SKETCHES MADE BY M. L. MIL DURING V-12 HELICOPTER DESIGN AND DEVELOPMENT

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Abstract

In 1963 in compliance with the USSR Government Decision, the Mil Design Bureau started to develop a heavy-lift military transport helicopter of 20–25-metric ton payload capacity using the Mi-6 dynamic system. The paper presents the diary and private notes made by M. L. Mil during 1964 to 1967, as well as sketches showing how the Designer's mind worked trying to select the most suitable design configuration, to find the required structures for attaching separate assemblies, to investigate trim and stability performance of the side-by-side rotor helicopter. A number of sketches are devoted to studies of different helicopter configurations such as single-rotor, tandem rotor and side-by-side rotor ones; the latter configuration having three and even four rotor systems. Finally the Designer's choice was made in favour of an original side-by-side rotor layout incorporating sweptforward wing.

Introduction

In 1963 in compliance with the USSR Government Decision, the Mil Design Bureau started to develop a heavy-lift military transport helicopter of 20–25-tonne payload capacity using the Mi-6 powerplants and rotor system.

The diaries and private notes made from 1964 to 1967 contain sketches showing how the Designer's mind worked trying to select the most suitable design configuration, to find the required structures for attaching separate assemblies, to investigate trim and stability performance of the side-by-side rotor helicopter.

Thirty years later it is interesting to see the considerations used in developing such expensive and complex helicopters. Heavy-lift helicopters were designed in the USA as well, thus Boeing worked at its HLH project which was never fully completed. Let us remember that the Cold War was in full swing at that time. Here is a note made by M. L. Mil in his diary in 1962.

..."NATO considerations about a 4–5-day nuclear war. All security factors including geographic remoteness are no longer effective. Instead of this mobility becomes a must. Therefore there is a demand for aircraft that will never land on the site from which they have taken off. Thus, what is needed is a powerful helicopter on the one end of the airfield and an aircraft on the other one..." (Ref 3).

To carry out this plan, the V-12 capable of lifting loads up to 20–25 tonnes was supposed to be built. It was intended to carry missiles and cargoes compatible with those carried by the An-22 transport aircraft to almost inaccessible areas. The overall dimensions of the V-12 and An-22 cargo cabins were similar.

Design and Development

Fig 1a shows a fragment containing a note made in his diary dated April, 1964. "The last task was to make sure again that the Mi-16 is suitable to carry tanks (although nobody knows clearly why and where they are to be carried)." (Ref 3). He drew one of the helicopter versions (designated Mi-16 by him) that was intended to carry out the mission: a single-rotor helicopter with jet-driven rotor blade tips. But in this case it was necessary to design a rotor system of 42–44-meter diameter, hydraulic jacks and so on. This version was rejected.

The time from 1963 to 1967 was a period when M. L. Mil was on the rise in his creative work. He was able to write in cooperation with his colleagues A. V. Nekrasov, A. S. Braverman, L. N. Grodko and M. A. Leikand and then publish "the book of all his life" – "Helicopters. Calculation and Design". (Ref 1). There great attention was paid to such problems as helicopter aerodynamics, vibration and strength. He had summed up the experience accumulated in the field of rotorcraft design and analysed all the helicopter configurations existed at that time. There is no doubt the book summed up the experience gained by the Mil Design Bureau in the process of selecting the configuration of the heavy-lift helicopter of 20–25-tonne payload capacity then under design. It seems to us that the book is still of great interest as it reflects the history of helicopter technology progress from 1920 to 1970.

That is what M. L. Mil wrote trying to find the optimal helicopter configuration: "How is the next (larger) helicopter to be developed? It is im-possible to calculate the parameters of an optimal design since there are too many contradictory considerations to be weighed by the designer..."(Ref 1).

After studying different helicopter configurations (including single-, tandem- and side-by-side rotor ones) the Designer's choice was made in favour of an original

side-by-side rotor layout incorporating sweptforward wing which allowed him to solve a number of problems. It was decided to mount the engines on the outboard truss structures with part of the truss structure supporting the wing with inverse taper. This type of wing appreciably allowed to solve the problem of minimising losses caused by the vertical downwash and to build a twin-engine mount structure which was sufficiently rigid in bending and torsion. Fig 2 presents sketches of the truss structure with main and additional struts ensuring wing attachment.

