MI-6 HEAVY-LIFT HELICOPTER IN Dr. MIL DIARY NOTES AND SKETCHES

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Abstract: In 1954 in compliance with the USSR Government Decision the Design Bureau headed by Dr. Mil started to develop a military heavy-lift helicopter of 6,000 -12,000 kgf payload capacity using turbine engines. The paper presents the diary and private notes made by Dr. Mil during from 1952 to 1965 as well sketches showing how the Designers mind worked trying to select the most suitable configuration. One of the problems was to design main rotor with blades of 35 m diameter. Dr. Mil was the first to offer a steel tabular spar combined all structural members by means of filling them with foamed polyurethane and glassfibre-reinforced plastic. The sketches of composite blades layout are presented.
In total, about one thousand Mi-6 helicopters were built. It was the first helicopter to bridge over the velocity of 300 km/our in 1957. Dr. Mil and his team were awarded by Sikorsky Award in 1961.

1 INTRODUCTION

In 1952 the Design Bureau headed by Dr. Mil was engaged in further development of the Mi-1 and Mi-4 helicopters. At the same time the Chief Designer was working at a concept of a helicopter of greater payload capacity. A helicopter of this payload capacity existed neither in the USSR nor in foreign countries. If the Mi-4 could carry 12 troops or a light field gun, or a light truck inside its fuselage, the new helicopter under development should carry a truck having a 6,000 kgf capacity approximately over 1,000 km.

In the late 1952 projects of a single rotor configuration of 6,000 kgf payload capacity appeared; the dimensions of its cargo cabin were unprecedented: 12 m long, 2.88 wide and 2.6 high. Dr. Mil made an entry: “Now the category of assault/transport helicopters is determined by the dimensions and weight of ground transport vehicles used in the armed forces that should be airlifted. The fact is that the weight of weapons systems carried by prime movers is close to that of the latter. That is why the payload capacity of the first helicopters was 1,200-1,600 kgf (the weight of a light military motor vehicle used as a prime mover). Then the required helicopter payload capacity has increased up to 6,000-8,000 kgf which corresponds to military vehicle based on the automobile chassis of 3,000-4,000 kgf capacity”.

Dr. Mil started to look for an optimal solution to the problem of carrying loads weighing up to 6,000-8,000 kgf.

2 POWERPLANT AND GEARBOX

The problems connected with the selection of the powerplant and main rotor parameters were of utmost importance among problems to be analyzed. At that time turboprop engines were developed first for military, then to civil aircraft. But no engine incorporating a free turbine required for the helicopter was available yet. Under those conditions the use of the turbine part of the Kuznetsov TV-2 turboprop engine of 5,500 hp successfully powering aircraft was considered to be reasonable. The engine designer P.A. Soloviev took upon himself the task of further development of that engine to power the helicopter.

The main rotor capable of developing this lifting capacity could be designed only by a dramatic increase of its solidity matching the corresponding disk loading. Otherwise it would be necessary to increase considerably its diameter. A decision was made to design a five-bladed rotor. The disk loading of the new rotor increased up to 40 kgf/cm^2, i.e. it became twice higher as compared to that of the Mi-4 main rotor where it was only 20 kg/cm^2. Up to that time no helicopter having this disk loading was developed and there were concerns whether a helicopter equipped with such a rotor could operate safely as the rotor tip speed would be 1.5 times higher than that of the known helicopters.

The main rotor chord was also dramatically increased which could result in higher hinge moments.

Taking into account all the difficulties, a decision was made to design a 5-bladed main rotor of 35-meter diameter. It was impossible to reduce the diameter any more.

Dr. Mil offers this design in 1953. The project is approved and in June 1954 the Design Bureau got the request for proposal to develop a new Mi-6 heavy-lift helicopter powered by two Soloviev turbine engines.

A lot of problems faced the Design Bureau at the first stage of developing this helicopter. First of all, it was a problem of designing the main rotor of 35-meter diameter and the main gearbox capable of transmitting 11,000 hp and having output torque up to 60,000 kgfm.

All the above problems were successfully solved in the course of designing.

The overall configuration of the main gearbox was made by A.V. Kotikov and V.T. Koretsky from the Design Bureau. It was supposed to design a four-stage main gearbox with two pairs of bevel gears per each engine.

