ROTOR OF THE HELICOPTER MI-60. SELECTION OF PARAMETERS AND DEVELOPMENT OF A DESIGN.

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Abstract

The Mi-60 helicopter is a lightweight helicopter. Such helicopters, as it is well known, are the most widespread class in the world. Thereof, during designing a lightweight Helicopter it is necessary to take into account extraordinary high level of a competition in the global market.

To increase competitiveness of the Helicopter it is necessary to improve as much as possible its strength and flight performance, to improve reliability and to reduce expenses both in manufacture, and in operation. The creation of a perfect rotor is a key task in achievement of these purposes.

During designing of the Mi-60 Helicopter rotor various versions of its aerodynamic layout, design and technology of manufacturing were analyzed.

The preliminary estimations of the cost of series production of alternative versions of the design were also made. The result of activity was the creation of a rotor made on the scheme close to bearingless with all-composite blades. The main technological feature of these blades is that they practically are completely made by a winding method. This method of composite blade manufacturing has been developing at the Mil Moscow Helicopter Plant for several decades and, the experience gained, was used during designing of the Mi-60 Helicopter rotor and has allowed to design the rotor with very high characteristics.

1. Introduction.

The control system of the Mi-60 helicopter has no hydraulic actuators. In order to ensure acceptable forces in a flight control system, during rotor parameters selection a special attention was given to aerodynamic layout of the blade.

During development of the rotor design, the authors of the project proceeded from the assumption that the modern requirements to the helicopter rotor aerodynamic characteristics, weight, strength and service life can be only met with the use of composite materials. If composite materials are used in a main rotor design, two essentially different approaches to selection of the rotor design concept are feasible.

The first approach is to keep partitioning of a rotor into separate aggregates – rotor hub and blades. In this case the blades can be completely "composite" and the hub - completely metal with conventional hinges with bearings. The classical metal hinged rotor hub is a rather intricate aggregate and requires significant expenses for maintenance in operation. The replacement of such a conventional hinges by elastomeric bearings or torsion bars (metal or composite), is obsolete by its "philosophy" and does not correspond to capabilities of modern materials and technologies. With such an approach the hub remains to be one of most complicated and expensive aggregates of a helicopter (both in manufacture and in operation). The number of parts and connections in a rotor decreases, in comparison with a classical hinged rotor, but does not change in essence.

The second approach is based on the fact, that though the rotor hub became one of the main aggregates of a helicopter (if to judge by design complexity), in technical essence it is not a mandatory element of a helicopter. It is known that in the first models and full-scale samples of rotary-wing vehicles the rotor hubs, as a separate aggregate, were actually absent and looked like a simple boss, fixed on the shaft of the

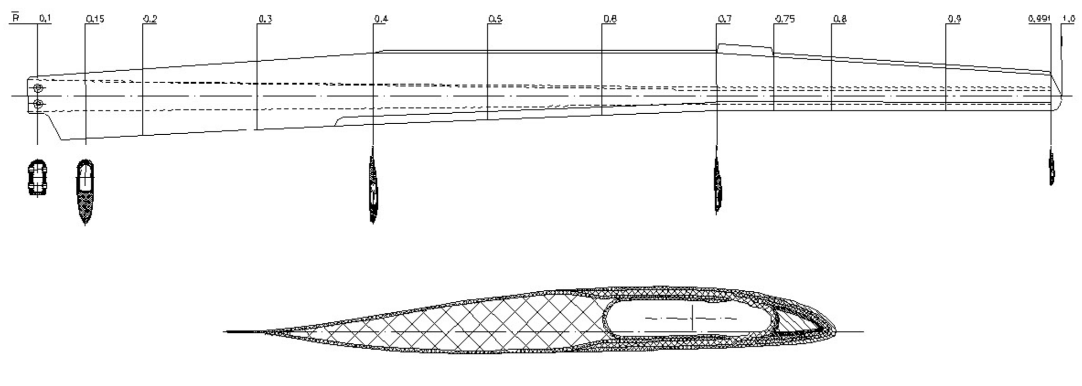

Fig. 1

gearbox. However materials, available at tat time, did not allow to solve problems of rotorcraft stability and to ensure necessary strength without hub articulation. The invention of the ingenious designer of gyroplanes Sierva has initiated operational use of rotors with articulated hubs. With the modern composite materials available, which allow to provide blade flapping motions and angle of attack changes through elastic deformations, the return to "hub-less” to helicopter rotors began. Such a rotors either have blades with an elastic root end, or they have modulus design with built-in elastic elements and lead-lag blade dampers. Owing to fundamental decrease of parts number and elimination of "unnecessary" joints and consequent weight reduction, as well as service life improvement, such a design - technological scheme was chosen during the Mi-60 helicopter main rotor development.

