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SELECTION AND OPTIMIZATION OF FUSELAGE COMPONENTS FOR MODERN AIRPLANES

Nowadays the level of development of airplane materials shows the tendency of usage of advanced composite structures. However, these materials have plenty of advantages and disadvantages, the most crucial is the ability to absorb water from the environment and because of this layers of composite structures disbonded and consequently became useless. This issue demonstrates the limitation of usage of advanced composite structures. Despite this fact application of conventional materials (such as Aluminum or Titanium alloys) are limited by the weight of structure and manufacturability. In given article question of optimization for choosing of the airplane, the material is considered. The necessity to maintain equilibrium between minimal weight and appropriate strength pushes designers to develop new advanced materials, mechanical properties of which satisfy strict criteria of strength, despite lightweight of the material.

The goal of this research elaborating work is to estimate the necessity of usage of advanced composite structures vs well known conventional materials. It was researched sizing and optimization of choosing of structural materials for the primary structure. On top of this, properties and peculiarities of conventional materials (such as Aluminum and Titanium alloys) and advanced composite structure. It was demonstrated that the usage of conventional materials for primary structure has a significant advantage in comparison with advanced composite structures. Additionally, manufacturability and maintainability of materials were discussed in the given article. As a result, the application of conventional materials for primary airplane structure is the most suitable way for the design of modern airplanes. Today, the structural designer no longer chooses a material solely based on its strength qualities, but on its proven ability to withstand minor damage in service without endangering the safety of the aircraft. The residual strength after damage, described as the toughness, is now uppermost in the engineer's mind when he chooses alloys for airframes. Damage caused by fatigue is the main factor because it is difficult to detect and can disastrously weaken the strength of critical components. So whereas about a decade ago aluminum alloys looked as if they had reached a technical plateau, engineers have now been able to clarify their needs as a result of the work done on fracture mechanics, and metallurgists have changed their composition and treatment techniques to meet the new toughness requirements. The best option to consider the usage of both advanced composite structure (for secondary structures) and conventional material (for primary structures).

Keywords: aircraft materials; composite structure; fatigue; sandwich materials; optimization.

Introduction

Knowledge and understanding of the uses, strengths, limitations, and other characteristics of structural metals is vital to properly construct and maintain any equipment, especially airframes. In aircraft maintenance and repair, even a slight deviation from design specification, or the substitution of inferior materials, may result in the loss of both lives and equipment. The use of unsuitable materials can lead to decreasing of safety levels and consequently to death of people. The selection of the correct material for a specific repair job demands familiarity with the most common physical properties of various metals. Of primary concern in aircraft maintenance are such general properties of metals and their alloys as hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity contraction and expansion, and so forth.

The materials used in the airplane power plant and those used in the remaining structure, or airframe, are selected and proportioned by different criteria. Materials used in the airplane power plant are often subjected to high temperatures and must not "flow" or "creep" when stressed at the operating temperatures. The structural members of the power plant may also be subjected to repeated loadings of several millions of cycles during their service life. Such members must not be stressed beyond their "fatigue limit," or the minimum stress at which fatigue failure may occur for an infinitely large number of repetitions of loading. Other obvious considerations, which are important in the selection of materials for engine parts, are the friction and wearing properties of parts which are in contact and which have relative motion.

The necessity to maintain equilibrium between minimal weight and appropriate strength pushes designers to develop new advanced materials, mechanical properties

of which satisfy strict criteria of strength, despite lightweight of the material.

The goal of this research elaborating work is to estimate necessity of usage of advanced composite structures vs well known conventional materials.

1. Mechanical properties of aircraft materials

Airframe materials are subjected to much different loading conditions. The temperature variations are never sufficient to affect the properties of the materials. The maximum loads occur only a few times during the service life of the airplane, and fatigue failures of the type, which are considered in the engine design, need not be considered in the airframe design. The materials used for the airframe members are therefore different from those used for the power plant members. Since the design of the power plant is beyond the scope of this diploma, the future discussion will be confined to airframe materials, and references to aircraft, materials or aircraft structures are understood to apply only to the airframe.

