Analysis Of The Regularities Of Changing The Amplitude Values Of The Torque On The Driving And Drived Shaft Of A Chain Drive With An Elastic Element

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Abstract: The article provides a structural diagram and the principle of operation of the recommended chain drive with a compound roller of the chain and a driven sprocket with elastic elements. The results of experimental studies to determine the loading of the chain drive shafts are presented. On the basis of the analysis of the laws of motion of the shafts and the constructed graphical dependencies, the substantiation and the main parameters of the developed design of the chain transmission for the driving mechanisms of technological machines are recommended.

Keywords: Chain drive, sprocket, compound, rubber bushing, angular speed, torque, swing, oscillation, stiffness, loading, drive, technological machine.

Introduction.

Chain drives are widely used in the transmission mechanisms of technological machines [1,2]. The known design of the chain drive contains a driving and driven sprocket and a flexible flail element transmitting movement from the driving sprocket to the driven one [3]. The disadvantage of this chain drive is, in the process of operation, a decrease in the angle of the chain of sprockets, a significant sagging of the driven (idle) chain branch, leading to a decrease in efficiency, and in some cases to rupture or disengagement of the chain with sprockets. In addition, when transferring significant loads at high speed modes of movement, noise occurs and due to the shock interactions of the teeth of the sprockets with the surfaces of the chain rollers, friction increases, thereby the wear of both the chain rollers and the teeth of the sprockets.The chains used in mechanical engineering are divided into three main groups according to the nature of the work they perform: drive, traction and cargo. Drive chains are the most common. They transmit the movement from the energy source to the receiving body of the machine; work both at low and high speeds (up to 30-35m/s) and at different distances between the axes (centers) of the sprockets. One chain can drive several shafts at the same time [4]. The disadvantage is that in almost all types of chain design noise occurs in gears due to the impact interactions of the teeth of the sprockets with the surfaces of the chain rollers, and friction also increases, thereby the wear of both the chain rollers and the teeth of the sprockets.

Development of a resource-saving chain drive design.

The structure of a chain drive containing a driving and driven sprocket, a tension roller and a chain enclosing them, including an outer and inner links, a roller, a bushing and a roller, and the driven sprocket is made of a composite, consisting of a base with an output shaft, an elastic annular sleeve put on it and an outer part sprockets with teeth. In this design, the transmission resource is somewhat increased, the noise is reduced [5].

The disadvantages of this design are also significant noise and wear of the chain rollers and sprocket teeth, rapid failure of the transmission chain. A new design is recommended to increase the reliability and service life of the chain drive. A chain transmission containing a driving and driven sprocket, a tension roller that encloses them, a chain that switches off the outer and inner links, a roller, a sleeve and a roller put on it, and the driven sprocket is made of a composite, consisting of a base with an output shaft, an elastic annular sleeve put on it , and the outer part of the sprocket with teeth, the roller is made up of an outer and inner bushings, between which a rubber sleeve is installed, while the outer surface of the rubber sleeve is made of a curvilinear concave shape, and the inner surface of the outer sleeve is made of a curved convex shape [6,7,8].

Figure 1 shows a diagram of the recommended chain drive. The chain drive works as follows. Rotational motion from the driving sprocket 1 is transmitted to the driven sprocket 2 through the chain 3. Further, the movement from the sprocket 2 is transmitted to the base 6 with the output shaft 7 through the elastic annular sleeve 5. In this case, the change in the angular displacements of the driven sprocket 2 arising from the gaps between the chain 3 and the teeth of the sprocket 2, as well as due to changes in friction and wear in the engagement, etc., to some extent are leveled (amortized, absorbed) by the elastic annular sleeve 5. In this case, the rotation of the base 6 with the output shaft 7 of the sprocket 2 becomes more uniform and smooth.

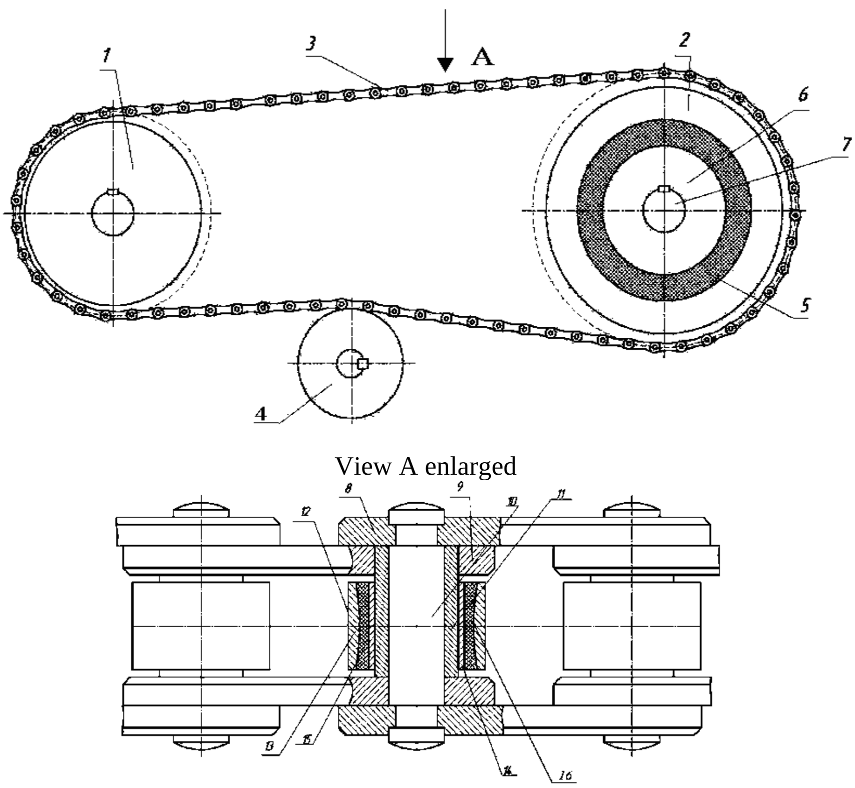


Figure 1. Chain drive

When the teeth of the sprockets 1 and 2 interact with the roller 12, due to the deformation of the rubber bushing 15, the wear of the bushing 13 and the teeth of the sprockets 1 and 2 is significantly reduced. This also reduces the friction between the bushing 11 and the roller 10. This leads to an increase in the durability and reliable operation of the chain drive. In the process of operation, due to the execution of the outer surface 16 of the rubber bushing 15, when interacting with the teeth of the sprockets 1 and 2, the necessary deformations of the bushing 15 occur, especially along its edges, a kind of centering of the pressure on the roller 12 from the side of the teeth of the sprockets 1 and 2 is ensured. This leads to an even distribution of the load along the entire length of the roller 12, which makes it possible to increase reliability, thereby increasing the resource of the transmission chain 3.

Methods of conducted experiments

The proposed composite roller chain drive was attached to the test stands for testing of prototypes. Devices for determining the torque, rotational speed and the amount of noise generated at the junction of the sprocket and the chain on the extension shaft were installed (Figures 2 and 3). Figure 2 shows the electrotenesometric scheme for determining the kinematic and dynamic parameters of the chain drive drive shaft. The torque, rotational speed and noise on the proposed drive shaft were determined in the following order: From electric motor 1 ($N = 3$kW, $n = 3000\ Rpm$), the motion is transmitted to the belt drive 2, from which the variable speed is adjusted to the variator 3, from the variator to the belt drive 4, and then to the cylindrical gearbox (Ц2H-450, $i = 20$) 5 with a two-speed transmission. The rotational motion exiting the gearbox 5 is transmitted to the chain drive 7, which must be checked. The main function of the brake device 11 located on the chain drive drive shaft 9 is to provide the amount of technological resistance. Deformation occurs on the surface of the shaft 9 as a result of the effect of the technological resistance force transmitted by the brake device 11 located on the proposed chain drive drive shaft. The resulting deformation value is transmitted to the tokosyomnik 12 through the strain gauge 10 attached to the shaft by the bridge method, from the tokosyomnik to the Arduino Nano V3.0 CH340 microcontroller 13. The Arduino Nano V3 is also equipped with a laser photoelectric sensor (3pin IK) 8 and a high-sensitivity sound microphone 6 (sensor-Erfassungs module-avr pic ky-037) to detect the amount of noise generated by the extension chain and asterisk teeth. The V3.0CH340 microcontroller transmits signals to 13. 3 types of signals received in parallel are transmitted to the computer through the microcontroller 13. The data is processed on a computer based on a program that works with the Arduino Nano V3.0CH340 microcontroller.

