ASPECTS REGARDING THE KINEMATIC ANALYSIS OF POWER TRANSMISSION FROM HELICOPTER DESIGN

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Abstract: *The main power transmission of helicopters is a complex technical system, which fulfills its functional role of transforming the kinematic parameters from the turboshaft into the kinematic parameters necessary for the optimal operation of the main rotor of the helicopter. The paper presents a method of kinematic analysis of the power transmission for the main rotor and the anti-torque rotor of a helicopter. Based on the kinematic diagram of this mechanical transmission, the angular velocities and the transmission ratios achieved by the double-planetary gearbox of the main and the secondary transmission are determined.*

Keywords: planetary gear, anti-torque rotor, power stage, transmission ratio, IAR 330 Puma

1. INTRODUCTION

The mechanical power transmissions used in helicopter design have the functional role of transmitting to the main rotor and anti-torque rotor, the rotational motion and torque developed by turboshafts of the helicopter, while achieving (simultaneously) considerable reduction of angular speeds and torque increase.

In designing these power transmissions of helicopters, the following conditions are required):

- the weight of the mechanical transmission should be minimal;
- the reliability to be as high as possible, by adopting optimal design and technological technical solutions;
- regardless of the operating mode, the power transmission should operate without noise and vibration;
- ensuring an easy maintenance activity;
- ensuring a power transmission cooling system as efficient as possible, in any flight situation;
- the mechanical efficiency of the power transmission to be as high as possible.

Planetary gearboxes and gearboxes with fixed axles are used in the design of these mechanical transmissions. Planetary gearboxes have been adopted as a constructive solution for helicopter power transmissions due to the achievement of very high transmission ratios (i = 8… 3600) [3], ensuring a high load-bearing capacity, ensured by the degree of coverage of the gears. For the transmission of the same child, with the same transmission ratio, the planetary gearboxes in the design of helicopters have a weight 4… 6 times lower compared to the usual gearboxes with fixed axles.

For optimal dynamic balancing, the planetary gearboxes are equipped with several satellites, so that structurally and cinematically, only one satellite is considered active, the other satellites being passive, shown in (Fig.1).

a

b

FIG. 1 Planetary gearboxes of the helicopter [6, 7]

2. STRUCTURAL ANALYSIS OF HELICOPTER POWER TRANSMISSION

The main power transmission of helicopters is a complex technical system, which fulfills its functional role of transforming the kinematic parameters from the turboshaft into the kinematic parameters necessary for the optimal operation of the main rotor of the helicopter.

Following the kinematic flow shown in (Fig.2), at the entrance to the mechanical transmission, the rotational movement and the torque are transmitted by means of a bevel gear, in which the gears have curved teeth. This technical solution has been adopted due to the advantages of conical gears with curved teeth: they operate at high peripheral speeds, up to 40 m/s; they have a quiet operation, a high degree of coverage, a very high reliability.

