DYNAMIC PARAMETERS OF A CHAIN TRANSMISSION IN METAL AND POLYMER DESIGN

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Abstract: *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.*

Comparative analysis of dynamics 3D computer design modeling of chain transmission in metal and polymer design by means of program complex SolidWorks are presented. From the analysis of graphic dependences precisely traced advantages of application components of polymer composites as compared with traditional metal parts of chain transmission: dynamic loads in chain contour, force of the impact between the oncoming roller and sprocket, dynamic irregularity of rotation the sprockets.

KEYWORDS: CHAIN TRANSMISSION, PARTS OF POLYMER COMPOSITES, COMPARATIVE DYNAMIC PARAMETERS

1. Introduction

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.

A multi mass chain drive is the system, which consists of interactive and intercaused indivisible elements, has many possible realization in the process of functioning and that is why behaves to the complicated systems. The new approach to calculation and designing of chain drives must be based on the account of the real dynamic processes which take place during their work, use of polymeric composites for making of sprockets and chains and change-over to the automated optimal design, which will enable to choose the aggregate of values of their parameters, at which yet on the stage of design high dynamic quality of transmissions and drives will be provided. The majority of machines demands advancing their drives, in particular chain drives, with the purpose of a decrease of specific consumption of materials and power costs of speeding up and braking of driven parts. One of basic directions of achievement of this aim there is the use of modern CAD of the programs [1-3]. Main reason of the use of CAD of the programs is ability of realization of computer experiment on the terms of work of machine or mechanism, near to the real.

The decline of the dynamic loading, pin tensions and wear of parts of chain drive is reached at by application of polymeric and metal-polymeric sprockets and chains. Production of parts for chain-drives from the polymeric compos of low-waste and not very much power-consumption. From polymeric compos it more easily to make the parts of complicated form, they are so technological, that allow to create the so-called integrated parts production of that from a metal far more expensive or it is impossible in general.

2. Preconditions and means for resolving the problem

2.1. Theoretical Model

A linear dynamic analysis is based on frequency researches. Software expects the reaction of model by means of summation influences of every mode (functions, equation) on loading [4]. Influence of mode depends on the frequency spectrum of loading, value, straight, duration and coordinates of location of model. The equations of motion are not only linked the parameters of mass, rigidity and damping, but depends on the coordinate system used to describe them.

In cases where the linear dynamic analysis generates false results, such as a violation of the assumptions on which it is based, uses a non-linear dynamic analysis is based on the incremental method of managing loading. It is used to solve the problems of nonlinearity, caused by material behavior, large displacements and contact conditions.

In nonlinear dynamic analysis equation equilibrium of dynamic system in the time interval t + D$_t$, will have the form [4]:

$$[M]^{t+D_t}\{\ddot{U}\}^{(i)}+[C]^{t+D_t}\{\dot{U}\}^{(i)}+{}^{t+D_t}[K]^{(i)}\,{}^{t+D_t}[DU]^{(i)}={}^{t+D_t}\{R\}-{}^{t+D_t}\{F\}^{(i-1)}, \quad (1)$$

where $[M]$ – matrix of mass system;

$[C]$ – damping matrix of the system;

${}^{t+D_t}[K]^{(i)}$ – stiffness matrix of the system;

${}^{t+D_t}\{R\}^{(i)}$ – vector of external nodal loads applied;

${}^{t+D_t}\{F\}^{(i-1)}$ – vector of internal forces generated in the nodes upon repetition (*i* – *1*);

${}^{t+D_t}[DU]^{(i)}$ – vector of nodal displacements at increasing repetition (*i*);

${}^{t+D_t}\{U\}^{(i)}$ – complete displacement vector to repeat (*i*);

${}^{t+D_t}\{\dot{U}\}^{(i)}$ – vector full speed on repeat (*i*);

${}^{t+D_t}\{\ddot{U}\}^{(i)}$ – vector of full acceleration on repeat (*i*).

