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THE EFFECT OF ROTATION SPEED OF THE DRIVER SHAFT AND RESISTING TORQUE OF THE DRIVEN SHAFT ON THE FORCE GENERATED IN A HELICAL GEAR

Abstract: *The article presents the results of a computer experiment demonstrating the effect of rotation speed of the driver shaft and resisting torque of the driven shaft on the force generated in a helical gear. It is noted that the rotation frequency of the shaft affects the vibration of the helical gear during operation, and resisting torque of the shaft affects the value of force in the helical gear. At the same time, low speeds of rotation of the driver shaft do not lead to a change in force, and high speeds of rotation of the driver shaft lead to a two-fold increase in force in the helical gear.*

Key words: *resisting torque, force, rotation speed, driver shaft, driven shaft, helical gear.*
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1. Introduction

Mechanical gears affect the accuracy of the functional options of machines and other technological equipment. Wear of the transmission elements and friction on the contact surfaces during operation lead to a decrease in the useful operation of the mechanism. Thus, an increase in the durability and rigidity of the kinematic gear elements will ensure the efficient operation of the mechanism, and hence the accuracy of technological equipment as a whole.

Gears are often used to efficiently transfer torque from one shaft to another. There are different types of gears that are used depending on certain technological conditions. Spur gear drive with external gearing is manufactured with various types of teeth (straight, helical, double helical and spiral) [1]. When comparing spur gears and helical gears, it can be noted that these mechanisms have both advantages and disadvantages. Considering the helical gears, a number of researchers performed an analysis on the effect of the action of forces and moments in the mechanism on its accuracy of functioning [2-10]. The resulting axial force in the helical gear leads to stretching and compression of the driver and driven shafts, and a large contact area in the engagement can lead to vibrations in the elements of the mechanism.

The purpose of this study is to analyze the effect of rotation speed of the driver shaft and resisting torque of the driven shaft on the nature of the force change in the shafts, which can cause vibrations in the elements of the helical gear.

2. Materials and methods

Forces on the helical gear shafts were calculated using the Comsol Multiphysics application. On shaft models with diameters of 40 mm, pinion and gear wheel models with a number of teeth of 20 and 30, respectively, were installed. All solid-state models of the helical gear had the properties of structural steel. The experiment to determine the change in shaft forces included 32 tests of a gear train with constant and variable operating parameters of the mechanism. The constant parameters of the experiment include: pitch diameters the pinion and gear wheel – 100 and 150 mm, respectively; pressure angle – 25 degrees; helix angle – 30 degrees; gear mesh stiffness – 2×10^6 N/m; bearing stiffness – 1×10^7 N/m. To perform a comparative analysis of the experimental results, the following variable parameters of the mechanism were set: for the first test – rotation speed of the driver shaft (50 rpm) and resisting torque of the driven shaft (50 N×m); for the second test – rotation speed of the driver shaft (100 rpm) and resisting torque of the driven shaft (50 N×m); for the third test – rotation speed of the driver shaft (200 rpm) and resisting torque of the driven shaft (50 N×m); for the fourth test – rotation speed of the driver shaft (350 rpm) and resisting torque of the driven shaft (50 N×m); for the fifth test – rotation speed of the driver shaft (500 rpm) and resisting torque of the driven shaft (50 N×m); for the sixth test – rotation speed of the driver shaft (700 rpm) and resisting torque of the driven shaft (50 N×m); for the seventh test – rotation speed of the driver shaft (1000 rpm) and resisting torque of the driven shaft (50 N×m); for the eighth test – rotation speed of the driver shaft (1500 rpm) and resisting torque of the driven shaft (50 N×m); for the ninth test – rotation speed of the driver shaft (50 rpm) and resisting torque of the driven shaft (100 N×m); for the tenth test – rotation speed of the driver shaft (100 rpm) and resisting torque of the driven shaft (100 N×m); for the eleventh test – rotation speed of the driver shaft (200 rpm) and resisting torque of the driven shaft (100 N×m); for the twelfth test – rotation speed of the driver shaft (350 rpm) and resisting torque of the driven shaft (100 N×m); for the thirteenth test – rotation speed of the driver shaft (500 rpm) and resisting torque of the driven shaft (100 N×m); for the fourteenth test – rotation speed of the driver shaft (700 rpm) and resisting torque of the driven shaft (100 N×m); …; for the twenty-second test – rotation speed of the driver shaft (700 rpm) and resisting torque of the driven shaft (200 N×m); …; for the twenty-eighth test – rotation speed of the driver shaft (350 rpm) and resisting torque of the driven shaft (500 N×m); for the twenty-ninth test – rotation speed of the driver shaft (500 rpm) and resisting torque of the driven shaft (500 N×m); for the thirtieth test – rotation speed of the driver shaft (700 rpm) and resisting torque of the driven shaft (500 N×m); for the thirty-first test – rotation speed of the driver shaft (1000 rpm) and resisting torque of the driven shaft (500 N×m); for the thirty-second test – rotation speed of the driver shaft (1500 rpm) and resisting torque of the driven shaft (500 N×m).

