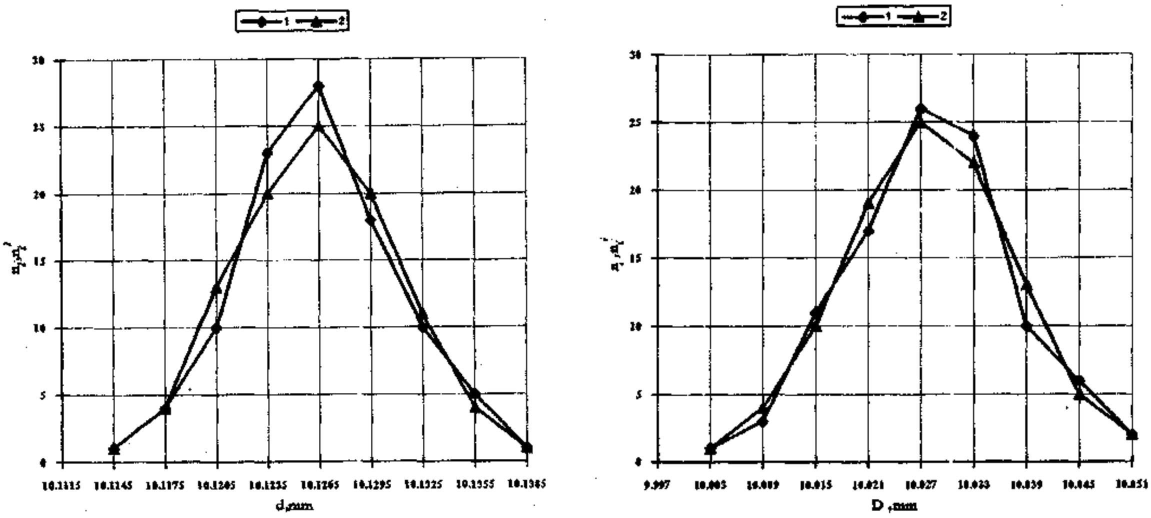
Inputting this value into the formulae (2), we found out that the value of the contact pressure is p_k = 1000MPa. This value is in the permissible limits.



a b

Fig. 1 Normal distribution curves of sizes: a – in teeth; b – in rolling cutter holes;
1 – diagram of empirical frequencies; 2 – diagram of theoretical frequencies

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УДК 621.855.001.24

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3D COMPUTER MODELING OF CHAIN TRANSMISSION IN METAL AND POLYMER DESIGN

Представлено порівняльний аналіз результатів дослідження комп'ютерного 3D-моделювання ланцюгової передачі у металевому та полімерному виконанні за допомогою програмного комплексу SolidWorks. З аналізу графічних залежностей простежуються переваги застосування деталей з полімерних композитів порівняно з традиційними металевими деталями ланцюгової передачі.

Comparative analysis of research results of 3D computer design modeling of chain transmission is in metal and polymer design by means of program complex SolidWorks are presented. From the analysis of graphic dependences advantages of traceable components of polymer composites as compared with conventional metal parts of chain transmission.

Statement of the problem. Today the development of formalized methods of synthesis of chain transmission for mechanical engineering are observed. Solving it gives the opportunity to raise designing quality and labor productivity of the designer and the constructor when applying these methods directly in computer-aided design.

Automation of calculations and 3D modeling of working parts chain transmission, including parts of polymer composites with the aim of search and decline dynamic loads will not only radically reduce labor input in the design and construction, but also will allow to conduct imitation of 3D motion of any chain contour in order to optimize both of constructive and operational parameters and will provide the effective application of numerical analysis methods and optimal synthesis of chain transmission.

Analysis of recent publications. As the basis of elaboration optimal synthesis automation of roller chain transmission on the PC are assumed on the results and dependences which are received in [1] are, built on the principle of modular block designing in the form of applied programs packages of geometric, strength and dynamic calculations. They made complex methodology of automated optimal design of chain transmission KMAOPCT with a practical mass number (2 to 24). Same fragments of the advanced complex methodology are published in [2-6], where the transition to more modern languages of programming is implemented [2], examples of applications are shown [3-5] and the program of parameter optimization is introduced [6]. The most powerful approach to reduce the dynamic loads is the use of polymer composites are parts of chain transmission and the latest production technologies of these parts [7-11]. The use of modern program complexes of 3D computer modeling of published only for kinematics of chain transmission in [12, 13].