Using implicit time integration schemes such as Newmark-Beta or Wilson-Theta and using the iterative Newton method, equation (1) has the form:

$${}^{t+D_t}[\overline{K}]^{(i)}\,\{DU\}^{(i)}={}^{t+D_t}\{\overline{R}\}^{(i)},$$

where ${}^{t+D_t}\{\overline{R}\}^{(i)}$ – effective loading vector;

$${}^{t+D_t}\{\overline{R}\}^{(i)}={}^{t+D_t}\{R\}-{}^{t+D_t}\{F\}^{(i-1)}+[M]\left(-a_0\left({}^{t+D_t}\{U\}^{(i-1)}-{}^{t}\{U\}\right)+a_2\,{}^{t}\{\dot{U}\}+a_3\,{}^{t}\{\ddot{U}\}\right)+$$
$$+[C]\left(-a_1\left({}^{t+D_t}\{U\}^{(i-1)}-{}^{t}\{U\}\right)+a_4\,{}^{t}\{\dot{U}\}+a_5\,{}^{t}\{\ddot{U}\}\right)$$

${}^{t+D_t}[\overline{K}]^{(i)}$ – effective stiffness matrix;

$${}^{t+D_t}[\overline{K}]^{(i)}={}^{t+D_t}[K]^{(i)}+a_0[M]+a_1[C]$$

a_0, a_1, a_2, a_3, a_4 i a_5 – constants implicit integration methods.

Iterative schemes for solving nonlinear dynamic analysis available: Newton-Raphson algorithm (NR) and variable algorithm Newton-Raphson (MNR).

Equation contact force between two contacting parts, N [4]:

$$F_n=k\cdot\left(g^{e}\right)+Step\left(g,\quad 0\quad 0\quad d_{MAX},\quad c_{MAX},\right)\cdot dg/dt\ ,$$

where *k* – stiffness of the material at the boundary interaction between two contacting parts;

g – penetration of one body into another geometry;

e – rate of perceived exponential force compared with offset model;

d_{MAX} – limit penetration;

c_{MAX} – maximum damping on the boundary interaction;

dg/dt – speed of penetration at the point of contact.

Consider the example of using SolidWorks to analyze the dynamic parameters of the chain transmission according to [5] in the metal (Fig. 1) and the polymer performance (Fig. 2). In 3D simulation used parameters and qualitative characteristics of sprockets chain transmission ГОСТ 592-75; metal chain - ГОСТ 13568-97, corresponding to ISO 606-94, and polymer – according to [6]. Unfortunately, Fig. 1, 2 not fully reflect the actual movement of the chain contour (exists authored animated version).

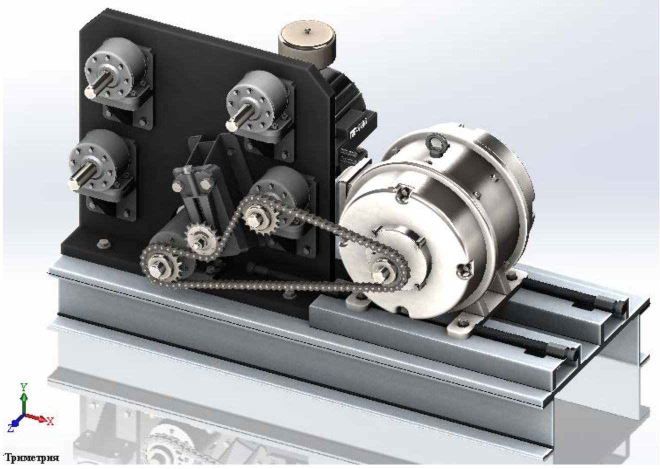

Fig. 1. *3D model of experimental stand in metal performance*

Fig. 2. *3D model of experimental stand in polymer performance*

The main dynamic parameters conducted analysis of motion 3D models of chain contours SolidWorks software package are:

- change of kinetic energy with a change in velocity of the metal (Fig. 3) and polymer (Fig. 4) performance;
- change of impulse force oncoming on the sprocket in a metal joint (Fig. 5) and the cylindrical part of the elastic monolithic link [6] in the polymer (Fig. 6) performance;
- the power contact (impact) between the leading sprocket and oncoming joint chain (Fig. 7) in metal and elastic monolithic link in the polymer performance (Fig. 8);
- dynamic irregularity rotation driving mass with metal an sprocket (Fig. 9) and polymeric sprocket (Fig. 10);
- dynamic load of metal (Fig. 11) and polymeric (Fig. 12) performance contours.

