ON THE NEW DESIGN OF HELICOPTER'S MAIN REDUCER

О НОВОМ КОНСТРУКТИВНОМ РЕШЕНИИ ГЛАВНОГО РЕДУКТОРА ВЕРТОЛЁТА

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Abstract: *A new design of Mi-8/Mi-17 helicopter's main reducer with a higher technical level and built on the basis of the kinematic scheme of the three—stage double-flow reducer AN is being considered. At the same time the requirements for the reducer to be multi-flow and to have the required kinematic parameters at all of its output shafts for driving the main and tail rotors and all the auxiliary units are being observed.*
***KEYWORDS**: MAIN REDUCER, KINEMATIC SCHEME, TECHNICAL LEVEL, NEW DESIGN*

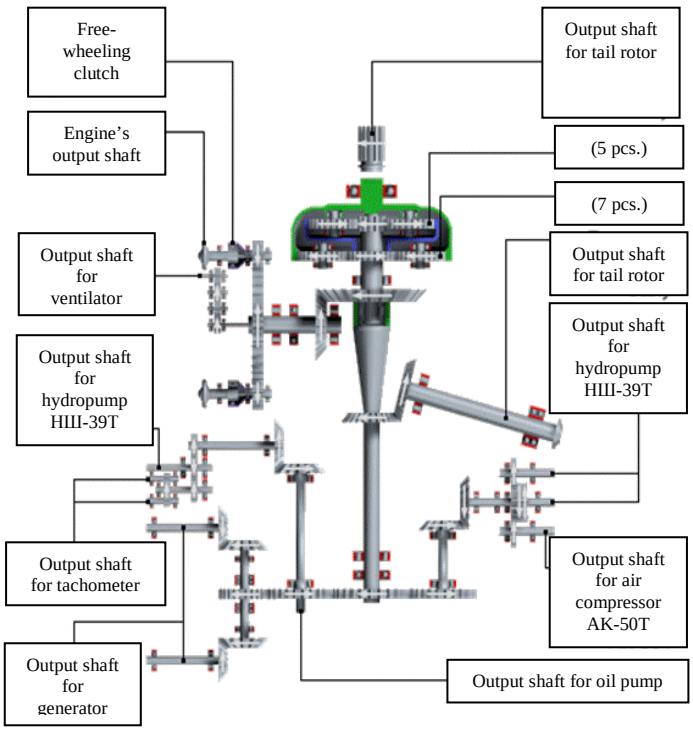
1. Introduction

Modern helicopters are mainly characterised by power and weight-dimensional parameters of their internal combustion engines and main reducer respectively. The weight of the transmission is about 10% of the total helicopter weight and the weight of the main reducer is – 75% of the total transmission weight [1]. Therefore any improvement in the kinematic scheme of the main reducer, i.e. its design, with increased efficiency and reliability level and decreased weight-dimensional parameters presents a very topical problem.

2. *Objective and research methodology*

In order to decrease the main reducer's weight they are currently being designed on the basis of multi-flow schemes, i.e. the input torque is divided into several equal parts, which are transmitted in parallel and then summed up on the main rotor's shaft. One of the main problems to be solved while designing a main reducer is to provide the most possible equal division of the torque into parallel flows [2].

Taking into consideration that the main reducer's scantlings are restricted along the main rotor's axis all the widely used earlier planetary kinematic schemes of the main reducer are lately used less and less often although being quite effective (compact set up in horizontal direction; all loads from gear wheels are applied to the internal wheel of internal engagement and by this taking the load from the reducer's body) as they can not contribute any further towards decreasing of the reducer's scantlings and subsequently its weight. The main drawback of planetary gears is the difficulty to provide an equal division of the load between satellites as the relative angular orientation of each satellite depends on a big number of randomly combined errors of the members of the planetary gear. Low-frequency vibrations from the main rotor especially at the last stage of reduction influencing inequality of load distribution between the satellites. As a result the coefficient of inequality of load distribution between the satellites at the last stage of the main reducer reaches the value of 1,35÷1,4. This leads to gearing becoming heavier at the last stage of reduction as well as the main reducer itself. Apart from the above said planetary mechanisms quite labour intensive in production and assembly because of the certain technological difficulties. Therefore it is recommended to use multi-stage kinematic schemes with simple gearing and with division of the torque between the flows at the first stages and their subsequent merging at the last stage on a gear wheel with a big number of teeth. An example of such combined three-stage multi-flow kinematic scheme (simple and planetary gearing) of the reducer BP-8(A) / BP-14 is shown on the Fig. 1. and is currently being used in almost all modifications of the helicopter series Mi-8 / Mi-17.



