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THE METHODS OF ASSESSING THE LOAD-BEARING PROPERTIES OF THE ELEMENTS OF WING MECHANIZATION HONEYCOMB STRUCTURE WITH CONSIDERATION OF EXPLOITATION

OKSANA ZAKORA

National Technical University of Ukraine
"Kyiv Polytechnic Institute"

Abstract

To restore the load-bearing properties of heavy transport aircraft cellular structure spoiler, finite-element model spoiler repair scheme was developed and performed. The result of structures deformation, analysis and comparison with other types of spoiler structure, including the original cellular structure The analysis showed that the tension and movement that occur in structure when calculating the strength does not exceed the specified requirements of strength and rigidity. Developed spoilers repair scheme does not leaded to significant weight gain.

The design of repair is chosen for reasons of:

- *economic profitability;*
- *ease of production;*
- *possible changes of technical parameters and use of other type fasteners.*

The discussion of layered composites with cellular honeycomb core usage in aircraft structure designs is included in the paper, together with the brief description of published domestic and foreign literature monographs treating about the subject

INTRODUCTION

The process of aircraft creation is not finished after it's serial production and it's placement into exploitation. The reliability of aircraft is verified in the process of it's exploitation. The quality of servicing and repair is of great importance for support of flying vehicle functioning and adherence to high requirements, what guarantees it's safety. At the time, the repair works and qualitative technical ensuring of aircraft updates immediately influence on the economical usage of aviation technology. This increase of expenses are tied with the tendency for complication of aircraft design and prorogation of its exploitation. Therefore, at this time, the improvement of repair process and search for alternative award for its execution to spare a large attention, while one with basic factor of rise of general economic efficiency of aviation transport.

Amenable to the statics, the significant part of repair works that it performed during the exploitation of modern aircraft nestle on the renewal of working capacity and normal functioning of airplane, another part consists of removal different damages of the structure panels. But the repair methods of the honeycomb panel structures which exist today not always give the optimum result, thus the repaired panel often have the excessive load-bearing properties. The cause for such situation is the absence of reliable scientific-substantiate methods and algorithms of determination of damage scale and character type, determination of types and parameters of repair, and the assessment of the value of damage and repaired structure, too.

The treatment with such methods allows not only guarantee to regulate renewal load-bearing properties of damaged structure by the minimum influence on it characteristic (stiffness, weight, strain-deform state and other), but also diminish the expenses and time spent on the repair, too.

THE LITERATURE REVIEW

In the modern aircraft designs continue the tendency to substitute the structures and parts made of metals for the one made of composites.

Also the change of the composite material generation happen, that is related with the new technology treatment masking and creating them. As from the 7th decade of previous century, the glass fiber reinforced composite materials made by the woven method started the wide usage. The carbon composite come as the substitution of glass fiber reinforced composite, which demonstrate the excellent correlation of strength and mass properties.

This composite material is characterized by defects in composite fibers, namely, impact damage (cracking of composites over carbon fibers), as well as significant stratification. The new generation of non-metallic structural materials are carbon – carbon composites with high temperature degradation. Along with solid materials in the aircraft industry began to extensively use assemblies that represent the two plates, which are located outside cellular core structure. Core cells are made of honeycomb aluminum, glass, boron and carbon fiber. In aircraft structures the honeycomb cores made entirely of metal (aluminum and titanium) are also used.

A common feature of the mentioned above new materials and structures made from them is that they are characteristic for specific defects, which are formed during their production and operation.

Given the high potential for above mentioned defects and damage of cellular structures, control and repair of them pay much attention.

At certain stages of the life of certain aircraft, the work to control the technical condition of machine is performed.

According to the results of work done on the conclusion of the damages the aircraft units and examination of possible options for their removal and repair. Repair of the damages is done by the established operational procedures and aircraft repair documentation.

Widespread use of composite materials is one of the most important and promising areas of accelerating scientific and technological advances in aviation technology. On the specific characteristics scale graph of strength and stiffness, composites are placed 2 to 3 times higher than traditional materials and alloys.

Investigation of the benefits of composite materials and features of their application is considered in many papers published in the last decades of the previous century and the first years of the twenty–first century.

Today there is a great number of reference works, in which the collected information on the characteristics of composite materials and structures made of them is published.
I have listed some of them below.