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

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

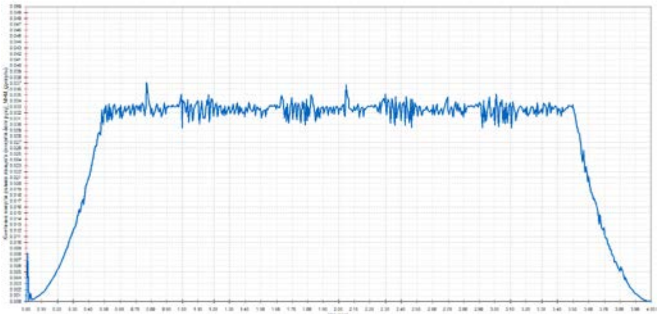

Fig. 3. *Change of kinetic energy in metal performance (J)*

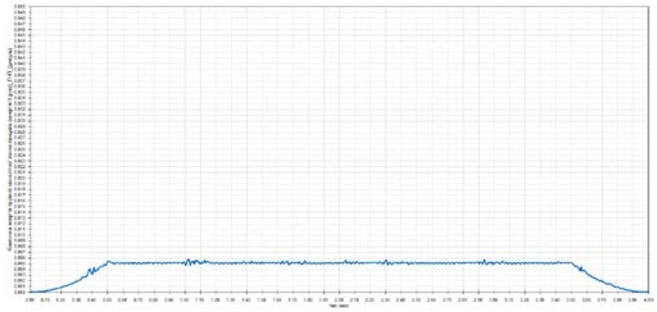

Fig. 4. *Change of kinetic energy in polymer performance (J)*

The maximum change in kinetic energy is several times greater in metal chain transmission (Fig. 3), as compared to its performance polymer (Fig. 4). 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.

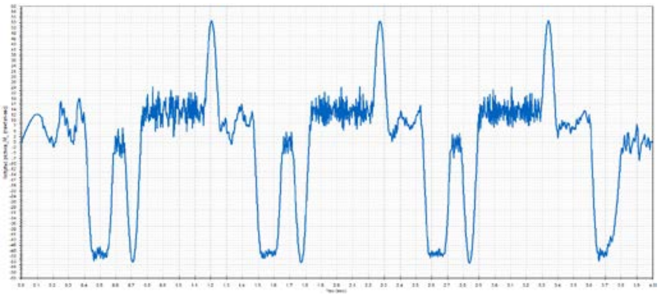

Fig. 5. *Changing impulse force along the axis Y, (N · s) in metal performance*

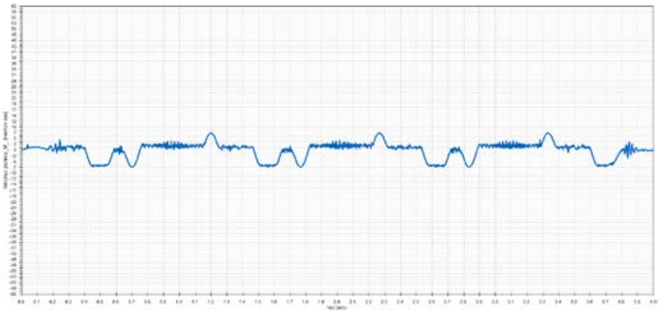

Fig. 6. *Changing impulse force along the axis Y, (N · s) in polymeric performance*

The upper graph peaks characterize the changing in force impulse of joint chain (Fig. 5) and of elastic monolithic link (Fig. 6) during contact with the driven sprocket, and lower peaks are with the driving. The intervals of time between the contacts with the sprocket joint chain and elastic monolithic link are in driving and driven branches of the chain contour. The graphs (Fig. 5, 6) clearly show the advantages application of chain transmission parts of polymeric materials: maximum and minimum values of change impulse force is several times smaller.

