Mechanisms and Machine Science 78

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Robotics and Mechatronics

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Contents

Dynamic Model of a Crank Press in the Process of Braking

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Abstract. The paper studies the dynamic of a brake of crank press. At present, the dynamic research of brake of the crank presses, with account of interaction with other links, is a priority. The crank press contains movable parts and links, the mass of which is from one hundred kilograms to several tons. These parts and links are cyclically stopped when braking with a crank press almost instantaneously, and they are subject to high dynamic loads. To simulate and analyze the movement of crank press with brake, a software package: SimulationX is used. SimulationX is a software package for modeling and analyzing the dynamics and kinematics of cars, industrial equipment, electric, pneumatic and hydraulic drives, hybrid engines, etc. As a result of dynamic calculation, important dynamic parameters of the crank press brake and working ram are determined. It is shown that dynamic loads sharply increase almost in all links of the crank press when the brake is switched on.

Keywords: Dynamics · Crank press · Brake · SimulationX

1 Introduction

Crank press is a machine with a slider-crank mechanism, designed for stamping various parts [1–3]. During the work of crank press, significant dynamic loads occur in links and mechanisms, especially when it is turned on. These dynamic loads are associated with operational feature of the crank press, which includes shock cyclic loads with sudden, almost immediate stops. In this connection, the study of the dynamics of brake of the crank press, is of great interest. Figure 1 shows scheme of the press [3].

Operating principle of the crank press (see Fig. 1): the crankshaft 10 rotates about an axis and activates through the connecting rod 2 a ram 1 with punch. The press drive consists of an electric motor 7, a V-belt drive and a flywheel 5. The press clutch 11 is located on the end of the crankshaft 10. Brake 4 serves to stop the press. Brake 3 serves to stop the crank mechanism of the press. The drive of the press is carried out from an electric motor with a flywheel. Since the parameters of motion of the actuating link – ram, depend only on the kinematic links of the main working mechanism, crank presses are referred to uncontrolled machines with limited movement of the ram, equal to the double radius of the crank or double eccentricity of the eccentric.

C.-H. Kuo et al. (Eds.): ISRM 2019, MMS 78, pp. 141–150, 2020.
https://doi.org/10.1007/978-3-030-30036-4_12

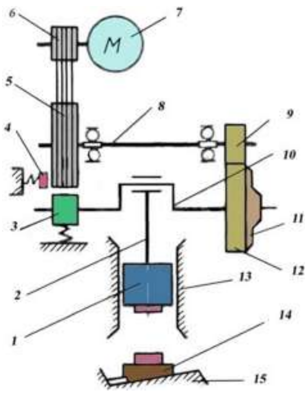

Fig. 1. Scheme of crank press: 1-ram, 2-connecting rod, 3-brake of crank mechanism, 4-flywheel brake, 5-flywheel, 6-sheave, 7-electric motor, 8-drive shaft, 9-drive gear, 10-crank shaft, 11-clutch, 12-driven gear, 13-crosshead guide, 14-wedge-type platten, 15-press board.

Asynchronous electric drive accelerates with power flywheel and all the guide links with the corresponding moment of inertia to the steady angular velocity during the technological cycle and dispatches kinetic energy of the rotational motion of the flywheel to it. In this case, the crank shaft and all driven links of the crank-slider mechanism are fixed, the slide is in the upper (initial) position. When the clutch 11 is turned on, the crank shaft (cranked axel 10) is rotated; driving and driven members move together, the ram with fixed upper die make a working stroke. After completion of the working stroke, the ram makes a return stroke. If the press works by single stokes, then when the ram reaches its initial position, the clutch 11 is turned off and at the same time the brake 3 is turned on. The ram stops in the upper (initial) position and the work cycle is completed.

2 Brake of Crank Press

The crank press brake absorbs the energy of the clutch driven parts after it is turned off and holds the actuator with the drive part in the position corresponding to the upper position of the ram. Band and disc brakes are used in crank presses. Disc brakes are more reliable than band brakes. Disc brakes provide greater friction moments and less inertia.

