Using Computers in Machine Design

Edward M. Vavrek
Purdue University North Central

I. Introduction

Machine Elements is a course that covers topics of machine components such as gears, bearings, belt drives, and other power transmission components. The students learn how to size, select, and design these components for machines. It also involves the stress analysis of manufactured parts such as shafts and brackets. I have written 4 programs to be used to assist the student in learning these topics. Each software program simplifies and streamlines the design and selection process by allowing the student to do calculations quickly and easily, while learning the design procedure. The programs follow the manufacturers procedures on sizing machine components. Many manufacturers have their own software to size and select components. The focus of their software is to make it as easy as possible for the user to size and select a machine component. Their goal is not to educate the user on how the sizing is done. The difference between a manufacturer's software and this software is this program is intended to teach students how to size and select machine components. This software will explain and show each step of the design procedure. This program will assist in the understanding of machine components.

All the programs are written in visual basic, which is an event driven program. The student can go through the program inputting values into text boxes and initiating events by clicking on command buttons. One significant advantage of the software is, that graphs, figures, pictures, tables, and charts are incorporated into the program so the program functions like an interactive book. The student does not need to look up any information in a textbook or a manufactures catalog. All the information required to solve the design problem is given in the tables and graphs in the program. The program is visual and interactive which helps guide the student through the design process. The user should have some basic knowledge of machine elements before using the program. Most inputs are taken from graphs, charts, or tables so the student sees where and how the information is obtained and used. Outputs are shown with their appropriated figures, drawings, or calculations to assist the student in understanding what the output means.

The software program has a main menu to allow the user to select different options. Some of the programs the student can select from are: Belt Drive System Analysis, Single Row Ball Bearing Design, Spur Gear Design, and Horsepower Requirements for Equipment. These software programs are used as a tool to help students learn the design process. The students are lectured on the topics mentioned above, and solve problems on these topics. The students can solve the same problems using the software. Design problems are an iterative process by nature. As the user goes through the process of designing a machine component, the first output is usually not acceptable. The user recalculates the design problem changing certain variables to improve the design output. The software has the advantage of calculating minor changes to the problem easily and quickly so you can make changes to the problem and see how it affects the output. This allows students to progress to more advanced problems. Also the software shows how all calculations are done so students understand what the software is doing. The following sections will describe some of the different programs and how they are being used.

II. Belt Drive Analysis Program

This program has the students learn how to size and select a belt drive system. A belt drive system[1] consists of two pulleys, two bushings, two keys, and a belt as shown in figure 1. Belt drive systems are used to transmit power from one source to another.

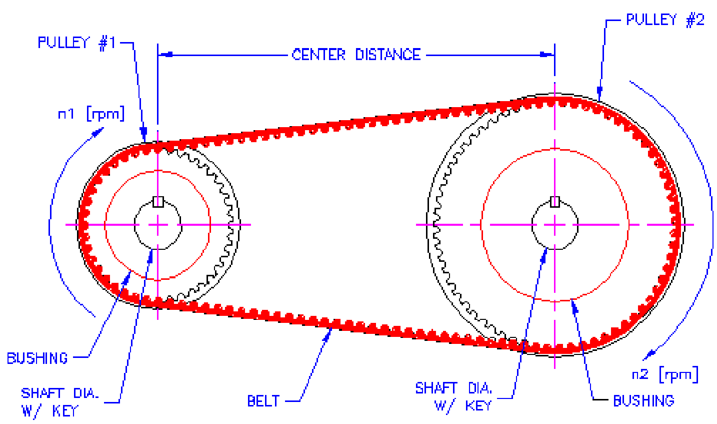

Figure 1 Belt Drive System

The program starts with the main menu shown in figure 2. The main menu has six options the student can select from. The first option is the student can select is the *Pulley Specifications* command button.

