# Engineering Materials

**Materials Science vs Materials Engineering**

## 5 Types of Engineering Materials:

## Materials Tests/Loading Conditions:

**Static vs Dynamic:**

## Mechanical Properties:

**Ductility**: The ability of a material to elongate a considerable extent before rupture.

**Brittleness** (Non-ductile): The ability of a material to fracture with relatively little or no elongation.

**Elasticity**: The ability of a material to recover its original shape and dimensions after release of stress.

**Plasticity**: The ability of a material to remain permanently deformed after release of stress.

**Stiffness** (rigidity): The ability of a material to resist deformation.

**Strength**: The stress a material can resist.
(Ultimate Strength = the maximum stress a material can resist prior to failure.)

**Resilience**: The ability of a material to absorb energy without permanent deformation.

**Toughness**: The ability of a material to absorb energy without rupture.

**Hardness**: The ability of a material to resist indentation or abrasion.

# Laboratory No. 2: Mechanical Properties of Materials from the Candy Shop*

**Objective:** To illustrate such mechanical properties as ductility, brittleness, elasticity, plasticity, stiffness, strength, hardness, durability and composite behavior of candy products.

| **Supplies:** | | | |
|---|---|---|---|
| | Chewing gum (sticks) | Taffy | Coated Candy |
| | Hard candy | Peanut brittle | Licorice |

**Procedure:**

CHEWING GUM: Pull a stick of gum from both ends. The gum will deform in a ductile manner, i.e. when it fractures, you can note a necking area and considerable deformation. If the gum is put in the freezer to cool for about fifteen minutes, you can cause the gum to break in a brittle manner. This phenomenon is known as a ductile to brittle transition, and is very important in designing structures which will experience variations in temperature. A similar fracture can be demonstrated if you allow the gum to lose moisture and become stale. The loss of moisture causes the gum to become less ductile. Wood exhibits a similar behavior and has drastically different mechanical and thermal properties when the moisture has been removed. Taffy can be substituted for gum in this demonstration.

TAFFY: A material's mechanical properties depend critically on its microstructure; however, it also depends on the conditions under which you are testing the material. It is possible for a material to be ductile, or very pliable when deformed very slowly. This same material can be brittle when it is deformed rapidly. This phenomenon is called strain-rate sensitivity. It describes a material whose mechanical properties depend on the rate of deforming ("straining"). On one end of the taffy, pull the taffy slowly with both hands and observe that it will stretch quite a bit before breaking. Now, grab the taffy on the other end, but this time pull it very rapidly. The taffy will extend slightly and snap with a fracture surface perpendicular to the pulling direction. You have just demonstrated strain-rate sensitivity. When materials are subjected to forces, they will either deform or fracture (or a combination of the two). Whichever is "easiest" will take place. With taffy, when pulled quickly, it is easier for the material to separate in a fracture than for the polymer molecules to rearrange and slide past one another. In metals, the deformation mechanisms are different, so its an entirely different story. However, the phenomenon of strain-rate sensitivity is well demonstrated with taffy.

COATED CANDY: Gum is coated for several reasons such as to give the customer double treat, a sweet rather hard candy and chewing treat, and also for convenience of packaging and the added convenience of not needing a wrapping. Coated candy is an excellent example of one type of composite where a coating is placed on another material to protect the inner material from deterioration. Regular candy without a wrapper or coating would become sticky and lose its appeal. Coatings such as zinc on steel, paint on wood or walls, and asphalt on foundations are used to protect these materials from the outside elements and provide corrosion resistance, esthetic appeal, and waterproofing, respectively.

HARD CANDY: Any hard candy can be used to demonstrate a brittle fracture. Hard candies are meant to last longer than other candies and give the consumer a lengthier taste experience. Striking a hard candy lightly with a hammer will result in several pieces of candy. Quite often designers need very hard materials which can withstand large compressive loads without deformation. Foundations and superstructures for large buildings are examples of brittle materials.

PEANUT BRITTLE: Peanut brittle is a combination of a syrup (taffy-like) and nuts. The nuts are added to the syrup to provide a double treat, and this addition of nuts also changes the mechanical properties. The pure brittle would act in a typical brittle or hard manner; however, when the nuts are added, the brittle is strengthened. Although this may not mean much to the consumer, it is an important materials consideration. This phenomenon is an example of another type of composite. In this case, two different materials are combined as a mixture to enhance the properties. In the case of peanut brittle, the manufacturer wants to enhance the taste, and incidentally has changed the mechanical properties. Concrete is a mixture of stones and cement which is the most abundant building material in the world. The Egyptians added straw to clay to make more durable bricks, and steel or composite bars or mesh are added to concrete to improve the load bearing capacity.

LICORICE: Licorice sticks come in a variety of colors. The color is added to appeal to the desires of the consumer. If a licorice stick is pulled gently from opposite ends and then released the licorice will deform, but then almost immediately return to its original length, pull a little harder and it will deform but take a little longer to return to its original length, pull even harder and the licorice will become permanently deformed. This behavior is known as elasticity, anelasticity and plasticity, respectively. Continued pulling on the licorice will cause a ductile fracture. Many engineering materials are designed to take advantage of this range of behavior of materials.

