Session 4560

Implementation and Assessment of Knowledge Based Systems In Various Engineering Courses

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Abstract

Knowledge-Based Systems (KBS), which mimic human problem solving expertise in computerized form, have been widely used in many manufacturing processes for planning and decision-making purposes. These "expert systems" help a wide range of students be more productive by enabling them to access to the collective experience and proven techniques in their field. This paper reports the following developed systems and their implementations:

- Hydraulics Circuits Design and Assembly
- Soldering Process Design
- Machining (i.e.: Turning, Drilling, Milling, Broaching, Shaping, Grinding) Process Design.
- Bearing Selection
- Hot Forging Design

The elements involved in hydraulic system design are the component selectors, power and force calculator, and flow, pump, motor, and cylinder calculators. Soldering includes laser soldering and its implementation within a modular software tool created. Knowledge base of machining contains algorithms and decision tables for selecting the proper cutting tool and machining parameters. Features of a required bearing for a shaft assembly are selected via an online bearing selection tool developed by the authors. Hot forging part and process design tool

developed via Pro/Engineer and ACES (Advanced Concurrent Engineering Software system) is used for process design of buster, blocker and finisher dies and lifecycle analysis. This paper presents KBS developed and practiced by the authors for undergraduate level design, manufacturing, and automation courses and their assessment.

1. Introduction

KBS tools have been commonly practiced within many engineering operations, including system design, process planning, robot control, and component selection etc[1-3]. These 'expert systems' provide opportunities for productivity improvement by making valuable knowledge available to a wide range of users, who otherwise might have little access to the cumulative experience and proven techniques in their field. One application area, however, which has not been widely addressed by the engineers is process planning for manufacturing processes. Process planning is a broader activity involving selection of components, operations and parameters needed to produce multiple features on a part and transform the raw material into a finished part. For machining operations, this activity includes selection of the cutting tool, cut sequence, cutting conditions, etc., to produce a single feature (slot, hole, etc.) on a part. While important work is being done in developing new user interfaces and knowledge based computer programs, the specific field of planning through the use of artificial intelligence (AI) is becoming very popular. This is due to the intuitive nature of KBS user interfaces that are relatively easy-to-learn and implement in a practical environment. Java, C++, and Visual Basic programming languages are commonly used to implement knowledge-based planners for various engineering applications. Other application-specific software tools and systems are also being developed to improve the decision-making and planning capabilities of industrial systems. This paper presents some KBS tools already developed and used in practice by the authors in undergraduate level design, manufacturing, and automation courses.

2. KBS Background

Computerized systems have been extensively used by engineers. However, early versions of such systems were expensive and cumbersome to use. Typically, a human expert had to serve as an interface between the application specialist (e.g., engineer) and the computer application itself. Although most of these systems included some representation of a relevant knowledge base (data, algorithms, and rules), the high cost of utilizing this knowledge and extreme difficulty of maintaining it made such systems useful only for special large applications or projects where costs could be justified. However, a modern KBS can be implemented on an inexpensive computer platform and contains software tools that permit a novice or apprentice to perform the tasks normally reserved for a professional with a higher degree of training. In other words, the modern use of artificial intelligence provides a solution that guides an apprentice through a complex application. Recent developments in software technology have reduced the time required not only to acquire the knowledge base relevant to particular applications, but also enhanced the creation and execution of the underlying software code needed to build the knowledge base to a point that rivals that of actual human thought. These powerful systems provide various mechanisms to find fast and correct solutions to problems. The following sections describe some specific applications.

3. Laser Soldering

Laser soldering is one of the most common reflow processes practiced in electronics manufacturing.

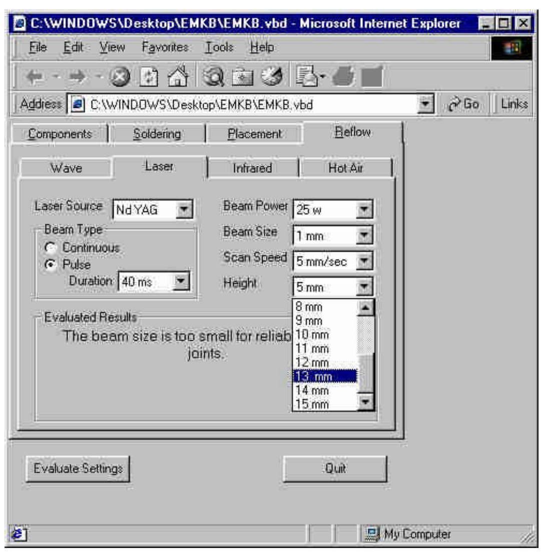

Figure 1. Knowledge-based laser soldering user interface.

