Results of dynamic analysis of double-inlet screw conveyor machine assembly

Anvar D. Juraev[1], *Bahtiyordjan* N. Davidbayev[2], *Nodirbek* N. Juraev[3*], and *Jasur* Kh. Beknazarov[3]

[1]Tashkent Textile and Light Industry Institute, Tashkent, 100001, Uzbekistan
[2]Fergana Politechnic Institute, Fergana, 150100, Uzbekistan
[3]Navoi State University of Mining and Technology, Navoiy, 210100, Uzbekistan

Abstract. The article presents the results of theoretical studies of vertical and deflecting vibrations of two-stroke screws with a wavy surface and conveyor screws with a curved base and an elastic element. Based on the analysis of the obtained graphs of the relations of laws and motion parameters, their optimal values are justified. Here, the options for applying rubber gaskets to bearing bearings are considered in two versions, that is, with the same and two different types of stencils. When the rubber bushings of the bearing supports are taken in two different elasticities, the change laws of the vibration of the screw are obtained depending on the size of the supports, the moment of inertia of the screw and the change of the technological resistance force. Introduction

1 Introduction

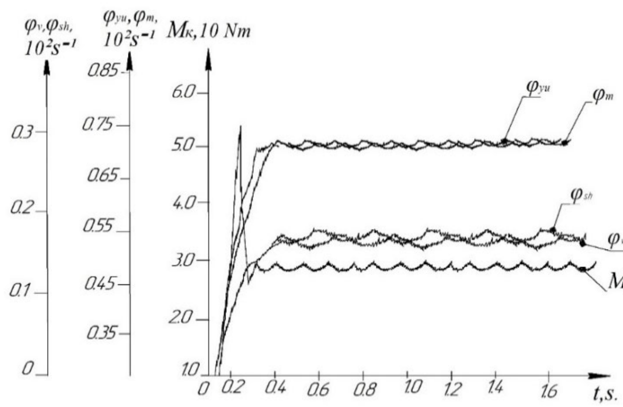
The dynamic analysis of the machine unit is mainly to determine the movement laws and loads of the driver, coupling, belt transmission, drive pulley and screw depending on the resistance moment from the transported material, the frictional resistance of the oscillating bearing support, and the change of the friction-dissipative parameters. Based on the numerical solution of the obtained system of differential equations, the laws of change of rotor shaft, coupling, drive pulley and screw shaft angular velocities and driver loading were obtained.

2 Research methods

From the point of view of the theory of machines and mechanisms, it can be noted that the scientific innovation of the system is mainly due to the deformations of the screw bearings and the belt bushing, its vibrations are taken into account due to the changes in the torque of the frictional forces, and the belt transmission has a VTR and the drive pulley is equipped with an additional shock absorber. Therefore, it is of scientific importance to study their influence on the law of motion of masses. In the obtained laws, when the load is $M_t+M_f=(95\pm1.5)$ Nm, the values of are on average 68.05 s^{-1}, and the angular speed of the driver is in

* Corresponding author: Nodirjura@mail.ru

the range of 72.1 s^{-1}. In this case, their average difference reaches 4.0 s^{-1} [1]. In this case, it is appropriate to emphasize the influence of technological resistance and the torque of frictional forces.



M_q=80,5 Nm+5,6 $sin\omega t$±1,5 Nm; M_{muf}=(12÷14) Nm

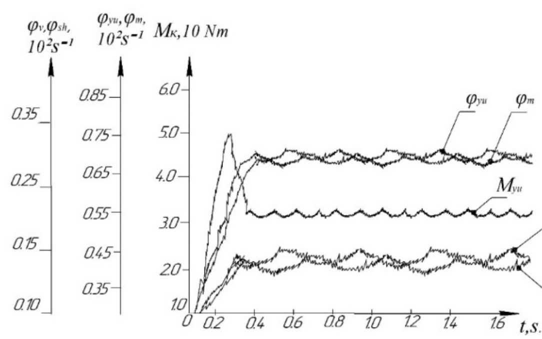


Fig. 1. The driving shaft of the screw conveyor machine unit, the coupling, the drive pulley, the angular speeds of the screw shafts and the laws of change of the loading of the driver.

