Research Article

Analysis Of Regularities Of Rotation Frequency Change And Noise Values Of Chain Drive Shaft With Elastic Element

Anvar Djurayevich Djurayev[1], Azam Abdumajitovich Mamakhonov[2], Ismoilkhon Azamhuja ugli Khikmatillayev[3]

[1]Doctor of technical Sciences, Professor, Tashkent Institute of textile and light industry, Uzbekistan,
[2]Candidate of technical sciences, docent, Namangan Institute of Engineering and Technology, Uzbekistan
[3]Master of Machinery Namangan Institute of Engineering and Technology, Uzbekistan

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 16 April 2021

Abstract: The article provides a diagram and constructional peculiarities of a chain drive with a composite driven sprocket and a composite roller in the transmission mechanisms of technological machines. The regularities of the driven sprocket shafts movement, as well as the noise indicators of the compared chain drives are presented. Based on the analysis of the obtained experimental results, the main parameters of the recommended chain transmission with elastic elements were substantiated.

Keywords: Chain drive, driving, driven, sprocket, flail, compound, roller, rubber bushing, angular velocity, swing, deformation, stiffness, loading, noise, justification

Resource-saving chain drive design

In most technological machines, mainly in agricultural machinery, automotive, mining and mechanical engineering, chain transmission is widely used [1,2,3]. Their main disadvantage is a low service life due to wear of the chain rollers, noise in transmission. We recommend a new constructive scheme of a resource-saving chain transmission [4,5,6].The essence of the proposed design of the chain drive is that the chain drive consists of a driving and driven sprocket, a tension roller and a chain that covers them, turning off the outer and inner links, a roller, a bushing and a composite roller from the inner and outer bushings, between which a rubber (elastic) bushing, while the sprocket is made composite, consisting of a base with an output shaft, an elastic annular bushing put on it and the outer part of the sprocket with teeth. The rubber sleeve can be made in a concave curved shape along the outer surface and, accordingly, the inner surface of the outer sleeve is made in a curved convex shape. In this design, the compound roller allows a reduction in friction during impact interaction with the teeth of the sprockets, due to the shock absorption (deformation) of the elastic sleeve. Noise during operation is reduced, reliability and transmission resource are increased.

Methods of conducting experiments

The proposed composite roller chain drive was mounted on test stands for testing of prototypes. Devices were installed to determine the torque, rotational speed, and the amount of noise generated at the star and chain coupling on the extension shaft (Figures 1 and 2). Figure 1 shows the electrotenesometric scheme for determining the kinematic and dynamic parameters of the chain transmission's drive shaft. The torque, rotational speed and noise on the proposed drive shaft were determined in the following order: From the electric motor 1 ($N = 3\text{kW},\ n = 3000\ RPM$) the motion is transmitted to the belt drive 2, from which the variable speed is set to the variator 3, from the variator to the belt drive 4, and then to the cylindrical gearbox 5 (Ц2Н-450) with the number of $i = 20$ two-stage transmission. The rotating motion coming out of 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 guide 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 tokosyomk to the Arduino Nano $V3.0, CH340$ microcontroller 13.The change in the rotational speed of the driven sprocket is detected by a laser photoelectric sensor (3pin ИК) 8, a high-sensitivity sound microphone 6 (sensor-Erfassungs module - avr pic ky-037), which detects the amount of noise generated by the extension chain and the sprocket teeth, then transmitted to the microcontroller 13 whose model is Arduino Nano V3.0CH340. 3 types of signals received in parallel are transmitted to the computer through the microcontroller 13. The computer processes data based on a special program that works in accordance with the Arduino Nano V3.0CH340 microcontroller. Figure 2 shows a kinematic diagram of an experimental stand for determining the speed of the leading and driven shafts.

