PLANETARY AND DIFFERENTIAL MECHANISMS USED IN CONSTRUCTION OF THE COMMAND AND DRIVING SYSTEMS OF THE AIRSHIPS

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Keywords: airships, mechanical transmission, differential, planetary, gear reducer

Abstract. *The paper presents some general aspects regarding the use of the planetary and differential mechanisms in the construction of reducers used in the kinematic transmissions and unit transmissions. We continue by presenting a number of constructive solutions of planetary reducers used in the kinematic transmissions and unit transmissions. The functional role, kinematic schemas, some constructive parameters and a number of constructive characteristics of the transmissions are presented.*

1. INTRODUCTION

For the modern airships, a main category of subassemblies is represented by the mechanical transmissions destined to drive the different units or their command systems. In this category, the gear transmissions represent a distinct group, as weight and, especially, as design and manufacturing problems. By comparison with the reducers of the turbopropeller engines and with the main reducers of the helicopters, where there are prevalent the problems regarding the transmitted power and the efficiency of the transmission, for the reducers used in the command and driving systems of the units, there are very important the aspects regarding the kinematic precision. There are still important the aspects regarding the overall size and mass transmission, its cost and reliability, adjustment possibilities. Just these demands have lead to use the planetary and differential mechanisms inside of these transmissions.

Generally, the reducers from the command and driving systems of the units have complex kinematic schemes, where we find fixed axles gears, and serial or parallel elementary planetary mechanisms. Further on, we shall introduce a few constructive solutions of such kind of reducers, together with their certain functional characteristics.

2. CONSTRUCTIVE SOLUTIONS OF THE PLANETARY REDUCERS FROM THE AIRSHIPS TRANSMISSIONS

A first example of combined planetary reducer, made by fixed axles gears and elementary planetary mechanisms of serial type is presented in Fig. 1, where is introduced the kinematic scheme of the transmission for driving of a slotted antenna of an airship. The transmission is driven by an electric motor and has a reduction ratio $i_{17} = 8000/24 \approx 334$, distributed as follows: 7.64 in each planetary step; $i_{45} = 1$ in the conical gear; $i_{67} = 5.72$ in the cylindrical gear with geared segment.

Planetary mechanisms are used, also, inside the command systems of the airships. Such example is the command mechanism of flaps for the airplane Iak-42. The construction of this mechanism contains: 1 central reducer; 4 devious reducers (two on each plane); 8 screw mechanisms (four on each plane), cardan shafts, the transmission shafts and the intermediate bearings. Pulling out and retraction of flaps is made by using the screw mechanisms. When taking off, the flaps are deflected at an angle of 20° during

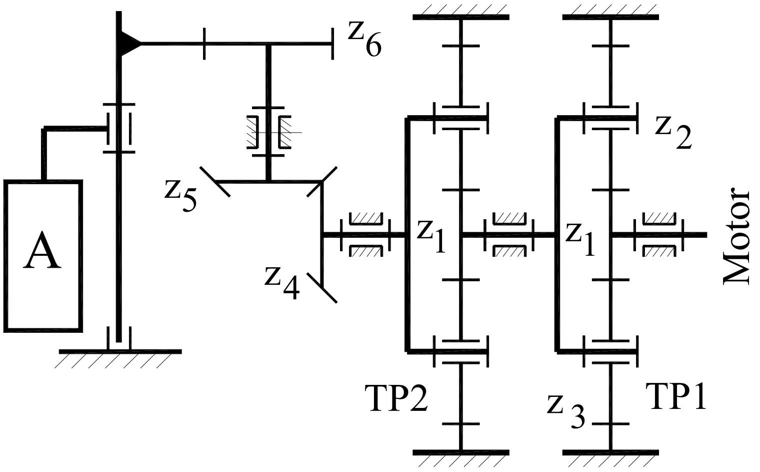

Fig. 1 The kinematic scheme of the transmission for driving of a slotted antenna

23s, at least and when landing at an angle of 45° during at least 50s. The command mechanism of flaps is driven by two hydraulic motors, supplying from the main hydraulic system and the breakdown system, connected to the central reducer. The transmission's shafts and the screw mechanisms are driven to motion thru the central reducer and the devious reducers. In Fig. 2 is presented the kinematic scheme of the central reducer, having a straight toothed cylindrical gear and a planetary step.

