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CLASSIFICATION ASPECTS OF RATIONAL UTILIZATION OF POLYMER COMPOSITE MATERIALS IN THE CIVIL AIRCRAFT STRUCTURES

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Abstract

The article analyzes the classification aspects of the rational choice of the polymer composites types for aircraft structures. Based on the analysis, criteria for the effective selection of polymer composite materials are proposed taking into account various factors operating in the production. The problem is formulated on the need to develop an effective method for assessing the choice of polymer composites for aircraft structures.

Keywords: analysis;aircraft;criteria;polymer composite material;efficiency

1. Introduction

Starting from 1960-ies, General Designer Oleg K. Antonov has been directing the aircraft industry of Ukraine towards continuous introduction of polymer composite materials (PCM) in the structure of civil airplanes developed in the country as an efficient reserve for improvement of the airplanes' performance characteristics[1].

During the years that followed, the ANTONOV Company continually increased the scopes of the materials introduction by expanding the sphere of design and technological solutions (DTS) from secondary structural members to those that condition the load-carrying capability of an aircraft (A/C)[2-4]. Productive research and educational collaboration with numerous organizations was also broadening, including the "Kharkiv Aviation Institute" National Aerospace University (KhAI) [5].

2. Main part

Analysis of multiple publications [2-6] and the experience accumulated by the ANTONOV Company in the field of the PCM utilization in civil Antonovaircraft structures make it possible to state that the effectiveness of design and technological solutionsfor the PCM products is predetermined by the totality of the following criteria:

K_ρ – specific characteristics of load-carrying capacity conditioning the structural load ratio;

K_c – criterion of cost, determining integral financial inputs in the creation of a unit of mass of a PCM structure;

K_s – safety criterion, determining the degree of freedom from harmful effects on the operator and environment in the course of manufacture and operation of the PCM structure;

K_{tech} – technological effectiveness (processability) of a semifinished PCM product conversion into a structure ;

K_{mc} – manufacturing content involved in the conversion of a semifinished PCM product into a structure.

Each of these criteria has by now been more or less explored in terms of quality or quantity [8-12]. Moreover, several attempts have been made to investigate their mutual effects [13].

The level of the criteria is shaped by specific factors and predetermined by these factors (Fig. 1).

These factors differ for each criterion. Criteria K_c, K_s,K_{mc},K_{tech}, that shape the criterion K_ρ, are interconnected, i.e., the level of each of them depends to a specific degree on the level of other criteria (1).

The meaning of the symbolic formula (1) is that the level [K_ρ], governed by the decision maker, is ensured by the minimum level $K_{c\ min}$ in combination with the maximum level of K_s, which provide for the acceptable levels of K_{tech} and K_{mc}.

$$\left\{\left(\begin{array}{ccc} & K_{tech} & \\ \swarrow\nearrow & & \searrow\nwarrow \\ K_{c\,min} & \leftarrow & K_{c\,max} \\ \searrow\nwarrow & & \swarrow\nearrow \\ & K_{mc} & \end{array}\right) \rightarrow \left[\ K_\rho\ \right]\right\} \quad (1)$$

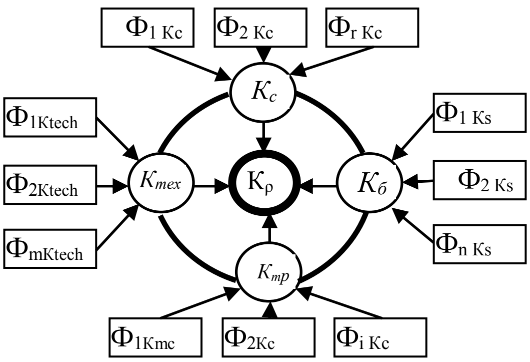

Fig. 1. Interrelation of PCM effectiveness criteria

The level of K_ρ is specified by the decision maker who decides on the selection of the type of PCM to be used for each specific element of an aircraft structure. In the meantime, the motives (grounds) for the selection may differ, based on this or that conception of effectiveness (praxiological, technical, cost, or strategic).

This level can however be provided in different ways by different combinations of the levels of other criteria of effectiveness of the PCM type selection for a specific DTS.

High priority of attainment of a lower level of K_c or a higher level of K_s, depending on the purpose of the concrete DTS for a structure, seems to be a preferable one among the above-mentioned combinations.

Objective (quantitative) analysis of the preferred alternative is required in this case.

To implement the method of selection of efficient PCM application in aircraft structure of type (1), it is necessary to reduce all criteria to dimensionless formreferring their values to baseline counterparts:

$$\overline{K}_i = \frac{K_i}{K_{ibase}}, \quad (2)$$

where $K_i = (K_\rho, K_c, K_s, K_{tech}, K_{mc})$.

