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ESTIMATION OF THE ROTATION SPEED OF GEARS IN OIL DEPENDING ON THE LOAD

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Abstract. *This article shows the wear and the amount of load that occurs in the gears under different loads and under different operating conditions of the contact surfaces, and is given by the formulas. The values of loads and wear rates on gears are given in tabular form based on the curves. According to the results of the study, an increase in the load value affects the wear rate, as well as the load values q = 100; 200; 300; 400; at N/mm, a decrease in the wear rate is found. The load concentration and accumulation of dislocations in the material, their approach and appearance of cracks, as well as the deep propagation of small cracks on the metal that occur mainly on the friction surface under the influence of normal pressure and friction force are studied.*

Key words: *gear drive, coupling module, feed rate, contact surface, particle polishing, load, food endurance, mechanical impurities, load factor.*

Melnikov V. Z. the results of the tests also indicate a significant impact of dust entering the aggregate oil on the power supply of gearboxes of transmission units and on the service life, when being exposed to which there is an abrasive slip in the gears [1,2]. The power intensity and service life of the gears largely depend on the amount of abrasive particles in the oil. When the dust content in the oil is up to 2%, an intense violation of the surface tension occurs, resulting in a violation of the tooth profile and, as a result, an increase in dynamic loads, which leads to the gear replacement in the first case. If the amount of dust in the soil exceeds 2%, then tooth surface friction occurs only at abrasive slide, as the higher the number of abrasive particles in the oil, the more of the tooth surface friction from abrasion do not have time to develop in the upper parts of the tooth due to abrasion of the damaged surface polished under the action of abrasive particles in the oil, resulting on the surfaces of gear teeth slows down the appearance of microparts.
In most cases, they fail prematurely as a result of contact with aggregate oils of abrasive particles of a soil nature, absorption of machine transmission units along the thickness of the gear teeth. In this case, the speed of eating of the gear teeth will depend on the number, size and shape of abrasive particles in the oil, as well as on the mechanical properties of the gear material. The presence of abrasive particles in aggregate oils leads not only to abrasive eating, but also accompanies the development of wilting and rotting processes from sticking to the friction surface of the gear teeth, as a result of which they prematurely fail, since during abrasive eating of the teeth, parralinal disorders also occur in them [3,4,5].
According to the analysis of the technical condition of machines, 10-15% of the mechanism failure in them is due to gears. The DIN 3990 standard was developed as a result of the intensive research in the field of resistance to damage and wear of gears. This standard sets out the test procedure and durability limits for methods of thermal and mechanical treatment of gears made of various types of materials. The complex research in this area continues, but many questions in this area still remain unanswered. To assess the load capacity, the surface layer filling is investigated. In such conditions, the process of failure of gears can slow down or accelerate [6]. The depth of the tooth surface thinning is calculated using the developed mathematical model.
Traumatic processes in the teeth occur in different ways for different materials. The operation of gears under different load conditions leads to a sharp change in the nutrition intensity of their teeth. Meanwhile, at shifting or compressing, you can eliminate cracks in the initial period and slow down the process of eating [7,8,9]. Each of the injuries caused by intensive nutrition can be

irritated or supported by others. Increasing the specific strength of gear materials is carried out by changing the composition and quantity of the working medium of the friction surfaces, optimizing the mechanical properties of materials in the field of friction and the correct selection of reinforcement technology.

The set speed of feeding the wheel teeth can be achieved only if the established standards of the gear operating conditions are met. This issue is considered depending on the viscous modulus, the distributed load, the amount of abrasive particles in the oil, their size, and the gear ratio. The results of the research show that abrasive particles in aggregate oil enter the body as a result of air exchange of the aggregate crankcase with the external environment [10,11,12]. The amount of abrasive particles that accumulate in the aggregate oil depends on the tightness of the unit, the number of loads during operation since the oil was replaced by gears. The tensile strength of threaded joints operating in an abrasive environment depends on the number and size of abrasive particles, geometric and kinematic parameters of the fastener. The stiffness and leakage of the gear material to the speed of the edible wheel teeth border effect will also exist. It is also important to determine the hardness of the gear material for cases when the oil contains and does not contain an abrasive particle that provides a set speed for feeding the leading (leading) gears of the teeth of closed gears. When the hood is working, the profile of the wheel teeth changes, and interaction conditions are created. When changing the transmission unit oil, some contaminants are retained. For example, after an oil change, 37-67% of mechanical impurities remain in the crankcase of an automobile engine, which corresponds to the level of oil contamination with abrasive particles at 6000-7000 km. The choice of materials for threaded gears operating in an abrasive environment requires not only a responsible approach, but also a scientific approach to their work. The tensile strength of gears operating in this environment depends on the number and size of abrasive particles, geometric and kinematic parameters of the coupling. The stiffness and leakage of the gear material to the speed of the edible wheel teeth border effect will also exist.