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# Candy Lab Worksheet

1. How does temperature affect a material's ductility and brittleness?

2. How does moisture affect a material's ductility and brittleness?

3. How does age affect a material's ductility and brittleness?

4. How does the loading rate ("strain-rate sensitivity") affect a material's ductility, brittleness and strength?

5. The hard coating on the m&m protects the inner chocolate. Using material engineering terms, the hard candy makes the chocolate _____________ resistant.

6. Why do you think brittle failures are more fatal than ductile failures?

7. What are composites? Why are composites used in engineering design?

8. What is the difference between elasticity and plasticity?

9. What is meant by the term anelasticity?

10. Perform a tension, bend, torsion, and/or hardness (scratch) test on each of the candies provided. Complete the following table by rating the candies 1 to 10 with 1 exhibiting the highest property.

| CANDY TESTED | Ductility | Elasticity | Plasticity | Stiffness | Strength | Resilience | Toughness | Hardness |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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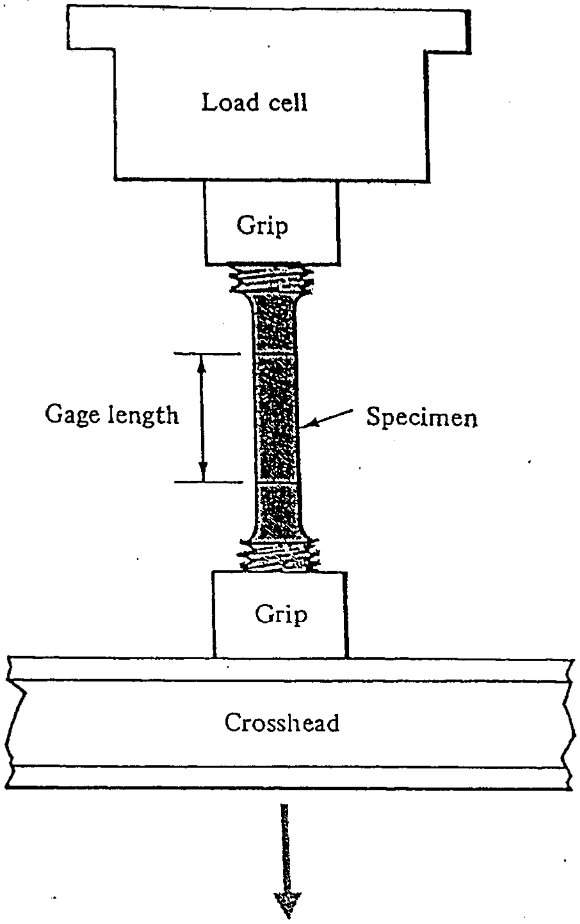
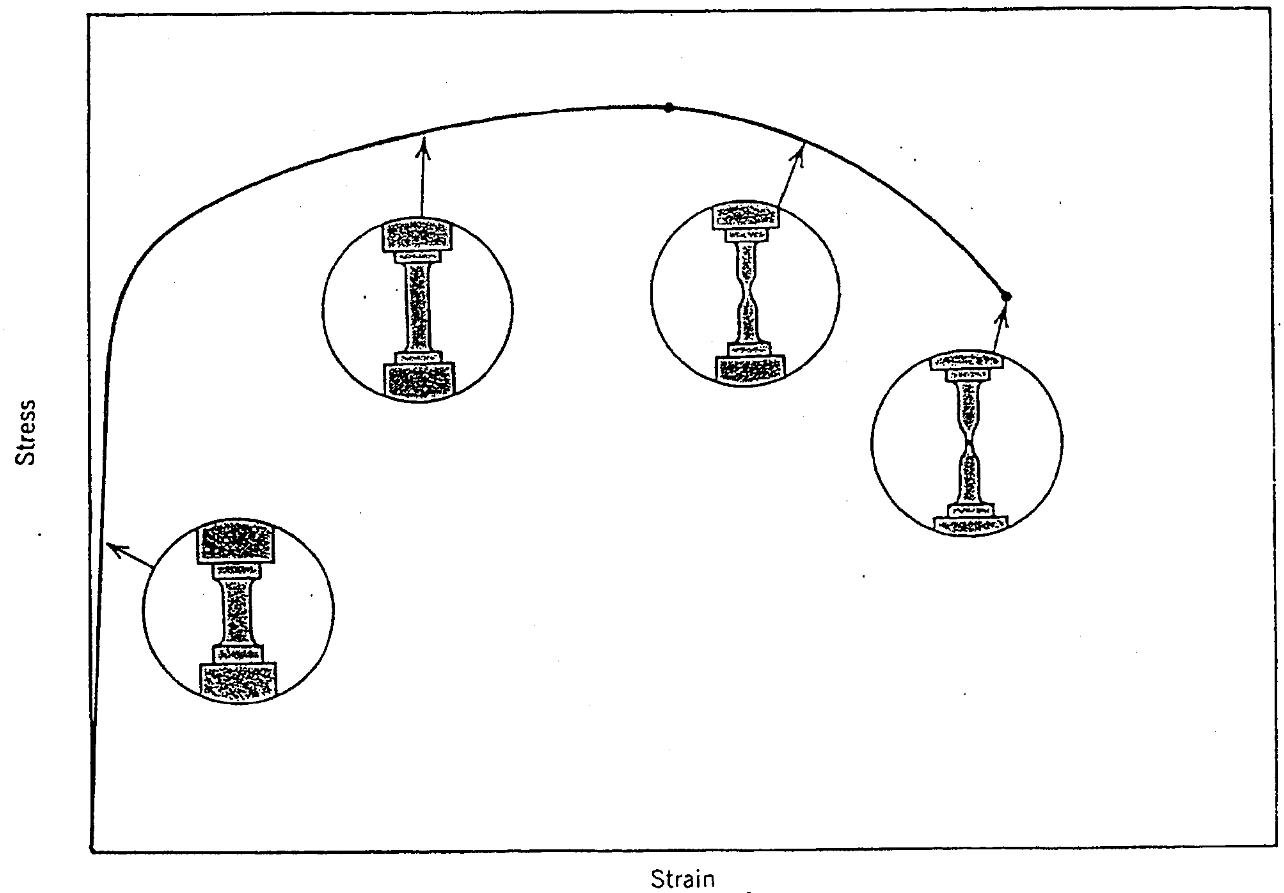
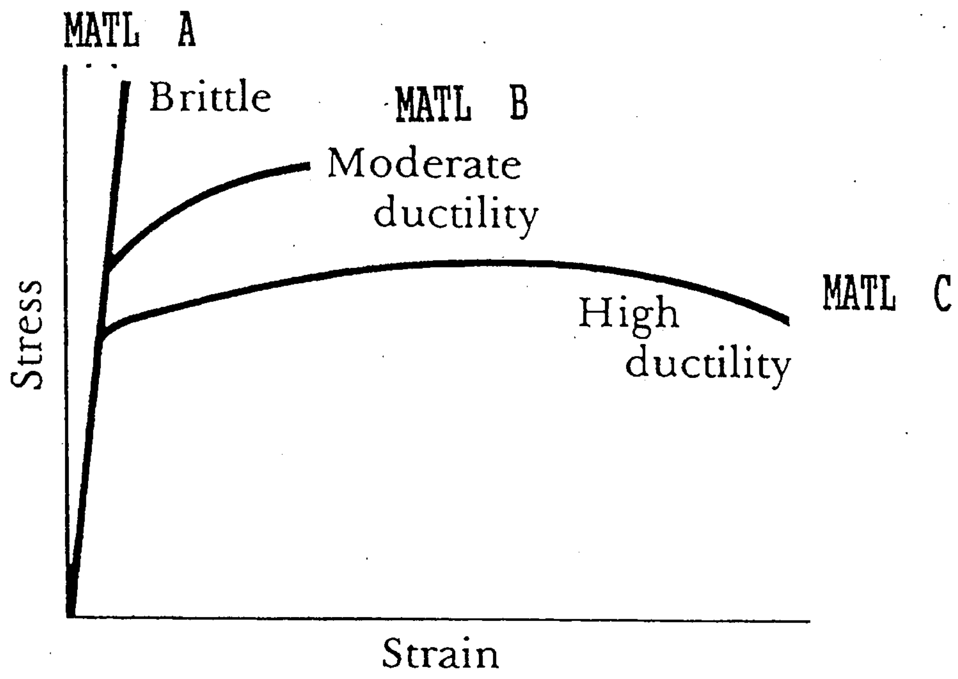
# TENSION TEST