In the book „Композиционные материалы", edited by L. Brautman, R. Krok collected information about the benefits of composite materials and their application in aircraft design, problems and more is mentioned. Airplanes are different from other vehicles because of their low safety factor design and high power to weight ratio.

The latter is achieved by using materials with high specific characteristics and methods of modern design. The problem of weight constantly stimulated the development of aviation technology in selecting superior materials, new design concepts, improved understanding and analysis of the structure. The choice of materials and the design of structures of any assembly or assemblies of passenger aircraft should be conducted not only by analyzing the mechanical properties or structural features, but also with the necessary consideration of their performance and value. In the paper the micromechanical theory of composite materials strength is considered, which is used to predict the strength of composites of different properties and in various forms of stresses, in particular, unidirectional composites in uniaxial loading are considered. Also layered composites, and their physical structure are considered.

In the book „Справочник по композиционным материалам", edited by G. Lubin brought the issue of environment influence on the properties of composite materials. The effect of corrosion, electromagnetic effects, fatigue, flammability, shock effects, lightning, moisture and other effects is considered. Materials described in the book reveal the preferences of a composite material for a particular design. Also presented are the methods of composite materials production and structures made of them (parametric study). The properties of composite materials layers, analysis of treatment layered composite materials consisting of different layers, performed by finite element method. Given basic information on the application, the calculation of cellular structures. Resulted is the choice of materials for such structures.

DISADVANTAGES AND ADVANTAGES OF MAKING CELLULAR STRUCTURES

Great time between scientific and technical literature created in the study of strength and rigidity of composite structures, materials, features of their choice and design.

In translations from English UKRNYYNTY Jack Vynson, Sydney Shore. „Слоистые панели минимального веса с сотовым заполнителем, подверженные одноосному сжатию" developed analytical methods for calculating layered panels with a honeycomb core, that can be used for the calculation to ensure minimum weight while maintaining integrity of design under the given load, length and width of the panel, as well as to determine the surface layer material and walls, numerical examples are given.

Considered fracture mechanics of composites, present the general theory of stratification cracks in multilayer membranes in the book [7].

[8] - highlighted the problem of determining layered composites load bearing properties, the emphasis is on studying the ability of the material to resist cyclic loading, resulting in a chart obtained strength.

In the work [9] considered the process of destroying solid, restored version of the classification types of fracture, obtained criteria for brittle fracture. Described the effects of changes of defects (their size), the association of defects, new.

In the works [10], [16] brought variant methodology of calculation of composite panels for resistance using finite-element modeling technique is an attempt to take into account the universal nature of composite materials.

V.N. Kobelev and others in the paper: „Расчет трехслойных конструкций" presented calculation methods for three-ply plates and shells, the parameters of the stress-strain state, the critical loads. The first calculation considered three-ply design, backed by force set.

The data are presented for calculating sandwich structures with stratification. The handbook provides guidelines for designing sandwich structures with regard to detachment, the main ways of reducing the influence of detachment on the strength sandwich design.

In the monograph [12] is presented the general theory of calculating the strength of structures made of composite materials and principles of their rational design. Much attention is paid to calculating the panel structure under different loading conditions. The recommendations on creating products rational in terms of strength.

The use of composites in aircraft technology enables:

- create designs with predetermined characteristics;
- reduce the number of parts;
- increase utilization of the material twice;
- improve corrosion resistance;
- reduce metal structures;
- reduce energy costs.

It allows you to:

- reduce weight of design;
- improve aerodynamic quality;
- increase operational reliability, survivability and service life;
- increase the level of automation and mechanization of production.

Provides:

- savings of metals;
- substantial savings in labor;
- fuel economy, increased flight range or payload.

Application of the three-ply panels with core in design allows:

- to reduce weight and complexity compared to riveted structures;
- reduce the number of parts in a design;
- improve thermal properties;
- significantly increase the number of streamlined surfaces;
- increase the stiffness of the structure.

Sandwich panel with the core can be used in caudal parts of the wings and tail, nose and wing fillers, flaps, slats, spoilers, brake shields, trimmers, aileron, manhole covers, pods panels, pylons, and more.

Design of cellular structures can be made based on these criteria, and proposed criteria determined by the type of applied stress:

- bearing plates must be thick enough to withstand the specified stress in tension, compression and shear;
- core should have sufficient strength to withstand the specified shear;

- aggregate must have sufficient thickness and modulus of elasticity in shear to ensure no destruction of cellular structures with bending loads;
- modulus of elasticity at compression core and carrier plate boundary strength at compression should be sufficient to avoid the surface jam under load;
- the core cell size should be sufficiently small, to avoid potential loss of stability of load bearing plates between cells at the given construction loads;
- core should have sufficiently high compression strength on the border to resist creasing in apposition to the normal load bearing surface tension or compression, resulting in bending [15].

