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RESULTS OF THE EXPERIMENTAL RESEARCH OF THE CONSTRUCTION OF A BEEL-GEAR MECHANISM WITH TWO-STAGE BELT ELEMENTS

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Abstract
Based on the results of the theoretical research, the purpose of the experimental research is to determine the torques, rotation frequencies and noise on the drive and intermediate shafts in the copy of the S2U-160 brand reducer. This article is dedicated to the design and experimental research results of a two-stage compound helical gear mechanism with an elastic element. Helical gear mechanisms are widely used in industries to reliably transmit rotational motion under high loads while maintaining efficiency and stability. The use of elastic elements in these mechanisms helps to improve their dynamic characteristics by reducing vibrations and dynamic loads. The study examines the impact of elastic elements on the performance of the gear system. Throughout the experiments, changes in key parameters such as the angular displacement, angular velocity, and torque of the mechanism were observed. Additionally, the stability of the system's dynamics and the reduction of vibrations were evaluated.
These types of mechanisms are widely used in cotton processing plants as well as in other industries with high-load demands. The inclusion of elastic elements enhances the lifespan and efficiency of the mechanism. The results obtained in this study demonstrate the benefits of applying elastic elements in mechanical transmissions for improving the durability and load-bearing capacity of the gear wheels. Moreover, the findings suggest new opportunities for the efficient application of elastic components in various industrial mechanical systems. The study confirms that by using elastic elements, dynamic loads can be reduced, leading to greater durability and performance of the helical gear mechanism.

Keywords. Belt element, gear wheel, external flange, stub, matrix, pulley, raw material, ring.

Introduction

Bevel gear mechanisms are widely used in industry and have the ability to work efficiently at high loads. Such mechanisms must ensure durability and stability when transmitting high loads and torques. The use of belt elements in the construction of mechanisms helps to reduce dynamic loads and vibrations, which increases the overall efficiency. In this study, the

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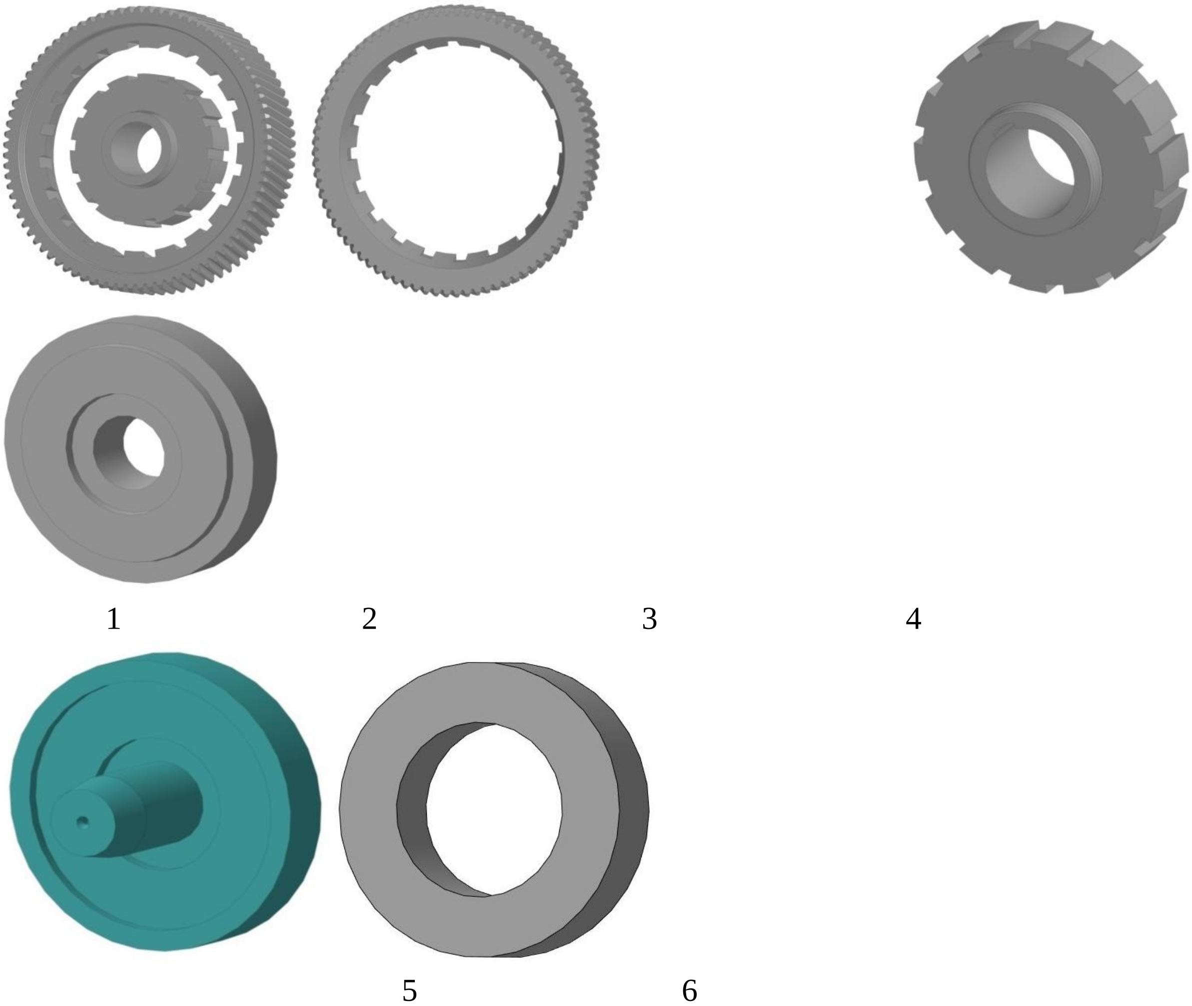
performance characteristics of the bevel gear wheel mechanism with two belt step elements were studied on the basis of experience. The results of the experiment are aimed at evaluating the influence of the strapping elements on the dynamics of the mechanism and determining their stability and long-term use of the mechanism. The purpose of the research is to find ways to reduce dynamic loads and increase the efficiency of the mechanism through the use of belt elements in gears with inclined gears.

