TECHNICAL TIDBITS

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Don't Stress on Stress - this discussion of stress and strain concepts will explain why some designs work in theory but fail in practice.

- **Stress & Strain**
- **Engineering Stress vs. True Stress**
- **Elastic Modulus**
- **Proportional Limit**
- **Elastic Limit**
- **0.2% Offset Yield Strength**

Why Good Designs Fail

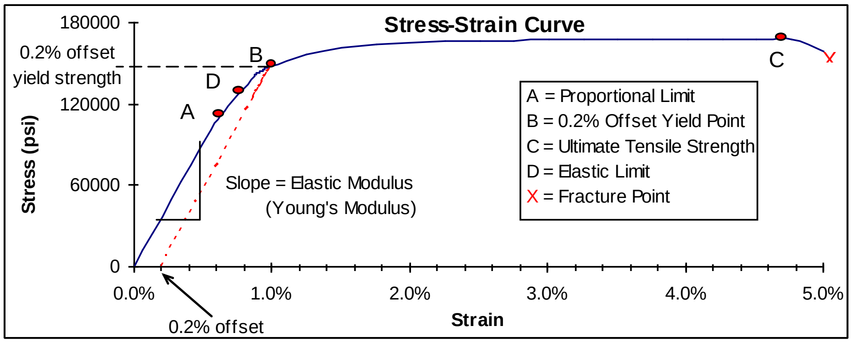
Why do some designs appear adequate on paper and fail in service? Despite the most meticulous design process, components may fail for several reasons. Parts made in prototype tooling can exhibit different behavior than parts made in production tooling. This could be the result of differing forming processes, edge conditions, or geometry. Another possible reason for failure is the residual stress in a component after forming and stamping operations. Typically, finite element analysis and other techniques do not account for this type of stress. Most importantly, designs may fail due to the basic difference between the definitions of the elastic limit and the 0.2% offset yield strength of a given material.

A material's strength (the ability to resist failure) is measured by stress and strain, which play key roles in the performance of all designs. For example, a few grams of force may cause permanent deformation in a contact used in a cellular phone. However, a large switch may be able to withstand several pounds of force with no ill effects. In reality, it is not the force applied to the part that determines the strength; it is the stress inside the metal. Therefore, it is vital to thoroughly understand the stress - strain curve of the material before beginning design work.

Stress and strain are usually measured by tensile testing. A piece of wire or strip is clamped at both ends and gradually pulled apart. The tensile tester measures the amount the piece is stretched and the force required to stretch it. The tester computes stress, strain, and strength from these measurements. **Strain** is defined as the change in length divided by the original length. For example, if a ten inch bar is stretched until it is eleven inches long, the change in length is one inch. This gives a strain of 1/10, or 10%. During tensile testing, strain gages repeatedly measure the amount of elongation that the test piece experiences. Likewise, an engineer may be strained by several projects pulling him or her in different directions, causing the engineer to feel stress.

Stress is defined as force per unit area. A three pound force applied to a two square inch area induces a stress of 1.5 pounds per square inch (psi). During tensile testing, the force required to stretch the test piece is divided by the cross sectional area of the piece to find the stress at each strain value. However, it is important to note that the cross sectional area shrinks during the test. **True stress** is the force at any time divided by the actual area at that time. This is difficult to measure and is rarely used. Since design engineers like simplicity, they use **engineering stress**, which is the force divided by the original cross sectional area.

Figure 1. Stress-Strain Curve



The next issue of Technical Tidbits will include an informative discussion the ramifications of minitaturization in electronic devices.

Why Good Designs Fail (continued)

After testing, the corresponding values of stress and strain are plotted, as shown in Figure 1. For many metals, the first part of the stress-strain curve is linear, with its slope defined as the Young's Modulus or **Elastic Modulus**. This is an indication of the stiffness of the material, with higher moduli producing higher stress for a given deflection. In this region, the stress and strain are linearly proportional to one another. The highest stress level where this relationship holds true is known as the **proportional limit**, (point A). When the stress exceeds this level, the curve is no longer linear.

The stress - strain curve is divided into two regions, elastic and plastic, joined by point D, the **elastic limit**. When any given load is removed, the measured stress will always return to zero along a path parallel to the elastic modulus. In the elastic region (area to the left of point D), the metal will return to its original size and shape when the tensile load is removed. In the plastic region, the metal will distort and have some degree of permanent deformation when the load is removed. This permanent deformation is defined as yielding. Once the elastic limit is exceeded, a design will experience a decrease in performance.

If stress continues to increase, the curve will rise to a peak (point C). This is called the ultimate strength. At this stress level, the metal begins to neck. This means that the cross sectional area at a given point will begin to shrink much more rapidly than in the rest of the specimen. If further stress is applied, the engineering stress - strain curve will turn downward. However, the true stress - strain curve will continue to increase. Eventually, when the true stress exceeds the fracture strength, the specimen will break at the location of necking, where the cross sectional area is smallest. Similarly, there is a point where an engineer will not be able to take any more stress without losing sanity or requesting a transfer.

In general, it is undesirable for a part to yield during service. This makes it necessary to define a stress level that should not be exceeded for a given material. Permanent deformation starts at the elastic limit, which is usually around 75% of the yield strength. However, it is difficult and time consuming to measure this value. The proportional limit may be used, although it is often not defined, and may be well below the elastic limit. Therefore, most designers use the **0.2% offset yield strength** (point B). This is the level of stress that will result in a 0.2% permanent set when the load is removed. However, this means that a contact that is stressed to a point just below the yield strength will already have yielded. In other words, the performance of the design will be affected before the stress reaches the yield strength. This is why a design may appear adequate on paper and fail in service.

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