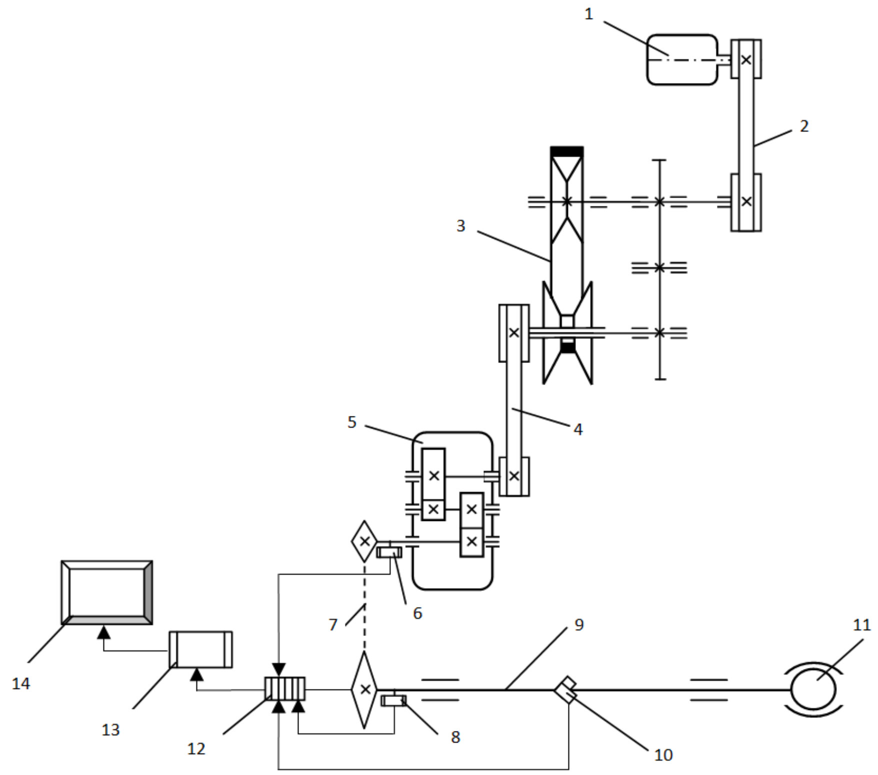


Figure 2. Electrotensometric scheme for determining the kinematic parameters of a chain drive drive shaft.

Figure 3 shows the kinematic scheme of the experimental stand in order to determine the torque on the leading and driven shafts. From the electric motor 1 (N = 3.5 kW. 950 Rpm) 1 the motion is transmitted to the belt drive 2 (B1270, $i = 3{,}14$; $d_1 = 80mm$, $d_2 = 160; 200; 240mm; z = 2$). The drive shaft 4 of the chain drive is transmitted to the drive shaft 9 via the chain drive 7. Graphs of the dependence of the amplitude values of the torque on the drive shaft on the chain speed and the moment of resistance acting on the shaft were constructed.

The studies were conducted on the values of the number of revolutions of the drive shaft which is $180Rpm; 216Rpm; 270Rpm$ and the moment of technological resistance which is $50N \cdot m; 60N \cdot m; 75N \cdot m$. As a process resistance device, a step brake device 10 was mounted on the end of the output shaft.

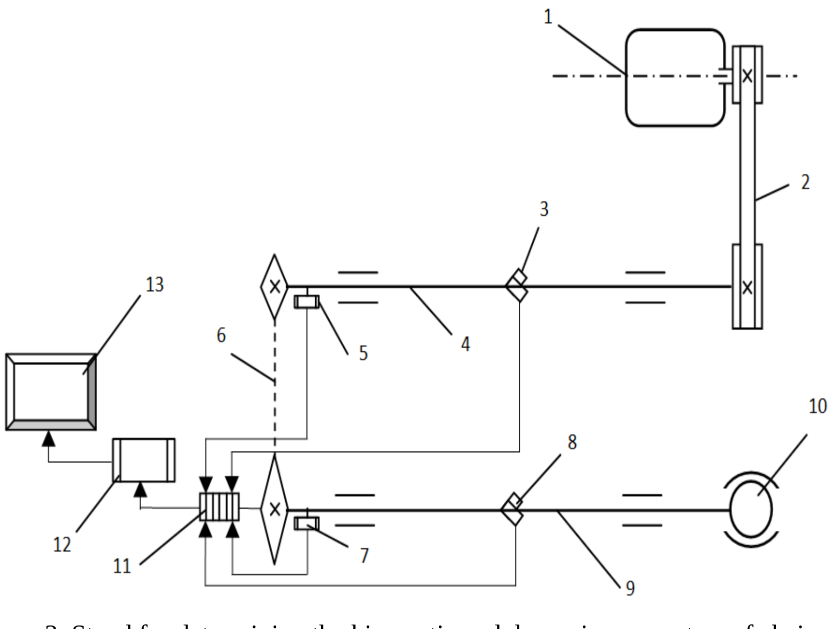
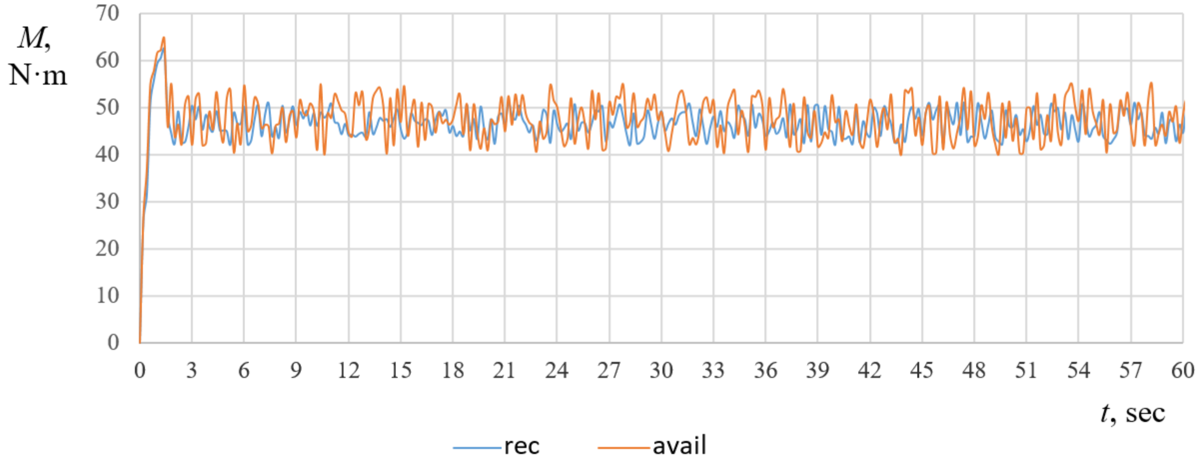


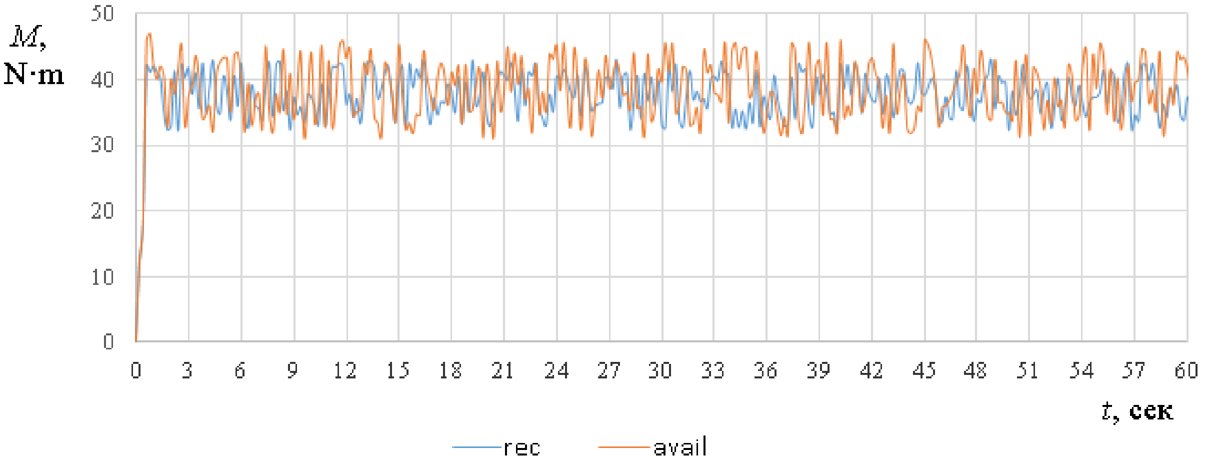
Figure 3. Stand for determining the kinematic and dynamic parameters of chain drive