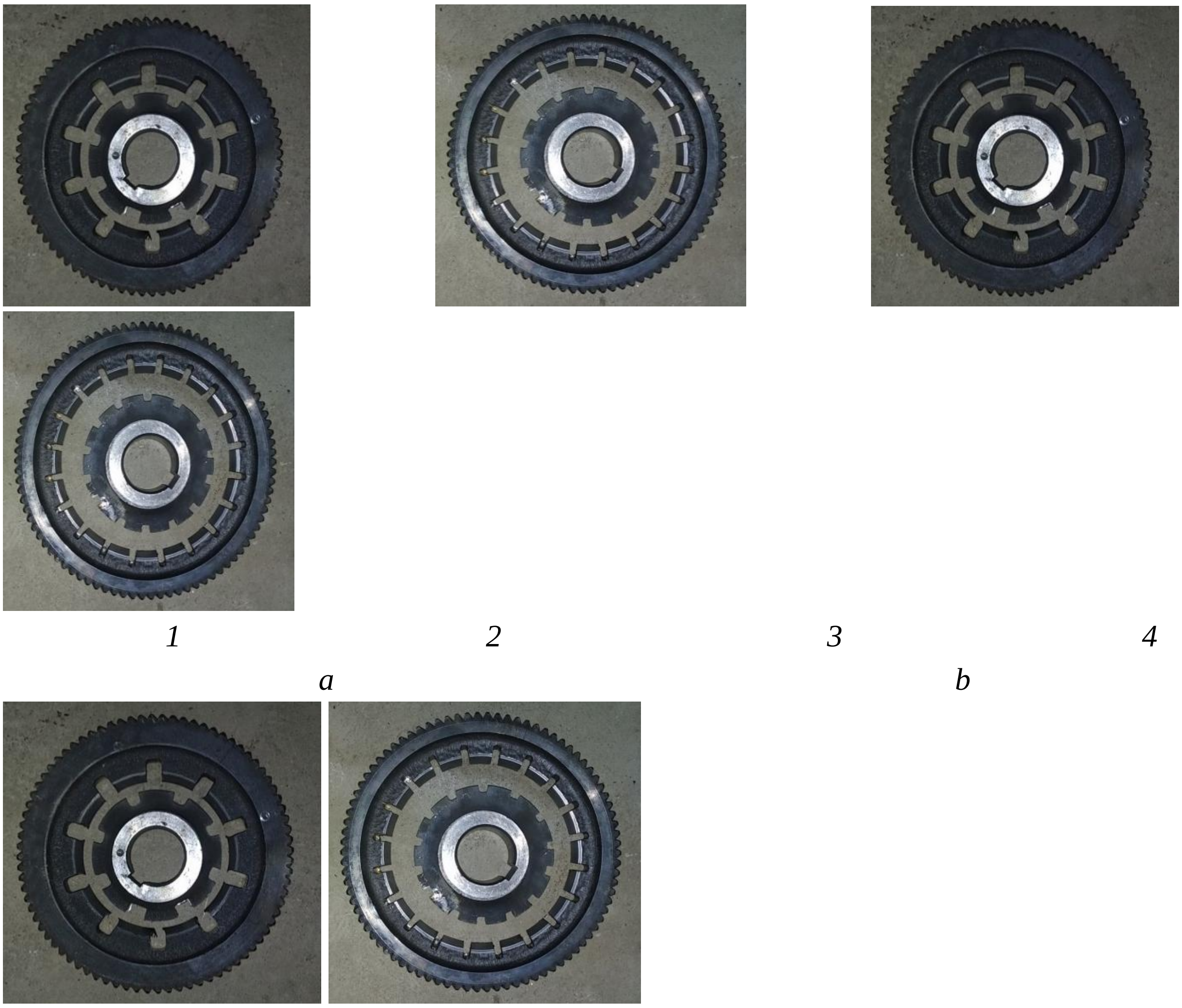


1-component gear wheel, 2-external flange, 3-stupisa, 4-matrix, 5-poison, 6 raw materials

Figure 1. A view of a bevel gear with a belt element and their components.

Research Method:

During experimental research in laboratory conditions, bevel gear wheels with 3 different tooth angles, i.e. 15˚, 17˚, 19˚, were prepared. The reason for this is that the tooth angle of the gear reducer we use is in this range.



1 *2* *3* *4*

a *b*

5 6

c

a-slope angle 15°; b-slope angle 17°; c- slope angle 19°;
1, 3, 5 intermediate shaft gear wheel; 2, 4, 6-last shaft gear wheel.

Figure 2. A view of a bevel gear wheel with a belt element and their components.

In experimental studies, the rubber brands in the bevel gear wheels with belt element are taken as 3 types (PL118-11, TU MRTU3S-5-1166-64, MRTU38-5-1166-64). As a result of the experiments, the recommended bevel gear was prepared, which is made of cemented steel 10, 15, 12XNZA, 20XNZA. The recommended bevel gear wheel with a belt element is made of heat-treated and cemented steel 15 grade material, the hardness index is equal to HRC 50. In the preparation of bevel gears with belt elements, a special Tip-top glue is applied between the stub and the outer ring through a special press, filled with PL118-11, TUMRTU3S-5-1166-64, MRTU38-5-1166-64 raw rubber and the required pressure and temperature of 120 °C are maintained for 45 minutes. This type of rubber is resistant to technical oil, ethanol and petroleum products, and can be used in the temperature range from -60 to +100 s. PL118-11, TUMRTU3S-5-1166-64, MRTU38-5-1166-64 rubber products are made of synthetic

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butadiene-nitrile rubber. The technical characteristics of the recommended rubbers are listed in Table 1.

Table 1 Indicators of rubber brands used for a bevel gear wheel with a belt element

Characteristics of PL118-11 rubber	**Unit of measure**	**Indicator**
Tensile strength	MPa	11
Relative elongation	%	160
Hardness according to SHoru A	SHor A	72…79
Working temperature	℃	-60…+100
MRTU3S-5-1166-64, MRTU38-5-1166-64 rubber characteristics	**Unit of measure**	**Indicator**
Tensile strength	MPa	8
Relative elongation	%	120
Hardness according to SHoru A	SHor A	80…90
Working temperature	℃	-30…+100

Figure 3 shows the views of prepared bevel gears.