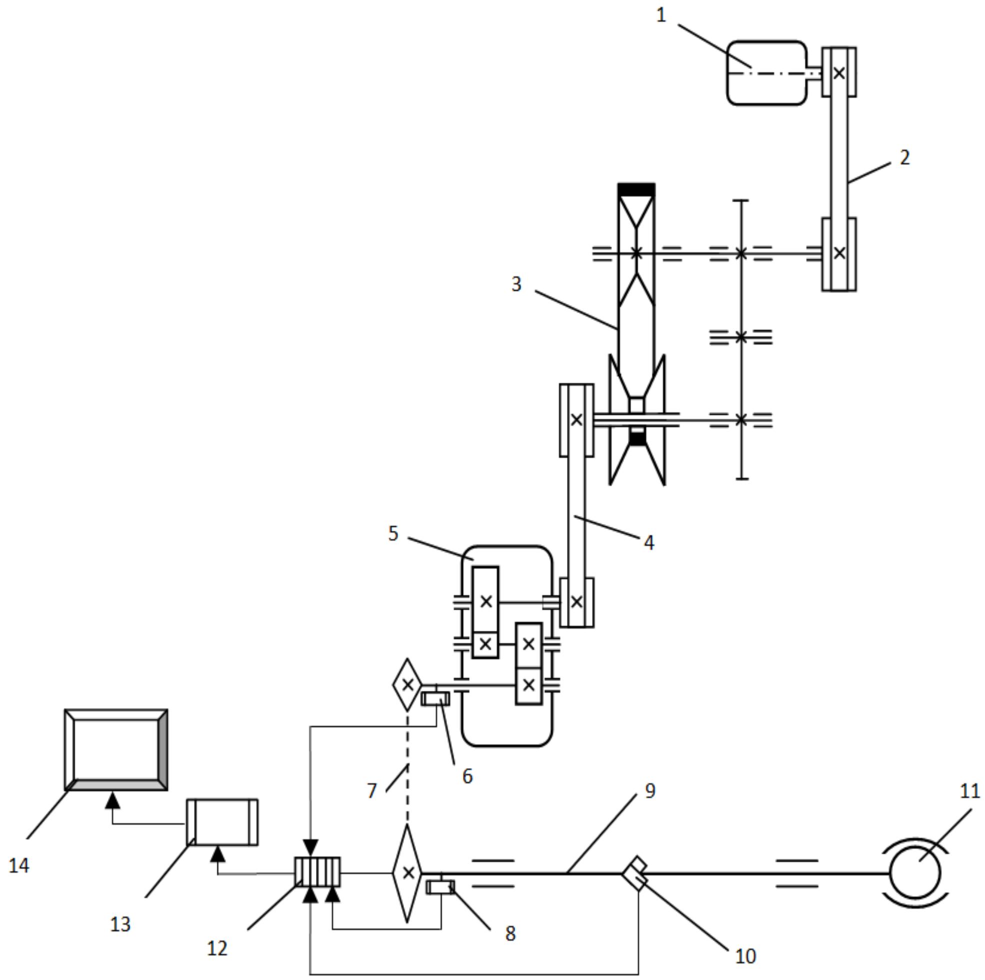


Figure 1. Electrotensometric scheme for determining the kinematic and dynamic parameters of the chain drive shaft.

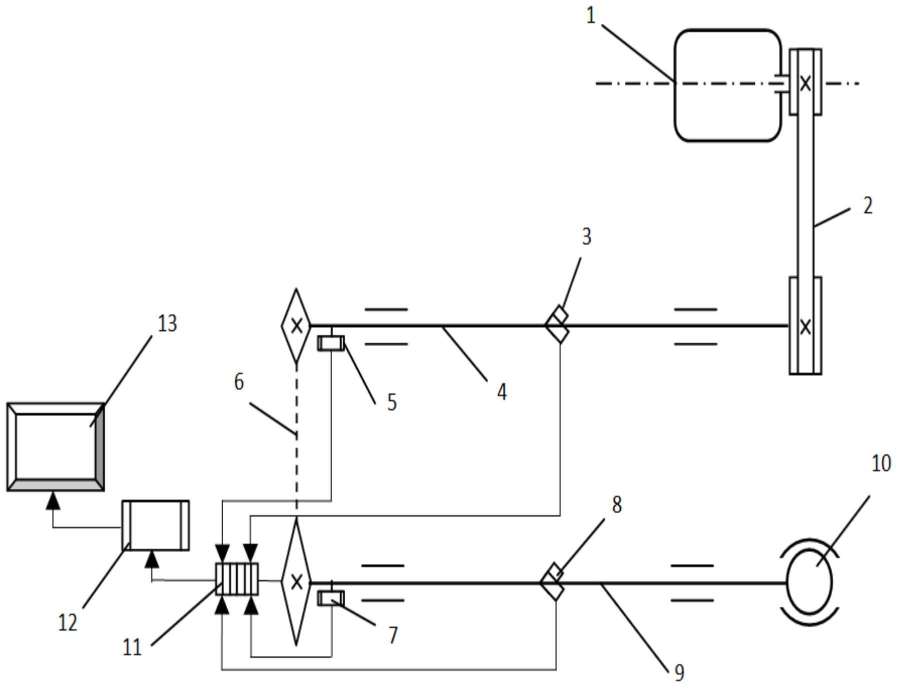
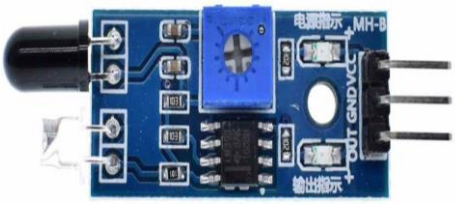


Figure 2. Stand for determining the kinematic and dynamic parameters of chain drive shafts.

It is known that the amplitude values of the parameters of motion of the drives of technological machines vary due to the technological resistances acting on the working bodies. This in itself has a direct negative effect on the transmission mechanisms of the car. It has been studied that there is a degree of reduction of these negative impact values through the proposed design. A sharp change in the amplitude values of the rotational speeds of the drive shafts leads to uneven movement and the formation of overloads on the bearings. A special photoelectric sensor (3pin ИК) was mounted on the driven sprocket to detect the change in rotational speed due to the dynamic loads mentioned above (Figure 3). In order to determine the rotational frequency of the guide sprocket, a sprocket disk moving along the sprocket was attached to the drive shaft (Fig. 3, a).