None of the other attachment processes has potentially been practiced in rework since laser's localized application feature makes it the best for attachment. Figure 1 illustrates a KBS tool for laser reflow developed by the authors[4-5].

The data and knowledge available in the system were collected from various numbers of catalogs, handbooks, technical papers, and textbooks. The information gathered was tabulated into Microsoft's Excel data folders based on laser and solder type, and then they were all coded into KBS.

The developed system for the laser reflow runs as follows: After clicking on the "Reflow" tab four buttons are displayed on the window. Each of those buttons is labeled with a different process that could be used in that step. Next the user selects one of the buttons; we will use [Laser]. This results in the parameters for laser reflowing. Some of the parameters are Laser Source, Beam Power, and Scan Speed etc. This particular process provides all of the values in drop-down lists for the user. Once all the required information is selected the user can click on [Evaluate Settings] to evaluate the settings and return the outcome of actually implementing this set of parameter values in the electronics manufacturing process.

4. Knowledge-Based Machining

The current KBS is based on a database for six different machining processes, which are Turning, Drilling, Milling, Broaching, Shaping, and Grinding[6]. 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.

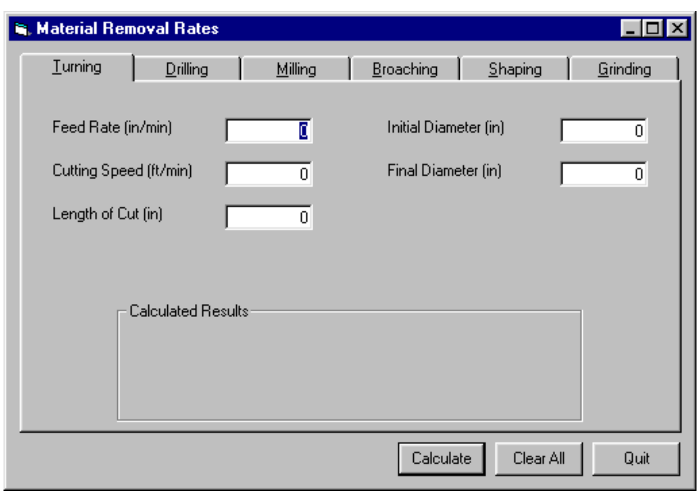

Figure 2. Knowledge-based machining user interface.

An interactive, menu-driven technique is used for the interfacing as shown in Figure 2. 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.

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. 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 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 removal rate are evaluated. The spindle speed and feedrate information received from the KBS is plugged into the workpiece CNC G&M coding.

The parameters obtained through the current system have not given any tool, machine and workpiece breakdown problems for the CNC students. Since both KBS and CNC simulation softwares can be run at the same time students save a lot time in their G&M code writing. They quickly estimate the values and plug them into their CNC simulators, and then simulate the same program right away. The KBS is easy to use and learn and it takes as little as five minutes to learn and start developing applications.

5. Hot Forging

The ACES, Automated Concurrent Engineering Software system, is a knowledge-based engineering design system that facilitates the integrated engineering design process from the initial concept to production. This system was originally designed for injection molding and resin transfer molding processes at the Design and Manufacturing Institute of Stevens Tech. It evaluates the feasibility of a geometric design as it is created in the underlying solid modeling software and provides immediate feedback on product performance, producibility, and unit cost.

The system is displayed in Figure 3. When starting a design project, the system user first specifies the basic design requirements such as production rate and lot size, strength requirements, surface quality and tolerance specifications, unit cost limits, for instance. Based on

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prior experience, the user then selects a piece of machinery and a workpiece material deemed suitable from databases integrated in ACES. Then, the part geometry is generated in the associated CAD system in a feature-by-feature fashion. The relationship between customer requirements and the part model is established with constraints (on the feature/part level as well as on the process/cost level) that are automatically imposed on the system. As the part design progresses through the addition of further features, the user is instantly alerted by any resulting constraint violations. Design corrections can therefore be initiated immediately by modifying the feature, part, or process parameters or by changing the selection of the material or machine. Thus, the part design process becomes an iterative procedure, which considers form, function, producibility and cost in an integrated fashion.