C=450-550 Nm/rad


C=550-650 Nm/rad

C=650-700 Nm/rad

Figure 3. View of bevel gears with belt elements

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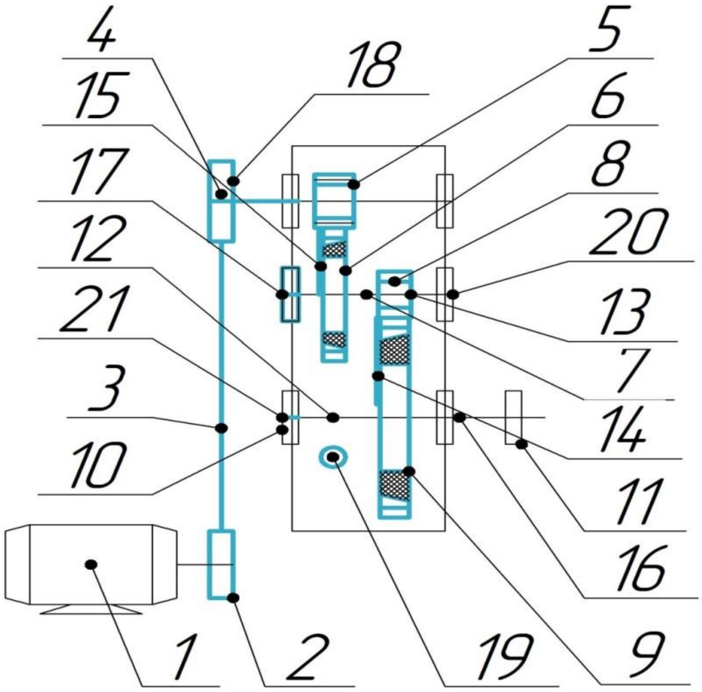
A method of experimental research in laboratory conditions

The pilot scheme of the Ts2U-160 reducer, which transfers the incoming torque from one mechanism to the next mechanism, is shown in Fig. 3.5. When the test stand starts up, the electric motor 1 transmits the movement to the leading bevel gear 5 through the driving pulley 2, the belt transmission 3, the driving pulley 4. Then the movement is transmitted to the bevel gear wheel 6 with the recommended belt element, and the movement is transmitted through the shaft 7 to the bevel gear wheel 8, and then the movement is transmitted to the next recommended belt element bevel gear wheel 9. The movement is transmitted to the brake drum 11 through the bearings 10 fixed at both ends of the shafts. To measure the required values, special sensors are installed on the shafts in the form of a half-bridge 12 13 and on the bevel gear wheels 14 15, these sensors, in turn, detect the necessary data and transmit it to the Arduino device through the torque converters 16 17 attached to the ends of the shafts, and this device processes and transmits this data to the computer. To determine the angular speed of the shafts, a special sensor 18 is installed on the drive pulley 4 and connected to the Arduino assembly. The noise generated in the gears is determined by a special noise measuring device 19. Special weight measuring 20 21 sensors are installed to determine the axial forces. Through these special sensors, torques, angular velocities and noise on the shafts can be measured with the required accuracy.

To improve the accuracy of the results, the tests are repeated 3 times in the same mode.



1. Electric motor, 2. Drive pulley, 3. Belt drive, 4. Drive pulley, 5. Bevel gear, 6. Bevel gear with belt element, 7. Shaft, 8. Bevel gear, 9. Bevel gear with belt element , bearing 10, 11-brake drum, 12-special sensor, 13-special sensor, 14-special sensor, 15-special sensor, 16-17-tokasyomniks, 18-angular speed measuring sensor, 19-sumometer, 20-21-axial force sensors.

Figure 4. Electrotensometric scheme of the Ts2U-160 reducer experimental stand.

Research results and discussion. The results of calculations show that the slowest rotating shaft rotates 1.2 times in 1 second when the number of revolutions in the electric motor is 1500