a



b

Figure 3. a) spinning device, b) laser photoelectric sensor-3pin IK

During the operation of technological machines, noise is generated from complex vibrations in the kinematic joints. There are broad and tonal types according to the spectral nature of the noise. It is known that one of the main disadvantages of chain transmissions is that they work with noise. The flexible element in the proposed chain drive structure receives the impact forces on the roller sprocket teeth. This causes the forging forces to self-extinguish and absorb the noise generated by the collision between the chain parts.In order to measure the noise, a high-sensitivity avr pic ky-037 module was installed on the experimental stand (Figure 4).

a

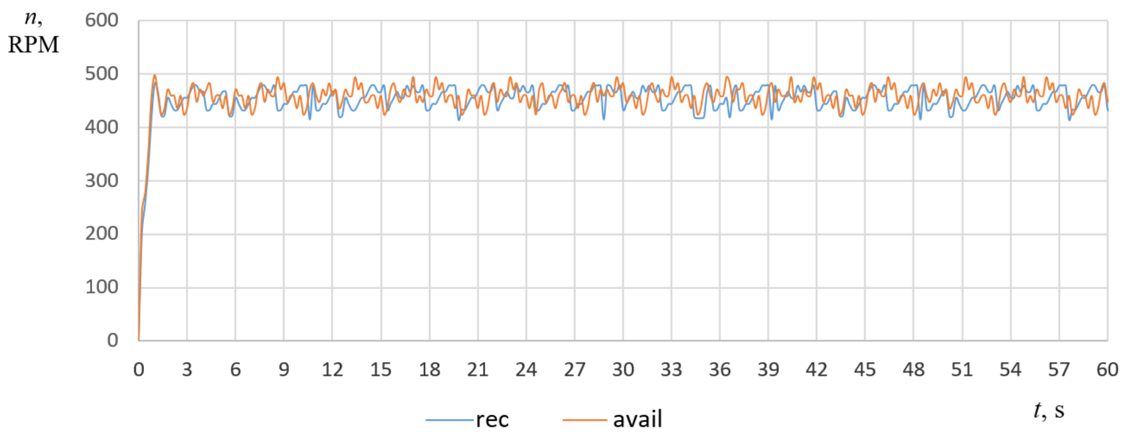
б

Figure 4. Here a) high-sensitivity sound microphone sensor release module –avr pic ky-037 b)-mounting on an experimental stand

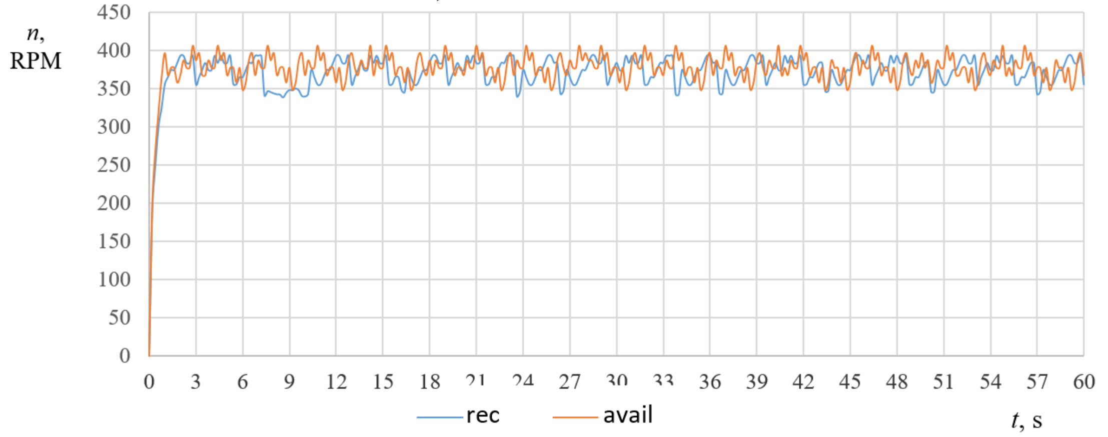
During chain drive operation, the amount of noise emitted from the transmission is transmitted through the module to the Arduino Nano V3.0. Noise signals are transmitted to the computer via the Arduino Nano V3.0. It is advisable to obtain the amount of noise at 3 different speeds in each of the recommended chain drives. In the existing chain drive, experiments were also performed at 3 different speeds.The research results from the available and recommended chain extensions were compared. In order to increase the accuracy of the study results, the tests were repeated three times in each mode. A high-sensitivity sound microphone was installed at a distance from the test stand.