Analysis of the results of experiments to determine the law of loading of the driven sprocket shaft

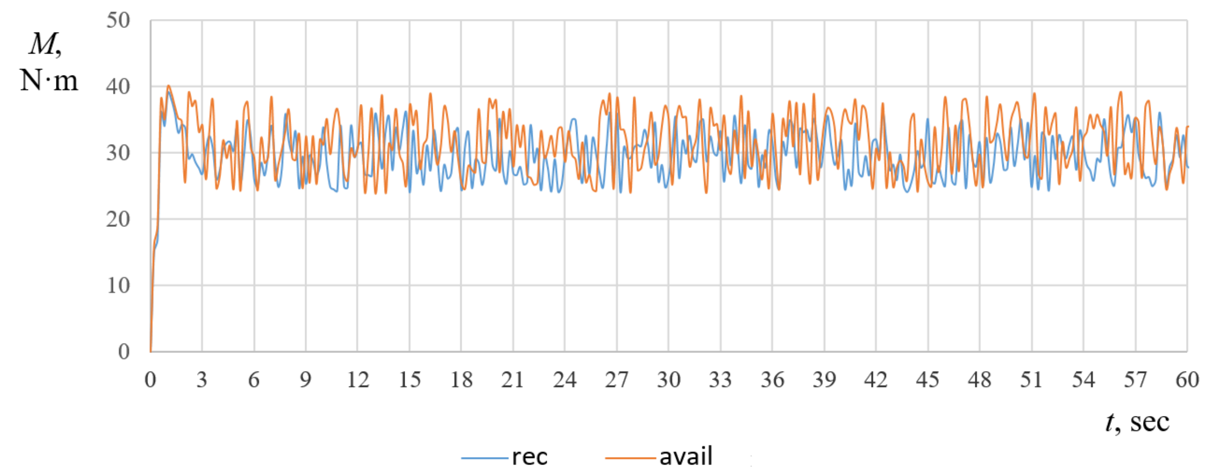
Experimental tests were carried out on 3 types of components (В − 14 МБС, В − 14 ДМБС, ТМКЩ − С 1009) and existing chain drives with the frequency of rotation of the shaft to test the experimental tests which is $180, 216, 270$ Rpm, while technological resistance is $50,60,70 N \cdot m$ respectively. The torque on the drive shaft in parallel, the values of the rotational speed were obtained. Each of the results of the experimental studies was studied in relation to the existing construction and graphs were obtained.Figure 4 shows the laws of torque change in the drive shafts in chain drives at different rotational frequencies and technological resistance, for cases when the bushing rubber on the chain roller whose mark is В − 14МБС is used. Similarly, the oscillograms obtained in Figures 5 and 6 show the loading laws for the cases where the bushings on the composite roller are used, from branded tires whose marks are В − 14ДМБС and ТМКЩ − С 1009 respectively. Analysis of the obtained oscillograms shows that when the bushing in the composite rollers is made of soft rubber (В − 14МБС and В − 14ДМБС) we can see that the load on the drive shaft, ie the value of torque should not exceed $(50 \div 52) N \cdot m$ (Fig. 4, a, b, c and Fig. 5, a, b, c). However, when a roller bushing with a chain made of rubber with a high torque is used, the load (torque) values on the drive shaft of the drive increase significantly and reach $(55 \div 57) N \cdot m$ the average values. The main reason for this is a slight increase in the friction between the chain components when they interact with the sprockets. Because the deformation of the rubber bushing is not high (Fig. 6 a, b, c). It should be noted that as the process resistance torque is further increased, the torque amplitude of the torque on the drive shafts of the chain drive depends mainly on the value of the rotational frequency (Fig. 6 a, b, c), but the average values increase accordingly. The average values of these torques depend on the bushing rubber marks used on the chain compound roller (Fig. 7 a, b, c and Fig. 8 a, b, c).