It seems reasonable to assume as baseline counterparts the maximum values of criteria K_{imax} attained according to worldwide statistics.

The PCM selection criterion [K_ρ] regulated by decision maker, as was already mentioned above, is attained with a somewhat higher value of the integral PCM selection criterion [K_ρ]which is formed, considering the effect of the combinations of other criteria on [K_ρ], in different ways in the general case.

It follows from the world statistics that, as a general rule:

$$\overline{K_\rho}\uparrow, \text{ if } \overline{K}_c\downarrow, \overline{K}_s\uparrow, \overline{K}_{tech}\uparrow, \overline{K}_{mc}\downarrow.$$

A number of research by the employees of the ANTONOV Company and KhAI examine the components of the criteria of effectiveness of PCM application [7-13].

Thus, paper [10] formulates the PCM composition components included in criterion $\overline{K_\rho}$, which shows the contributions of criteria $\overline{K}_{tech}$ and $\overline{K}_s$ (block 2), and criterion $\overline{K}_c$ (block 5), Table.

A similar kind of interaction is also observed for other criteria.

Table

Level component shares of PCS composition in criterion $\overline{K_\rho}$

No	Level component shares
1	1.1 Heat resistance 1.2 Level of the coefficient of linear thermal expansion 1.3 Combustibility level 1.4 Level of chemical resistance to corrosive media, atmospheric effects (ageing resistance), and crack growth resistance 1.5 Power (level) of static accumulation
2	2.1 Level of technological effectiveness (processability) 2.2 Level of toxicity (safety) in the course of reprocessing
3	3.1 Level of dominating specific static strength (tensile, compression, shear) 3.2 Level of adhesive power (compatibility of the PCM composition components) 3.3 Level of specific fatigue strength 3.4 Level of specific dynamic strength 3.5 Level of specific acoustic strength
4	4.1 Level of the dominating ultimate elastic deformability 4.2 Level of creep 4.3 Brittle fracture power (ultimate strain level)
5	5.1 Relative level of cost
6	6.1 Availability level

Paper [8] summarizes the types and components of the complex of technical object safety that are taken into consideration to a certain degree in criterion $\overline{K}_s$, and paper [9] presents a scheme of decomposition of the technological effectiveness indicators considered in $\overline{K}_{tech}$.

Thus, sufficiently consistent prerequisites have been created for development of a method of rational selection of PCM composition for certain structures of the civil domestic aircraft based on a comprehensive criterion considering specific features of their manufacturing and operation.

These investigations should be based both on the results discussed above and on their generalization that is partially contained in monographs [14-15], directorates/manuals of PCM properties and other classification aspects of PCM application [16-18].

3. Conclusions

1. Review and analysis have been made of the classification aspects of rational selection of PCM types for structures of domestic civil aircraft produced by the ANTONOV Company.
2. Principal effectiveness criteria of PCM type selection have been proposed, including the criterion of specific characteristics of the material load-carrying capacity, cost of inputs in the creation of a unit of mass of a PCM structure, safety criterion determining the degree of harmful effects on the operator and environment in the course of manufacture and operation of the PCM structures, technological effectiveness (processability) of a semifinished PCM product conversion into a structure and manufacturing content involved.
3. Based on numerous publications by the authors and other ANTONOV employees, the task has been formulated for development of an efficient method for assessment of the rational PCM selection for the structures of civil domestic airplanes that takes onto consideration the interrelationship between the proposed criteria.

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Класифікаційні аспекти раціонального використання полімерних композиційних матеріалів у конструкціях цивільних літаків

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Виконано аналіз класифікаційних аспектів раціонального вибору видів полімерних композитів для конструкцій авіаційного призначення. На базі виконаного аналізу запропоновано критерії ефективного вибору полімерних композиційних матеріалів з урахуванням різних факторів, які діють на виробництві. Сформульована задача щодо необхідності розробки ефективного методу оцінки вибору полімерних композитів для виробів авіаційної техніки.

Ключові слова: аналіз; повітряне судно; критерій; полімерний композиційний матеріал; ефективність

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Классификационные аспекты рационального применения полимерных композиционных материалов в конструкциях гражданских самолетов

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В статье проанализированы классификационные аспекты рационального выбора видов полимерных композитов для конструкций авиационного назначении. На основании выполненного анализа предложены критерии эффективного выбора полимерных композиционных материалов с учетом различных факторов, действующих на производстве. Сформулирована задача о необходимости разработки эффективного метода оценки выбора полимерных композитов для изделий авиационной техники.

Ключевые слова: анализ; воздушное судно; критерий; полимерный композиционный материал; эффективность

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