In order to protect structural aluminum-alloy sheets from corrosion, they are often manufactured with a thin, integral coating of pure aluminum. This coating is softer and weaker than the alloy, but is lighter and more durable than a similar covering of paint. These sheet materials are designated as Alclad. An Alclad 24X-T sheet, for example, would be similar to a 24%T sheet, except for the thin coating of pure extrusions, forgings, or castings. The stress-strain curves for Alclad sheet have a slightly smaller slope above a stress of about 10,000 psi, where the aluminum surface material passes its yield stress. The two values of the modulus of elasticity of Alclad materials are designated as primary and secondary moduli. Thus, Alclad 24S-T sheet has a primary modulus of elasticity of 10500000 psi and a secondary modulus of elasticity of 9500000 psi.

The primary structural material in perhaps 90 per cent of all of the metal airplanes built before 1945 was 24S-T aluminum alloy. The sheet material was either Alclad material or was painted in some manner. Sheets which had only a single curvature, such as wing skins with developable surfaces, were formed from the sheet in the T condition. Members such as wing ribs, which were formed to shapes with a, double curvature, were formed from 24X-O material and heat-treated after forming. Stiffeners and stringers were usually made of 24S-T extrusions. The extrusion process consists of forcing the plastic metal through a die of the desired cross section, in the same manner that toothpaste is forced from a tube.

2. Strength-Weight Comparisons of Materials

In the selection of aircraft structural materials, it is desirable to choose the material, which will yield the desired strength for a minimum structural weight. It, is, of course, necessary to consider the ease of fabricating the material into the desired structural members. The weights of tension materials required to resist a given load may be compared as the product of the inverse ratio of their ultimate strengths F and the ratio of their weights per cubic inch ω

$$\frac{W_1}{W_2} = \frac{\omega_1}{\omega_2} \cdot \frac{F_2}{F_1},$$

where W_1 , and W_2 represent, the weights of tension members of different materials resisting the same loads. Members resisting bending or compressive loads cannot, be compared in this manner. Wood and plastic materials usually have a smaller unit elongation at the ultimate tensile strength and are termed brittle materials. Brittle materials are undesirable for structures which have numerous bolted connections, or numerous cutouts which produce local high stress concentrations. Ductile materials, which have a large unit elongation at the ultimate tensile strength, will yield slightly at points of high local stress and will thus relieve the stress, whereas brittle materials will fail under the same conditions. Wood and plastic materials have been successfully used for aircraft structures, but such structures must be carefully designed to eliminate high stress concentrations.

3. Aluminum Alloys

In commercial aviation and military transport aircraft where aluminum material counts for about 80 % of the structural materials used, that material and its cost become major economic problems. Aluminum 2014 (aluminum-copper-magnesium alloy) has been used since 1920 on aircraft structures. In the 1940s the demand for more tensile strength led to the introduction of the 7000 series alloys (Al-Zn-Mg-Cu), but the problems of stress corrosion cracking and low fatigue resistance soon become apparent.

Stress corrosion remained a problem until 1960 when the introduction of the T73 double ageing treatment produced a dramatic improvement. But the treatment reduced the tensile strength by about 10 % and the additional development work was on to regain strength while retaining satisfactory stress corrosion resistance. In the early 1970s it resulted in the appearance of 7050 and 7010 with an improved balance of properties. The problems of fatigue became prominent since the 1950s and metallurgists have been

less successful in developing fatigue resistant alloys. One of them is 2024-T3 and it still remains the yardstick for good fatigue resistance. The fatigue failure of aircraft wing spars caused several accidents in the early 1950s and the 7000 series alloys were in part to blame in that it had offered the designer higher tensile strength but no commensurate improvement in fatigue strength. By the late 1950s the safe-life design philosophy was giving way to fail-safe design since material growing cracks could be more safely monitored in service, following a much improved understanding of crack behavior. Crack stoppers could be designed in - but usually with weight penalties - so the demand was increasing for 7000 series strength with 2024-T3 levels of fatigue crack growth resistance and toughness.