M_q=140 Nm+8,2 $sin\omega t$±2,5 Nm; M_t=(20÷25) Nm

a) graphs of angular velocities of masses of the machine assembly and technological resistance and torque of the load on the drive shaft, b) vibration coverage of the angular velocities of the rotor shaft, clutch, drive pulley and screw shaft of the double-inlet screw conveyor machine assembly and torque on the drive shaft graphs of technological resistance and torque dependence of friction forces

Accordingly, when the technological loading is on average (165±2.5) Nm, the values are on average (7.0÷7.5) s^{-1} and the values are (1.2÷1.6) s^{-1}. In this case, it can be seen that the angular velocity on the screw shaft is almost reduced to (2.1÷2.5) s^{-1} compared to the nominal value. It can be seen that the average values fluctuate between (14.9÷16.3) s^{-1}. By reworking the obtained laws, graphs of connection of parameters were constructed. Figure 2 shows graphs of dependence of the angular velocities of the mass of the machine and the technological resistance of the load on the drive shaft and the torque of the frictional forces [2].

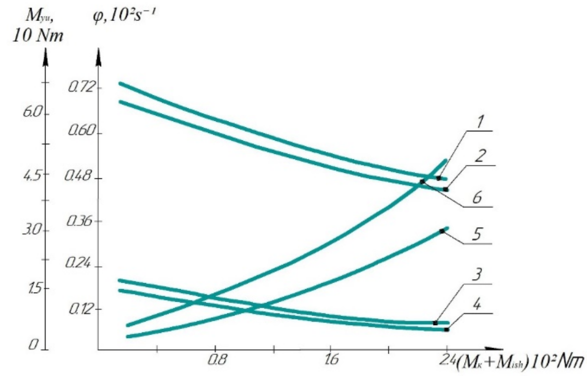


Fig. 2. Graphs of angular velocities of machine unit masses, technological resistance to loading on the drive shaft, and torque dependence of frictional forces.

1- $\dot{\varphi}_{\text{ю}}=f(M_q+M_t)$; 2- $\dot{\varphi}_{\text{м}}=f(M_q+M_t)$; 3- $\dot{\varphi}_{\text{ш}}=f(M_q+M_t)$; 4- $\dot{\varphi}_{\text{в}}=f(M_q+M_t)$;
5, 6-$M_u=f(M_q+M_t)$; 5-$J_{\text{ю}}$=0,25 *kg m*^{2}; 5-J_u=0,128 *kg m*^{2}

Based on the analysis of graphs, the average values of (M_q+M_t) increased from $0.9\cdot10^2$ Nm to $2.4\cdot10^2$ Nm, the average values increased from $0.726\cdot10^2$ s^{-1} to $0.584\cdot10^2$ s^{-1}, and the average values decreases from $0.695\cdot10^2$ s^{-1} to $0.56\cdot10^2 s^{-1}$ in a nonlinear pattern, the values decrease from $1.58\cdot10$ s^{-1} to $0.91\cdot10$ s^{-1}, and the average values are M_q, M_t, c_1, Depending on the values of c_2, c_3 and moments of inertia, it decreases from $1.505\cdot10$ s^{-1} to $0.87\cdot10$ s^{-1} in a nonlinear pattern. In the expressions of technological resistances, the input, step, rotation frequency of the screw are taken into account. It is noted that the angular velocity of the screw shaft is higher than 19 s^{-1}, which ensures sufficient conveyor performance. Therefore, $M_q \leq [(120\div125)\pm(8.5\div11)]$ Nm in order for the conveyor to provide enough work output; It is recommended to have $M_t \leq (20\div23)$. It should be noted that when the load on the rotor shaft is J_u=0.125 kg m^2, it can be seen that the average values of M_u go from $0.32\cdot10$ Nm to $3.1\cdot10$ Nm in a non-linear pattern. (Figure 2. Graph 5). It can be seen that the average values of Mu increase from $0.78\cdot10$ Nm to $4.61\cdot10$ Nm when the values of M_q and M_t increase, respectively, and the value of J_u is 0.25 kg m^2 [3].

