Building Mechanical Intuition Through Hands-on Learning with Truss Components

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Abstract

Statics is an introductory Mechanical Engineering class that all types of engineers are required to take. One difficulty students often face is the inability to visualize how forces are transferred through truss systems. The goal of this project is to create a hands-on system that students can interact with to reinforce their understanding of tension and compression in an affordable manner. This project will build on previous 3-D modeling work to create an entire 3-D printed truss system for in-class demonstrations and may provide a framework for future student projects. The interactive system will demonstrate the effects of a load by using force-dependent, length-adjustable plastic components as bars and foam ear plugs as joints. This poster discusses the educational benefits of the project for Statics students and illustrates the Solidworks parts files available for dissemination. This hands-on tool built to enhance comprehension of forces may lead to reduced lab fees in follow-on upper division courses that demonstrate tension and compression by using expensive metals and heavy machinery. This project provides an affordable and easily accessible solution for learning the effects of tension and compression in a truss system, and a live demonstration will be held at the Creative Collaborations Undergraduate Research Conference.

Trusses in Statics

Trusses are frames that support structural loads and are often used in the design of roofs and bridges. Trusses are composed of slender members joined together at the end points. Simple trusses can be created by adding two members and a joint to an existing triangle. Planar trusses only have loads in within one plane and are often used in parallel to support vertical loads. Figure 1 shows two examples of simple, planar trusses used in roofing structures. This project focuses on simple planar trusses to limit the scope of analysis.

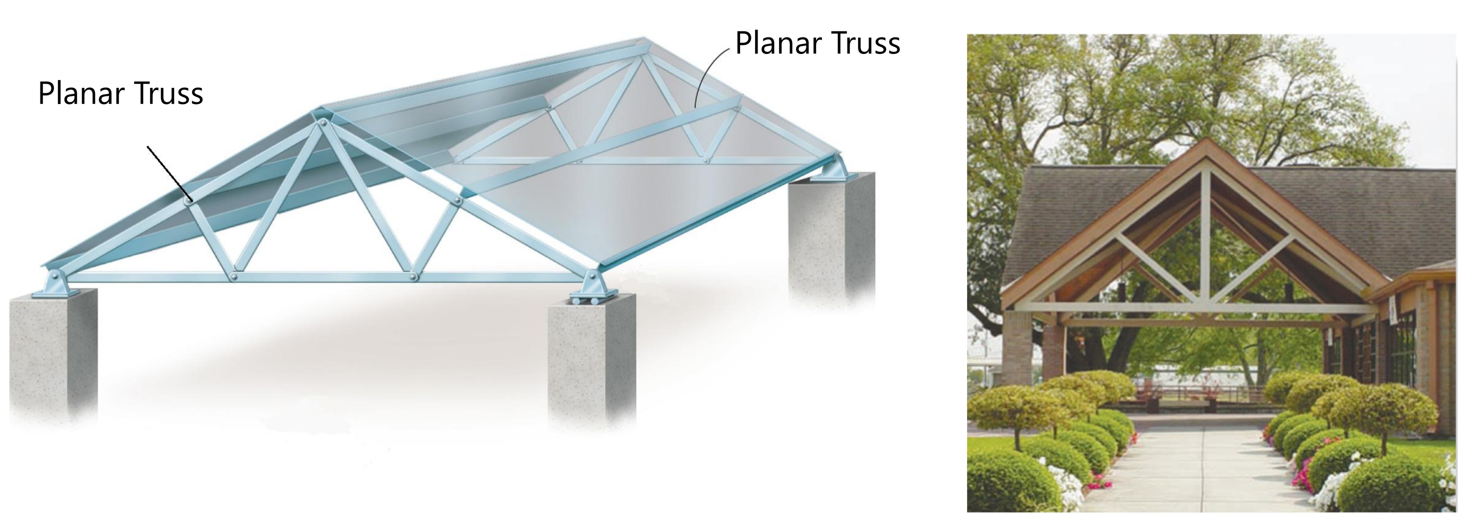

Figure 1: Examples of Planar Trusses in Roof Systems [1]

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Current State of Truss Education

Traditional Statics education teaches truss analysis by practicing the Method of Joints and Method of Sections on simple, planar trusses. Figure 2 shows a typical textbook problem Statics students may see in class. The first step to solving this problem is to replace the external connections (e.g., pin and roller connections shown) with reaction forces. By properly drawing the free body diagram of a system (as shown in Figure 3), the tension and compression forces experienced by each truss member can then be determined.