a) $n_1 = 312 Rpm$; technological resistance $46 N \cdot m$

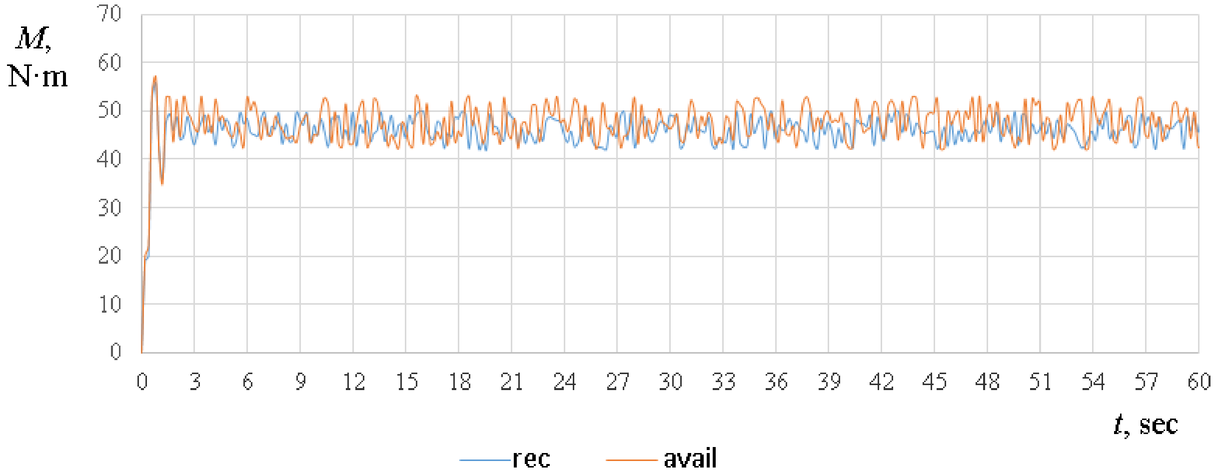


b) $n_1 = 374 Rpm$, technological resistance $37 N \cdot m$

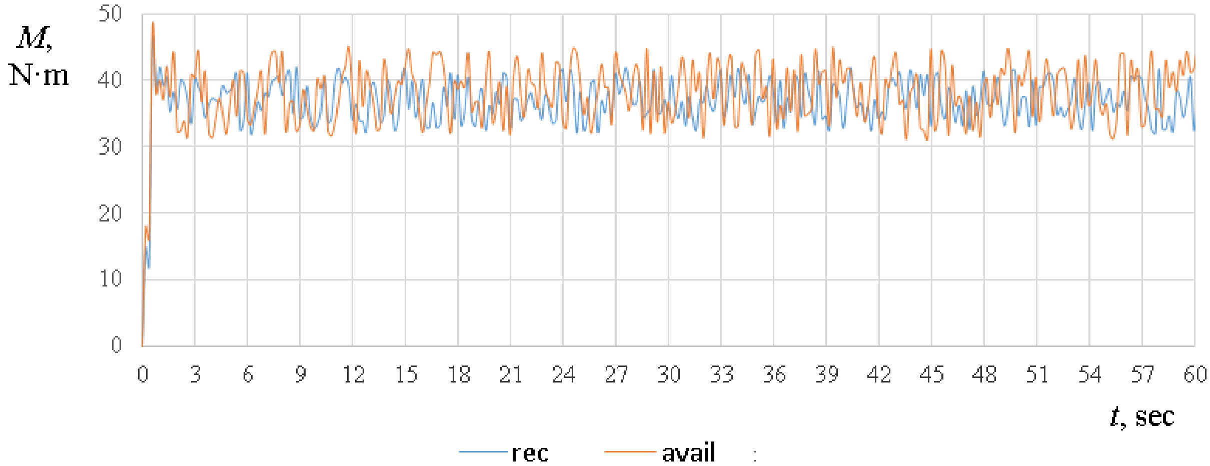


c) $n_1 = 468\ Rpm$, technological resistance $29{,}5\ N \cdot m$

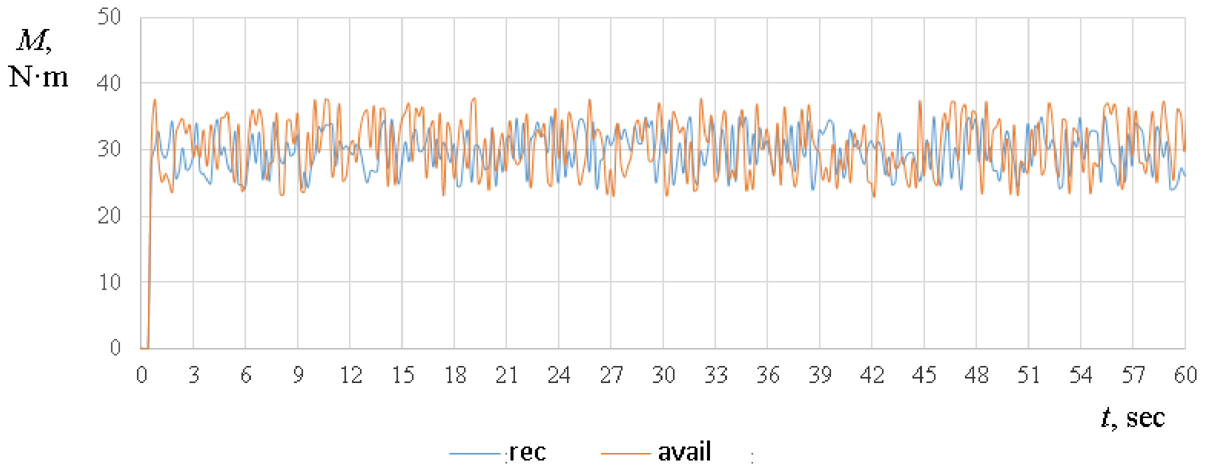
Figure 4. Oscillograms obtained in the case of a roller bushing brand rubber whose mark is В − 14МБС with the laws of change of torque on the drive shafts in chain drives and depending on the change of technological resistance.



a) $n_1 = 312 Rpm$, technological resistance $45{,}5\ N \cdot m$

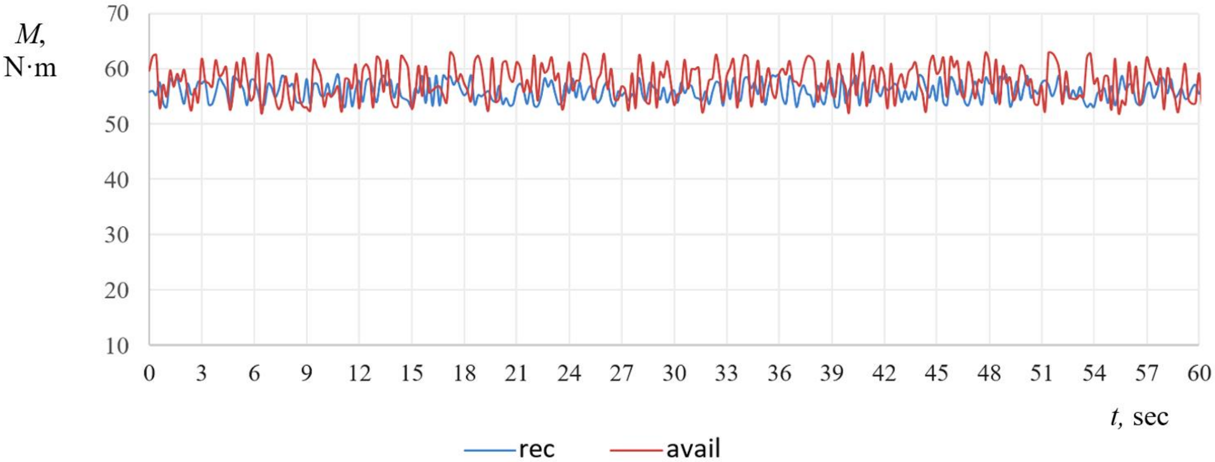


b) $n_1 = 374\ Rpm$, technological resistance $36{,}5\ N \cdot m$

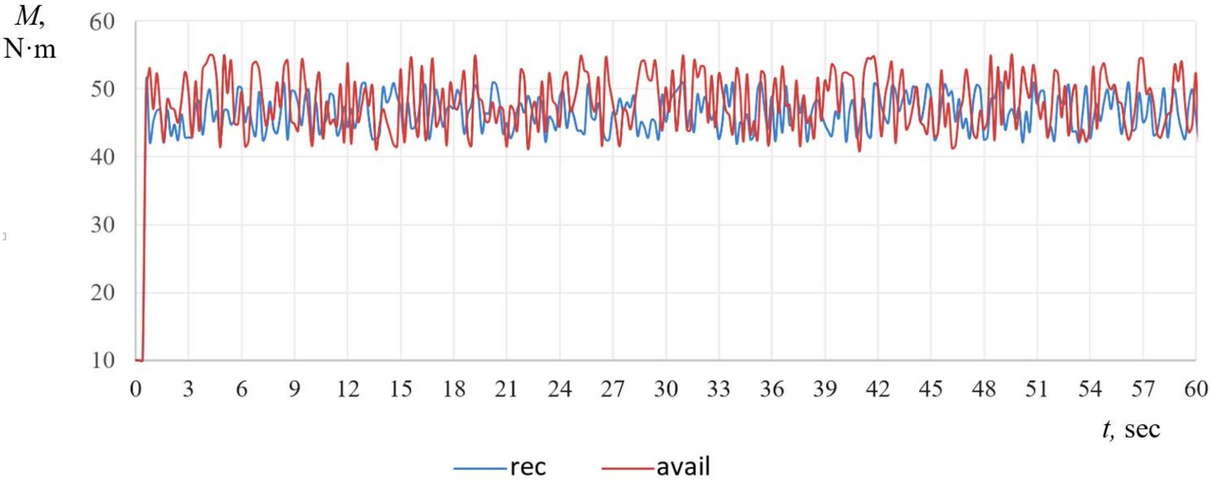


c) $n_1 = 468\ Rpm$, technological resistance $29\ N \cdot m$

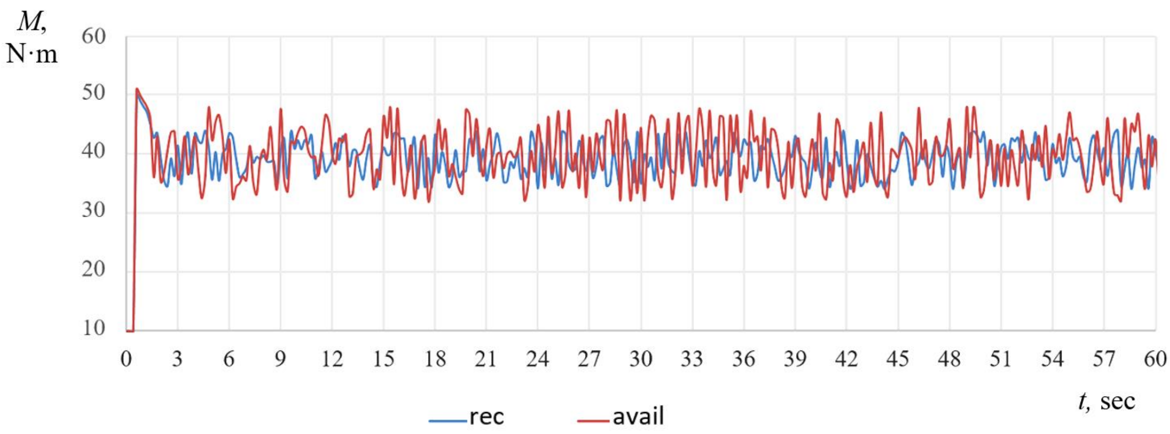
Figure 5. Oscillograms obtained for the case when the torque on the drive shaft of the chain drive is changed at different technological loads and in the case of a roller bushing rubber whose mark is $\text{В} - 14\text{ДМБС}$.