Composite structures are widely used in prefabricated elements of the aircraft: wing skin panels (sandwich structure), panels of wings mechanization, tail panel, tail, etc. [3].

The book [1] examined in detail the features of technological processes of sandwich structures production, gives recommendations on making technological equipment sandwich structures, examples are given for making sandwich structures and analysis of their strength.

Based on the literature review, one can draw the following conclusions on the status and availability problems and unsolved problems in this direction:

1. Distribution of cellular structures is complicated by the peculiarities of their operation, design and fabrication.
2. There is a need for improved methods and apparatus for nondestructive testing of core connection with bearing layers in the cellular structure panel.
3. Lack of reliable methods of valuation acceptable defects of cellular structures panel, especially the type of detachment defects.
4. Lack of methods for determining the type and nature of the repair of damaged cell structures, resulting in unreasonably high costs and aircraft weight to its subsequent exploitation.

PROBLEM STATEMENT

Nowadays in heavy transport aircraft elements of wing mechanization of composite honeycomb structure are widely used. The calculation for the strength classification of bringing the basic parameters and characteristics, methods of selection and design of these structures resulted in many scientific and technical papers, some of which are given in the previous section. Maintenance of parts and components of modern aircraft is a complex process, for which you want to do next with a set of organizational activities and the use of advanced and modern production processes, and also the best ways to repair, choose materials with sufficient specific strength, maintain the required reliability of refurbished products and high surface treatment that streamlines the air flow.

Especially problematic in the operation of heavy transport aircraft panel is cellular structures that are widely used in aircraft wing mechanization (aileron, slats, flaps, spoilers, shields), tail empennage (elevator, directional ruder) and more. They have their own specific manufacturing processes and applications.

Despite the relatively large amount of time to use cellular structures at this stage, no clear method of repair and elimination of defects that occur on them during operation of the airplane are defined.

The paper investigated the problem of damage to the extension of the aircraft.

As a special case considered construction mechanization wing panel elements (in this case spoiler) of metallic cellular sandwich structure.

When the visual and instrumental control units of mechanization wings sandwich metallic cellular structures in the park during the operation of heavy transport aircraft are found, that individual units of the design are damaged as a cladding peeling of honeycomb, size and number of such injuries increases with increasing plaque and lifetime.
This is due to:

- breach of manufacturing units processes;
- insufficient adhesive joints sealing;
- mechanical damage;
- aging adhesives;
- a variety of weather conditions in which the aircraft is operated, and more.

If you find damage in metallic cellular structure spoilers of heavy transport aircraft, there are several options for its removal:

- replacement unit (sandwich metallic honeycomb structure spoilers should be replaced every ten years of operation);
- repair of units at specified levels of damage;
- unit replacement to change its design.

One of the load bearing properties of spoilers repair options is studied in [18]. The paper presents the design and technological solutions repairing aircraft paneling by forming composite lining. To solve the problem using the method of finite-element modeling, laboratory research.

Damage arising from the operation, established in accordance with operational documentation on typical repairs sandwich metallic honeycomb structures. Type of repair is determined depending on the size and location of detachment. Maximum area of detachment, is repaired in accordance with operational and repair documentation, in excess flaking areas repairs are carried out in accordance with operational documentation.

To date, in consequence of the presence of lesions on the size and condition of parts not subject to repair, detachment force elements (force in the overlap zone nodes Hinge-plate) in the construction spoiler, a large number of available units of heavy transport aircraft for which it is impossible to perform repairs, that will ensure their safe operation within the project again be set in the resource. These units require replacement in achieving project resource, which is half of the set operating time plane.

It noted some feature of the cellular aggregates sandwich design. Size and magnitude of damage depends on technology components and conditions which kept while, therefore, directly related to the enterprise on which the parts are manufactured.

Replacement units should be taken to increase resource more than half the prescribed period for aircraft operating under the decision of experts. In this case spoilers frame sections should be replaced.

Given the significant cost of new spoilers panels, one was asked to find an alternative spoiler carrier recovery properties. Performance spoilers of another structural scheme (riveted construction assembly) needs a new snap and great material and economic costs.

