

MATLAB Courseware for Machine Design

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Abstract

MATLAB Courseware for Machine Design is a comprehensive collection of MATLAB modules to supplement teaching and learning in machine design. The courseware is to help users visualize the computation process with interactive graphics. Each courseware module has a GUI (Graphical User Interface) with a consistent format to allow users to enter data and display results in both graphical and numerical forms. The GUI allows a different set of input before quitting for “what-if” scenarios. Additionally, each module has a help window to explain the computation process.

Introduction

Equations, tables, and figures in engineering textbooks are being supplemented by electronic versions to automate the computation process. For example, Roark's Formula for Stress and Strain [1] has an interactive version based on TK Solver [2]. The Engineering Mechanics Toolbox [3] is a MATLAB package to supplement textbooks in Mechanics of Materials, covering axial loading, shafts, beams, columns, and Mohr's Circle.

The MATLAB courseware is developed to assist teaching and learning in machine design. For example, it takes a long time to demonstrate one example of the shear force and bending moment diagrams of a beam because the computation and drawings are quite extensive. With the courseware, many examples can be illustrated quickly and effectively, and students can use it after class to review the concept and for homework assignments.

MATLAB is chosen for the courseware because in many universities, it is the primary computational software in engineering. MATLAB integrates computation, visualization and programming in an environment that is easy to learn and use. MATLAB is also easy for GUI development with GUIDE (Graphical User Interface Development Environment) [4]. GUIDE provides a set of tools to create a GUI by dragging and dropping different components, a process similar to that in Visual BASIC [2]. However, as compared to Visual Basic, codes in MATLAB are much shorter and the coding is much faster.

Courseware Overview

The courseware covers topics in strength of materials, static and fatigue failures, and design of machine elements. For the subject of strength of materials, a module calculates and plots bi-axial and tri-axial Mohr circles (as shown in Figure 1) with a GUI of biaxial stresses as input, and principal stresses and the maximum shear stress as output. In Figures 2a and 2b, the beam module

calculates and plots shear force and bending moment diagrams of a simply supported beam and an overhanging beam respectively, with a GUI of loads and beam dimensions as input, and the maximum moment and shear force as output. In Figure 3, the column-buckling module displays Euler equation, Johnson's equation, and secant equation.

For the subject of static and fatigue failures, the module on the static failure of ductile materials calculates safety factors of given stresses based on the maximum shear stress theory and distortion energy theory respectively, and the module plots the contours of different theories, as shown in Figure 4. In Figures 5, the static failures of brittle materials are shown with Column-Mohr theory. In Figure 6, the fatigue failure module calculates safety factors based on Goodman, Gerber, Soderberg respectively, and plots the contours of different theories.

For the subject of design of machine elements, the gear dynamic factors module is to calculate the factor based on input parameters and to plot a family of curves, as shown in Figure 7. In Figure 8, the gear geometry factors module is to calculate the factor based on input parameters and plot a family of curves. In Figure 9, the bolted joint module calculates the force on the bolt and clamped members with an external load and initial preload.

Applications in Classroom

Using computers to assist teaching is getting easier as the hardware cost is getting lower. Many classrooms in the author's university are now equipped with network connections and ceiling-mount LCD projectors. For instructors, the courseware can expedite the computation process with accurate results, and can present accurate graphs with multiple colors in production quality.

Although graphs are effective to present an overall picture of data, in the past, they can only be represented using transparencies or hand drawings on the board. To those instructors who lack drawing skills, it is challenging to draw accurately simple plots like Mohr circles or a complex set of curves like the static failure contours. As compared with transparencies of static images, the computer courseware, with its GUI, not only accurately plots the graphs but also re-plots the graphs with a different set of input data, ideal for "what-if" scenarios.

Another advantage of the courseware is the precision in output results. Courseware modules can better interpolate curves than estimation by sight from a plot in a textbook. This is especially helpful when there is a family of curves, like the gear geometry factors, and reading data correctly becomes challenging. Furthermore, some equations do not have closed-form solutions, like the secant formula in the column buckling, and the computer courseware is well suited for this type of computation.