a) $n_1 = 312 Rpm$, technological resistance $55 N \cdot m$

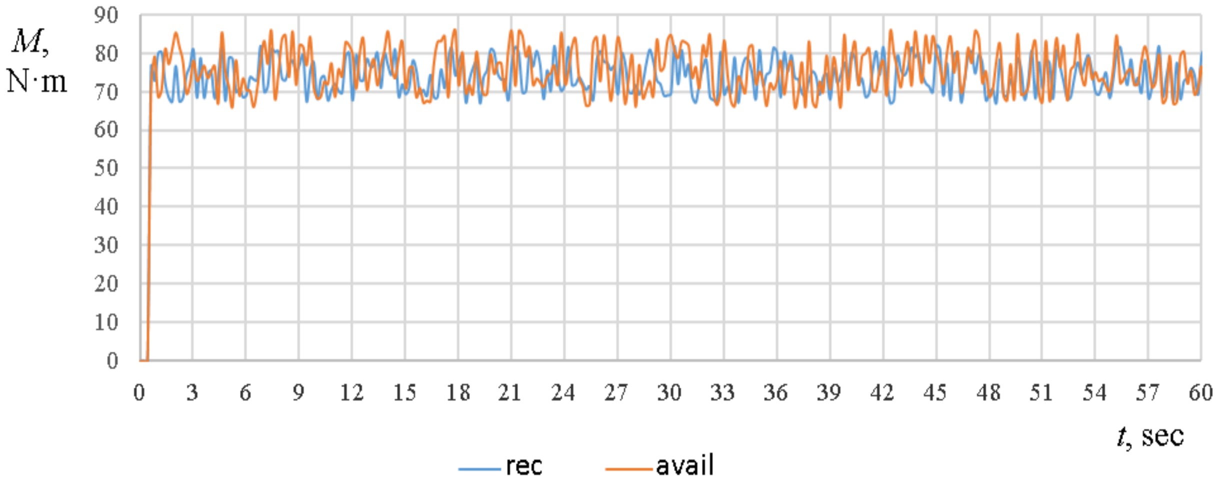


b) $n_1 = 374 Rpm$, technological resistance $46\ N \cdot m$

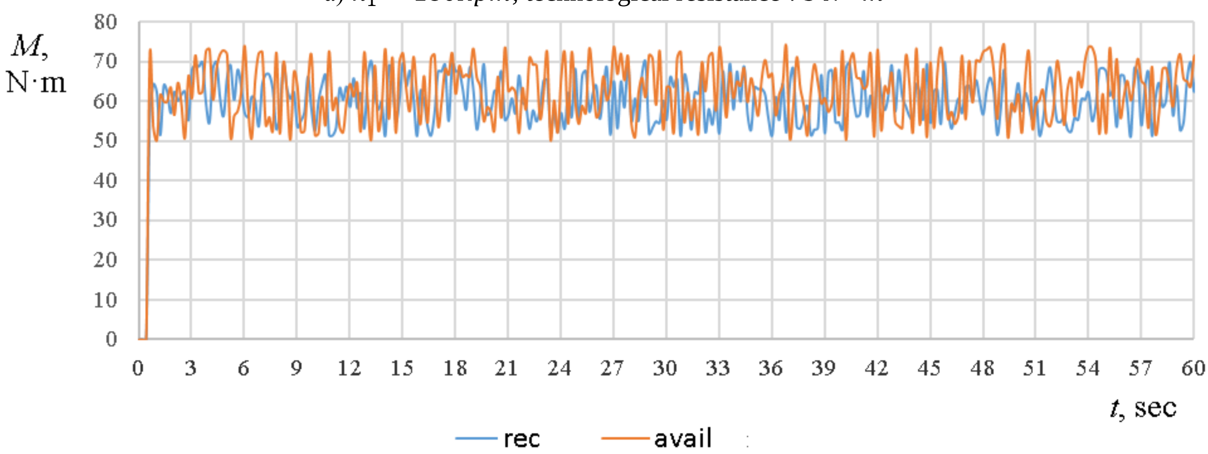


c) $n_1 = 468\ Rpm$, technological resistance $28{,}5\ N \cdot m$

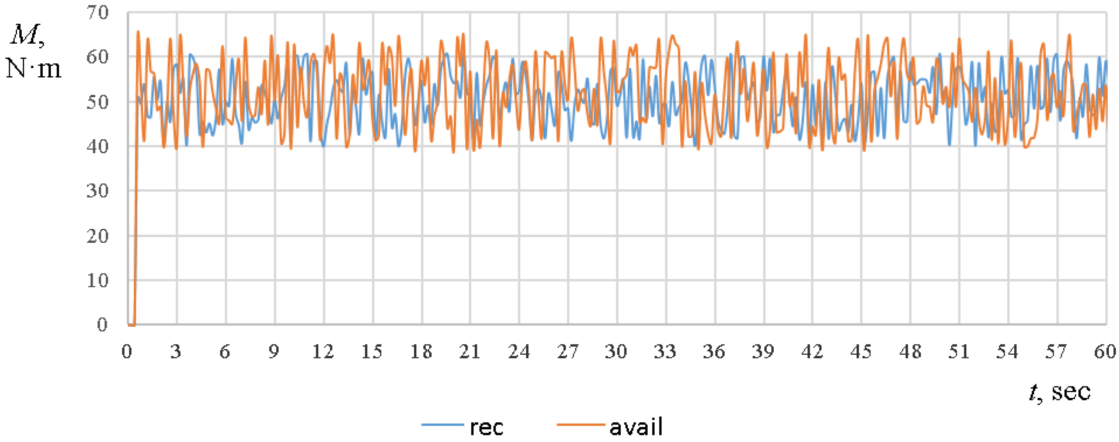
Figure 6. Oscillograms obtained for the case when the torque on the drive shaft of the chain drive is changed at different technological loads and in the case of a roller bushing rubber whose mark is $\text{ТМКШ} - \text{С1009}$.



