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EXPERIENCE IN FABRICATING POLIMERIC COMPOSITE ROTOR BLADES

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Abstract

Shown in this report is the possibility in bettering helicopter tactical-technical characteristics through the improvement of a rotor blade design by using polymeric composite materials and those with some fillers as well.

The table listing mechenical properties of various constructive materials and emphasizing the merits of composite materials is given.

Presented here are the control methods of rotor frequency characteristics.

Comparative and economic indices of polimeric composite blade aduantages are given here.

The objective of this report is to show good practice of using polymeric composite materials in helicopter rotor blade constructions.

Modern helicopter building is characterized by flight rate growth,weight efficiency increase and substential power supply growth.

To improve helicopter flight characteristics rotor improvement is of paramount importance along with the overall helicopter aerodynamic improvements and more rational selection of basic parameters. Rotor blade is one of the most vital helicopter components.

Blade quality effects not only blade resource and relia-

bility but the level of helicopter variable loads as a whole.

At Kamov Helicopter plants for rotor blade fabrication sateen weave glassplastic T 10 has been selected and then other polymeric composite materials have been used. In practice, this choice appeared to be valid.

Because of this, when working out new types of helicopters our plant develops and produces polymeric composite blades.

Fabrication of glassplastic blades showing limitless resource represents a considerable step forward in home helicopter building.

In the Soviet Union our plant was the first to develop, fabricate and successfully put through test glassplastic blades for Ka - 15 and Ka - 26 helicopters. Flight stress measurements and dynamic tests of full-size sections of these blades have shown that the life of the blades mentioned vs endurance is practically unlimited.

From the blades after 3000-4000 hrs. in operation full-size sections have been fabricated and dynamic tests have been performed to determine these sections endurance limit. The tests have shown that these blades have the same carrying capacity as when new. Comparative tests of various blades on the same helicopter show that glassplastic blade traction characteristics are higher due to perfect acrodynamic configuration, they are simple when adjusting and stable under operating conditions due to their similarity.

Besides, blade cost price comparative analysis shows that wear and tear deduction for 1 glassplastic blade flight hour is 2-3 times less than that of metallic blades.

The glassplastic advantages over other types of blades are:

- much more resource and reliability due to high specific durability of materials and insensitivity to stresses (scratches etc.) appearing in production and operation processes
- high geometry and weight stability making possible blade interchangeability
- simple and cheap method of blade production and complex aerodynamic arranging of high efficiency
- good stability under environments
- techniques and less labour-consuming nature of production
- glassplatic constructions feature internal damping extremely useful for vibration energy absorption.

With increase in helicopter flight rate and energy supply rotor loads increase greatly and glassplastics applied in the past prevent rotor overloading or to be precise it is not the problem optimum solution.

Blade stiffness is of great importance in puttiny together single and coaxial rotor helicopters. Great blade bending by gravity as the rotor rotates or stops in windy conditions may constitute a serious threat of blade impact against a helicopter coustruction and with coaxial design blades will hit each other. To avoid this we have to increase helicopter size.

For heavy loaded rotors torsion deformations relative to blade longitudinal axis become substantial, great strains are brought about and may be a decisive factor at blade resource determination.

Blade twisting rigidity affects safety margin resulted from flutter developing, blade pin momentum and dynamic torsion and hence rotor control draft loads and control expenses.

By this means when producing blades it is desirable to increase blade twisting rigidity and strength to exclude tangential stresses. In designing modern rotor blade a designer needs such new materials which would provide the required blade bending and twisting rigidity and make possible to sort out the rigidity characteristics meeting good control requirements and providing frequency characteristics far from resonance phenomena.

In practice however the inherent frequencies of metallic and glassplastic blade oscillations are sometimes close to the frequencies of generating forces. This involves an increase in the amplitude of blade bending and twisting vibrations and hence a spar strain increase and as a result resource reduction and an increase in vibrational impulses of the generating forces directed from blades toward the rotor bush and helicopter construction.

As the characteristics of the fatigue deformation E/σ_{-1} of glassplastic (Table I) are 2,5 times less than those of steel and 3,9 times less than those of aluminium alloy, glassplastic blades show higher resource than metallic ones. When designing rotor blades however one of the important problems is inherent frequencies control of blades; the solution of this problem will help to avoid closeness in the inherent frequencies of the rotary blade to the frequency of the forces exerted on a blade.

Consider some possible constructive methods of changing rotor blade inherent frequencies of a helicopter.