Discussion

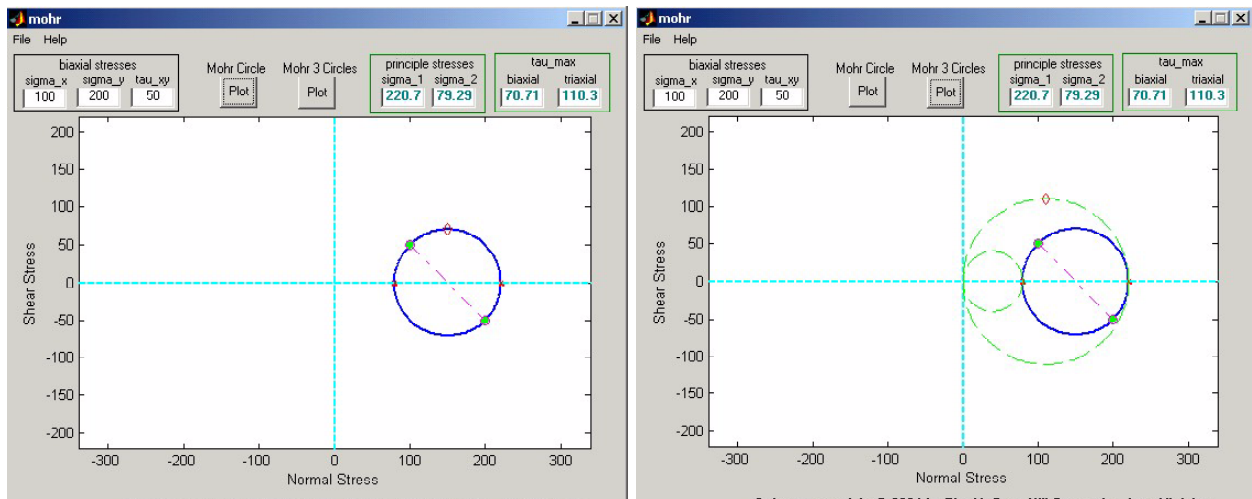
A comprehensive collection of MATLAB modules is developed to supplement teaching and learning in machine design. All MATLAB files are linked to one module with a menu-driven selector, making every module easily accessible.

With the GUI, users who are not interested in the source codes can treat these modules as a black box, and use them as a tool for homework and design projects. Other users can modify the source codes to meet their needs.

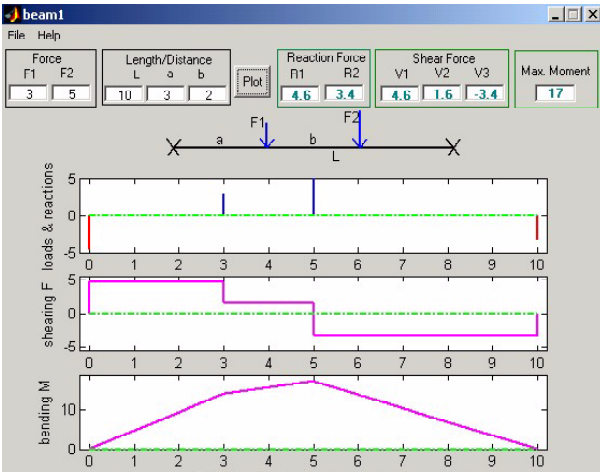
The courseware will be enhanced with additional modules, like stress concentration factors and bearing reliability. Once sufficient MATLAB modules are developed, the courseware can be used as an essential interactive reference resource for practicing engineers. Part of the courseware will be published this year.

Reference:

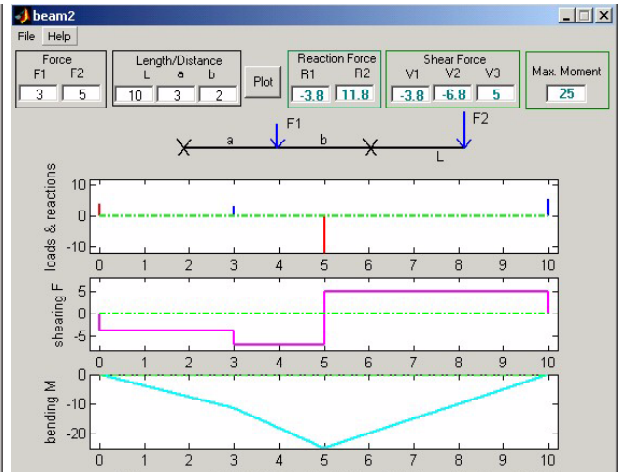
1. Roark, R.J., Budynas, R.G., and Young W. C., *Roark's Formula For Stress and Strain*, 7th edition, McGraw-Hill June 2001.
2. Universal Technical Systems, Inc., *Interactive Roark's Formulas* URL: <http://www.roarksformulas.com/>
3. Mechworks Software, Inc. *Solving Mechanics of Materials Problems with MATLAB*, Prentice Hall, 1999.
4. The MathWorks, Inc, URL: <http://www.mathworks.com>