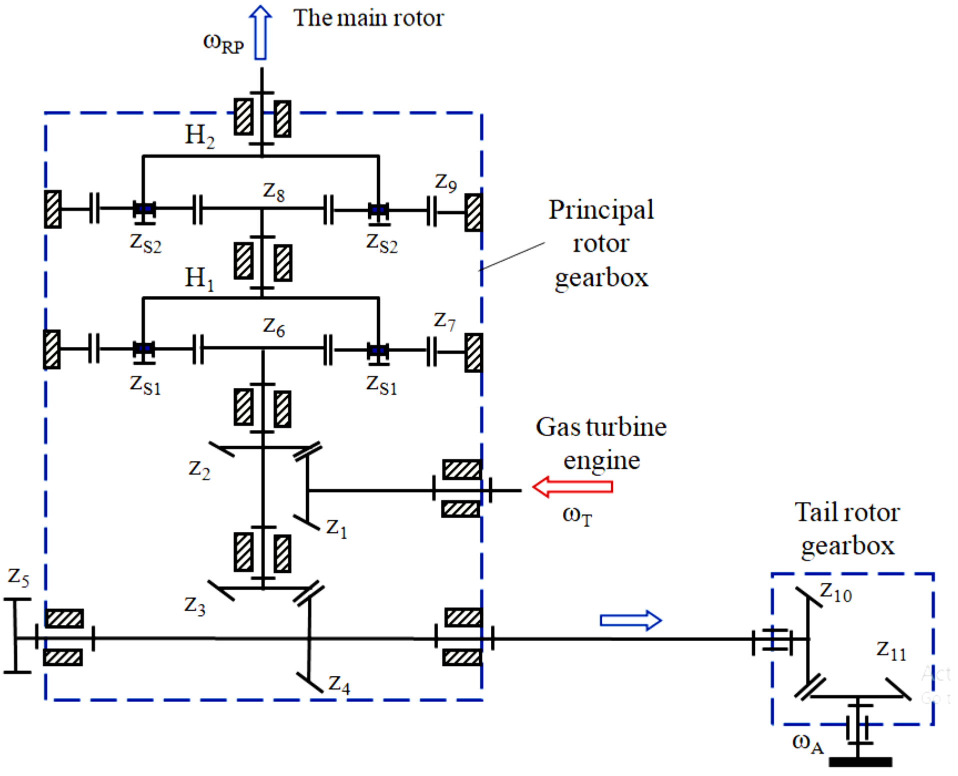

FIG. 2 Gear-train diagram of the power transmission of the helicopter [2]

The driven bevel gear is mounted on the vertical shaft of entry into the planetary transmission. At the top of the vertical input shaft is mounted the satellite carrier arm of the first stage of the planetary mechanical transmission. The two power stages of the planetary mechanical transmission are constructively identical and are connected in series.

Each power stage of the planetary mechanical transmission consists of two centrally gear wheels, the first movable, having external toothing of gears, and the second fixed to the gear casing, having internal gearing.

From a constructive point of view, as many satellites as possible were placed, equidistantly, in order to dynamically balance the mechanical transmission. In this case, the problems from the geometric point of view were also observed: the condition of proximity of the satellites, the condition of mounting, respectively the condition of coaxiality of the central wheels.

3. DETERMINATION OF THE KINEMATIC PARAMETERS OF THE POWER TRANSMISSION

For the kinematic analysis of the main mechanical transmission of the helicopter, based on the gear-train diagram (FIG.1), for the planetary mechanisms is applied the method of motion inversion, known in the professional literature as "Willis principle" [1]: subtract the speed of each kinematic element component, the angular velocity of the satellite carrier arm, thus transformed into a mechanism equivalent to gears with fixed axles.

The transmission ratio of gear partially achieved by the bevel gear is given by the relation [1]:

$$i_{1-2} = \frac{\omega_T}{\omega_2} = \frac{\omega_1}{\omega_2} = \frac{z_2}{z_1} \tag{1}$$

Considering that the driven bevel wheel *2* is mounted on the same vertical shaft as the central wheel *6*, it results that the angular velocities of the two constructive elements are equal: $\omega_2 = \omega_6$.

For the first power stage of the double-planetary gearbox, from a kinematic point of view, the relationship between the angular velocity of the central wheel *6* and the satellite carrier arm H_1 can be written:

$$\frac{\omega_6 - \omega_{H_1}}{\omega_7 - \omega_{H_1}} = -\frac{z_7}{z_6} \tag{2}$$

Since the central internal toothing of gears *7* is fixed, respectively the angular velocity $\omega_7 = 0$, the relation (2) becomes:

$$\omega_{H_1} = \frac{z_6}{z_6 + z_7}\omega_6 \tag{3}$$

The connection between the two stages of the double-planetary gearbox is made by means of the satellite carrier arm H_1 and the central internal toothing of gears *8*, resulting in $\omega_{H1} = \omega_8$.

