Introduction to Aircraft Materials

2. Aircraft Material

Several factors influence the design of an aircraft because of the selection of aircraft materials—load factors, stresses, shear loads, compression, bending, buckling, and other aerodynamic forces that the aircraft structure will be able to withstand—but among these, strength allied to lightness is probably the most important. Other properties have varying, though sometimes critical, significance and stiffness, toughness, resistance to corrosion, fatigue, effects of environmental heating, ease of fabrication, availability and consistency of supply, and not least important, cost.

The main groups of materials used in aircraft construction have been wood, steel, aluminum alloys with, more recently, titanium alloys, and fiber-reinforced composites. In the field of engine design, titanium alloys are used in the early stages of a compressor, while nickel-based alloys or steels are used for the hotter later stages.

In this chapter we discuss the aeronautical properties part of the aircraft materials and their definition, the knowledge and understanding of the uses of strength limitation, and other characteristics of structural metals vital to properly construct and maintain any equipment, especially the airframe.

2.1. Properties of Materials

Material properties that define the strength related characteristics of any given material and sometimes mechanical strength properties are used interchangeably with material strength properties. Typical examples of material strength properties normally define the yield point of the material and as well as the ultimate capability of the material.

Material design values and material strength properties that have been established based on the regulatory requirements account for the effects on the operational environment in which the materials operate. Generally, these values are statistically determined based on enough data that, when used for design, the probability of the structural failure due to material variability.

One important concern in aircraft maintenance is such general properties of metals and their alloys as hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity, contraction and expansion, and so forth. These terms are explained to establish a basis for further discussion of structural metals.

2.1.1. Hardness

Hardness refers to the ability of a material to resist abrasion, penetration, cutting action, or permanent distortion. Hardness may be increased by cold-working the metal and, in the case of steel and certain aluminum alloys, by heat treatment. Structural parts are often formed from metals in their soft state and are then heat-treated to harden them so that the finished shape will be retained. Hardness and strength are closely associated properties of metals.

2.1.2. Strength

One of the most important properties of a material is strength.*Strength* is the ability of a material to resist deformation. Strength is also the ability of a material to resist stress without breaking. The type of load or stress on the material affects the strength it exhibits.

2.1.3. Density

Density is the weight of a unit volume of a material. In aircraft work, the specified weight of a material per cubic inch is preferred since this figure can be used in determining the weight of a part prior to actual manufacture. Density is an important consideration when choosing a material to be used in the design of a part in order to maintain the proper weight and balance of the aircraft.

2.1.4. Malleability

Malleability allows for a metal to be hammered, rolled, or pressed into various shapes without cracking, breaking, or leaving some other detrimental effect. This property is necessary in sheet metal when it is worked into curved shapes, such as cowlings, fairings, or wing tips. Copper is an example of a malleable metal.

2.1.5. Ductility

Ductility is the property of a metal that permits it to be permanently drawn, bent, or twisted into various shapes without breaking. This property is essential for metals used in making wire and tubing. Ductile metals are greatly preferred for aircraft use because of their ease of forming and resistance to failure under shock loads. For this reason, aluminum alloys are used for cowl rings, fuselage and wing skin, and formed or extruded parts, such as ribs, spars, and bulkheads. Chrome molybdenum steel is also easily formed into desired shapes. Ductility is similar to malleability.

2.1.6. Elasticity

Elasticity is the property that enables a metal to return to its original size and shape when the force causing the change of shape is removed. This property is extremely valuable because it would be highly undesirable to have a part permanently distorted after an applied load was removed. Each metal 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 designed so that the maximum loads to which they are subjected will not stress them beyond their elastic limits. This desirable property is present in spring steel.

2.1.7. Toughness

A material that possesses *toughness* will withstand tearing or shearing and may be stretched or otherwise deformed without breaking. Toughness is a desirable property in aircraft metals.

2.1.8. Brittleness

Brittleness is the property of a metal that allows little bending or deformation without shattering. A brittle metal is apt to break or crack without change of shape. Because structural metals are often subjected to shock loads, brittleness is not a very desirable property. Cast iron, cast aluminum, and very hard steel are examples of brittle metals.

2.1.9. Fusibility

Fusibility is the ability of a metal to become liquid by the application of heat. Metals are fused in welding. Steels fuse around 2600°F and aluminum alloys at approximately 1100°F.

2.1.10. Conductivity

Conductivity is the property that enables a metal to carry heat or electricity. The heat conductivity of a metal is especially important in welding because it governs the amount of heat that will be required for proper fusion. The conductivity of the metal, to a certain extent, determines the type of jig to be used to control expansion and contraction. In aircraft, electrical conductivity must also be considered in conjunction with bonding, to eliminate radio interference.

2.1.11. Thermal expansion

Thermal expansion refers to contraction and expansion that are reactions produced in metals as the result of heating or cooling. Heat applied to a metal will cause it to expand, or become larger. Cooling and heating affect the design of welding jigs, castings, and tolerances necessary for hot-rolled material.

2.1.12. Isotropic materials

In many materials, the elastic properties are the same in all directions at each point in the material, although they may vary from point to point; such a material is called *isotropic*. An isotropic material having the same properties at all points is called *homogeneous* (e.g., mild steel).

2.1.13. Anisotropic materials

Materials having varying elastic properties in different directions are known as*anisotropic*.

2.1.14. Orthotropic materials

Although a structural material may possess different elastic properties in different directions, this variation may be limited, as in the case of timber, which has just two values of Young's modulus, one in the direction of the grain and one perpendicular to the grain. A material whose elastic properties are limited to three different values in three mutually perpendicular directions is known as *orthotropic*.