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APPLICATION OF RESOURCE-SAVING TECHNOLOGIES TO INCREASE THE GEAR TRANSMISSION SERVICE LIFE

Abstract

The paper considers the gear transmission of a two-stage gear reducer, calculates its geometric parameters and develops a gearbox drawing. The results of calculations in the program APM WinMachine showed that the effective contact stresses on the pinion and wheel are equal to the permissible ones, which is the reason for the small transmission resource of 384 hours due to the lack of a safety margin. To increase the durability of the gear transmission, suggested replacing of the material of the gear and wheels Steel 45 with structural alloy Steel 20CrN. Due to the replacement of the material, it is necessary to change the heat treatment "Improvement" to saturation of the surface with carbon "Cementation". The measures taken increase the resource of the gear transmission to unlimited.

Keywords: resource-saving technology, wear resistance, mechanical drive, friction pair, gear reducer.

Introduction

The present study contains a selection of resource-saving technologies to increase the service life of the gear transmission. The purpose of the presented work is to develop resource-saving technologies for increasing the service life of a friction pair of a gear transmission. The object of the study is a gear transmission. The subject of the study is resource-saving technologies for increasing the service life of friction pairs [1].

The relevance of the research topic is determined by economic and environmental factors. An important task of resource conservation is the most appropriate monetary costs and conservation of natural resources [2]. Further influence of technology in the process of work, accompanied by repair or other type of modernization to ensure the lowest consumption and pollution of the environment is envisaged [3].

The gear train is a mechanical system of meshed gears for smooth transmission of rotation (Figure 1) [4].

Figure 1 – Gear train

The selection of resource-saving technology for gear transmission is based on critical factors and the durability of the transmission [5]. The reasons limiting the gears service life can be the following: wrong material, wrong choice of heat treatment, insufficient strength of the gears, non-optimal shape of the gearing, improper installation with wrong lubricant, overloading of the gear, etc [6]. There are dangerous criteria affecting durability of almost any friction pair, such as contact stresses, corrosion, accumulations of dislocations, which increase speeds with a raise of temperature on the surfaces of frictional contact [7].

Gear transmissions are used in chain blocks for easy lifting of heavy objects, in gear pumps for pumping liquids, in gearboxes for transmitting torque to working mechanisms [8].

Theoretical basis and methodology

A preliminary calculation of the mechanical drive of a two-stage gear reducer (Figure 2) was carried out in order to determine the main parameters of the gear drive. The initial data were the torque on the actuator shaft T = 2,7 kN·m and the angular velocity of the drive shaft ω = 4,3 rad/s.

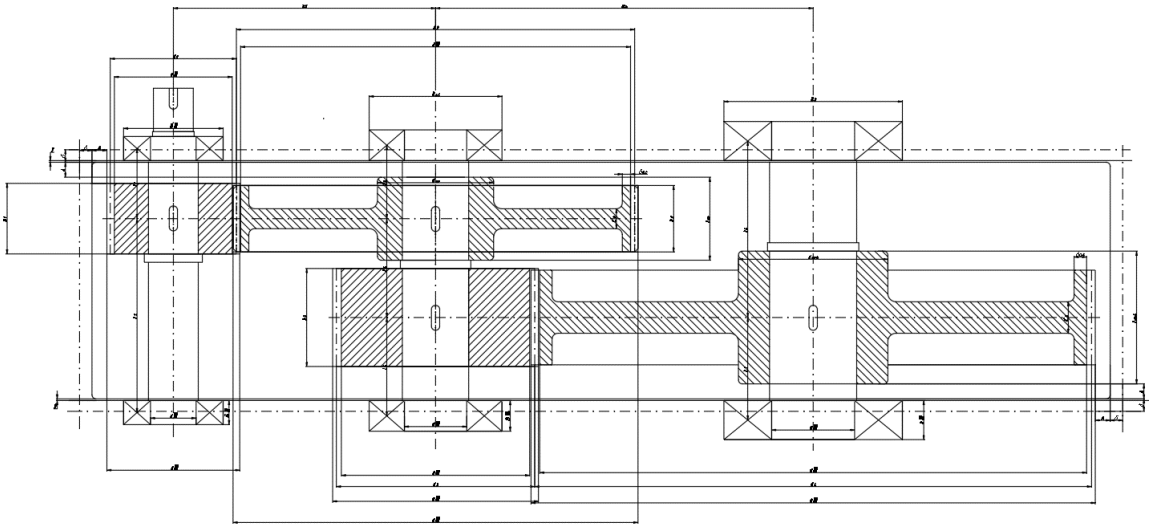

Figure 2 – Section sketch of the two-stage gear reducer

The materials of gear wheels were adopted for the pinion Steel 45, heat treatment – improvement, hardness HB 230; for the wheel Steel 45, heat treatment – improvement, hardness HB 200 [9].

The calculation is carried out in the APM WinMachine program in the Trans module and is set according to manual calculation data (Table 1) in order to identify resource limiting factors and their changes to increase the durability of the gear drive.

Table 1 – Parameter of the gears

Parameter		**Value**
Module, mm		4,5
Number of gear teeth	pinion	53
	cogwheel	149
Width	pinion , mm	119
	cogwheel , mm	114
Torque, kg·m2·s−2		2700
Rotation frequency, radians per second		258
Number of gears	pinion	3

Parameter		Value
	cogwheel	2
Material	pinion	Steel 45
	cogwheel	Steel 45
Heat treatment	pinion	Improvement
	cogwheel	Improvement
Mode		Average probable
The location of the gear on the shaft		Asymmetrical
Center distance, mm		450

The results and discussion

Preliminary results were performed to ensure the correct shape of the teeth and engagement to eliminate impacts with a change in shape due to chipping of the surface layer and subsequent wear. The calculation result showed that the optimal engagement shape indicates the correct design dimensions of the gear transmission and eliminates the occurrence of crushing (Figure 3).