M. L. Mil wrote the following (Ref 1): "... In the case of high-power and thus heavy engines mounted to the wing tips, the side-by-side rotor helicopter almost certainly will have a vibration mode of a frequency close to or even smaller than the rotor rpm... This may set up oscillations of the "ground resonance" type not only on the ground but also in the air. Therefore, the designer who has decided to design a side-by-side rotor helicopter is faced with the difficult task of making the wing as small as possible in area, light in weight, and sufficiently rigid in bending and torsion."

At first, the helicopter was expected to have 6 Soloviev D-26-VF of 6,500 horsepower each (Fig 1b); but finally 4 engines were installed in pairs driving two main gearboxes.

However, to get the assignment, involved with building of the helicopter of the proposed design, a fierce battle with the Ministry of Aviation Industry and the TsAGI Research Institute (Central Aerohydrodynamic Institute) had to be won. The scientific opponents from the TsAGI were insistent on their suggestion that the military transport helicopter should be built as a tandem one. A commission headed by V. P. Myasischev, a well known aircraft designer, was set up. However, he backed up the design proposed by M. L. Mil. And the Design bureau started its work at the project. Two V-12 prototypes were built.

At last, in 1967 the helicopter piloted by V. P. Koloshenko became airborne for the first time. Suddenly, the helicopter started to sway. A rough landing was made during which one of the main landing gear wheel tyre blew out and a shock strut got bent. There was no flight accident, as some foreign magazines repeatedly stated.

The investigations conducted revealed that the cause of this event was intensive vibration that had occurred due to the fact that the frequency of one of the airframe normal modes had coincided with that of the control linkage. After a minor modification of the control system the helicopter flew successfully and carried out the whole programme of flight tests prescribed.

The successful selection of the configuration with inverse tapered wings resulted in a reduction of losses from rotor wash over the inverse tapered wing by 3–4%, and an increase in main rotor lift up to 6,000 kg as compared to the design figure.

While designing new helicopters, M. L. Mil, their designer, usually developed the concept of their application. He thought how to solve the problem of carrying tanks by using several helicopters (Fig 1b) and asked himself a question: "What cargo can the V-12 carry in the national economy when used as a flying crane?" He arrived at an unfavourable conclusion, – "Two Mi-6 helicopters will have the same payload capacity and they will operate better and with more certainty, i. e. it (the V-12) won't be needed in real life."

When the V-12 helicopter was virtually prepared for quantity production, after M. L. Mil's death, the V-12 programme was cancelled as by that time the military doctrine had changed.

The notes dated 1966 contain sketches of the side-by-side rotor helicopter with three and four rotors installed; those designs were no Designer's engineering fantasies (Fig 3). They were also studied and given up.

M. L. Mil believed that designing of multirotor helicopters would require increasing installed power. He writes in his diary with an emotion: "Theory has a great power! What you feel or are empirically aware of gives you an impulse or force to start, but an explicit theoretical conclusion gives you invincible strength and clear understanding of the future. The fundamental theory is a weapon, an instrument used to convince and win a victory over any opponents. Who can object to the statement that the V-12 needs new engines if the following theorem has already been proven: double useful load cannot be achieved by a simple twofold increase of installed power." (March 12, 1964). The diary of 1964 contained a draft letter to be sent to the Government in which reasons to improve the engine weight/power ratio were given.

Fig 4 a, b shows sketches of engine nacelles. M. L. Mil suggested that the engine nacelle cowls when hinged down should be used as work platforms. Therefore after walking along the wing one could get to the opened cowls and, standing on them, inspect the rotor system without any ground equipment. Later, the same layout was used for the Mi-26 helicopter.