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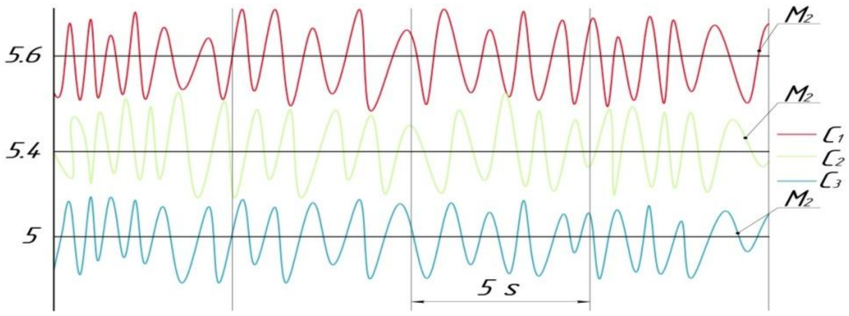
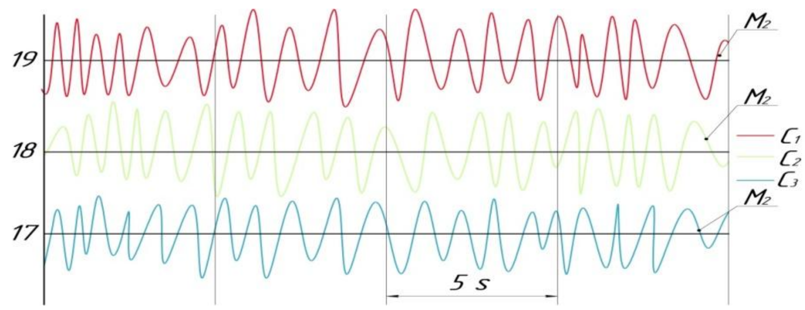
rpm, 1.1 times in 1 second when it is 1400 rpm, and 1 time when it is 1300 rpm. Therefore, it was considered sufficient to study the process at a time interval of 5 seconds. Their accuracy levels were calculated using the methods of G. V. Vedenyapin and R. Manley.

The bevel gear that we are studying is widely used in the industry, mainly in the cotton ginning screw conveyor, taking into account this, we will be able to determine the performance of our structure by the resistance coming from the screw conveyor. In laboratory conditions, the resistance torque was changed from 30 Nm to 170 Nm with the help of the handbrake, and the laws of change were obtained. The average value of the loading force is 100 Nm. As the load forces increase, the angular velocity decreases, but the range of their change values increases. In the researches, when the average value of the resistance torque applied to the leading (last) link is 100 Nm, when using existing types of gear wheels, the average value of the angular velocities for the leading shaft is $1.4*10^2 c^{-1}$ (1345 rev/min; Figure 3.9, oscillogram-a), on the intermediate shaft $0.33*10^2$ c^{-1} (322 rev/min; oscillogram-b) and due to the fact that the leading (last) shaft is connected to the load working drum shaft, the value of the average angular velocity in it is $0.069*10^2$ c-1 (70 rev/min; oscillogram-c) oscillates in the interval. The average torque values were $0.047*10^2$ Nm (oscillogram-d) for the leading shaft, $0.19*10^2$ Nm for the intermediate shaft (oscillogram-e) and $0.93*10^2$ Nm (oscillogram-f) for the final shaft. The amount of the average axial force of the shot was equal to $0.74*10^2$N (oscillogram-g) for the intermediate shaft and $1.81*10^2$N (oscillogram-h) for the final shaft.



Mr=30Nm



Mr =100Nm

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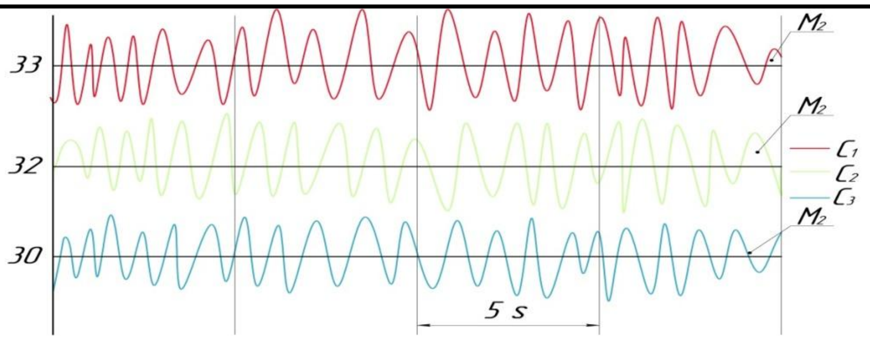

Mr=170Nm

C_1=450…550 Нм/рад; C_2=550…650 Нм/рад; C_3=650…700 Нм/рад

Figure 5. Torque oscillograms of a second helical gear wheel shaft with a component belt element

During experimental studies, in order to study the influence of rubber rotation uniformity on technological loading, we used rubber (MRTU38-51166-64 (C=450...550 Nm/rad), MRTU3S-51166-64 (C=550...650 Nm/rad), v-PL118-11 (C=650…700 Nm/rad)) we studied at different loads, changing the types.