It is known that with the increase of the moment of inertia, the movement is smoothed, but the load and power consumption increase. Therefore, it is recommended to be in the range of $J_u \leq (0.2\div0.22)$ kg m^2. Figure 3 shows graphs of dependence of technological resistance and torque of friction forces on the vibration range of angular speeds of the rotor shaft, clutch, drive pulley and screw shaft of the double-inlet screw conveyor machine unit, and the torque vibration range on the drive shaft. Based on the analysis of the resulting connections, the technological and frictional resistance moments generally increased from $0.4\cdot10^2$ Nm to $2.4\cdot10^2$ Nm, with values from 0.45 s^{-1} to 3.1 s^{-1} increases in a non-linear pattern up to, it can be seen that the values are on average $(0.35\div0.4)$ s^{-1} more than it. Therefore, since the moments of resistance act directly on the screw, the values of its angular velocity decrease with respect to, and its values with respect to are greater. In this case, the impact of the screw on the transported product will be effective. However, according to experimental results, if the value of is greater than $(3.0\div3.5)$ s^{-1}, the quality of the product will decrease and damage will increase. Therefore, $M_q \leq [(120\div125) \pm (8.5\div11)]$ Nm; It is desirable to be in the range of $M_t \leq (20\div25)$ Nm. It should be noted that the values are not high and do not exceed $(6.5\div7.5)$ s^{-1}, the rotation is stable. Correspondingly, when the range of vibration of the torque on the electric drive shaft is J_u=0.128 kg m^2, it does not exceed $(4.2\div5.3)$ Nm.

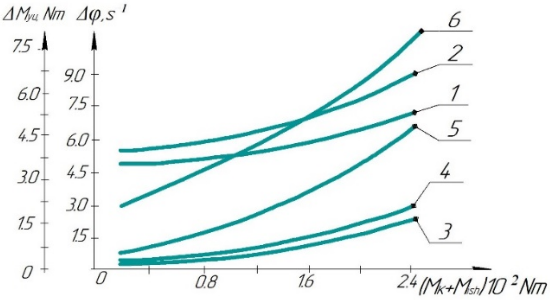
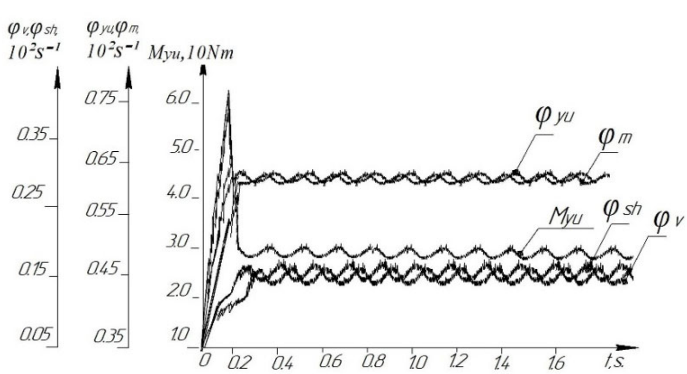


Fig. 3. Graphs of dependence of technological resistance and friction forces on the vibration range of angular velocities of the rotor shaft, clutch, drive pulley and screw shaft of the double-inlet screw conveyor machine assembly and the torque vibration range on the drive shaft.

