

# Resource Assessment of Spiroid Gears Under Variable Loading Conditions

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**Abstract.** The brief analysis of reasons of failure of mechanisms and drives of lifting, construction, and road-building machines based on engagement drives, and worm-gear class drives, represented by contact destructions of active surfaces of cog-wheel cogs resulting in malfunctions, breakages, failures, such as wear and furrows, was carried out. The need to create a method for calculating the wear of spiroids with regard of variable loading mode and time was substantiated. The method developed allows, with regard of real modes of operation of handling machinery, equipment and machines, determine the wear intensity values and calculate the spiroid gear drive resource with regard of duration of action of driving torque values in accordance with the set variable loading schedule for lifting, construction, and road-building machines under the wear intensity of the spiroid wheel cog on values of driving torque on the spiroid gear drive output shaft, obtained from experiments.

## 1 Introduction

Due to the action of useful resistances, constant or variable in time in the process of operation, occurring on operating equipment, contact destructions of active surfaces of links, wear, furrows on cog side surfaces and fractures, which are the reason of failure of mechanisms of drives of lifting, construction, and road-building machines, form in cog engagements of power transmissions [1]. This type of destruction is typical for quenched surfaces of cog-wheel cogs and is revealed by progressive pitting of material that may reach considerable size, and on work-hardened cog surfaces by flaking larger areas of metal pad [2].

For cog wheels of both open and closed drives, and worm-gear class drives operating in the environment contaminated with abrasive particles, the typical reason of failure is wear and binding of cogs.

The typical feature of worm-gear class drives is the relative slippage at any point of contact of active surfaces of the couple links, the speed value of which increases with the transmission ratio increase.

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Mechanisms of drives of lifting, construction, and road-building machines are characterized by intermittent-duty loading modes with the change of drive torques on the gear drive output shaft during the operating cycle time. These modes are characterized by low line speed and related high loads, along with frequent startups and high contacts voltages leading to destruction of the surface of cogs of contacting links and, consequently, wear.

Spiroids belonging to worm-gear type (see figure 1 [3, 4, 5]), have been applied in various fields of technology for the last fifty years in parallel with worm-gear drives. They became widespread in drives of handling machinery, equipment and machines operating both at constant and variable loading modes.



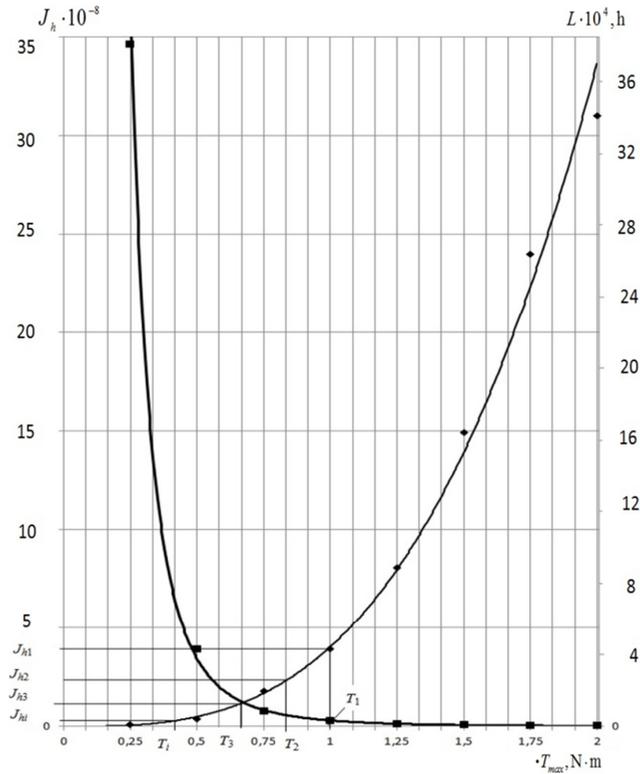
**Fig.1.** The spired gear.

Due to the fact that the considerable number of drives in mechanisms of lifting, construction, and road-building machines is operated at variable loading modes on the operating equipment during the cycle, creating a method of calculation of the spiroid resource by wear with regard of the loading variable nature becomes an actual challenge.

The complexity of building the universal method of calculating gears by wear is in determination of the values of driving torques on the gear drive output shaft during loading cycles and their duration with regard of operating conditions for lifting, construction, and road-building machines [6].

