IOP Conference Series: Earth and Environmental Science

Substantiation of basic diagram and determination of energy and design parameters of the volumetric-type hydrohammer for vibroimpact punching of holes in soil

Substantiation of basic diagram and determination of energy and design parameters of the volumetric-type hydrohammer for vibroimpact punching of holes in soil

BB Danilov* and AA Rechkin

Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

E-mail: *bbdanilov@mail.ru

Abstract. The feasibility to use the ring elastic valve in volumetric-type hydrohammers is substantiated. The relationships of impact power versus the ratio of working area, diameter and length of interchamber throttle are determined by applying a simulation model of hydrohammer mechanism. Rational parameters of the study mass-size dimensional-type hydraulic hammers are selected.

1. Introduction

The use of a hydraulic drive mechanism preserves its significance and actuality in design of present-day impact mining machines due to such advantages of the hydraulic drive as appreciable increase in power, higher performance efficiency as compared to pneumatic impact machines, consequently, higher rock-breaking efficiency [1, 2]. The volumetric-type impact machines are distinguished for the best efficiency factor among hydraulic impact machinery. The volumetric-type impact machines are machines where motion and impact action of the anvil-piston is forced under pressure of a fluid supplied into working chambers of the cylinder [3]. A pneumatic hydraulic accumulator is usually used in most this-type machines with the purpose to save energy during an idle stroke of the anvil and to give off energy in its working stroke.

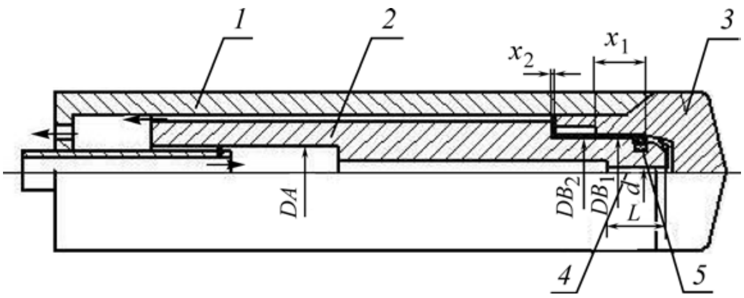

Figure 1. Design scheme of a hydraulic impact machine with elastic valve: *1*—body; *2*—striking element; *3*—anvil; *4*—interchamber throttle; *5*—ring elastic valve.

The design complexity and necessity to manufacture their details with high specific precision are imperfections of hydraulic volumetric-type machines. A way to simplify their design is to use elastic

IOP Conf. Series: Earth and Environmental Science **262** (2019) 012013 doi:10.1088/1755-1315/262/1/012013

shut-off-and-regulating elements intended to distribute flows of the working fluid [4, 5]. At the Institute of Mining SB RAS the researchers developed pneumatic impact machines Typhoon where the ring elastic valve is employed as an elastic shut-off-and-regulating element to lock the back-stroke chamber [6]. The long-term successful application of these machines in construction and mining industries, design simplicity and operational reliability provide all the grounds to consider applicability of this design (Figure 1) in hydraulic impact volumetric-type machines.

2. Simulation model development

The simulation model of impact mechanism operation is developed in SimulationX software to complete a design and energy parameters of a hydraulic impact machine with a ring elastic valve. The calculation scheme of the machine is shown in Figure 2.

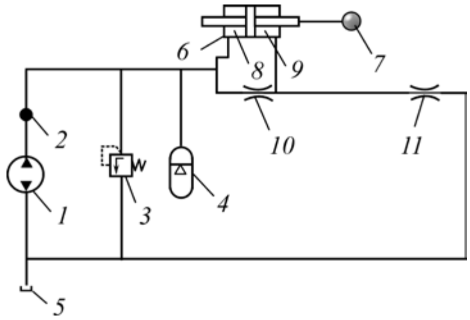

Figure 2. Calculation scheme of a hydraulic impact machine with a ring elastic valve: *1*—pump; *2*—fluid volume; *3*—safety valve; *4*—pneumatic hydraulic accumulator; *5*—overflow, *6*—two-stock hydrocylinder with variable area of the back-stroke chamber, *7*—mass of the striking element; *8*—direct-stroke chamber; *9*—back-stroke chamber; *10*—interchamber throttle; *11*—locking throttle.

To determine initial parameters, the sketch design of the striking device is executed, then computation experiments were undertaken using earlier design parameters: mass of the striking element m = 4 kg, diameter of the ring-shaped elastic valve prior to extension (a direct stroke) DB_1 = 0.025 m, post-extension diameter of the ring elastic valve (a back stroke) DB_2 = 0.028 m, coordinate of valve locking (or distance from the striking element to anvil at valve locking) x_2 = 0.001 m, working stroke of the striking element x_1 = 0.05 m. The work of the ring elastic valve is modeled by locking throttle *11* (Figure 2), when the valve in its direct stroke reaches coordinate of the back-stroke chamber locking, thereto piston area is increasing from the side of this chamber after the impact. The valve is considered operating instantly, quite discretely. Diameter of the direct stroke chamber *DA*, diameter *d* and length *L* of interchamber throttle were measured in view to select optimal energy parameters of the mechanism. The pre-impact velocity of the striking element, impact frequency, impact energy, and impact power were considered as basic estimation criteria.

