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USE OF CONSTRUCTION MATERIALS IN UNMANNED AERIAL VEHICLES

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Abstract

The design process is mostly connected with a proper selection of construction materials. Newly designed UAVs must undergo assessment in terms of performed tasks, range or fuel consumption. A significant influence upon the selection of materials, which are long lasting and resistant to damage, is exerted by the conditions of work of Unmanned Aerial Vehicles. They mainly execute their tasks at high altitudes with high speeds, where temperature and pressure differences may extensively damage not only the airframe skin, but also the equipment and the propulsion system itself.

The aim of this study is to present the characteristics of materials currently used as well as their assessment in employed construction elements of UAVs.

Polymer composites are superior to Al and Ti alloys, steel within the parameters of tensile strength and stiffness. As for the density gradient, polymer carbon fibre composites exceed glass fibre composites, also under cyclically variable loads. Glass fibre composites during tensile testing show higher values and a higher capability of absorbing energy under static and dynamic forces. Polymer matrix composites, reinforced with Kevlar, are less stiff than carbon-fibre composites, due to lower values of elasticity modulus, however they demonstrate higher impact load. Strength tests provide valuable data concerning the properties of a given material, such as tensile modulus E [MPa], tensile strength UTS [MPa], or resistance to high temperatures. It must be noted that these properties significantly affect the functioning of the airframe and its components.

Keywords: *Unmanned Aerial Vehicle (UAV), construction materials, material properties*

1. Introduction

In recent years, Unmanned Aerial Vehicles have been developing dynamically and have won an unquestionable position on the civilian labour market and the contemporary battlefield. UAVs (Unmanned Aerial Vehicles) are made with model complex materials of heightened fatigue resistance to exploitation in various atmospheric conditions.

Quick development of UAVs aims at creating specialized vehicles, which will secure reliability, stealth capabilities and technological durability, based on modern construction materials, in particular smart materials, fibre-metal laminates or piezoelectric fibres [1, 2].

A successful combination of experience in the field of materials science may become crucial in innovative design processes of future Unmanned Aerial Vehicles.

2. Analysis of construction materials and their overall assessment in applied UAV fittings

2.1. Steels

Steels are iron-carbon alloy, which is plastically and thermally processed, with the content of up to 2.11% C and other chemical elements. Casting ferrous alloys are called cast iron or cast steel, they are found useful in production of following aviation parts [3, 4].

Tab. 1. Application of materials in the manufacture of aviation constructions-steels

Steels
• shafts • crown wheels • parts of landing gear • bulkheads and ribs
Alloy structural steel for thermal strengthening, chrome –silicon - manganese e.g. 30HGSA (PN)
• main parts of landing gear • motor body frames • fuselage trusses • spar flanges • bulkheads and ribs • screws and bolts, • hydraulic cylinders • undercarriage fittings
40HM, 40HMNA (PN) 42CrMo4 (EN)
• shafts • spindles • rotor hubs • bolts and connecting rods for rotors

2.2. Aluminium alloys

The alloys, which have won the biggest popularity in aviation industry are **Al– Cu– Mg alloys**, also called **durals**. They consist of ~4.5% Cu, 1.5% Mg and a slight addition of manganese.

Copper and manganese increase resilience and toughness, whereas manganese improves resistance to corrosion. Durals are non-weldable alloys due to the fact that they are crack-sensitive; therefore, they are joined by bolts or by bonding [7].

Cast aluminium alloys consist mostly of silicon, magnesium and copper. The most popular representatives of the group are **silumins**, which contain silicon, for the most part.

They are characterized with very good casting qualities (good castability, small shrinkage, little sensitivity to hot cracking) and mechanical properties to tensile testing.

Al – Mg alloys demonstrate the highest resistance to corrosion and the lowest density. Unfortunately, this alloy cannot be used in higher temperatures.

2.3. Titanium and its alloys

Titanium alloys, have been introduced due to problems connected with achieving high speeds by airframes, accompanied by high temperatures, which in consequence might lead to the destruction of the propulsion system and skin.

They are characterized with very high tensile strength UTS = 1500 MPa, with density equalling 4.5 g/cm^3. Such properties as high creep resistance up to 800 °C and excellent resistance to corrosion, definitely have a positive influence on the constructions of propulsion systems.