# DUCTILITY or BRITTLENESS

Ability to Elongate to a Considerable Extent

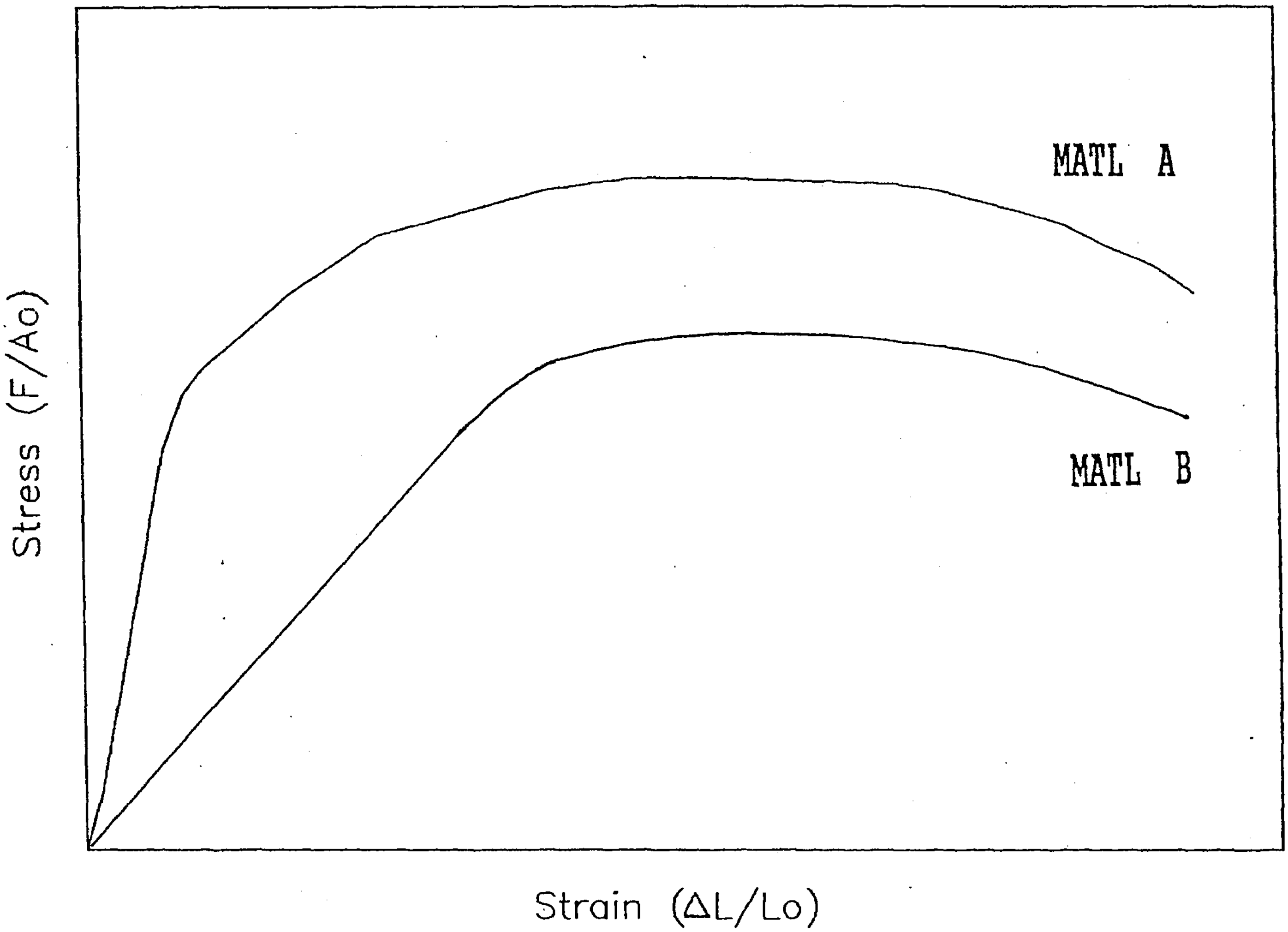



Measured by Percent Elongation:

% Elongation = Strain (at Breaking Stress) * 100

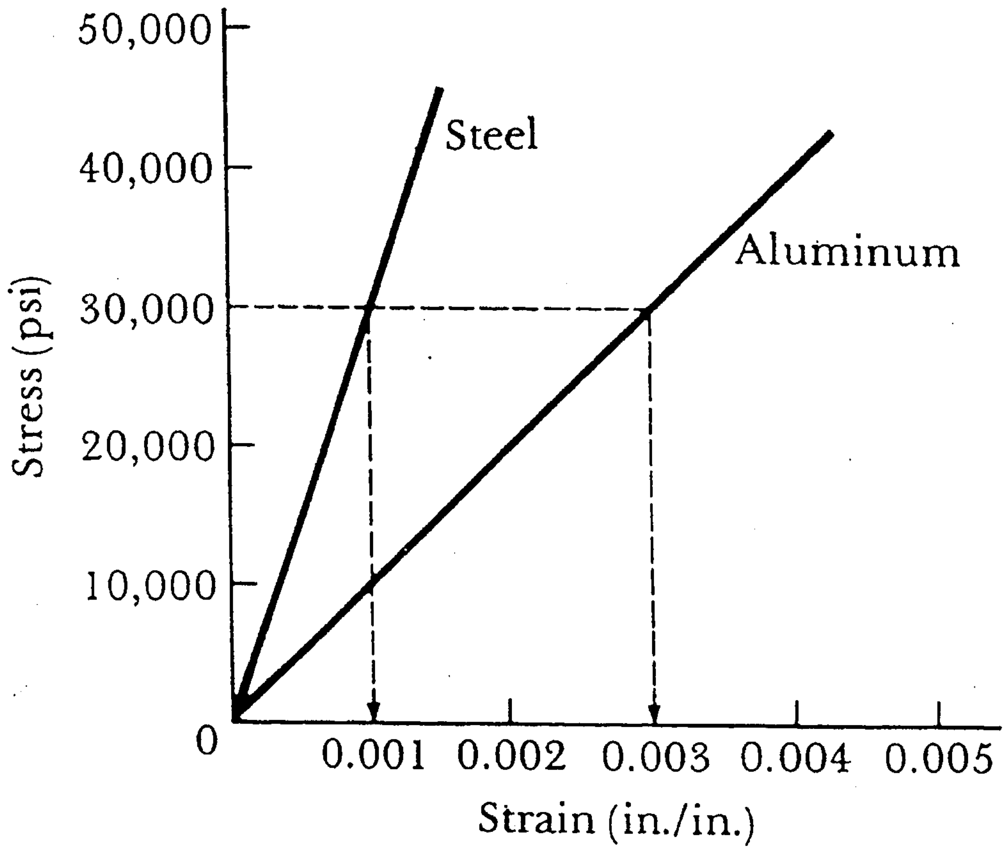
Ductility: Matl C > Matl B > Matl A

# ELASTICITY & PLASTICITY



# STIFFNESS

Ability to Resist Deformation




Measured by Young's Modulus = slope of elastic region

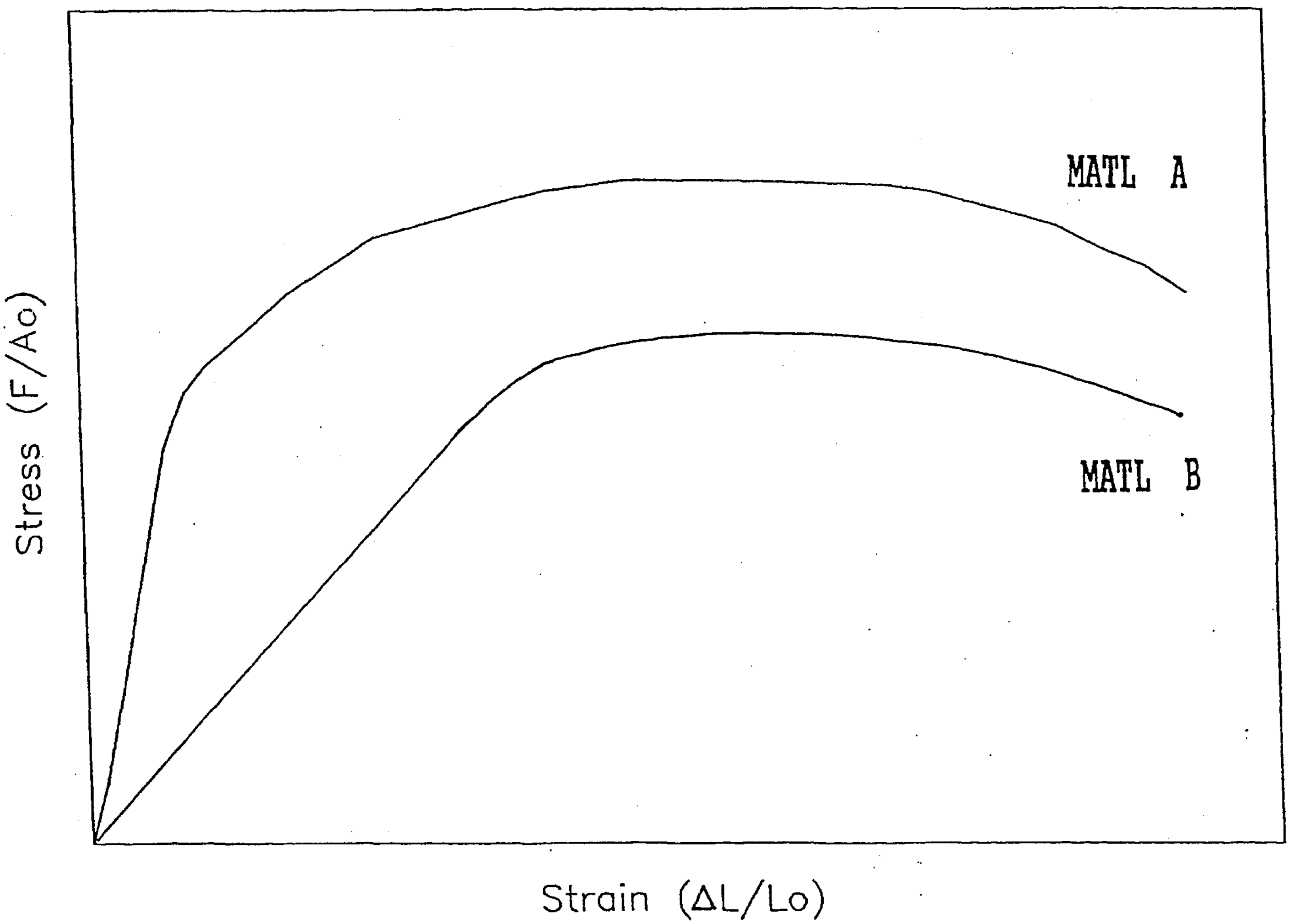
Steel: $YM = \frac{30,000}{0.001} = 30,000,000$ psi

Aluminum: $YM = \frac{30,000}{0.003} = 1,000,000$ psi

Steel sample is stiffer than aluminum sample.