The command systems of flaps is equipped with a tuning system, that stops flaps movement when the difference between the deflection angles of the left and right flaps exceeds 2°. On the screw mechanism nr. 4 on each plane is installed the reducer of the tuning mechanism, whose kinematic scheme is presented in Fig. 3. First step of the reducer is set up by a planetary-differential mechanism (same type with that analyzed in [7], see Fig. 4), that achieves a reduction ratio $i = 203.6$. The output shaft of this mechanism provides rotation of the transducer's shaft with selsin DS-10 of the flaps tuning system with an angle $\alpha_1 = 208^\circ$. The second step of the reducer is set up by a straight toothed cylindrical gear, the output shaft from this step providing rotation of the transducer's shaft with selsin DS-10 of the position indicator of flaps with angle $\alpha_2 = 80^\circ$.

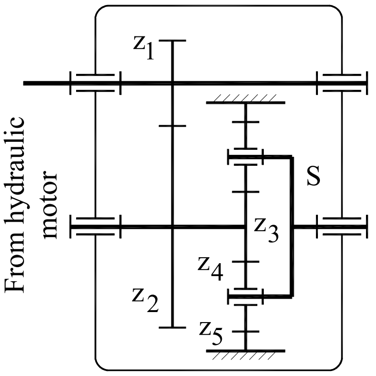

Fig. 2. Main reducer of the flaps command mechanism of the airplane Iak-42

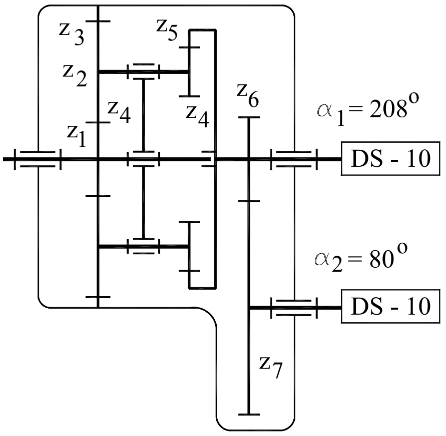

Fig. 3. Reducer of the tuning system of the flaps position on the aireplane Iak-42

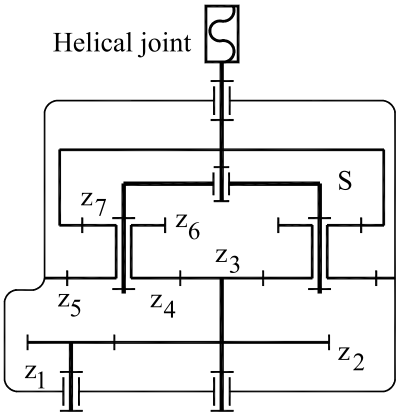

Fig. 4. Reducer of the command mechanism of the installation angle of the stabilizer on the airplane Iak-40

A planetary mechanism is found, also, in the construction of the command mechanism of the installation angle of the stabilizer at the airplane Iak-40. During flying, the stabilizer can modify its installation angle between $-3^\circ \ldots -6^\circ$. This allows to provide the centering of the plane during flying and to extend the centerings take off interval. The command mechanism of the installation angle of the stabilizer has electrohydraulic command and includes a reducer and a helical couple (Fig. 4).

The reducer is driven in motion by a hydraulic motor. The command of the installation angle of the stabilizer is achieved from the cabin crew by using a switch and a valve with 3 positions. When coupling the command the shaft of the hydraulic motor is rotating and thru the reducer – the leading screw of the helical couple. The helical couple is with autoblocking and set up the stabilizer in the ordered position. The extreme positions of the stabilizer are limited by displacement switches.

În Fig. 5 is presented the trimmer transmission mechanism of an airship, where is used a planetary mechanism. First, we shall analyze the functional principle of the trimmer mechanism and then how it is built. During flying with high speed on the command aerodynamic surfaces, appear high dynamic pressures, which demand high efforts on the command elements. For the manual and automatic command of the deflection angle of the elevator is used, in this case, a trimmer mechanism that reduces the load that has to be provided by the pilot upon the control column. The main scheme of this mechanism is presented in Fig. 5a and it contains the control column 1, spring for creating the load 2, connecting road 3, transmission of the trimmer mechanism 4, hydraulic transmission 5 and the elevator 6.