The purpose of the report is a comparative analysis of the results given in 3D computer modeling of chain transmission in polymer and metal design.

The main material

1. Linear dynamic analysis is based on frequency investigations. The software calculates reaction model using summing up influences of each mode (functions, equations) to the load [14]. Impact mode depends on the frequency spectrum of load values direction, duration and location of coordinates.

1.1. *Systems with one degree of freedom (SDOF).* Let's consider a simple elastic system (Fig. 1) [14]. On the mass *m* acts force *F (t)* in the direction *u (t)* as a function of time. The mass can move only in the direction *u (t)*. The spring stiffness *k* is resisted to motion of the mass.

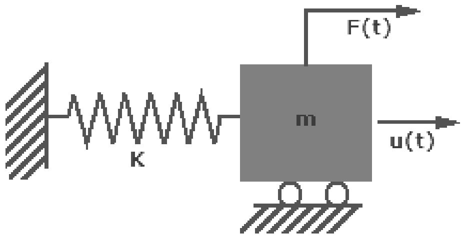


Fig. 1. Simple elastic system with one degree of freedom (SDOF)

Let's write the Newton's second law for the system, which varies with time *(t)*, then we obtain:

$$F(t) - k \cdot u(t) = m \cdot \ddot{u}(t) \tag{1}$$

or

$$F(t) = m \cdot \ddot{u}(t) + k \cdot u(t), \tag{2}$$

where $\ddot{u}(t)$ – acceleration of the mass, which varies with time *t* and is equal to the second derivative of the path *u (t)* in time *t*.

Theoretically, if the mass is displaced and escaped, it will continue to oscillate with the same amplitude infinitely for a long time. In practice (Fig. 2) [14], the mass vibrates with an amplitude, which gradually is diminished until it comes in a dormant state of rest.

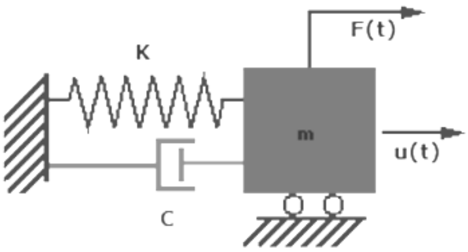


Fig. 2. Simple elastic system with one degree of freedom (SDOF) with the account to damping (c)

This phenomenon is known as the damping, which is caused by the loss of energy due to friction and other effects. Let's assume that the damping force is proportional to velocity. With damping the above equation (2) would be:

$$F(t) = m \cdot \ddot{u}(t) + k \cdot u(t) + c \cdot u(t), \qquad (3)$$

where $\dot{u}(t)$ – mass velocity, which varies with time *t* and is equal to the first derivative of the path *u (t)* in time *t*.

1.2. *Systems with many degrees of freedom (MDOF).* For this system *m*, *c* and *k* becomes matrices instead of single values and the equation of motion (modes) can be expressed as:

$$[M]\{\ddot{u}(t)\} + [C]\{\dot{u}(t)\} + [K]\{u(t)\} = \{f(t)\}, \qquad (4)$$

where $[M] = n \times n$ – symmetric matrix of inertia; $[C] = n \times n$ – symmetric damping matrix; $[K] = n \times n$ – symmetric stiffness matrix; $\{f(t)\} = n$ – dimensional vector of force; $\{u\}$, $\{\dot{u}\}$, $\{\ddot{u}\}$ – *n*-dimensional vectors of displacement, velocity and acceleration respectively.

Equation (4) is a system *n* of ordinary differential equations compatible with constant coefficients. The equations of motion are not only interconnected through the parameters of mass, stiffness and damping, but also depends on the coordinate system used to describe the equations of motion.

The parameters which were set to research the dynamics of chain transmission:

– direction of rotation of the driving sprocket – counterclockwise speeds n_1 = 300m^{-1};

– moment resistance of the driven sprocket T_2 = 100 N·m;

– period of time during which the research will be – from 0 to 4 seconds, which corresponds to more than two periods of rotation of the chain contour;

– acceleration of gravity (g = 9,80665 m/s^2) right in the direction opposite to the axis of *Y*.