The working principle of disc brakes is similar to the operation of friction clutches with the difference that in the brake part of the discs are fixed (not rotating), and the other part rotates with the shaft. Most often, the brake is installed on the crank shaft (Fig. 2) [1].

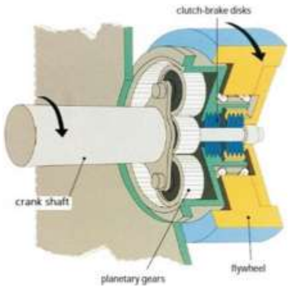

Fig. 2. Dick brake on the crank shaft.

Often the brakes are rigidly interlocked with the clutch, i.e. drive disks interlock with either clutch driven disks or brake (fixed) disks (Fig. 3) [1].

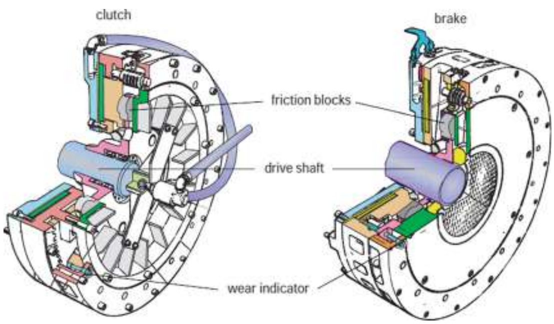

Fig. 3. Dick brake with the clutch.

The slotted hub of the brake is mounted on the left end of the eccentric shaft on the wedge keys [3]. Two steel discs with friction linings and a slotted connection with a hub are constantly clamped between the casing, intermediate and pressure discs with the help of tension springs with pushers (Fig. 4). The force of tightening the springs is determined based on the required pressure on the friction contact (2.4 … 2.5 MPa). During braking, compressed air with a pressure of 0.45 … 0.5 MPa is fed into the cavity under the piston.

Calculation of the disk brake is reduced to the determination of the braking torque and the choice of power elements ensuring the receipt of such torque.

The work of braking is equal to the kinetic energy of the driven parts of the press drive (taking into account the details of the ram), are determined by equality [3]:

$$\frac{I_{b.m}\omega_m^2}{2} = \frac{\pi}{180} M_m \cdot \alpha_m^0 \cdot u_m \tag{1}$$

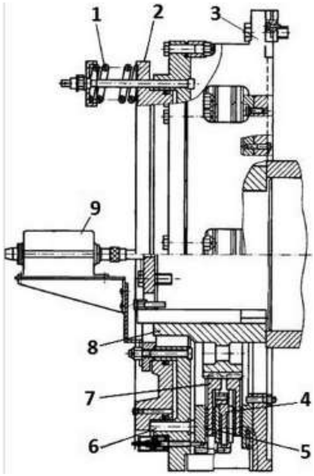

Fig. 4. Scheme of a two-disc brake: 1 - pressure springs; 2 - pressing piston; 3 - a housing with a cylinder; 4 - intermediate disk; 5 - pressure disc; 6 - push finger; 7 - driven discs with friction linings; 8 - hub with slots; 9 - control device.

where $I_{b.m}$ - the moment of inertia of the driven parts of the drive is reduced to the brake shaft; ω_m-angular velocity of the brake shaft; M_m - braking torque [Nm]; α_m^0 - braking angle, $\alpha_m^0 = 8^\circ - 12^\circ$ - for sheet metal stamping presses; u_m- the gear ratio from the brake shaft to the main shaft.

From Eq. (1) determine the braking torque

$$M_m = \frac{28,65 I_{b.m} \omega_m^2}{\alpha_m^0 \cdot u_m} \qquad (2)$$

And the sizes of the single-disk brake with linings are determined [3]:

$$M_m = 2f \cdot q_m R_{cp} \cdot n \cdot F_{bc}$$

where f = 0.35 is the friction coefficient; q_m = 0.6–1.2 MPa is the pressure on the friction surface; R_{cr} is the average radius of the lining; n is number of lining; F_{bc} is the square of the working surface of the lining.