***Puc.1.** Kinematic scheme of reducer BP-8(A) / BP-14*

The torque is transmitted to the main rotor through three stages of reduction. The power coming from both engines merging and then being transmitted by means of free-wheeling clutches at the first stage from the driving cylindrical single-helical cogs to the driven cylindrical single-helical cog. The second stage consists of two spiral bevel cogs and is used for transmitting the horizontal axis of rotation into the vertical one. The third stage represents a differential gear with three straight cylindrical cogs (all three cogs rotating) and the other three make power return differential gear. Thus the torque at this stage is transmitted to the main rotor in two ways: through differential gear and its power return gear [3, 4].

Classification and the main technical parameters of the helicopters series Mi-8 / Mi-17 are presented in the Table 1.

Table 1. *Classification and the main technical parameters of the helicopters series Mi-8 / Mi-17*

Mi-8 Helicopter modification	**Engine type and capacity (total number of engines – 2)**	**Type of main reducer and its output shaft speed, min^{-1}**	**Main rotor's shaft speed, min^{-1}**	**Tail rotor's shaft speed, min^{-1}**
1	**3**	**4**	**5**	**6**
Ми-8П (Passenger)	ТВ2-117 (1500)	ВР-8 (12000)	192	2589
Ми-8(АТ)Т (Cargo)	ТВ2-117(АГ)А (1500)	ВР-8А (12000)	192	2589
Ми-8МТ (Military)	ТВ3-117МТ (2200)	ВР-14 (15000)	192	2594
Ми-8МТВ-1 (Passenger, cargo, for works in remote locations)	ТВ3-117ВМ (2200)	ВР-14 (15000)	192	2594
Ми-8АМТ (Passenger, cargo, for works in remote locations with an external suspension bracket for load transportation, with a removable modular gibbet. and an electrical winch)	ТВ3-117ВМ (2200)	ВР-14 (15000)	192	2594

3. *Problem solution*

A new design of helicopter's main reducer with a high technical level is being considered. At that three-stage double-flow reducer AN [5] is used as a basis for the kinematic scheme of the helicopter's driving gear, which is presented later as a four-flow mechanical system consisting of the two embedded single-stage bevel gearing with a set of cylindrical and bevel wheels. The input shaft of the three-stage double-flow cylindrical reducer AN (Abdullayev – Najafov) is connected on both sides (the first and the second flows) to the internal combustion engines located in the horizontal plane by means of bevel gearing.

Free-wheeling clutches are used for transmitting the rotation from the engines to the bevel gearing, i.e. helicopter's main reducer.

The rotation is transmitted with the required frequency (the third flow) to the intermediate and tail reducers by means of the sets of cog blocks consisting of cylindrical and bevel wheels, which are rigidly connected to the output axis.

Three-row cog blocks consisting of cylindrical and bevel wheels and non-rigidly fixed to the counter shaft are used for transmitting rotation with the required frequency in the vertical plane to helicopter's main rotor (the fourth flow). Bevel gearing embedded into the main part of the three-stage double-flow reducer AN can also be used for transmitting rotation to fans, hydro pumps, oil pumps, tachometer, generator and air compressor.

4. *Results and problem discussion*

An optimal distribution of the overall gear ratio between the stages and the approximate dimensions of the diameters of the bevel reducer's and reducer AN's input shafts as well as reducer AN's counter and output shafts and the main rotor's shaft with consideration of their torsion are presented in the Table 2.