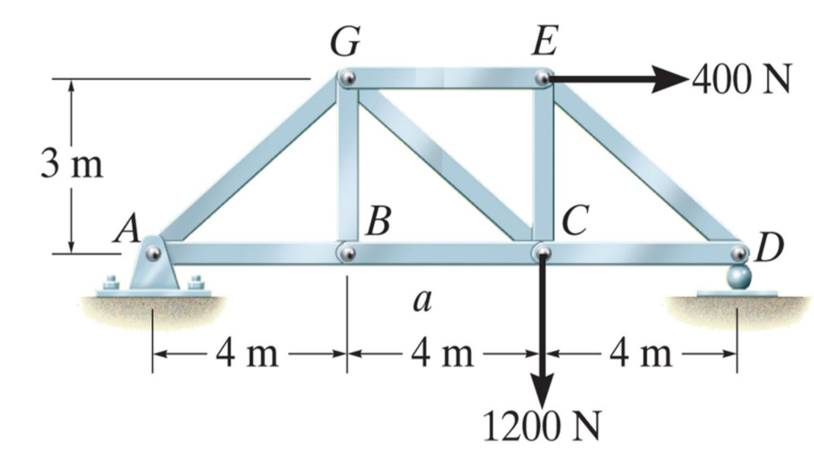

Figure 2: Example of a Typical Truss Problem [1]

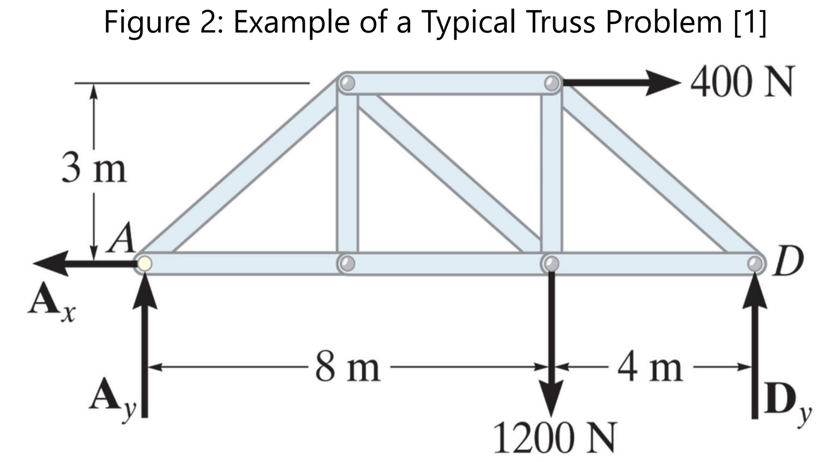

Figure 3: Free body diagram equivalent for the truss shown above [1]

Tension and Compression

Truss members act as two-force members, meaning forces are only transferred along their longitudinal axis. These members are only loaded in either compression or tension. Compression and tension are two key types of forces involved in the support of any structure and is a key point in Statics. Tension is a pulling force to elongate the member, whereas compression is a pushing force that shortens the member.

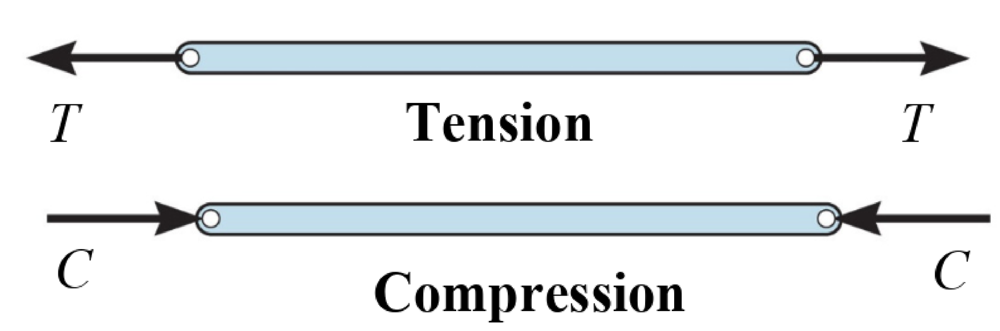

Figure 4: Truss members experience either tension (pulling) or compression (pushing) forces