The presence in this system of the hydraulic transmission provides reducing effort upon the control column at the elevator's command. Virtually, the command thru the driving hydraulic system is reduced to the displacement by the pilot of the slide-valve of the amplifier of the hydraulic driving. Because of the small effort necessary for this displacement, at high flight speeds, the reverse connection by force between the command column and elevator becomes insufficient for providing of a reliable control of the deflection angle of the elevator.

Therefore, to provide the command's uniformity and the necessary effort upon the command column that ascertains the control of the deflection angle of the elevator, it is introduced an artificial reverse connection thru the spring used to create the load 2. Then, when move the command column, simultaneously with the displacement of the slide-valve of the amplifier of the hydraulic driving, it extends or compresses se spring 2. Thru this, the effort upon the command column is proportional to the deflection angle of the elevator, because, in this case, it raises adequately the effort of counteraction from the spring 2, also, against the command column. In order to reduce this effort until acceptable values, it is used the trimmer mechanism. The transmission of the trimmer mechanism 4 transforms the effort from the spring 2 against the command column, in the sense of its decrease. In this case, the transmission of the trimmer mechanism transforms the rotation motion of the shaft of an electric motor into a translation motion of the rod 3, reducing in this way an important part of the effort in the spring 2 and, in this way, also, against the command column 1.

To create the axial force F_a on the rod 3 is used a transmission achieved by two kinematic chains (see Fig. 5b): from the motor-generating set M1 to the port – satellite arm screw 7, that moves the nut 8 tight to the rod and from the motor-generating set M2 to the same port-satellite arm screw.

The rotation motion from the motor M1 (power 3W, speed 10,000 rot/min) is transmitted thru the reducing kinematic chain of the speed z_1-z_7 to the solar gear $z_{7'}$ of the planetary reducer. The planetary reducer, made by the central gears $z_{7'}$ and z_9 and the satellite gears z_8, transmitts the motion to the port-satellite arm screw 7, that together with the nut 8, make a screw mechanism that provides the displacement of the rod 3.