$$1-\Delta\dot{\varphi}_{ю}=f(M_{к}+M_{ишк});\ 2-\Delta\dot{\varphi}_{м}=f(M_{к}+M_{ишк});\ 3-\Delta\dot{\varphi}_{ш}=f(M_{к}+M_{ишк});$$
$$4-\Delta\dot{\varphi}_{в}=f(M_{к}+M_{ишк});$$ 5, 6-$\Delta M_{yu}=f\,(M_{q}+M_{ishq})$; 5-$J_{yu}$=0,25 *kg m*^{2}; 6-$J_{yu}$=0,128 *kgm*^{2}

3 Results and discussion

Three belt elements were used in the machine assembly. Their actions directly affect the laws of motion of masses. Figure 4 shows the laws representing the influence of the coupling rubber bushing of the machine assembly, the rubber bushing of the drive pulley, VTR belt torque coefficients on the law of rotation of the screw, pulleys, coupling and rotor shaft, and on the engine load [4]. The analysis of the received laws shows that with the increase in the frequency of the belt elements of the machine assembly, the amplitudes of speed fluctuations decrease, but their average values also decrease. Also, the load on the driver increases accordingly. The main reason for this is that the increase in the weights is almost a mass in the interconnection of the masses, the movement is normalized, and the load increases, mainly the connection graphs were built.



c_1=430 *Nm/rad*; c_2=380 *Nm/rad*; c_3=320 *Nm/rad*; M_q=120 *Nm*+6,5*sinωt*±2,2 *Nm*; M_r=(20÷22) *Nm*

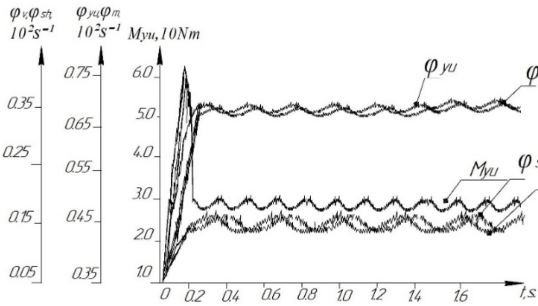


Fig. 4. Laws representing the influence of the coupling rubber bushing of the machine unit, the rubber bushing of the drive pulley with VTR, the belt friction coefficients on the law of rotation of the screw, pulleys, clutch and rotor shaft and the load of the engine.

c_1=400 *Nm/rad*; c_2=320 *Nm/rad*; c_3=290 *Nm/rad*; M_q=120 *Nm*+6,5*sinωt*±2,2 *Nm*; *Mt*=(20÷22) *Nm*

To increase the efficiency of the screw, its rotation frequency is increased. Also, when a double-inlet screw is used, the oscillation frequencies of the angular velocities on the shafts and the torque on the electric drive shaft increase by two times (Figure. 5). The main reason for this is that because the screw threads are displaced by half a step, the loading effect is almost twice the effect on the screw blades as a result of the spatial displacement. In this case, the laws of change of φ_{yu}, φ_m, φ_{sh}, and φ_v depend not only on the moment of technological resistance and friction forces, but also on the changes in the thickness of the belt elements of the machine assembly. This is especially noticeable when double-threaded screws are used. Also, Figure 5 shows the laws of change of φ_{yu}, φ_m, φ_{sh}, and φ_v for M_{yu} the double-inlet version of the machine assembly [5,6].

