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Original Research Article

Strength estimation of the impact zone – A critical area of the tools of the hydraulic hammers

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ABSTRACT

The hydraulic hammers are subjected to the impact loads, under which the elements of the tools can fail. The basic cause for this is the stress concentration in the critical contact areas and negative effects of environmental conditions – such as low temperatures, high humidity, or presence of salt. The particular critical area of the tools of the hydraulic hammers is the impact zone, which defines a limit of maximum impact velocity and blow energy of the piston. Taking this into consideration, the analysis of the stresses generated by impact on the contact surface of the tool was carried out. On this basis the realized as well as the required values of the safety factor for the impact zone were estimated as well and allowable impact velocity was determined which was conditioned by the strength of both the piston and the tool.

1. Introduction

Hydraulic hammers are used in many industries, among them, in mining and quarrying, civil and building engineering, as well as in metallurgy and foundry industries. Such a wide spectrum of application of hydraulic hammers is possible due to use of various replaceable tools (Fig. 1) which are selected for particular applications.

For example, in mining application or in quarries the typical tools used for breaking oversized lumps or rock mining are blunt (flat ended) tools, moil (pyramid) tools or conical tools. In contrast, in civil engineering for tearing up road surfaces or subgrade compacting more sophisticated tools are used, such as spade tools or tools with tamping plates [11,12].

Application of the hydraulic hammers is often the only solution when the usage of blasting materials is precluded, e.g. in subway tunneling or demolition performed in urban areas [11,12].

One of the basic problems in operation of the hydraulic hammers is the degradation of the working tools. The principal cause of the tool tip wear and blunting are large impact loads which generate high stresses concentrated in the specific areas of the tool.

The additional factor contributing to tool degradation is an influence of environmental conditions such as high moisture and presence of salt that create corrosion or low temperatures that reduce the crack resistance and fatigue strength of the tool material.

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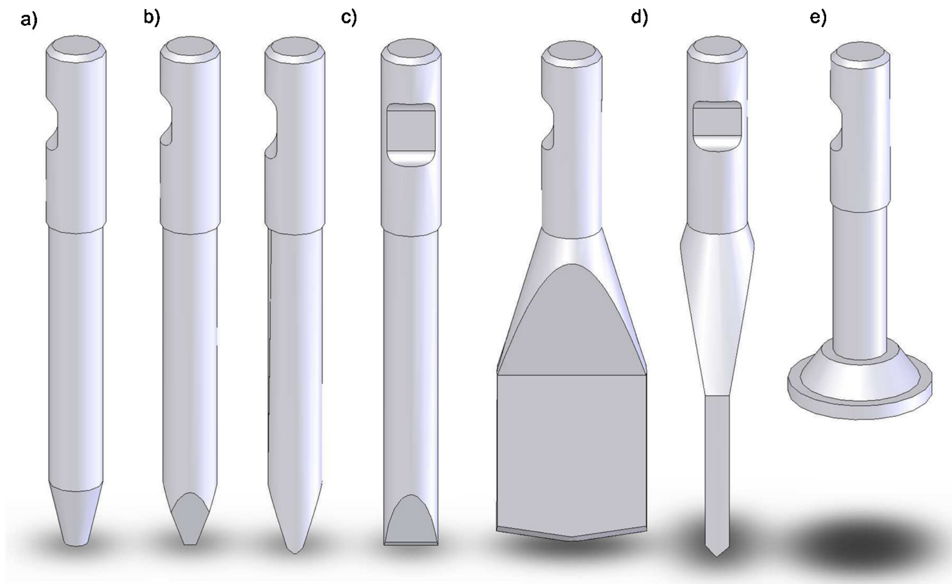

Fig. 1 – Typical set of replaceable tools of the hydraulic hammers: (a) cone, (b) moil point (pyramid), (c) chisel, (d) spade (wide chisel), and (e) tamping plate.

2. The critical areas of the tools of the hydraulic hammers

The blow energy is the most important parameter which determines the performances of the hydraulic hammer. In fact, the magnitude of energy which should be applied to a rock to fragment it can be estimated as a function of the size of lumps and rock properties as follows:

$$L_V = \frac{R_c^2 V}{2E_r} \tag{1}$$

where R_c, E_r is the rock compressive strength, E_r is the rock modulus, and V is the rock volume.

Therefore, in modern hydraulic hammers the impact energy applied to the tool should be as high as possible. However, the maximum energy is limited by the strength of the pistons and tools, because the high impact energy transmitted from the piston to the tool can easily lead to tool damage, both progressive and instantaneous.

The degradation of the tools of the hydraulic hammers can have various forms and intensity, but in general damage develops in some characteristic zones, called critical areas. These are: the impact zone, the pin groove zone, the shank zone and the tool tip zone (Fig. 2).

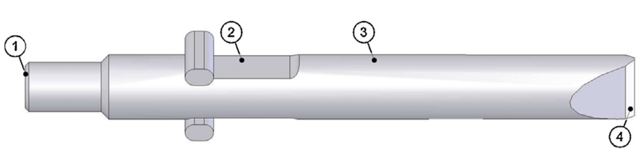

Fig. 2 – The basic critical areas of the tool of the hydraulic hammer: 1 – impact zone, 2 – pin groove zone, 3 – shank zone, and 4 – tip zone.

The impact zone, i.e. the rear part of the tool is particularly among the critical areas because this zone includes the area of the direct impact. The loads generated in this area depend mainly on the impact velocity. Therefore, the strength of the impact zone determines the allowable level of the piston velocity and thereby it creates a limit of the impact energy in the hydraulic hammers.

Degradation of the tools in the impact zone occurs as a result of the local exceedance of the yield stress or the ultimate strength of the tool material. The damage created by a plastic deformation most frequently assumes a shape of a mushroom and it is therefore often called mushrooming of the rear part of the tool.

In extreme cases chipping of the material can occur. Monitoring of this critical area is difficult because the impact zone is located inside the hammer and the access to this area is possible only after the tool is taken out from the hammer.

The principal factors which create degradation of the impact zone of the tool are the excessive velocities of a piston that can create instantaneous damage and long repeated blows of a piston that cause fatigue failures. One of the simple solutions to prevent material degradation is to limit the time of blowing the tool to a period of 15–20 s which is recommended by most producers of the hydraulic hammers [12,14].

To achieve the operational reliability of the hydraulic hammers, the evaluation of the degradation resistance of the tools, especially its resistance to sudden (catastrophic) failures in the impact zone, is a very important problem. One of the approaches to this problem is to perform stress and strength analyses in this critical area taking into consideration an effect of the impact velocity.

As discussed earlier, the impact energy is a basic parameter of each hydraulic hammer. That is why the determination of the allowable limit of the impact velocity that minimizes the risk of the tool damage is an important task.