For disc brakes, dimensions are determined on the basis of recommendations, the required pressure on the discs is determined, springs are calculated, and the diameter of the piston is determined.

3 Dynamic Model of Crank Press with Brake

When modeling the dynamics of a crank press with the brake and simulation of the operation of the brake, various software systems are used [4–8].

To simulate and analyze the movement of a crank press with the brake, this work uses a software package: SimulationX [9].

SimulationX – is software for modeling and analyzing the dynamics and kinematics of automobiles, industrial equipment, electric, pneumatic and hydraulic actuators, hybrid engines, etc. It is used for the design, modeling, simulation, analysis and virtual testing of complex mechatronic systems. It simulates the behavior and interaction of various physical objects of mechanics (1D and 3D), driving equipment, electrical, hydraulic, pneumatic and thermodynamic systems, as well as magnetism and analog and digital control systems. It performs the following tasks: system modeling in the time and frequency domains; simulation of transient processes in linear and nonlinear systems or stationary simulation to calculate a model in a periodic state (nonlinear or linear). Model libraries are divided by simulated physical applications. Tools and interfaces complement SimulationX for integrated analysis of systems and structure.

Figure 5 shows dynamic model of a crank press with brake on the SimulationX software package [9–12].

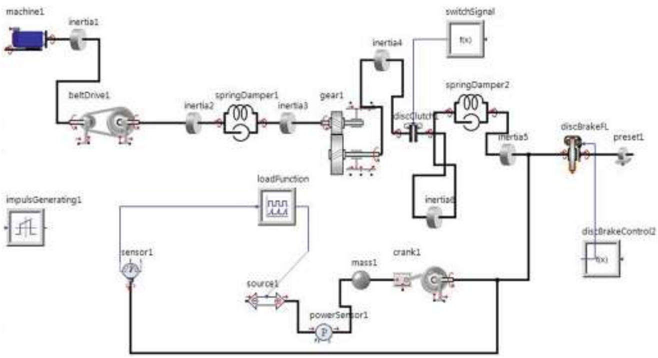

Fig. 5. Dynamic model of a crank press with brake on the SimulationX software package.

The elements of the SimulationX library that were used to compile the model are shown in Fig. 6.

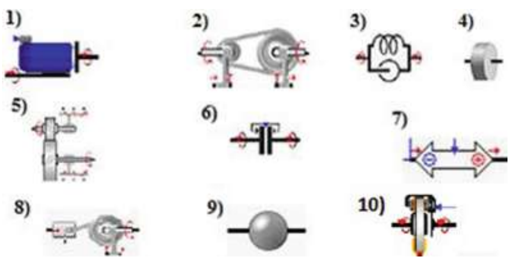

Fig. 6. The elements of the SimulationX library.

List of symbols (see Fig. 6) and description of the elements of the SimulationX library:

1. Asynchronous motor. This element simulates the simple asynchronous motor. The model is based on the stationary characteristics of the motor. This element models the asynchronous motor with sufficient accuracy when simulating the drive of a machine. It simulates engine starting, transient and steady-state processes, depending on the load and the speed of rotation of the shaft.
2. Belt drive. This element models the operation of belt transmission, with the account of elastic-dissipative characteristics. The model takes into account the reactions and movements in the bearings of the pulleys of the belt drive that allows you to simulate the interaction of the transmission with the base.
3. Spring - Damper – backlash. The model represents elastic and /or damped behavior between the rotational links, with the possibility of taking into account backlash. Springs always acts in parallel with the dampers.
4. Inertia. This element models the moment of inertia of a rotary link. It is also possible to simulate a variable moment of inertia.
5. Gear. The Transmission element is an ideal converter of rotational movements and forces operating between two components in a rotating mechanical system. It works as an ideal converter without taking into account dissipation and, fulfills the specified gear ratio or the conditions of power balance in input and output. The Transmission element allows you to model fixed and variable ratios for angles or velocities in input and output.
6. Disc clutch. The Model Disc Clutch is a component that turns on or interrupts the flow of torque (and therefore power transmission) between the drive components. The model can be used to simulate multi-plate clutch of machines or gearboxes. In addition, it is possible to simulate the friction of the brakes (for example, an automatic transmission). Elasticity, damping and clutch friction parameters can be considered. In transmission of the models, the clutch can be activated by a signal from the switch.
7. External force. This type of element allows you to simulate the forces between two components, or only on one component of the mechanical model. It provides universal, functional power transfer in the mechanical model.
8. Crank mechanism. The element models a slider-crank mechanism, taking into account the backlash in the hinges, the elastic-dissipative properties of the connecting rod.
9. Mass. This element models the mass of a linear link. Variable mass modeling is also possible.
10. Disc brake. The Model Disc brake is a component that turns on or interrupts the flow of torque (and therefore power transmission) between the drive components. The model can be used to simulate multi-plate brake of machines or gearboxes. In addition, it is possible to simulate the friction of the brakes (for example, an automatic transmission). Elasticity, damping and brake friction parameters can be considered. In transmission of the models, the brake can be activated by a signal from the switch.