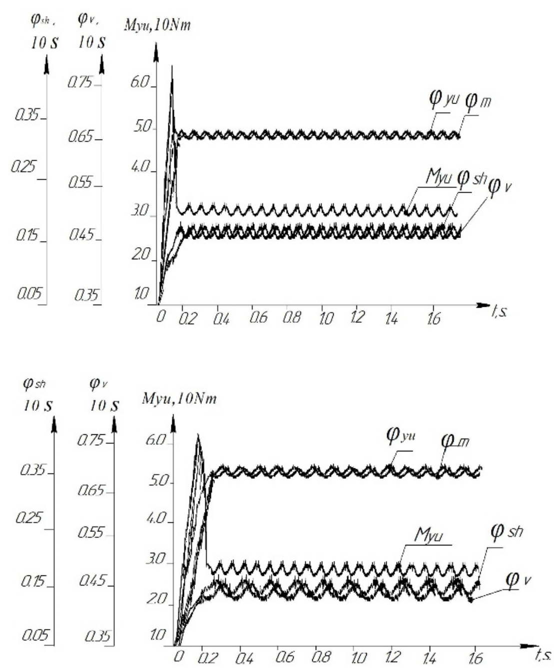


Fig. 5. The appearance of the laws that change of the angular shafts' speeds of the machine unit when the screw is made with double-inlet.

According to the analysis of the graphs, when the stiffness of the belt element that transmits motion to each mass increases from $2.2\cdot10^2$ Nm/rad to $5.5\cdot10^2$ Nm/rad, the values of are decreasing in a non-linear law. In this case, the values of M_{yu} increase from 5.0 Nm to 3.52 Nm when J_u=0.128 kg m^2, and when M_{yu} is 0.25 kg m^2, the increase of M_{yu} goes up to 5.23 Nm. It should be noted that the vertical vibration of the screw decreases with the increase of the uniformity coefficient of the rubber support. This also reduces the friction force. So, the frequency of change of the resistance of the screw increases twice, and affects the laws of change of the angular speed and load.

Figure 6 shows the graphs of the dependence of the rotational speed coefficients of the corresponding belt transmissions on the vibration range of the rotor shaft, coupling, drive pulley and screw shaft angular velocities of the double-inlet screw conveyor machine assembly and the torque vibration range on the drive shaft. However, the reduction of this vibration causes the product to mix and brake less. Therefore, recommended values of sn are recommended in the range of $(5.0\div7.0)\cdot10^3$ N/m. Accordingly, c_1=(380÷450) Nm/rad, c_2=(360÷400) Nm/rad; c_3=(320÷350) Nm/rad values are desirable. It should be noted that when using a double-inlet screw, due to the equalization of the load distribution along its length, the amplitudes of the angular velocity change are up to (8.0÷12)% can be seen to decrease.

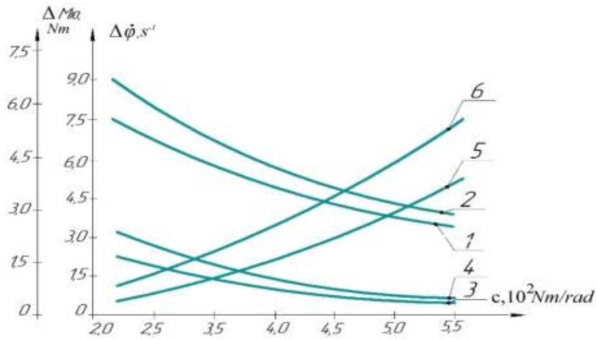
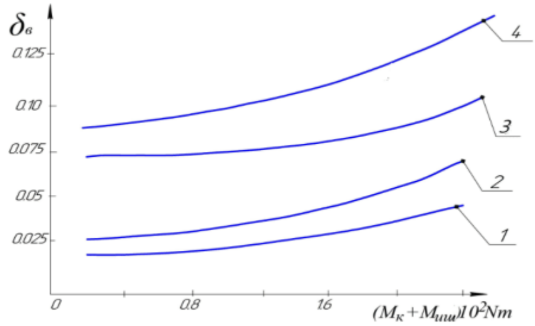


Fig. 6. Dependence graphs of the vibration range of the angular velocities of the rotor shaft, clutch, drive pulley and screw shaft of the double-inlet screw conveyor machine assembly and the torque range of the drive shaft on the rotational speed coefficients of the corresponding belt drives.