While thinking over the structure of the wing truss, engine nacelle attachment fittings, the Designer drew animal figures on the same pages. He wondered about ultimate strength, body weight-to-support-area ratio, modular structures existing in nature (Fig 5). Here are sketches of large and small animals and fish. How are heavyweight structures attached? What is the support area of the main bones? He is writing in his diary, that he has been struck with a new idea about the extinction of dinosaurs, the most heavyweight animals ever lived on the Earth. Most probably their size was gradually increasing until their feet could not support their weight any longer. As soon as the pressure applied to their feet exceeded the ground resistance, dinosaurs got stuck in swamps.

In some sketches a sceptic man is present; he seems to say: "Come on, go on orking, and I shall look and see what will become of it." You can see also an instrument containing moving balls which allow to monitor mass distribution.

Direction of Rotor System Rotation

Choosing the right direction of rotor system rotation was of great importance for the side-by-side rotor helicopter. M. L. Mil suggested that the rotation should be directed outboard of the fuselage, or in swimming terms, "breast-stroke" direction should be adopted. A very interesting paper (unfortunately, not published in the open press) is devoted to this subject; in addition, it contains M. L. Mil's impressions about his talks with his foreign colleagues, a pilot of Focke Company, and Friedrich Doblhoff, a designer, devoted to stability and controllability of side-by-side and tandem rotor helicopters.

Fig 6 presents sketches of forces and moments applied to the side-by-side rotor helicopter in turns; they were made for his paper entitled "Lateral Trim, Controllability and Stability". This paper was a part of Proceedings published by the Mil Moscow Helicopter Plant in 1970, after his death (Ref 2).

He writes in his paper that the first side-by-side rotor helicopter was designed by V. N. Yuriev in 1926 and its model passed wind tunnel tests. "The first helicopter controllable to such a degree that it was able to fly over the circus ring within a building in the presence of hundreds of spectators thus proclaiming the beginning of practical application of this type of aircraft in the history of helicopter industry was that of the side-by-side rotor configuration. This helicopter designated FW-61 was designed by Professor H. E. Heinrich Focke in 1937. It was followed by another successful helicopter, FW-233.

In 1939-1941 Professor I. P. Bratukhin developed 5 different types of the helicopter in the USSR. All of them flew successfully. Later on the same arrangement was used in the design of helicopters built by Platt-LePage and MacDonnel Douglas in the USA, but they did not find any practical application. The direction of rotation of all the nine helicopters of this configuration was directed outboard of the fuselage, or in swimming terms, they had "breast-stroke" direction of rotation.

Then there was a break in developing helicopters of this type, and it was N. I. Kamov who resurrected this configuration by building his Ka-22 Vintokryl in 1958. But in this case the direction of rotation was opposite, i.e. the "butterfly" direction. Two prototypes were built. They made many flights, however they had serious flight accidents whose causes were never found out. As a result this type of helicopter was given up."

As mentioned earlier, when M. L. Mil started to design the V-12 using the side-by-side configuration he selected the "breast-stroke" direction while his opponents from various research institutes were persistent in their suggestions that the "butterfly" direction used by the Ka-22 should be taken. "Thus the point was raised again," – M. L. Mil writes, – " what considerations should be taken as guidelines in selecting the direction of rotor rotation."

M. L. Mil makes an interesting observation that refers to him as a scientist. "In engineering, it often happens that only the pioneer deeply thinks about all the aspects of the problem to be solved. Then a successful and proven arrangement finds a lot of followers and imitators who have no need to know all the aspects of the problem. Therefore it would be interesting to find out what Professor Focke's considerations for selecting this particular direction of rotation were."

It was a happy chance that at the 1965 Paris Airshow, almost thirty years after the maiden flight of the Focke FW-61, the author of the lines above happened to meet the sixty-seven-year old Franz Bode , chief test pilot for Focke Company. Replying to the question concerning the considerations determining the direction of rotation, he simply said, "so that coordinated turns could be obtained, i. e. so that the yawing moment produced by rolling should act in the direction of roll. Speaking about some shortcomings, he mentioned insufficient stability near the ground and somewhat greater drag of the aircraft due to brace struts which was quite widely known. I. P. Bratukhin in his thesis for a doctor's degree defended in 1962 proceeded from the same assumptions: the secondary directional (yawing) moment produced due to lateral control (i. e. in rolling) should act in the direction of the turn.