1. Selection of the main rotor blade optimum aerodynamic layout.

As lightweight helicopters have no hydraulic actuators in flight control system, it is essentially important to provide small hinge moments on the main rotor blades. During designing of the main rotor for «Авиатика-600» helicopter, with takeoff weight of 800 kg, the blade shown in a fig.1 was investigated 1.

The blade with such a plane form has rather good hinge moment characteristics and was considered as a parent version for the Mi-60 helicopter rotor, which in the beginning of development had a take-off mass of 750 kg. However, because of impossibility to

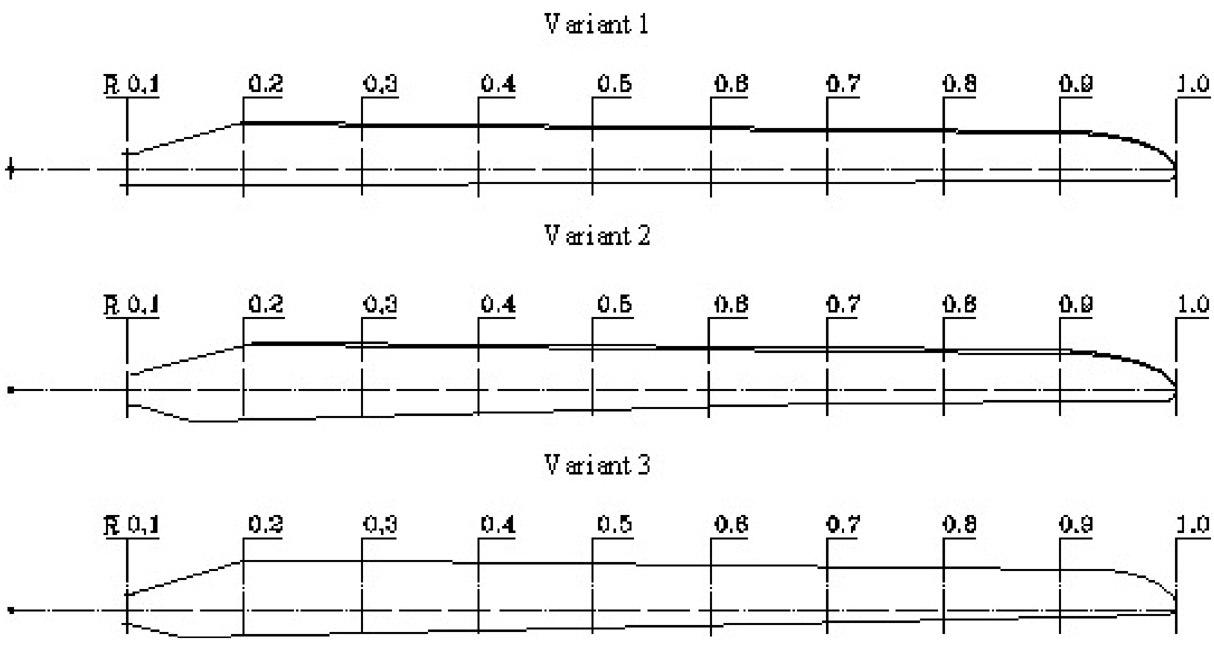

Fig. 2

mechanize the process of manufacturing of the blade with such complex shape, this variant was rejected and later on the versions presented in fig. 2 were considered. The basic geometrical and mass characteristics of variants of blades are submitted in a fig. 3.