In the general case the differential equation of blade vibrations with parameters steadily distributed in the field of centrifugal forces takes the form:

$$(EJy'')'' - (Ny')' + m\ddot{y} = 0 \qquad (I)$$

where

EJ - blade bending rigidity

N - blade section centrifugal force

M - length unit mass (linear mass)

y - blade section shear

$y' = \frac{dy}{d\tau}$; $y'' = \frac{dy}{dt}$

τ - current blade radius

The ways of solving these equations are given in papers 5,6.

Having solved equation (I), for simplicity we find frequencies of inherent vibrations for the blade of steady linear weight and rigidity.

$$P_{oj} = \alpha^2_j \sqrt{\frac{EJ}{m}} \qquad (2)$$

where

j - vibration coefficient

j=1,2,3...

From equation (2) it follows that the frequencies of blade inherent vibrations depend on the relation between rigidity characteristics and blade mass characteristics, i.e. on the ratio EJ/m.

Now consider constructive possibilities of this ratio change.

When designing blade geometry-a rotor diameter, a blade contour in plan, cross section type and relative thickness, geometric torsion are selected with regard to helicopter rotor acrodynamic properties and blade efficient cross centralizing is selected according to M number. Thus, constructive possibilities of ratio change EJ/m by redistributing constructive materials over the blade section are limited. This suggests that rigidity change EJ over a wide range can be achieved by elasticity modulus change of constructive materials of blade power element, that is a spar.

Combined composite materials (CM) in which several fillers of various mechanical properties go well together in one or more matrixes enable this problem to be solved. These (CM) properties are dependent on the component content.

As a first approximation elasticity modulus of a combined composition can be determined from the "summation" law from the following equation:

$$E_K = (E_m V_m + E_1 V_1 + E_2 V_2)/V_K \tag{3}$$

where E_m, V_m, E_1, V_1 E_2, V_2 - elasticity modulus and matrix and filler content.

In this case the material porosity is neglected, i.e. assume $V_m + V_1 + V_2 = 1 = V_K$

and start from shear coincidence conditions.

Hence the optimum combinations of combined (CM) particularly in limiting condition will be those when fibres with near properties on elasticity modulus and fatique deformation E/σ_w go well together. Therefore from Table I it is felt that carbon and high modulus fibreglasses go well together best of all.

Fibrecarbon density is less than that of glass fibres. Consequenty, on retention of linear load the spar cross section increase and can be defind from the ratio:

$$F^y(\tau) = F^c(\tau) \cdot \rho_c/\rho_y \tag{4}$$

where $\rho_y, F^y(z), \rho_c, F^c(z)$ - density and cross section of the spar made of carbonplastic.

From equations (3) and (4) it follows that carbonplastic spar stiffness depend on carbonfibre content. Increase of the latter causes blade stiffness increase and hence an increase in inherent vibration frequency of the blade on retention of linear load.

Blade airfoil rotor using graphite power component spar blade for improving frequency properties has been fabricated from the 16 m rotor.

At first carbonplastic properties have been examined on flat specimens and then used in construction. Some (CM) properties are shown in Table 2.

Initially the blade spar has been fabricated from glassplastic with cord fabrics. After flight load harmony analysis it was found that the 7 th part in frequency spectrum is rather high because of closeness of inherent frequencies of 3 tone vibrations of rotary blade to the 7th part of generating forces. For adjusting from closeness position to resonance 20% of glassfabric have been replaced with carbon tape in upper and lower spar shelves. It increased both inherent vibration frequencies and margin safety from resonance (Figures 1,2). Flight tests have shown a 30% decrease in load level on helicopter airfoil system components. This in turn caused 2-3 times resource increase in these assemblies.

An increase in blade tortional stiffnes was the next step of using carbon tape for a spar. Because of insufficiant blade tortional stiffness at high rates twist difference in blade tapering due to dynamic blade tortion develops and as a result it increases helicopter vibrations.

To increase the spar blade tortional stiffness 20°/o of fiberglass plates packed under +-45° angle to the blade axis have been replaced by carbon tapes. Blade stiffness has been doubled with some reduction in weight.

On the spar blade of the next helicopter about 40°/o of carbon tape were placed at +-45° angle and 60°/o of fibreglass were placed along blade axis.

To increase blade tortional stiffness carbon tape has been used. Spars are fabricated by pressure method due to platen press located in spar canal. This pressing method allows to install balance weights and electrical deicing system with antierosion covers of blade edge.

Besides spars carbon tapes are used in blade and root end section skins.

To date root end section skin has been fabricated from Kevlar in which 3 plates are packed with outward plates under 45° to chord for bending reduction in root end fabrication and maintenance.

In this case, however, when employing honeycomb filler as viewed from the cell 5 mm. skin stiffness is found to be insufficient and deviations of the aerodynamic profile bending develops considerably as a result of skin gap in a cell.

