OPTIMAL HIGH-SPEED HELICOPTER TRANSMISSION DESIGNS

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Abstract

In the recent years, there has been significant interest in the new developments and improvements of the rotorcraft transmission systems. CIAM research the feasible solutions for the development of regulated transmission for advanced helicopters, including those for high-speed types of helicopters.

It is assumed that in the next generation of helicopters will be a significant breakthrough in increasing the forward airspeed through the use, in addition to rotor thrust pushing systems. This will require the development of a new type of transmission for the engine power separation between rotor and pusher blades.

1 Problem definition

Rotor drag is just one reason why conventional helicopters cannot fly faster than about 180kts by simply applying more engine power to turn their blades more quickly. The combination of high rotor speeds and high forward air speed can make the blade tips go supersonic, particularly during the forward part of their sweep forward part of their sweep.

However, the critical problem is so-called retreating blade stall. In forward flight, a rotor blade's relative air speed is higher when sweeping forward than when sweeping rearward. Thus, each blade's angle of attack must be flatter on the way forward and steeper when retreating, so that blades on either side of centre provide equal lift. As helicopter air speed rises, this differential is exacerbated until such point as the retreating blades reach a stall angle of attack - and the helicopter becomes unstable.

Among the existing projects may be noted the draft high-speed helicopter firm Sikorsky X2, and the Russian project of high-speed helicopter the Ka-92.

Hence the attraction of counter-rotating blades; on each rotor, one blade is always moving forward on each side, so the angle of attack of retreating blades need not be raised to balance the lift.

Necessity of rotor rotation velocity variation during constant rotation velocity of engine according to the flight mode demands using of mechanisms with transmission ratio changing. Solution for this task is very difficult because such a mechanism placement follows to total helicopter mass growing and increasing of dynamic loads in transmission.

The aerodynamics of high-speed rotary wing aircraft show a noticeable benefit by reducing rotor RPM in high speed cruise flight. The RPM reduction from a hover profile to a high speed flight profile is typically on the order of about 30%. Such a reduction at the engine, however, may cause problems with auxiliary systems, engine operation and available power while, a rotary wing aircraft, which always operates at a relatively low rotor RPM, may present penalties in rotor and transmission weight, as well as maneuverability constraints. Thus, there is a need for a rotary-wing transmission gearbox system, which provides variable rotor system speeds.

Thus, a transmissions of high-speed helicopters are presented entirely new challenges, such as the drive the part of engine power to the push blades system, the ability to control speed and torque of the pushing blades regardless of the speed of the rotors, changing the gear ratio transmission, which will provide at least two flight mode with the increase to the maximum flight characteristics of the aircraft during the flight to hover and cruise. The appearance of these requirements significantly change the type of transmission mechanism, the research is conducted in the present study. Explore the possibility of progressive transmission in the types of aircraft also carried out with an analysis of the possibility of reducing the mass of the helicopter and to improve its performance through the use of variable speed drives a pusher blades. A distinguishing feature of such transmissions should be able to change the gear ratio during the flight, as well as the redistribution of power from the engine between the systems of blades.

For the specific choice of the design concept of the variable gear ratio mechanism and power distribution is necessary to determine: the range of variation of gear ratio, a way to change (stage or continuously variable), type of control strategy.

We considered the transmission with step gear ratio and continuously variable transmission (CVT). Options for a step change in the transmission gear ratio of helicopters can be implemented most easily compared to CVT.

2 Stage variable transmissions

Such variable transmissions are similar transmissions in land transport, where the ratio is changed by turning off the motor shaft from the transmission, which works in one mode, mode change, due to changes tight coupling between the elements of transmission and the motor shaft connected to the system, which has rigid connection to the output shaft with the new gear ratio. In this dynamic process of transition that accompanies the moment of switching will be the biggest challenge for the reliable operation of such a mechanism. Mechanisms, leveling the angular speed of the motor and the transmission output shaft may be either friction or overrunning clutch. Using the clutch in the transmission transfer capacity of up to 5 MW will require the solution of complex engineering problems associated with the great loss of power and a strong heat in the friction disks. To do this, carry out research to find new types of friction materials and manufacturing technology of friction disks.

The most rational option for dual-mode transmission is a combination of parallel transmission power flows and the frictional overrunning clutches, as shown in the Figure 1. This scheme makes it possible to rigid connection in one of the modes without any loss to the slipping of the friction discs due to the automatic inclusion of overrunning clutch. Figure 1 shows the kinematic scheme of the possible variants of dual-mode speed transmissions for high-speed helicopter. Prior to entering the cruise power pusher propeller slowed down due to the included clutch position 2. Power from the engine goes to the input link 0 and divided into two streams: the power of the sun gear is fed to the summing planetary gear set, the rest goes to the power of the planetary range switching mechanism and, when stopped at the cage is a link, adding epicycle after summing planetary gear set. When flight configuration of helicopter change to cruise mode clutch disinhibited and part of the power supplied to drive a pusher propeller. At the same time triggered freewheel, and all parts of planetary gear set rotating switching mechanism as a whole with the same angular velocity. Summing planetary gear units rotate with the same angular velocity.

