Engineering Property - Stress-Strain

Tensile strength and ultimate elongation, while sometimes useful for compound development and control, are of lesser importance to the design engineer. Elastomeric parts are seldom loaded in tension and then only to a small fraction of their ultimate strength or elongation. Tensile strength and elongation generally cannot be correlated with performance in service. The relationship of stress to strain is more useful because it shows how an elastomer responds to loading.

Tensile properties are measured by recording axial stress in a standard ASTM dumbbell specimen at a constant rate of strain. Tensile strength and elongation, as applied to rubber, are defined as follows:

Tensile Strength is the force per unit of the original cross-sectional area which is applied at the time of the rupture of a specimen.

Elongation or Strain is the extension between bench marks produced by a tensile force applied to a specimen and is expressed as a percentage of the original distance between the marks. Ultimate elongation is the elongation at the moment of rupture.

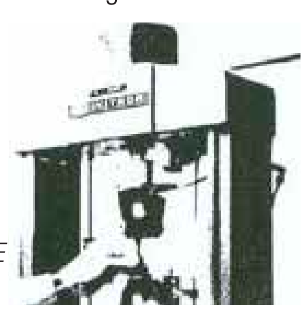
Modulus is the stress in pounds per square inch (of original cross-section) required to produce a certain elongation.

If a tensile stress of 1800 psi produces an elongation of 300%, the compound is said to have a 300% modulus of 1000 psi. In rubber, unlike steel, stress and strain in tension are not proportional; and, therefore, the term modulus has a different meaning. When applied to steel, modulus is stress divided by strain a ratio and a constant. Applied to rubber, modulus means stress at a certain strain – not a ratio and not a constant, merely the coordinates of a point on the stress-strain curve.

Procedures for conducting stress-strain tests are standardized and described in ASTM D-412. Dumbbell shaped specimens four or five inches long are die-cut from flat sheet and marked in the narrow section with bench marks one and two inches apart (Figure 1). Ends of the specimen are placed in the grips of a testing machine (Figure 2). The lower grip is power driven at 20 inches per minute and stretches the specimen until it breaks. As the distance between bench marks widens, measurement is made between their centers to determine elongation.

POCKET-SIZE DUROMETER, TYPE A

TESTING MACHINE



Stress-strain properties are useful in compound development and for manufacturing control. As control tools, stress-strain properties reveal whether or not the ingredients have been mixed properly or if contaminants are present. Property changes by environmental conditions are easily detected by a change in stress-strain properties. For a product which has been put in production, modulus and elongation measurements can be used as quality control tools. They are sensitive to manufacturing variations and indicate if the product has been properly processed.

Natural rubber must be loaded with carbon black to obtain a modulus approaching that of Poly-Pro urethane rubber with no filler (Figure 3). Tensile stress-strain curves for compounds of Poly-Pro are shown in Figure 4. The tensile strength of commercial compositions of Poly-Pro will vary from 2000 psi to over 11,000 psi. Elongation will vary from 250% to 800%. Generally, tensile strength increases with an increase in hardness.

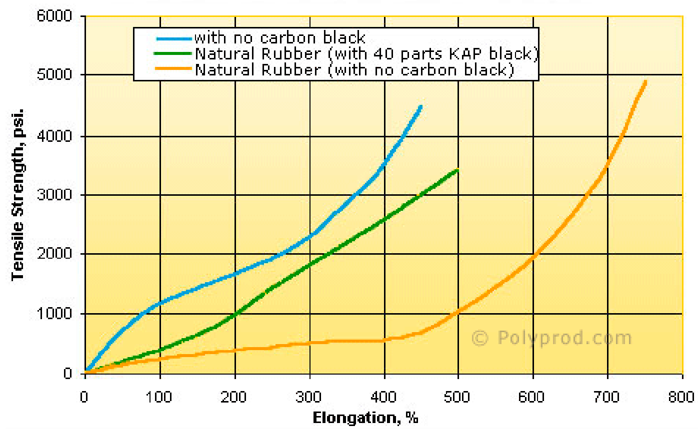


FIGURE 3 STRESS-STRAIN OF POLY-PRO P 90 COMPARED TO NATURAL RUBBER

Figure 4 also shows that Die-Thane elastomers retain extensibility at high hardness. Elongation at break of a 75 durometer D, achieved with P.P.C compound P-675 is usually 250%.