The conducted studies show that with the increase of the load affecting the structure, the value of the speeds decreases and the value of the torque increases. In this case, the value of the angular speed of the bevel gear wheel mounted on the drive shaft and the vibration frequencies of the falling force directed along the axis (parallel to the axis) increases, while for the shafts of the bevel gear wheels with belt elements, these parameters are (1÷1.2) times lower. Connection graphs were constructed by determining the frequency values based on the observed oscillograms. Working drum resistance moment of the angular speeds of the leading bevel gear wheel shaft of the improved Ts2U-160 reducer, the intermediate shaft with the belt element of the first composition with three different types of belt elements (C=450…700 Nm/rad) and the bevel gears with the belt element of the second (driving) composition the effect on the change was studied. It can be seen from the given graphs that when the load from the working drums, where the rings with three types of belt elements are used one by one, the laws of the angular speeds of the shafts decrease compared to those without a belt element. In this case, when the load value increases from 0.3*102 Nm to 1.7*102 Nm, the angular speed of the leading bevel gear is from 1.53*102c-1 (1467 rev/min) to 1.3*102 c-1 (1242 rev/min min), the angular speed of the intermediate shaft with a bevel gear with a belt element is from 0.37*102 c-1 (362 rev/min) to 0.32*102 c-1 (306 rev/min) and the drive with a bevel gear with a belt element (last) shaft angular speed decreases from 0.077*102 c-1 (74 rev/min) to 0.064*102 c-1 (62 rev/min) in a nonlinear law. The torque values are also proportional to this law, from 0.014*102 Nm to 0.08*102 Nm for the drive shaft, and the torque on the gear shaft with helical (intermediate) gear is from 0.06*102 Nm to 0.34*102 Nm, and on the gear shaft with the second gear torque values increase from 0.29*102 Nm to 1.68*102 Nm. The amount of the axial force of the projectile increased in a non-linear law from 0.195*102 N to 1.28*102 N for the shaft with a belt element (intermediate) and from 0.47*102 N to 3.14*102 N for the shaft with a belt element (last). The torque values determined above are based on oscillograms obtained from our laboratory setup. Figure 6 below shows graphs of torque, projectile force, and angular

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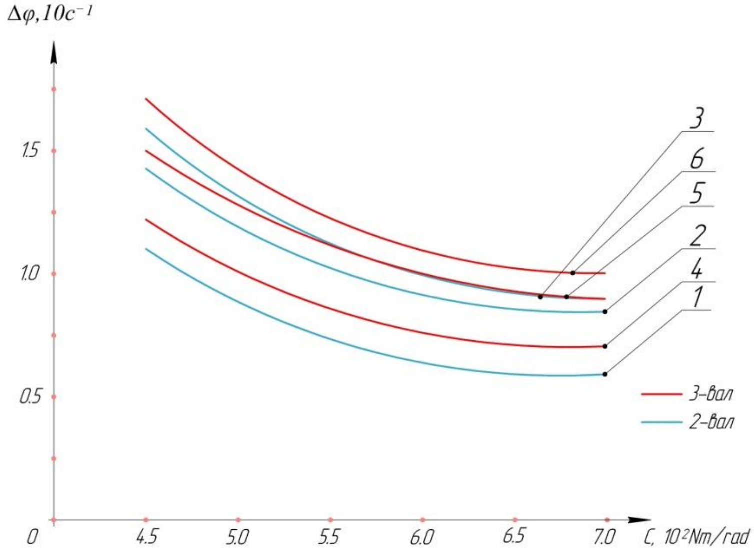
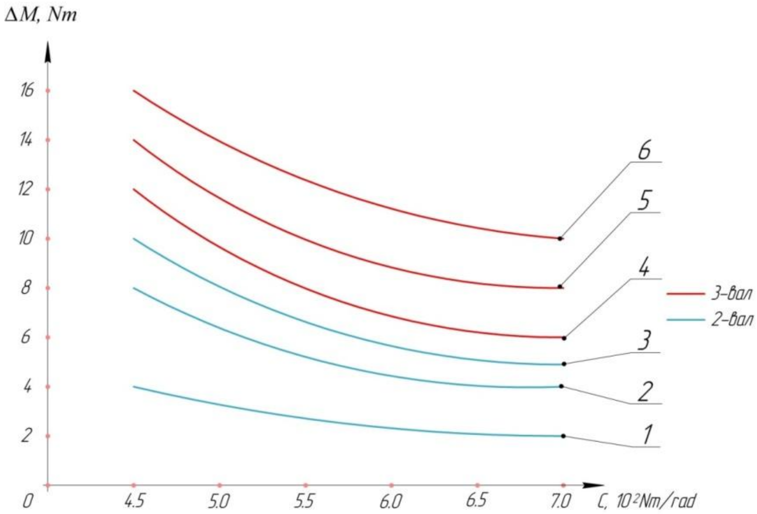
velocities on the shafts depending on technological load (from 30Nm to 170Nm) using each type of belt elements separately.