The demand for improved toughness reflects another deficiency in the 7000 series alloys. By using higher purity alloys much has been achieved and the 7075 and 7010 alloys have appreciably better strength in the presence of cracks than its predecessors. Recently, the premier new alloys, perhaps the most important aluminum material development are aluminum-lithium alloys which is about 10 % lighter than conventional aluminum alloys, and about 10 % stiffer. Substitution of aluminum-lithium for conventional alloys in an existing aircraft design would reduce weight by 8 to 10 %, and about 15 % weight reduction could be achieved for new design. Primarily because of its superior fatigue performance, the high cost of lithium material, safety precautions in casting, the need for scrap segregation and handling, and closer control of processing parameters all continue to increase product costs more than three times above those of conventional aluminum alloys. But the advantage of using this material is that the manufacturers can use existing machinery and equipment to work and workers do not need special training. Other recently developed aluminum alloys can provide outstanding combination of strength, fracture toughness, fatigue resistance, and corrosion resistance for aircraft components. The basis for these alloy systems, called wrought PM alloys, is the rapid-solidification process. The commercially available wrought PM aluminum alloys are 7090 and 7091.

4. Design Considerations

Today, the structural designer no longer chooses a material solely on the basis of its strength qualities, but on its proven ability to withstand minor damage in service without endangering the safety of the aircraft. The residual strength after damage, described as the toughness, is now uppermost in the engineer's mind when he chooses alloys for airframes. Damage caused by fatigue is the main worry because it is difficult to detect and can disastrously weaken the strength of

critical components. So whereas about a decade ago aluminium alloys looked as if they had reached a technical plateau, engineers have now been able to clarify their needs as a result of the work done on fracture mechanics, and metallurgists have changed their composition and treatment techniques to meet the new toughness requirements. For pressurized cabins and lower wing skins – two areas particularly prone to fatigue through the long continued application and relaxation of tension stresses - the standard material (for commercial transports, the entire fuselages of which are pressurized) is an aluminium alloy designated 2024-T3. For upper wing skins, which have to withstand mainly compression stresses as the wing flexes upwards during flight, 7075T6 (with zinc and chromium introduced) is used. This alloy is also used extensively for military aircraft structures, which generally have stiffer wings and - except for the cockpit area – unpressurized fuselages [1].

The use of titanium as a commercial material goes back only to about 1950. Offsetting its industrially attractive properties is an extreme chemical reactivity, and there were considerable difficulties to be overcome in refining the metal from its ore and forming it into forging or castings. These problems delayed its introduction until the demands of aviation bulldozed them aside. Several titanium alloys are used in aeronautical engineering, among them Ti-6Al-4V, and Ti-4Al-4Mo-2Sn-0.5Si. Ti-6Al-4V was developed in 1956 in America and is now probably the most widely used titanium alloy. Ti-4Al-4Mo-2Sn-0.5Si is a more specialized alloy developed in Britain and is little used elsewhere. The first large-scale airborne application of titanium was the Lockheed SR71 and North American XB-70 in the 1960s. These projects, along with other investigations of titanium in support of aerospace programs, were responsible for solving many of the production problems. Titanium is a suitable alternative to light alloys (i.e. aluminium alloys) when prolonged operating temperatures are greater than the 150°C or so that can be withstood by aluminium without excessive deformation due to creep, or when somewhat greater strength is required without significant weight increases. Titanium alloy bolts are now produced in quantity. For the same size as the equivalent steel bolts they have the same strength, about $F = 95000$ psi in shear strength, and adequate fatigue properties, but weigh only two-thirds as much. They are, however, more expensive, though over the life of the airplane the weight reduction may outweigh this disadvantage. Titanium rivets are also quite extensively employed hi-lok titanium fasteners for instance. Due to the very high cost of machining of titanium parts, the economic production of titanium components therefore depends to some extent on forming them as nearly as possible to the required