On the example of a correct gear wheel, we will see the definition of the gear profile based on a methodological approach [13,14]. The size of the linear cross-section of the gear profile is determined by the formula Uo, which allows you to determine the cross-section in one cycle of the gear section, that is, in one rotation of the gear:

$$U_o = k \cdot p \cdot l\ , \tag{1}$$

Here k - is a constant coefficient, the value of which mainly affects the properties of the material, as well as its sliding conditions; l - is the friction path passing through the contact points of the teeth in one rotation of the gear wheel; p - is the pressure in the contact zone. The relative sliding speed of the tooth profile points to the points of the friction path profile is determined by multiplying the time spent on the loop during the cycle, (2):

$$l = v_c \cdot t_i\ , \tag{2}$$

The pressure in the contact zone, in turn, is determined by the formula (3):

$$p = Z_e \cdot Z_y \cdot Z_n \sqrt{\frac{K_n \cdot q \cdot (u+1)}{d_1 \cdot u}}, \tag{3}$$

Here Z_e – coefficient that takes into account the gear material;

Z_y – coefficient that takes into account the total length of the contact line;

Z_n – coefficient that takes into account the shape of adjacent surfaces;

K_n – load factor;

According to Hertz's law, without taking into account the coefficients Z_e and Z_y , the formula will look like this:

$$p = Z_E\sqrt{\frac{K_n \cdot q \cdot (u+1)}{d_1 \cdot u}} \tag{4}$$

Expressing the friction path as a function of the turning radius, we get the number of teeth eaten:

$$U = k \cdot p \cdot (1 - \frac{\rho_p}{\rho}) \cdot \frac{u+1}{u} \cdot N \tag{5}$$

Here, k - is the coupling coefficient for the gear wheel; $\rho_p -$ radius of curvature of the pole; $\rho -$ radius of curvature at a point; N- number of loading cycles; $u -$ number of transmissions. The formula shows that N - the number of load cycles occurs until it reaches the maximum consumption. If the elongation occurs n times per minute, then its resource will consist of the absorption intensity determined by the formula:

$$T = \frac{N}{n} \tag{6}$$

(4) and (5) determine the number of N - load cycles using the formula:

$$N = \frac{U}{k \cdot Z_E \sqrt{\frac{K_n \cdot q \cdot (u+1)}{d_1 \cdot u}} \cdot (1 - \frac{\rho_\Pi}{\rho}) \cdot \frac{u+1}{u}} \tag{7}$$

Feeding the tooth surface in an abrasive environment with open sprains that are not sufficiently lubricated is more common, but in some cases, even with closed sprains, some oil contamination may occur over time.

Nutrition, which occurs until the teeth adapt to each other, basically continues until the irregularities on the surface of the teeth end. When this process ends, the food also stops. Another type of feeding on the surface of the teeth is a meal that occurs during a stop or while walking, which leads to an increase in load. Such food consumption is dangerous for carriers of heavy loads, since if the load value exceeds a certain limit, then eating leads to tooth breakage [15,16,17]. This circumstance leads to an increase in the gap formed between unconnected teeth as a result of bonding, which leads to additional dynamic forces and noise. In addition, it reduces the strength of the eaten tooth [18,19]. In order to prevent ingestion of food, work is being done to increase the rigidity and cleanliness of the tooth surface, as well as technological extraction, which helps to preserve abrasive particles from falling out.

The importance of the relationship between the resource of the threaded connection and the number of contact surfaces is due to the fact that then we equate the power transfer coefficient with the dynamic coefficient, which is the dependence of the coefficient on the above-mentioned dental slits as follows:

$$K_n = K_C = \frac{b \cdot c \cdot \sqrt{\frac{1}{i}}}{2 \cdot \pi \cdot q} , \tag{8}$$

In this case, b - is the width of the contact field (obtained by the Hertz count); i - is the number of contact fields; s - is the tooth stiffness; q - is the distributed load. $\gamma = f(i)$ - creating a program for calculating the cost of the function. According to the graph of the function, we can determine the optimal value of the number of contact areas where the degree of wear is minimal. Theoretical studies are conducted for gears with the following parameters: z – number of teeth, m- knitting module, d_1- the separating diameter gear wheels. Here, z=10, m=8 мм, d_1=8,175 mm.