Tab. 2. Application of materials in the manufacture of aviation constructions-aluminium alloys

Aluminium alloys
• aluminium foil is used as cellular filler • low endurance strength bolts
Aluminium alloys for plastic working
Double alloys: Al –Mg and Al - Mg - Mn
• fuel and oil tanks • suspended tanks • low pressure fuel and oil lines • drain pipes • fairings • wing tips
Aluminium alloys – copper – magnesium durals (Al – Cu – Mg)
• girders • longerons • ribs • boltheads • covers exposed to stresses
Cast aluminium alloys
• heads of piston engines • pistons • casings: engines, fuel pumps and hydraulic pumps, aggregates of hydraulic and pneumatic systems

Tab. 3. Application of materials in the manufacture of aviation constructions-titanium alloys

Titanium alloys
• blades of compressors and fans • external ducts in turbofans • fireproof covers • studs and screws (lighter than screws made with alloys of structural steel for thermal toughening by 40 %) • girders • xenon lights in wings • boltheads and ribs • in leading edges of airframes, which fly at speeds up to 3.3 Ma • bolts (due to low mass) • undercarriages • hub heads of main rotors

2.4. Polymer fibre-reinforced composites

Polymer composites are a group of materials, which have been more and more commonly used in aviation constructions, due to their unique qualities. From the standpoint of the parameters which are taken into consideration while classifying composites, such as tensile strength (relative) UTS / ρ·g, specific modulus E/ρ g and tensile modulus E, these materials are definitely superior to steels. The diagram below illustrates the characteristics of selected laminates, depending upon the form of the glass reinforcement [5, 6].

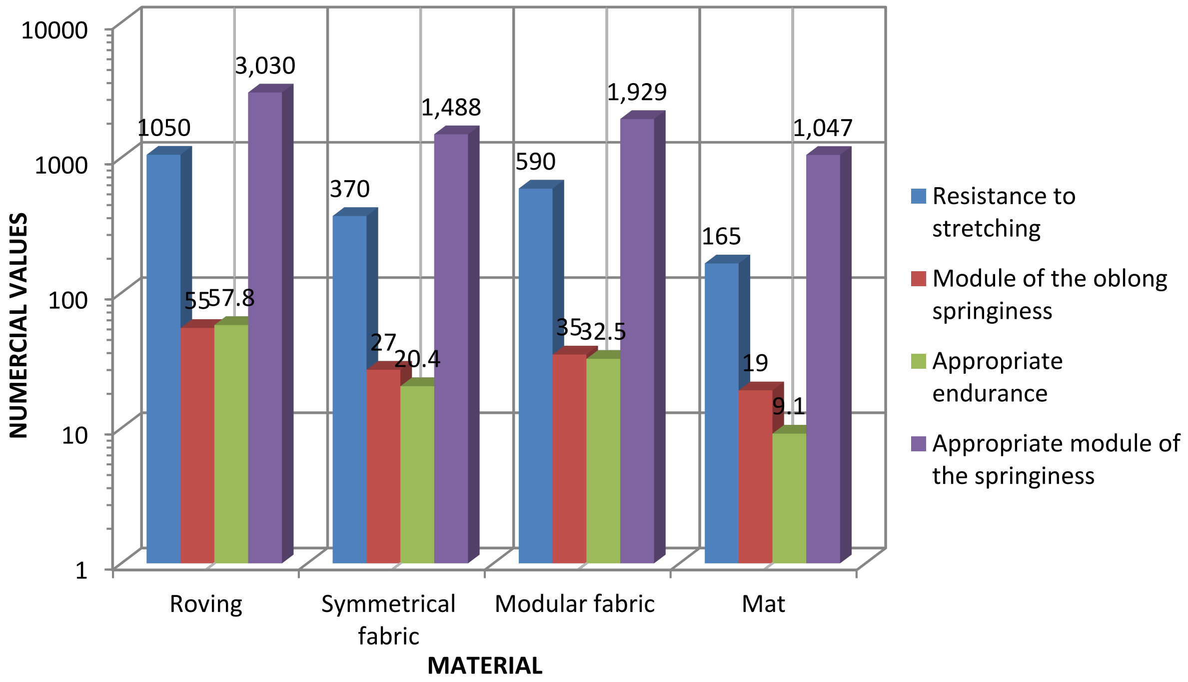

Fig. 1. Resistance properties of glass-epoxy composites

Based on the above diagram, it appears that roving demonstrates the best parameters in terms of tensile and specific modulus. These parameters exert a significant role in constructions, which are under heavy loads [8].