a) $n_1 = 180Rpm$, technological resistance 75 $N \cdot m$

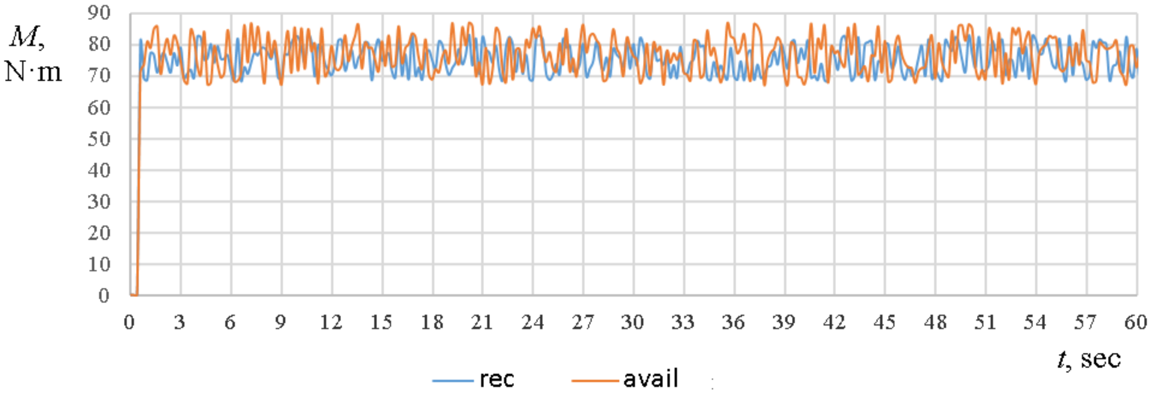


b) $n_1 = 216Rpm$, technological resistance 60 $N \cdot m$

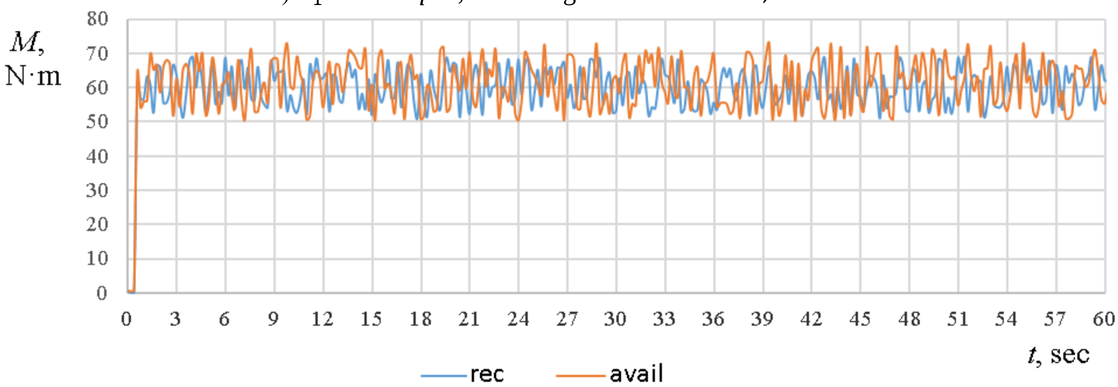


c) $n_1 = 270Rpm$, technological resistance $50\ N \cdot m$

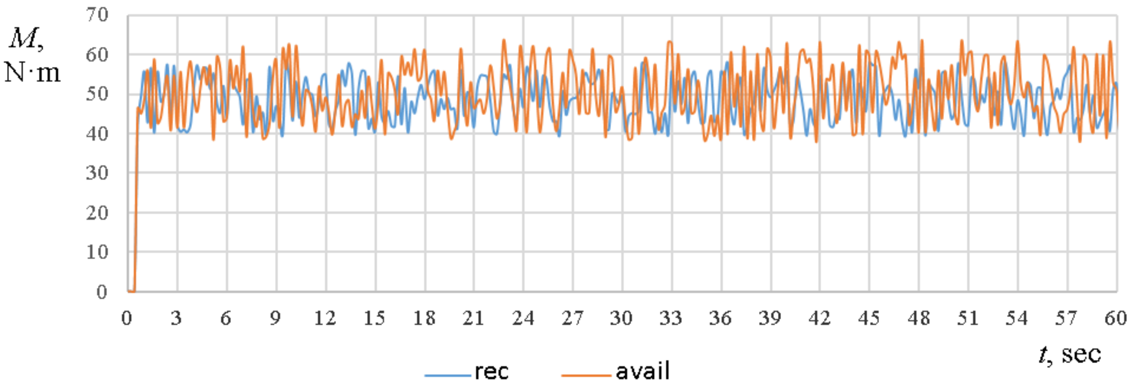
Figure 7. Oscillograms obtained from the laws of change of torque on the drive shaft of the chain drive in low operating conditions and high technological loads, and when the bushing on the composite roller is made of rubber whose mark is В − 14 МБС.



a) $n_1 = 180Rpm$, technological resistance $74{,}6\ N \cdot m$



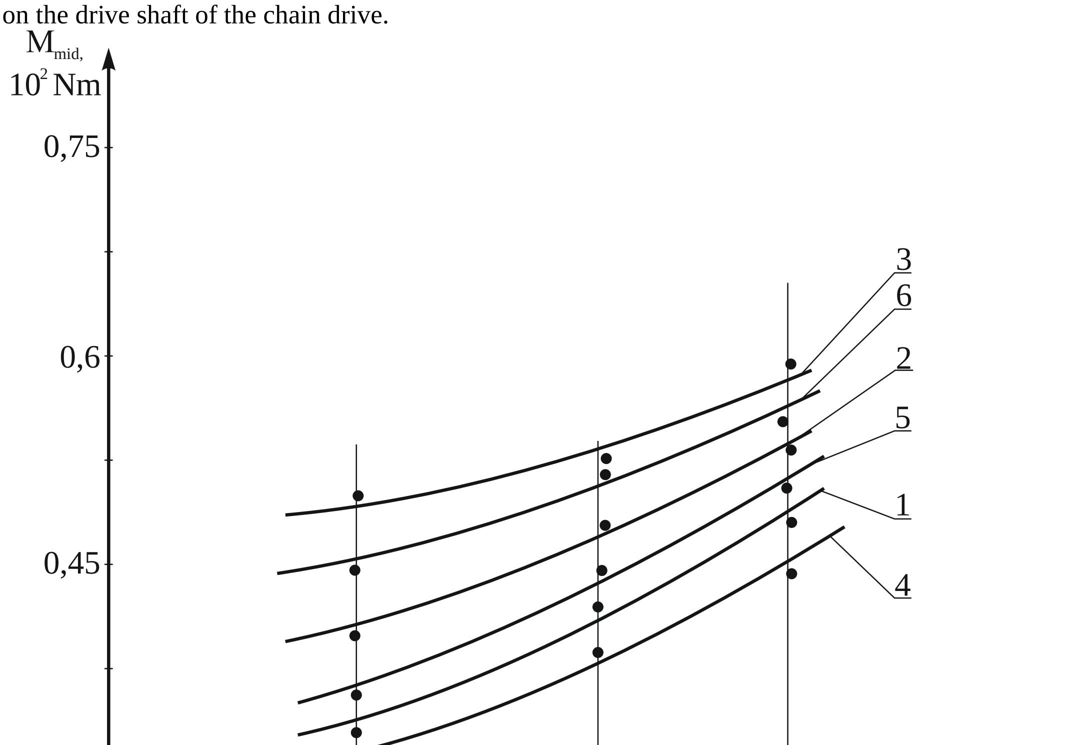
b) $n_1 = 216Rpm$, technological resistance $59{,}5\ N \cdot m$



c) $n_1 = 270Rpm$, technological resistance $48{,}4\ N \cdot m$

Figure 8. Oscillograms obtained from the laws of change of torque on the drive shaft of the chain drive in low operating conditions and high technological loads, and when the bushing on the composite roller is made of rubber whose mark is $В - 14$ ДМБС.

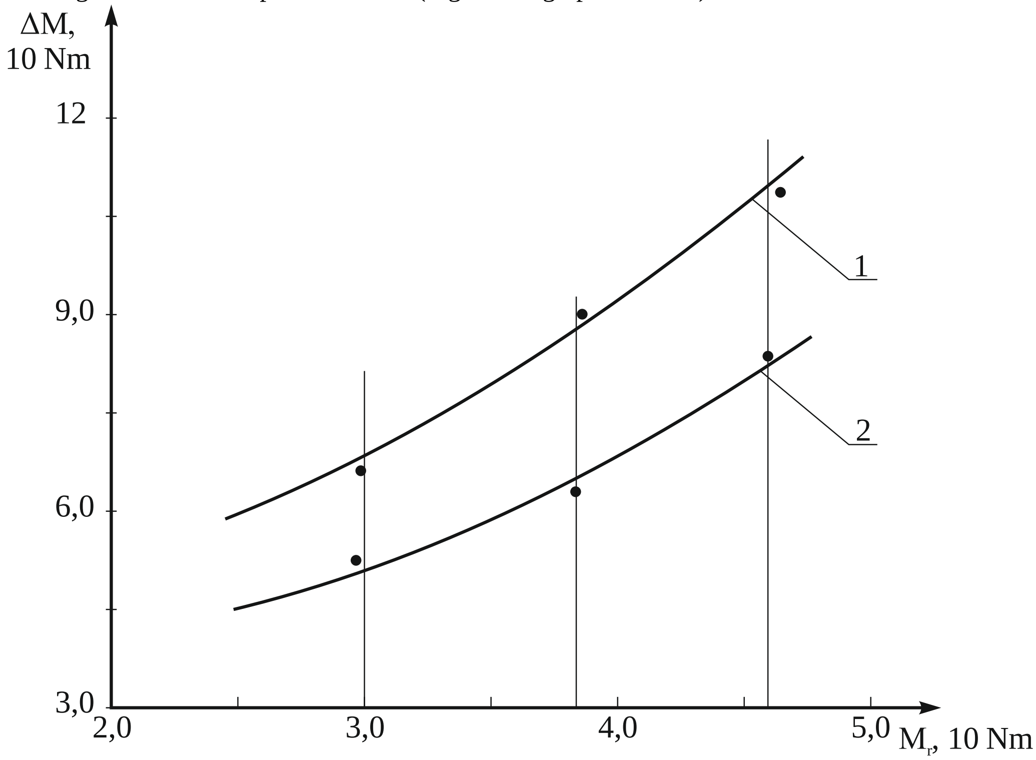
As a result of processing the obtained oscillograms, connection graphs were constructed. The obtained graphical links are shown in Figures 9, 10, 11, 12. We analyze them. Figure 9 shows graphs of the dependence of the average value of the torque on the chain drive shaft on the technological resistance. In this case, in the recommended chain drive, the component roller of the chain bushing is made of branded rubber whose mark is $В - 14$МБС.Based on the obtained graphs, it was found that the average value of the torque on the drive shaft increases from $30N \cdot m$ to $46N \cdot m$ in both comparable chain transmissions in the nonlinear law when the technological resistance of the drive shaft is obtained. At the same time, an increase in the rotational frequency leads to a significant decrease in the values of the drive shaft.In particular, when there is a rotational frequency of $462Rpm$, the torque on the drive shaft in the existing chain drive increases in a nonlinear pattern from $0{,}33 \cdot 10^2\ N \cdot m$ to $0{,}46 \cdot 10^2 N \cdot m$, and when there is a rotational frequency of $312Rpm$, it increases from $M_{mid} = 0{,}492 \cdot 10^2\ N \cdot m$ to $0{,}585 \cdot 10^2 N \cdot m$. However, it was observed that the torque values $В - 14$МБС on the drive shaft in the transmission using bushings made of the brand on the chain rollers are much less than $(7{,}5 \div 9{,}5)\%$ in the existing option. In this case, when the values on the drive shaft decrease to the rotational frequency of $462Rpm$, the values M_{mid} increase in a nonlinear pattern from $0{,}443 \cdot 10^2\ N \cdot m$ to $0{,}528 \cdot 10^2 n \cdot m$ (Fig. 9, graphs 4 and 6). This is because in the proposed chain drive, the rubber bushings of the chain rollers act as shock absorbers, reducing friction, reducing resistance, and reducing the values of vibration amplitudes of the load moments due to energy absorption. These effective situations can be seen from the graphs in Figure 10. Here are the graphs of the dependence of the torque oscillation coverage on the process resistance on the drive shaft of the chain drive.