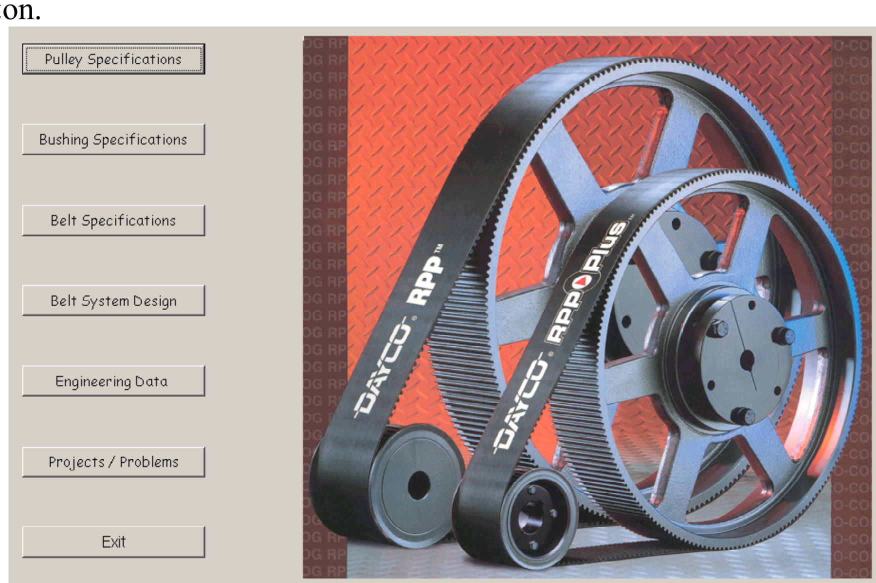

Figure 2 Belt Drive Main Menu

This shows the different specifications of the pulleys. Synchronized belt drives can have either

English or metric belt pitches. This program covers the metric pulleys and belts. The common belt pitches are 5 mm, 8 mm, 14 mm, and 20 mm. This program only uses only the 8 mm and 14 mm belt pitches to simplify the number of options the student has. The program shows the dimensional information of the different pulleys based on number of teeth and width of the pulley. It also shows a picture of the different pulleys. For example, if the student wanted to view the information on a 36 tooth-8 mm belt pitch-30 mm wide pulley, the program would show all the dimensional information and a picture of the pulley and bushing. It would also give the maximum and minimum bore sizes, show what bushing is required for the given pulley, and give the weight of the pulley and bushing selected.

The next option the student can select from is the *Bushing Specification* command button. A bushing is used to mount and lock the pulley to the shaft. It also allows the manufacturer to mass produce pulleys and bushings, because the pulley would never change and the bushing would be modified depending on shaft diameter. The bushing bore is changed depending on the size of shaft required. There are different bushings depending on the pulley size. As the pulley and bushing are bolted together on the shaft, the bushing clamps the shaft for a positive drive connection. The bushing is also keyed to the shaft so the bushing does not move relative to the shaft. For example, a 36 tooth-8 mm belt pitch-30 mm wide pulley uses a "SH" bushing.

The next option the student can select is the *Belt Specifications* command button. This shows the different sizes of belts available. This also gives the weights of the belts and explains the nomenclature of the belt.

The next option is the *Belt System Design* command button. This takes the user through the process of sizing and selecting a belt drive system. A belt drive system consists of two pulleys, two bushings, two keys, and a belt as shown in figure 1. The belt drive system is sized base on speed and horsepower requirements of the application. The correct length belt needs to be selected in order to have the required center distance between the two pulleys. The pulleys are selected based on speed requirements of the input and output shafts. This is the ratio between input and output shafts. The program takes the user step by step through the selection procedure to determine the number of teeth, size of teeth and width of the pulleys and belt. The student inputs basic design information into the program. All data and design parameters that are required are taken from charts and graphs that are prompted while running the program. The student does not need to reference the textbook to select information from a chart or table. The software organizes all the design parameters and information for the student. The program also includes design problems and applications for the student to solve. These problems are found in the *Projects/Problems* form.

II. Bearing Design Program

The bearing design program assist the students in learning how to size and select a single row ball bearing. The program has the user start off by selecting a bearing based on the diameter of the shaft needed and the series size of the bearing[2]. The inexperienced user would start off with the smallest bearing series and the smallest diameter bore of bearing required. As the student goes through the program and finds the bearing is not acceptable the student can rerun the program with the next higher bearing series or a larger bearing bore or a combination of the two. As the user becomes more experienced in sizing and selecting bearings, the user would select a more appropriate size bearing as a starting point. Students will not achieve this level in this class. Machine design engineers who use bearings on a regular bases do attain this level of knowledge.