$$1-\Delta\dot{\varphi}_{\text{ю}}=f(c_1)\ 2-\Delta\dot{\varphi}_{\text{м}}=f(c_2)\ 3-\Delta\dot{\varphi}_{\text{ш}}=f(c_2)\ 4-\Delta\dot{\varphi}_{\text{в}}=f(c_3)$$

5, 6-M_{yu}=f_c; 5-J_{yu}=0,25 *kg m*^{2}; 6- J_{yu}=0,128 *kg m*^{2}

Graphs of dependence of its angular velocity, unevenness coefficient, technological resistance, and friction force moment changes were obtained when a double-inlet screw was used. According to the analysis of the graphs, when the load increases from $0.4\cdot10^2$ Nm to $2.4\cdot10^2$ Nm, the coefficient of unevenness of the angular velocity of the screw is J_v=2.28 kg·m^2 in a single-threaded screw, the values of δ_v are from 0.088 to 0.415 in a nonlinear law increases, and when J_v=3.5 kg·m^2, it increases from 0.075 to 0.115. Accordingly, it can be seen that the values of δ_v increase nonlinearly from 0.023 to 0.049 when J_v=3.5 kg·m^2 due to the flattening of the load distribution when using a double-threaded screw (Figure. 5, 1 2 graphs) [7,8,9]. So, when a double-threaded screw is used, it is possible to increase the productivity by (25÷35)%. that is, to ensure that the values of δv do not exceed 0.075, the recommended value of technological resistance and torque of friction forces is M_q ≤[(175÷210)±(6.5÷8.0)] Nm and M_t ≤(15÷20) Nm . It should be noted that when c_n=(5.0÷7.0·10^3 N/m), the torque of the friction force decreases by almost (1.3÷1.5) times when using a double-threaded screw compared to a single-threaded screw.



1, 2- for double-inlet screw; 3, 4- for single-inlet screw; 1, 3-J_v=2.28 kg·m^2; 2, 4- J_v=3.5 kg·m^2

Fig. 7. Graphs of the dependence of the angular speed of the machine assembly screw on the unevenness coefficient of the technological resistance and the change of the torque of the friction forces.

It is known that belt elements absorb certain energy during movement. To express this absorption, the dissipative properties of the strap elements are taken into account. 4 belt elements are used in the unit of the machine in question. Absorption in them significantly changes the law of screw movement. According to the results of the research, graphs of dependence of the angular velocities of the double-inlet screw and drive pulley shafts, and the dissipation coefficients of the belt transmissions corresponding to the torque in the driver were constructed. These connections are shown in Figure 7. Analyzing the resulting graphical connections, it can be seen that the angular velocities of the screw and driven pulley decrease in a non-linear manner as v_2 and v_3 increase (Figure 7, graphs 1, 2). In this case, when the values of v_1 and v_4 increase from 1.5 Nms/rad to 8.0 Nms/rad, the screw angular velocity decreases from 16.25 s^{-1} to 14.8 s^{-1}, and the driven pulley shaft angular velocity decreases from 16.95 s^{-1} to 13. It can be seen that it decreases in a nonlinear pattern up to 78 s^{-1}.

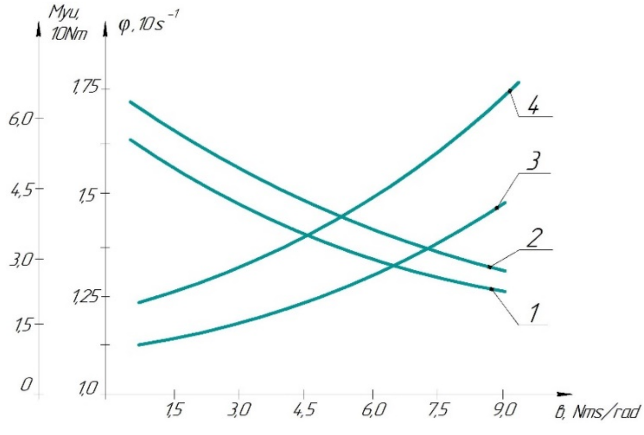


Fig. 8. Graphs of the dependence of angular velocities of double-inlet screw and drive pulley shafts, torque on the driver on the dissipation coefficients of suitable belt drives.