M. L. Mil studied the physical nature of the phenomenon and calculated forces and moments produced in turns and in straight flight. The calculations showed that the "breast-stroke" direction tended to increase the control effectiveness in roll, as added stability in this case tended to increase directional control effectiveness. In case the "butterfly" direction was used, there were conditions under which directional control failed in rolling. "The pilot moves the control stick fully to the right with the pedal being in the limit position, and the aircraft executing a spiral rolls over the left wing." The above statement is in full compliance with the evidence given by Yu. A. Garnaev who survived the Ka-22 crash.

Then M. L. Mil studied the stall phenomena. He found out that the side-by-side rotor helicopter with the "breast-stroke" direction of rotation tended to be more stable in stall when the aircraft got out of trim as compared with that using the "butterfly" direction of rotation. Relying on the results of this work it was decided to choose the "breast-stroke" direction of rotation. However, M. L. Mil was unable to make his wise opponents from the TsAGI change their mind.

Later on the results of the V-12 flight tests confirmed the correctness of the direction of rotation chosen. Two prototypes of the V-12 were built; it had good stability and handling qualities (Fig 7). V. P. Koloshenko who was the chief test pilot stated that the helicopter remained stable with hands off the control stick for 3–7 minutes.

M. L. Mil considered this helicopter his best design, "his swan song". In 1969 the V-12 lifted a payload of 40,200 kg to a height of 2,250 m setting up a world record which is still unbroken. The Design Bureau was awarded the

Igor I. Sikorsky International Trophy "in recognition of outstanding achievement in the advancement of the helicopter art."

References

1."Helicopters. Calculation and Design" by M. L. Mil' et al., NASA TT F-494, 1967.

2. M. L. Mil " Lateral Trim, Controllability and Stability". M. L. Mil Moscow Helicopter Plant Proceedings, Moscow, 1970).
3. M. L. Mil's Diaries and Notes, 1964-1967

FIigures

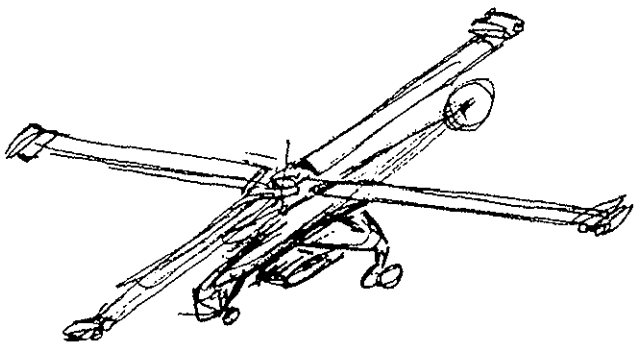

Fig 1a. A heavy-lift helicopter version with jet-driven rotor blade tips. The engines are installed on the rotor blade tips.

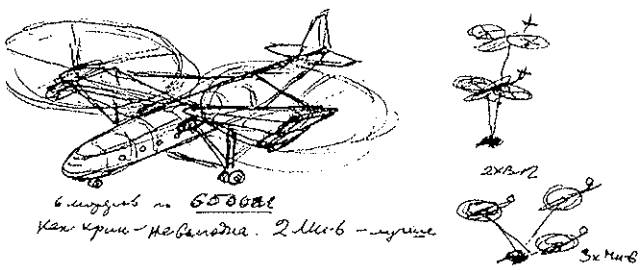

Fig 1b. Side-by-side rotor helicopter powered by 6 engines and different ways to be used in carrying tanks by several helicopters.

