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STUDY AND ANALYSIS OF THE EFFECT OF THE CHARGE INITIATION METHOD ON STEMMING MOVEMENT IN A BLAST HOLE

Mardanov I. N.
PhD, Senior Lecturer, Department of Mining Engineering,
Tashkent State Technical University (TSTU), Tashkent, Uzbekistan

Abstract
A review of literary sources is presented, reflecting the efficiency and necessity of using stemming in blast holes during the explosive fragmentation of rocks, as well as the influence of the charge initiation method on rock fragmentation.

Keywords: Blast hole, stemming, rocks, explosive, stemming length, line of least resistance, charge initiation, rock fragmentation.

Introduction

Internal stemming of blast holes is one of the factors that determines the blasting efficiency (explosive efficiency or utilization coefficient), uniform rock fragmentation, as well as the amount of toxic gases and dust released into the mine atmosphere during blasting [1,2,3].
Many years of blasting practice show that the same type of stemming provides different blasting results under varying conditions. Therefore, all new types of stemming must be carefully studied, and the selection of materials for blast-hole stemming should be based on a comprehensive consideration of the specific blasting conditions, the properties of the rock being broken, the explosives used, the type of working face, and other factors.
While studying the influence of blasting conditions of blast-hole charges on the parameters of shock waves, A. N. Khanukaev established that the use of stemming results in higher stress-wave energy compared to the detonation of identical charges without stemming. This is confirmed by the data presented in [4] and summarized in Table 1, which show that the maximum stresses at the shock-wave front when using stemming made of drill cuttings are almost 1.5 times higher than those observed during blasting without stemming.

Table 1 Effect of Stemming Type on Charge Blasting Conditions

Blasting conditions of charges	Maximum Stress at the Shock Wave Front, MPa	Duration of Shock Wave Action, ms	Shock Wave Length, m	Specific Impulse, N/cm²	Energy Flux Density, N·m/m²
Without stemming	2,25	1500	6,25	1850	12000
With water stemming	3,12	1130	5,87	2450	26000
With stemming made of drill cuttings	3,33	1610	8,35	2650	33000

One of the primary requirements for the results of drilling and blasting operations during the excavation of mine workings is to ensure sufficiently fine and uniform fragmentation of the rock mass, which is of critical importance during explosive rock breaking. In this case, good fragmentation facilitates excavation and transportation.

Many years of blasting practice show that when blasting elongated charges (blast-hole and borehole charges), unsatisfactory rock fragmentation most often occurs in the upper part of the charge cavity, which is not filled with explosives. The author [5] explains this phenomenon by the uneven distribution of specific impulses along the lateral surfaces of the blast holes or boreholes.

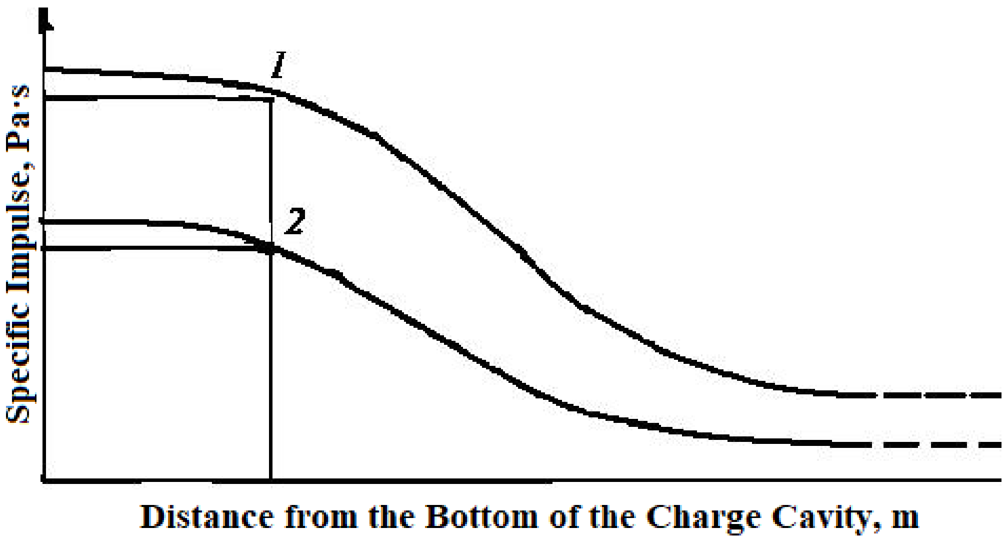

Figure 1 – Diagram of the distribution of specific impulses along the axis of an elongated charge cavity (according to F. A. Baum): 1 – with stemming; 2 – without stemming.