(a) (b)
Figure 1 Mohr Circle Showing Principal Stresses and Maximum Shear Stress

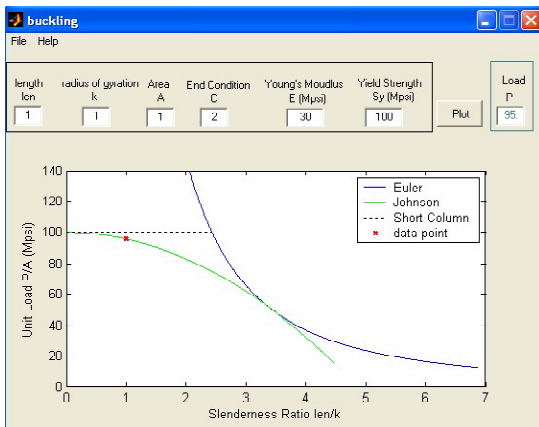


(a)

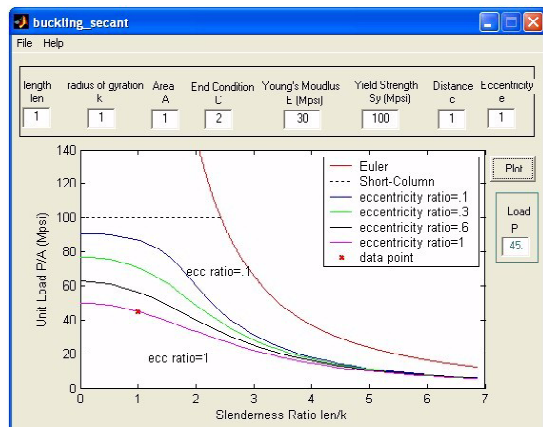


(b)

Figure 2 Shear Force and Bending Moment Diagrams of Beams



(a)



(b)