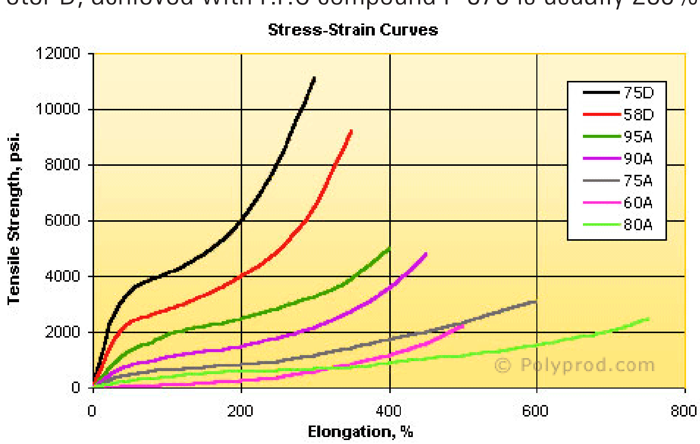


FIGURE 4 STRESS-STRAIN CURVES

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The response of materials at low modull is more important to the design engineer than the design engineer than the ultimate tensile strength. As shown in Figure 5, tests from the same material can yield widely varying tensile strengths based on small differences in elongation. In this case, an elongation at break of only 50% can result in a 2200 psi change in tensile strength. The variability in tensile strength can be due to small volds in the specimen or a small invisible nick in the sample. Stress at 100% modulus yields very consistent results and are reproducible compared to other tensile properties.

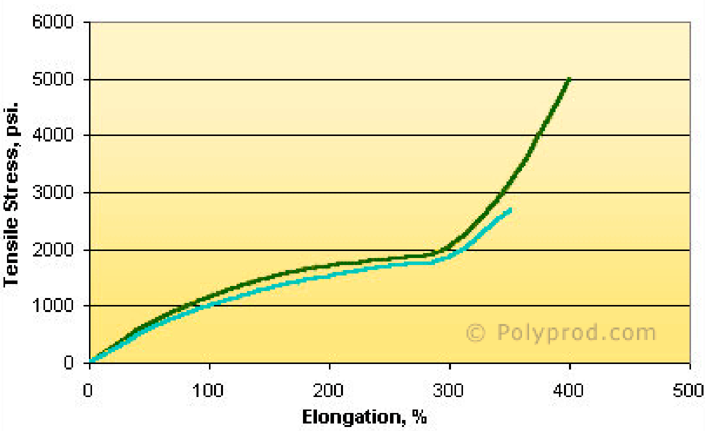

FIGURE 5 INFLUENCE OF SLIGHT CHANGES IN ELONGATION

In many non-rubber materials, Young's Modulus may be taken in tension or compression, the values being approximately the same; it is the ratio of stress to strain, expressed in psi per unit strain. In rubber, the assumption that tension modulus equals compression modulus is valid only for extremely small deformation and for certain shapes, such as specified in ASTM D-797, " Young's Modulus in flexure of Natural, and Synthetic Elastomers" and STMD-1053, (Sec.7) "Measuring Low-Temperature Stiffening by the Gohman Torsinal Apparatus".

Modulus of elasticity in tension for three vulcanizates of Die-Thane compounds are given below. The values given are the-slopes of the stress-strain curves, as near to the point of origin as could be measured and should be considered only approximate. The values were measured at 720 F (220 C).

Die-Thane DT-25	7,000 psi
Die-Thane DT-15	11,000 psi
Die-Thane DT-5	52,000 psi