Moreover, the experimental determination of wear intensity of the cog-wheel material is of considerable labour intensity and complexity because it requires the creation of universal laboratory equipment for testing natural and model samples would provide the wide range for changing test conditions approximating the real modes of machines and mechanisms operation.

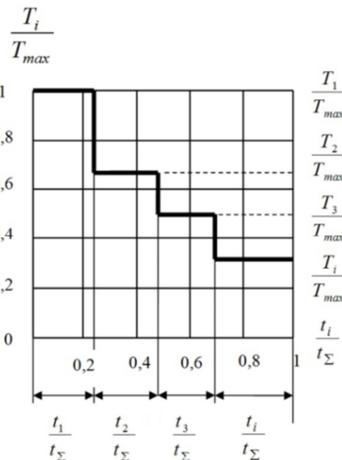
Figure 2 shows experimental dependencies of wear intensity  $J_h$  and resource  $L$  of the spiroid wheel cogs on the values of driving torque on the gear drive output shaft  $T_i$ . This dependence  $J_h=F(T_i)$  allows finding wear intensity of the spiroid wheel cog for the corresponding driving torque values  $T_i$  of the set variable loading schedule.



**Figure 2.** The procedure for determining the intensity of wear, depending on the values of torque on the output shaft of the spiroid gearbox according to the schedules of the wear and the resource intensity of the spiroid wheel on the values of torque on the output shaft of the spiroid gearbox [7].

## 2 Research methods

1. Establish the mechanism loading schedule in accordance with the number of ranked relative values of drive torques on the spiroid gear drive output shaft in order of descending and with the relative duration of their action (see figure 3).
2. Calculate main parameters of the spiroid gear drive required for the resource calculation (Table 1).



**Fig. 3.** Established schedule of variable loading mechanism [7].

**Table 1.** The main parameters of the spiroid gearbox required to calculate the resource in accordance with GOST 22850-77.

№	Name of the main geometric parameters of the gearbox	Designation (calculation formula)	Dimension
1	Center distance	$a_w$	mm
2	Nominal (maximum) torque at the output shaft	$T_2=T_{max}$	N·mm
3	Nominal rotational speed of input shaft	$n_1$	min <sup>-1</sup>
4	Nominal output speed	$n_2=n_1/u$	min <sup>-1</sup>
5	Direction rotational speed of output shaft		
6	Efficiency coefficient in continuous operation (calculated)	$\eta$	
7	Gear ratio (from worm to worm wheel)	$u_{12}$	
8	Worm material	Steel 40Ch	
8.1	Modulus of elasticity	$E_1$	MPa
8.2	Poisson's ratio	$\mu_1$	
9	Material of a spiroid wheel	Bronse Bra9Zh4	
9.1	Modulus of elasticity	$E_2$	MPa
9.2	Poisson's ratio	$\mu_2$	
10	Roughness of worm turn surfaces	$Ra$	µm
11	Parameters of the worm		
11.1	diameter factor of the worm	$q$	
11.2	screw parameter	$P_y=mz_1/2$	mm
	angle of inclination of the straight line	$\alpha=\gamma$	degree
11.3	design module of the spiroid worm coil along the generatrix	$m$	mm
11.4	calculated axial module of the spiroid worm	$m_x=m$	mm
11.5	number of sets	$z_1$	
11.6	dividing elevation angle of the worm turn line	$\gamma$	degree
11.7	kind of worm		
11.8	direction of the turn line		
11.9	dividing diameter of the worm	$d_1=qm$	mm
11.10	the diameter of the turn tops	$d_{a1}$	mm
11.11	length of the cut part	$b_1$	mm
11.12	diameter of troughs	$d_{f1}$	mm
11.13	dividing axial turn profile angle	$\alpha_{xR}$ $\alpha_{xL}$	degree degree
12	Worm wheel parameters		
12.1	internal diameter	$d_{i2}$	mm
12.2	outer diameter	$d_{e2}$	mm
12.3	number of teeth wheel	$z_2$	
13	The given radius of curvature at the calculated point of		