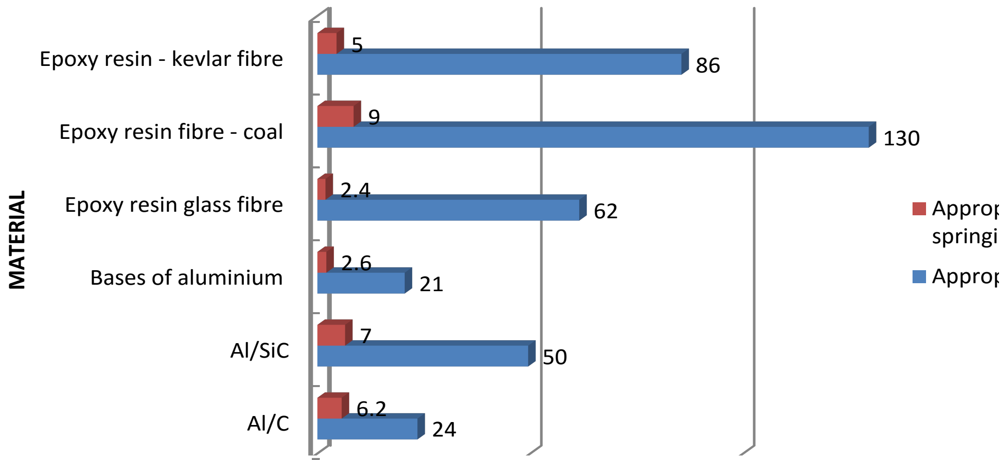

Fig. 2. Values of relative strength and elasticity modulus of construction materials

The above diagram shows that the most advantageous mechanical properties are exercised by a composite with an epoxy resin matrix, reinforced with carbon fibre. From the economical point of view, the technological process of reinforced materials largely exceeds the prices of commonly used materials [5].

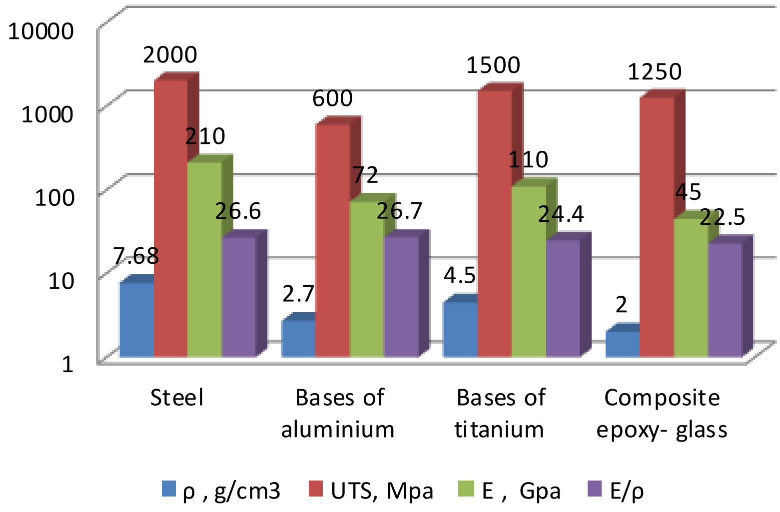

Fig. 3. Comparison of mechanical properties of selected materials

The above diagram illustrates basic qualities of materials, which are in common use in aviation industry. While analysing their parameters, we can judge that the epoxy-glass composite has the lowest mass density and very high strength. On the other hand, aluminium alloys have comparable density, however they are not as strong as composites, since their UTS = 600 MPa.

2.5. Comparison of properties of materials used in the constructing of the airframe – specification of materials

The following specification analyses the main properties of materials, commonly used in aviation constructions. A preliminary analysis of the properties of steel, aluminium and titanium alloys as well as composites reveals perfect capabilities of composites, as a material widely used in aviation constructions, due to their low specific weight combined with excellent strength and good technological processing.

A proper material selection based on the conditions of exploiting an airframe guarantees a high level of using it; therefore, competitiveness of composite materials as regards metals and their alloys plays such a vital role [9].