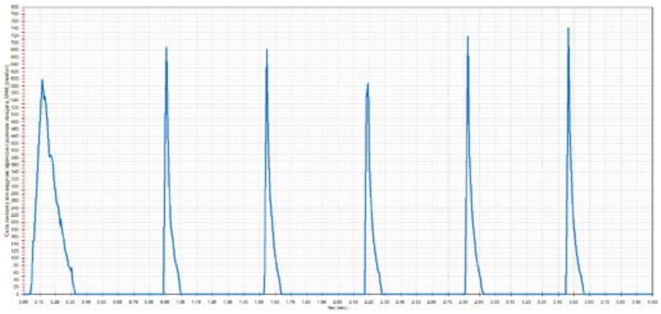

Fig. 7. *Power contact between the sprocket and the driving oncoming joint*

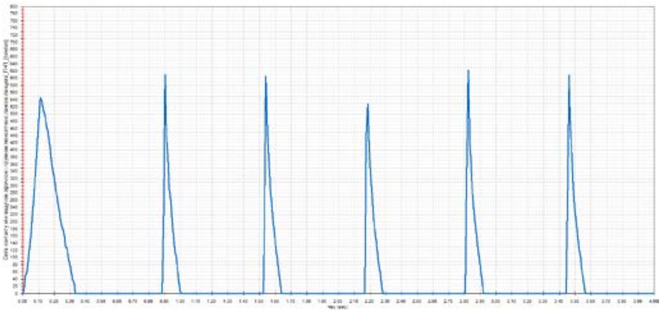

Fig. 8. *Power contact between the driving sprocket and elastic monolithic link*

Figures 7 and 8 show that the force of contact (impact) between the driving sprocket and oncoming joint chain (Fig. 7) higher compared to monolithic elastic contact links and driving sprocket (Fig. 8).

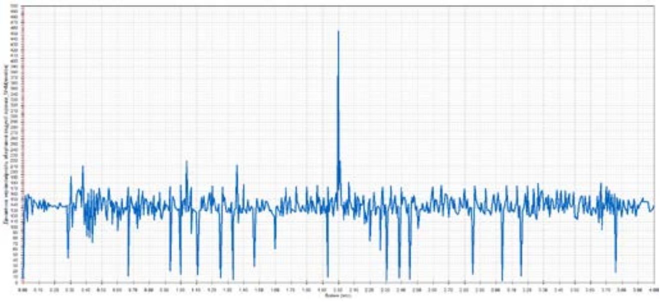

Fig. 9. *Dynamical irregularity rotation of driving mass with metal sprocket*

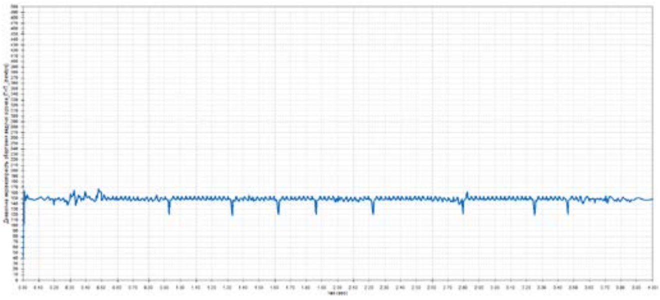

Fig. 10. *The dynamic irregularity rotation of driving mass with polymeric sprocket*

The curve of the graph (Fig. 10) clearly shows a decrease of dynamic range values dynamic irregularity of rotation driving sprocket and its constancy and stability in performance compared to the metal (Fig.9), in which it is much more.

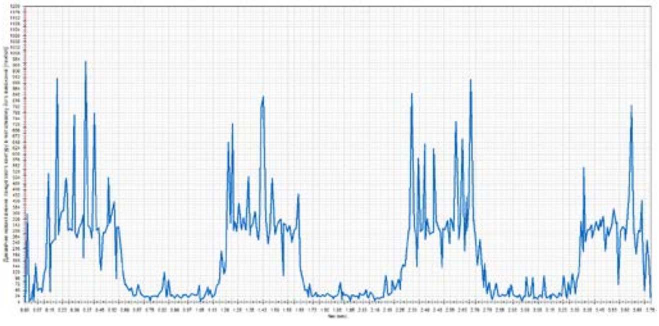

Fig. 11. *The dynamic loading chain contour in metal performance*

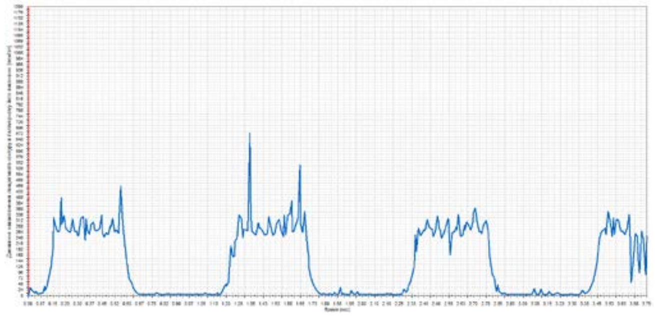

Fig. 12. *The dynamic loading contour in polymeric chain performance*

Fig. 12 clearly shows the decrease of dynamic load in polymeric performance chain contour (mean 134N) in comparison with a dynamic load (Fig. 11) in a metal contour (mean 182N).

2.2. Experimental stand

In Fig. 13 and 14 are photos of the experimental stand [5] equipped a metal and polymeric chains and sprockets.

