

GT Shear - An Interactive Graphic Program for Shear and Bending Stresses of Thin Walled Structures

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Abstract

Engineering students historically find it difficult to deal with the subjects of shear and bending stress distribution, and shear flow as it relates to thin-walled structures. This is particularly true for complex cross-section that are common in Aerospace Engineering, such as z-sections and hat-sections. These type of cross sections are unsymmetric in both the vertical and horizontal direction, making hand calculations difficult. As a result, these topics are usually introduced only after students have had several mechanics courses. To assist with the solution of such problems an interactive graphic program, GT Shear, has been developed to design beam cross-sections by graphically showing the resultant shear and bending stress distribution on the cross-section.

Introduction

There has been a growing need over the last decade to use computers in the educational process. However, good engineering programs are generally too complex to use in basic undergraduate structural analysis courses and too costly [1]. To overcome both of these difficulties, topic specific programs that cover only one well defined subject has been developed [2]. These topic specific programs are generally non-commercial and developed by universities specifically for education which minimizes the cost. Since they are topic specific, the learning curve to use the programs are small when compared to a commercial program.

An added benefit with these topic specific programs, is their possible application to design in freshman and sophomore engineering classes. With these programs, freshman students can do engineering design problems without first learning all the theory. This does not mean that the students should not learn the underlying engineering concepts, but it does allow interesting engineering problems to be examined in the early stages of the students training. These programs expose the students to some advanced topics while not being overwhelming and burdensome to

both instructor and student. There are also other factors that have fueled this need namely, cost and availability of such programs.

GT Shear was commissioned to fulfill the need for a program that solves bending and shear stresses as well as shear flow problems of user defined cross-sections. The program is limited to thin-walled structures, since these are the structures commonly encountered in Aerospace Engineering. The thin walled assumptions however do not detract from the usefulness of the program as a learning and design aid for the subject matter.

GT Shear uses a graphical user interface that is intuitive to the Macintosh users and those that are already familiar with the Macintosh or Windows graphical environment should be able to use the program in a short time. Even for those not familiar with the Macintosh or Windows, the simply designed interface is structured to minimize the time needed to learn how to use it. It is assumed that the instructor will not spend any classroom time demonstrating the program.

The program allows users to draw their own cross-sections, place loads (forces and moments) and choose the type of solution desired, see Fig 1. The types of solutions offered are for shear stresses, shear flow and bending stresses. The results of the calculations are displayed superimposed on the structure that the user creates. The program offers the user an effective drawing environment which facilitates the ease of design of the cross-sections. The platform for the program is the Macintosh and the program is designed with a user friendly interface. There is a tool palette on the main screen which allows the user quick access to the drawing and load placing functions of the program. There are also menus from which all of the programs' commands can be executed. The program also displays the maximum and minimum values and the points of their occurrence along the webs/flanges of the cross-section. There is also the facility to have varying thicknesses and moduli. The program is limited to open cross-sections and for the time being there is a limitation on the amount of webs/flanges that a cross-section may possess.

The shape of the web/flanges are assumed to be rectangular (thus there are no rounded edges).

Benefit

This is not a program that replaces the practicality of the classroom and it is certainly not to be used as a substitute for thinking through problems and/or doing problems by hand. However it does aid in finding solutions to what is considered a tough problem for engineering students. This will help students to further understand the subject matter as well as tackle more complex problems, knowing that the solution to the problem can be gained from the program. The design solution is presented in much the way that it is presented in the classroom. The user has the opportunity to change the design and find new solutions in an effort to see the effect of changing the loads and the geometry on the distribution of the shear and bending stresses.

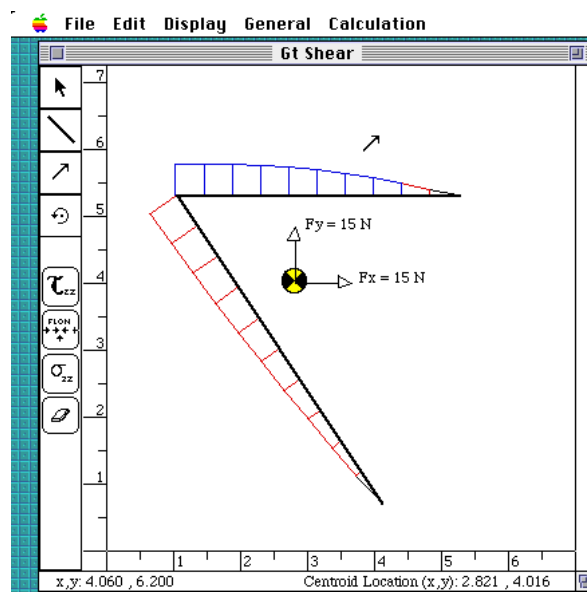


Figure 1. GT Shear interface showing shear flow distribution diagram.

Program Operation

In order to find solutions to problems using GT Shear there are several tools that are helpful to the user. The menu bar is available at the top of the screen (see Figure 1). This allows users access to all the functions of the program which includes customizing program parameters (changing units, zoom scale, etc.). To the left of the screen is the toolbar. When a tool is chosen the cursor will change to indicate that the tool is currently active and will remain active until another tool is chosen. The tools are for editing, line drawing, shear loads and moment loads. Also, beneath the tool bar is the calculation bar indicating the three types of calculations that are possible as well as a clear graph button to remove the graph results. At the bottom of the screen is the information bar which tells the user the location of the cursor on the screen, the length of the part, the angle the part is being drawn and the current location of the centroid.

The user is allowed to draw the cross-section of the beam. This is accomplished by selecting the line drawing tool from the tool bar on the right of the screen. It is important to note that if there is more than one part to the cross-section then all the parts must be connected to at least one other endpoint of another part, before choosing to run the calculations. The thickness and modulus of the members maybe input for each member. This is done by double-clicking on the member and a dialog will appear for inputting the data.

