Session 2793

Development and Implementation of a Virtual Gear Design and Simulation Tool for Undergraduate Education

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Abstract

Gear drives are the most important mechanisms in transmitting mechanical power compromising several cost effectiveness and engineering advantages. Most of the undergraduate level-engineering design courses detail the design, assembly, and classification of gear drive systems. So many universities also have a separate course for the advanced design, analysis and performance of the gears at the graduate level.

With the aid of powerful computers, many software systems are developed for design and analysis of gears. The processes from design to manufacturing of gears are automated with the developed CAD/CAM systems. The developed programs can also be used in the production of visual materials in education.

The objective of this study is to prepare visual gear design materials for Machine Design courses and establish a design system in CAD laboratory, so that the students can run the program with their own design parameters.

Engineering Design Curriculum

In Mechanical Engineering Design Curriculum of Istanbul Technical University, there is a number of core courses in the junior and senior levels. MAK341, and MAK342 are the core courses for all junior students. MAK422E is an elective course for the senior students[1].

The developed gear design system has been actively used in MAK342 course. Students have practiced it in the lab and lecture hours and some homework and design projects have been assigned to student teams since Spring 2002 Semester.

The following gives a brief description for the Design Curriculum:

MAK 341 - Machine Design I (3+2)
A quick review on the material science and strength of the materials are given. Then the fundamental design knowledge about the welding, soldering, and riveting technology is covered. A number of machine components (i.e. shaft, bolt, nut, screw, spring, bearing, and lubrication technologies) is covered in detail.

MAK 342 - Machine Design II (2+2)
Various gear mechanisms are covered with detailed design projects. Belt and drum systems and chain mechanisms are also given.

MAK 422E Engineering Design (3+0)
The project based product development process is practiced from problem identification through detail design and evaluation.

Program Development

A command line BASIC program is the main input mechanism for the gear design program. The equations for involute tooth profile formulated by Salamoun and Suchy[2] is taken to the core program to generate the tooth form accurately. The inputs are entered to this core program through the BASIC code. The following is the list for the inputs: module, number of the teeth, pressure angle, helical angle and addendum modification factor. The flow diagram of the BASIC program is presented as seen in Figure 1.