The user inputs the bearing speed, radial and thrust loads, and the design life of the application. The program takes the student through the design procedure of sizing a bearing based on the inputs. If the original bearing selected has a rated dynamic load capacity higher than the calculated dynamic load required, the bearing is acceptable. If the bearing is not rated high enough, the user reruns the program with either a larger bearing diameter or a large bearing series. The bearing rated speed also has to be acceptable for the application. The program will give the rated speed of the bearing base on grease or oil. Once the user is satisfied with the bearing selected for their application, the user will select the bearing type based on the application. The different bearing types are sealed, shielded, snap ring. A bearing can use any combination of bearing types base on the application. The program assist the user in selecting a bearing type required for the application. The program gives the bearing dimensional information. It also gives the recommended fit to the shaft and housing. This is based on whether the shaft is rotating or the housing is rotating as shown in figure 3. The student has the option of using metric or English units by selecting the unit option button. The program gives the housing bore tolerance and the shaft diameter tolerance for the selected bearing. The program also gives the recommended shoulder diameter for the inner and outer races of the bearing. These dimensions are used to trap the bearing.

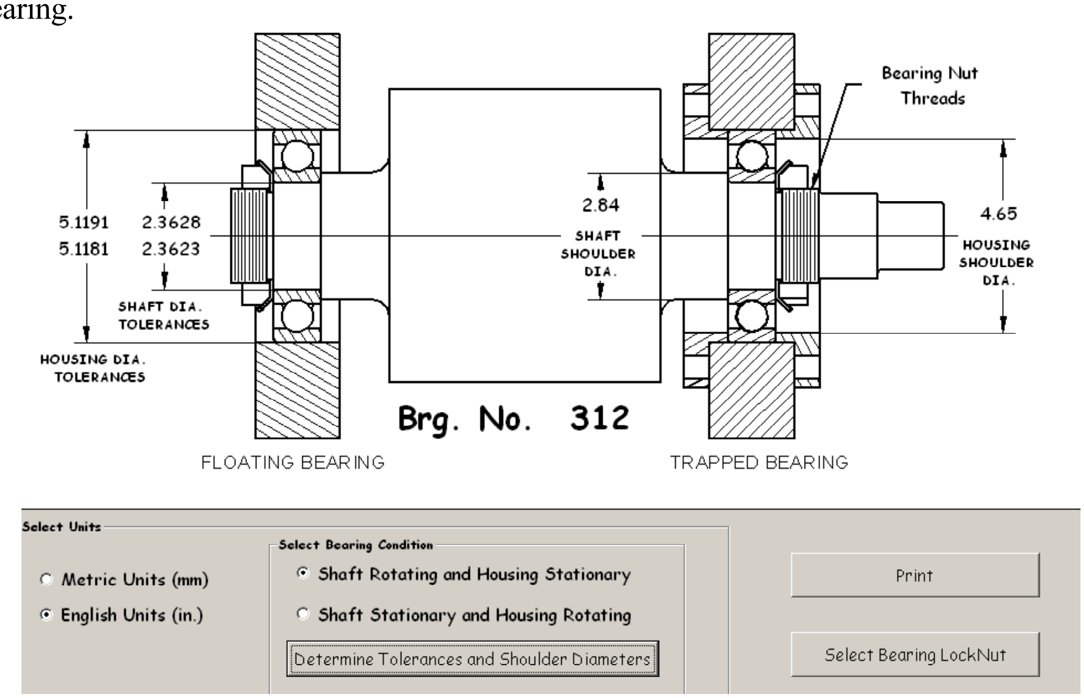

Figure 3 Housing and Shaft Dimensions for Bearing Selection

Next the program allows the user to select a bearing lock-washer and locknut for the bearing selected. The bearing lock-washer and locknut are used to trap the bearing. The program shows dimensional specifications of the lock-washer and locknut. The program also gives the shaft thread and keyway information for the locknut. This information is used to dimension the shaft on a detailed drawing. Specifications such as major diameter, minor diameter, pitch diameter of the thread is given. The last form summarizes all the inputs and outputs of the bearing design program as shown in figure 4. The ball bearing form shows the ball bearing selected is bearing number # 212. It shows the bearing type selected was a two seal. The bearing locknut and lock-washer select is a number #07. The bearing thrust and radial load, bearing speed, and design life is shown in the inputs. The bearing dimensional information is shown along with the rated speed of the bearing and the rated load capacity of the bearing.