Analysis of the laws of change of the frequency of rotation of the drive shaft of a chain drive

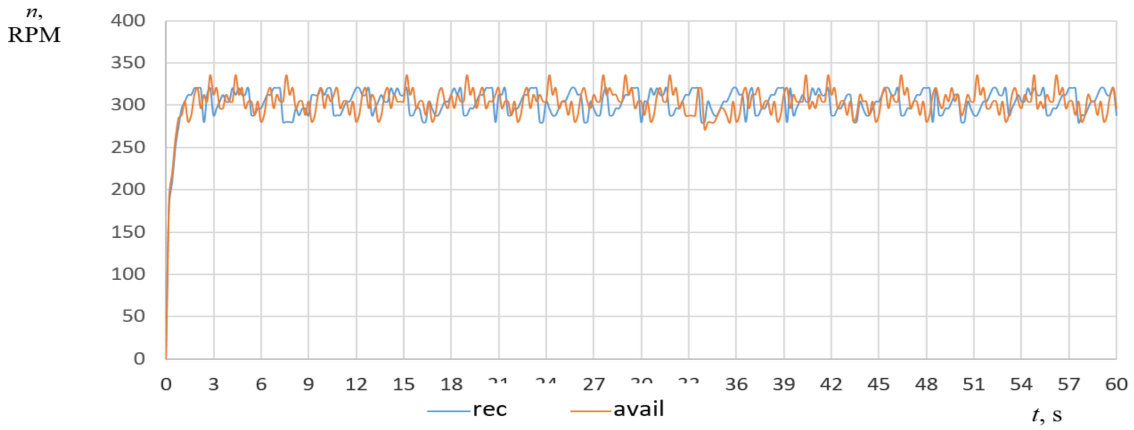
It is known from the theory of machines and mechanisms [7,8] that an increase in the load on the shaft leads to a decrease in its angular velocity accordingly. According to the results of the experiment, the regularities of the rotational frequency of the drive shafts of the existing and recommended chain drives depending on the change of technological load values are given in the oscillograms in Figure 5 [9,10,11,12].