Let's characterize the time research of 3D mechanisms:

– from 0 to 0,5 second driving sprocket transmission is gradually gaining speed (0 – 300 m^{-1});

– from 0,5 to 3,5 seconds – the system goes in to steady motion of chain transmission;

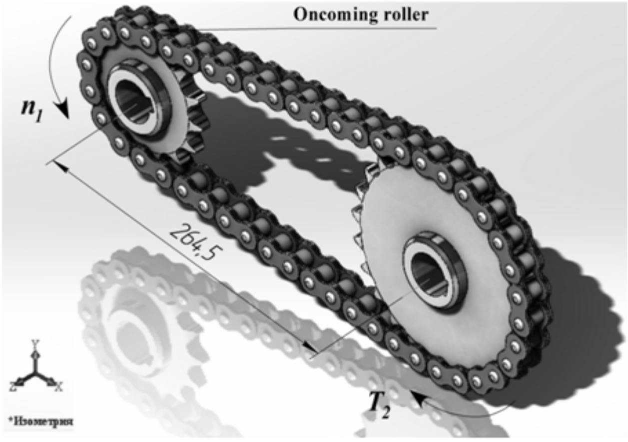
– from 3,5 to 4 seconds driving sprocket gradually reduces its speed (300 – 0 m^{-1}).

Note that the software package SolidWorks gives the possibility to determine position relative to the global coordinate system of any parts in chain contour at the appropriate time.

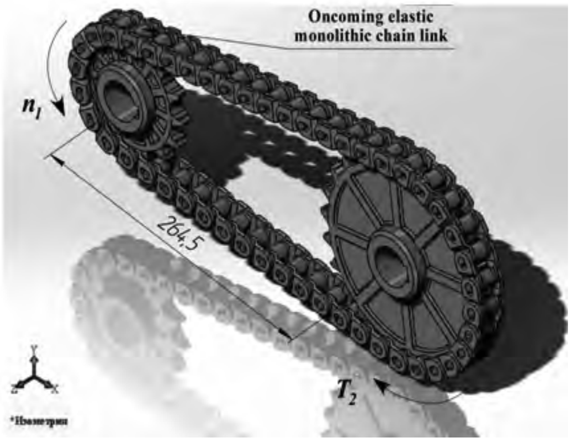
2. Let's construct a 3D model of chain transmission in metal (Fig. 3, a) and polymer (Fig. 3b) design on the following parameters: teeth number of the driving sprocket z_1 = 15, the teeth number of the driven sprocket z_2 = 25; tooth profile – “with displacement”; class precision of sprocket “A”; chain ПР-19,05-3108, slope angle of line centers “0”.

For constructing a chain transmission in polymer design we use elastic monolithic chain link, the invention patent for which was granted [15]. Material of sprockets and chain links is polyamide ПА6-210КС.

3. Let us consider and analyze graphs, which are obtained from the research of motion of chain transmission through the software SolidWorks. For constructing the comparable dynamic characteristics we select oncoming roller chain (Fig. 3, a) to the driving sprocket in the metal design and an oncoming elastic monolithic chain link (Fig. 3b) in the polymer design and their contact pair on the contact results of which we obtain graphics of friction contact points.



a – in metal design



b – in polymer design

Fig. 3. 3D models of chain transmission

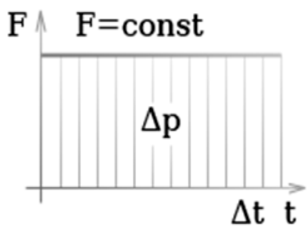
3.1. *Changing the force impulse.* Force impulse is the change of body's impulse (quantity of motion). Force impulse due to acceleration (change is velocity) or the force effect and is equal to the integral of force that varies in time:

$$\vec{F} = m \cdot \vec{a} = m \frac{\Delta \vec{u}}{\Delta t} \tag{5}$$

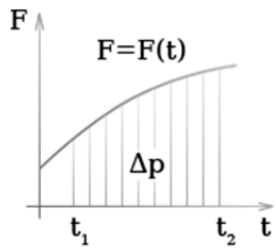
$$\Delta \vec{p} = m \cdot \vec{u} = \vec{F} \cdot \Delta t \ , \tag{6}$$

where F – constant force that accelerates the body, N; Δu – change in the speed of body, m/s; Δt – the duration of the force effect, s; Δp – change in body's impulse (force impulse), N·s.