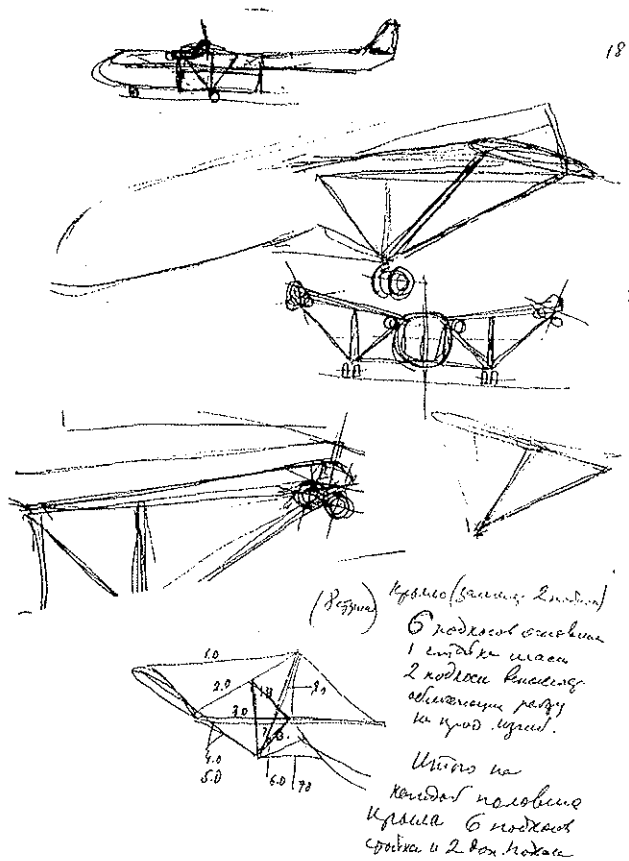

Fig 2. Sketches of the wing truss structure containing main and additional struts.

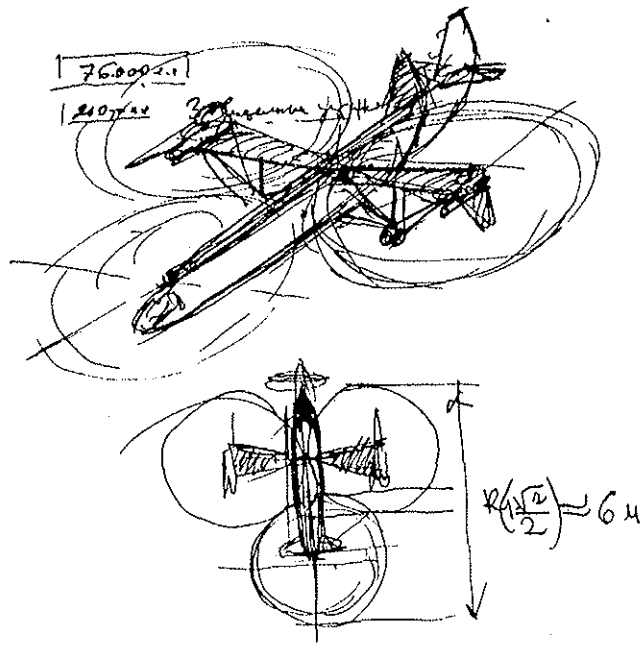

Fig 3. Side-by-side rotor helicopter in different versions having different number of rotors.

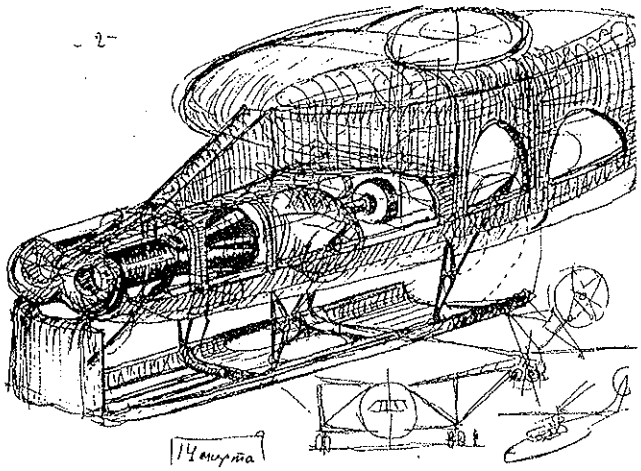

Fig 4a. Sketch of engine nacelle.