size, usually by forging, or by the newer precision forging so that as little as possible is machined where the cost of metal removal is paramount. Titanium is now finding increasing use in aircraft as volume production increases. Titanium alloys may comprise up to 5 % of the structural weight of commercial aircraft. This figure rises to as much as 25 % on the newer military aircraft (the F-14 structure contains 24.4 % by weight, that of the F-15 contains 26 %) and the Rockwell B-1 contains 21 % titanium. Nevertheless, there is no prospect that it will displace aluminium and its alloys because strength is not the only criterion. Rigidity is frequently essential, particularly where thin members act in compression, and a reasonable bulk such as that provided by low-density light alloys is necessary to resist buckling. On a strength/density basis, titanium has an edge over both aluminum and steel. Also, it generally has corrosion resistance superior to both. Aluminum has usually not been considered for applications above the 350°F region. Titanium, on the other hand, is used to 1150°F, with most of its applications lying between room temperature and 1000°F. It is used in airframes as high-strength and high-toughness forgings, or where there is too little airframe space for aluminum. It is used in firewalls to isolate engines from structures, and in wing skins and support structures for military aircraft, ie. both the F-14 and B-1 use titanium carry-through wing center box structures, and the familiar SR71 reconnaissance aircraft with its extreme speed, requires an all-titanium surface. In addition, the titanium alloys have better ratios of fatigue properties to strength than do either the aluminum or steels.

5. Composite Materials

Research into composite materials started in the early 1960s and at this early stage the target was a material as stiff as metal but less dense. Composite materials are now reaching the production line and aircraft designers, appreciating the weight savings available, are continually looking for further applications. Composite or advanced composite materials will be defined as a material consisting of tiny diameter, high strength, high modulus (stiffness) fibers embedded in an essentially homogeneous matrix. This results in a material that is anisotropic; having mechanical and physical properties that vary with direction and heterogeneous: consisting of dissimilar constituents that are separately identifiable. Broadly speaking, today's advanced composite materials can be broken down into two basic classes; organic matrix and metal matrix materials. The organic matrix systems consist of high strength fibers, such as boron or graphite, which provide the basic strength of the material and a matrix such as epoxy, polyamide, or any

of the thermoplastic materials which stabilize these thin or tiny fibers in compression and acts to redistribute load in shear between fibers in case of individual fiber failure or laminate transition. The metal matrix composites in current use are boron/aluminum and graphite/aluminum, although some much higher temperature matrix materials such as titanium and nickel are currently being developed. The benefit of these materials is found primarily at higher temperatures. In addition, the metal matrix provides a much better foundation.

In the 1940s, the aircraft industry began to develop synthetic fibers to enhance aircraft design. Since that time, composite materials have been used more and more. When composites are mentioned, most people think of only fiberglass, or maybe graphite or aramids (Kevlar). Composites began in aviation, but now are being embraced by many other industries, including auto racing, sporting goods, and boating, as well as defense industry uses. A "composite" material is defined as a mixture of different materials or things. This definition is so general that it could refer to metal alloys made from several conductivity or whatever characteristics are desired. Likewise, the composition of composite materials is a combination of reinforcement, such as a fiber, whisker, or particle, surrounded and held in place by a resin, forming a structure. Separately, the reinforcement and the resin are very different from their combined state. Even in their combined state, they can still be individually identified and mechanically separated. One composite, concrete, is composed of cement (resin) and gravel or reinforcement rods for the reinforcement to create the concrete [2].

6. Composite Safety

Composite products can be very harmful to the skin, eyes, and lungs. In the long or short term, people can become sensitized to the materials with serious irritation and health issues. Personal protection is often uncomfortable, hot, and difficult to wear; however, a little discomfort while working with the composite materials can prevent serious health issues or even death. Respirator particle protection is very important to protecting the lungs from permanent damage from tiny glass bubbles and fiber pieces. At a minimum, a dust mask approved for fiberglass is a necessity. The best protection is a respirator with dust filters. The proper fit of a respirator or dust mask is very important because if the air around the seal is breathed, the mask cannot protect the wearer's lungs. When working with resins, it is important to use vapor protection.

