Lever-type percussion mechanisms for removal of adhered deposits from holding reservoirs

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Abstract. The authors discuss designs of Abdraimov’s lever-type percussion mechanism with the longest piston rod for removal adhered deposits from ash-and-slag pipelines and hoppers. The kinematic and kinestatic test results are presented for three layouts of Abdraimov’s mechanism with the longest base. The basic parameters of the layouts for high-frequency percussion plants for cleaning holding reservoirs and surfaces are determined and recommended.

1. Introduction
Modern ecological setting dictates mining, oil processing, energy generating and other industries to introduce and apply advanced technologies ensuring no-waste removal of coal and oil contamination (subject to low cost cleaning).

When thermal station burn low-quality solid fuel (with low combustion heat and high ash content), much ash left requires disposal. Currently most power plants remove ash and slag by hydraulic method and store in ash-disposal areas. One tenth of as is only used economically—in manufacturing of building materials, in construction and agriculture.

Figure 1. Ash-and-slag pipeline and portable machine MP-1: (a) ash-and-slag line (1—steel pipe; 2—hard ash and slag layer); (b) portable machine MP-2 for ash-and-slag deposit removal (1—fluid-power motor KHSH-32; 2—vibropercussion mechanisms; 3—frame; 4—ash-and-slag pipe).

Wide application of hydraulic ash-and-slag removal is explained by its advantages: continuous removal of huge amounts of ash-and-slag to great distances (to 30 km), full mechanization of haulage
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and dumping, comparatively simple and reliable equipment. However, the method has disadvantages as well. The most essential drawbacks are high water consumption (10–30 m³ of water per 1 t of ash and slag) and contamination of natural water bodies with process water with high content of toxic substances after hydraulic ash-and-slag removal. Inside ash-and-slag pipelines, hard ash layer accrues, which worsens capacity of the lines, and it is required to undertake preventive treatment, i.e. remove hard deposits on the inner surfaces of equipment and surface utility lines included in the system of collection and discharge of combustion products [1, 2].

During operation of ash-and-slag pipelines, deposit accumulation results in formation of hard ash layer 2 up to 80–120 mm thick (Figure 1). This diminishes useful diameter and worsens passability of the pipes.

One of the problem of heat power plants is elimination of coal bridging in hoppers as dynamic choking-up always takes place above hopper inlets during flow of granular fuels (Figure 2) [3, 4]. During free outflow, choking is continuously broken under the pressure of overlying layers. Above smaller size inlets, choking is more stable and can terminate fuel outflow from hopper.

![Figure 2](image)

**Figure 2.** Filling of hoppers and percussion machine design: (a) filling of hopper (1—conveyor; 2—coal; 3—filling facility; 4—hopper; 5—choking-up; 6—outlet); (b) MB-10 machine to break chokes in receiving hopper (1—percussion mechanism; 2—hold-down; 3—electric motor; 4—assembly platform; 5—hopper walls; 6—guiding sleeve; 7—waveguide; 8—overhanging support; 9—bolts; 10—guiding bolt; 11—adjusting nuts; 12—reduction unit; 13—shoe).

### 2. Technology for deposits removal

Based on the afore-said, it is of the current concern to develop efficient technology for high-quality and high-productive removal of deposits from the inner walls of holding reservoirs using the lever-type percussion mechanisms proposed by Abdraimov [5].

Configurations of Abdraimov’s lever-type percussion mechanism depend on the size of the largest component: with the longest piston rod \( l_2 \) max (Figure 3a), with the longest yoke \( l_3 \) max (Figure 3b) and with the longest base \( l_0 \) max (Figure 3c), and the lengths of the elements should obey the one of the conditions below:

\[
\begin{align*}
l_0 - l_1 &= l_2 - l_3, & (1) \\
l_0 + l_1 &= l_3 - l_2, & (2) \\
l_0 + l_1 &= l_2 + l_3, & (3)
\end{align*}
\]
where $l_1$, $l_2$ and $l_3$ are the lengths of the crank arm, piston rod and the yoke, respectively; $l_0$ is the distance between the crank arm and yoke supports.

**Figure 3.** Kinematic scheme of crank arm-and-yoke variable structure percussion mechanism by Abdraimov.

In the course of research and development, the scientific team of the Institute of Machine Science within the Kyrgyz Republic Academy of Sciences has designed different percussion machines and facilities based on Abdraimov’s lever mechanisms, such as: sleeve-free automatic press; jacks with manual, electric and hydraulic drives; manual jackhammers with different drives; compacting machines; drilling rifs; ash-and-slag removal device to clean ash-and-slag pipelines, feed hoppers of heat power plant boilers; hammer attachments with blow energy to 2.5 kJ; shock pulse generators of high capacity for deep soil compaction for construction of various structures, and to reinforce beds for railway and motor roads, as well as for vibration generation in soil (to stimulate oil and gas recovery) with unit blow energy up to 50 kJ.