The user is also capable of editing the cross-section. To move an endpoint of one of the members, the member must first be highlighted (dark squares visible on endpoints). Holding the mouse down in the endpoint region and moving the mouse will change the length of the line. To move the whole line, simply hold the mouse down on or close to the member and draw the mouse.

The results are superimposed on the cross-section design. The positive values of the stresses and shear flow are shown in blue and the negative values are shown in red. The values for each segment (at the beginning and end) of the cross-section is also indicated. This information along with the location of the centroid will prove to be valuable in showing students what is happening to the stresses and the shear flow as the cross-section and loading conditions change.

In summary, the user simply draws the cross section, applies the loading conditions and then selects the type of calculation that is needed. The program will then calculate the results and display them in a fashion that is useful and familiar to the user. The simplicity of the operation of the program is designed to allow students a quick way to see the effects of loading and cross-section geometry on the shear flow and shear stresses.

Program Capabilities

Another important aim of the program is to allow students to become comfortable with the subjects of shear flow, shear stress and bending stress. This is done by allowing users to draw a cross-sections of their choice (complexity limited only by the number of webs/flanges), choose the type of analysis and then the program will calculate the stresses based on the input of the user information.

The program was designed to facilitate ease of use in an intuitive environment. Therefore a graphical user interface was adopted namely the Macintosh user interface. The ease of use is gained by the ability to create the cross-sections graphically. The results are displayed in graphically so as to help the user visualize and understand the results quickly. The program is written in 'C' and is currently 60K bytes in size. It has been tested with both Macintosh systems 7.0 and 7.1 using the Mac IIci, Mac IIvx,

Quadra 700, Quadra 840, Classic, PowerBook, and even the new PowerPC 7100.

Certain assumptions were kept in accordance with the limitations of the program. The main assumptions are those assumed in the solution of thin walled structures, thus the thickness of must be small compared to the length of the sides of the cross-section for applicable results. Also, all forces and moments are assumed to act through the centroid of the cross-section.

There are limitations to the operation of the program. The shear flow solutions are limited to the open sections only and as a result, the shear and bending stresses are also limited to open cross sections. Another limitation is the calculations and assumptions made are thin-walled assumptions. As stated before this is to facilitate the programs' use in Aerospace Engineering. Also as of this publication the type of the cross-section is limited to only one material type.

The model for the calculations used in the program are primarily from Megson [3]. The method for calculating the shear flow and shear stress, as shown in Megson, uses the following equation,

$$q_s = - \left(\frac{S_x I_{xx} - S_y I_{xy}}{I_{xx} I_{yy} - I_{xy}^2} \right) \int_0^s t x ds - \left(\frac{S_y I_{yy} - S_x I_{xy}}{I_{xx} I_{yy} - I_{xy}^2} \right) \int_0^s t y ds \quad (1)$$

where t = thickness

$$S_x = \frac{\partial M_y}{\partial z}$$

$$S_y = \frac{\partial M_x}{\partial z}$$

The method for the bending calculations uses the following equation,

$$\sigma_z = \frac{M_x (I_{yy} y - I_{xy} x)}{I_{xx} I_{yy} - I_{xy}^2} + \frac{M_y (I_{xx} x - I_{xy} y)}{I_{xx} I_{yy} - I_{xy}^2} \quad (2)$$

In finding the solution to the problems the program first finds the moment of inertia. This is done by first finding the moment inertia for each part of the cross-section. The total moments of inertia are found by use of the parallel axis theorem. The program then tests the cross-section for integrity, making sure that the cross-section fits the assumptions that are made above. Then the calculations of the stresses can begin.

The calculation of the shear flow and shear stress are similar, differing only by a factor of the thickness, thus the same code is used for both of these calculations. The shear flow/stress for a single part of the cross-section is calculated by stepping along the part and using Eqn. (1) to find the corresponding shear flow/stress at that point in the cross-

section. For complex cross-sections the method used is to find the free ends first. Begin the calculations at the free ends then repeat the calculations until all the members have been calculated. When this is done the program draws the distribution diagrams superimposed on the cross-section.

The program calculates the bending stress, using Eqn. (2), at both ends of each member. The ease of this method is realized since the bending stresses of the cross-section are always a linear function of the geometry of the cross-section. The stress diagrams are then drawn superimposed on the cross-section (though unable to show in the paper, the positive stresses are shaded in blue and the negative stresses are shaded in red).

Summary

This program was developed to assist students in designing structures. With the aid of the graphical user interface, the program facilitates fast construction of cross-sections and quick calculations of the stresses. This helps students to see the effect of how changes in the geometry and loading conditions affect the shear flow, shear stress and bending stresses. Because of the ability to get the results of a design quickly, students are able to understand the subject matter as well as solve a greater number of problems of varying complexity than would be possible using hand calculations.

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References

1. Graham, E.D. and B.L. Willis, "Appropriate Uses of Computers in the Undergraduate Engineering: New Applications and Their Evaluations," 1990 ASEE Conf. Proc., Toronto, Canada, June 1990, pp. 281-285.
2. Gramoll, K.C., "Interactive Beam Analysis Program for Engineering Education," *Computer application in Engineering*, to appear in 1994
3. Megson, T.H.G., *Aircraft Structures for Engineering Students*, Halsted Press, New York, 1990.

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David Thomas graduated from the Georgia Institute of Technology in 1993 with a BS in Aerospace Engineering. He has worked in both the Aerospace Multimedia Lab since November 1992 and was involved in composites manufacturing NASA project in the Manufacturing Research Center. Currently, he is developing windows applications for an Atlanta based consulting company.

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