

Engineering of Impulse Mechanism for Mechanical Hander Power Tools

Anatoliy Nikolaevich Drozdov¹

¹PhD in Technical Sciences, assistant professor in Moscow State University of Civil Engineering

Abstract. The solution to the problem of human security in cities should be considered on the basis of an integrated and multidisciplinary approach, including issues of security and ecology in the application of technical means used to ensure the viability and development of technocracy. In this regard, an important task is the creation of a safe technique with improved environmental properties with high technological characteristics. This primarily relates to mechanised tool — the division of technological machines with built in engines is that their weight is fully or partially perceived by the operator's hands, making the flow and control of the car. For this subclass of machines is characterized by certain features: a built-in motor, perception of at least part of their weight by the operator during the work, the implementation of feeding and management at the expense of the muscular power of the operator. Therefore, among the commonly accepted technical and economic characteristics, machines in this case, important ergonomic (ergonomics), regulation of levels which ensures the safety of the operator. To ergonomics include vibration, noise characteristics, mass, and force feeding machine operator. Vibration is a consequence of the dynamism of the system operator - machine - processed object (environment) in which the engine energy is redistributed among all the structures, causing their instability. In the machine vibration caused by technological and constructive (transformative mechanisms) unbalance of individual parts of the drive, the presence of technological and design (impact mechanisms) clearances and other reasons. This article describes a new design of impulse mechanism for hander power tools (wrenches, screwdrivers) with enhanced torque. The article substantiates a simulation model of dynamic compression process in an operating chamber during impact, provides simulation results and outlines further lines of research.

1. Introduction

Both, conventional percussive mechanisms and various types of impulse sockets are used for generating torque pulses in hander power tools (such as wrenches and screwdrivers). The latter have enhanced reliability and better ergonomic properties. The main disadvantage of many impulse mechanisms is their low volume energy which limits their field of application to threaded connections with small bolt diameter. [1-4].

The article introduces a new impulse wrench mechanism design providing enhanced torque although having a small size and low weight. The mechanism combines both, the advantages of a conventional bumping block mechanism, and a pulse socket which implies the absence of a spring, damping impact energy with oil, and reduced axial vibration due to low weight of the hammer piston. [5, 6].



2. Design and operating principle

Figures 1 and 2 show a 3D model of the mechanism with parts of the impact pair: a shaft 1 and a hammer 2, and auxiliary return ring 7, casing 11, and a cover 12. When assembled, the interior of the casing is filled with oil and separated with the cam into two sealed chambers: for High pressure and for Low pressure. Return ring 7 has a square hole and is fastened to the shaft with square 6. The cam and the casing interact via ballscrew (parts 9, 10, and 13). The shape of the groove in cam 9 provides repeating reciprocating action of the cam when the casing moves against it. During operation, the casing is connected directly to the gear, while the shaft is connected to the bolt (shaft, etc.) via square 3 and an operating head.

A crossover valve (not in the pictures) is installed inside of the hammer. The valve provides free flow of fluid from the low pressure chamber into the high pressure chamber but prevents back flow.

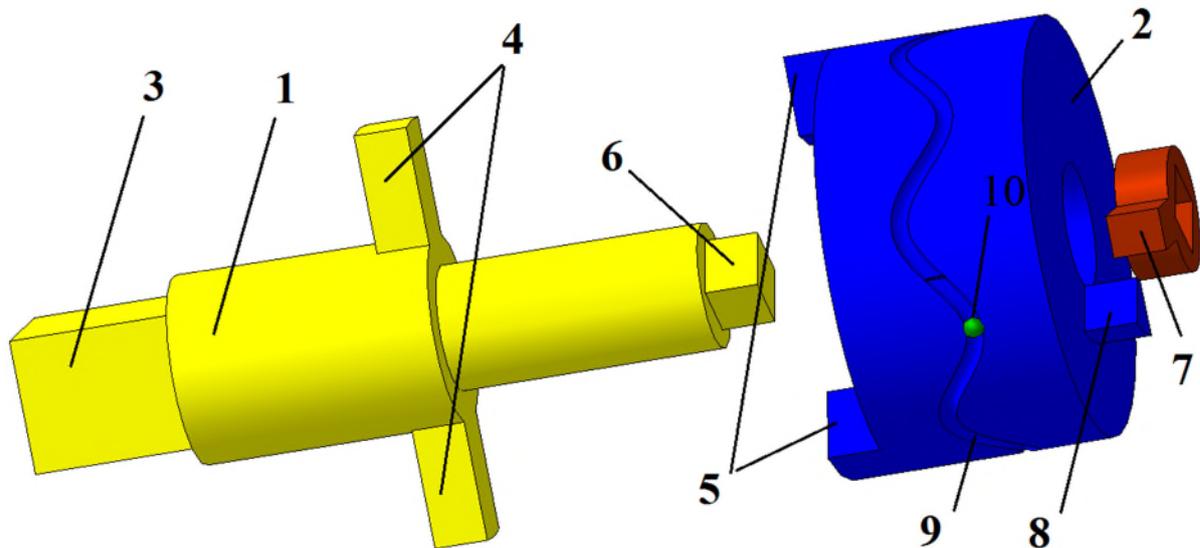


Figure 1. Parts of the impact pair of the impulse mechanism.

