

The Development of a Knowledge-Based Engineering Tool for CNC Machining*

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Although there are many kinds of computer-aided manufacturing (CAM) packages available on the market, there is no educational system developed for the fundamental estimations of machining process parameters, 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 system (KBS) developed for the Computer Numerical Control (CNC) processes and its implementation in a junior level CNC class are presented.

INTRODUCTION

WHILE IT IS important for technology programs to educate students about the use of CAM 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 cutting edge technology continues to be a challenge.

All manufacturing technology disciplines are usually required to take a course in manufacturing processes or CNC. The underlying philosophy of these courses is to introduce students to the basic processes that are potentially used in technology practices. Approximately one quarter of the courses is devoted to machining processes. Besides the lectures, students use CAM simulation packages, namely SurfCAM, GibbsCAM, CNCez, and MasterCAM [1] before their laboratory practices. In this study, KBS has been developed to aid both lectures and laboratory activities. Its main objective is to help students comprehend and visualize the fundamentals of machining. KBS 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 [2].

KBS 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 future. The user enters the geometric features of the machining part and cutting tool. KBS outputs are the machining time, feed rate, spindle speed, MRR, etc. This paper reports the KBS for CNC

machining and its implementation in a CAM environment.

CNC TECHNOLOGY

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 stabilize manufacturing costs [3].

Since the introduction of the first NC machine, there have been many applications of NC machining technology [4-5]:

- turning
- grinding
- drilling
- flame and laser cutting
- forming and bending
- punching and nibbling
- electric discharge machining.

All machine tools follow the same standard, that is EIA 267-C standard for motion nomenclature and coordinate system [3]. A sample is shown in Fig. 1. 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.

It is very important to understand the correct value of NC machining parameters. For example: too fast a speed or feed rate will result in early tool failure or poor surface finish; too slow a speed or feed rate will lead to increased machining time and,

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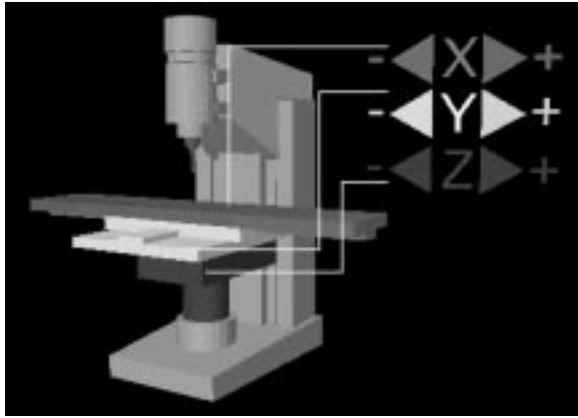


Fig. 1. Coordinate selection in a CNC machine.

possibly, greater part cost. In NC there are many sources and look-up tables available for selecting these correct parameters [4–5]. For milling, the correct speeds and feed rates are determined in part by the diameter of the cutter, spindle speed, 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 feed rates [6–7].

Spreadsheet-based, modular design tools are popularly used in NC machining technology [3]. The user directly enters most of the process level data into these programs created by a macro language as can be seen in Fig. 2. The main objective in our development is to reduce the number of the look-ups and data readings from the manuals and handbooks and support the CNC programmer with the estimated machining parameters. The developed tool helps the user select some of the NC machining properties and use them in a G&M (Ground and Miscellaneous) programming code. The current KBS is used for estimating feed rates, MRRs, and spindle speeds and serves as a turnkey solution for technology and engineering students.

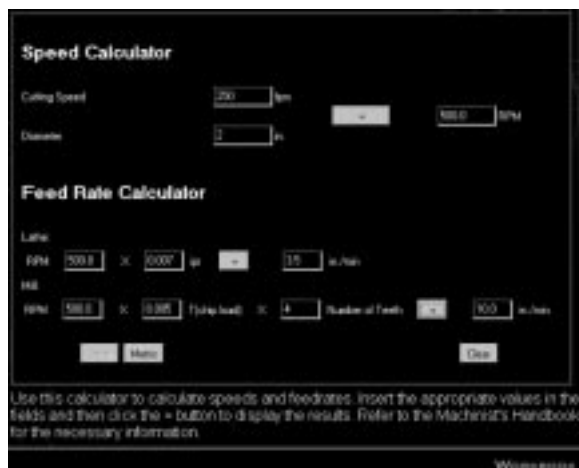


Fig. 2. CNC machining calculator developed by Torcomp.

SYSTEM STRUCTURE

The current KBS is based on a database for six different machining processes, which are 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.

An interactive, menu-driven technique is used for the interfacing [8]. Once all the necessary data are fed to the KBS a message is presented to the user in the calculated results. Depending on the selected machining process, different processing outputs are obtained from the KBS.

The system is pretty user friendly and easy to update. Some extra machining processes and parameters can also be added into the current KBS easily. The machining data, formulas, and parameters available in the system are gathered from different manufacturing process books and manuals [4–5, 9]. The following knowledge panels are available in the current KBS:

- workpiece material properties (e.g. aluminum, steel, cast iron);
- cutting tool material properties (e.g. HSS, tool steel, carbide);
- process design (e.g. milling, grinding, turning).