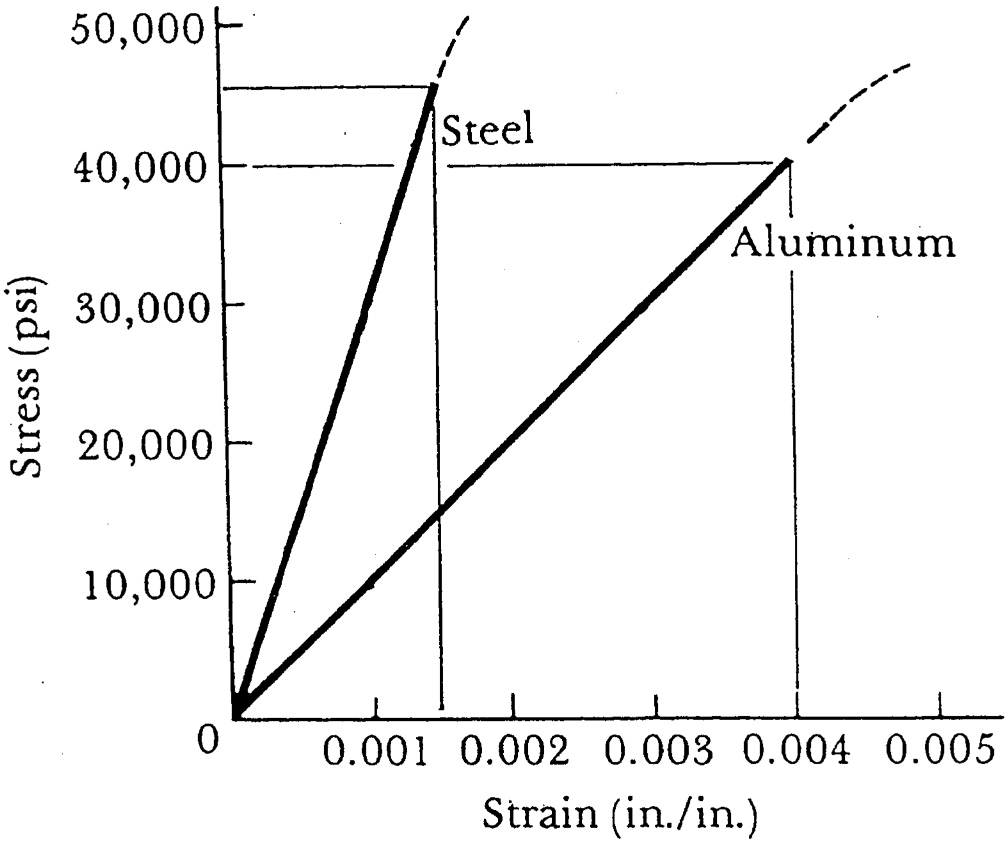
# ULTIMATE STRENGTH

Maximum Stress a Material can Resist Prior to Failure



# RESILIENCE

Ability to Absorb Energy w/o Permanent Deformation




Measured by Modulus of Resilience =
area under elastic region

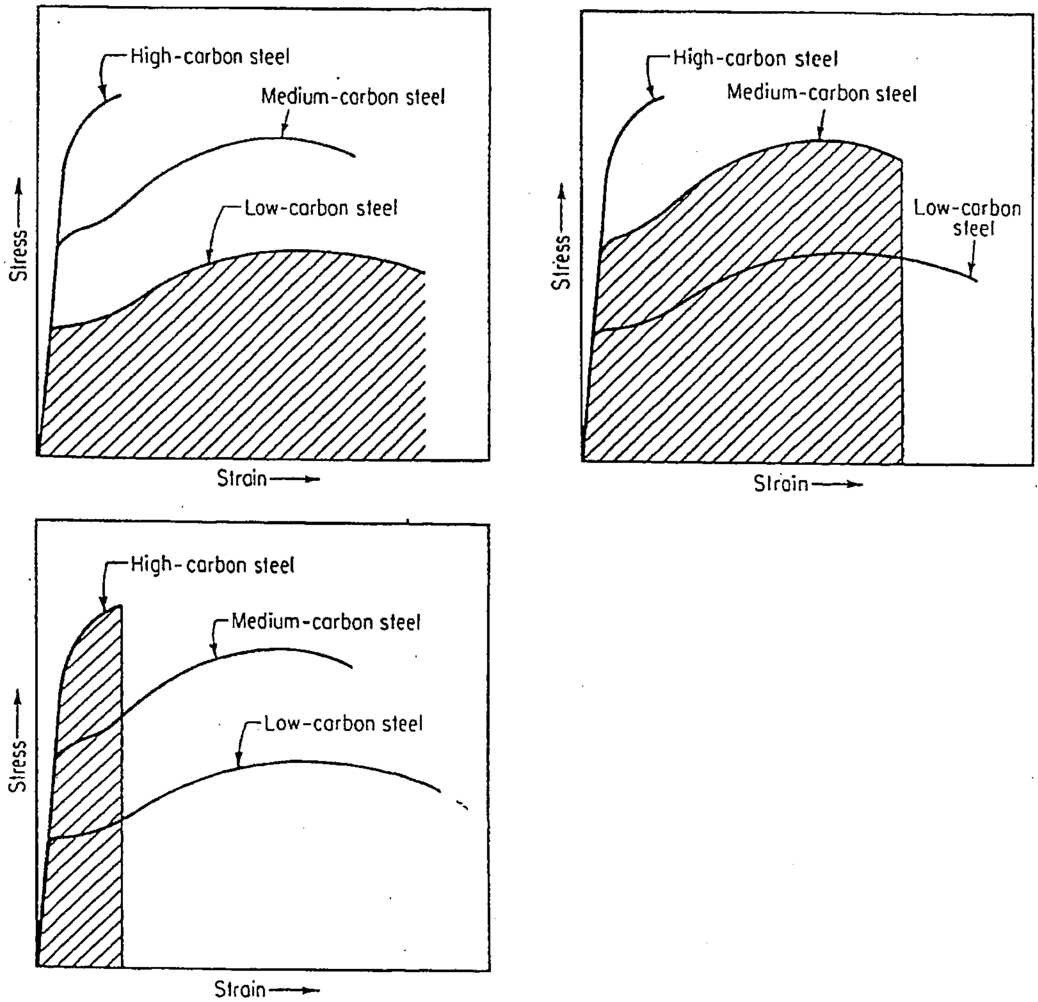
Steel: 0.5 (45,000 * 0.0015) = 34 psi

Aluminum: 0.5 (40,000 * 0.004) = 80 psi

Aluminum sample is more resilient than steel sample.