Therefore developed a scheme of repair existing spoilers structures to restore their load-bearing properties.
Research repair sandwich metallic cellular structure includes the following:

- determine the impact of size and type of load of damage in structures;
- calculation and stressed-strained state (SSS), construction, beyond repair;

- assessment of carrying capacity of damaged structural elements;
- consideration of the geometry of additional structural elements;
- determine the type and stages of repair;
- consideration of conditions of work to restore the level of load carrying capacity and more.

THE PURPOSE OF WORK

The purpose of this work is cresting of methods valuation of the load carrying properties honeycomb construction of the mechanization wing elements on the base of spend research of the process repair such as design and peculiarities in exploitation of them; creating of the algorithm determining the type, character and scale damage and repair panel, and in dependence from this, determination of honeycomb structure panel type of the repair.

The problem, which necessary decide for the achievement of put purpose

1. The investigations of honeycomb structures actual types of the damage.
2. The investigations of honeycomb structures actual types of the repair.
3. The investigations of influence of loading types and of exploitation conditions on the rise of damages.
4. The building of adequate finite-element model of the wing mechanization element with honeycomb structure.
5. The building of adequate finite-element model of the wing mechanization element with honeycomb structure with modeling of covering delamination.
6. Comparing and analyzing the model of deformation.
7. The creation of adequate finite-element model of wing mechanization non-damaged element with honeycomb structure.
8. The comparison of deformation mode of the received models.
9. The analysis of renewal level of elements of mechanization wing honeycomb structure by such indexes as what is the rise of deformation and maximum stresses in the structure.
10. On the base receive date, the determination of method of character and scale of damage, determination of the possible structure failures, execute its functions, determination of the structure damages repair type.

DESCRIPTION OF REPAIR OPTIONS, BEARING PROPERTIES OF CELLULAR STRUCTURES ON THE EXAMPLE OF HEAVY TRANSPORT AIRCRAFT SPOILER

Fig. 1 shows a scheme of heavy transport aircraft spoiler.

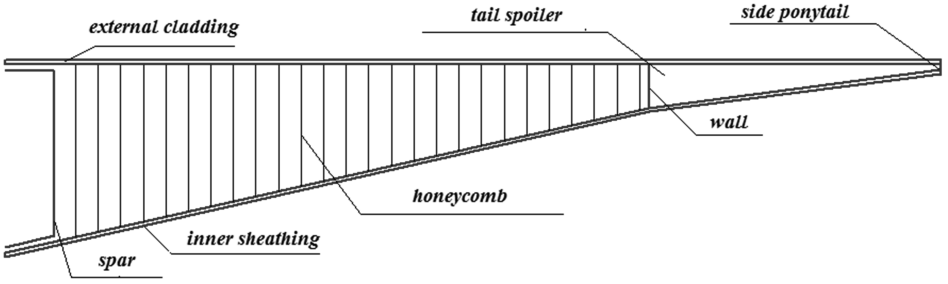

Fig. 1. Scheme of heavy transport aircraft spoiler (view from side)

To restore the load-bearing properties of heavy transport aircraft cellular structure spoiler, the finite-element model spoiler repair scheme was developed and performed. The result of structures deformation, analysis and comparison with other types of spoiler structure, including the original cellular structure The analysis showed that the tension and movement that occur in structure when calculating the strength does not exceed the specified requirements of strength and rigidity. Developed spoilers repair scheme does not leaded to significant weight gain.

The design of repair is chosen for reasons of:

- economic profitability;
- ease of production;
- possible changes of technical parameters and other fasteners.

CONCLUSION

The concept of repair the damages of parts and elements of the heavy transport aircraft consist in the determination of damage character, level of it's expansion, it's scale and development the possible variant of the damage removal.

The variant of damage removal is chosen with consideration of the economy, expediency, simplicity of application, demands of the strength and stiffness norms and other conditions.

The modernization of heavy transport aircraft spoilers honeycomb structure, which was conducted to allow to reduce the material, economic, time expenses on the damage removal for further successful continuation of aircraft exploitation.

At present time the next to perform are:

- the possible variant of observed damage removal, that arise in the panel construction of heavy transport aircraft;
- the circuit of developed alternative repair of honeycomb spoiler of the heavy transport aircraft;
- the finite element model of spoiler design and calculate, the mode of deformation of received construction.

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