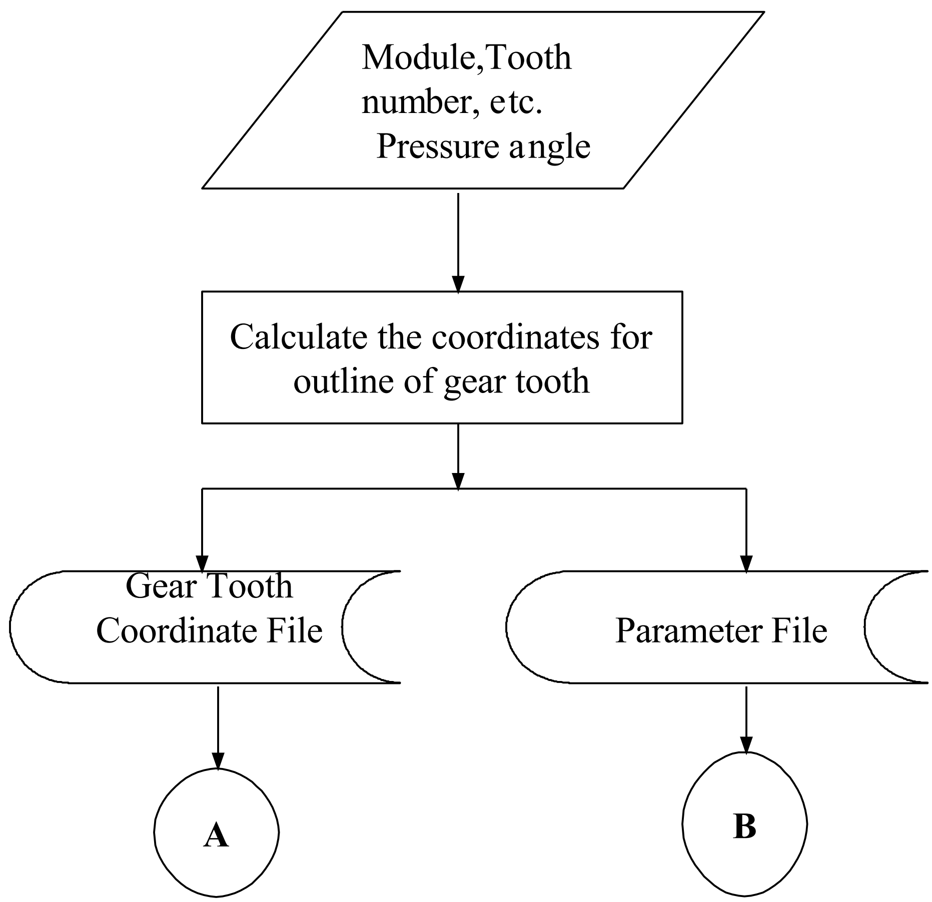

Figure 1: The Flow Diagram of Generating Tooth Profile Data

All inputs are used in a number of different calculations to estimate the coordinates of the points that determine the profile of the gear. The coordinates are saved in a data file so that they can be used in graphical processor called GRAPHER-1.32. The outline of the gear is generated in GRAPHER[3] by reading the coordinate file.

A different Finite Element program has also been created for the generation of the solid model of the gear tooth. This program has been accomplished by using ANSYS 5.4. Another output file from the BASIC program includes parameters that are needed for establishing the finite element model of the gear and used for applying boundary conditions to ANSYS® system automatically.

The flow diagram of the developed system that produces visual gear materials is shown at Figure 2.