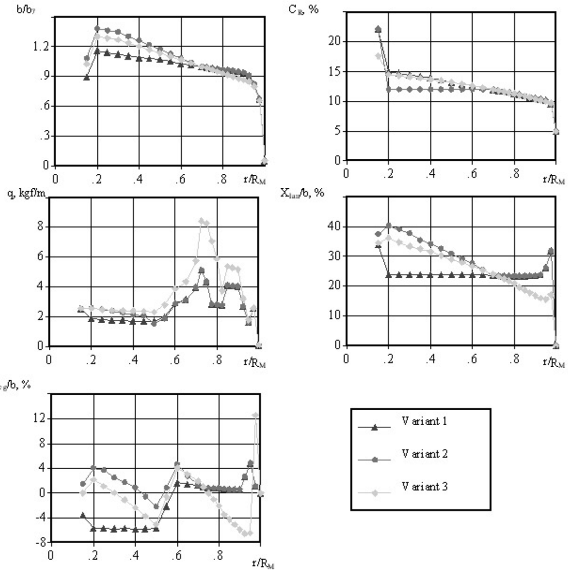

Fig. 3

The first layout is close to a conventional taper blade. Second one has so-called «excrescence» on its root end. It was jointly developed by TsAGI and the Mil Moscow Helicopter Plant and has demonstrated good results in terms of combination of high helicopter flight performance and moderate loads in a control system. The third layout represents a blade with taper plane form with the changed position a feathering hinge axis relative to the blade centerline. In order to reduce the wave and induced drag at the blade tip, and also to reduce a blade noise level, all versions have practically identical tip, which plane form is close to elliptical.

Taking into account the field of helicopter application and for the purpose of technological effectiveness improvement, one modern CTM airfoil was chosen. It was developed by TsAGI and has high aerodynamic efficiency and high enough maximums lift coefficient.

In order to analyze the blade plane form the calculations for all blade layouts, with same linear twist of 9°, were made. Comparative data for hovering, horizontal flight and vertical maneuver with ny=3.1 load factor are represented in table 1.

From experience of rotor designing it is known, that in development of new blade layouts it is most important to give attention to cosine component of a blade hinges moment first harmonic. This is because on an assembled it is practically impossible to adjust this parameter without introduction of major changes to blade design. Unlike cosine, the sine component of hinge moment first harmonic may be changed by means of trimmer, used for concinnity adjustment, or by bending of an airfoil tail plate.

The results of calculations (Fig. 4) have allowed to make a conclusion that the best combination of the aerodynamic characteristics and hinge moment for the blade of the helicopter being designed has a layout №2. The favorable combination of tip and root plane form allows to ensure high helicopter performance with a moderate hinge moments of the blade. However such a form results also in production processes complications and, hence, in increase of cost of both the tolling and the helicopter as a whole. Therefore, for the further studies, the blade layout a taper plane form was chosen (Fig. 5). It has similar aerodynamic characteristics, more simple and cheap production technology with slight increase of hinge moment level.

Table 1.

	Variant	1	2	3
Mode of flight	Parameter			
Hover	η_o H=0, ISA	.708	.708	.713
	TOW, kgf H=0, ISA	1033	1033	1038
	Static ceiling, m TOW=820, kgf H=0, ISA	1330	1330	1350
	N_E, hp	180	179	190
Horizontal flight V=175, km/h H=0m, ISA	M_{b0}, kgfm	-0.1	0.6	-1.9
	M_{bc}, kgfm	1.4	0.8	2.0
	M_{bs}, kgfm	0.7	1.1	1.1
	N_E, hp	216	219	233
Horizontal flight V=200, km/h H=0m, ISA	M_{b0}, kgfm	-0.3	0.1	-2.7
	M_{bc}, kgfm	2.4	1.1	2.90
	M_{bs}, kgfm	0.6	0.8	0.8
	N_E, hp	120	123	126
Horizontal flight V=200, km/h H=4000m, ISA	M_{b0}, kgfm	-0.3	-0.2	-2.0
	M_{bc}, kgfm	0.4	0.1	0.6
	M_{bs}, kgfm	0.2	0.3	-0.1
Steep climb, n_y=3.1 V_{in}=175 km/h H=0 m, ISA	M_{b0}, kgfm	-8.5	-5.2	-13
	M_{bc}, kgfm	5.4	3.4	6.2
	M_{bs}, kgfm	13.3	10.3	11.4