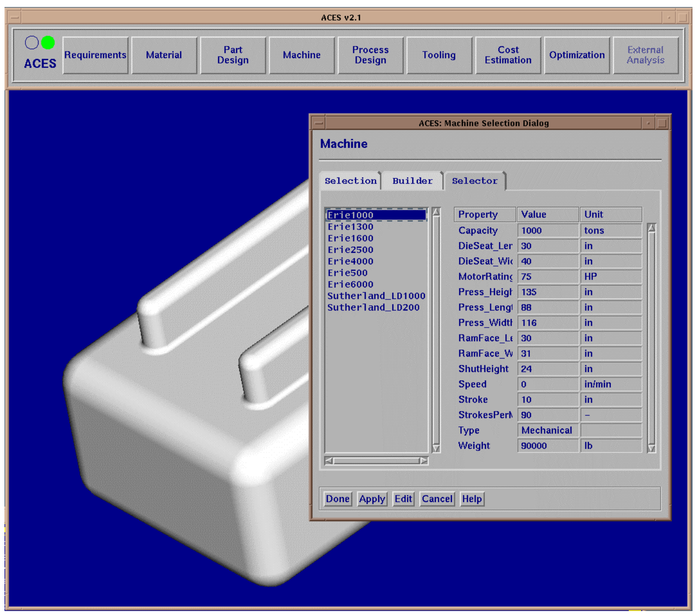

Figure 3. Knowledge-based hot forging user interface.

The underlying software architecture is a system that manages and optimizes the imposed constraints. The status of all constraints can be reviewed at any time to reveal the ones that are violated. Changes in the constraint status are displayed as pop-up messages, and the design engineer is apprised through user-friendly dialogs of the effects that changes in part design and processing conditions may have. The result is a system that provides guidance to the user in part geometry generation, material selection, performance evaluation, choice of processing conditions, tooling design, and unit cost estimation. The knowledge blocks of the ACES forging

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module developed by Fidan span from part design, to process and tool design, and cost estimation[7]. The following summarizes the content of each of the knowledge elements:

- A *material selection* knowledge block that allows materials to be chosen from a built-in extendible database including billet material and shape data, die material data, and lubricant data for the process design. This element includes estimations of material properties and suggestions for certain material-dependent design parameters.
- A *machine selection* knowledge block that includes a library of commercially available hydraulic, mechanical and screw presses. It contains the technical specifications of those presses such as force and energy capacity, stroke, ram speed, etc.
- A *part design* knowledge block that provides the designer with structural part features and design rules that include appropriate constraints and guidance in the use of analytical tools (empirical and deterministic formulae or other engineering rules).
- A *process design* knowledge block that generates processing parameters for forging parts such as forging load, energy, and number of steps in the forging sequence, billet size selection etc.
- A *die design* knowledge block that includes knowledge concerning material selection and tool design rules consistent with the production requirements.
- A *cost estimation* knowledge block approximates the costs for material, tooling, equipment, labor, etc.

6. Hydraulic Calculator

Hydraulic Calculator is a versatile program that employs standard methods of calculating various hydraulic functions[8-9]. This program employs bi-directional calculation to allow fast and easy design as shown in Figure 4. When any field is exited via tab, the enter key, or picking another field, all fields are updated for the new value which you entered, just as a spreadsheet would be. Unlike a spreadsheet, however, in most cases you can calculate from the answer back to the input. For instance, in the flow calculator, you can enter a diameter and flow to solve for fluid velocity - or you can enter the fluid velocity and solve for diameter for that flow.

Most data entry fields in the program support multiple units, which can be changed by using the right mouse button's pop-up menus. Simply place the cursor on a field, press the right mouse button, and select the units you wish to use. The units are persistent from session to session, thus

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preserving your preferences. This tool has been used in the Industrial Automation and Applied Fluid Power Courses and Labs.

