Aircraft Materials And Their Physical Terms

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IN AIRCRAFT construction, it is essential that materials with a high strength/weight ratio be used. For this reason, the terms used in describing the properties of materials should be clearly understood by the amateur aircraft builder. Many of these terms have acquired popular meanings which are not necessarily correct, while others are very hazy in the minds of many people. For that reason, the following definitions are intended to clarify these terms.

HARDNESS

Hardness is the property of resisting penetration or permanent distortion. The hardness of a piece of metal can usually be increased by hammering, rolling, or otherwise working on it. In the case of steel, some aluminum alloys, and a few other metals, hardness can also be increased by a heat treatment. A modified form of heat treatment, known as annealing, will soften metals.

Increased hardness and strength go hand in hand. Testing apparatus has been developed for testing hardness rapidly without destroying or harming the tested metal or part. The principal usually employed in this type of apparatus is to sink a hardened steel ball under a definite load into the material being tested. The impression made by the ball is then measured and recorded; the smaller the impression, the harder the material. For each type of material, there is a fairly definite relationship between the depth of penetration (which is represented by a Hardness Number for convenience) and the ultimate strength of the material. Tables have been worked up for different materials based on this relationship. By means of a simple hardness test, and the use of such a table, the approximate tensile strength of a piece of material or finished part can be obtained without cutting out tensile test specimens or mutilating the part.

BRITTLENESS

Brittleness is the property of resisting a change in the relative position of molecules, or the tendency to fracture without change of shape. Brittleness and hardness are very closely associated. Hard material is invariably more brittle than soft material. In aircraft construction, the use of too-brittle material must be avoided or failure will be caused by the shock loads to which it will be subjected.

MALLEABILITY

Malleability is the property of metals which allows them to be bent or permanently distorted without rupture. It is this property that permits the manufacture of sheets, bar stock, forgings, and fabrication, by bending and hammering. It is obviously the direct opposite of brittleness.

DUCTILITY

Ductility is the property of metals which allows them to be drawn out without breaking. This property is essential in the manufacture of wire and tubing by drawing.

It is very similar to malleability and, in fact, is generally used in place of that term to describe any material that can be easily deformed without breaking. Thus, in aircraft work, a material is usually referred to as soft or hard, or else as ductile or brittle. Ductile material is greatly preferred because of its ease of forming and its resistance to failure under shock loads. In order to obtain the required strength, it is often necessary, however, to use a hard material.

ELASTICITY

Elasticity is the property of returning to the original shape when the force causing the change of shape is removed. All aircraft structural design is based on this property, since it would not be desirable to have any member remain permanently distorted after it had been subjected to a load. Each material has a point known as the elastic limit beyond which it cannot be loaded without causing permanent distortion. In aircraft construction, members and parts are so designed that the maximum applied loads to which the airplane may be subjected will never stress them above their elastic limit.

DENSITY

Density is the weight of a unit volume of the material. In aircraft work, the actual weight of a material per cubic inch is preferred, since this figure can be used in calculating the weight of a part before actually making it. The density of a material is an important consideration in deciding which material to use in the design of a part.

FUSIBILITY

Fusibility is the property of being liquefied by heat. Metals are fused in welding. Steels fuse around 2,500 deg. F., and aluminum alloys around 1,100 deg. F.

CONDUCTIVITY

Conductivity is the property of transmitting heat or electricity. The conductivity of a metal is of interest to the welder as it affects the amount of heat he must use and, to a certain extent, the design of his welding jig. Electrical conductivity is also important in connection with the bonding of airplanes to eliminate radio interference.

CONTRACTION AND EXPANSION

Contraction and expansion are caused by the cooling or heating of metals. These properties affect the design of welding jigs, castings, and the tolerances necessary for hot rolled material.

HEAT TREATMENT TERMS

CRITICAL RANGE

Critical range, applied to steel, refers to the range of temperature between 1,300 deg. and 1,600 deg. F. When steel passes through this temperature range, its internal structure is altered. Rapid cooling of the metal through this range of temperature will prevent the normal change of the structure, and unusual properties will be possessed by the material so treated. The heat treatment of steel is based upon this phenomenon.

ANNEALING

Annealing is the process of heating steel above the critical range, holding it at that temperature until it is uniformly heated and the grain is refined, and then cooling it very slowly. Other materials do not possess critical ranges, but all are annealed by a similar heating process which permits rearrangement of the internal structure. The annealing process invariably softens the metal and relieves internal strains.

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NORMALIZING

Normalizing is similar to annealing, but the steel is allowed to cool in still air, a method that is somewhat faster than annealing cooling. Normalizing applies only to steel. It relieves internal strains, softens the metal somewhat less than annealing would, and at the same time increases the strength of the steel about 20 percent above that of annealed material.