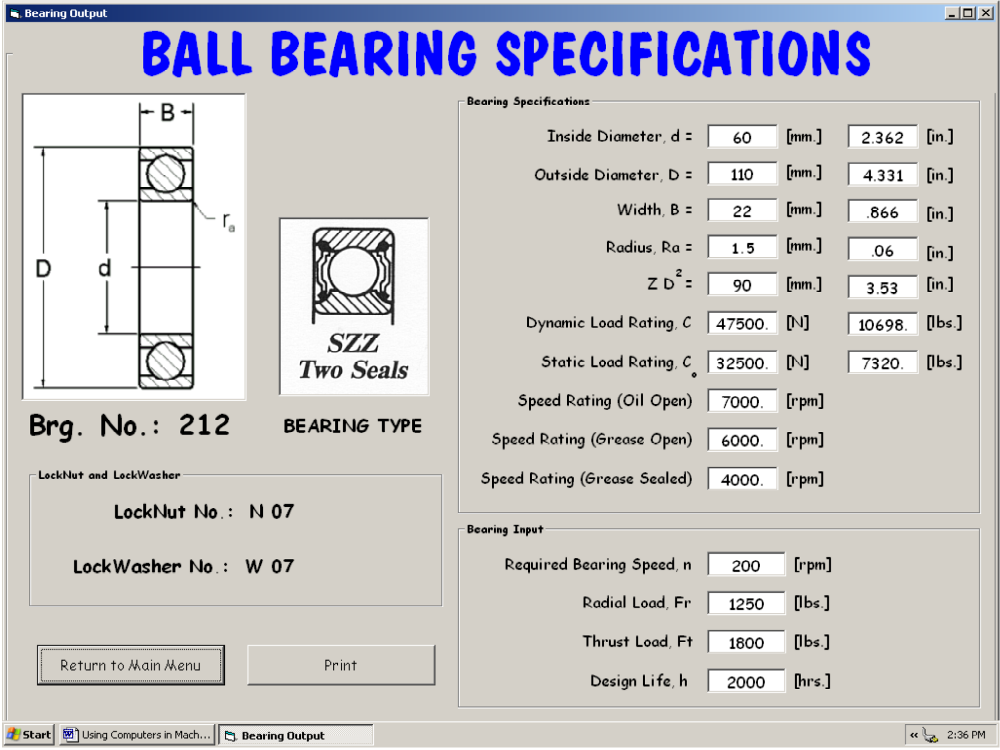

Figure 4 Ball Bearing Selection Summary

III. Spur Gear Design

The spur gear design program assist students in learning how to design a spur gear. The spur gears main menu shown in figure 5, allows the student to pick from two options. *Spur Gear Features and Dimension Over Wires* and *Spur Gear Material Based on Bending and Contact Stress.*