The graphs constructed by the author (Fig. 1) show that the specific impulse reaches its maximum value in the zone of the charge and decreases significantly toward the mouth of the charge cavity. The uneven fragmentation of the rock mass is explained by the non-uniform distribution of impulses along blast holes and boreholes.

The quality of rock fragmentation from the detonation of elongated charges is largely determined by the charging density and the magnitude of internal stemming.

In the case of direct initiation of charges (from the mouth of the charge cavity), the detonation products, acting on the end face of the stemming, tend to displace it. According to the scheme of interaction between the detonation products, the rock mass, and the stemming proposed by the author in [5], a shock wave simultaneously arises in the charge cavity and propagates in the direction of charge detonation, i.e., opposite to the direction of stemming movement. After being partially reflected from the bottom of the charge cavity, the shock wave—whose velocity is significantly higher than the ejection velocity of the stemming—catches up with it and, upon reflection, is again directed toward the bottom of the charge cavity (Fig. 2a). Such pulsation in the detonation products continues until the stemming is completely ejected from the mouth of the charge cavity.

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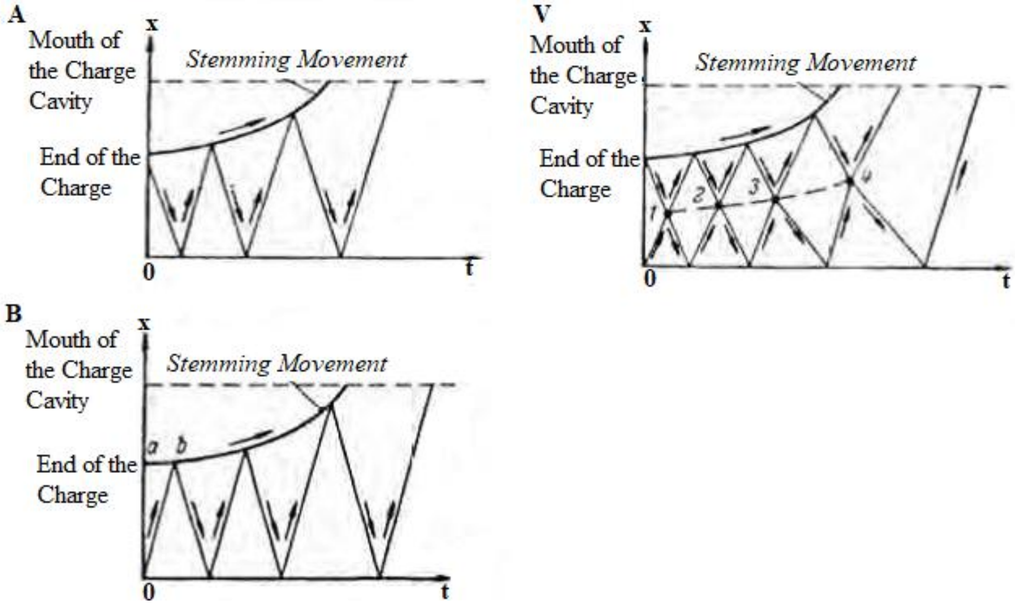

Figure 2 – Diagram of stemming and shock wave movement during the detonation of an elongated charge: a – with direct initiation of charges; b – with reverse initiation of charges; c – with double-sided initiation of charges

In the case of reverse initiation of charges (from the working face of the charge cavity), the rock surrounding the charge is subjected to the detonation products before the stemming begins to move. The delay in the movement of the stemming relative to the onset of the detonation products acting on the rock mass is represented by the segment **ab** (Fig. 2b), which corresponds to the explosive decomposition time of the charge and depends on its length and the detonation velocity of the explosive used. Therefore, with reverse initiation, the stemming has less influence on the blasting results than with direct initiation (from the mouth of the charge cavity).
Finally, in the case of double-sided initiation (Fig. 2c), the presence of two detonation fronts generates two shock waves moving toward each other, which, interacting with one another, reduce the effect of the detonation products on the stemming. Naturally, in this case, the ejection velocity of the stemming will be lower than with one-sided initiation of charges.
Leakage of detonation products, which reduces blasting efficiency, can occur either through the mouth of the charge cavity (in the case of poor-quality stemming) or through cracks formed as a result of rock mass failure in the direction of least resistance. Therefore, the explosive energy can be utilized most effectively only if the stemming ensures retention of the detonation products in the charge cavity until the onset of rock mass failure and displacement.
The time interval from the completion of charge detonation to the initiation of rock detachment and displacement depends on the pressure of detonation products in the charge cavity, the resistance characteristics of the rock being broken, the number of free surfaces in the working face, the line of least resistance, and, for homogeneous rocks and working faces, represents a well-defined value. Let, for certain specific conditions, the time of rock detachment and displacement be determined by the abscissa (Fig. 3).

