

***The Visual Stress Transformer:***  
**An Animated Computer Graphics Program for Engineering Mechanics Education**

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*State of stress at a point. Stress transformation. Maximum principal stresses. Mohr's Circle.* These topics often strike fear in the hearts of undergraduate engineering students; and teaching these topics effectively is an equally daunting challenge for the engineering mechanics educator. In my experience, the fundamental problem with teaching (and learning) stress transformation is that students just *don't see it*. With time and practice, they learn to solve problems. They master the equations, sign conventions, and graphical solution techniques. But, their mastery of these skills notwithstanding, many students do not truly understand and internalize the fundamental concepts:

- . that the two-dimensional state of stress at a point is uniquely defined by the normal and shear stresses acting on *any* two orthogonal planes passed through that point;
- that the stresses acting on the x- and y-planes are statically equivalent to the stresses on any other pair of orthogonal planes;
- . that the maximum principal stresses and their orientations are unique characteristics of a given state of stress.

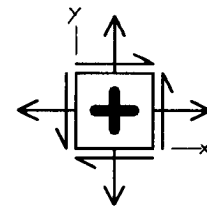
This paper describes a simple animated computer graphics program developed by the author to address this problem. Called the ***Visual Stress Transformer***, it is designed to help students visualize the state of stress at a point and to understand the nature and effects of stress transformation. The software is written in the Microsoft Visual Basic™ programming language and runs on an IBM-compatible personal computer with Windows 3.1. It requires less than 25 kilobytes of hard disk space and is very easy to use. The program performs the following functions:

- It displays a two-dimensional stress block for any user-supplied state of stress.
- . On command, it rotates the stress block slowly, through a full 360 degrees, to show the variation in normal and shear stresses with changing orientation.
- As an option, the program displays Mohr's Circle for the same user-supplied state of stress.

I have used ***Visual Stress Transformer*** in an undergraduate mechanics of materials course and found it to be an invaluable aid to classroom instruction on stress transformation and Mohr's Circle.



— A typical **Visual Stress Transformer** screen display is shown in Figure 1. To run the program, the user enters the normal stresses,  $\sigma_x$  and  $\sigma_y$ , and shear stress,  $\tau_{xy}$ , in the three text boxes at the upper left corner of the screen. (The positive sign convention for stresses is indicated in the diagram at right.) As soon as a stress is entered into its respective text box, the corresponding arrow appears on the stress block in the display window. Note that the lengths of the arrows are directly proportional to the magnitudes of the corresponding stresses.



A mouse click in the **Mohr's Circle** check box causes Mohr's Circle to be displayed in the lower right-hand corner of the display window. The two plotted points and the connecting line segment on the circle correspond to the current orientation of the stress block. The plotted points are displayed in two different colors, and those same colors are used to highlight the corresponding sides of the stress block; thus the relationship between a *plane* on the stress block and a *point* on Mohr's Circle is immediately visible and unambiguous. Note that the magnitudes of stresses are not included on Mohr's Circle, to keep the display from becoming too cluttered.

To start the animation, the user clicks the **Start** button. The stress block begins rotating slowly in the counterclockwise direction, with a new set of stresses displayed for each degree of rotation. As the block rotates, the lengths of the arrows change in direct proportion to the magnitudes of the corresponding stresses. If Mohr's Circle is displayed, the two plotted points rotate around the circumference of the circle, consistent with the orientation of the stress block. The animation will continue indefinitely, until the **Stop** button is clicked. By clicking the appropriate check boxes, the user may cause the animation to pause at the maximum principal stresses (and maximum in-plane shear stress), or at any user-supplied angle. (See Figure 2.) Numerical values of stresses are not displayed while the animation is in progress, but appear whenever the motion of the stress block is stopped. A **Reset** button is included to move the stress block back to its original position, aligned with the x- and y-axes.

As the animation proceeds, a number of important teaching points are clearly displayed:

- c1 Shear stress vanishes on the planes of maximum and minimum principal normal stress.
- 1 On the planes of maximum in-plane shear stress, normal stresses are equal to each other, and their magnitude is equal to the average of  $\sigma_x$  and  $\sigma_y$ .
- ☐ The maximum principal planes are always oriented 45 degrees from the planes of maximum in-plane shear stress.
- 1 The relationship between the orientation of the stress block and the corresponding plotted points on Mohr's Circle is continuously shown.

More important, in observing the animation, one can readily see that the ever-changing combinations of normal and shear stresses *are all equivalent* and all represent one unique state of stress—a fundamental concept which is frequently lost on students. The **Visual Stress Transformer** illustrates this concept more vividly than words or static pictures ever can.

In the classroom, the **Visual Stress Transformer** is run on a cart-mounted computer with a 33" color monitor, clearly visible to all in the room. It is used throughout a three-lesson block on stress transformation

and Mohr's Circle. The animation is started before each class begins and is allowed to run continuously for the duration of the class. It thus becomes the natural focal point for the instructor's introductory remarks and conclusion, and a frequent point of reference for all of the critical teaching points noted above. It is also used to verify the solution of the example problems worked in class. Subsequently, the software is distributed to students for their own personal use, for verification of problem solutions and for self-paced study.

The author has found the **Visual Stress Transformer** to be a simple yet effective learning aid for use in mechanics instruction. Its success has stimulated the development of a series of similar software products, all written in Visual Basic, and all intended to enhance students' ability to visualize difficult concepts and phenomena.

