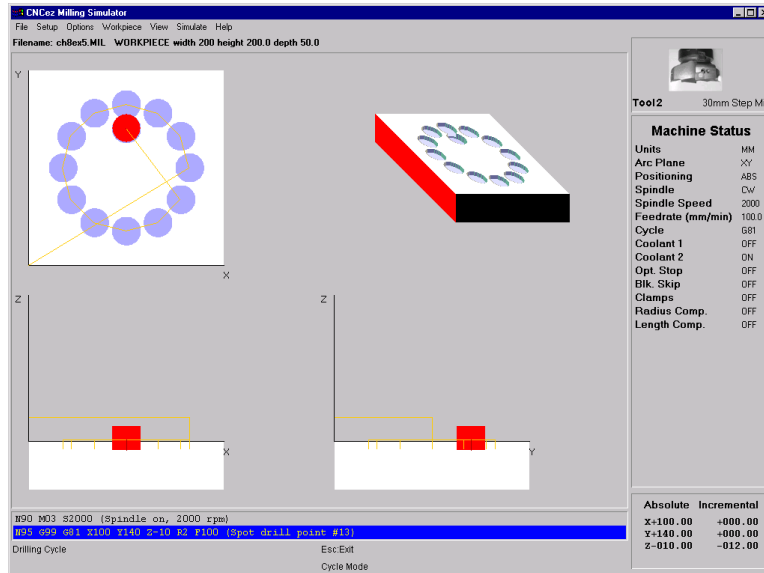


Figure 4a: Alarm Clock simulation in CNCez 2.0 (Spindle Speed and Feed Rates highlighted at the bottom)

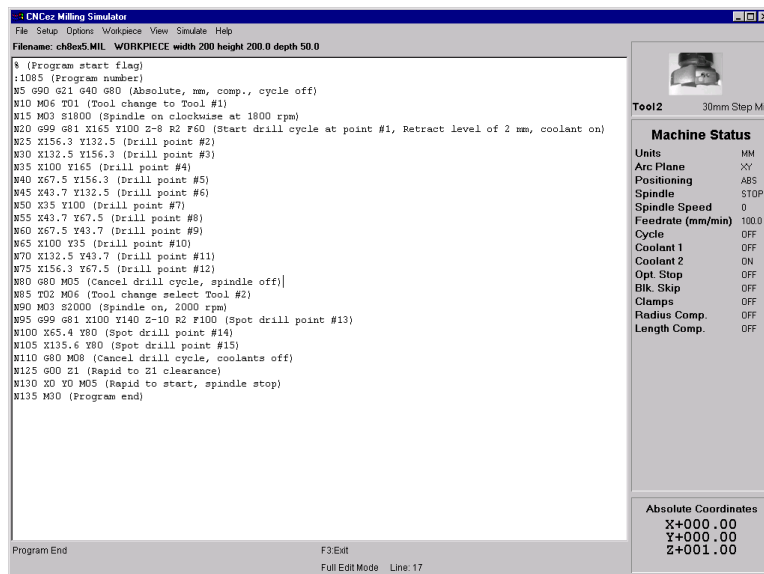


Figure 4b: G&M code written for the Alarm Clock simulation in CNCez 2.0

## VI. Conclusion

In this paper, the authors demonstrate the use of the current KBT for machining practices in a CAD/CAM environment. KBT was used for determining the spindle speed, feed rate, cutting time, and MRR, and then these results were inserted into CNCez 2.0 CAD/CAM software package for a testing. It was proved that having such a KBT in a production environment saves both time and money. In the future more process level outputs and constraints will be added into the current KBT and the results will be benchmarked with the industrial tests.

## Acknowledgements

The authors greatly appreciate the technical supports obtained from Alan Lamborn (The University of Northern Iowa), Ahmet Guner (University of Iowa), and Serdar Tumkor (Stevens Institute of Technology).

## Bibliography

1. Singh, N., *Systems Approach to Computer-Integrated Design and Manufacturing*, 1<sup>st</sup> Edition, John Wiley & Sons, Inc., 1996.
2. Degarmo, P. E., Black, J. T., Kohser, R. A., *Materials and Processes in Manufacturing*, 8<sup>th</sup> Edition, Prentice Hall, 1997.
3. Kalpakjian, S., *Manufacturing Engineering and Technology*, 3<sup>rd</sup> Edition, Addison Wesley, 1995.
4. Nanfara, F., Uccello, T., Murphy, D., *The CNC Workshop-A Multimedia Introduction to Computer Numerical Control*, Addison Wesley, 1999.
5. Seethaler, R. J., "Integrated Planning Monitoring, and Control of Milling Operations," *PhD Thesis*, University of British Columbia, 1997.
6. Radwan, A., "Computer-Aided Turning Machines Selection Systems," *Advances in Materials and Processing Technologies*, pp. 831-839, 1995.
7. Yellowley, I., Seethaler, R. J., Yeung, F. W., "The Integration of Process Planning, Monitoring and Control in a Machine Tool Environment," *Proceeding of the SPIE Conference on Sensors and Controls for Intelligent Machining*, v. 3832, pp. 38-47, 1999.
8. Yellowley, I., Oldknow, K., Ardekani, R., "A Critical Evaluation of Open Architecture CNC Design," *Proceeding of the SPIE Conference on Sensors and Controls for Intelligent Machining*, v. 3832, pp. 6-16, 1999.

## Biography

### ISMAIL FIDAN

Dr. Fidan received his Ph.D. in Mechanical Engineering from Rensselaer Polytechnic Institute, Troy, NY, in 1996. He worked at Polytechnic University, Brooklyn, NY as an instructor and Stevens Institute of Technology, Hoboken, NJ as a post-doctoral research associate. He worked as a faculty member at the University of Northern Iowa, Cedar Falls, IA in 1999, and joined the College of Engineering of the Tennessee Tech University, Cookeville, TN in August 2000. He is a member of IEEE, ASME, SME, NAIT, ASEE, and FPS. He has been an associate editor in the IEEE Transactions on Electronics Packaging Manufacturing since December 1999 and an editorial board member in the Journal of Industrial Technology since January 2000. His research interests include CAD/CAM, CNC, CIM, computer-aided process planning for manufacturing processes, and knowledge base development for electronics manufacturing.

AHMED ELSAWY

Dr. ElSawy is a professor and Chairperson, Department of Industrial Technology in the College of Engineering at Tennessee Technological University. Before assuming the current position, Dr. ElSawy was a professor and Graduate Program Coordinator, Department of Industrial Technology, University of Northern Iowa for seven years. From 1987 to 1992, Dr. ElSawy was a Professor and Director of the Manufacturing Engineering Program at St. Cloud State University in Minnesota. Before that, Dr. ElSawy was a project manager in the Center for Manufacturing Productivity and Technology Transfer and the Materials Engineering Department at Rensselaer Polytechnic Institute, Troy New York. Dr. ElSawy holds a Ph.D. in Mechanical Engineering from Cairo University, Egypt. He is a member of ASEE, AWS, and ASM. His research interests are in the areas of the Mechanical Design, Materials Engineering and Manufacturing Systems.