Charcoal filters in a respirator will remove the vapors for a period of time. If you can smell the resin vapors after placing the mask back on after a break,

replace the filters immediately. Sometimes, charcoal filters last less than 4 hours. Store the respirator in a sealed bag when not in use. If working with toxic materials for an extended period of time, a supplied air mask and hood are recommended. Avoid skin contact with the fibers and other particles by wearing long pants and long sleeves along with gloves or barrier creams. The eyes must be protected using leak-proof goggles (no vent holes) when working with resins or solvents because chemical damage to the eyes is usually irreversible.

7. Laminated Structures

Composites can be made with or without an inner core of material. Laminated structure with a core center is called a sandwich structure. Laminate construction is strong and stiff, but heavy. The sandwich laminate is equal in strength, and its weight is much less; less weight is very important to aerospace products. The core of a laminate can be made from nearly anything. The decision is normally based on use, strength, and fabricating methods to be used. Various types of cores for laminated structures include rigid foam, wood, metal, or the aerospace preference of honeycomb made from paper, Nomex, carbon, fiberglass or metal. It is very important to follow proper techniques to construct or repair laminated structures to ensure the strength is not compromised. A sandwich assembly is made by taking a high-density laminate or solid face and backplate and sandwiching a core in the middle. The selection of materials for the face and backplate are decided by the design engineer, depending on the intended application of the part. It is important to follow manufacturers' maintenance manual specific instructions regarding testing and repair procedures as they apply to a particular aircraft.

8. Reinforced Plastic

Reinforced plastic is a thermosetting material used in the manufacture of radomes, antenna covers, and wingtips, and as insulation for various pieces of electrical equipment and fuel cells. It has excellent dielectric characteristics which make it ideal for radomes; however, its high strength-to-weight ratio, resistance to mildew, rust, and rot, and ease of fabrication make it equally suited for other parts of the aircraft. Reinforced plastic components of aircraft are formed of either solid laminates or sandwich-type laminates. Resins used to impregnate glass cloths are of the contact pressure type (requiring little or no pressure during cure). These resins are supplied as a liquid, which can vary in viscosity from a water like consistency to a thick syrup. Cure or polymerization is

effected by the use of a catalyst, usually benzoyl peroxide.

Solid laminates are constructed of three or more layers of resin impregnated cloths "wet laminated" together to form a solid sheet facing or molded shape. Sandwich-type laminates are constructed of two or more solid sheet facings or a molded shape enclosing a fiberglass honeycomb or foam-type core. Honeycomb cores are made of glass cloths impregnated with a polyester or a combination of nylon and phenolic resins. The specific density and cell size of honeycomb cores varies over a considerable latitude. Honeycomb cores are normally fabricated in blocks that are later cut to the desired thickness on a bandsaw. Foam-type cores are formulated from combinations of alkyd resins and metatoluene di-isocyanate. Sandwich type fiberglass components filled with foam-type cores overall thickness of the molded facing and core material. To achieve this accuracy, the resin is poured into a close tolerance, molded shape. The resin formulation immediately foams up to fill the void in the molded shape and forms a bond between the facing and the core [3].

9. Sandwich Materials

The advantages of both high-density and low-density materials may be obtained by using sheets which have a layer of low-density material sandwiched between two layers of high density material. This type of construction has long been used for plywood, in which the outer veneers are often of a stronger, more durable wood than the inner veneers. Techniques have recently been developed for cementing thin surfaces of metal or plastic materials to low-density core materials of balsa wood, foam rubber, or wood fiber board. While there are many production difficulties in the construction of complete aircraft components of these materials, it is possible that such materials will be used much more extensively in the future. It will be assumed that the low-density filler material, having density ratio of the two materials is small and that the thickness of the face material is small compared with the thickness t . The bending moment resisted by a unit width of the sheet is approximately as follows:

$$M = F \cdot k \cdot t^2 \quad \text{or} \quad t = \sqrt{\frac{M}{k \cdot F}}$$

The weight of 1 sq in. of the sheet material is approximately as follows:

$$W = \omega_1 \cdot t + 2 \cdot \omega_2 \cdot k \cdot t.$$

Eliminating the term t , there is obtained

$$W = (\omega_1 + 2 \cdot \omega_2 \cdot k) \cdot \sqrt{\frac{M}{k \cdot F}}.$$

The value of k for the minimum weight may be obtained by differencing with respect to k and equating the derivative dW/dk to zero. The following value is obtained for a minimum weight:

$$k = \frac{\omega_1}{2 \cdot \omega_2}.$$

Equation shows that for a sandwich material resisting bending moment, the minimum weight is obtained when the two layers of the face material have approximately the same total weight as the layer of filler material. For the most efficient sandwich material to resist buckling under compression loads, the face material should not have the same thickness ratio as that given [4]. The buckling load per unit width of sheet is approximately as follows:

$$P = \frac{\pi^2 \cdot E \cdot I}{L^2} = \frac{\pi^2 \cdot E \cdot k \cdot t^3}{2 \cdot L^2},$$

$$t = \sqrt[3]{\frac{2 \cdot P \cdot L^2}{\pi^2 \cdot E \cdot k}}.$$

Substituting the value of t , differentiating the resulting expression, and again equating the derivative dW/dk to zero, the following equation is obtained:

$$k = \frac{\omega_1}{4 \cdot \omega_2}.$$

Equation shows that the total weight of the two layers of face material should be approximately one-half the weight of the core material, in order to obtain the lightest construction to resist compression buckling loads. It is now possible to compare the weight of a sandwich material with the weight of a solid sheet of the corresponding face material, assuming that they both resist the same loads. A sandwich material designed to resist bending moments will have a total weight equal to twice the total weight of the face material, if the face and core materials have equal weights:

$$W = 4 \cdot \omega \cdot k \cdot t,$$

where W , is the weight of a unit area of the sandwich and ω is the unit weight of the face material.

$$W = 4 \cdot \omega \cdot k \cdot \sqrt{\frac{M}{k \cdot f}}.$$

The weight W of a solid sheet was obtained, and the ratio of the weight of a sheet of sandwich material to that of a solid sheet of the corresponding face material is obtained.

$$\frac{W_\varepsilon}{W} = \frac{4 \cdot \omega \cdot k \cdot \sqrt{\frac{M}{k \cdot F}}}{\omega \cdot \sqrt{6 \cdot \frac{M}{F}}},$$

$$\frac{W_\varepsilon}{W} = 1.63 \cdot \sqrt{k}.$$

Equation applies only to sandwich materials in which the total weight of the face material is equal to the weight of the filler material. In order to compare the weights of sandwich materials with the aluminum materials, a sandwich sheet consisting of 24S-T aluminum alloy face material, and a filler material weighing 0.01 lb/in.³ will be considered.

$$k = \frac{\omega_1}{2 \cdot \omega_2} = \frac{0.01}{2 \cdot 0.1} = 0.05,$$

$$\frac{W_\varepsilon}{W} = 1.63 \cdot \sqrt{0.05} = 0.37.$$

This sandwich material consequently has only 37 percent of the weight of a solid sheet resisting the same bending moment. The value of 0.37 is less than any of the other values for aluminum materials. The weight of a sandwich material designed to resist compression buckling loads may be obtained by a method similar to that used above. The following equation is obtained, by assuming that the thickness of the face material, or that the total weight of the face material is one-half the weight of the filler material:

$$\frac{W_\varepsilon}{W} = 2.45 \cdot k^{2/3}.$$

In the case of 24S-T aluminum-alloy face material and a filler material weighing 0.01lb/in.³, the thickness ratio is obtained as follows:

$$k = \frac{\omega_1}{4 \cdot \omega_2} = \frac{0.01}{4 \cdot 0.01} = 0.025.$$

The weight ratio obtained as follows:

$$\frac{W_\varepsilon}{W} = 2.45 \cdot (0.025)^{2/3} = 0.21.$$

This sandwich material therefore has only 21 percent of the weight of a corresponding solid sheet of 24S-T which is designed to resist the same buckling load. In the preceding discussion it was assumed that the