Having studied this configuration, the engine Design Bureau headed by Solovyov suggested replacing it with a two-stage differential planetary gearbox. The new main gearbox design was approved and it was manufactured for the first time in the history of helicopter industry. Design and development were carried out in the above engine Design Bureau.

3 METHOD OF BLADE PERFORMANCE CALCULATION

Design of a helicopter main rotor blade possessing high aerodynamic performance and strength was always considered by Designer Mil as a task of great importance. “A blade is a half of the helicopter”, - he used to say.

It is impossible to imagine designing of modern helicopters without a great scope of sophisticated analyses and computation, laboratory and flight tests, without profound development.

Dr. Mil was a brilliant aerodynamicist, he understood perfectly that it was impossible to design the Mi-6 main rotor blades without finding out the stresses that could occur in them. It was a must to develop a method of blade performance calculations.

To do this, as Dr. Mil believed, it was necessary:

1. To clarify the then existing methods and to draw up calculation tables making it possible to set aerodynamic loads required for design.
2. To develop methods allowing the designer to select the blade stiffness and mass distribution in such a way that no overstresses could occur.
3. Not only explain phenomena, but also control them. We should answer the question how to calculate aerodynamic characteristics, i.e. to set blade twist and shape to obtain the most uniform distribution of induced velocities so that the value of variable disturbing forces changing with the frequency of higher harmonics could become smaller.

In designing a rotor blade the task should be as follows:

1. Disturbing forces should be small
2. There should be no resonance
3. Blade life taking into account the existing structures and materials should increase several times.

Thus Dr. Mil put forward the idea of mastering the then existing theory.

At relatively high airspeeds and blade tip speeds the application of the Glauert/Lock theory resulted in a great error. Therefore it was necessary to develop actually new prediction methods and obtain reliable experimental data. To do this, M.K. Speransky and M.L. Mil tested the Mi-6 main rotor model of 12.5-meter diameter on the full-scale helicopter test rig designed by Dr. Mil.

To offload the main rotor in forward flight the Mi-6 was equipped with wings. New aerodynamic methods developed by Dr. Mil and Dr. Braverman (both from the helicopter Design Bureau) were used in predicting the flight performance of the winged helicopter.

It should be noted that from the very beginning the Mi-6 main rotor blades were designed with account of the flutter theory developed when designing the Mi-4 helicopter (the Design Bureau faced that problem then for the first time). "Now, having the theory, we could easily start to design blades for the Mi-6 main rotor of 35-meter diameter. In the future we had no problems involving flutter in our Mi-6 within the whole wide airspeed range. Wishing to displace the CG position forward we placed the spar at 20% of chord in the root and at 16% of chord at the tip thus allowing us to obtain a much more forward CG position as compared to that of earlier blades, with a quite low weight of the blade counterweight [1].

3 MAIN ROTOR BLADE DESIGN

Dr. Mil suggested that the blade design should comprise a steel spar and separate frame sections fixed only at one point and therefore they would not participate in the total blade bending. It made the frame free of considerable variable loads and allowed riveted and bolted joints common in aircraft structures to be used here. Fig.1, 2 show the with separate frame sections and attachment to the spar. This design was a further development of Mil's idea used in the Mi-4 blade design where, unfortunately, the blade frame was not made free of bending loads [2]. The blade was comprised 21 sections and a spar of three tubes joined together. The attempt to launch a single-tube spar in production failed and instead the triple tube spar with flange joints was used in accordance with A. Malakhovsky's proposal. Finally the blades were of rectangular shape with the spar of a single tube of variable cross-section whose walls were of variable thickness. The manufacturing process used to produce the tube was constantly improved mainly with the aim to increase its dynamic strength. It was the first time in the history of engineering that a combination of the latest materials and advanced technological procedures was used: metals specifically treated to get them free of impurities, mechanical spar surface hardening (shot peening), common use of bonded joints, anticorrosion coatings. Quality control was improved. The result was a blade structure having a much longer life. Honeycomb was introduced into the tail edge section structure of the blade frame. The above said resulted in a higher dynamic strength of the blade and its improved dynamic characteristics.

4 COMPOSITE BLADES

The Mi-6 rotor blade design was constantly improved. The invention entitled "Helicopter Main Rotor Blade" by M.L. Mil, N.N. Leontyev, A.E. Malakhovsky initiated application of composite materials in the blades designed by the Design Bureau headed by Dr. Mil [3].