Machining process parameters are estimated and displayed in Imperial and Metric units. KBS has been developed using VB 5.0 and will be accessed through WWW in the near future.

KBS RUN

After picking the workpiece material and cutting tool, 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 Fig. 3. The machining inputs are entered into the blank blocks, and then any block left unfilled is informed to user. Finally the calculated machining outputs are 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 a Clear All option, and Quit is used to log out the KBS. Depending on the part and cutter material, calculated spindle speed, cycle time, and MRR are evaluated. The spindle speed and feed rate information received from the KBS is plugged into the workpiece G&M coding.

It was proven that Calculated Results obtained through the current system have not caused any tool, machine and workpiece breakdowns. Since both KBS and CNCez can be run at the same time students saved a lot of time in their G&M programming. They quickly estimated the required

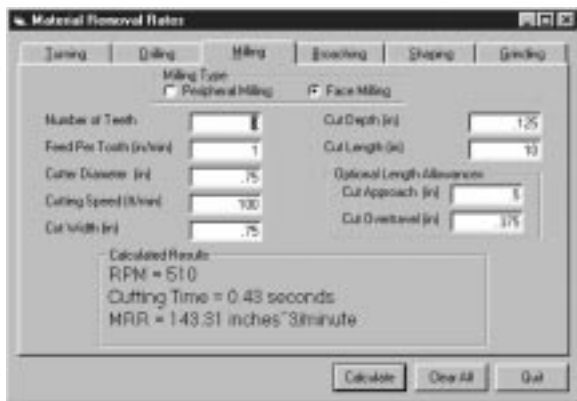


Fig. 3. Process types in the current KBS.

process values, and then plugged them into their CNCez, and finally simulated the generated G&M program in a short period of time.

CNCEZ SIMULATION SOFTWARE

CNCez essentially performs a graphical verification of CNC programs [3]. The simulation is considered interactive, since it will display the G&M programming steps as they are keyed into the editing interface. The editing interface is fairly intuitive; most students manage to learn to enter, edit, and simulate their programs by simply trial and error. The interactive computer-based training module provides instructions on the use of the simulation software [10].

The CNC programs created in CNCez are saved in text format, and programs created in a text editor can be brought into the simulator if they are formatted correctly [11]. We were able to bring student part programs created in the simulator to our FADAL™ Vertical Machining Center (VMC) simply by changing the program file name to .nc and removing the program number.

CNCez comes with copies of the example problems, which are located throughout the CNC workshop textbook, especially in conjunction with the presentations of G&M codes. This allows the simulator to demonstrate particular programming techniques and strategies. There is a CNCez Mill and CNCez Lathe program as part of this package. Our students worked with both programs. Some of the helpful features, which offered us some programming flexibility, included the ability to select from common tool diameters, to set part sizes, and select part coordinate systems.

IMPLEMENTATION

The current KBS was implemented in the CNC Machining Practices course in Fall 2001. The implementation was to machine an aluminum



Fig. 4. Aluminum elliptical flange simulation in CNCez.

elliptical flange. The machined part details were given in AutoCAD 2000. Students estimated the required spindle speed and feed rates by using the current KBS, and then used CNCez as a CAM simulation package. Figure 4 shows the elliptical flange generated in CNCez 2.0. Figure 5 presents the G&M code written for machining the elliptical flange. Finally the real milling operation was performed on a FADAL™ VMC.

The outcomes of the integrated use of KBS and CNCez were very promising. Before this implementation the lecture and lab practices used for CNC Machining Practices students were based on manual calculations, writing programs, and machining the workpiece without using any computer and simulation package. The current enhancement accomplished by the authors has changed the teaching and practicing way of the CNC in the department. The assessment received from the Fall 2001 graduating seniors, as shown in Table 1, clearly expresses the challenge of the integrated use of KBS and CNCez. This survey proves that our students are extremely happy with this enhancement added into the CNC Machining Practices course.



Fig. 5. G&M code written for the aluminum elliptical flange simulation in CNCez.

Table 1. Graduation Survey on CNC Practice Classes
Total number of graduated students: 11

	Satisfaction with KBS (8 students)	Satisfaction with CNCez (8 students)	Old lectures (3 students)	Old labs (3 students)
Excellent	×	×		
Good				
Average			×	×
Fair				

CONCLUSION

In this paper the authors demonstrate the structure and implementation of the current KBS tool in a CAM and real machining environment. KBS was used for determining the spindle speed, feed rate, cutting time, and MRR, and then these

results were inserted into a CNCez CAM software package in order to simulate the G&M code created for a given part. It was proved that having such a tool saves both time and money. In the future more process level outputs, constraints, cost estimation, and a CNC program editor with syntax check will be added into the current one and finally the results will be benchmarked with industrial tests. A set of the recommended values of speed, feed, and depth of cut for certain tools and materials will also be added.

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