In this case, the bushing on the chain roller is made of branded rubber $В - 14$МБС, $1{,}4 - n = 468Rpm;\ 2{,}5 - n = 374Rpm;\ 3{,}6 - n = 312Rpm$; 1,2,3-available chain transmission, 4,5,6-recommended chain transmission.

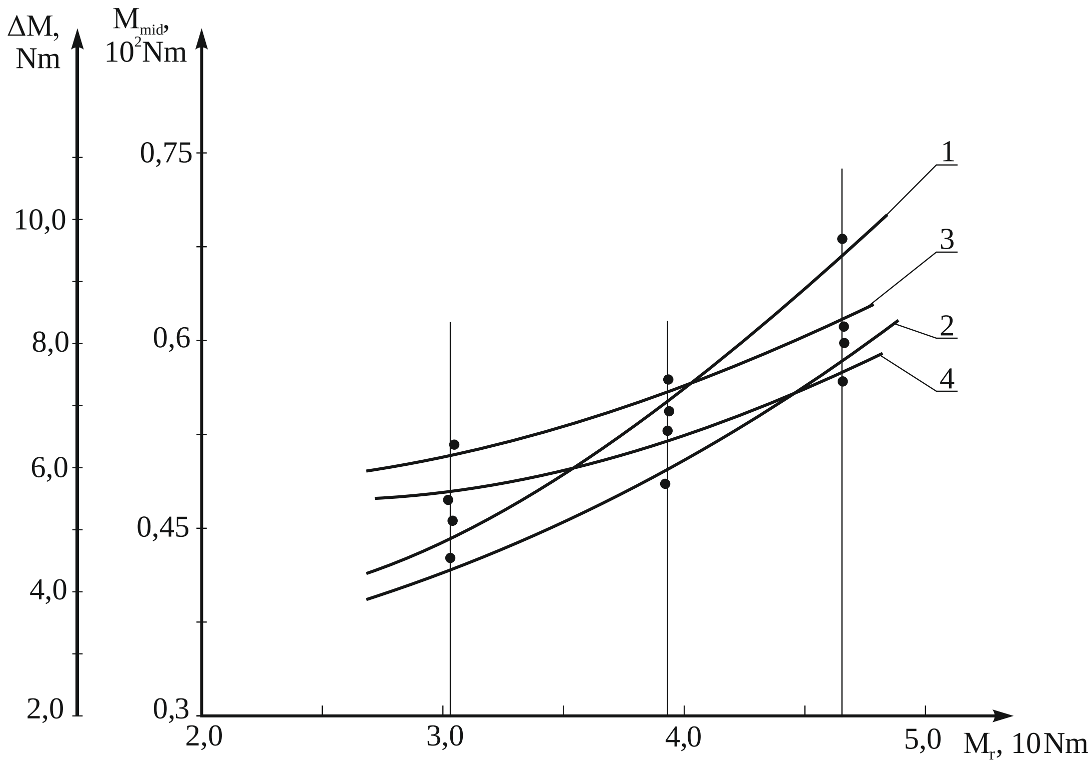
Figure 9. Graphs of the technological resistance dependence of the average value of the torque on the drive shaft of the chain drive.

Based on the analysis of the graphs, it can be noted that when the technological resistance moment on the drive shaft increases from $30N \cdot m$ to $46N \cdot m$, we can see that the torque coverage values of the torque on the drive shaft in the existing chain drive increase from $6{,}34\ N \cdot m$ to $10{,}54\ N \cdot m$ in a nonlinear pattern. Accordingly, the use of a rubber bushing on the composite roller in the recommended traction drive increases the ΔM values from $4{,}83\ N \cdot m$ to $7{,}92\ N \cdot m$ due to the load amortization and the reduction of friction. In this case, the average difference is up to $3{,}1\ N \cdot m$ (Figure 10. graphs 1 and 2).

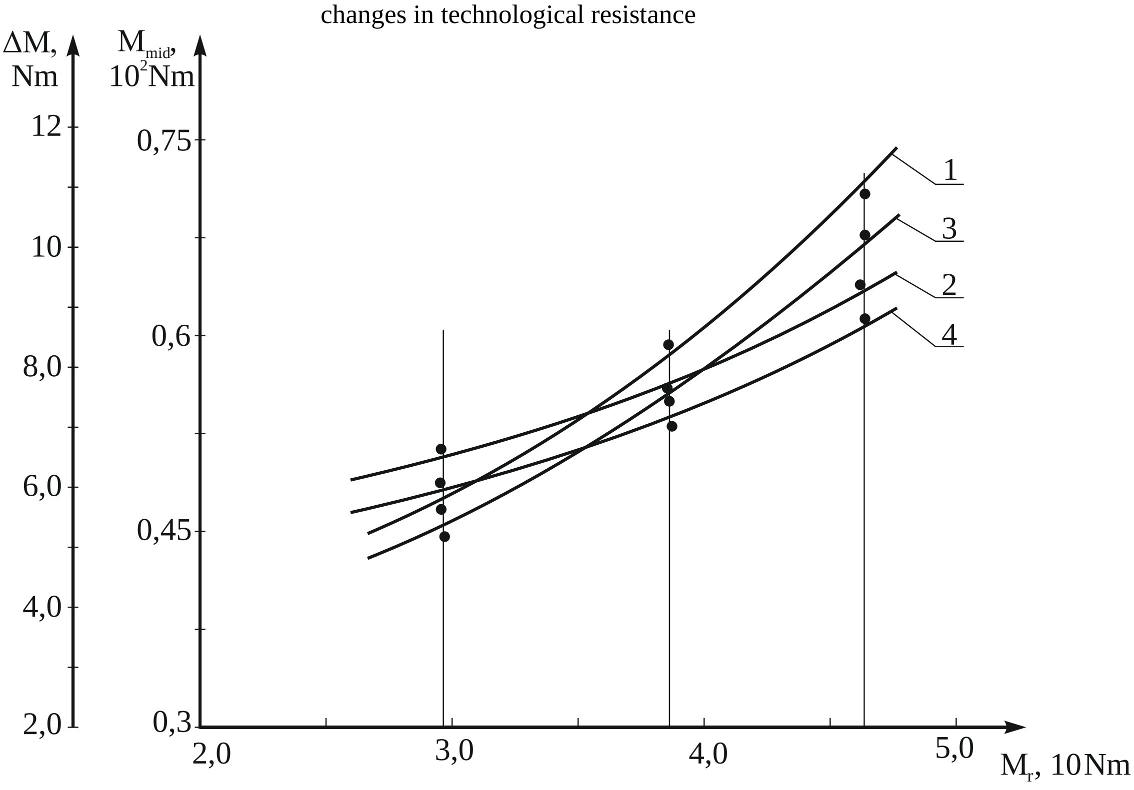


In this case 1 in the existing chain drive: 2 in the recommended chain drive.
Figure 10. Graphs of the dependence of the torque vibration coverage on the process resistance on the drive shaft of the chain drive.