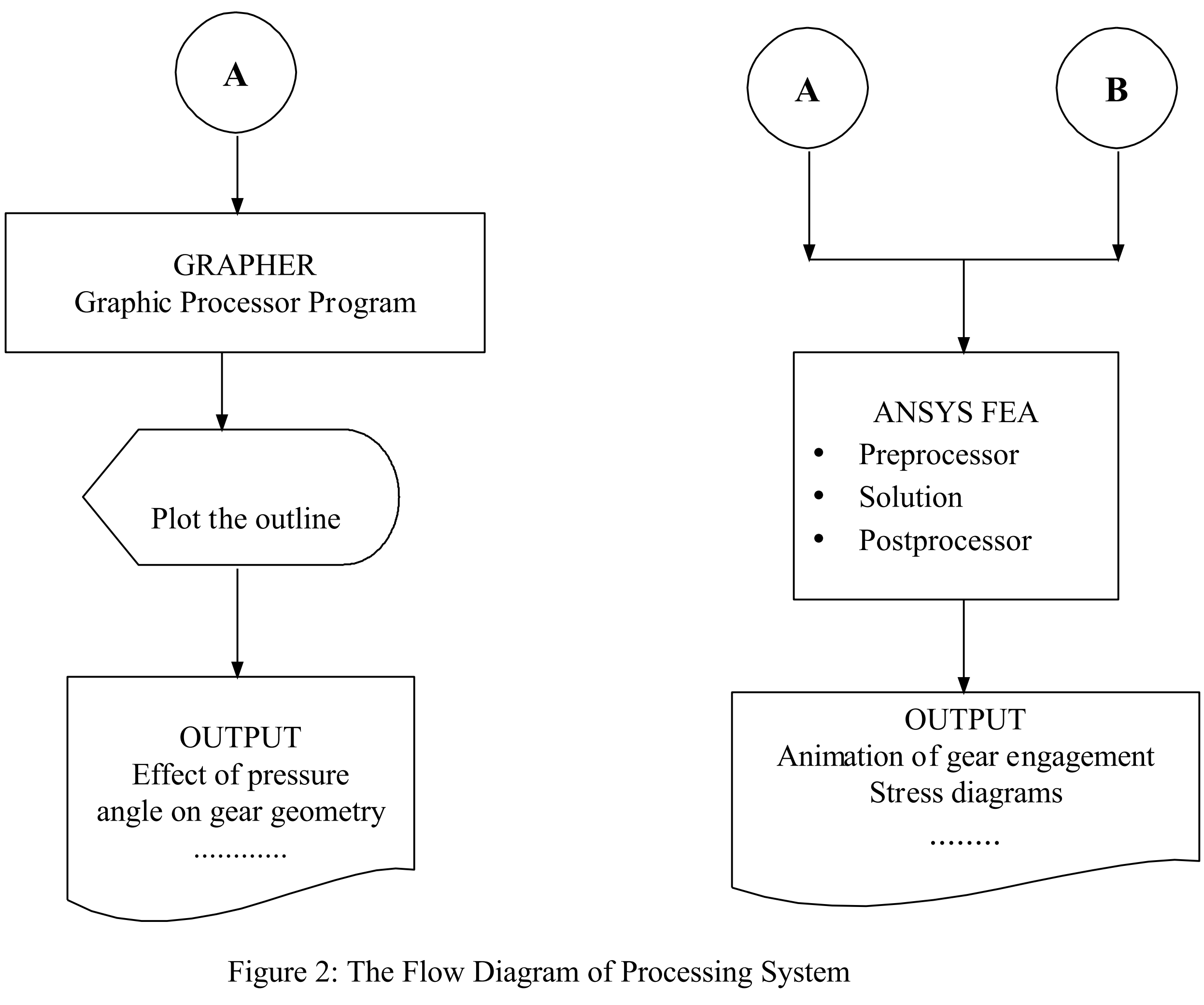

Figure 2: The Flow Diagram of Processing System

Case Studies

Many case studies were developed to enhance our students' comprehension and understanding. This tool has been used as a visual aid for course lectures and laboratory practices in MAK 342.

Case studies cover many different runs related to pressure angle, addendum modification factor, helix angle, effect of tooth number to the geometry. A bunch of different cases and views will be given in the following sections.

In Figure 3, the effect of pressure angle to gear geometry is presented. The student can easily examine that at higher pressure angles the tip of the tooth is peaked and at lower pressure angles undercutting occurs.

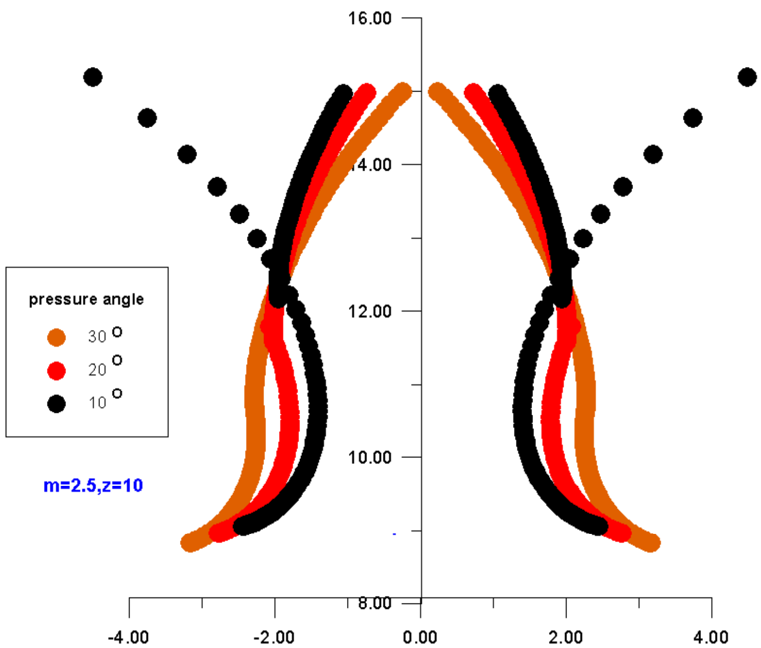

Figure 3: The effect of pressure angle on gear geometry

The effect of addendum modification factor on gear geometry is shown in Figure 4. There is a maximum value for the addendum modification, which results in a pointed tooth and a minimum value causing severe undercutting.