$1-\dot{\varphi}_в=f(в_3)$; $2-\dot{\varphi}_ш=f(в_3)$; 3, 4- $M_ю=f(в_1)$;

3- J_u=0,128 $kg{\cdot}m^2$; 4- J_u=0,25 $kg{\cdot}m^2$

In this case, the screw torque on the drive shaft increases from 1.1·10 Nm to 4.41·10 Nm at J_u=0.128 kg·m^2, while the values of M_u when J_u >0.25 kg·m^2 increase from 1.83·10 Nm to 7, Increases nonlinearly up to 3.5·10 Nm, that is, increasing the dissipation coefficients v_2

and v_3 leads to a decrease in the angular velocities of the two lead screws and the driven pulley, which causes an increase in the loading of the driver. This, in turn, leads to an increase in power consumption. Therefore, the recommended parameters are: $v_2 \leq (3.4 \div 3.6)$ Nms/rad; $v_2 \leq (4.5 \div 4.8)$ Nms/rad; $v_3 \leq (5.1 \div 5.4)$ Nms/rad [8,9].

4 Conclusions

Graphs of dependence of the vertical vibration range of the double-inlet screw of the conveyor on the friction coefficients of the rubber bushings of the bearings were constructed. An increase in the rotation frequency leads to a significant increase in the value of Δz. Therefore, the following parameter values are recommended: $\Delta z \leq (10 \div 12) \cdot 10^{-3}$; $F = (1.5 \div 2.5) \cdot 10^2$ N; $c \geq (3.5 \div 4.0) \cdot 10^3$ N/m).

In order to ensure that the vertical vibration of the two-feed screw does not exceed $(10 \div 12) \cdot 10^{-3}$ m, the rotation frequency of the screw is less than 160 rpm when $m = (0.25 \div 0.35) \cdot 10^2$ kg it is desirable to obtain.

Significantly reduces the amplitudes of the dissipation coefficients of the supports during the vibration of the screw. In order to ensure $\Delta z \leq (10 \div 12) \cdot 10^{-3}$, it is recommended that the values of v be greater than $(3.5 \div 4.0)$ Ns/m.

References

1. A. Djuraev, N.N. Juraev, S.T. Parmonov, Electronic journal of actual problems of modern science, education and training **2181-9750**, 86 (2021). http://khorezmscience.uz
2. I.P. Egamberdiev, Mining Bulletin of Uzbekistan **2**, 97-99 (2011)
3. M.T. Khojiev, A.D. Juraev, O.D. Murodov, A.K. Rakhimov, International Journal of Recent Technology and Engineering **8(2)**, 5806-5811 (2019)
4. O.J. Murodov, A.S. Adilova, In IOP Conference Series: Earth and Environmental Science **1112(1)**, 012150 (2022). https://doi.org/10.1088/1755-1315/1112/1/012150
5. J.Kh. Beknazarov, N.N. Jurayev, Journal of northeastern university **25(04)** (2022). https://dbdxxb.cn/
6. Sh. Kenzhaboev, A. Juraev, Zh. Beknazarov, Actual problems of informatics, mechanics and work technology. Digital technologies in mechanical engineering (2018)
7. I.K. Aleksandrov, Bulletin of mechanical engineering **4**, 33-35 (2005)
8. R.O. Muminov, G.E. Raykhanova, D.A. Kuziev, Coal **5**, 32-36 (2021). https://www.doi.org/10.18796/0041-5790-2021-5-32-36
9. D.A. Kuziev, V.V. Zotov, E.S. Sazankova, R.O. Muminov, Eurasian mining **1** 76–80 (2022). https://rudmet.ru/catalog/journal/2129/