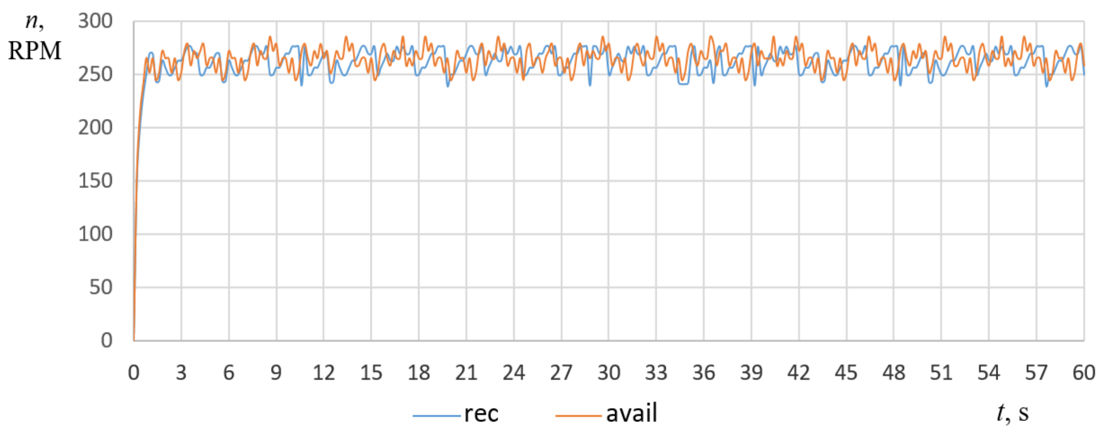
a) $M = 29{,}5 \pm 12\ N \cdot m$



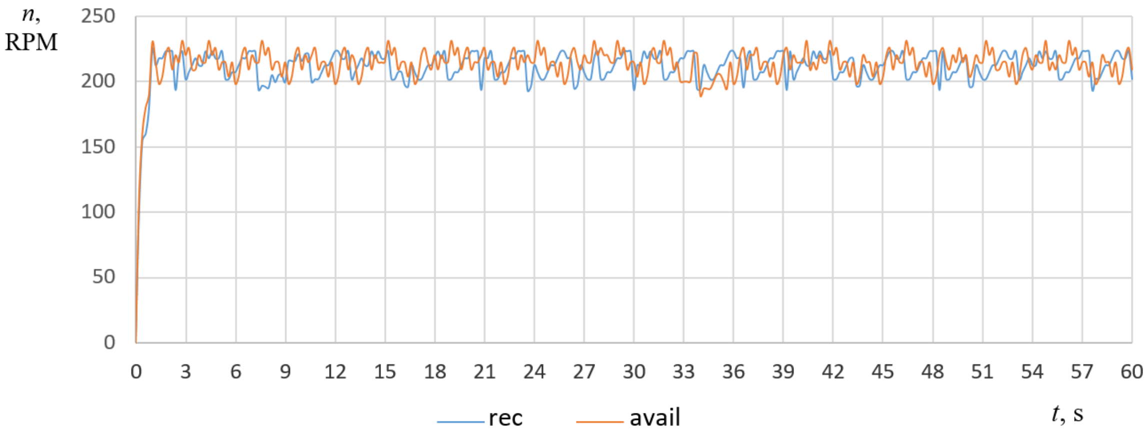
b) $M = 37 \pm 10\ N \cdot m$



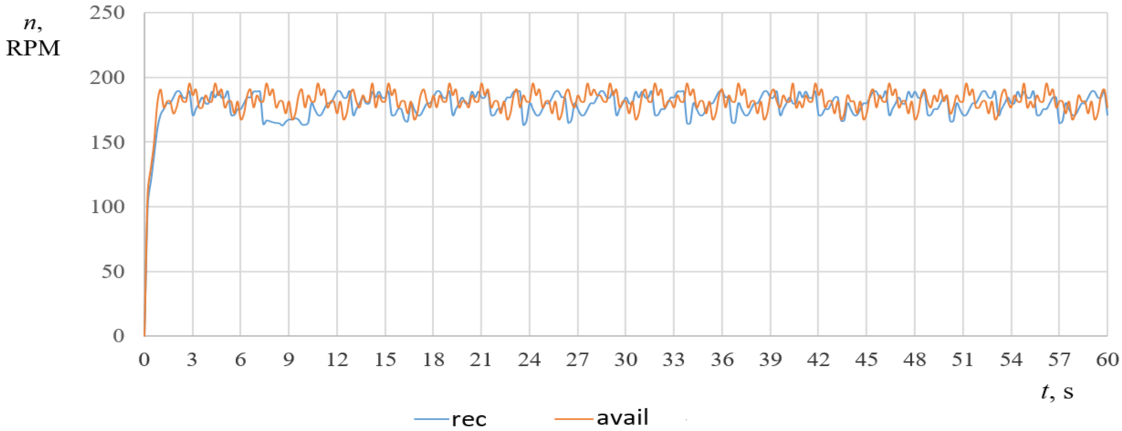
c) $M = 46 \pm 8\ N \cdot m$



d) $\mathrm{M} = 50 \pm 20\ N \cdot m$



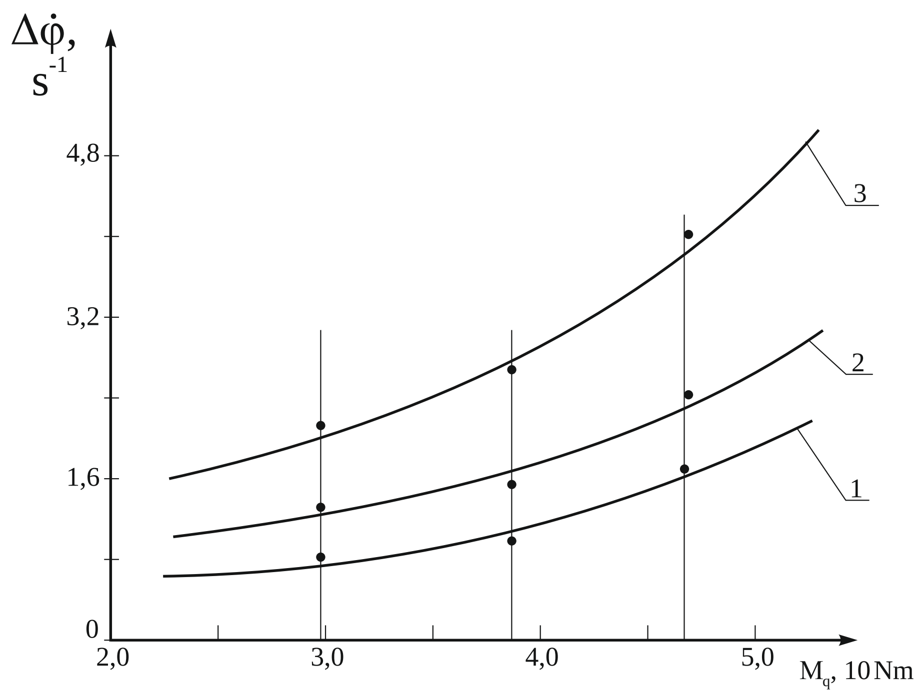
e) $\mathrm{M} = 60 \pm 18\ N \cdot m$



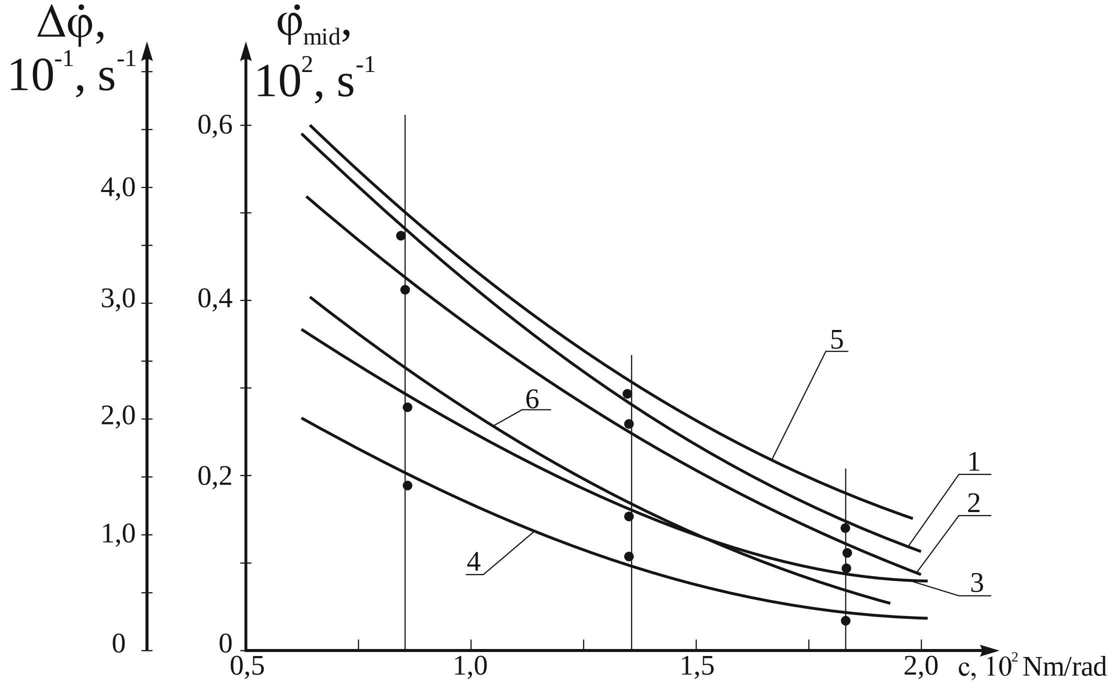
f) $\mathrm{M} = 75 \pm 16\ N \cdot m$

Figure 5. Oscillograms obtained from the change of the technological load of the frequency of rotation of the drive shaft of the chain drive and the composition of the roller bushing $\mathrm{B} - 14\mathrm{МБС}$ made of rubber

According to the analysis of the obtained oscillograms, it can be noted that in both comparable chain transmissions it can be seen that the rotational frequency of the drive shaft and its oscillation coverage decrease with increasing technological load. As a result of processing the obtained laws, connection graphs were constructed. Figure 6 shows graphs of the dependence of the angular velocity of the chain drive shaft on the oscillation coverage of the technological resistance. It is taken into account that three types of branded rubber bushings are used. According to the analysis of graphs, when the roller bushings are made of branded rubber$\mathrm{B} - 14\mathrm{МБС}$, the coverage of the change in the frequency of rotation of the drive shaft, the values of $\Delta\dot{\varphi}$ from the resistance of which is from $30N \cdot m$ to $46\ N \cdot m$ increases in a nonlinear pattern can be seen from $0{,}81\ s^{-1}$ to $1{,}45 s^{-1}$. Correspondingly, when the B-14ДМС brand rubber is used, $\Delta\dot{\varphi}$ the values from $0{,}11\ s^{-1}$ $2{,}35 s^{-1}$ increase to the maximum resistance when the brand rubber $\mathrm{ТМКЩ} - \mathrm{C}1009$ is used. Therefore, it is advisable to use branded rubbers $\mathrm{B} - 14\mathrm{МБС}$ and $\mathrm{B} - 14\mathrm{ДМБС}$ that do not exceed the technological resistance $50N \cdot m$ to