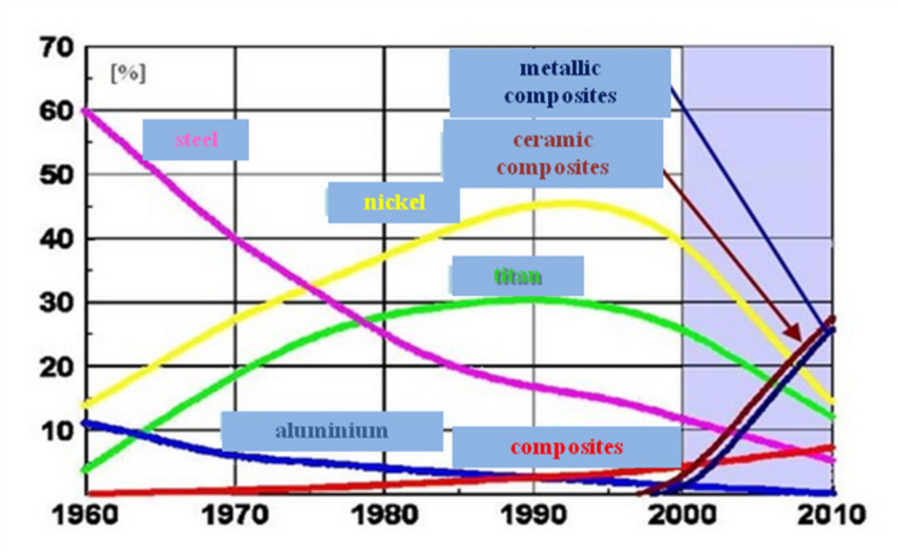

Fig. 4. Materials used in aircraft propulsion systems [10]

Tab. 4. Main properties of materials, commonly used in aviation constructions

Material	Advantages	Drawbacks
Steel	• Low price • Very strong • Good stiffness • Quite a good ability to damp vibration • Shear treatment of most elements	• High specific weight • Resistance to corrosion • Construction limitations connected with treatment
Aluminium alloys	• Low price • Low specific weight • Relatively strong • Very stiff in relation to specific weight • Rather resistant to corrosion in the environment deprived of salt • Easy for technological processing • Easy mechanical treatment	• Low fatigue strength • Poor ability to damp vibration • Construction limitations connected with treatment • Crack-sensitive • Not resistant to corrosion
Titanium, titanium alloys	• Low specific weight • Very strong • Ability to damp vibration • Quite resistant to corrosion • High fatigue strength • Rather easy for technological processing	• High price • Construction limitations connected with difficult treatment • Not very stiff
Polymer composites	• Low price • Very low specific weight • High ability to damp vibrations • Easy to design and modify structure • Very resistant to corrosion and temperature • High fatigue strength • Increased strength and stiffness	• Low resistance to temperature • Strong and stiff, depending upon a construction • Difficult to bond elements • Difficult to repair damages

Composite materials offer the most extensive possibilities of development, as illustrated in the diagram below. A significant rise in interests in ceramic and metal composites is linked with their outstanding mechanical properties. This might denote that composite materials will dominate the aviation industry and new technologies in materials science will facilitate further development of aviation constructions.

The rapid development of composite materials is undoubtedly a technological revolution, which enabled engineers to model the airframe in any way, similarly to the unmanned X-45B, consisting of 50% composite materials that reduce the size, weight and fuel consumption. A new application of composites is also connected with the absorption of radar radiation.

3. Conclusions

A growing demand for new generation unmanned aviation contributes to an increase in interests in modern construction materials. Composite materials can satisfy high technological demands, which create endless possibilities, while searching for new raw materials of unique qualities. Therefore, the type of used materials significantly influences the quality and reliability of the airframe. Selecting proper material is, to a large extent, linked with the character of the tasks that will be performed by the airframe.

Polymer composites are superior to Al and Ti alloys, steel within the parameters of tensile strength and stiffness. As for the density gradient, polymer carbon fibre composites exceed glass fibre composites, also under cyclically variable loads. Glass fibre composites during tensile testing show higher values and a higher capability of absorbing energy under static and dynamic forces. Polymer matrix composites, reinforced with Kevlar, are less stiff than carbon-fibre composites, due to lower values of elasticity modulus, however they demonstrate higher impact load.

Strength tests provide valuable data concerning the properties of a given material, such as tensile modulus E [MPa], tensile strength Rm [MPa], or resistance to high temperatures. It must be noted that these properties significantly affect the functioning of the airframe and its components.

The findings of bend tests, tensile strength or impact loading do not fully specify the properties of a given material; therefore, it is necessary to extend the scope of the analysis by fatigue strength.

A modern unmanned aircraft should be fast, should fly at high altitudes, should have a long range, should not be easily detected by radars and, most importantly, should carry a proper amount of necessary equipment.

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