The equation (6) is valid only when the force F does not change with in a time Δt (Fig. 4 a).



a – force is not changed with time



b – force that varies with time

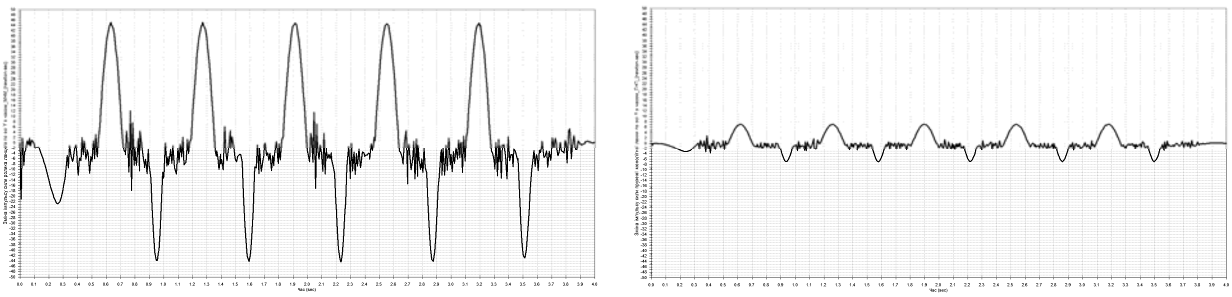
Fig. 4. Impulse force

If the force F varies with in a time (Fig. 4b), the formula (6) will have the form:

$$\Delta \vec{p} = m \cdot \vec{u} = \int_{t_1}^{t_2} \vec{F} dt \tag{7}$$

Fig. 5 shows a graph of change in force impulse.

The upper graph peaks characterize the changing in force impulse of roller chain (Fig. 5, a) and of elastic monolithic link (Fig. 5, b) during contact with the driving sprocket, and lower peaks are with the driving. The intervals of time between the contacts with the sprocket roller chain and elastic monolithic link are in driving and driven branches of the chain contour. The graphs (Fig. 5) clearly show the advantages application of chain transmission parts of polymeric materials: maximum and minimum values of change impulse force is several times smaller.



a – in metal design *b – in polymer design*

Fig. 5. Changing of the force impulse in the investigated part of the chain contour on the axis Y, (N·s)

3.2. *Moment of friction forces.* Let's define for the movable cylinder brake moment of the body's rotational motion. If we consider this moment relatively to the center of a rotating wheel (eg, car wheels) it is equal to the product of the brake axial force on the wheel radius. As for the point of contact of the moving body to the ground, the moment is equal to the product of tractive force that balances the force of friction on the wheel radius (Fig. 6 a).

a *b*

Fig. 6. Moment of rotational motion of the body

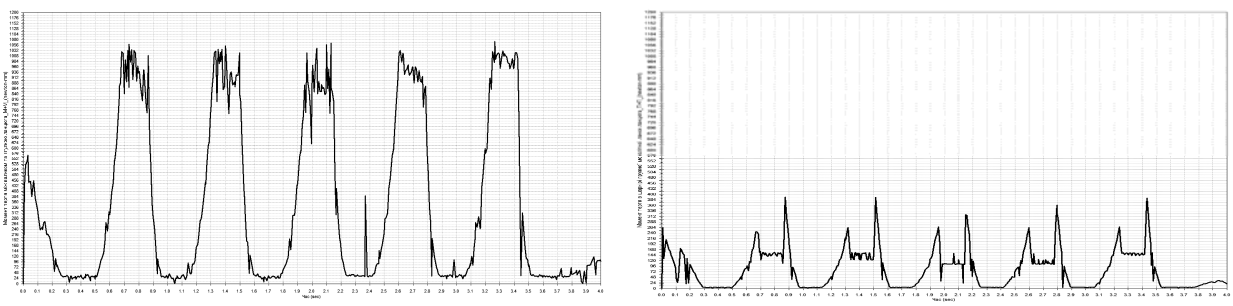
$$M_t = F_{t(\kappa)} \cdot R = F \cdot R\,, \tag{8}$$

where $F_{t\,(\kappa)}$ – friction force; R – radius of the body; F – tractive force.