# TOUGHNESS

## Ability to Absorb Energy w/o Rupture



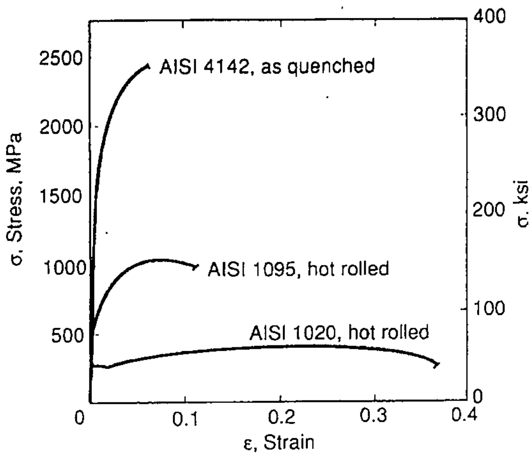



**Figure 4.15** Engineering stress-strain curves from tension tests on three steels.

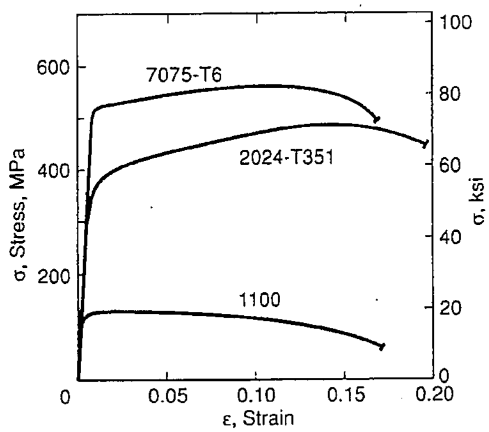



**Figure 4.16** Engineering stress-strain curves from tension tests on three aluminum alloys.

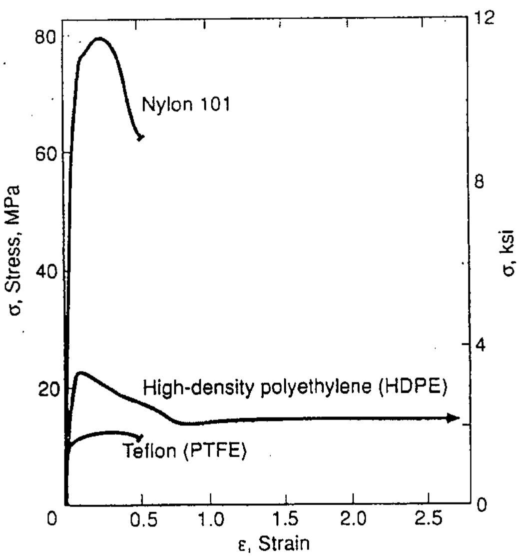
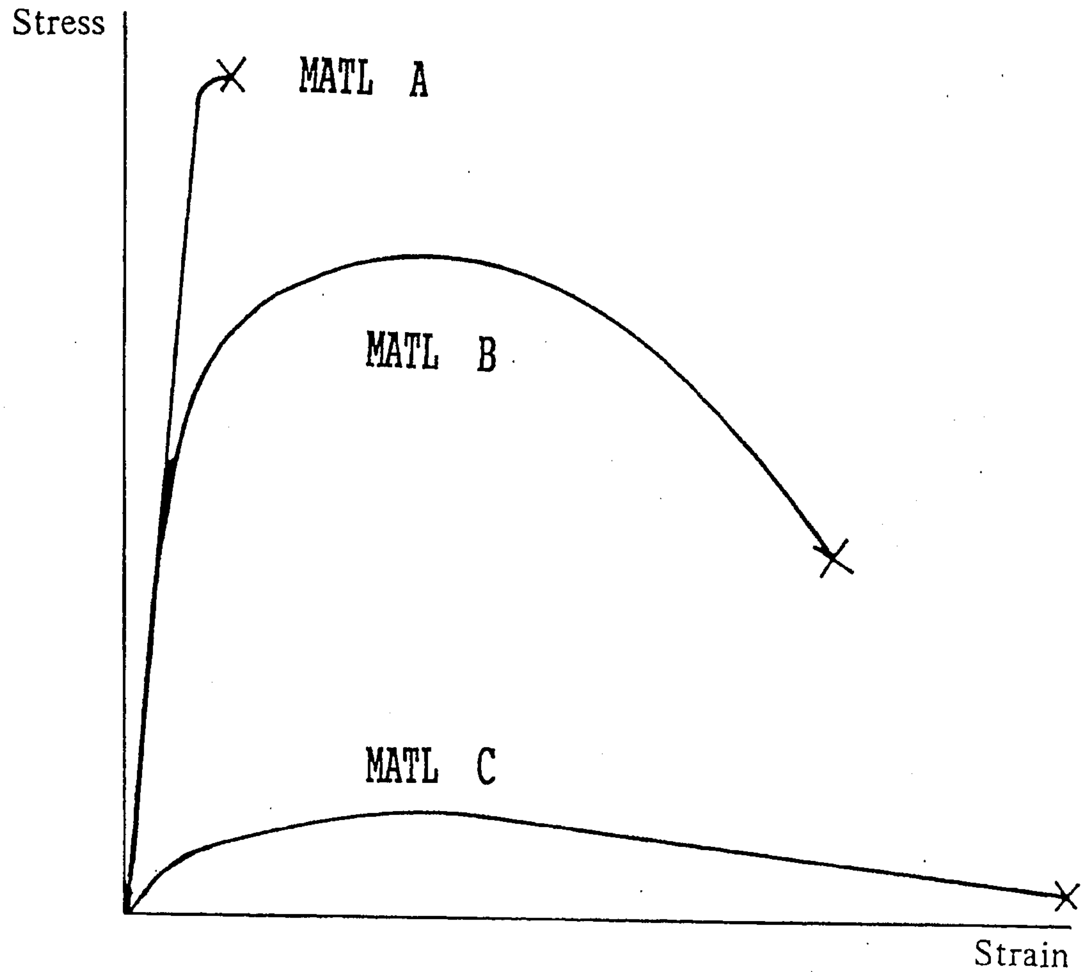



