FEATURES OF CUTTING TITANIUM ALLOYS

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Abstract*. Structural materials used in aircraft structures are considered. The main characteristics of aviation materials and titanium alloys are presented, the advantages and disadvantages of titanium alloys are studied. Conclusions are drawn about the need to further improve the technology of mechanical processing of titanium alloys.*
Keywords*: titanium alloys, aerospace components, advantages of titanium, limitations of titanium alloys.*

The importance of the materials used in aviation cannot be overstated. The materials used in airframe structures and turbojet engine parts are critical to improving the reliability and safety of the aircraft . The materials used have the impact on the profitability of the aircraft, their physical and mechanical properties in many ways determines the performance and suitability of the aircraft for operation .

Despite the large number and variety of materials (it is estimated that there are more than 120,000 materials) available for aircraft structures, only a small percentage of materials, less than 0.05%, are suitable for use in airframe and engine components of aircraft, helicopters and spacecraft. Most materials are too expensive, too heavy, inadequate for strength, or lack sufficient corrosion resistance, toughness, or other important properties.

The main groups of materials used in aircraft structures are aluminum alloys, titanium alloys, steels and composites. Other materials have specific uses for certain types of aircraft, but are not the primary materials used in large quantities. Table 1. provides a rough classification of common aviation materials based on several key factors and properties.

Table 1.

Classification of Aerospace Materials by Key Design Factors

Property	Aluminum	Titanium	Magnesium	High strength steel	Nickel superalloy	Carbon fiber composite
Price	Cheap	Expensive	Average	Average	Expensive	Expensive
Weight (density)	Easy	Average	Very light	Heavy	Heavy	Very light
Stiffness (modulus of elasticity)	Low/medium	Average	Short	Very tall	Average	High
Strength (yield strength)	Average	Medium/High	Short	Very tall	Average	High

Fracture toughness	Average	High	Low/mediu m	Low/mediu m	Average	Short
Fatigue	Low/mediu m	High	Short	Medium/Hig h	Average	High
Corrosion resistance	Average	High	Short	Low/mediu m	High	Very tall
High temperatur e creep	Short	Average	Short	High	Very tall	Short
Ease of recycling	High	Average	Average	High	Average	Very low

In recent years, along with the development of aviation, the characteristics of the materials used in aircraft construction have improved. This is mainly a positive trend due to new production technologies and materials processing. From the diagram you can see that the amount of aluminum alloys used in modern aircraft is gradually decreases, while the amount of composite materials and titanium alloys increases (Fig. 1.).