- 1 – shaft; 2 – hammer; 3 – square for attaching operating heads; 4 – shaft cams;
 5 – hammer operating hams; 6 – square for attaching return ring; 7 – return ring with a cam;
 8 – hammer return cam; 9 – ballscrew groove; 10 – ballscrew ball

The mechanism operates as follows: during the first stage when the threaded connection is tightened with low strength, hammer 2 is in the lower position, cams of shaft 4 and cams hammer 5 are interlocked, the crossover valve is closed, and the torque is transmitted to the hammer via ballscrew connection. This is the static operation mode where all parts of the mechanism rotate as a whole.

As the resistance increases, the shaft and the hammer are triggered, and the hammer start moving to the upper position gradually disengaging the shaft. During progressive motion, the hammer is subjected to resistance due to the change of volume in the HP chamber, the displaced fluid flows into the LP chamber solely via the capillary channel formed by the surface of the hammer and the casing inner wall. (During progressive motion, the hammer is subjected to resistance due to the change of volume in the HP chamber, the displaced fluid flows into the LP chamber solely via the bypass channel of (not shown in the pictures).)

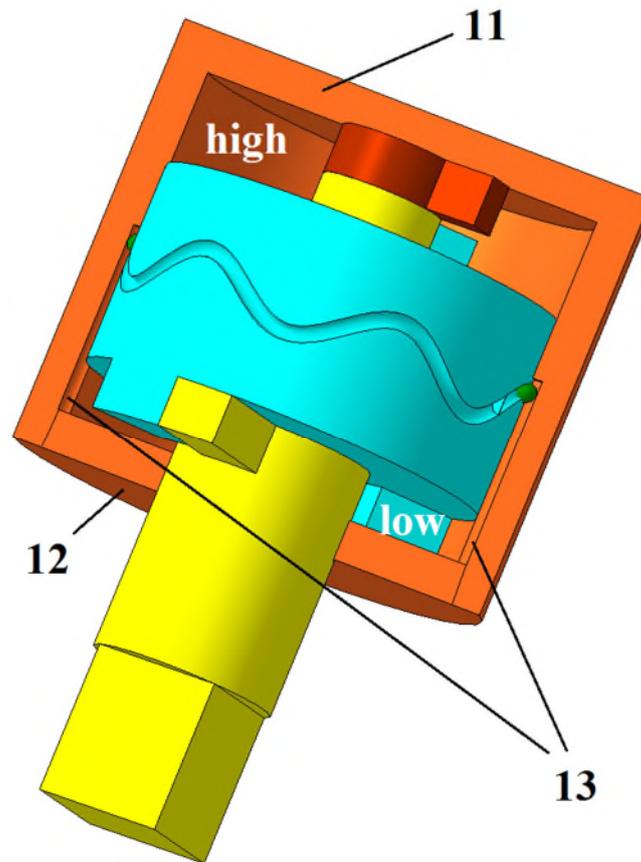


Figure 2. Complete impulse mechanism

11 – casing; 12 – balls of the casing ball screw gear; 13 – casing cover;
high – HP chamber; low – LP chamber

When the hammer reaches its high point, it disconnects from the shaft. The casing and the hammer start to move freely to the engagement point of the cam of return ring 7 and the return cam of casing 8. The hammer is triggered and pressed into the lower position; during this, the crossover valve is open due to which the LP chamber furnishes practically no resistance. In the lower position, the hammer and the casing, move freely again, till the point where the shaft is engaged. After this, the process repeats. This is the dynamic operating mode of the mechanism.

3. Substantiation of the simulation model

The general simulation model of dynamic compression process for the mechanism constitutes a continuity equation for HP chamber expressing equality between the rate of chamber volume change and the oil flow from the capillary channel considering the fluid compressibility: [7-10].

$$\frac{d\Delta V}{dt} = Q + \frac{d\Delta V_{c\text{ж}}}{dt} \quad (1)$$

where ΔV is the change in the HP chamber volume; Q is fluid flow rate; $\Delta V_{c\text{ж}}$ is change of fluid volume due to compression.

Assuming that casing rotation rate is constant and the law of axial motion for the cam is $Z = R_n \omega t$, let's expand members of (1):

$$\Delta V = 2(\pi R_n^2 - \pi R_k^2)h - (\pi R_n^2 - \pi R_k^2)R_n\omega t,$$

$$\frac{d\Delta V}{dt} = -(\pi R_n^2 - \pi R_k^2)R_n\omega,$$

where R_n is hammer radius; R_k is radius of the return ring; h is height of cams; ω is angular speed of the casing.

$$\frac{d\Delta V_{c\omega}}{dt} = \frac{\Delta V}{E} \frac{d\Delta P}{dt},$$

where E is fluid elastic modulus liquid; ΔP is chamber pressure.

$$Q = \left[\frac{\Delta P}{12\mu e^{b\Delta P} m} \delta^3 - \frac{R_n \omega \delta}{2} \right] 2\pi R_n,$$

where μ is oil dynamic viscosity; b is dependency ratio between viscosity and pressure; m is height of the hammer (length of capillary gap); δ is the size of opening between the casing wall and the cylindrical surface of the cam (depth of capillary gap).