**Figure 4.17** Engineering stress-strain curves from tension tests on three polymers.

# SUMMARY




| PROPERTIES | MATERIAL A | MATERIAL B | MATERIAL C |
|---|---|---|---|
| DUCTILITY | | | |
| BRITTLENESS | | | |
| ELASTICITY | | | |
| PLASTICITY | | | |
| STIFFNESS | | | |
| STRENGTH | | | |
| RESILIENCE | | | |
| TOUGHNESS | | | |

| Sample | Brass | |
|---|---|---|
| Initial length | 2.305 | in |
| Initial Diameter | 0.506 | in |
| Initial Area | 0.201 | in^2 |

| Time (s) (sec) | Load (lb) | Stress (psi) | Change in Length (1/1000 in) | Strain (in/in) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0.000 |
| 10 | 3300 | 16410 | 7 | 0.003 |
| 20 | 9000 | 44754 | 25 | 0.011 |
| 30 | 10050 | 49975 | 47 | 0.020 |
| 40 | 10200 | 50721 | 70 | 0.030 |
| 50 | 10400 | 51716 | 94 | 0.041 |
| 60 | 10750 | 53456 | 117 | 0.051 |
| 70 | 10950 | 54451 | 141 | 0.061 |
| 80 | 11100 | 55196 | 165 | 0.072 |
| 90 | 11200 | 55694 | 188 | 0.082 |
| 100 | 11300 | 56191 | 212 | 0.092 |
| 110 | 11400 | 56688 | 236 | 0.102 |
| 120 | 11500 | 57185 | 260 | 0.113 |
| 130 | 11550 | 57434 | 284 | 0.123 |
| 140 | 11550 | 57434 | 310 | 0.134 |
| 150 | 11600 | 57683 | 334 | 0.145 |
| 160 | 11650 | 57931 | 358 | 0.155 |
| 170 | 11650 | 57931 | 384 | 0.167 |
| 180 | 11650 | 57931 | 408 | 0.177 |
| 190 | 11650 | 57931 | 433 | 0.188 |
| 200 | 11600 | 57683 | 457 | 0.198 |
| 210 | 11450 | 56937 | 483 | 0.210 |
| 220 | 11250 | 55942 | 510 | 0.221 |
| 230 | 10950 | 54451 | 537 | 0.233 |
| 240 | 10500 | 52213 | 560 | 0.243 |

| Sample | Copper | |
|---|---|---|
| Initial length | 2.384 | in |
| Initial Diameter | 0.506 | in |
| Initial Area | 0.201 | in^2 |

| Time (s) (sec) | Load (lb) | Stress (psi) | Change in Length (in) | Strain (in/in) |
|---|---|---|---|---|
| 0:00 | 0 | 0 | 0 | 0.000 |
| 0:10 | 3500 | 17404 | 0.015 | 0.006 |
| 0:20 | 8250 | 41024 | 0.035 | 0.015 |
| 0:30 | 8950 | 44505 | 0.052 | 0.022 |
| 0:40 | 8750 | 43511 | 0.076 | 0.032 |
| 0:50 | 8600 | 42765 | 0.102 | 0.043 |
| 1:00 | 8500 | 42268 | 0.127 | 0.053 |
| 1:10 | 8350 | 41522 | 0.154 | 0.065 |
| 1:20 | 8100 | 40278 | 0.179 | 0.075 |
| 1:30 | 7900 | 39284 | 0.206 | 0.086 |
| 1:40 | 7650 | 38041 | 0.231 | 0.097 |
| 1:50 | 7250 | 36052 | 0.257 | 0.108 |
| 2:00 | 6900 | 34311 | 0.282 | 0.118 |
| 2:10 | 6500 | 32322 | 0.307 | 0.129 |
| 2:20 | 6050 | 30085 | 0.331 | 0.139 |
| 2:30 | 5000 | 24863 | 0.356 | 0.149 |