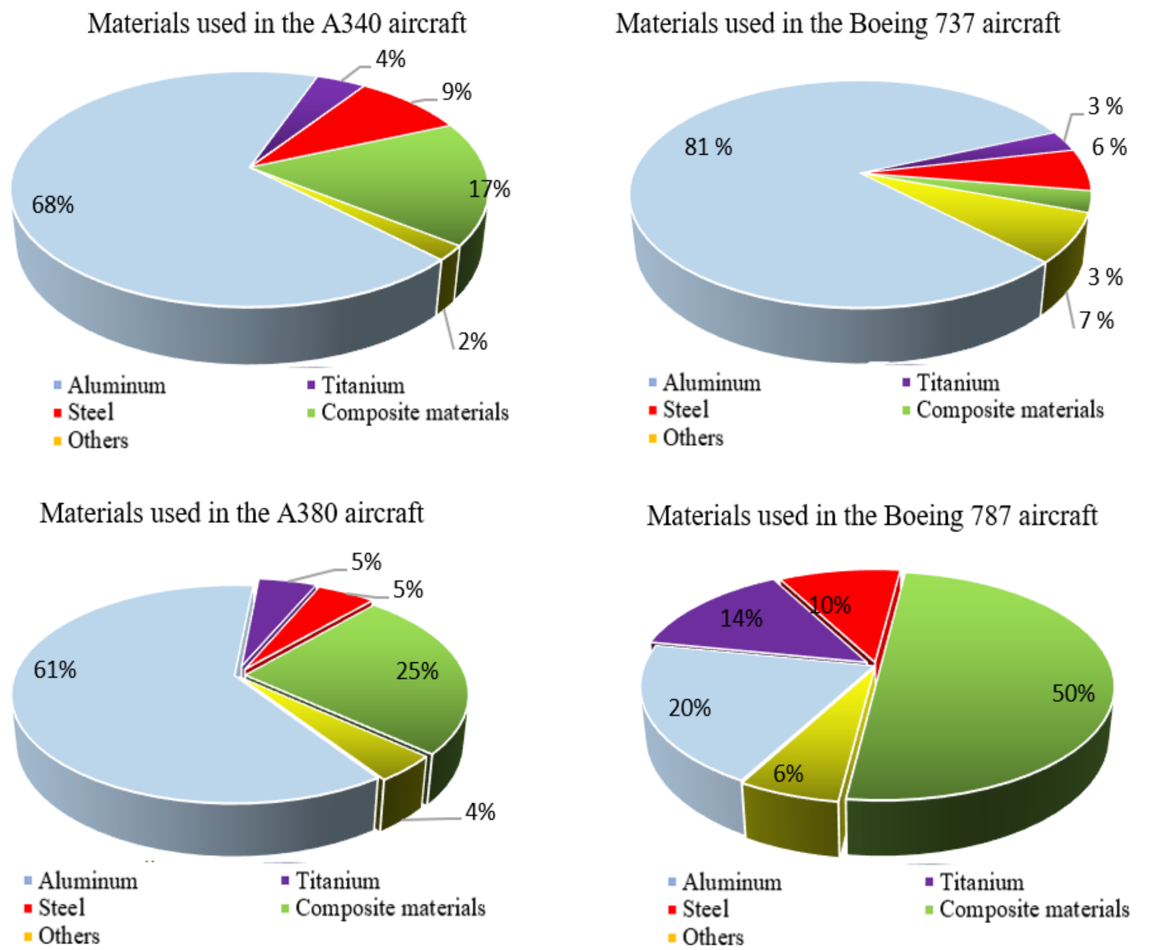

Fig. 1. Structural materials and their weight fraction used in the airframe of civil aircraft.

Titanium alloys are one of the main structural materials used in the aviation industry. Their widespread use is associated with its complex of properties - high specific strength, corrosion resistance, non-magneticity, good heat resistance at operating temperatures up to 500–600 ^{0}C.

The technological properties of titanium alloys differ significantly from the properties of the main structural alloys based on iron and aluminum due to their inherent differences in the level of physical properties (Table 2.) [1].

Table 2.

Basic physical properties of aluminum, titanium, iron

Properties metals	Aluminum	Iron	Titanium
Density, kg / m^3	2698	7874	4540
Temperature melting, T, ^{0}C	660	1535	1665
Thermal conductivity, λ, W/mK	238	72.4	15.5
Thermal expansion coefficient, $\alpha * 10^6$, 1/°C	23.86	11.7	8.35
Heat capacity, s, J / gK	0.90	0.45	0.52
Specific electrical resistance , nOm * m	26.5	97.1	420
Module elasticity , E, GPa	70.6	200	103

But machining parts made of titanium alloys is significantly more difficult compared, for example, with aluminum alloys and structural steels.

This is explained by the characteristic properties of titanium alloys: high ratio of yield strength to ultimate strength ($\sigma_{0.2} / \sigma_{in}$, amounting to 0.85 - 0.95 (for steels 0.65-0.75); relatively low thermal conductivity; adhesion of titanium on the tool; high chemical activity towards gases at elevated temperatures; heterogeneity of the properties of the cut layer due to the segregation of alloying elements; features of the processes for obtaining semi-finished products, etc.

All these conditions, reducing tool life, lead to the need to use more wear-resistant materials for cutting tools than for processing steels.

But even when such measures are taken, cutting conditions, especially speeds, must be reduced by 3-4 times compared to the processing of steels to ensure acceptable tool life, especially when processing on CNC machines.

Therefore, productivity when machining parts made of titanium alloys is significantly reduced compared to machining steel.

The main difficulties when processing titanium include:

— adhesive wear of the cutting part of the tool due to excessive heat generation in the cutting zone;

— poor heat transfer and slow heat transfer due to the low thermal conductivity of titanium alloys, as a result of which the cutting part experiences a colossal thermal load;

- deterioration in processing accuracy and quality of the machined surface due to vibration caused by a low elastic modulus [3].

For the cutting part of metalworking tools, high speed steels, hard alloys, ceramics, as well as tool materials with wear-resistant coatings, etc. are used (Fig. 2).

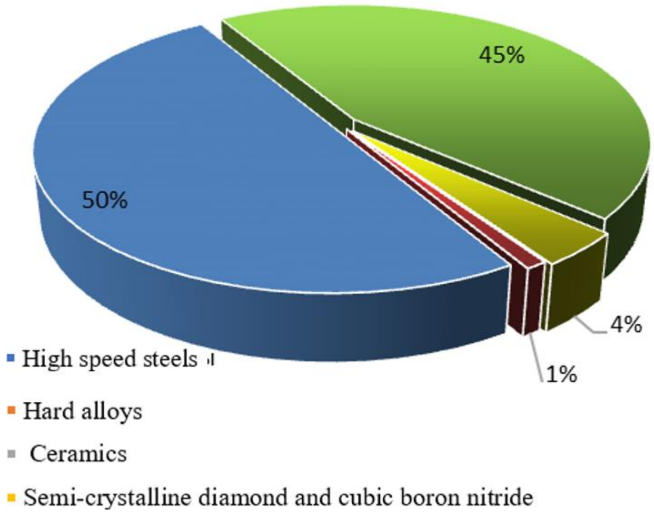

Fig. 2. Materials used as the cutting part of various tools

Conclusions. Based on the analysis of the reviewed works, we can draw a conclusion about the relevance of further improving the performance properties of cutting tools through the use of new materials and technologies for their production. One of the determining factors in the development of the use of titanium alloys in the aviation industry is the development of metal-cutting tools that provide increased productivity and increased wear resistance during cutting.

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