ensure that the value of the change coverage of the extension drive shaft with a roller chain of the recommended composition does not exceed the value of the coverage in accordance with the experimental copy parameters. This can also be assessed by determining the effect of the rotational stiffness of the tires used for the composite roller. Figure 7 shows graphs of the mean value of the angular velocity of the roller bushing rotation coefficient of rotation and its value of vibration coverage.



Here $1 - $ ТМКЩ $-$ С1009 Branded rubber; $2 - $ В $-$ 14ДМБС Branded rubber;
$3 - $ В $-$ 14МБС Branded rubber. Figure 6. Graphs of the dependence of the angular velocity of the chain drive drive shaft vibration coverage on technological resistances



$1,2 - \Delta\dot{\varphi} = f(c)$; $3,4 - \varphi = f(c)$; $1,3 - \text{M}_\text{r} = 45\text{Н} \cdot \text{м}$; $2,4 - \text{M}_\text{r} = 28\text{Н} \cdot \text{м}$
$1,2,3,4 -$ experimental graphs, $5,6 -$ theoretical graphs.
Figure 7. Graphs of the dependence of the angular velocity of the drive shaft on the chain drive and the change in its vibration coverage on the coefficients of wear of the chain-roller bushing

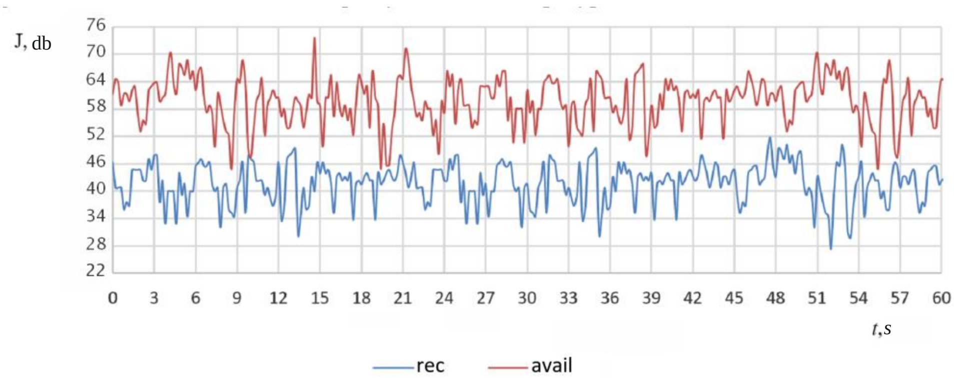
According to the analysis of the graphs, the composite roller of the chain decreases from $0{,}2 \cdot 10^2 s^{-1}$ to $0{,}05 \cdot 10^2 s^{-1}$ when the rotational idle coefficient increases $0{,}8 \cdot 10^2 N \cdot m/rad$ to $1{,}79 \cdot 10^2 N \cdot m/rad$, and when the average angular velocity of the drive shaft decreases. When there is technological resistance $29\ N \cdot m$, $\dot{\varphi}$ decreases to $0{,}145 \cdot 10^2 s^{-1}$ ($\dot{\varphi}$ nominal value $0{,}188 \cdot 10^2 s^{-1}$). Correspondingly, the angular velocity decreases from $3{,}65 \cdot 10^2 s^{-1}$ to $1{,}32 \cdot 10^2 s^{-1}$ when there is vibration coverage $\text{M}_r = 45 N \cdot m$, and $\Delta\dot{\varphi}$ decreases to $1{,}1 \cdot 10^{-1} s^{-1}$ n when the resistance decreases to $29\ N \cdot m$.