Fig. 3 shows the invented blade comprised a steel tubular spar of variable cross-section along which an airfoil frame consisting of the nose and tail sections was bonded. The outside surface of the nose and tail sections was made of glass fibre. Foamed plastic core was used to fill the nose section, while aluminium foil honeycomb core was used in the tail one.

. The sketches taken from the 1964 diaries and shown here (Fig. 4,5,6) demonstrate how Dr. Mil was in constant search of the blade shape. He was the first to propose a tubular spar for the blade, combining the blade structure the nose and tail sections filled with foamed plastic and honeycomb cores respectively by using adhesive bonding.

The Mi-6 modified main rotor blades were used in the rotor system of the experimental Mi-12 (1967) whose weight was 100,000 kgf. It had two five-bladed rotors of 35-meter diameter. The blade weight was greatly reduced as compared to that of the Mi-6 production blades. The new blades were installed in the Mi-6 later on.

The Mi-6 made its maiden flight in 1957, and it was manufactured in large numbers by Rostov helicopter production plant till 1980. In total, about 1,000 of these aircraft were produced.

Its takeoff weight was 40,500 kgf, its cargo cabin accommodated loads weighing up to 12,000 kgf or 120 passengers, and loads weighing up to 9,000 kgf could be carried externally over 1,000 km.   Fig. 7 shows the Mi-6 carrying the Vostok spaceship which was flown by Yu. Gagarin.

Sixteen speed and payload capacity world records were set up by this helicopter, including absolute ones; it was the first helicopter that overcame the speed limit of 300 km/h.

The Design Bureau headed by M.L. Mil was awarded the Sikorsky Trophy in 1961 by the American Helicopter Society for the speed world record set up by pilot N. Lyoshin in Mi-6. This Trophy is awarded for outstanding achievements in helicopter industry.

The Mi-10 and Mi-10K helicopters were designed by using the Mi-6 rotor system. At present two Mi-10K helicopters are still operating in Russia, their calendar life is about 14 years. And their service life is approaching 1,200 hours. It is a great success of the Russian helicopter design school.

The Mi-6 was widely used in the USSR and Russian economy. It was used as a water bomber in France to fight forest fires, it was used in Switzerland to erect structures and power lines. It was common opinion that the application of the Mi-6 in opening up oil and gas deposits in Siberia made it possible to reduce the time of their coming into service by 15 years.

5 FIGURES

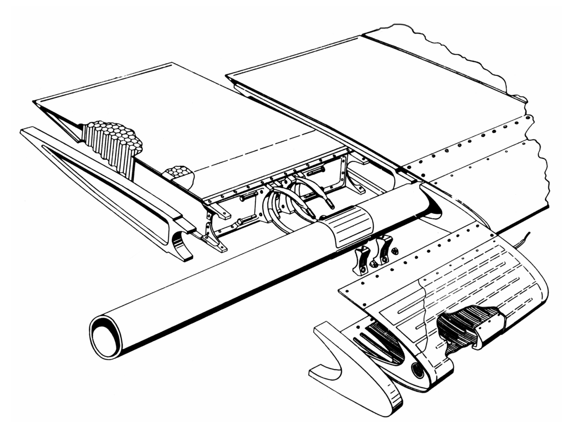

Figure 1:The blade comprising a spar and separate frame section fixed only at one point [2]

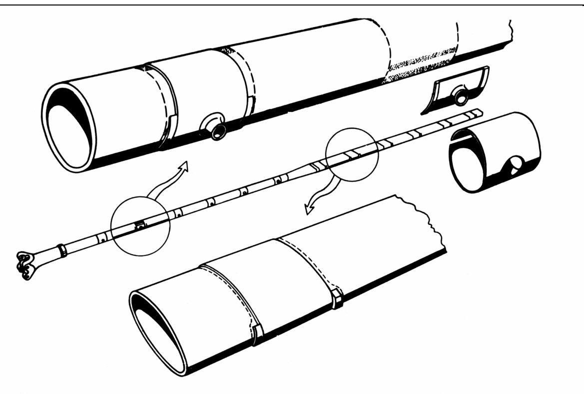

Figure 1: Section-to spar attachment with the help of metal tapes [2]