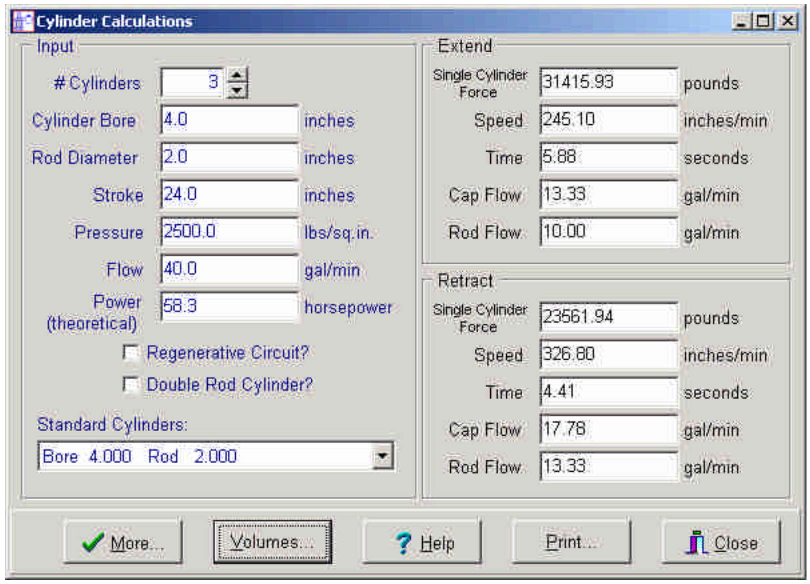

Figure 4. Knowledge-based hydraulic calculator user interface.

System has seven major modules:

- Hydraulic Cylinders: provides the calculations relating to the design of cylinders. It quickly allows the designer to size a cylinder for a load, and learn flows, stroke times, etc. for both normal and regenerative circuits. This module supports printing, as well as the ability to modify the design in several ways.
- Pumps: allows detailed design calculations for a single pump.
- Multi - Pumps: provides calculations for flow and horsepower requirements for multiple pumps.
- Motors: allows detailed design calculations for a single motor.
- Multi - Motors: allows power and flow calculations for multiple motors.
- Flow: is used for selecting the proper size piping to stay within good design practice for flow rates. Either steel tube or pipe can be selected from a list, or you can enter any diameter you wish.
- Equations: is a notebook of hydraulic equations. Each equation supports the multiple unit features. Each equation can be solved for any unknown simply by entering the known values, and double clicking on the unknown fields.

Hydraulic Calculator program is intended to be a quick calculator to help with design problems. The modules have printer support, which can give any student a hard copy of his or her work. The authors proved that solving a simple design problem takes almost three hours, but the same problem can easily be solved with the Hydraulic calculator in ten minutes. Design time is greatly reduced and different possible design configurations can easily be obtained from this knowledge-based interface.

7. Catalogue for the Bearing Selection

This catalog is a web-based system, which provides to the remote designer some information, and aids him to design shaft and then selects the rolling-element bearing correctly as shown in Figure 5. This system has been designed and used by Tumkor and Fidan in undergraduate level machine design courses[10]. Once a bearing type is chosen, selection of an appropriate-size bearing is based on the magnitudes of applied static and dynamic loads and the desired fatigue life. The remote designer enters the shaft position and external loads, and then the reactions and equivalent load are estimated for the bearings by the system. Finally, the designer selects a bearing from the database, which contains the dynamic and static load rating values for bearings. The parametrically prepared solid models of the shafts are also provided to the designer for further investigations.

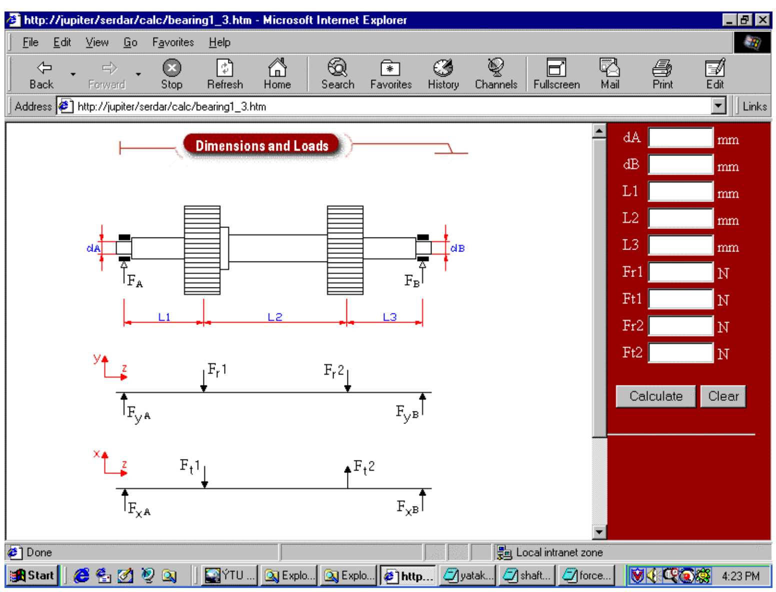

Figure 5. Knowledge-based bearing selector.