proportions for sandwich materials were limited only by theoretical considerations. In actual structures, practical considerations will be much more important. The core material was assumed to support the face material sufficiently to develop the same unit stress that was developed in a solid sheet, whereas the actual low-density materials might not provide such support. In conventional aircraft, structures, the skin is supported by closely spaced stringers or stiffeners, and the resistance of the sheet itself may not be as important as assumed in the calculations [5, 6]. In some cases the sheet is stiffened by beads. The beads provide much greater resistance to bending or buckling than the flat sheet. Another practical bending or buckling real posed method of stiffening flat sheet is to provide integral ribs. It is possible to manufacture sheet with such ribs.

10. Composites vs. Aluminum Alloys

For some time it seemed as if composite materials would replace aluminum as the material of choice in new aircraft designs. This has put pressure on the aluminum developers to improve their products, and the result was aluminum-lithium. The first aluminum-lithium alloy, called 2020, was actually developed in the 1950s for the U.S. Navy RA-SC Vigilante. Aluminum-lithium has several goals to meet: 1 Damage tolerance similar to 2024 aluminum alloys but with 10 % lower density 1 High strength similar to 7075-T6 aluminum alloy but with 8 % lower density 1 Same properties as 2024-T3 but with a 10 % lower density Price not more than two to three times the conventional 2000 and 7000 series alloys. The 25-35 % weight savings composites offer over aluminum constructions plus a substantial reduction in the number of parts required for each application represents a major attraction of these composites [7, 8]. The obstacles to a wider use of these composite materials are their high acquisition cost compared with aluminum, the labor-intensive construction techniques and substantial capital costs of buying a new generation of production equipment. However, the labor-intensive construction can be solved by automation of the manufacturing process, which is the key technology in developing composite materials. The use of tape laying machines, for example, can cut the time and cost of constructing composite components by a factor of ten or more.

The use of composites in the U.S. began in the early 1970s under USAF funding and in the late 1970s NASA helped kick some life into composite technology and produced the desired results - aircraft manufacturers became more comfortable with the materials and more efficient construction techniques were developed; the increased demand led to lower costs of composite materials [4].

Conclusion

The goal of this research elaborating work was to estimate necessity of usage of advanced composite structures vs well known conventional materials. It was conducted research in sizing and optimization of choosing of structural materials for primary structure. On top of this, properties and peculiarities of conventional materials (such as Aluminum and Titanium alloys) and advanced composite structure. It was clearly demonstrated that usage of conventional materials for primary structure has significant advantage in comparison with advanced composite structures. Additionally, manufacturability and maintainability of materials were discussed in given article. As a result, application of conventional materials for primary airplane structure is the most suitable way for design of modern airplanes. It is proposed to use such approach for modern airplane design.

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ПІДБІР ТА ОПТИМІЗАЦІЯ МАТЕРІАЛІВ ДЛЯ ФЮЗЕЛЯЖА СУЧАСНИХ ЛІТАКІВ

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На сьогоднішній день рівень розвитку авіаматеріалознавства свідчить про тенденцію використання передових композитних конструкцій. Однак ці матеріали мають безліч переваг і недоліків, найважливішим недоліком є здатність поглинати воду з навколишнього середовища і внаслідок цього шари композитних структур роз'єднуються і, отже, стають неспроможними витримувати розрахункові навантаження. Через це існує обмеження на використання найновіших композитних структур. Незважаючи на це, застосування звичайних матеріалів (таких як алюмінієві або титанові сплави) мають обмеження використання через надлишкову вагу та технологічну спроможність виробництва. У даній статті розглянуто питання оптимізації вибору матеріалу для літака. Необхідність збереження рівноваги між мінімальною вагою і належною міцністю штовхає конструкторів до розробки нових сучасних матеріалів, механічні властивості яких відповідають суворим критеріям міцності, а також мають найменшу вагу.