A physical model allows for better comprehension of the concepts of compression and tension due to the visual nature of the movements in the truss system. The goal of the 3-D printed model created for this project is to help students build intuition for how forces are transferred through a truss and whether this results in compression or tension in each member.

3-D Models of Truss Pieces

The figures below show the 3-D models of the truss components created for this project. The truss is comprised of two members that differ in length, resulting in four separate CAD models, with three components per member. The male and female pieces slide together to demonstrate elongation or shortening of the member. Figure 5 shows the truss pieces aligned, while Figure 6 illustrates the components separately to demonstrate their connection method. The different truss components were combined and 3-D printed to create the truss system assembly shown in Figure 7.

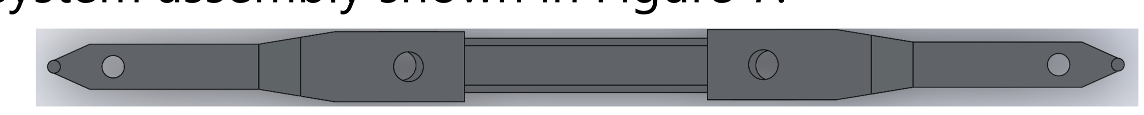

Figure 5: Model of Assembled Truss Member

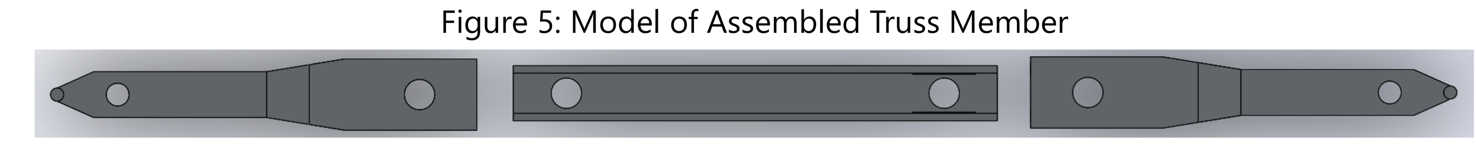

Figure 6: Exploded View of the Truss Member

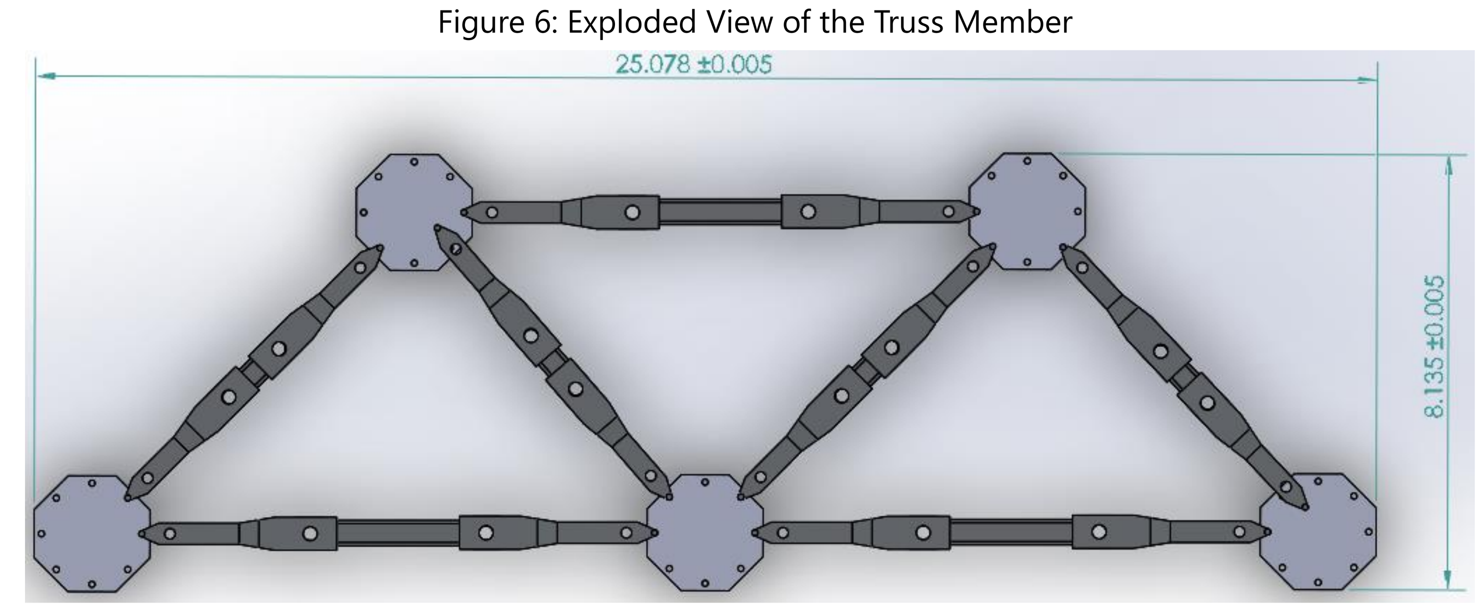

Figure 7: Model of Completed Truss System

Completed 3-D Printed Model

The 3-D printed model will be used in teaching demonstrations to help students better grasp the concepts of compression and tension. The physical model allows for the addition of loads to any joint, which propagates forces throughout the truss to support the external load. By making all of the members in the truss extendable, the user is able to observe the patterns of compression and tension throughout the entire system. Figure 8 shows a student developing intuition by interacting with the completed physical model.

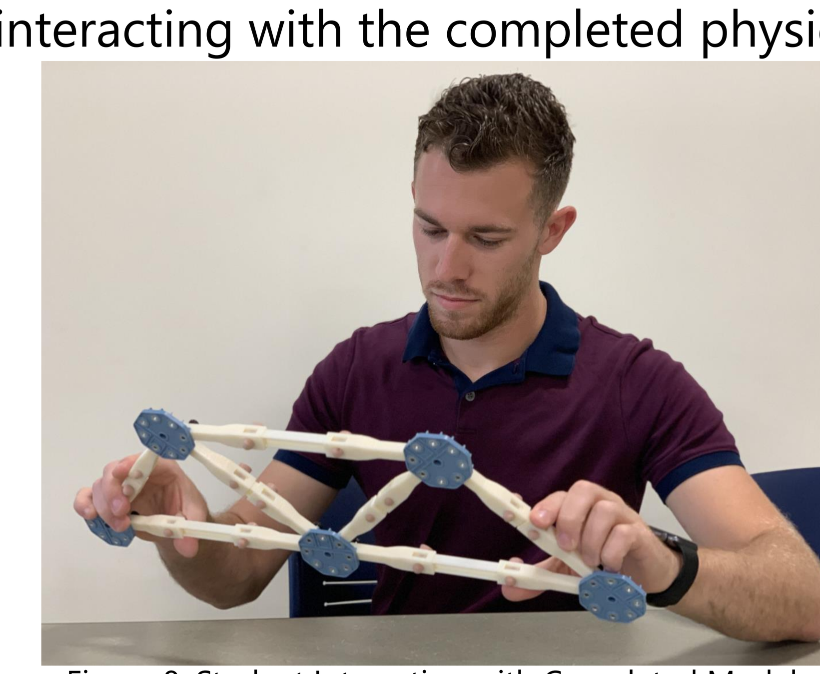

Figure 8: Student Interacting with Completed Model.

References

[1] Hibbeler, R. C. *Statics*. Fourteenth ed., Pearson Prentice Hall, 2016.
[2] Wickert, Jonathan A., and Kemper E. Lewis. *An Introduction to Mechanical Engineering*. 4th ed., Cengage Learning, 2017.