№	Name of the main geometric parameters of the gearbox	Designation (calculation formula)	Dimension
	contact of the wheel teeth		
13.1	For the right dividing axial angle of the turn profile	$(\rho_{red12})_R$	mm
13.2	For the left dividing axial angle of the turn profile	$(\rho_{red12})_L$	mm
14	Elastic constant of contiguous links	$\eta$	mm <sup>2</sup> /N
15	Peripheral speed at calculated points of the wheel teeth profile	$V_{FY2}$	mm/s
16	Sliding speed at calculated points of the wheel teeth profile	$V_{SY2}$	mm/s
17	Lubricating material: CAT TDTO SAE 30 API GL-3 transmission oil - an analog of TM-3-9 according to Russian State Standard GOST 17479.2 - 85		

3. Calculate the maximum wear of the spiroid sheel cogs  $[h_2]$  [8]:

$$[h_2] = [1,57 - (\text{tg}\alpha_{xR} + \text{tg}\alpha_{xL})]m_x \quad (1)$$

4. Specific calculated force in the engagement corresponding to the driving torque on the gear drive output shaft  $T_i$  [8]:

$$w_{HEi} = \frac{T_i}{T_{max}} w_{HEmax}, \quad (2)$$

where  $T_i / T_{max}$ -relative driving torque values determined from the set variable loading schedule;  $w_{HEmax}$ - specific calculated force in the engagement corresponding to the driving torque on the gear drive output shaft  $T_{max}$ .

5. Establish the value of the gear drive spiroid wheel cog per the mechanism operating cycle, corresponding to the value of the operating driving torque on the gear drive output shaft  $T_i$  and its action duration  $t_i$ , mm [8]:

$$h_i = 2,25 J_{hi} \sqrt{w_{HEi} \eta (\rho_{red1,2})_R} \frac{V_{SY2}}{V_{FY2}} n_2 i \left( \frac{t_i}{60} \right), \quad (3)$$

where  $J_{hi}$ - the value of wear intensity of the spiroid wheel material, obtained from experiments, corresponding to the operating driving torque  $T_i$  (to be determined under the graph, see figure 2);  $t_i$ - duration of the operating driving torque  $T_i$  on the spiroid gear drive output shaft per its operating cycle in accordance with the set variable loading schedule (see figure 3), sec;  $i$ -umber of engagement couples with the cog-wheel under consideration.

6. Establish the value of the mechanism operation cycles to the maximum wear of the spiroid sheel cogs  $[h_2]$  [8]:

$$N_{\Sigma} = \frac{[h_2]}{\sum_{i=1}^n h_i}, \quad (4)$$

where  $n$ - loading step number according to the set variable loading schedule.

7. Calculate the resource of the mechanism spiroid gear drive with the set variable loading schedule [8]:

$$L = \frac{N_{\Sigma} t_{\Sigma}}{3600} \quad (5)$$

### 3 Results and discussion

Dependence of the wear intensity  $J_h$  of the spiroid steel cogs (material: bronze BrA9Zh4) on the values of the driving torque on the spiroid gear drive output shaft  $T_i$  was obtained from experiments, allowing to determine the wear intensity and calculate the resource of the mechanism spiroid gear drive with the set variable loading schedule.

### 4 Conclusions

The algorithm of calculating the resource of the spiroid gear drive by spiroid wheel wear based on the experimental dependance of the wear intensity on loading torque  $J_h=F(T_i)$  is given.

Experimental dependence of the wear intensity  $J_h$  of the spiroid steel cogs (material: bronze BrA9Zh4) on the values of the driving torque on the spiroid gear drive output shaft  $T_i$  was obtained based on bench test results of disc and roller analogy method.

### References

1. Yu. Drozdov, *Gears and transmissions*, **2**, 37-43, (2002).
2. D. Reshetov, A. Gusenkov, Yu. Drozdov, *Mechanical Engineering. Encyclopedia*, 864, (1995).
3. O. Saari, *Patent 2954704 USA. Skew-axis gearing*, (1960).
4. O. Saari, *Speed-Reduction Gearing, Patent USA №269612*, (1954).
5. A. Zaitsev, *Mechanization of construction*, **10**, 42-45, (2015).
6. A Zaitsev, *IOP Conf. Ser.: Earth Environ. Sci.*, **403**, (2019).
7. V. Anferov, A. Tkachuk, A. Zaitsev, *Fundamental and applied issues of mining sciences*, **32**, 11-17, (2016).