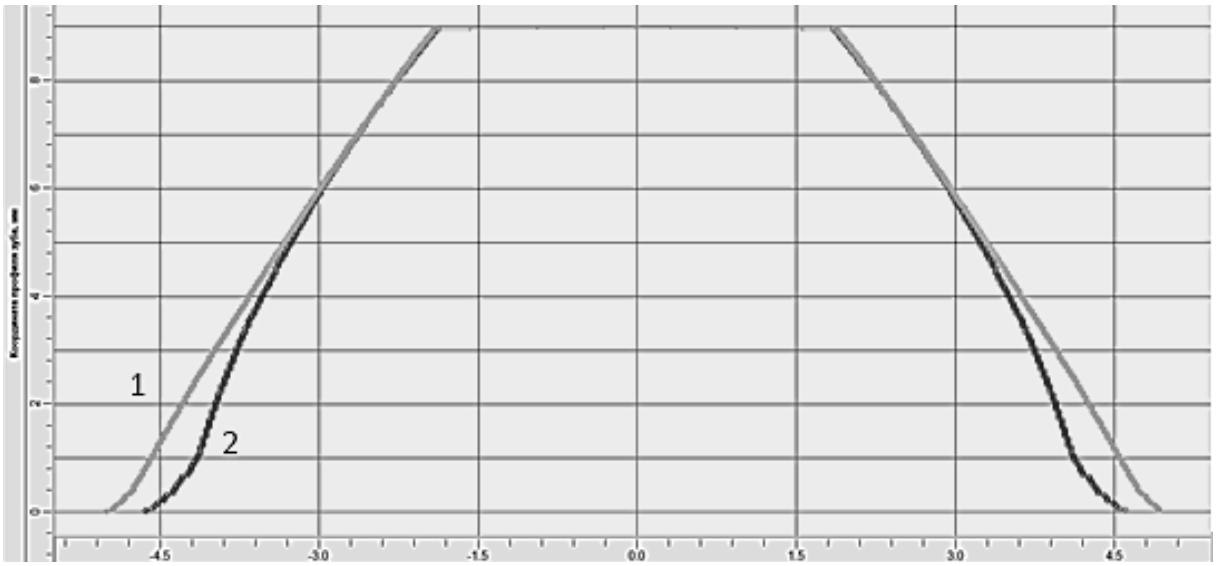

Figure 3 –Tooth profile: 1 – pinion tooth shape, 2 – gear wheel shape

Reducing the operating mode from average probable to average normal did not affect the contact stresses, but increased the service life to 533 hours. This insignificant increase in service life also indicates the critical influence of contact stresses in the gear transmission.

To increase the durability of the gear transmission, it was proposed to replace the material of the pinion and wheel Steel 45 with structural alloy Steel 20CrN. Due to the substituting of the material, it is necessary to change the heat treatment Improvement to surface saturation with carbon Cementation [10]. The measures taken increase the resource of the gear transmission to unlimited (Table 2).

Table 2 – Calculation results

Material	Heat treatment	Contact stresses, MPa		Safety margin	Service life, h
		acting	permissible		
Steel 45	Improvement	409	409	0	384
Steel 20CrN	Cementation	475	1112	2	Unlimited

The effective contact stresses after the use of resource-saving technology are two times less than the permissible contact stresses, which indicates a high contact strength and is the reason for the failure-free operation of the mechanism.

Calculations using the APM WinMachine computer program showed a significant influence of contact stresses on the durability of the gear transmission. The selection of material and heat treatment of the product ensures a greater reserve of contact stress and the longest trouble-free operation under the specified conditions. This means the need to use a technological method to save resources, i.e. the optimal selection of parameters when designing a transmission. To identify the best resource, the influence of different materials and types of heat treatment on the transmission resource was considered (Table 3).

Table 3 – Preliminary results

Material	**Heat treatment**	**Contact stresses, MPa**	
		acting	**permissible**
Steel 45	Improvement	409,6	409,6
Steel 40Cr	Hardening	476	800
Steel 14Cr1MnMoW	Nitriding	476	875
Steel 20CrN	Carburizing	476	1112

Therefore, the service life is affected by the selection of material with heat treatment. While the contact stresses tended to the permissible ones, the service life was too small for long-term trouble-free operation. Replacement of material and heat treatment provides a large margin of safety for the current contact stresses, the transmission operates without failure.

Conclusion

The results of the work done can be applied in chain pulleys for easy lifting of heavy objects, in gear pumps for pumping liquids, in gearboxes for transmitting torque to working mechanisms.

Calculations of a two-stage gear reducer were performed in order to obtain additional data for subsequent computer calculations of durability in the APM WinMachine program. Final results demonstrate the effective contact stresses on the gear and wheel are equal to the permissible ones, which was the reason for the short transmission resource of 384 hours due to the lack of a strength reserve.

Resource-saving technologies have been applied to replace the material with Steel 20CrN and heat treatment "Cementation". The use of it in the Trans module of the APM WinMachine program has helped to determine the resource limiting factor, in view of the above, it can also be concluded that the computer program for calculating and increasing of the durability is also a resource-saving technology.

Computer calculations of the gear transmission were performed in the Trans module and, based on the data obtained, methods for extending the service life of the transmission were adopted and the identified equipment failure due to dangerous contact stresses was prevented.

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