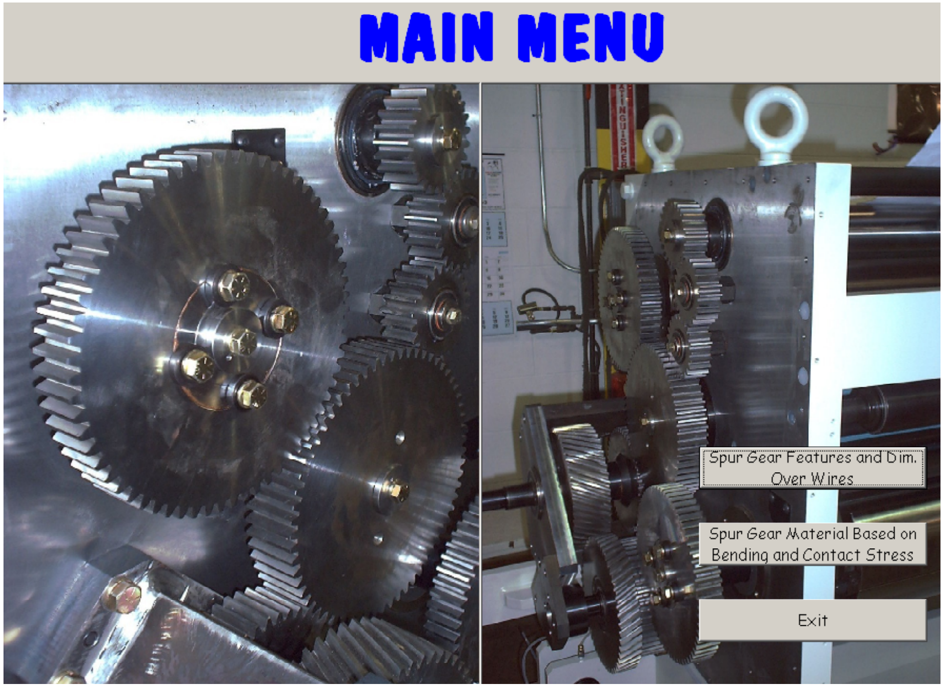

Figure 5 Spur Gear Main Menu

The first choice allows the student to calculate gear features and dimension over wires that are needed to manufacture a gear. The input form allows the student to enter basic spur gear inputs, such as diametral pitch, number of teeth, and pressure angle[3]. Figure 6 shows some of the calculated gear features output. The output is displayed with a figure and equations to explain how the output was determined and what the output means. The software is designed to assist students in learning the design process. The point of the software is not only to make it easy to select a machine element component but to be able to understand what the design process is. The student can print the output or just view the output.

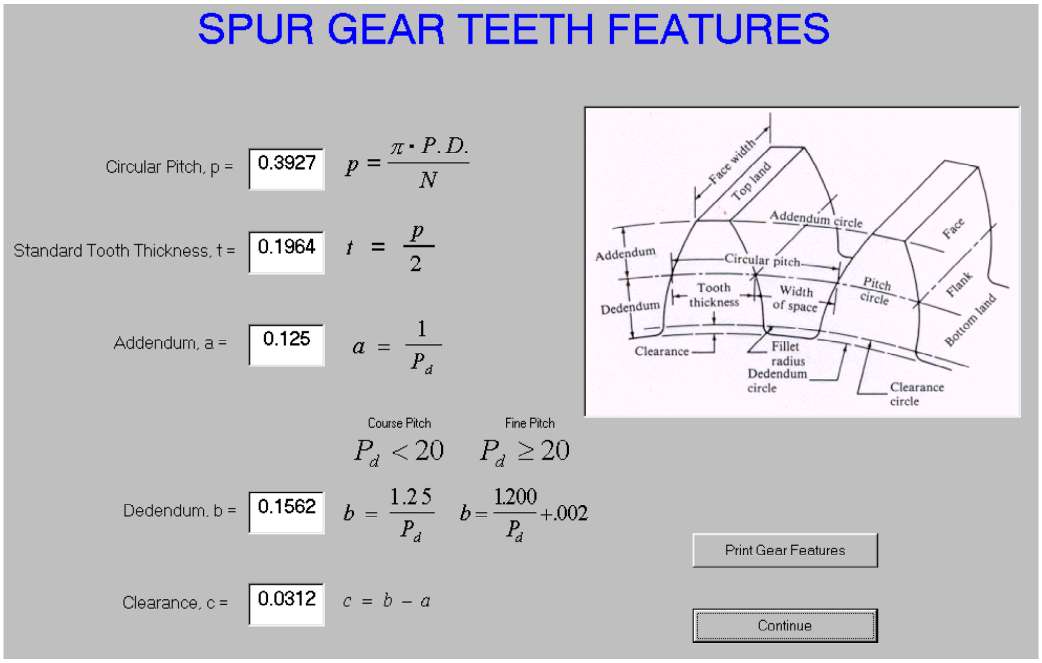

Figure 6 Spur Gear Features

The last calculation made on this part of the program is to determine the dimension over wires. This form allows the user to select pin diameter, input backlash to calculate the dimension over wires. This information is relevant to the manufacturing of a gear, and would be stated on a detailed drawing.