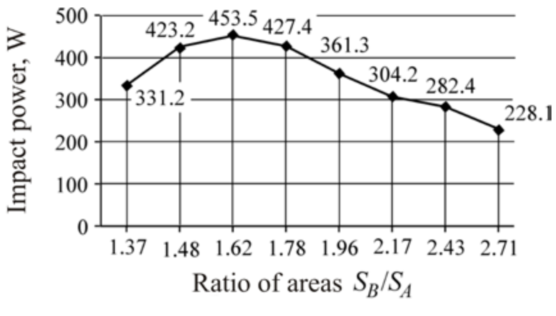

Figure 3. Relationship of impact power vs. ratio of the areas of front S_B and rear S_A chambers.

Figure 3 demonstrates the resultant relationship of impact power vs. ratio between areas of the front and rear chambers. In this case ratio of 1.78 is assumed the most optimal one, as at ratio of 1.62, providing a greater value of impact power, we fall outside the critical value of pre-impact velocity which it is limited to ≈ 4 m/s in reasonable terms of impact strength and long-term operation life.

At the selected ratio of working areas the geometric parameters of interchamber throttle were varied (Figure 4). The resultant relationship of impact power versus throttle length at fixed diameter of $1.8 \cdot 10^{-3}$ m indicates the actually proportional growth of impact power with increase in throttle length (Figure 4a). There are grounds to speak of value of 0.05 m as the optimal one, because higher values lead to excess of the above established limit of the pre-impact velocity.

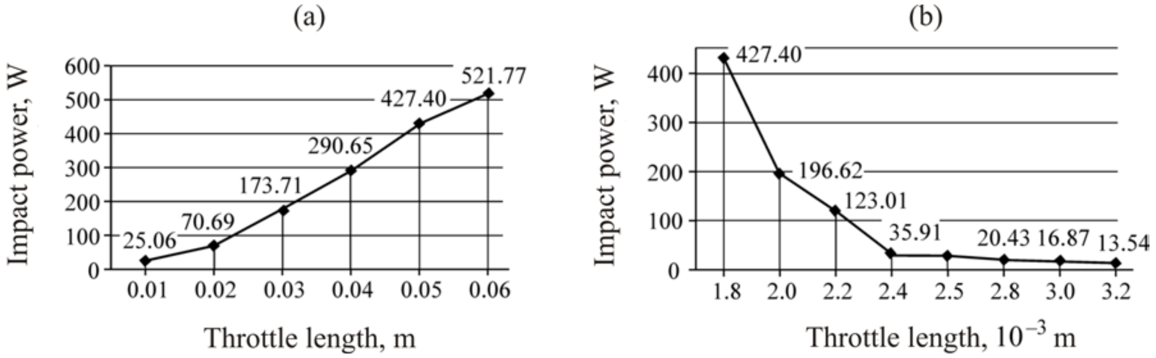

Figure 4. Relationship of impact power versus throttle parameters: (a) length; (b) diameter.

In final computations the diameter of interchamber throttle varied at fixed length and fixed area ratio, established at previous stages. The relationship in Figure 4b indicates hyperbolic growth of impact power with increase in throttle diameter, however, the researchers failed to obtain a solution for throttle diameter less than $1.8 \cdot 10^{-3}$ m.

3. Conclusions

The simulation model constructed in the present research justifies the feasibility to apply the design scheme with the ring elastic valve in hydraulic volumetric-type hammers and enables to determine optimal parameters using the criteria of the pre-impact velocity of the striking element, impact frequency, impact energy, impact power, etc.

Numerical experiments on the model made it possible to establish relationships of impact power versus some design parameters, to find rational ratios of working areas of direct- and back-stroke chambers and geometric parameters of the interchamber throttle to provide the maximum impact power of the selected type–size mechanism to design the hydraulic hammer for the vibration-impact hole-making process.

References

[1] Arkhipenko AP, Fedulov AI 1991 *Hydraulic Hammers* Novosibirsk: IGD SO AN SSSR (in Russian)
[2] Ushakov LS, Kotylev YuE and Kravchenko VA 2000 *Hydraulic Machines of Impact Action* Moscow: Mashinostroenie (in Russian)
[3] Gorodilov LV 2010 Development of the fundamentals of the theory of hydraulic impact systems of volumetric type for the executive bodies of mining and construction machinery *Dr Tech Sci Thesis* Novosibirsk (in Russian)
[4] Galdin NS 2005 *Multi-Purpose Hydroimpact Working Bodies of Road-Building Machines* Omsk: SibADI (in Russian)
[5] Galdin NS and Bedrina EA 2003 *Dynamic Buckets Based on Hydraulic Hammers for Excavators* Omsk: SibADI (in Russian)
[6] Smolyanitskiy BN and Chervov VV 2014 Enhancement of energy carrier performance of air hammers in underground construction *Journal of Mining Science* Vol 50 No 5 pp 918–928