Initial parameters of the model: crank press motor power W = 0.5 kw, rated engine speed n = 450 rpm. The numerical values of the dimensions, moments of inertia of the links of the crank press and the stiffness of the shafts are taken from [3]. The nominal force developed by the ram of the slider-crank working mechanism in the area before the extreme low point of the ram's stroke is modeled by a sine-wave signal generator (load Function) and linear force (load) [3] (Fig. 7). This load force depends on the angle of the crank. The maximum force is reached at the lower point of the ram's stroke and is equal to 4000 N.

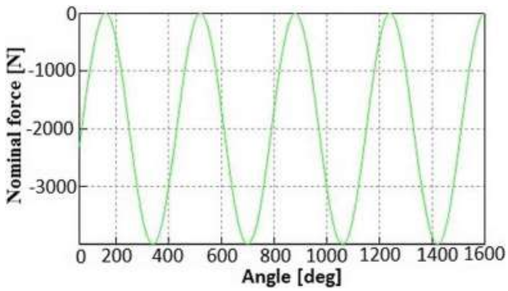

Fig. 7. The nominal force, developed by the ram of the slider-crank working mechanism.

Parameters of the brake of the crank press are shown in Fig. 8.

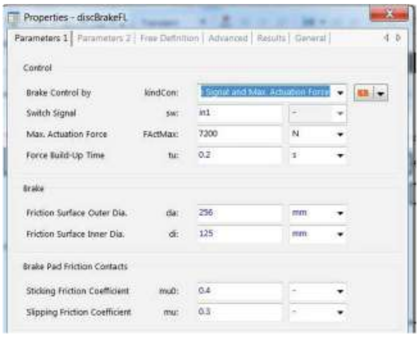

Fig. 8. Parameters of the brake of the crank press.

Simulation results: Brake of the crank press is activated and stops the moving flywheel. Figure 9 shows the torque on the crank shaft.

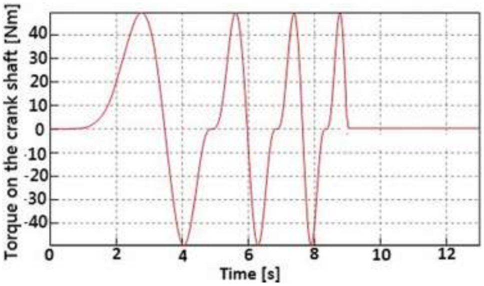

Fig. 9. The torque on the crank shaft.

Figure 10 shows the torque on the brake.

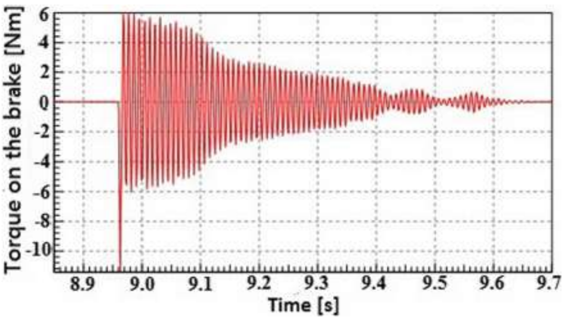

Fig. 10. The torque on the brake.