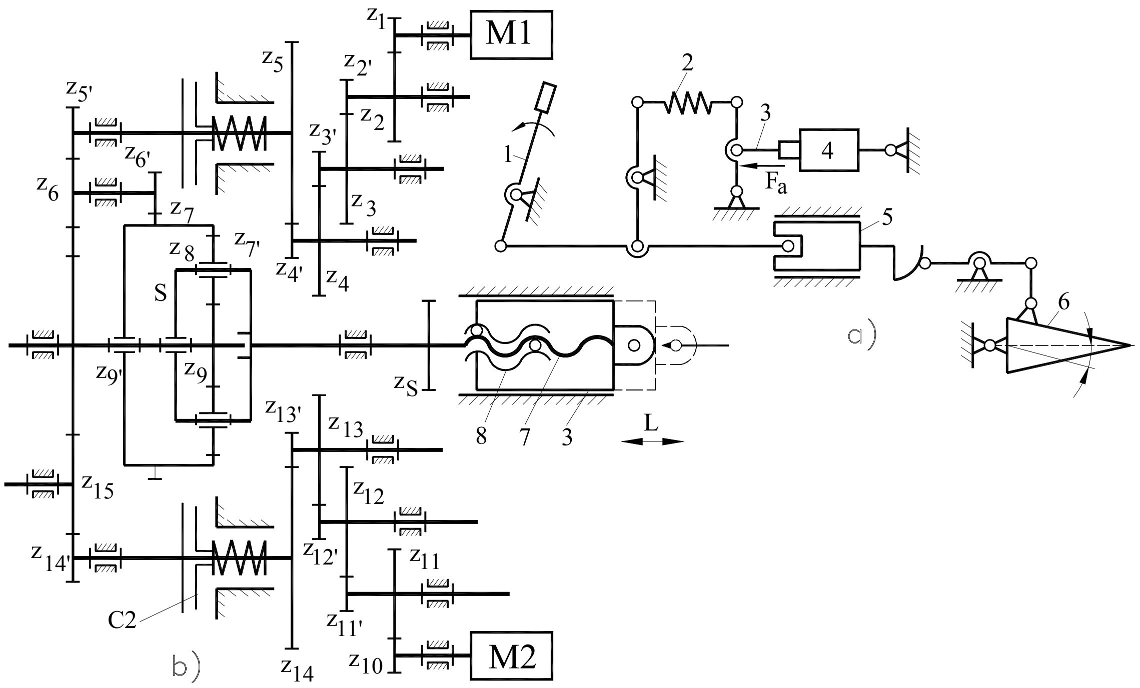

Fig. 5. The kinematic scheme of the command system which uses a trimmer mechanism (a) and the kinematic scheme of the transmission of the trimmer mechanism (b)

Similarly, the motion from motor M2 (power 3W, speed 10,000 rot/min) is transmitted thru the reducing kinematic chain of the speed z_{10}-$z_{9'}$ to the solar gear z_9 of the planetary reducer. Further on, thru the satellite gear z_8 the motion arrives at the port-satellite arm screw 7. Therefore, when working both motors, we obtain a differential mechanism, with the support of the planetary transmission being provided the composition of both motions from the motors M1 and M2.

The reducing ratios achieved on the two kinematic chaines are:

$$i_{1S} = (z_2/z_1)\cdot(z_3/z_{2'})\cdot(z_4/z_{3'})\cdot(z_5/z_{4'})\cdot(z_6/z_{5'})\cdot(z_7/z_{6'})\cdot(1+z_9/z_{7'}) \tag{1}$$

respectively

$$i_{10-S} = (z_{11}/z_{10})\cdot(z_{12}/z_{11'})\cdot(z_{13}/z_{12'})\cdot(z_{14}/z_{13'})\cdot(z_{15}/z_{14'})\cdot(z_9/z_{15})\cdot(1+z_{7'}/z_9) \tag{2}$$

The reducing ratios achieved are very big (aprox. 1,000) and there is a difference between them of about 1%. If only the motor M1is running, the gear z_9 is fixed and then, the speed of the port-satellite arm $n_{S'}$ is

$$n_{S'} = n_{7'}/(1+z_9/z_{7'}) = (n_1/i_{1-7'})/(1+z_9/z_{7'}) \tag{3}$$

When running both motors, the speed of the port-satellite arm $n_{S''}$, as differential transmission, is $n_{S''} = n_{7'} - n_9/i_{97'}^{S} < n_S$. The decoupling signal of the displacement of the rod 3 is given with the support of gear z_S, solidary with the screw 7, which, thru the kinematic chain that starts from it, provides interruption of the supplying of the electric motors and of the electromagnetic clutches C1 and C2. When one stop supplying the electric motors and the electromagnetic clutches, the pressure acting on discs by using some springs, creates a friction force between these ones, fixing the rod in the respective position.

The gears from the two kinematic chains have the module 0,5 mm. To increase the efficiency and to prevent the autoblocking phenomenon, the helical couple is achieved thru a balls-screw, the balls diameter being of 3 mm and the screw pitch of 4 mm.

A very interesting application of the planetary mechanisms we fiind in the construction of so-called planetary vehicles (PV), destined to move on the surface of other celestial bodies. The most known examples are the lunar robots *Lunohod*-1 and 2, used by Russia to study the Moon surface and LRV (*Lunar Rover Vehicle*), used by the American astronauts in missions *Appollo* for moving on the Moon surface. The PV construction presents certain specific features, erased from the necessity of a very high passing capacity when moving on accidented fields and because they are transported on the celestial bodies by using spaceships. These specific features impose a full series of demands regarding the PV elements, such as: minimum mass and overall size; to support big loads (vibrations, shocks, linear accelerations) when transporting; they have to keep their working capacity after a long stay in the outer space or on the celestial body surface; very high reliability, because when working there cannot be made maintenance operations or repairing (exceptionally it can be allowed to do some insignificant harming operations when there are astronauts aboard).