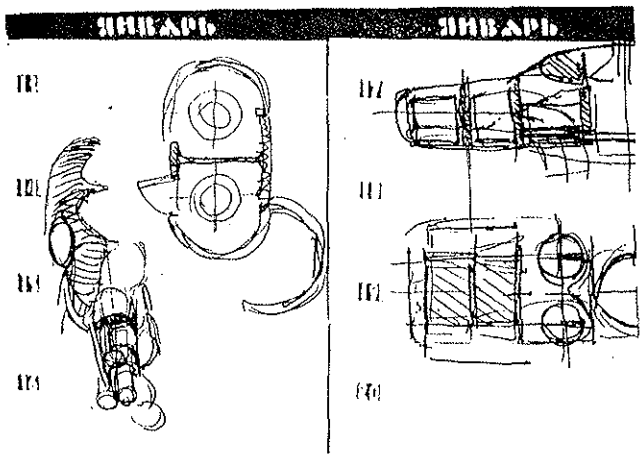

Fig 4b. Layout of engines with cowls opened.

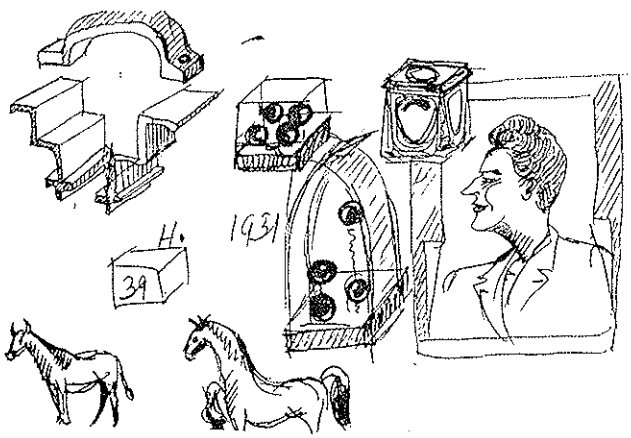

Fig 5. Modular structures in nature.
While thinking over the structure of the wing truss, M. L. Mil drew animal figures to understand what the body weight-to-support area ratio should be to provide ultimate strength existing in nature.

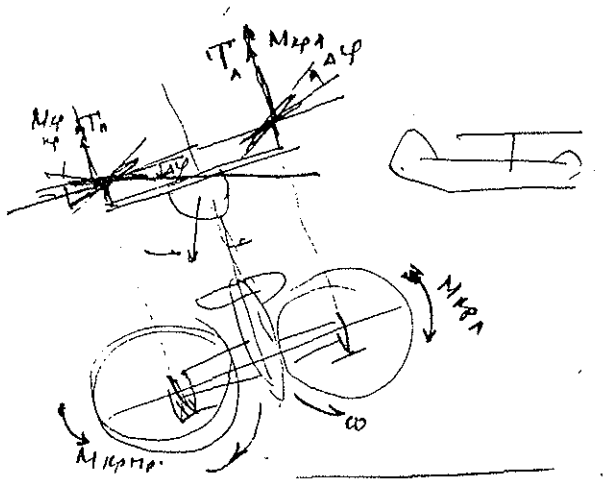

Fig 6. Sketches for the paper entitled "Lateral Trim, Stability and Controllability", 1966 (not published in the open press). Forces and moments applied to the side-by-side rotor helicopter in turns.

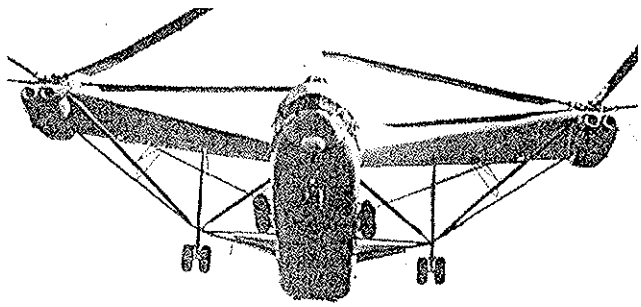

Fig 7. The V-12 (Mi-12) heavy-lift helicopter, 1967.