Figure 11 shows the vibration of drive shaft.

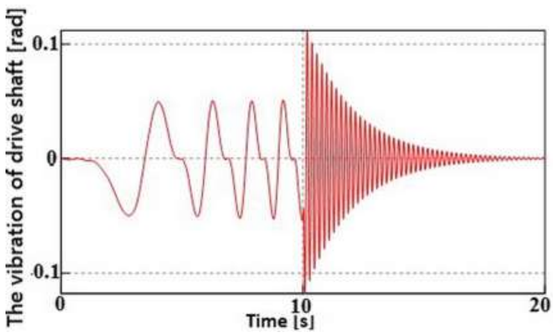

Fig. 11. The vibration of drive shaft.

Figures 12 a, b, c shows displacement, velocity, acceleration of the press ram.

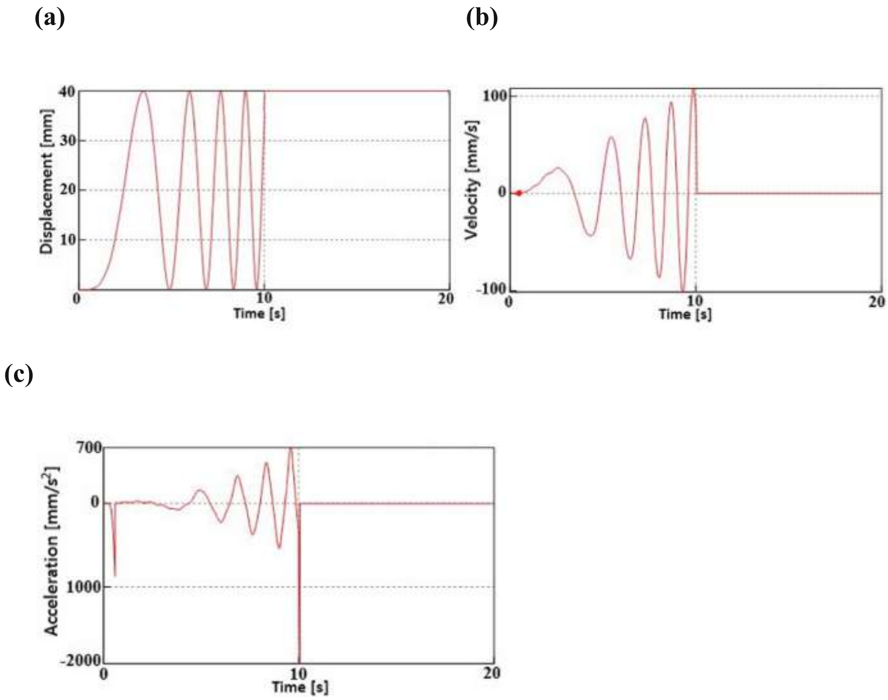

Fig. 12. Estimated data of the press ram (a) - displacement, (b) - velocity; (c) – acceleration.

In Fig. 12 (c), the reason downward spike on the acceleration plot occurs due to sudden braking crank press on 10-th second.

4 Conclusion

The SimulationX software package allows one to simulate the dynamics of the brake of the crank press, taking into account its design parameters as part of the crank press, and the interaction with its entire links.

As the result of the dynamic calculation following is determined: the torque on the crank shaft, the torque on the brake, the vibration of drive shaft. Displacement, velocity, acceleration of the ram of the crank press are determined at the moment of brake turn-on.

Dynamic loads in the links of the crank press sharply increase at the moment of brake turn-on. When researching the dynamics of a crank press, it is necessary to take into account the design features of the brake, especially brake pad wear and adjustment, which requires further research of this unit.

Visibility of the models and graphical results are especially useful for students and engineers in the research of brake of the crank presses.

Acknowledgments. This material is based upon work supported by the Ministry of Education and Science of the Republic of Kazakhstan under grant no. AP05134959.

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