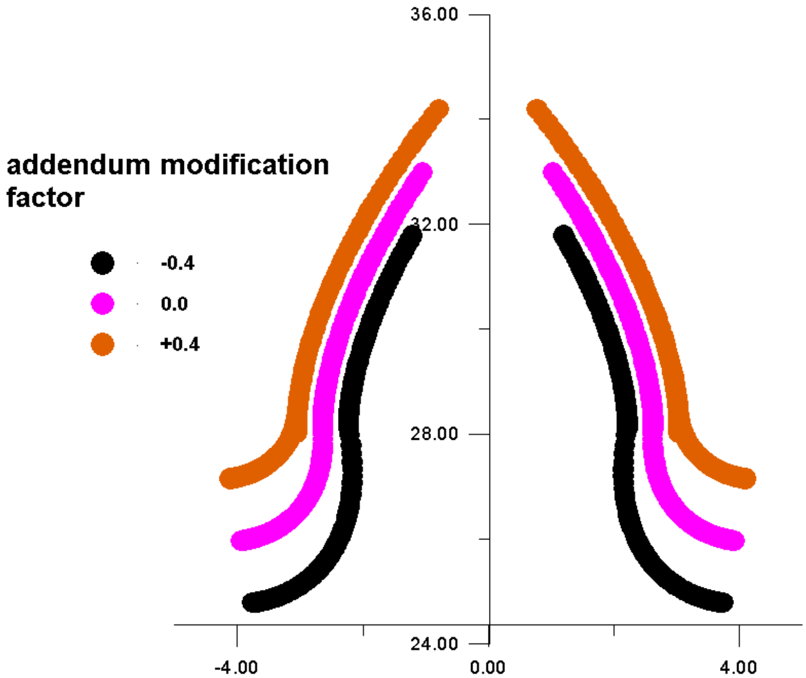

Figure 4: The effect of addendum modification factor

The undercutting occurs at lower teeth numbers. The fillet curve cuts the involute curve above the base circle so the active profile is reduced. (Figure 5)

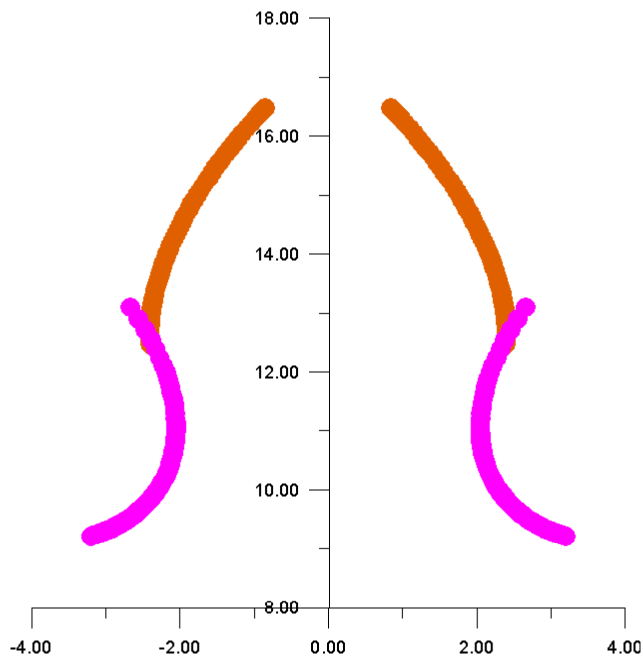

Figure 5: Undercut gear

The shape of the gear tooth for higher tooth numbers is shown in Figure 6. At higher tooth numbers, the base circle is below the addendum circle.