At PV one of the essential sub-assemblies is representing by the wheels transmission. It has the role to transform the electric power delivered by the board sources into motion mechanical energy of the PV, by providing the necessary wheels speed for a movement with a certain linear speed. For PV the most convenient constructive solution was gathering of the electromechanical transmission and of the wheel in one single sub-assembly, called motor – wheel, solution that ascertains a very compact transmission. Use of the motor-wheel has, as disadvantage, ununiformity of the load distribution between wheels that leads to an incomplete load of some wheels when moving on accidented field and to a decrease of the vehicle efficiency.

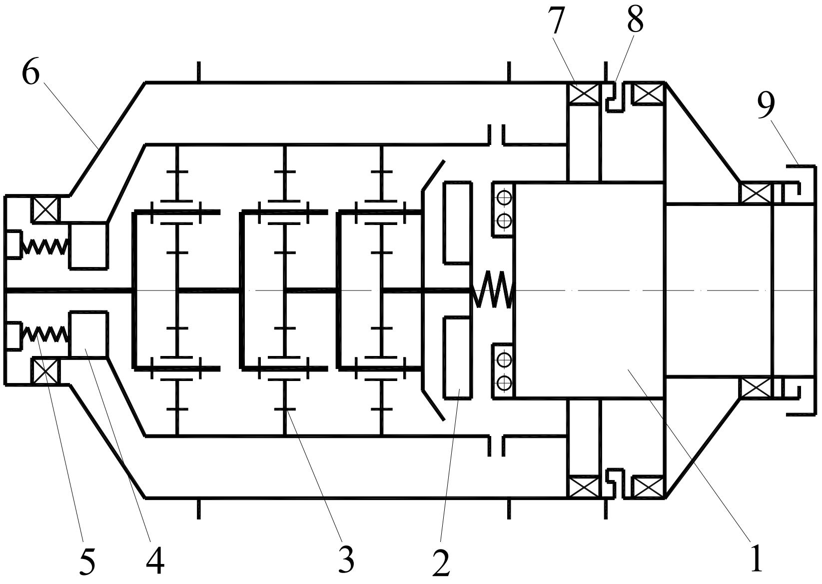

Fig. 6. Schema cinematică a transmisiei roţii-motor la vehiculul selenar „Lunohod”

The motor-wheel of the PV has a specific construction, distinguishing it from the similar models of the heavy terrestrial transportation machines, as regards the configuration and the materials used too. At VP the transmission of the motor-wheel is disposed, usually, inside the wheel. Even if the PV wheels are quite broad, the transmission’s dimensions are limited on the wheel axis direction. Practically, the transmission hasn’t to get out from the wheels’s overall, not to affect the passing capacity of the vehicle. In the LRV transmission has been used a harmonious reducer.

The motor-wheel of a PV has, as component parts, the electric motor, reducer, brake and some other elements, that work as an unitary assembly. In Fig. 6 is presented the kinematic scheme of the transmission of the motor-wheel of *Lunohod*. The transmission includes the DC electric motor 1 (with special brushes to work in vacuum), a brake with friction discs 2 and a three steps planetary reducer (reducing ratio 216, efficiency over 0,85). At the output of the reducer’s shaft is installed a mobile frontal seal gasket 5. The wheel’s hub 6 on the ball bearings 7 is installed on the reducer’s carcasse. Between the hub and carcasse is the seal thru the labyrinth 8. Each wheel is fixed on the vehicle by using a lever 9. All the eight wheels of *Lunohod* are motor-wheels and have a relieving mechanism 4. When the reducer is blocked or because of some other desertions, by command it is driving the relieving mechanism that breaks the shaft in a weak section. Thus, the wheel is no more motor-wheel but is free rotating on the axis, without making heavy the motion of the vehicle. Therefore, the vehicle keeps its capacity of displacement even when four motr-wheels are aut of order.

3. CONCLUSIONS CONCERNING USE OF THE PLANETARY REDUCERS IN THE AIRSHIPS TRANSMISSIONS

The planetary and differential mechanisms have many uses in the aviation transmissions, in those ones of force but, also, in those ones with kinematic role. These transmissions are made by planetary and differential mechanisms or by composed mechanisms, made by elementary gears and planetary mechanisms. The planetary and differential mechanisms present many constructive and functional advantages that ascertain the use inside of different types of transmissions.

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