In this case, in order to minimize the oscillation coverage of the angular velocity of the drive shaft, it is recommended that the component roller of the chain at nominal technological resistance be in the range of $(1{,}5 \div 1{,}65) \cdot 10^2 N \cdot m/rad$ rotation of the rubber bushing. An important aspect of the research is how mutually compatible the experimental and theoretical results obtained are. When the theoretical and experimental values are compared in Fig. 7, their maximum difference, i.e. the difference between the values of the oscillation coverage of the drive shaft angular velocity, is [13-16] $(8{,}0 \div 9{,}0)\%$.

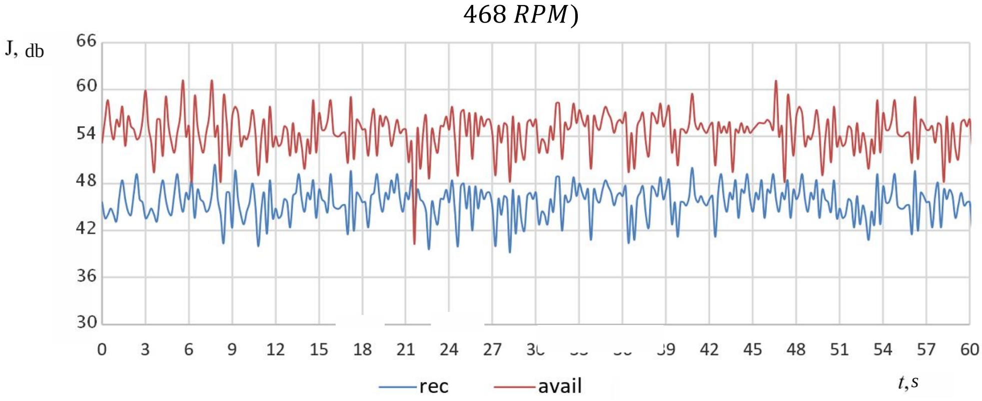
Comparative analysis of noise measurement results in chain drive. A sharp decrease in noise was observed in the mechanism used in the chain drive with a roller of the recommended composition (Fig. 8). Figure 8 shows the oscillograms representing the laws of noise variation in transmissions with a roller chain of existing and recommended content.

According to the analysis of the obtained oscillograms, we can see that the noise increases accordingly with the increase of the rotational frequency of the leading link and in the recommended chain transmissions.In particular, when there is an average value of $n = 460\ RPM$ the noise in the existing transmission, it goes to $3{,}1db$ the oscillation. In the proposed chain drive, the noise averaging is $46{,}1\ db$ 2 and the vibration coverage is $2,0db$. Correspondingly, when the drive shaft frequency decreases to $n = 180\ RPM$ the rotational frequency, the noise value is the average in the existing transmission, the oscillation coverage is $2,2db$.

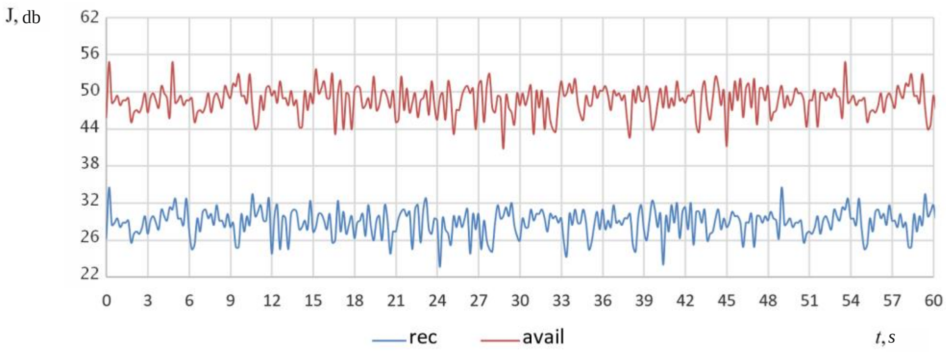
It was found that the composite roller of the proposed chain drive in the chain was reduced $(1{,}2 \div 1{,}5)$ by a factor of three when the rubber bushings were used, compared to the existing chain drive. Accordingly, the recommended chain extension processing resource was also confirmed to be increased.