If the composite roller of the chain is made of a rubber stamp В − 14ДМБС with a higher stiffness, the vibration coverage values will decrease as the average values of the torque increase (Fig. 5 a, b, c). It should be noted that since the motion in the chain drive is transmitted from the electric drive through the coupling, it is not large at the expense of depreciation, even if the values are the maximum at steady motion. Based on the analysis of oscillograms, graphs of the torque on the chain drive drive shaft and the dependence of its vibration coverage on the change in technological resistance are given. According to the analysis of the graphs, when the load increases up to $46\ N \cdot m$, the ΔM values are $2\ N \cdot m$ higher than the recommended extension in the existing chain drive.In this case, in the proposed chain drive, the oscillation coverage of the torque on the drive shaft increases from $4{,}2$ Н $\cdot\ m$ to $7{,}12\ N \cdot m$ in a nonlinear pattern from, in the existing extension, ΔM the values are up to $9{,}34\ N \cdot m$. Correspondingly, the M_{mid} values also reach up to $0{,}61 \cdot 10^2\ N \cdot m$ when there is a load of $46\ N \cdot m$ on the existing transmission, while in the recommended option, the torque on the drive shaft only increases up to $0{,}573 \cdot 10^2 N \cdot m$ the values. That is, it was found to go up to $10\ N \cdot m$ the mean difference (Fig. 11, graghs 3 and 4).Figure 12 shows a variant of the rubber bushing on the composite roller brand ТМКЩ − С1009. It can be noted that the higher the torque of the rubber bushing used, the lower the torque vibration coverage, but on average, its values increase significantly [9,10,11]. This is because an increase in the stiffness of a rubber bushing leads to a decrease in its deformation values and a decrease in amortization [12,13,14]. However, an increase in resistance is observed (Fig. 6, a, b, c). It should be noted that a further increase in the torque of the technological resistance in the drive shafts leads to an increase in both their ΔM values proportionally. (See Figures 9, 11, and 12).In particular, we can see that the roller bushing В − 14МБС is in the range of $75\ N \cdot m$values when the roller bushing$(73 \div 74) N \cdot m$ is made of branded rubber, and when the ΔM values are up to $180\ Rpm$ the torque, the roller bushing $(10 \div 12) N \cdot m$is in the range of $50\ N \cdot m$ torque on the drive shaft $(50 \div 52) N \cdot m$. Also, if the roller bushing is made of rubber with a high torque, including branded rubberТМКЩ − С1009, the torque on the drive shaft increases from$M_r = 74{,}1\ N \cdot m$ up to $(75 \div 77) N \cdot m$, and increases up to $M_{mid} = (51 \div 53) N \cdot m$ under load $47{,}9\ N \cdot m$ [15,16].It was found that the torque values were less than$(7{,}0 \div 9{,}0)\%$ the available chain drive. Therefore, in order to reduce the torque values on the recommended chain drive shaft and its vibration coverage, it is recommended to make the chain roller bushing from branded rubber
В − 14ДМБС.



In this case, the bushing on the chain roller В − 14ДМБС made of branded rubber,
$1{,}2 - \Delta M = f(M_r)$; $3{,}4 - M_{mid} = f(M_r)$; $1{,}3 - n = 312 Rpm, 2{,}4 - n = 468\ Rpm$.
Figure 11. Graphs of torque on a chain drive drive shaft and its vibration coverage dependence on changes in technological resistance



In this case, the bushing on the chain rollerТМКЩ − С1009 made of branded rubber.
$1{,}2 - \Delta M = f(M_r)$; $3{,}4 - M_{mid} = f(M_r)$; $1{,}3 - n = 312Rpm; 2{,}4 - n = 468Rpm$
12-figures. Graphs of torque on a chain drive drive shaft and its vibration coverage dependence on changes in technological resistance

Conclusion

Graphs of the torque on the drive shaft of the chain drive and the dependence of its vibration coverage on the change of technological resistance were obtained. It was found that the torque values were (7.0 ÷ 9.0)% lower than the existing chain drive in the proposed chain drive. Therefore, in order to reduce the torque values on the recommended chain drive shaft and its vibration coverage, it is recommended to make the chain roller bushing from Б-14ДМБС rubber.

References

1. Стоблин Г.Б., Готовцев А.А., Проектирование цепных передач: Справочник /, И.П. Котенок. –М.: Машиностроение, 1973.-376 с.
2. Готовцев А.А. Цепные передачи и элементы цепных устройств / Готовцев А.А., Стоблин Г.Б. // Детали машин. Расчет и конструирование: Справочник. Т.3/ Под ред. Н.С. Ачеркана. –М.: 196F9. – С. 279-345. Н. В. Воробьев. Цепная передачи, изд. Машиностроение, М., 1986 г, с.39-42.
3. Джураев А., Ортиков Р., Турдалиев В. Цепная передача, Патент UZ FAP №00413, 31.10.2008. Бюл №10.
4. Джураев А., Мухаммедов Ж., Мамахонов А. Цепная передача, Патент UZ FAP №00595, 31.12.2010. Бюл №12.
5. А.Джураев, А.Мамахонов, К.Юлдашев. Цепная передача. Патент. Рес. Узб. № IAP06200, 30.04.2020, Бюл..,№4. Цепная передача.
6. А.Джураев, А.Мамахонов, К.Юлдашев, Э.Алиев. Определение жесткости упругой втулки составного ролика цепной передачи, Журнал, "Научно-технический журнал" ФерПИ, Том 22. №3, Фергана-2018. С.175-177.
7. А.Джураев, А.Мамахонов. Э.Алиев. Неравномерность угловой скорости ведомой звездочки цепной передачи с упругой втулкой ролика, Журнал, "Научно-технический журнал" ФерПИ, Том 20. № 4, Фергана-2017. С. 44-47.
8. А.Джураев, А.Мамахонов, К.Юлдашев, Э.Алиев. Определение амплитуды собственных колебании оси на упругих опорах цепи передачи. Журнал, "Научно-технический журнал" ФерПИ, спец.вып 3, Фарғона-2018. С. 64-67.
9. А.Джураев, А.Мамахонов, К.Юлдашев. "Динамика машинного агрегата с механизмом привода винтового конвейера для транспортировки и очистки хлопкового линта" НамМТИ "Илмий техника журнали" 2020 №2. Б. 189-197.
10. A.Djurayev, A.Mamakhonov, S.Yunusov. Analysis of the uneven gear ratio chain transmission with elastic roller sleeve. Journal, European Science Review № 9-10 2017 ISSN 2310-5577. P. 102-106.
11. A.Djurayev, A.Mamakhonov, K.Yuldashev, Improvement of the Term of Service Life of the Drive Roller Chain of Transmission. International Journal of Advanced Research in Science, Engineering and Technology. Vol. 6, Issue 3, March 2019. P.8508-8514 ISSN: 2350-0328. (Impact factor 6.1).
12. A.Djurayev, A.Mamakhonov, K.Yuldashev. "Development of an Effective Design and Justification of the Parameters of a Screw Conveyor for Transporting and Cleaning Cotton Linters". International Journal of Advanced Research in Science, Engineering and Technology. Vol. 7, Issue 5 , May 2020. P. 13649-13653. ISSN: 2350-0328
13. A.Mamakhonov. Theoretical Investigation Of The Static Calculation Of A Composite Rolling Chain Drive Roller, International Journal of Future Generation Communication and Networking Vol. 13, No. 4, (2020), pp. 207–220.111
14. Джураев А. Мамахонов А., О.Муродов. Определение жескости упругой втулки составного ролика цепной передачи. «Молодежь и XXI век-2017» Материалы VII Международной молодежной научной конференции Курск-2017, Ст. 342-344.
15. А.Мамахонов, А.Джураев, К.Юлдашев, Результаты экспериментов по нагруженности цепной передачи с упругими элементами. 70-й Международной научно-практической конференции "Вклад университетской аграрной науки в инновационное развитие агропромышленного комплекса" Рязань, 2019 Ст-256-262.