Due to high accuracy, we perform a number of computational tasks for various distributed loads. This is done in the following graph using the calculation results. This graph gives us reason to assume that the power rate depends on the distributed load.
In the graph shown in the figure, we check the value of the absorption rate for certain values of the number of contact surfaces located on the abscissa axis. We also consider the values of the speed of eating with distributed load values q= 100; 200;300;400 N/mm.
$k = 3{,}1 \cdot 10^{-13}$ – coupling coefficient for a gear wheel (stal 45 GOST 1080-88);
$\rho_p = 16{,}168\ mm$ – radius of curvature of the pole, $\rho = 21{,}7$ мм – radius of curvature of the point, number of gears, tooth stiffness, E =2.15.10^5 MPa – modulus of elasticity of the wheel material, b = 60 mm – wheel width, $[U]$ = 0,4m= 3,2 mm n=1000 min^{-1} – the frequency of rotation of the wheel. When calculating the distributed load values look like this: q = 100;200;300;400 N/mm.

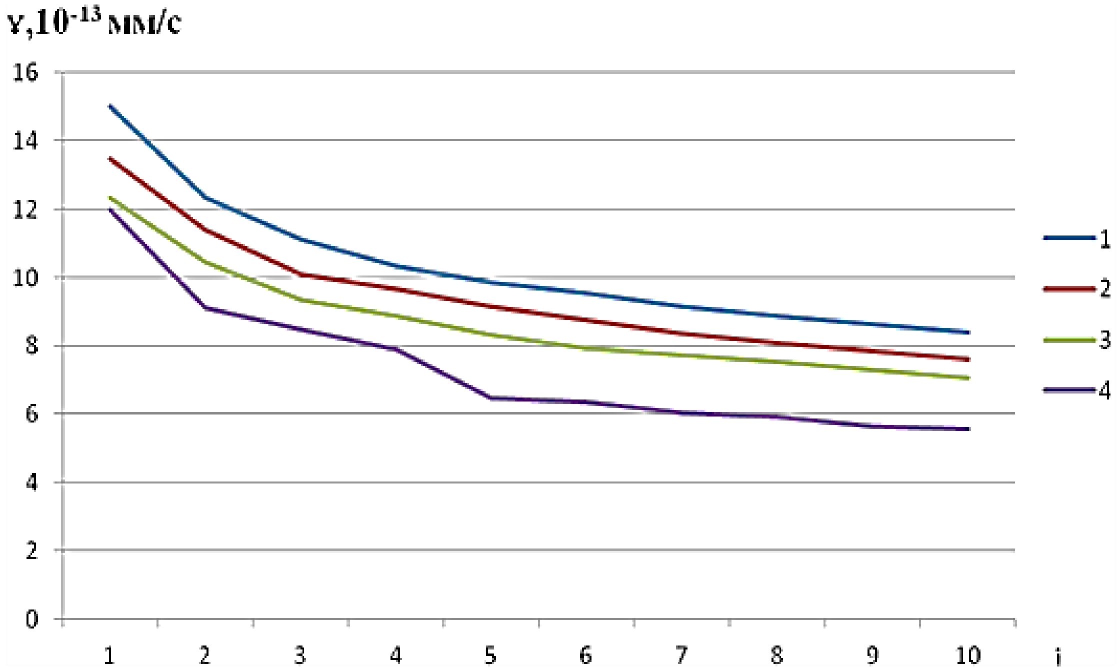

Figure 1. The speed of eating the wheel teeth depends on the number of contact surfaces: 1 - q=100 N/mm; 2 - q= 200 N/mm; 3 - q=300 N/mm; 4 - q=400 N/mm;

This graph shows that as the number of contact surfaces increases, regardless of the size of the distributed load, the speed decreases, which, in turn, has a positive effect on the performance of gears. Using the graph, we determine the values of the absorption rate corresponding to the loads caused by a certain value of the contact surfaces, and present it as a table.

For the following tables 1,2,3,4 load values q = 100;200;300;400; N/ MM, certain values of the food intake rate are given (based on the graph shown in figure 1).