3. Results and discussion

Some of the experimental results are graphically shown in the Fig. 1. The graphs show the dependences of the change in force on the shafts on the time of their rotation when the rotation speed of the driver shaft and resisting torque of the driven shaft change. The dependence indicated by a solid line characterizes the change in force on the shafts along the *X* coordinate axis (circumferential force), the dependence indicated by a dotted line characterizes the change in force on the shafts along the *Z* coordinate axis (radial force).

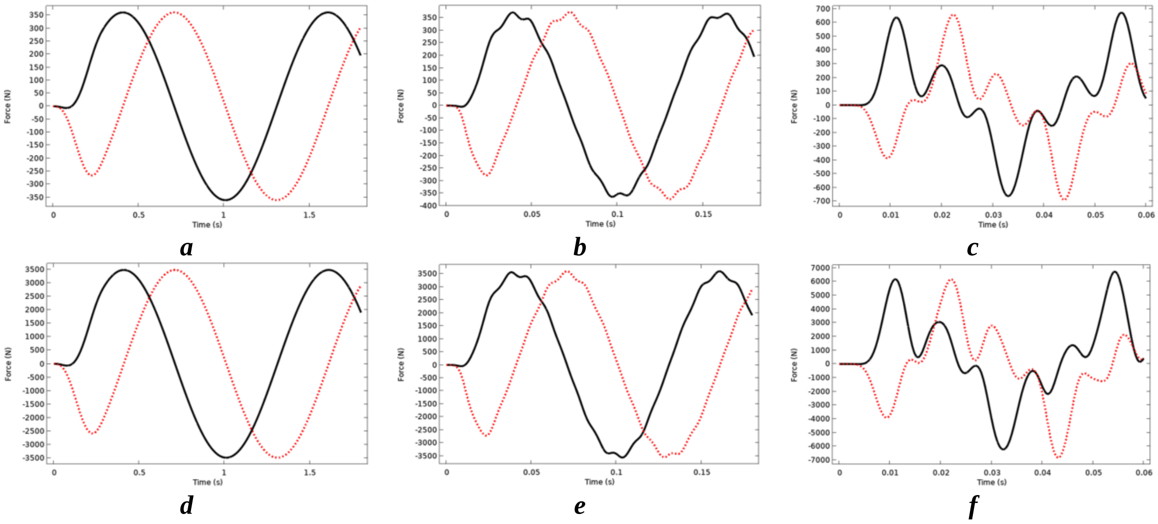

Figure 1. Dependencies of force on the shafts on the rotation time of the shafts under different operating conditions of the helical gear: *a*) rotation speed of the driver shaft is 50 rpm and resisting torque on the driven shaft is 50 N×m; *b*) rotation speed of the driver shaft is 500 rpm and resisting torque on the driven shaft is 50 N×m; *c*) rotation speed of the driver shaft is 1500 rpm and resisting torque on the driven shaft is 50 N×m; *d*) rotation speed of the driver shaft is 50 rpm and resisting torque on the driven shaft is 500 N×m; *e*) rotation speed of the driver shaft is 500 rpm and resisting torque on the driven shaft is 500 N×m; *f*) rotation speed of the driver shaft is 1500 rpm and resisting torque on the driven shaft is 500 N×m.

The graphs show that the force changes on the shafts are mirrored along the *X* and *Z* axes. Depending on the angle of rotation, the shaft is subjected to both stretching (positive values) and compression (negative values). At the same time, an increase in the resisting torque of the driven shaft at the same rotational speeds of the driver shaft only leads to an increase in the value of force, and the nature of change remains constant (for example, the Fig. 1, *a* and *b*). It is also noted that an increase in the rotation speed of the driver shaft (from 50 rpm to 700 rpm) does not lead to a change in the value of force on the shafts, but at high rotational speeds the force is doubled. At average speeds of rotation of the driver shaft, vibrations are observed at peak force values. High rotational speeds are characterized by steady vibration of the helical gear shafts.

4. Conclusion

Based on the analysis of the experimental results, the following conclusions can be drawn:

1. The force on the shafts varies according to the same functions within the specific rotational speed of the driver shaft and the increase in resisting torque of the driven shaft.

2. An increase in the resisting torque leads to an increase in the force on the shafts. However, at a high speed of rotation of the driver shaft (over 1000 rpm), there is a twofold increase in the shaft force.

3. An increase in the rotational speed of the driver shaft to 1000 rpm does not lead to an increase in the force on the shafts of the helical gear. High shaft rotation speeds cause vibrations in the gear train elements.

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