HEAT TREATMENT

Heat treatment consists of a series of operations which have as their aim the improvement of the physical properties of a material. In the case of steel, these operations are hardening (which consists of heating and quenching) and tempering.

HARDENING

Hardening of steel is done by heating the metal to a temperature above the critical range and then quenching it. Aluminum alloys are hardened by heating to a temperature above 900 deg. F. and quenching.

QUENCHING

Quenching is the immersion of the heated metal in a liquid, usually either oil or water, to accelerate its cooling.

TEMPERING

Tempering is the reheating of hardened steel to a temperature below the critical range, followed by cooling as desired. Tempering is sometimes referred to as "drawing."

CARBURIZING

Carburizing is the addition of carbon to steel by heating it at a high temperature while in contact with a carbonaceous material in either solid, liquid, or gaseous form. Carburizing is best performed on steel containing less than 25 percent carbon content.

CASE HARDENING

Case hardening consists of carburizing, followed by suitable heat treatment to harden the metal.

PHYSICAL TEST TERMS

STRAIN

Strain is the deformation of material caused by an applied load.

STRESS

Stress is the load acting on a material. Internal stresses are the loads present in a material that has been strained by cold working.

TENSILE STRENGTH

This is often referred to as the ultimate tensile strength (U.T.S.). It is the maximum tensile load per square inch that a material can withstand. It is computed by dividing the maximum load obtained in a tensile test by the original cross-sectional area of the test specimen. It is recorded as pounds per square inch.

ELASTIC LIMIT

The elastic limit is the greatest load per square inch of original cross-sectional area which a material can withstand without a permanent deformation remaining upon complete release of the load. As stated under ELASTICITY, the aim in aircraft design is to keep the stress below this point.

PROPORTIONAL LIMIT

The proportional limit is the load per square inch beyond which the increases in strain cease to be directly proportional to the increase in stress. The law of proportionality between stress and strain is known as Hooke's Law. The determination of the proportional limit can be more readily accomplished than that of the elastic limit and, since they are nearly equivalent, the proportional limit is usually accepted in place of the elastic limit in test work.

PROOF STRESS

The proof stress is the load per square inch a material can withstand without resulting in a permanent elongation of more than 0.0001 in. per inch of gauge length after complete release of stress. With the standard 2 in. gauge length, the total permissible elongation would be 0.0002 in.

YIELD STRENGTH

Yield strength is the load per square inch that a material exhibits a specified limiting permanent set, or a specified elongation under load. This load is fairly easily determined and is commonly used.

YIELD POINT

The yield point is the load per square inch at which there occurs a marked increase in deformation without an increase in load. Only a few materials have a definite yield point. Steel is one of these materials.

ELONGATION (Percentage)

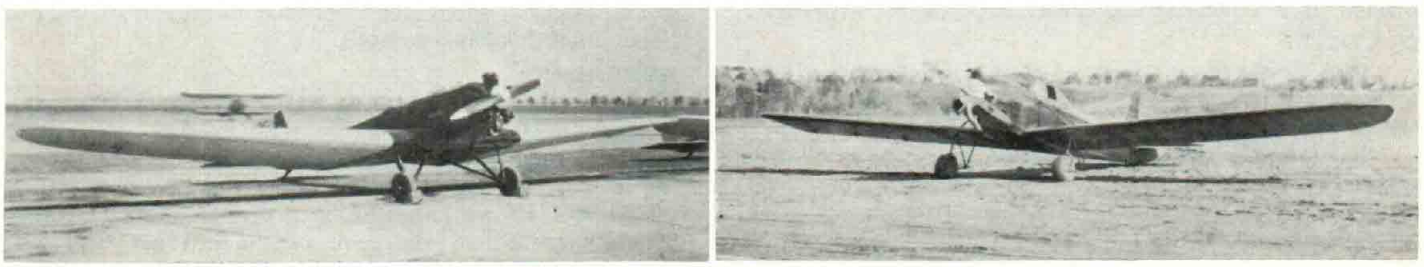
The percentage elongation is the difference in gauge length before being subjected to any stress and after rupture, expressed in percentage of the original gauge length. The length after rupture is obtained by removing the two pieces from the machine and piecing them together on a flat surface. The distance between the gauge marks is then accurately measured.

REDUCTION OF AREA (Percentage)

The percentage reduction of area is the difference between the original cross-sectional area and the least cross-sectional area after rupture, expresed as a percentage of the original cross-sectional area. This information is seldom used other than as an indication of ductility.

MODULUS OF ELASTICITY

The modulus of elasticity of a material is the ratio of stress to strain within the elastic limit. Thus, E = unit stress/unit strain.



SEPTEMBER MYSTERY AIRCRAFT

You will find the answers on another page in this issue.