Table 1

№	Number of contact surfaces	Loading, N/m	Knitting module, mm	Speed of food intake, mm/s
1	2	100	8	12
2	2	200	8	11.5

3	2	300	8	10.2
4	2	400	8	9.4

Table 2

№	Number of contact surfaces	Loading, N/m	Knitting module, mm	Speed of food intake, mm/s
1	4	100	8	10.5
2	4	200	8	9.5
3	4	300	8	9
4	4	400	8	8.4

Table 3

№	Number of contact surfaces	Loading, N/m	Knitting module, mm	Speed of food intake, mm/s
1	6	100	8	9.8
2	6	200	8	9.0
3	6	300	8	8.5
4	6	400	8	6.2

Table 4

№	Number of contact surfaces	Loading, N/m	Knitting module, mm	Speed of food intake, mm/s
1	8	100	8	8.7
2	8	200	8	8.1
3	8	300	8	7.3
4	8	400	8	5.8

When operating vehicles in dusty and dirty conditions, dust-collecting transmission units, it penetrates the crankcase, passing through unplanned parts. As a result, the oil is contaminated, of course under the influence of abrasive particles. This speeds up the process of eating gears and bearings. Hence, it is concluded that when the temperature in the crankcase increases to a certain ^{0}S and when the air exits the crankcase freely, the amount of dust in the crankcase increases to a certain gram.

Table 5

Reasons for rejection of parts of the main transmission units of motor graders during major repairs, in % of the total number of rejected parts

Defects	Parts to be rejected			
	Gears	Shafts	Bearings	Couplings
Wear	48,2	7,7	42,7	13,3
Plastic deformation	8,7	44,0	12,3	56,7
Burr	12,5	-	15,9	-
Fatigue failure	20,1	5,5	25,3	10,0

Twisting	0,9	16,5	-	-
Breakage	5,8	23,0	12,6	20,0
Other types of destruction	3,8	3,3	1,2	-

Due to heavy loads and elastic deformation of the car frame, the tightness is broken, and this allows the saw to penetrate the transmission.This means that the vibration of the units during the movement of the machine can lead to the penetration of abrasive particles into the crankcase [20]. Depending on the terrain of the road surface, the pressure in the crankcase of the unit constantly changes, and the oil level also decreases with friction, as a result of which the air containing dust is absorbed into the oil, which leads to oil contamination with abrasive particles. As you can see from the values on the tables, increasing the load value affects the speed of food intake.The concentration of the load and the accumulation of dislocations in the material cause them to rise and crack. Under the influence of normal pressure and friction force, microerics that occur mainly on the friction surface spread deeply to the metal. The spread of cracks on the gear wheel is facilitated by the deterioration of the quality of the lubricant. The cross-section of cracks in the wheel material during diffusion leads to the destruction of the metal volume, resulting in the formation of traffic jams on the friction surface. If there are abrasive particles in the oil, the leg and gear head are polished. Exceeding the load limit can also lead to breakage or damage to the teeth.Determining the speed of food intake through exercise also allows you to evaluate its performance. Increased adhesion, the coefficient of friction in microcontacts, leads to an increase in a certain temperature and plastic deformations. This leads to the destruction of the oil film and direct adaptation of the surfaces. The presence of abrasives in the oil, acceleration of fatigue and wheel teeth significantly affect the normal operation of the friction surfaces. The ends of the gears in the transmission units and gearbox are crushed under the load.

Conclusion. Various factors have their influence on the change in the rate of food intake, so to more accurately Express the value of the rate of food intake, it is necessary to conduct experiments in a number of conditions. When the load values q = 100;200;300;400; N/mm, we see that the power rate value decreases. In this case , we considered the case when the number of contact surfaces was i=2, i =4, i =6, when the value of the viscous modulus was unchanged m =8mm. In accordance with this, the contact surfaces i=2 and the load q=100 N/mm the value of the absorption rate of v=12 mm/s, when i =2 and a load of q=200 N/mm the value of absorption rate v=11.5 mm/s, for i =2, and C load=300 N/mm the value of absorption rate v=10.2 mm/s, when i =2 and a load of C=400 N/mm the value of absorption rate v=it will be equal to 9.5 mm/s. Tables 2,3 and 4 also show the values of the absorption rate determined using the graph in figure 1, when the number of contact surfaces i =4 and i =6 without changing the value of the viscous modulus. This means that changing the load value leads to a change in the speed of food intake. Thus, we can observe a positive or negative impact of the load on the power supply process that occurs in them, depending on the operating conditions of the gears.

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