**Note:** The author will make the **Visual Stress Transformer** available, at no cost, to all engineering educators who wish to use it. To obtain a copy of the program, write to:

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Or send E-mail to **is8874@westpoint-emh2 .army.mil**

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LTC Stephen J. Ressler is an Associate Professor in the Dept. of Civil and Mechanical Engineering at the U. S. Military Academy and is a registered professional engineer in Virginia. He graduated from USMA in 1979 and received a Ph.D. degree from Lehigh University in 1991. He has taught courses in statics and dynamics, mechanics of materials, steel design, reinforced concrete design, and design of structural systems.



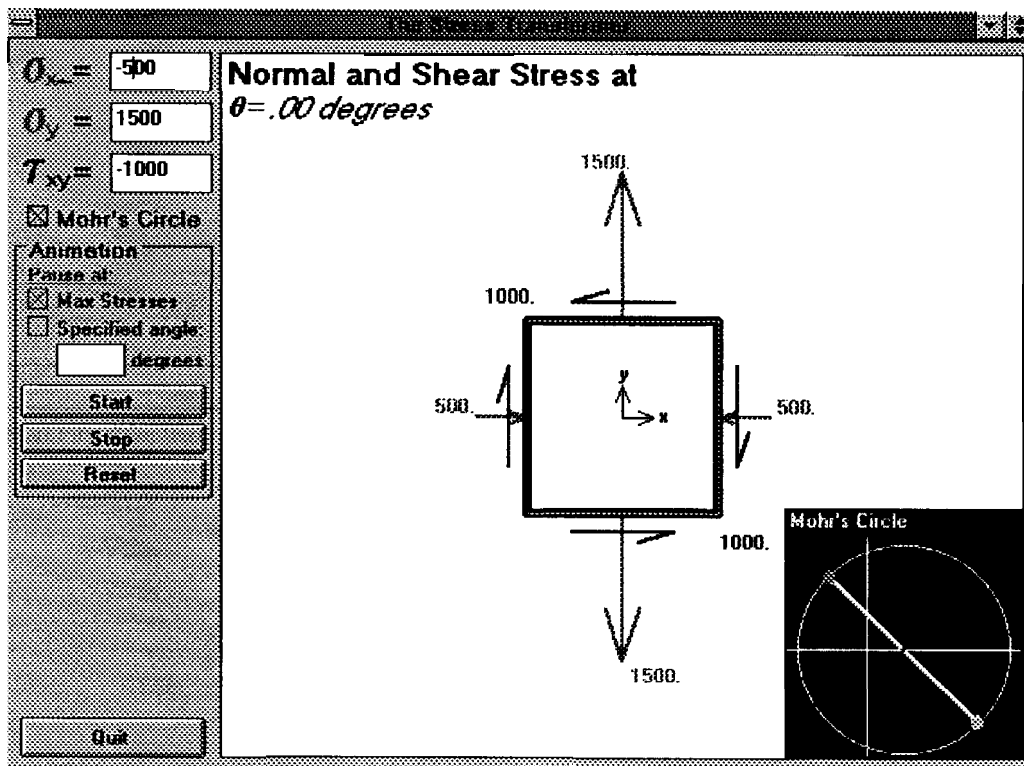


Figure 1. The **Visual Stress Transformer** screen display of user input data.

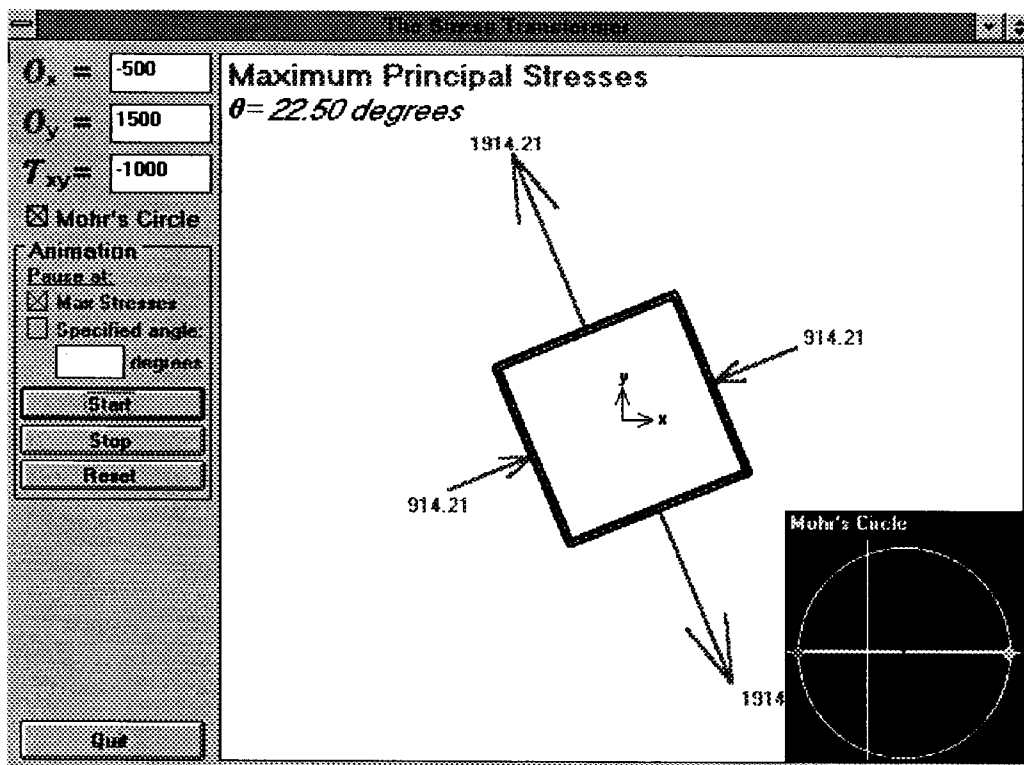


Figure 2. The **Visual Stress Transformer** screen display of maximum principal stresses.