The other option in the gear analysis program is to select a gear material based on bending stresses or contact stresses[4], refer to equations (1) and (2) respectively.

$$s_{at} = \frac{W_t \cdot P_d \cdot SF}{F \cdot J \cdot Y_N} \cdot K_o \cdot K_s \cdot K_m \cdot K_B \cdot K_v \cdot K_R \qquad (1)$$

$$s_{ac} = \frac{K_R \cdot SF}{Z_N \cdot C_H} \cdot C_p \cdot \sqrt{\frac{W_t \cdot K_o \cdot K_s \cdot K_m \cdot K_v}{F \cdot D_p \cdot I}} \qquad (2)$$

The spur gear program will assist the user in selecting a material based on bending stresses and contact stresses. This is a long and involved process to select a material. There are many factors and inputs that must be determined, as can be seen from the two equations shown above. This program is an excellent tool to help the student to sort through and organize all the steps to the process. There are many inputs and factors that need to be determined. Each form is set up with the appropriate table, graph, or chart to help determine the factor required. The software works very well for this type of problem. The final form shown in figure 7 has the student select a material for the pinion and the gear based on the bending stress calculated.

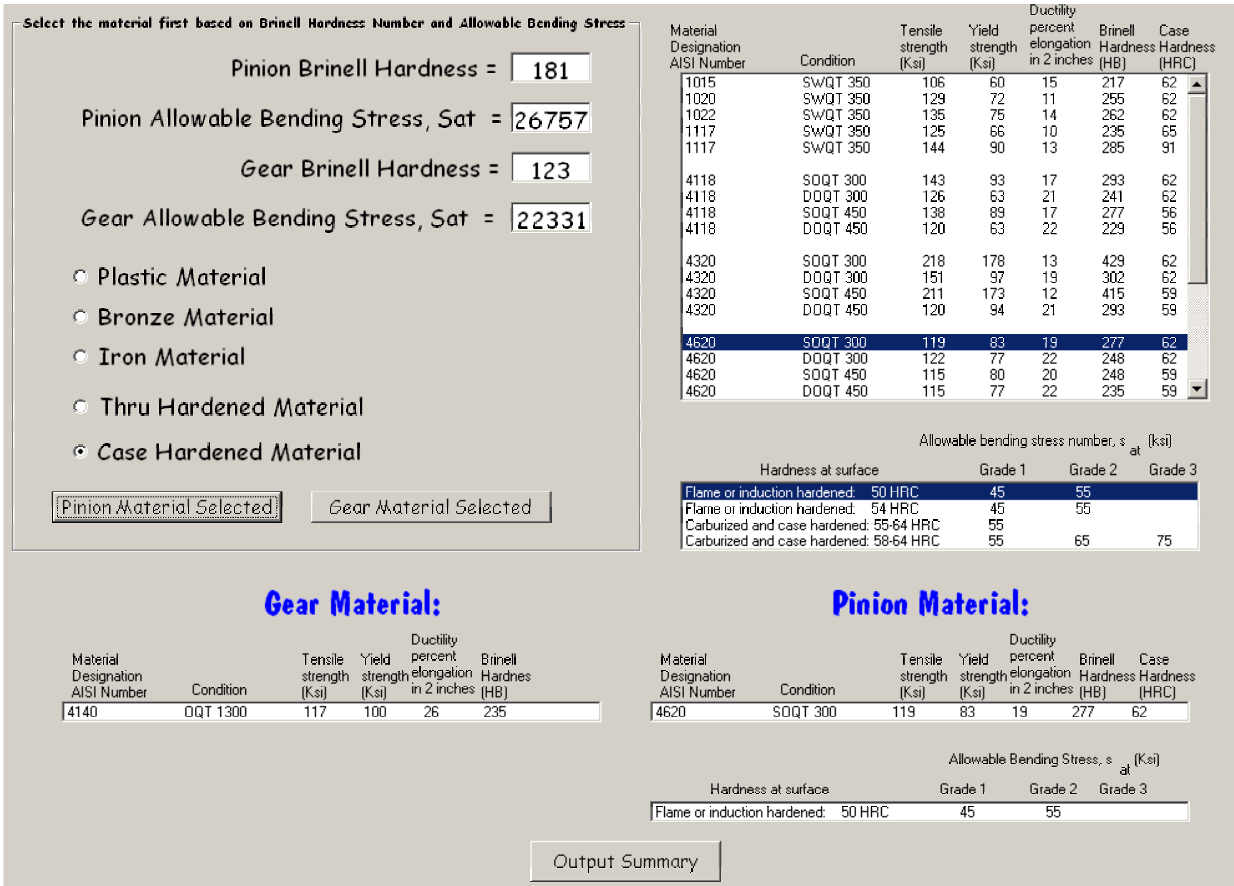

Figure 7 Material Selection Based on Bending Stress

The next section of the spur gear program has the student select a material based on contact stress. This follows a similar procedure that was done for selecting a material based on bending stress.