1-$\Delta\varphi_2=f(C)$, (Mr=30Nм); 2-$\Delta\varphi_2=f(C)$, (Mr=100Nм); 3-$\Delta\varphi_2=f(C)$, (Mr=170Nм);
4-$\Delta\varphi_3=f(C)$, (Mr=30Nм); 5-$\Delta\varphi_3=f(C)$, (Mr=100Nм); 6-$\Delta\varphi_3=f(C)$, (Mr=170Nм);

a)



1-$\Delta M_2=f(C)$, (Mr=30Nм); 2-$\Delta M_2=f(C)$, (Mr=100Nм); 3-$\Delta M_2=f(C)$, (Mr=170Nм);
4-$\Delta M_3=f(C)$, (Mr=30Nм); 5-$\Delta M_3=f(C)$, (Mr=100Nм); 6-$\Delta M_3=f(C)$, (Mr=170Nм);

b)

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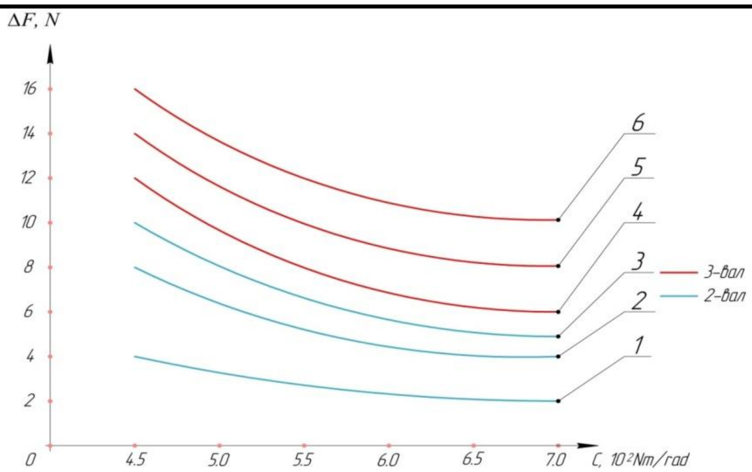

1-$\Delta\varphi_2=f(C)$, (Mr=30Nм); 2-$\Delta\varphi_2=f(C)$, (Mr=100Nм); 3-$\Delta\varphi_2=f(C)$, (Mr=170Nм);
4-$\Delta\varphi_3=f(C)$, (Mr=30Nм); 5-$\Delta\varphi_3=f(C)$, (Mr=100Nм); 6-$\Delta\varphi_3=f(C)$, (Mr=170Nм);
c)

Figure 6. Graphs of dependence of angular speed (a), torque (b) and thrust forces (c) on the shafts on technological load (from 30Nm to 170Nm).

Summary

The results of the experimental research of the bevel gear mechanism with two-stage belt elements showed that the use of belt elements is important in improving the dynamic characteristics of the mechanism. As a result of the experiment, it was found that these elements help to distribute the torque evenly and reduce vibrations. The two-stage construction increased the durability and load-carrying capacity of the mechanism. This, in turn, led to the strengthening of the long-term usability and efficiency of the mechanism. The research results further confirm the importance of effective use of belt elements in industrial mechanisms and serve as a guide for further improvement of these mechanisms.

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