In experimental researches used 4 sensors ohmic resistancethat are sealed in a special link measurement (2 - on the outside of the link and 2 - on the inside), which fixed the change in tension-squeeze deformation. For greater sensitivity of sensors connected by half-bridge scheme. In order to amplify the signal from the sensors used instrumentation amplifier AD 8555.

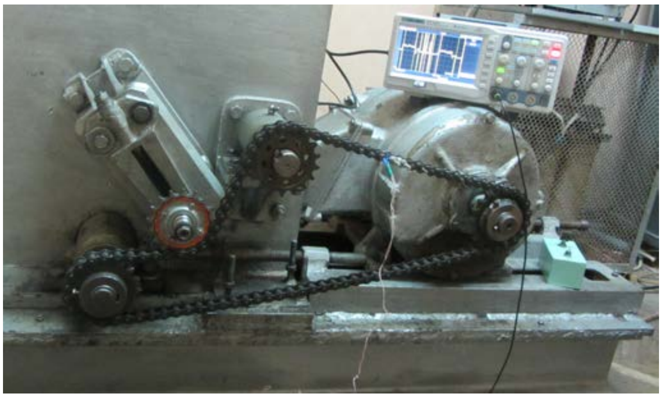

Fig. 13. *The experimental stand is equipped with a metal chain transmission*

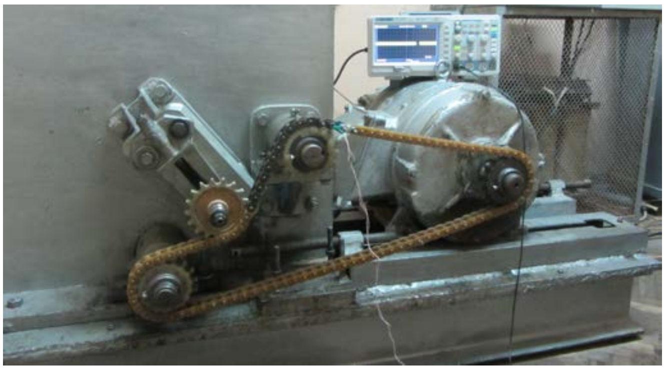

Fig. 14. *The experimental stand is equipped with polymeric chain transmission*

As a result of experimental research of chain drives (Fig. 13, 14) were obtained oscillograms dynamic loading of the chain contour (Fig. 15).

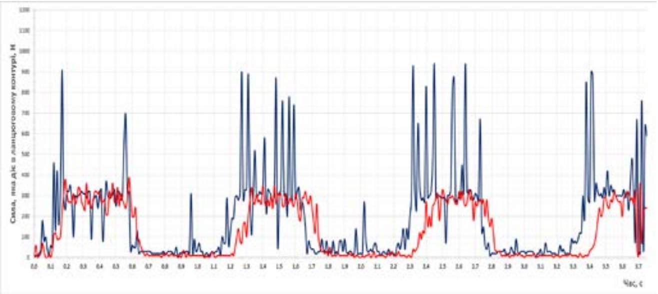

Fig. 15. *Experimental oscillograms dynamic loading:*
- blue curve - a metal chain drive at speed $n_1 = 300s^{-1}$,
- red curve - polymer chain drive at speed $n_1 = 290s^{-1}$.

From the analysis of oscillograms (Fig.15) that the average value of the dynamic loading in metal chain contour is 191N, and his performance polymeric - 128N.

3. Conclusion

From the analysis of the curves as the experiment and the simulation shows that the chain transmission to polymer performance provides:

- reducing the kinetic energy that allows to obtain greater reversibility, ie to change the direction of motion of the system is necessary to apply less force;
- reducing the force impulse oncoming on the sprocket joint several times that allows to put less force to change the direction of rotation of the contour;
- reducing the contact force (impact) due to greater damping coefficient of the material;
- lowering range, stability and constancy values dynamic irregularity rotation of driving mass.

Analyzing the graphs (Fig. 11, 12) and oscillograms (Fig.15), one could argue that the difference of theoretical and experimental mean values of dynamic loading in the chain contours does not exceed 5%, which demonstrates the possibility to use SolidWorks software for the calculation of any chain contours.

Application of SolidWorks software allows not only to modeling and simulation of real work chain drives, but also conduct their analysis with a view to switching to automated optimal design for high dynamic quality of material and energy consumption.

4. Literature

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