For the second power stage of the double-planetary gearbox, the relationship between the angular velocity of the central wheel *8* and the satellite carrier arm H_2, has the form:

$$\frac{\omega_8 - \omega_{H_2}}{\omega_9 - \omega_{H_2}} = -\frac{z_9}{z_8} \tag{4}$$

where the angular velocity $\omega_8 = 0$, resulting in:

$$\frac{\omega_8}{\omega_{H_2}} = 1 + \frac{z_9}{z_8} \tag{5}$$

or:

$$\omega_{H_2} = \frac{z_8}{z_8 + z_9}\omega_8 \tag{5'}$$

Substitute the relation (3) in the calculation relation (5 '), obtaining:

$$\omega_{H_2} = \frac{z_6 z_8}{(z_6 + z_7)(z_8 + z_9)}\omega_6 \tag{6}$$

For the constructive variant of the main power transmission of the helicopter, the total transmission ratio is given by the relation:

$$i_{T-RP} = \frac{\omega_1}{\omega_2} \cdot \frac{\omega_6}{\omega_{H_2}} \tag{7}$$

or:

$$i_{T-RP} = \frac{z_2}{z_1} \cdot \frac{(z_6 + z_7)(z_8 + z_9)}{z_6 z_8} \tag{8}$$

The transmission ratio for the mechanical system of secondary force to the anti-torque rotor is determined by applying the calculation relation:

$$i_{T-RA} = \frac{z_2}{z_1} \cdot \frac{z_4}{z_3} \cdot \frac{z_{11}}{z_{10}} \tag{9}$$

Depending on the characteristic and performance parameters of the IAR316B and IAR330 [4, 5 and 8] helicopters, the speeds and moments of torsion that occur during operation have been determined, (Fig.3) for the main areas of the main power transmission of these helicopters:

- zone A - at the entrance to the main power transmission of the helicopter;
- zone B - at the entrance to the first stage of the double-planetary reducer;
- zone C - at the entrance to the second stage of the double-planetary reducer;
- zone D - at the exit of the main power transmission of the helicopter.

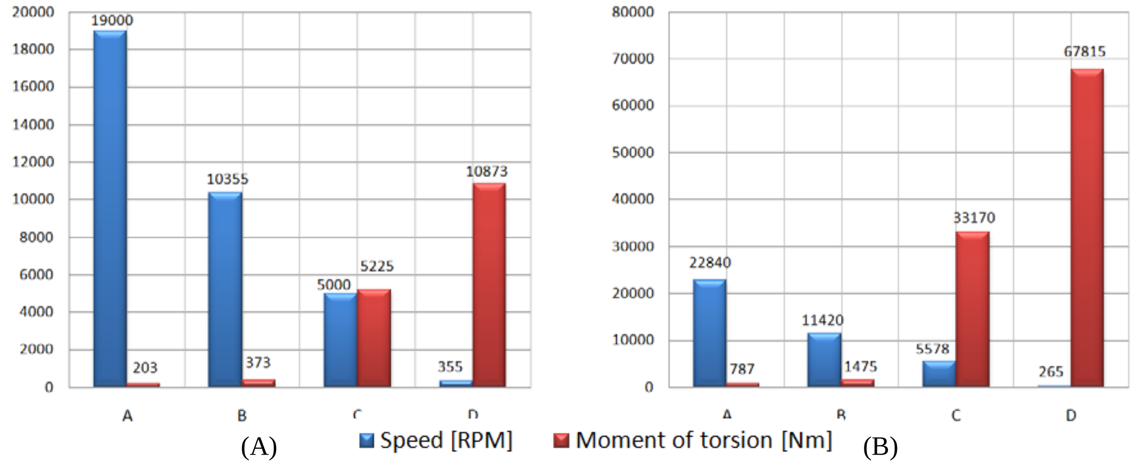

FIG. 3 Speeds and moments of torsion distributions in the four areas at the main power transmission of the IAR316B (A) and IAR330 (B) helicopters

4. CONCLUSIONS

By constructively adopting an optimal number of teeth of the gears with fixed and movable axes, a very high total transmission ratio is obtained at the main force transmission, respectively a necessary transmission ratio at the anti-torque rotor, to counteract the torque achieved during operation main rotor.

Future work on planetary transmission performance will be solved with the help of software tools.

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