Метою даного дослідження є оцінка необхідності використання передових композитних структур у порівнянні з широковідомими матеріалами. Було проведено дослідження з визначення розмірів та оптимізації вибору конструкційних матеріалів для навантаженої конструкції. Крім того, були розглянуті властивості та особливості звичайних матеріалів (таких як алюмінієві та титанові сплави) і композитні матеріали. Було чітко продемонстровано, що використання звичайних матеріалів для найбільш навантажених конструкцій має значну перевагу в порівнянні з сучасними композитними матеріалами. Також в даній статті обговорювалися технологічність і ремонтпридатність матеріалів. В результаті застосування звичайних матеріалів для навантаженої конструкції літака є найбільш оптимальним варіантом для проектування сучасних літаків. Сьогодні конструктор більше не вибирає матеріал виключно на основі його міцності, але й також його здатності витримувати незначні пошкодження в експлуатації, не ставлячи під загрозу безпеку літака. Залишкові сили після пошкодження, описані як міцність, тепер переважають у розумі інженера, коли він обирає сплави для літакобудування та двигунобудування. Пошкодження, спричинені втомою металів, є головним чинником, оскільки важко виявити і можуть катастрофічно послабити міцність силових елементів. Найкращим варіантом для сучасного літакобудування це використання композитних структур (для вторинних конструкцій), так і звичайних металевих матеріалів (титан, алюміній, тощо) для важливих та критичних місць посиленних конструкцій.

Ключові слова: авіаматеріали; композитні конструкції; втома металів; матеріали з наповнювачами; оптимізація.

ПОДБОР И ОПТИМИЗАЦИЯ МАТЕРИАЛОВ ДЛЯ ФЮЗЕЛЯЖА СОВРЕМЕННЫХ САМОЛЕТОВ

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На сегодняшний день уровень развития авиаматериаловедения свидетельствует о тенденции использования передовых композитных конструкций. Однако эти материалы обладают множеством преимуществ и недостатков, важнейшим недостатком является способность поглощать воду из окружающей среды и вследствие этого слои композитных структур разъединяются и, следовательно, становятся неспособными выдерживать расчетные нагрузки. Поэтому существует ограничение на использования новейших композитных структур. Несмотря на это, применение обычных материалов (таких как алюминиевые или титановые сплавы) имеют ограничения использования через избыточный вес и технологическую способность производства. В данной статье рассмотрен вопрос оптимизации выбора материала для самолета. Необходимость сохранения равновесия между минимальным весом и должной

прочностью толкает конструкторов к разработке новых современных материалов, механические свойства которых соответствуют строгим критериям прочности, а также имеют наименьший вес.

Целью данного исследования является оценка необходимости использования передовых композитных структур по сравнению с широко известными материалами. Было проведено исследование с определения размеров и оптимизации выбора конструкционных материалов для нагруженной конструкции. Кроме того, были рассмотрены свойства и особенности обычных материалов (таких как алюминиевые и титановые сплавы) и композитные материалы. Было четко продемонстрировано, что использование обычных материалов для самых нагруженных конструкций имеет значительное преимущество по сравнению с современными композитными материалами. Также в данной статье обсуждались технологичность и ремонтпригодность материалов. В результате применения обычных материалов для нагруженной конструкции самолета является наиболее оптимальным вариантом для проектирования современных самолетов. Сегодня конструктор больше не выбирает материал исключительно на основе его прочности, но и также его способности выдерживать незначительные повреждения в эксплуатации, не ставя под угрозу безопасность самолета. Остаточные силы после повреждения, описанные как прочность, теперь преобладают в уме инженера, когда он выбирает сплавы для самолетостроения и двигателестроения. Повреждения, вызванные усталостью металлов, является главным фактором, поскольку трудно выявить и могут катастрофически ослабить прочность силовых элементов. Лучшим вариантом для современного самолетостроения это использование композитных структур (для вторичных конструкций), так и обычных металлических материалов (титан, алюминий) для важных и критических мест усиленных конструкций.

Ключевые слова: авиаматериалы; композитные конструкции; усталость металлов; материалы с наполнителями; оптимизация.

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