Figure 3 Column Buckling

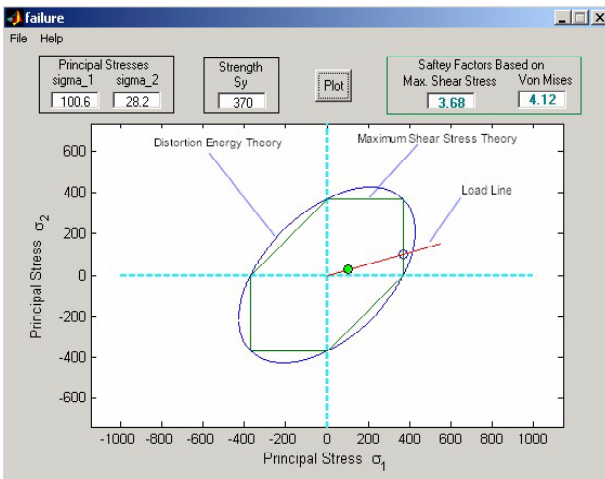


Figure 4 Static Failures

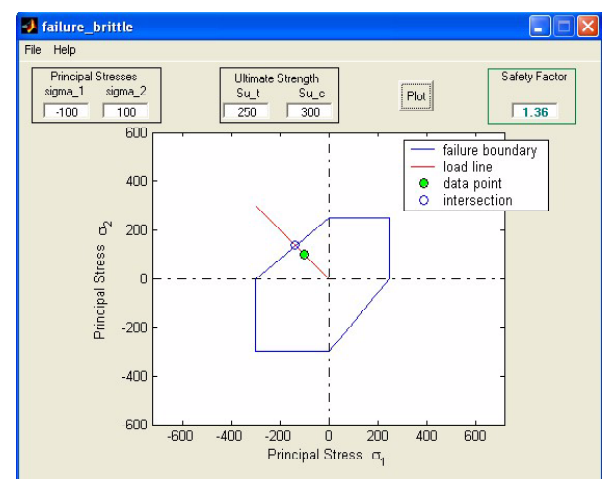


Figure 5 Column-Mohr Theory

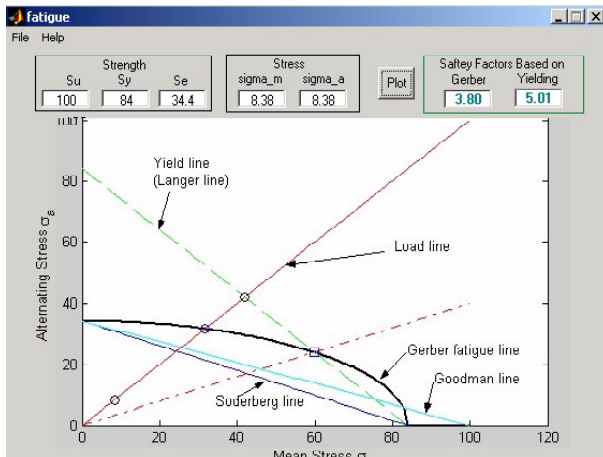


Figure 6 Fatigue Failures

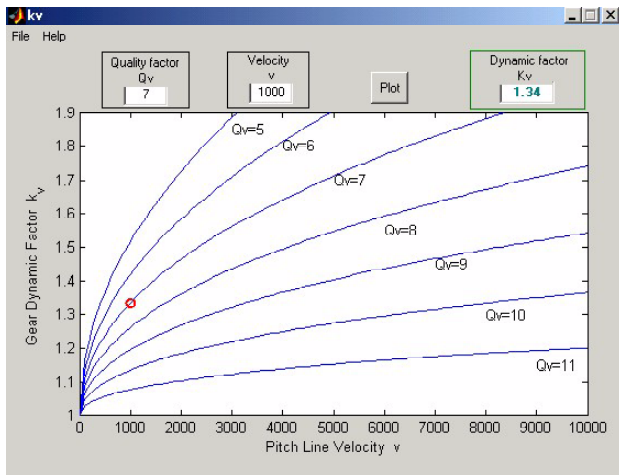


Figure 7 Gear Geometry Factors

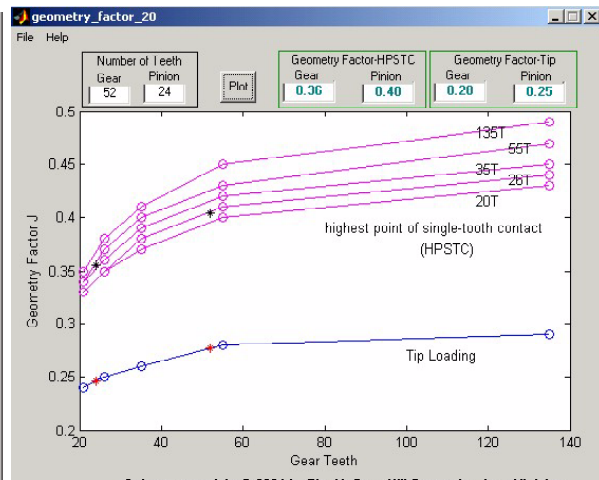


Figure 8 Gear Dynamic Factors

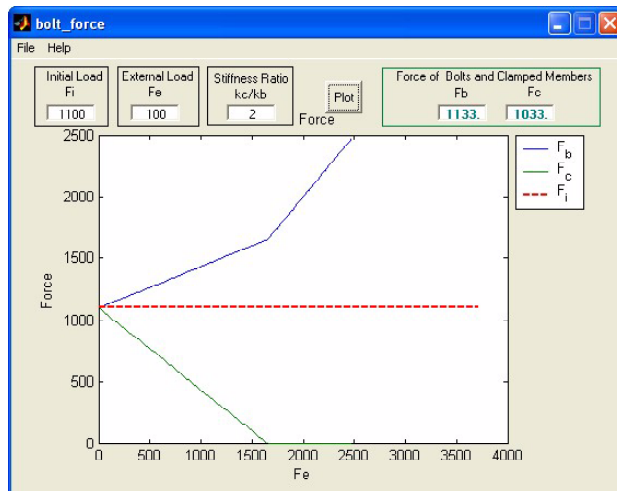


Figure 9 Forces on a Bolted Joint