In order to obtain the theoretical form of the impact pulse, (1) is integrated over the interval:

$$t = \left[0 \dots \frac{h}{R_n \omega} \right].$$

4. Simulation results

Figure 3 shows the design form of the pressure pulse in the chamber for the following parameters of the mechanism:

$R_n = 0.02$ m; $R_k = 0.02$ m; $h = 0.02$ m; $\omega = 104$ rad/sec; $E = 1350 \cdot 10^6$ Pa; $\mu = 0.0388$ N m/sec; $\rho = 850,2$ kg/m³ – density of oil; $b = 1.5 \cdot 10^{-7}$; $\delta = 0.0005$ m; $m = 0.04$ m.

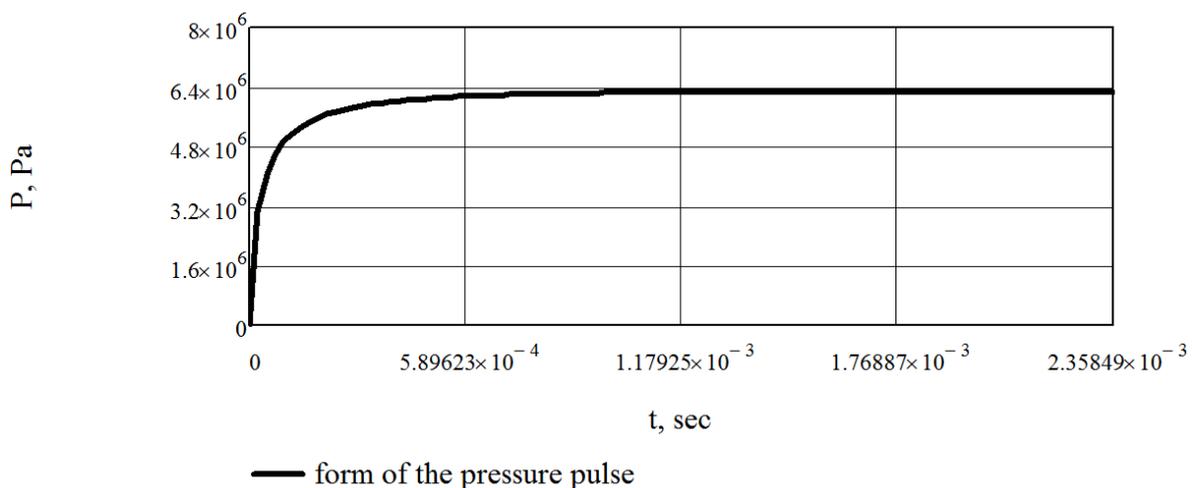


Figure 3. The calculated dependency of the impulse mechanism chamber pressure.

5. Conclusions and further line of research

- The article describes a new design of the impulse mechanism characterized by enhanced torque due to great surface area of the hammer piston;

- The new mechanism has small size and a relatively simple design, and the pressure in the chamber depends on a few parameters;

- Further research of the new mechanism implies substantiation of optimization techniques for its design parameters at a given torque, and manufacturing a prototype model for bench testing.

References

- [1] Vodolazsky N In. Vodolazsky E G, Iskriksky V M 2012 *Vestnik SevNTU* **128** 22–6.
- [2] Vodolazskaya N In. Vodolazsky E G, Iskriksky V M 2011 *Vestnik SevNTU* **117** 32–7.
- [3] Drozdov A N, Stepanov V V 2013 *Electric impact wrench. Dynamics: The Monograph*. Moscow: MGSU, 118.
- [4] Drozdov A N 1999 *Manual machines for construction works (the device and the basis of calculation)*. Moscow: MGSU, 252.
- [5] Ushakov H P 2013 *Hydraulic impact mechanisms. World experience of analysis and design*. Germany. Ed. House. Palmarium Academic Publishing 280.
- [6] Nikitin Y F 2010 *Hydraulics and hydropneumatic*. Moscow: MGTU named after Bauman, 414.
- [7] European Power Tool Association 2009 *Procedure 05/2009 – Measurement of the single impact energy of rotary hammers and breakers* Frankfurt: European Power Tool Association.
- [8] Doyle S 2012 *Impact Energy Testing – Trails and Triumphs*, Brookfield: Milwaukee Electric Tool Corporation, Internal Document.
- [9] Jatsun S F, Lupehina I V, Panovko G J, Volkova L Yu, 2011 *Dynamics of the vibration driven tool at its interaction with the processing material* Proc. 13th World Congress in Mechanism and Machine Science, Guanajuato, Mexico, 19-25.
- [10] Zhang S L, Tang J 2016 *J. Manuf. Sci. Eng.* **138**(11).