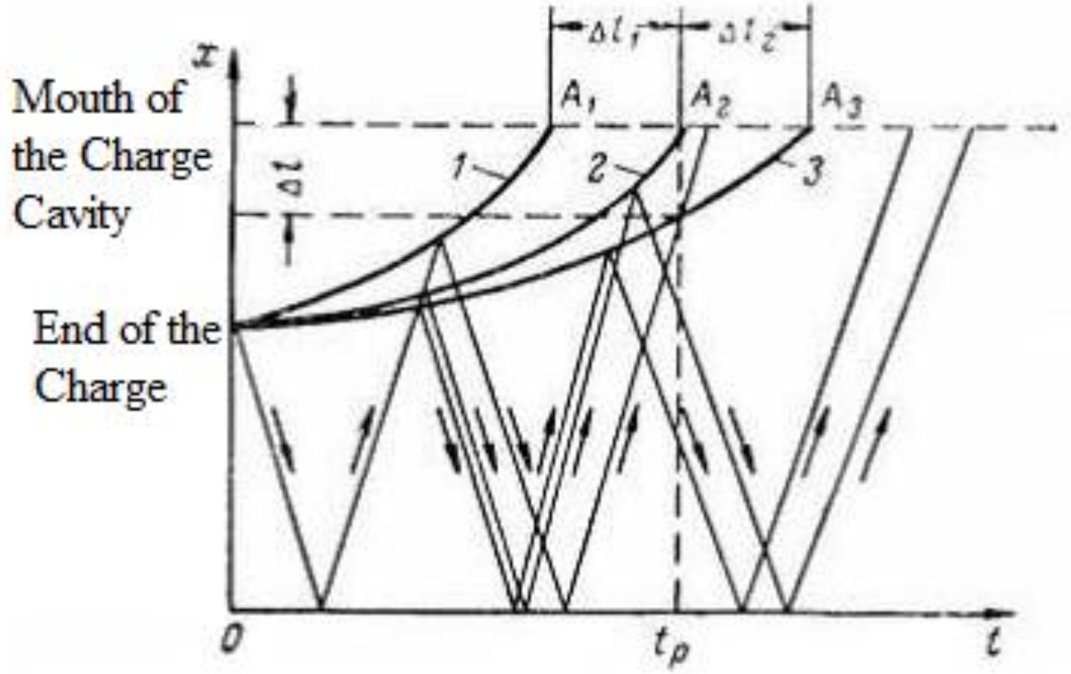

Figure 3 – Diagram of the interaction between stemming and shock waves generated during the detonation of an elongated charge: 1 – stemming shorter than optimal; 2 – optimal stemming; 3 – stemming longer than optimal

The stemming length, and consequently the velocity of its ejection from the cavity, can be selected so that sealing of the mouth of the charge cavity is maintained exactly until the onset of rock detachment and displacement. In this case, the stemming ejection time t_z, represented by the abscissa of point A_2, will coincide with the value t_p.

When the stemming length is reduced, the velocity of its movement under the action of detonation products increases, and the total ejection time of the stemming in this case is determined by the abscissa of point A1, whose value is smaller than t_p, by Δt_1. Consequently, with a reduced stemming length, the detonation products will act on the rock mass not for the entire time t_p permitted by the working-face conditions, but only for the time interval $\Delta t = t_p - \Delta t_1$. As a result, the portion of explosive energy transferred to the rock being broken will be less than the maximum possible.

If the stemming length is increased such that its ejection time rises by Δt_2, then, at an unchanged value of t_p, by the moment rock detachment and displacement begin, the upper part of the charge cavity with a length of Δl will remain filled with stemming. The walls of the charge cavity in this zone will not be directly exposed to the detonation products and, consequently, rock fragmentation in this area may be unsatisfactory.

Analysis of theoretical and experimental studies conducted over the past decades [6,7] shows that a complex effect on the rock mass can be achieved only through the simultaneous use of strong stemming, which retains the detonation products in the charge cavity until the moment of rock mass failure.

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