Table 2. *Geometrical, kinematical and power parameters of helicopter Mi-8 / Mi-17 series' main reducer*

No.	**Parameter Description**	**Reducer Type**	
		BP-8(A)	**BP-14**
	1	**2**	**3**
1	Main reducer's overall gear ratio	62,5	78,125
2	Bevel reducer's gear ratio	3,97	3,9
3	First stage's gear ratio of reducer AN	1	1
4	Second stage's gear ratio of reducer AN	4,5	5
5	Third stage's gear ratio of reducer AN	3,5	4
6	Gear ratio of bevel gearing to main rotor	1	1
7	Gear ratio of bevel gearing to tail rotor	0,297	0,333
8	Gas turbine turbo shaft engine power, kW	1102,94	1617,65
9	Bevel reducer's input shaft torque, Nm	877,76	1030
10	Diameter of bevel reducer's intput shaft. Mm	44,44	46,88
11	Reducer AN's intput shaft torque, Nm	3355	3775
12	Diameter of reducer AN's input shaft. Mm	69,48	73,03
13	Reducer AN's counter shaft torque, Nm	3287,9	3699,5
14	Diameter of reducer AN's counter shaft, mm	69,02	71,79
15	Main rotor's shaft torque, Nm	50601	74222
16	Calculated minimal diameter of main rotor's shaft, mm	171,18	193,38

At that the following mandatory conditions and requirements for designing a new scheme of helicopter Mi-8 / Mi-17's main reducer BP-8 (A) и BP-14 are observed:

- provision of low vibration activity for maximum reduction of vibration, which is transmitted from the main rotor to the last stage of the main reducer;
- equal distribution of the load between the parallel members of multi-flow gears;
- elimination of load concentration along the length and height of gear teeth;
- direction of rotation of gas turbine turbo shaft engine (TSE) (anticlockwise when looking from the main reducer towards the engine), which is connected to the main reducer's input shaft by means of free-wheeling clutch (FWC);
- direction of rotation of the main rotor (clockwise when looking at the rotor from top);
- direction of rotation of the tail rotor (clockwise when looking at the rotor);
- availability of enough number of the main reducer's output shafts (flows) for transmitting rotation with the required frequency to the auxiliary units (fans, generator, air pump, tachometer, oil pump and air compressor)
- roller bearings' reliability level $\geq 0{,}98$ [6, 7].

Taking into account all the above said the algorithm of designing of a new scheme of helicopter Mi-8 / Mi-17's main reducer can be presented as:

1) Calculation of the axle base distance value of reducer AN is done based on the solution of the contact problem for cylindrical wheels of the most heavy loaded stage of the reducer;
2) Calculation of the pitch circle diameter of the cogs and wheels for each stage based on the determined value of the axle base distance for the most heavy loaded stage and distribution of the overall gear ratio between the stages of reducer AN;
3) Determination of the number of teeth and their modulus based on the calculations for cylindrical gear wheels' bending resistance with consideration of the wheel material's mechanical characteristics;
4) After a generalised parameter of the helicopter's main reducer selected all the main geometrical parameters are calculated based on the generalised coordinate and a block-scheme of automated design of the suggested mechanical system is developed.

5. *Conclusion*

A new design of the main reducer' kinematic scheme can provide the required gear ratios for all four flows according to the required technical parameters of helicopter's transmission. At this mechanical system's reliability level and efficiency increasing and weight-dimensional parameters decreasing, i.e. raising the system's technical level and this has an important practical value at design stage of new schemes of helicopter's main reducer.

The developed algorithm of designing of new schemes of helicopter Mi-8 / Mi-17's main reducer with consideration of the length of the main rotor's shaft, which is determined by its air dynamical, lay out and performance considerations while retaining its durability and rigidity characteristics has a very important theoretical value.

As an application for patent has been submitted and due to the requirement to observe the main principle of non-disclosure the kinematic scheme and a more detailed description of the suggested helicopter's main reducer will be presented during reporting at the conference.

6. *Literature*

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