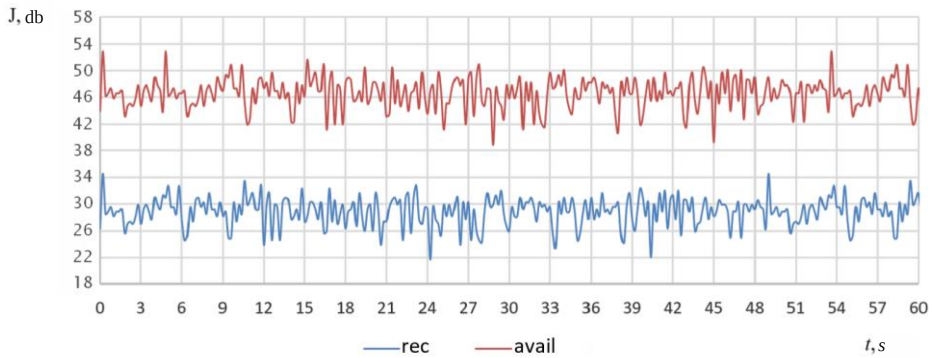
a) change of noise value in composite roller (В − 14 МБС) and existing chain extensions. $(n_2 = 468\ RPM)$



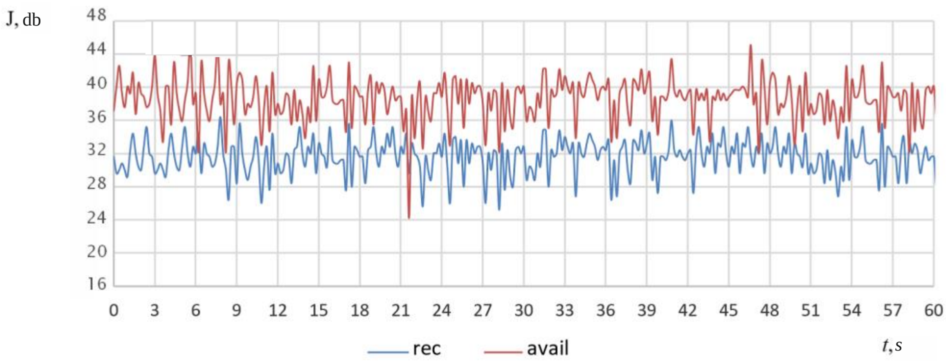
b) change in the value of the noise in the composite roller (В − 14 МБС) and the existing chain transmissions. $(n_1 = 374\ RPM)$



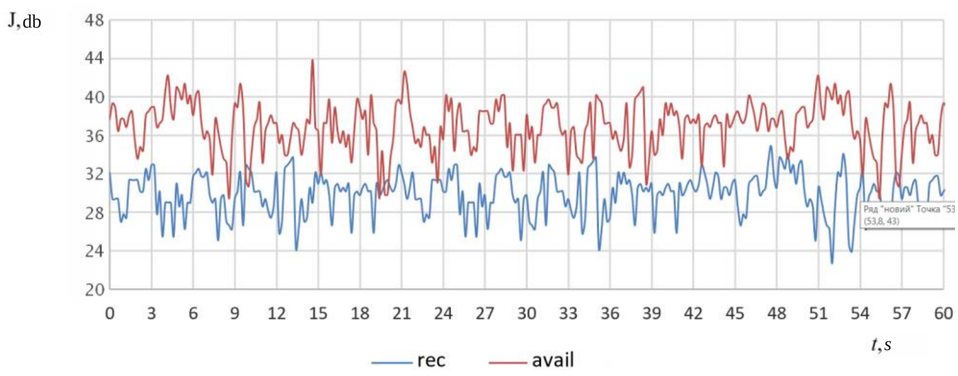
c) change of noise value in composite roller (B − 14 MБC) and existing chain transmissions. ($n_1 = 312\ RPM$)



d) change in noise value in composite roller (B − 14 MБC)and existing chain transmissions ($n_1 = 270\ RPM$).



e) change in noise value in composite roller(B − 14 MБC) and existing chain transmissions. ($n_1 = 216\ RPM$)



e) change in the value of the noise in the composite roller (B − 14 MБC) and the existing chain transmissions. ($n_1 = 180\ RPM$)

Figure 8. Oscilloscopes representing the laws of noise change in transmissions with a roller chain of existing and recommended content.

Conclusion

Graphs of the dependence of the vibration coverage of the angular velocity of the chain drive shaft on the technological resistance.To ensure that the rotational frequency of the extension drive shaft with the recommended composition roller chain does not exceed the change coverage value in accordance with the experimental copy parameters, it is advisable not to exceed the technological resistance $50Н \cdot м$and apply rubber marks. $В - 14МБС$ ва $В - 14ДМБС$. When comparing the theoretical and experimental values of the proposed chain drive, their maximum difference, i.e. the angular velocity of the drive shaft, is $(8{,}0 \div 9{,}0)\%$the difference between the values of the vibration coverage. It was found that the noise values were reduced $(1{,}2 \div 1{,}5)$by a factor of one compared to the existing chain drive when rubber bushings were applied to the chain drive of the recommended chain drive. Accordingly, it was confirmed that the performance of the proposed chain drive also increased.

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