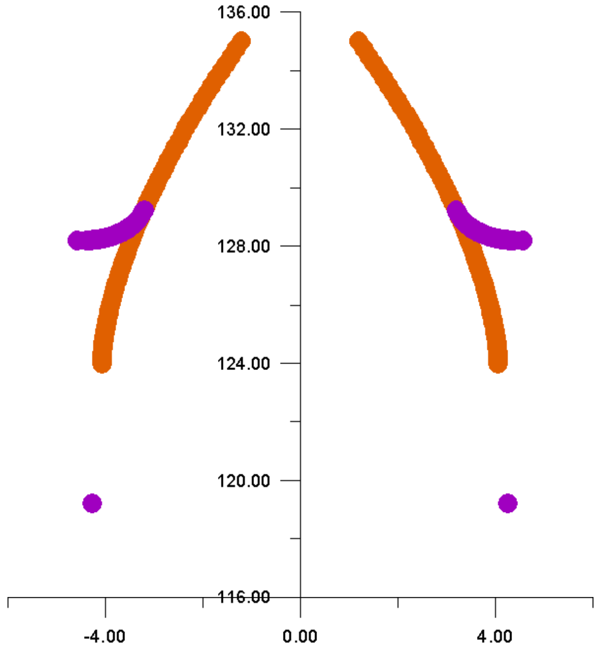

Figure 6: Gear geometry at higher tooth numbers

The effect of helix angle to gear geometry for a given tooth number is shown in Figure 7.

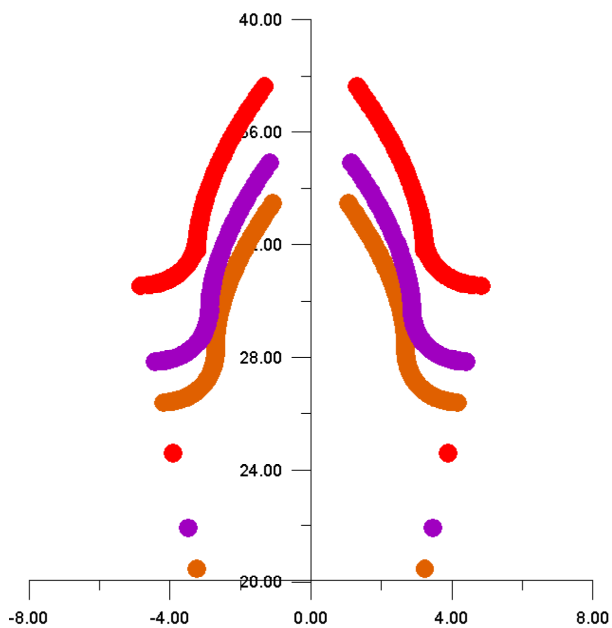

Figure 7: Effect of helix angle for a given tooth number

The animation file that displays gear pair during the engagement cycle is constructed at the preprocessor module of the ANSYS FEA® program. A program, which consists of ANSYS commands for creating this file, reads output files of the BASIC program. As can be seen in Figure 8, the gear pair is shown at the beginning of the engagement cycle.

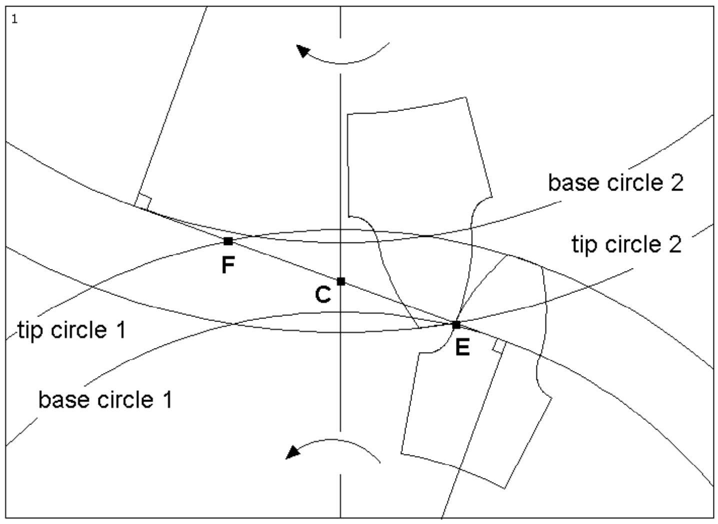

Figure 8: Start of the engagement

The equivalent cylinders for Hertzian stress model are also constructed as shown in Figure 9. Cylinders are drawn for each contact point during the engagement cycle.

