

MODULES IN MECHANICS OF MATERIALS

David Roylance
Department of Materials Science and Engineering
Massachusetts Institute of Technology
Cambridge, MA 02139

January 12, 2000

The Modular Approach

The National Science Foundation, under its Course, Curriculum and Laboratory Improvement (CCLI) program, has funded a collaborative project aimed at nurturing the linkage between Materials Science and Engineering and traditional Mechanics of Materials subjects in the undergraduate engineering curriculum. The co-principal investigators of this project are Prof. David Roylance (Department of Materials Science and Engineering, Massachusetts Institute of Technology) and Prof. Chris Jenkins (Department of Mechanical Engineering, South Dakota School of Mines and Technology) (SDSMT). Other co-principal investigators at SDSMT include S. Khanna, F. Marquis, and R. Winter.

The MIT portion of the project is centered on extending the text *Mechanics of Materials* (Roylance), used at MIT since 1996. This text was written with the materials aspects of the subject in mind, since it was intended principally for use by materials students. As such, it already represents an attempt at the materials-mechanics linkage. However, instructors at MIT and elsewhere may not choose to cover the subject in exactly the manner presented in the text, especially given some of its nontraditional features and topic selections.

One approach to increasing the flexibility and adaptability of the present text is to make discrete and coherent portions of it available as web-available text modules. Instructors could then pick and choose among topics, and assemble a subject offering in whatever way they choose. It would also be possible for instructors of specialty engineering subjects, for instance bridge or aircraft design, to add modules on mechanics of materials aimed at their own needs. Over the two-year course of the CCLI project, it is hoped that all of the topics in the text can be replicated in web-available modules.

Mechanics and Materials Science

The progress of human development is often reckoned in terms of the materials used by society, with the Stone Age in prehistory and progressing through bronze, iron and successively more sophisticated materials. Early people used materials largely as they were produced by nature, but today we have come to rely increasingly on *engineered* materials: materials we have optimized for various applications by careful selection and processing. For centuries, the relations between processing and properties were developed and used empirically, but this approach becomes cumbersome and expensive as requirements grow increasingly complex. As can be depicted by the tetrahedron shown in Fig. 1, modern Materials Science and Engineering deals

with a general rational approach to materials optimization: a material's *processing* is chosen so as to develop a desired *microstructure*; the microstructure controls *properties*, and finally the material's properties are important in dictating the *performance* of the structure in which the material is used.

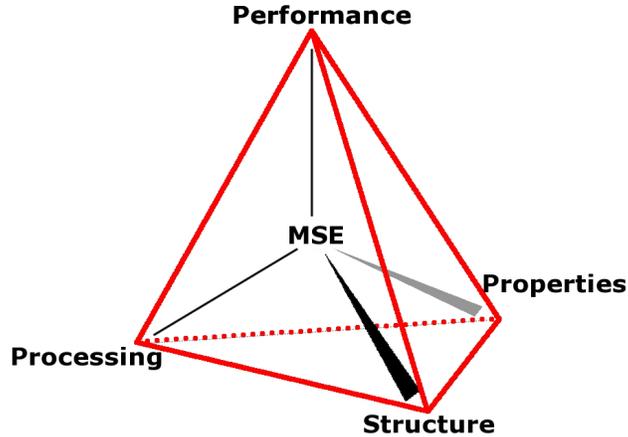


Figure by MIT OCW.

Figure 1: Modern Materials Science and Engineering.

Most engineering designs involve selection and manipulation of materials, and many of these designs are largely or partly *mechanical*: they require that the resulting structure support applied loads without fracture or excessive deformation. This requires that the designer be able to determine the magnitude and direction of internal forces tending to cause rupture or slippage of molecular bonds, and provide enough material of suitable strength to insure that these events do not occur. The techniques required to do this constitute the major part of the engineering science base in mechanical design.

As we study mechanics of materials, we must keep in mind that real designs must satisfy a number of criteria in addition to mechanical reliability. Cost is almost always very important: material costs money, and the designer must use only enough material to satisfy the strength requirements. Other important criteria might include thermal and electrical requirements, consideration of toxicity and flammability of the material that could endanger both the user and manufacturing personnel, and the environmental impact associated with both use and eventual disposal. But at its core, the design problem for load-bearing structures involves insuring the mechanical integrity of the material, and this aspect of the design process is the major goal of a study of Mechanics of Materials.

Analysis or design problems in the mechanics of materials generally involve two major areas:

- Determination of the internal forces set up within the material by loads or displacements imposed on it; this is a largely mathematical undertaking, termed *stress analysis*. These internal forces are often independent of the choice of material used in the structure, and it is often possible to carry out this analysis without much specific knowledge of the material itself. This is the *mechanics* of “Mechanics of Materials.”
- Understanding the material's response to these internal forces. The material may stretch or distort, this deformation may be reversible or permanent, or the material may fracture in any of several ways. This part of the problem is most certainly materials-specific; it is the *materials* of “Mechanics of Materials.”

Following modules will outline some of the basic concepts underlying both of these aspects. This will be done by describing the internal force distribution set up by a simple tensile load, and how materials can respond to these forces. Subsequent modules will extend these concepts to geometrically more complicated situations, and introduce gradually the mathematical language used by the literature of the field to describe them.