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SCIENTIFIC ANALYSIS OF THE DEPENDENCE OF SEISMIC WAVES ON DISTANCE AND TIME DURING THE EXPLOSION PROCESS

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Abstract

This article investigates the deformation zones of rock massifs, the impact of seismic air waves resulting from explosions in quarries, shock air waves, the dynamic characteristics of waves, vibrations in elastic zones, and the displacement of particles as a function of space and time. The study also examines time-dependent graphs of seismic waves and the attenuation of vibrations in the medium over time after an explosion.

Keywords: Deformation, seismic wave, shock air, explosion, energy, zone, rock, spatial, instantaneous initial, isotropic, volumetric force, elastic, vibration, signal, amplitude.

Introduction:

In open-pit mining operations using blasting methods, it is crucial to consider the impact of seismic and air shock waves. These waves can negatively affect surface structures, bench stability, rock fracturing, the geodynamic state of rock masses, and other related processes. As a result, they have a significant influence on the surrounding environment, mining operations, safety regulations, and economic indicators.

Since blasting operations are the primary source of seismic and air shock waves in quarries, selecting the most effective blasting technology and optimizing the process can help reduce undesirable seismic impacts. Therefore, the study of seismic and air shock wave effects, the assessment of seismic safety, and the development of optimal blasting technologies remain critical challenges in modern mining engineering.

Literature Review and Methodology:

Several researchers have conducted studies on the impact of seismic and air shock waves generated during blasting operations in open-pit mining. A.A. Sidorin and V.I. Ulomov have carried out research on explosion seismology and the propagation of seismic waves. M.S. Antsiferov has investigated air shock waves produced by blasting and their effects.

The dynamic characteristics of seismic blast waves change over a certain distance from the explosion site. In the vicinity of the blast source, an initial increase in vibration intensity is observed, followed by rapid attenuation. Based on the deformation zones of the rock mass, the affected areas are classified as follows: Near zone – the zone of plastic (irreversible) deformations; Intermediate zone – the zone of elastic-plastic deformations; Far zone – the zone of elastic deformations.

In the study of seismic vibrations, an analytical approach should include at least three main components: Characterization of seismic sources – determining the conditions of vibration generation and their properties; Equation of motion – a mathematical model describing how vibrations propagate through the medium; Theory linking the particular solution of this equation to the seismic source – this relationship allows for the determination of wave propagation characteristics based on the properties of the source.

In the near zone of an explosion, seismic vibrations primarily attenuate due to irreversible deformations. As the distance from the blast site increases, the attenuation characteristics of the vibrations change, and elastic deformations are observed at a distance approximately 2–3 times the wavelength. At greater distances and within elastic zones, the vibrations become closer to a sinusoidal shape (Figure 1).

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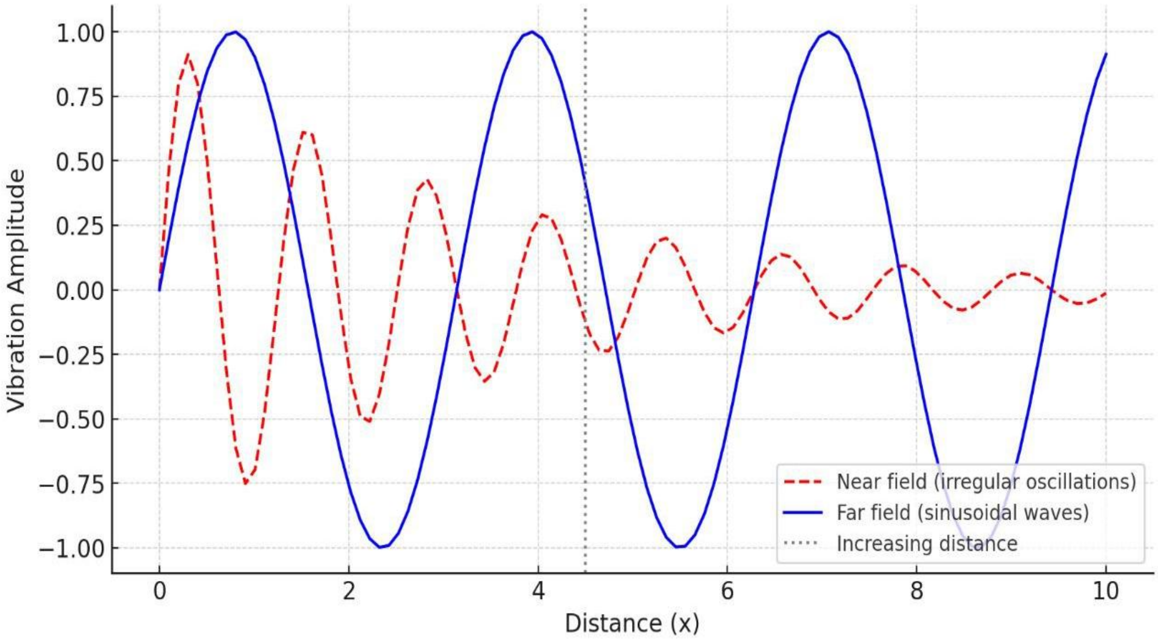

Figure 1. Variation of Vibration Amplitudes with Distance Due to Industrial Explosions.