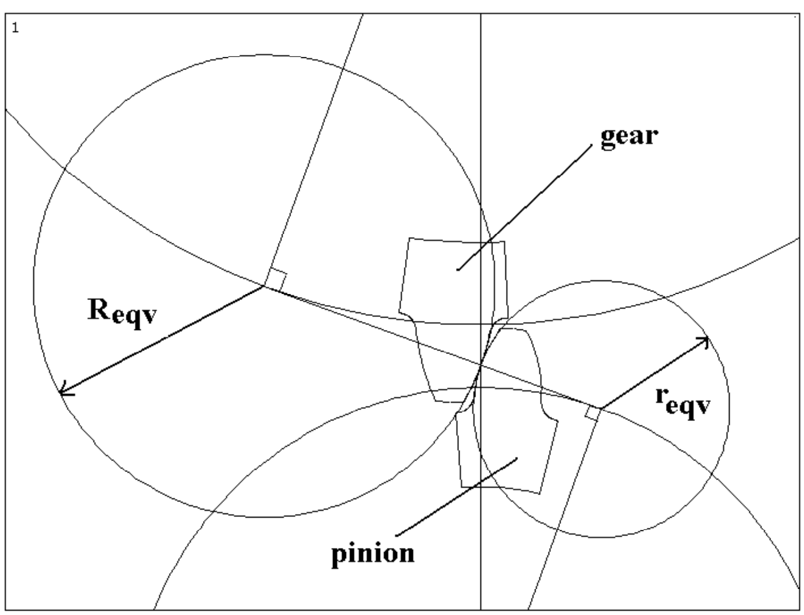

Figure 9: Equivalent cylinders for Hertzian stress model

For analyzing the variation of the tooth stresses during engagement a specific finite element model of the tooth is developed at ANSYS program. The model is solved for each contact points. The results of this series of solutions, when assembled, provide a pseudodynamic stress time history for a tooth[4]. The animation file obtained as a result of this process is used at the finite element course laboratory practices too[5]. The model developed is shown at Figure 10.

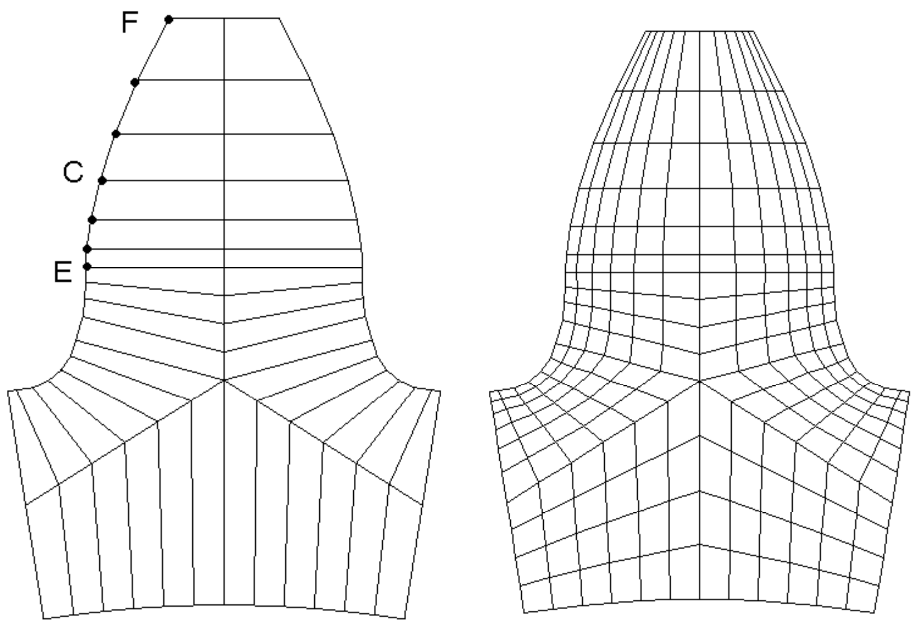

Figure 10: The construction of the finite element model for analyzing the tooth stresses during the engagement