The advantages of such a scheme with a variable transmission gear ratio on fixed gears are:

- simplicity and reliability of the design;
- compactness and low weight of the mechanism;
- stability of characteristics, a fixed value of gear ratio transmission.

The main disadvantage of this design in the first place is the inability to continuously change the transmission ratio. To solve the problem step-change in the speed of the rotors, and possible problems with the aerodynamics of flight, it is proposed to compensate for sudden changes in speed by the pitch control rotor blades at the moment of transition from hover to cruise flight mode and back again.

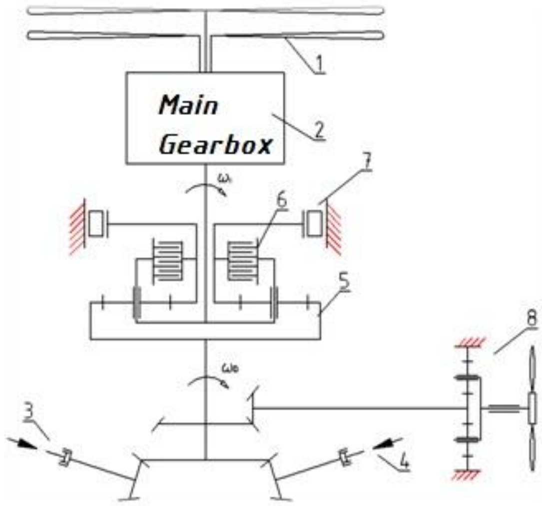

Fig.1 Kinematic scheme of dual-mode speed transmissions

To create a continuously variable transmission for helicopter is necessary to use advanced types of mechanisms, such as electromechanical, hydraulic, transmission types, as well as mechanical continuously variable transmission with a variator.

3 Continuously variable transmissions

By continuously variable mechanical transmissions are regulated drives, in which all or part of the engine power is transmitted via the variator - a mechanism for continuously change the transmission ratio by changing the geometry of the interacting surfaces of the working mechanism. Such mechanisms are now widely used in automatic transmissions in cars. However, the mechanical variable speed gear of all types have low reliability and stability, unacceptable for operation in the air transmission. In addition, the existing types of CVTs are limited in the amount of transmitted power in the ranges of the transmission ratio required for the transmission of high-speed helicopter. Of the existing designs of mechanical variator transmits the most power car Audi A6 with transmission capacity of 250 kW [3]. However, for high-speed helicopter with an estimated total capacity of the two engines of 6000 hp this design is acceptable. In addition, all types of continuously variable transmissions have relatively low efficiency, so that the whole power of the engines to pass through the variator is inefficient.

The solution to this problem is to use CVTs in the thread of the planetary transmissions. In complex planetary mechanisms the input power can be divided into streams through various parts of the mechanism, which may have two or more degrees of freedom. Due to the rational synthesis of such planetary mechanisms can be integrated mechanical CVT in one of the threads so that a CVT took place only a fraction of the total power. However, due to the additional degree of freedom of such transmission, the change in the variator gear ratio will lead to a change in gear ratio throughout the transmission [2].

At CIAM them search was carried out such a scheme of the planetary mechanism that would change the gear ratio transmission of high-speed helicopter with a total power of 5000 hp engines through the variator with a metal strap company Audi. Was synthesized by the scheme, which is part of a continuously variable power flow is 10 times less than the total engine power. The scheme of this mechanism with the split of power flow is shown in Figure 2.

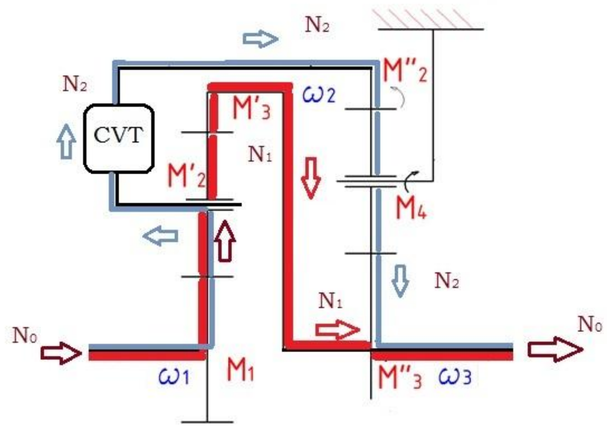

Fig.2 Power split in planetary mechanism with CVT

4 Electromechanical transmission

Opportunities and greater prospects for development are electro-mechanical transmission, which require in-depth study. The greatest difficulty with the use of electric actuators in the helicopter transmission are large mass and size of electric motors, with the critical values for the aircraft.

