ISSN 1062-7391, Journal of Mining Science, 2018, Vol. 54, No. 6, pp. 959–968. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © V.E. Erem'yants, B.S. Sultanaliev, Nazira kyzy Melis, published in Fiziko-Tekhnicheskie Problemy Razrabotki Poleznykh Iskopaemykh, 2018, No. 6, pp. 87–97.

SCIENCE OF MINING MACHINES

Modeling Impact Energy Transfer through Closed Chamber Filled with Fluid

V. E. Erem'yants*, B. S. Sultanaliev, and Nazira kyzy Melis

Institute of Machinery Science, Kyrgyz Academy of Sciences, Bishkek, 720055 Kyrgyz Republic
**e-mail: eremjants@inbox.ru*

Received September 5, 2018
Revised October 11, 2018
Accepted November 28, 2018

Abstract—Different models of a hammering system with impact energy transfer in a closed chamber filled with fluid are analyzed. It is proved that the piston and the tool in the model can be represented by solid nondeformable bodies while the fluid-filled chamber by an inertialess elastic element. Based on the analyses, the forces in the fluid-filled chamber and at the tool-and-rock contact, as well as the impact energy transfer ratio are related with the chamber parameters and the rock–tool contact stiffness. The algorithm is proposed to calculate such system dynamics with regard to fluid leaks, variable viscosity and bulk modulus of elasticity.

Keywords: Hammer, piston, chamber with fluid, tool, impact, pressure, bulk modulus of elasticity, leaks, calculation algorithm.

DOI: 10.1134/S1062739118065108

Efficiency of hammers to break rocks or strong and frozen soil depends on the impact capacity determined as product of unit blow energy and blow frequency. It is found to be expedient to increase impact capacity by adding blow energy [1, 2]. In this case, the required holddown pressure of a percussion machine grows less intensively than under in the increase in the impact capacity by means of buildup of blow frequency. The blow energy should be enhanced by speeding a piston at the moment of blow as the increase in the piston weight entails enlargement of the whole percussion machine in weight and dimension. On the other hand, the piston velocity is limited by stresses in the elements of the percussion system, and these stresses are proportional to the blow velocity.

The investigation of possibilities to increase the blow energy without essential growth of the weight and size of percussion machines results in the engineering solution to transfer energy from the piston to the rock-breaking tool through a closed volume of fluid. This solution ensures reduced amplitude and extended duration of the impulse generated in the tool. As a result, the pre-blow velocity of the piston is increased by 1.5–2 times as compared with the existing machines and, consequently, the blow energy increment is from 2 to 4 times.

Furthermore, as said in [3], transition of blow energy through a column of fluid eliminates influence exerted by malalignment of encounter end faces on stresses arising in the elements of the percussion system. In the meanwhile, this influence can be significant. For instance, the experimental research [4] proves that malalignment of end faces during impact can cause flexural deformation waves that, when combined with longitudinal waves, can double total stresses in the elements of the percussion system. With nonparallel impact faces, the dynamic moment arises at the contact of piston and rock-breaking tool. This moment induces whipping of the piston and tool in the guide bushes and results in wear of all elements.

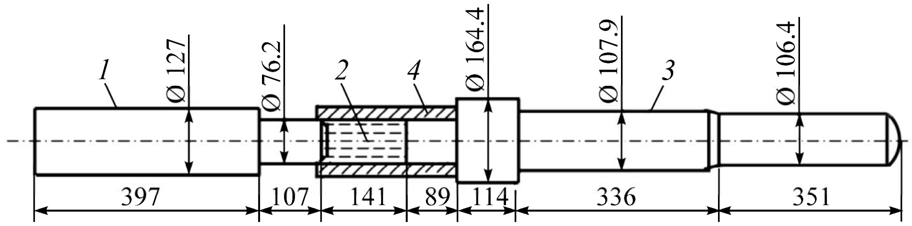

Fig. 1. Impact system of 514 HEFTI hammer.

One of the first machines with blow transition through a closed volume of fluid was model 514 HEFTI hydraulic hammer manufactured by Joy, USA and given publicity in the early 1980s. The impact system of the hammer consisted of two-stage piston *1* (Fig. 1), chamber filled with fluid *2*, and four-stage tool *3*. A closed chamber is formed by piston *1*, tool *3* and bush *4*. The estimated weight of the bit made of material with density of 7800 kg/m^3 is 43 kg, and the tool weight is 70.35 kg. The hammer was never produced in batch series for unknown reasons.

In the Soviet Union, the idea to transfer the impact energy trough the fluid column was developed in [5, 6]. Various configurations of percussion machines with adjustable impact impulse due blow transition through an interlayer or a fluid column were proposed and analyzed. Unlike 514 HEFTI, these machines were intended for rock drilling. The tool was 3 m long and more. For this reason, the tool was modeled as an elastic rod and the vibrations of the rod were described using the wave theory of impact. It was assumed that the length of the tool was such that the wave reflected from the bottomhole had no influence on the impact energy transfer to the tool. In this model (Fig. 2), fluid chamber *3*, formed by intermediate element *2*, shank *4* of tool *5* ad housing *6*, is stage-wise and blow is implemented by piston *1* on intermediate element *2* abut on the column of fluid.

Based on the analysis of this model [3], the conclusion is drawn that as the fluid column is diminished, the ratio of the energy transfer to the tool and and the maximum amplitude of the impact impulse grow up to one with an intermediate element represented by the fluid layer 0.2–15 mm thick. Under impact, the piston energy is split due to different weights of the piston and intermediate element, as well as owing to compressibility of fluid. As a consequence, the power impulse amplitude in rods can be reduced and the duration can be increased. The maximum amplitude of the impact impulse depending on fluid properties and diameter ration of the stage-wise fluid chamber varies by the linear law.

Despite all advantages, the series batch production of the machine never happened. Then, the Institute of Machines Science, National Academy of Sciences of the Kyrgyz Republic, designed a hammer with blow energy transition through a fluid column using the Russian hammer model GPM as a basis [7]. The percussive system of the hammer differs from the drill described in [3, 5, 6]. In the hammer, the tool and the piston have comparable lengths and insignificantly different diameters (Fig. 1). Thus, it was decided to continue the studies into the blow energy transition in the closed volume of fluid for rock-breaking hammers using the percussive systems of 514 HEFTI hammer (Fig. 1).

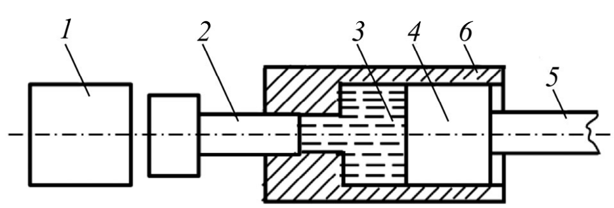

Fig. 2. Analytical model of percussion system [6].