Establishment of the System in CAD Laboratory

The developed system was installed at the CAD laboratory of the Mechanical Engineering Department. All the visual materials given above can also be seen at the web page created by Fetvaci[6]. The students at the laboratory can run the developed program and obtain the visual materials as a result of input values that they determine. The system will be also established in web environment soon, so that the students can easily reach the system via Internet. However, most of the practices have been used in a WebCT based, Industrial Computer Aided Design Course offered by Fidan[7]. Students practiced a number of different case studies developed by Fetvaci. Figure 11 shows a brief view from a sample lab window.

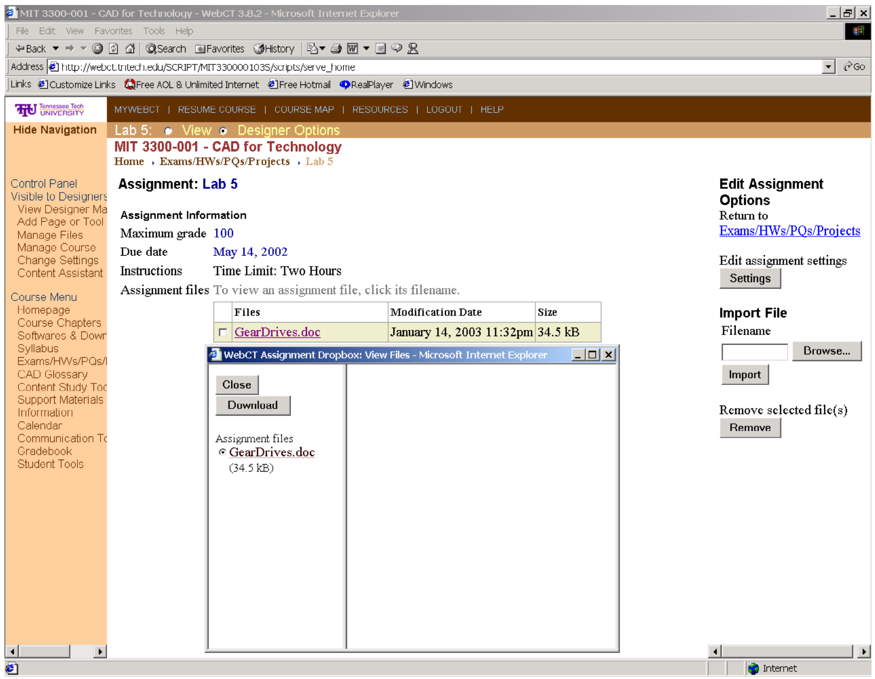

Figure 11: Sample Lab Window from WebCT-based Design Course

Conclusions

The computer-aided development of visual gear design materials for education helps the students to obtain the fundamental gear knowledge interactively. Students use their own parameters and comprehend the course topics given at the machine design course easily. This method also helps the students to enhance their own creativity.

Bibliographic Information

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7. http://iweb.tntech.edu/ifidan

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Dr. Ismail Fidan is a faculty member at the MIT department of Tennessee Tech University, Cookeville, TN. He began his academic appointment in August 2000. Dr. Fidan received his PhD in Mechanical Engineering from Rensselaer Polytechnic Institute in 1996. He is a senior member of IEEE and SME, and member of ASEE, NAIT, ASME, TAS and SMTA. Dr. Fidan also serves as an associate editor for the IEEE Transactions on Electronics Packaging Manufacturing and editorial board member for the Journal of Industrial Technology and SAE Transactions. Dr. Fidan is the recipient of 2003 Tennessee Tech University Exemplary Course Project Award, 2003 SME Outstanding Young Manufacturing Engineer Award, 2002 Provost 'Utilization of Technology in Instruction' Award, 2002 Technology Award by The Institute for Technological Scholarship, 2001 NAIT Outstanding Professor Award. His teaching and research interests are computer integrated design and manufacturing, electronics manufacturing, and manufacturing processes.