A feasible solution to this problem at the moment is the same solution as in the case of continuously variable mechanical transmission - the use of multi-threaded planetary mechanisms. This scheme is called a mixed electromechanical transmission and is widely used in hybrid cars. In electro-mechanical transmissions mixed scheme takes advantage of both parallel and mechanical circuits. Electric motor and generator transfer only "effective" part of the internal engine power needed to control the speed of the blades. The main advantage of this scheme, when used in the transmission of high-speed helicopter is a low power electric machines and battery compared to the parallel and serial circuits. Electric (generator in the engine and electric motor in the main gearbox) redirect a portion of the power required to change the gear ratio of the entire system, thus avoiding the high losses when converting mechanical power into electrical energy. Example of a kinematic scheme of electromechanical continuously variable transmission is shown in Figure 3.

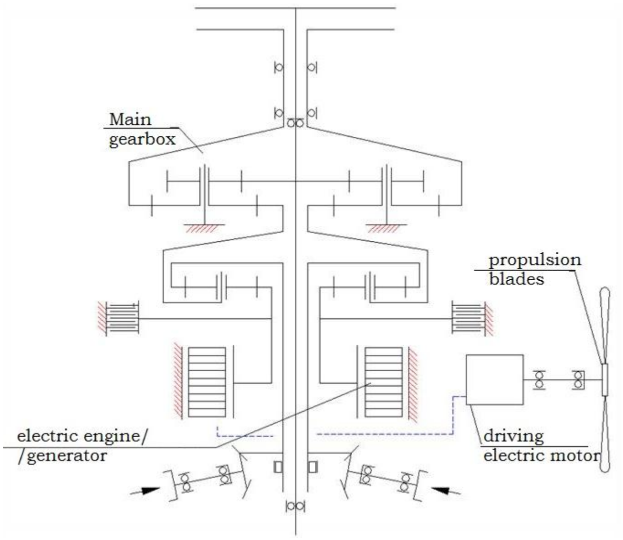

Fig. 3. Kinematic scheme of electromechanical transmission

In this scheme, one of the two-row planetary gear units unlocked and connected to the motor. The system of planetary gear-motor is an electromechanical stepless transmission. The choice of the optimal scheme of such a continuously variable transmission with appropriate methods of synthesis of the planetary mechanism Adder allows you to create such schemes, in which power, traversed parallel flow through the motor can be up to 10% of the total power of the engine. In addition, the use of electric transmission with a complex (mixed) way of organizing a large flow capacity reserve for the development of the advanced features of the scheme and increase its effectiveness (eg, the ability to generate energy from rotor when helicopter descend). However, the development of electromechanical transmission requires a considerable amount of research in a wide range of critical technologies: development of motor-generators (diesel / GTE) power required to create effective small electric machines of high power (200-300 kW) [1], the creation of efficient batteries (supercapacitors), etc.

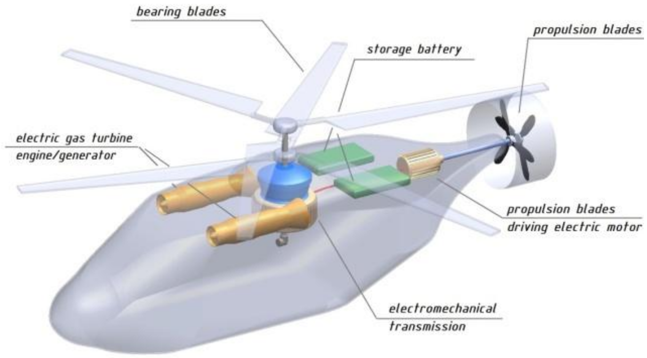

Fig. 4. Model of high-sped helicopter with electromechanical transmission.

5 Conclusion

The analysis of possible optimal design solutions for the transmission of high-speed helicopter identified the main advantages and disadvantages of each of the schemes, the main technological and structural problems of the realization of a circuitry for transmission of high-speed helicopter with variable gear ratio. Of these options the mechanisms of transmission gear ratio changes in terms of defining the criteria - reliability and stability of the transmission, to minimize weight and dimensions of the gearbox, as well as the safety and efficiency at the existing stage of technology development - preference should be given a mechanical continuously variable transmission with a parallel connection of the planetary gear unit and mechanical CVT.

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