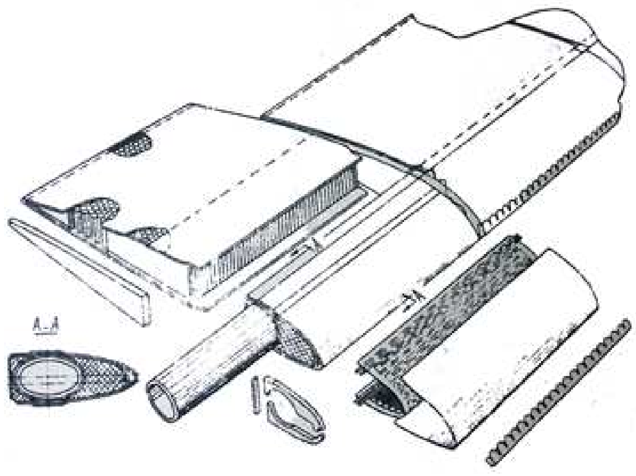

Figure 2: Composite blade with nose and tail frame sections adhesive bonded to the spar at one point (cross section A)[3]

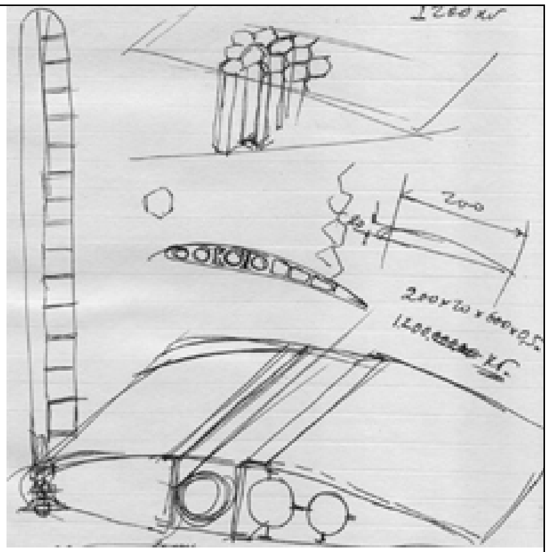

Figure 4: Variants of frame section filling

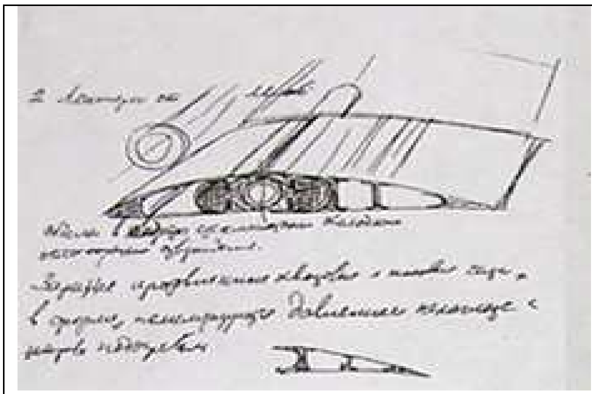

Figure 5: Sketch of composite blade layout. M.L. Mil was the first to offer a steel tubular spar combining all the structural members by filling them with foamed polyurethane and glass fibre reinforced plastic.

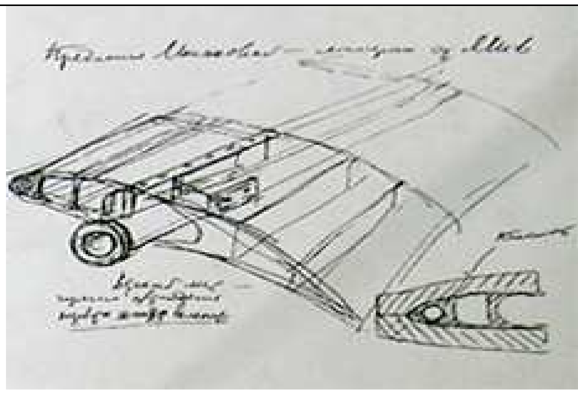

Figure 6: Sketch of composite blade layout Mi-6 main rotor blade incorporating a spar comprising several tubes attached to each other by their flanges.

Figure 7: The Mi-6 is carrying the Vostok spaceship which was flown by Yu.Gagarin.

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