With the goal of increasing skin stiffness and reducing bending the average plate has been replaced by carbon tape. The application of carbon tape has resulted in skin stiffness increase and bending reduction. In this case aerodynamic blade quality stability has been improved.

In conclusion it should be noted that theoretical and practical work conducted on fabricating rotor blades showed that it was good practice to use various composite materials for their construction.

Our experience gained in using composite materials suggests that construction design and materials are interrelated.

Such approach to designing offers considerable scope for using polymeric composite materials in helicopter rotor constructions.

Table I

Indexes of constructive materials used in helicopters

Indexes	Steel strengthened	Stainless steel 301 x HSR *)	ABAT strengthened	Aluminum alloy 2024-76 *)	Glass plastic "Э"	Glass plastic СК-5 211Б	Glass plastic ЭФ32 30I	Glass plastic "E" glass **)	Glass plastic "S" glass **)	Carbon plastic KMY-3	Carbon plastic Thornel 75S *)	Kevlar 7T	Kevlar PRD 49III *)	Boraplastic	Boraplastic
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
g/cm^3	7,85	8,03	2,8	2,77	1,85	1,95	1,85	2,10	2,04	1,4	1,66	1,25	1,38	2,0	2,02
	110	173	33,0	39,3	38,0	100	50,0	112	188	80	105	52,0	172	130	132
$\frac{kg}{mm^2}$	30,0	-	6,5	--	-	18,0	12,0	-	-	36,0	-	-	-	40	-
E	21000	20700	7200	7200	2750	5000	3500	5600	6900	12000	14800	3000	7600	26 000	20 700
$\frac{kg/cm^3}{mm^2\ g}$	15,3	22,0	11,8	14,5	20,6	51,3	27,0	53,3	92,1	57,0	63,2	41,6	127	65,0	66,1
E/ $\frac{g\ cm^3}{mm^2\ g}$	26,7	25,8	25,7	26,7	14,9	25,6	18,9	26,7	33,3	85,7	89,0	24,0	55,8	130	105
	1,43	-	0,90	-	--	3,6	1,9	-	-	3,0	-	-	-	1,54	-