IV. Horsepower Requirements for Machine Design

Horsepower requirements for machine design is an important part of the design process. This program allows the student to analyze three different power requirements as shown in figure 8. The student can analyze the power requirements for a rotating roller, conveyor system, or a lead-screw drive system. Selecting one of the three drive analysis command buttons, will take the student through the design process for that selection. The student enters inputs such as speeds, sizes, loads, and other information required to run the calculations. The conveyor system analyzes the power requirements for moving a load on a conveyor and rotating a roller based on speed and the time requirements. The lead-screw analysis calculates the required torque and horsepower to move a load on a lead-screw. The roller design calculates the power requirements to start or stop a roller in a set time.

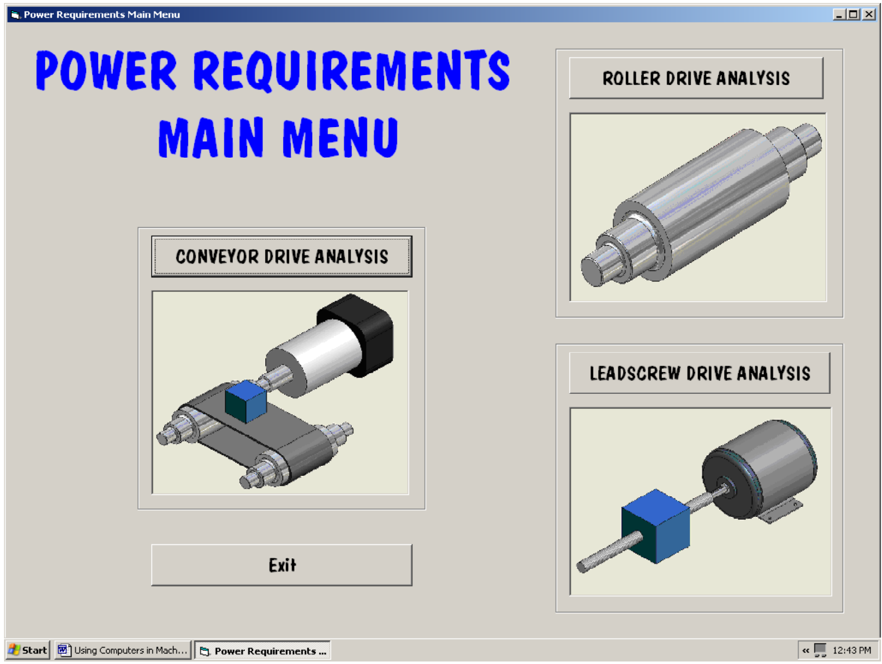

Figure 8 Power Requirements Main Menu

The roller design analysis form is shown in figure 9. The student can select from either a hollow roll or a solid roll. The student enters the dimension size of the roller into the text boxes and the material of the roller. The student also enters the speed requirements of the roller and the motor inertia. This information is used to calculate the power required to rotate the roller.