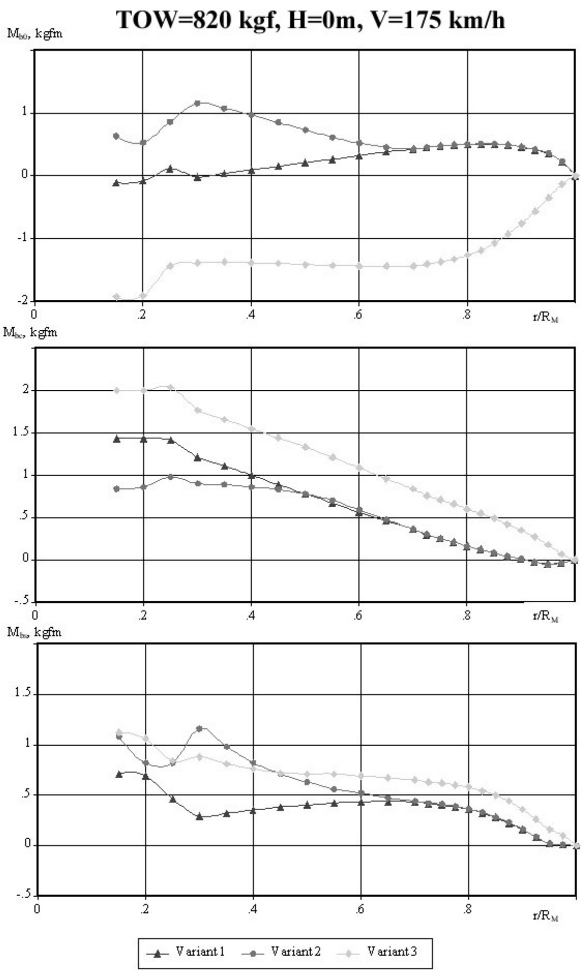

Fig. 4

3. Development of a Design.

During the development of the main rotor blade design " one material - one technological process " guiding principle was proclaimed. Quality, repeatability of characteristics and cost of products made of composite materials, largely depend on how their design is suitable for application of mechanized methods of composite materials processing, as the manual operations are an essential risk factor and, consequently, the reduction of their number to a minimum is extremely desirable.

It is known, that those designs made of composite materials are most weight efficient, in which the fibrous nature and anisotropy of composite materials strength properties are utilized at the most. For this reason the blade design makes use of the loopback joints and longitudinal composite material unidirectional plies. All blade design elements are supposed to be made by a winding by a winding method. Nowadays, except for winding, a hand lay-up method is also used during fabrication of composite blades. The selection of winding method was made for the following reasons:

- at serial production a lay-up processes require industrial premises of significant area. They must have controlled climate and special arrangements for

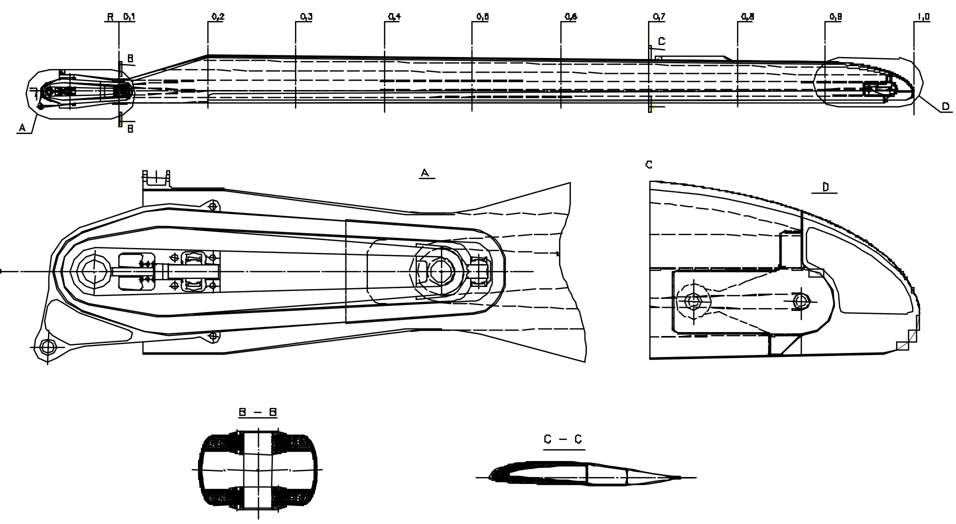

Fig. 5

workers health protection;

- special expensive equipment is required for high quality cut out of a huge number of plies;
- in order to ensure repeatability of mass and stiffness characteristics of the final products it is required to mark and weight each separate ply with subsequent sets selection;
- as the products made by lay-up technology are hundred percent handmade, and the man, as is known, is the most unreliable element in such fabrication schemes, a total quality control after each operation is required, plus implementation of all kinds of the non-destructive quality control of a final product;
- at serial production of composite parts with the use of lay-up method there are serious problems related to storage and transportation of the large number of "wet" long-sized plies of prepreg from the area of ply cut out to the area of part assembly; this is the stage where the wrinkles are most likely to emerge.

4. References.

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