On the other hand, the moment of friction force is the product of normal pressure force N on the shoulder length which is equal to the coefficient of rolling friction f (Fig. 6 b):

$$M_t = f \cdot N \tag{9}$$

Fig. 7 shows graphs of changing moment of friction forces in the joints of chain transmission.



a – in metal design (contact pair: bush-pin)

b – in polymer design (contact pair: two adjacent elastic joints monolithic links)

Fig. 7. Changes of moment friction force in the joints of investigated chain transmission (N · mm)

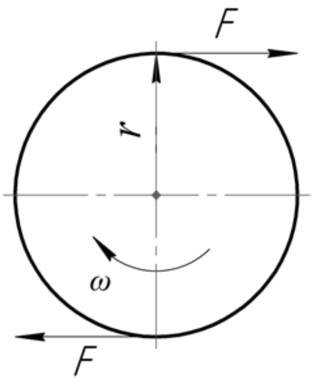


Fig. 8. A pair of forces acting on the rotor of the electric motor

The maximum values of changing moment of friction force (Fig. 7) correspond to the passage of joints on the driving branch of chain contour. Minimum values are on the driven branch. In the time interval between the minimum and maximum values (increase moment of friction forces) there is a contact of roller and elastic monolithic chain link with the driven sprocket. During the decreasing moment of friction forces from the maximum to minimum values there is a contact with the driven sprocket of chain transmission.

The graphical dependences (Fig. 7) show the reduction to 2.5 times the moment of friction forces while passing through the elastic polymer monolithic chain link round the chain contour in comparison with the value of the moment of friction force in metal contour.

3.3. *Torque engine.* As for the passport data of electric motor we can determine its motor torque and the force which it develops on the rotor (Fig. 8).

Fig. 8 shows how the applied force is in the form of a pair forces F to the rotor radius r, which rotates. Motor torque $M_{ОБ}$ is a measure of its effort that changes the angular velocity ω. Between the electric power P (W) of the motor angular velocity ω (rad/s), the force F (N), the rotor radius r (m) and torque $M_{ОБ}$ (N·m) there is the following correlation:

$$M_{ОБ} = \frac{P}{\omega} = \frac{P}{(\pi \cdot n/30)} = \frac{30P}{\pi \cdot n} = \frac{9{,}55 \cdot P}{n}, \tag{10}$$

where n – rotation frequency of electric motor, s^{-1}.

Torque asynchronous electrical motor with squirrel cage rotor varies depending on the rotating speed of the rotor on the curve is shown in Fig. 9 where three values of the rotary moment of electric motor are shown, which are of practical importance: the nominal moment of M_H which develops motor in the nominal operation, starting moment $M_П$, corresponding to the start, the maximum moment of M_M, which develops motor at rotating speed, less than the nominal and meet the critical speed of rotation n_{KP}.

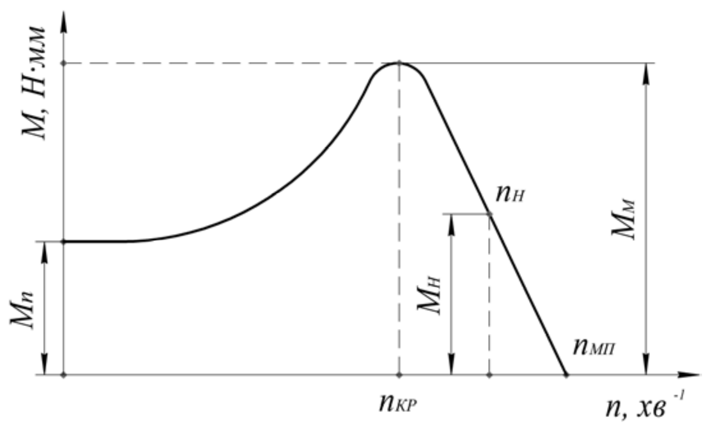
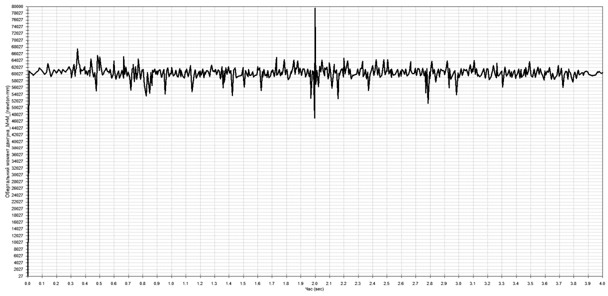