Abdraimov’s lever-type percussion mechanisms with variable structure feature high efficiency exceeding the known analogs, which implies reliable operation and wide application area. Their operation within percussion machines differs from conventional (hydraulic and pneumatic) mechanisms by simplicity of manufacture and maintenance in activities which go without bulky hydraulic stations and compressors.

According to the analysis of tested schemes, most of the listed percussion machines and facilities are designed sing one of the variable structure mechanisms, namely, the longest piston rod $l_2$ (Figure 3a) [6]. At request of the Bishkeke Heat Power Plant, the Laboratory of Theory of Mechanisms and Machines at the Institute of Machine Science has designed portable percussion plant MP-1 for cleaning ash-and-slag pipelines [7].

The portable plant MP-1 is intended to remove ash and slag deposits from pipes by vibropercussion. The plant has two percussion mechanisms actuated by hydraulic drive. The vibropercussion mechanisms are mounted on the common base and make impact on the pipe using special tools—waveguides. General view of this structure is shown in Figure 1b. Hydraulic drive of the percussion machine MP-1 can be powered by mobile hydraulic plant or hydraulics of a road construction machine (tractor, hydraulic crane, shovel, etc.) available.

Moreover, the Laboratory has designed the percussion machine MVB-10 to remove chocking in hoppers (Figure 2b). This machine is composed of a variable-structure percussion mechanism, single gearing, electric drive 4A80V4U3, hold-down and an assembly platform. The main output parameters of the vibropercussion machines for removal of adhered deposits are frequency $f$, blow energy $A$ and percussion capacity $N$. 
Aiming at improving capacity of these percussion machines at preset output characteristics, Abdraimov’s lever-type percussion mechanisms with the longest base were subjected to kinematic and force testing. Based on the test results, the curves of the transmission ratios of the mechanism, kinematic velocity recovery factor and support spacing \( r \) were plotted (Figure 4 and 5) [8, 9].

As experience of design, manufacture and testing of machines based on Abdraimov’s lever-type percussion mechanisms, the decisive factor in selection of schemes and sizes of components is the value of the kinematic velocity recovery factor. The latter should have close value to the velocity recovery factor of the yoke—striking element of the mechanism.

The kinematic velocity recovery factor is given by:

\[
R_{\text{kin}} = \frac{U_{31+}}{U_{31-}}, \tag{4}
\]

where \( U_{31+}, U_{31-} \)—post-blow and pre-blow transmission ratios which have significant influence on efficiency of the whole mechanism and are calculated from the formulas below:

after impact at the crank arm angle \( \phi = 0 \):

\[
U_{31+} = U_{31}(0) = \frac{(\lambda_0 / \lambda_3)^{1/2} - 1}{1 + \lambda_0}, \tag{5}
\]

before impact at \( \phi = 2\pi \):

\[
U_{31-} = U_{31}(2\pi) = -\frac{(\lambda_0 / \lambda_3)^{1/2} + 1}{1 + \lambda_0}, \tag{6}
\]

where \( \lambda_1 = l_1/l_1 = 1, \lambda_2 = l_2/l_1, \lambda_3 = l_3/l_1, \lambda_0 = l_0/l_1 \) are the relative lengths of the elements.

These parameters govern performance of percussion machines and facilities. Prior to selecting a layout and size ratio of percussion mechanism elements, it is necessary to analyze performance of the machine using the calculated values of blow energy, factor \( R_{\text{kin}} \) and blow frequency.

**Figure 4.** Curves \( U_{31}(r) \) for different schemes of the variable-structure percussion mechanism with the longest base: (a) \( l_1 < l_2 = l_3 < l_0 \); (b) \( l_1 < l_2 < l_3 < l_0 \); (c) \( l_1 < l_3 < l_2 < l_0 \).

**Figure 5.** Curves \( R_{\text{kin}}(r) \) for different schemes of the variable-structure percussion mechanism with the longest base: (a) \( l_1 < l_2 = l_3 < l_0 \); (b) \( l_1 < l_2 < l_3 < l_0 \); (c) \( l_1 < l_3 < l_2 < l_0 \).
3. Conclusions
Based on the research results, the recommendations have been made on selecting parameters of vibromachins for cleaning holding reservoirs:

1. It is advisable to accept the value of the kinematic velocity recovery factor in the range of \( R_{\text{kin}} = 0.3\text{–}0.5 \).

2. The collision velocity \( V_{\text{col}} \) should not exceed 10–12 m/s in order to undamaged the reservoir surface; for this reason, the blow energy \( A_{\text{blow}} \) should be low.

Finally, the research findings enable: selecting layouts and length ratios of the percussion mechanism components to be included in the structure of percussion machines meant for cleaning pipes, hoppers and other holding reservoirs from difficult adhered deposits; recommending the layout with the length ratio \( l_1 < l_3 < l_2 < l_0 \) and parameter \( r = 5 \), which is able to increase shock power and, thus, efficiency of percussion machine.

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