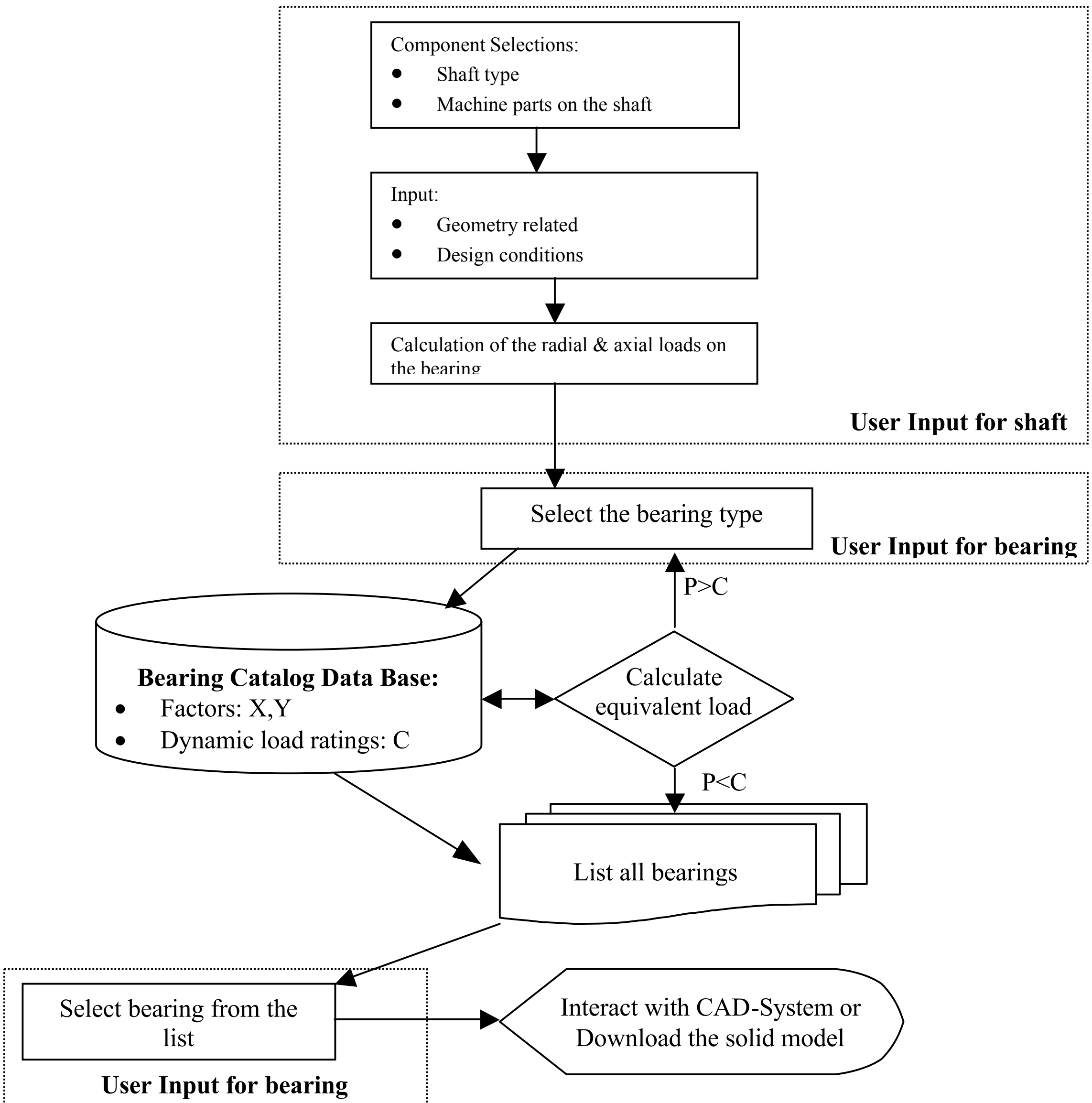

Figure 6. Structure of the knowledge-based bearing selector.

8. Conclusion

Various knowledge-based engineering systems developed and implemented by the authors have been described in this paper. The development and implementation of these systems, their capabilities for material, machine, and parameter selection, process design, cost estimation etc. have been shown to be a valuable tool in the manufacturing and educational processes. These knowledge based, artificial intelligence planning systems have shown a reduction in the time to

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properly prepare and execute a task with the quality results normally only attainable by a professional of much greater experience. The availability of such knowledge-based systems in the industry and education will greatly reduce the long and costly lead times associated with developing new products and determining proper component selection and design related issues for manufacturing projects.

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