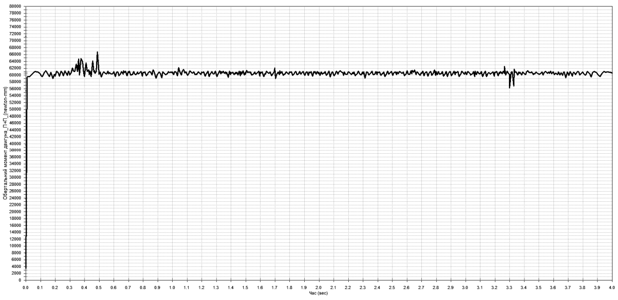
Fig. 9. Changing the starting points and the maximum asynchronous electric motor depending on rotating speed

Max torque determines the overload capacity of the motor. When it is overloaded, which is more than the maximum moment the motor reduces its rotational speed ($n<n_{KP}$), comes into unstable mode and stops. Steady regime of engine operation in the range of $n_{МП}$ to n_{KP} can be resumed only by removing the load from the rotor.

Fig. 10 shows a graph of change the rotary moment of electric motor.



a – in metal design



b – in polymer design

Fig. 10. Changing the motor rotary moment (N · mm)

The range of the motor rotary moment in metal chain transmission (Fig. 10, a) is much greater than in polymer design (Fig. 10 b).

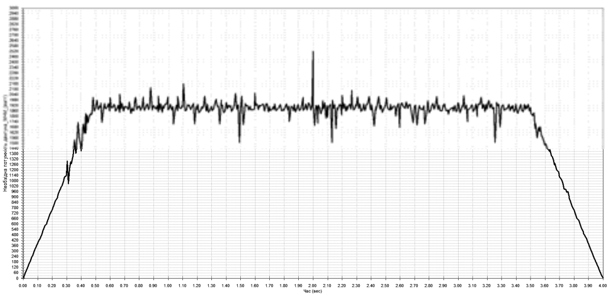
The use of chain transmission in polymer design give us a chance to reduce this range and increase the stability of the transmission the rotary moment to the driven sprocket.

3.4. *The required motor power.* Power on the output shaft drive $P_{ВИХ}$ (W) can be calculated:

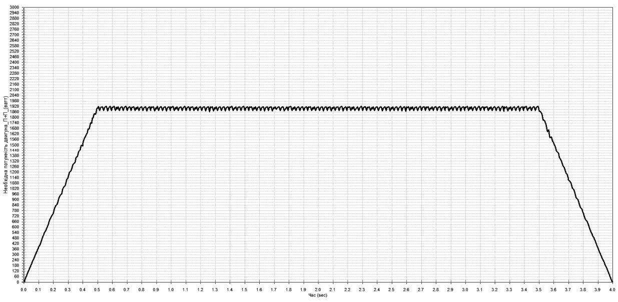
$$P_{ВИХ} = F_t \cdot R_p \cdot \omega_{ВИХ}\,, \tag{11}$$

where F_t – circular force, N; R_p – radius of the rotor, m; $\omega_{ВИХ}$ – angular velocity on the output shaft drive, s^{-1}.

Fig. 11 shows a graph of the changes in required motor power.



a – in metal design



b – in polymer design

Fig. 11. Change the required motor power (W)

The range of the required motor power during the steady regime of operation in chain transmission in metal design (Fig. 11, a) is several times greater than in the polymer design (Fig. 11, b). Reducing the range of change of the required motor power and its reduction is achieved in the polymer chain transmission.