NOTE: -foreign data *) - 6 ; **) - 7

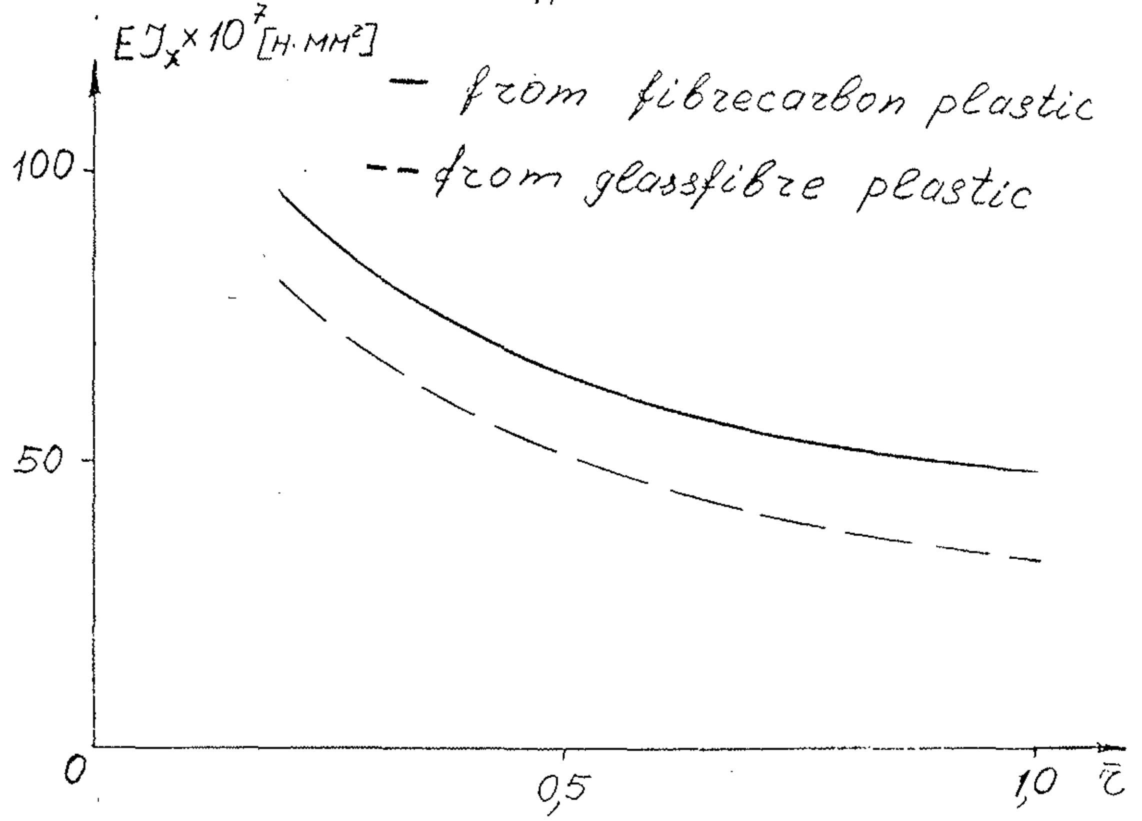

Figure 1. Blade rigidity in flapping plane

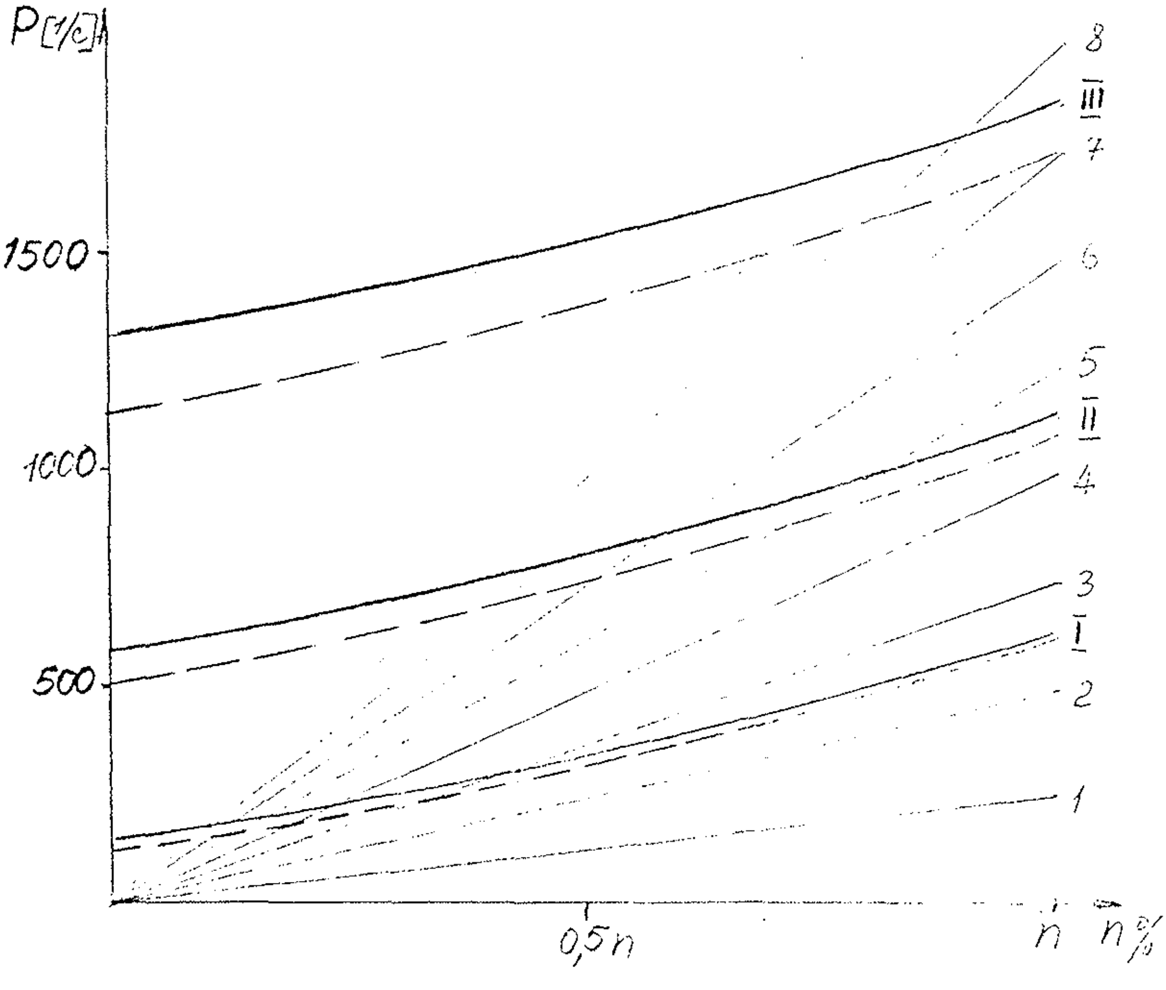

Figure 2 Blade frequency diagram

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