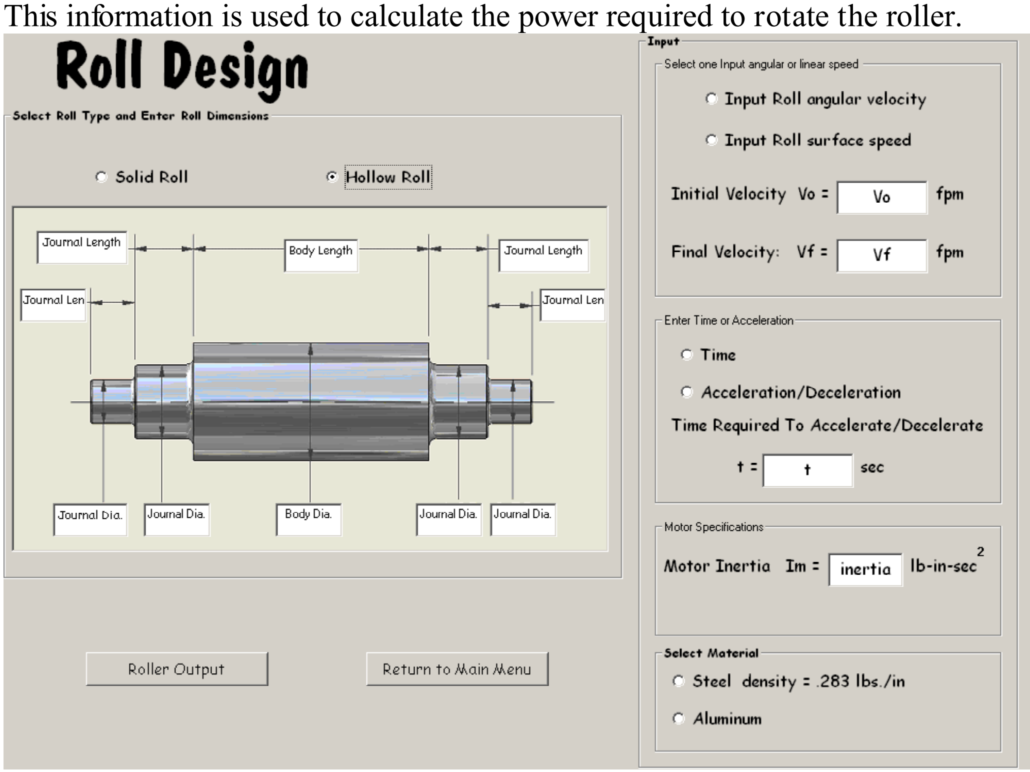

Figure 9 Roller Design Form

V. Conclusion

One advantage of using this program is the ease in which the user can rerun the program and make minor adjustments. This is important feature of the area of design, since design is an iterative process in nature. This program is made as an educational tool to assist the student in solving design problems. There are many design programs that assist the user in sizing and selecting machine elements. This program focuses on educating the user in sizing and selecting a machine components. This is the difference in this program and a manufacturers design programs. The manufacturer will make the program as simple to use as possible. The user will enter the inputs and the program will perform its function and give the user an output. This program makes the user go through the all the design steps to teach the user the design process. The purpose of this software is to assist the students in mastering skills in machine components design. The programs follow the manufacturers recommendations of sizing and selection of the machine element. The program allows the student to easily step through the process of selecting the components. It also reinforces the design principals and analytical techniques of properly selecting and sizing a component.

The gear program, belt program, and bearing program are finished. The power requirement program is a work in progress. Some of the topics that will be included in future programs are shaft design, seal selection, coupling sizing, clutches, and brake selection. Assessing the impact the software has on student learning will play an important roll in the development of the software. Student input and feedback is necessary in order to gear the software in a way that will enhance student learning. Although the software has been introduced to the students on a preliminary basis, the student feedback has been very positive. Also there has been a positive response from faculty teaching in the area of machine elements. My goal for the software is to complete all topics mentioned above and make the software available on a CD or through a web site.

References

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4 American Gear Manufacturers Association. Standard 2001-C95. *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*. Alexandria, VA: American Gear Manufacturers Association, 1995

Edward M. Vavrek
Edward M. Vavrek is an Assistant Professor of Mechanical Engineering Technology at Purdue University North Central. He has a B.S. in Mechanical Engineering from Purdue, a Masters degree in Mechanical and Aeronautical Engineering from Illinois Institute of Technology, and a Masters in Business Administration from Indiana University Northwest. He has worked as a design engineer for 14 years in various industries.