3.5. *Kinetic energy.* It is known to provide the body acceleration and make it move at a certain speed, it is necessary to perform a job that accumulates in the form of kinetic energy of the body. The kinetic energy of the body $W_К$ (energy of motion) can be written as:

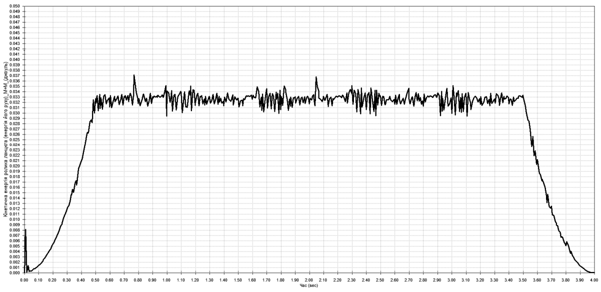
$$W_К = m \cdot a \cdot s = \frac{1}{2} m \cdot u^2\,, \tag{13}$$

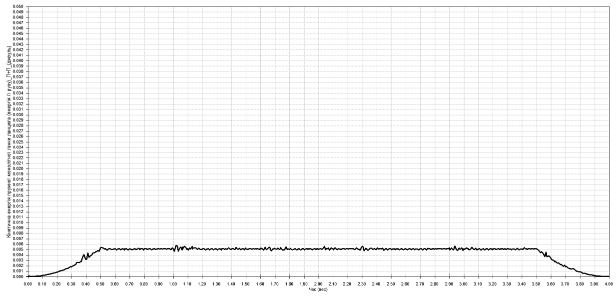
where s – displacement of the body, м; u – speed of the body, м/с; a – acceleration of the body, м/с^2.

Changes in the value of the velocity u_1 to u_2 leads to the changes of the kinetic energy:

$$\Delta W_К = \frac{m}{2}\left(u_2^2 - u_1^2\right) \tag{14}$$

Fig. 12 shows a graph of change of kinetic energy.





a – in metal design *b – in polymer design*

Fig. 12. Change in kinetic energy (J)

The maximum change in kinetic energy is several times greater in metal chain transmission (Fig. 12 a), as compared to its performance polymer (Fig. 12, b). The reduction of the kinetic energy increases the reversibility of chain transmission, ie to change the motion direction of the system it is necessary to apply less force.

Conclusions. With the help of SolidWorks software 3D model of two chain transmissions were built (Fig. 3) in metal and polymer design were analyzed.

The analysis of the chain transmission was based on frequency researches: reaction model calculation by summing of influences on each mode on the load.

The results of the research of chain transmissions specified software package are graphics (Fig. 5, 7, 10 - 12), the analysis of which suggest that the investigated parameters of chain transmission in polymer design significantly benefit as compared with metal:

– change impulse force along the axis *Y* (Fig. 5);

– change since friction force in the joints (Fig. 7);

– change in the rotary moment motor (Fig. 10).

The range reduction of required motor power change and its decline during steady regime of operation is achieved in the polymer chain transmission (Fig. 11).

Having analyzed the graphs of kinetic energy change (Fig. 12) it can be stated that chain transmission in polymer design is more reversible than in metal, that is to change the direction of motion of the system it is necessary to put less force.

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УДК 517.9+534.111

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IMPROVED RESILIENCE THREE ROLLING CUTTER DRILL USING CAD / CAE-SYSTEMS

Розглядаються типові конструкції кріплення твердосплавних зубців до корпусу шарошки у тришарошкових долотах. Запропоновано нову конструкцію посадки породоруйнувального елемента у шарошку, яка покращує якість закріплення зубця за менших напружень у з'єднанні. Проаналізовано напружено-деформівний стан запресованого зубця та шарошки у типовій конструкції та модернізованій за допомогою cad/cae системи.

Standard design fastening hard alloy teeth to the body of cutter of three rolling cutter drill are discussed in this article. new design landing rock cutting element in the rolling cutter, which improves the quality of the consolidation of the tooth at smaller stresses in the connection has been offered. exertion and strain condition of pressed tooth and rolling cutter in a typical and upgraded construction is analyzed for help cad/cae system.

Statement of the problem. Development of mineral resources is an important problem that faces the workers in the sector of the national economy. Industry requires oil and gas more. Engineers need to look for ways of improving production of hydrocarbons from wells. In this regard, reducing the cost of construction of wells is extremely actual problem. Now in Ukraine main volumes deep drilling performed by rotary method using three rolling cutter bits. That is why improving production technology and changes in instrument design parameters of the bit is important reserve increase technical and economic parameters of well construction [1, 3].

This is only possible when using the new upgraded high-performance drilling tools advanced construction technology of oil and gas wells. In a relatively short period of time rock cutting drilling tools used in oil and gas wells has changed. The design of the drilling tool is quite complicated and being