For the preliminary assessment of seismic impact, it is recommended to classify seismic zones based on wave types. These waves are divided into body waves and surface waves, each characterized by distinct attenuation properties, frequency content, and intensity.

In a dense medium, two main methods are commonly used to describe motion and analyze motion mechanics: Lagrangian method – considers the movement of a specific particle, where its initial position is defined by its coordinates at a given moment in time; Eulerian method – examines motion based on particles moving along a specific spatial trajectory. For many seismological problems, applying the linear theory of elasticity using the Lagrangian approach is considered more convenient.

Results:

The displacement of a particle is analyzed as a function of space and time. Displacement is denoted as $a=(x,t)$, which represents the vector distance of the particle at an instantaneous time t, where the particle was initially located at point x at time t_o. Since x - remains constant over time, the velocity of the particle is $\frac{\partial a}{\partial t}$, and the acceleration is $\frac{\partial^2 a}{\partial t^2}$.

To determine the displacement *a(x,t)* caused by a unidirectional point volumetric force, it is necessary to consider that this force has a time-dependent amplitude and is located in a homogeneous, infinite, isotropic elastic medium. By placing the origin of the coordinate system at point O and selecting the x_1 axis as the direction of the volumetric force, the differential equation that must be solved to find the displacement takes the following form:

$$\rho_{\mathrm{a}} = \Phi + +(\lambda + 2\mu)\, \mathrm{V}\, (\, \mathrm{V}\, \mathrm{x}a\,) - \mu\, \mathrm{V}\, \mathrm{x}(\, \mathrm{V}\, \mathrm{x}a), \qquad (1.1)$$

Here, V - Gamilton operator (differential operator), and $\Phi = X_o\,(t)\delta(x)\ \delta_t$ represents the volumetric force.

The initial conditions are given as $a(x,o$ at $x=o$, and for $x \neq o$, $a_n(x,t)=X_o\,G$, where G is the Grin's function in the dynamic theory of elasticity, and X_o - is the point force.

For a point force $X_o(t)$ acting in the x_j direction at the origin O of the coordinate system, the solution of equation (1.1) takes the following form:

$$a_i(x,t) = X_0 G_{ij} = \frac{1}{4\pi\rho}\left(3\gamma_i\gamma_j - \delta_{ij}\right)\frac{1}{r^3}\int_{r/\vartheta_P}^{r/\vartheta_S} \tau X_0(t - $$

$$-\tau)\, d\tau + \frac{1}{4\pi\rho\vartheta_p^2}\,\gamma_i\,\gamma_j\frac{1}{2}\,X_0\left(t - \frac{r}{\vartheta_p}\right) - \frac{1}{4\pi\rho\vartheta_S^2}\left(\gamma_i\,\gamma_j - \delta_{ij}\right)\frac{1}{r}X_0\left(t - \frac{r}{\vartheta_S}\right). \qquad (1.2)$$

This formula (first introduced by Stokes in 1849 as an equivalent expression) represents one of the most important solutions in the study of elastic waves.

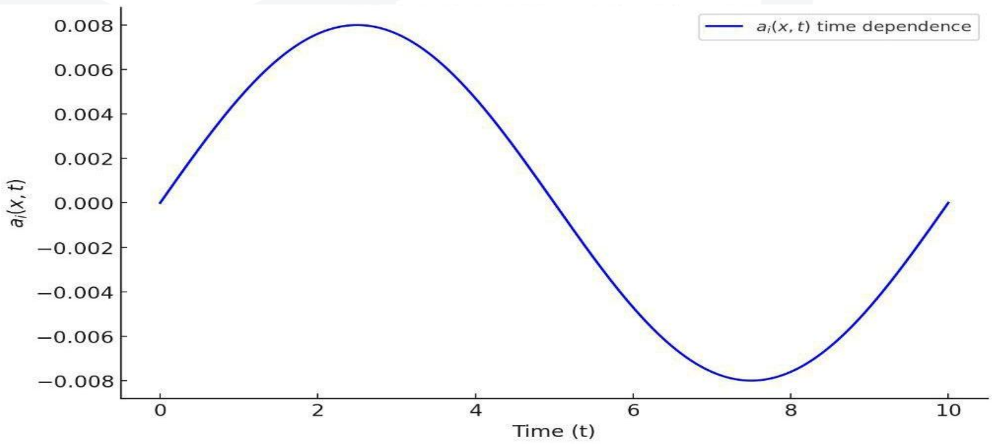

Figure 2. The graph of $a_i(x,t)$ as a function of time t is presented (with a fixed distance r = 10).

The graph illustrates how the vibration amplitude decreases over time. Initially, the signal has a high amplitude, but it gradually decreases as time progresses. Such functions are commonly referred to as Grin's functions and describe wave propagation in an elastic medium.

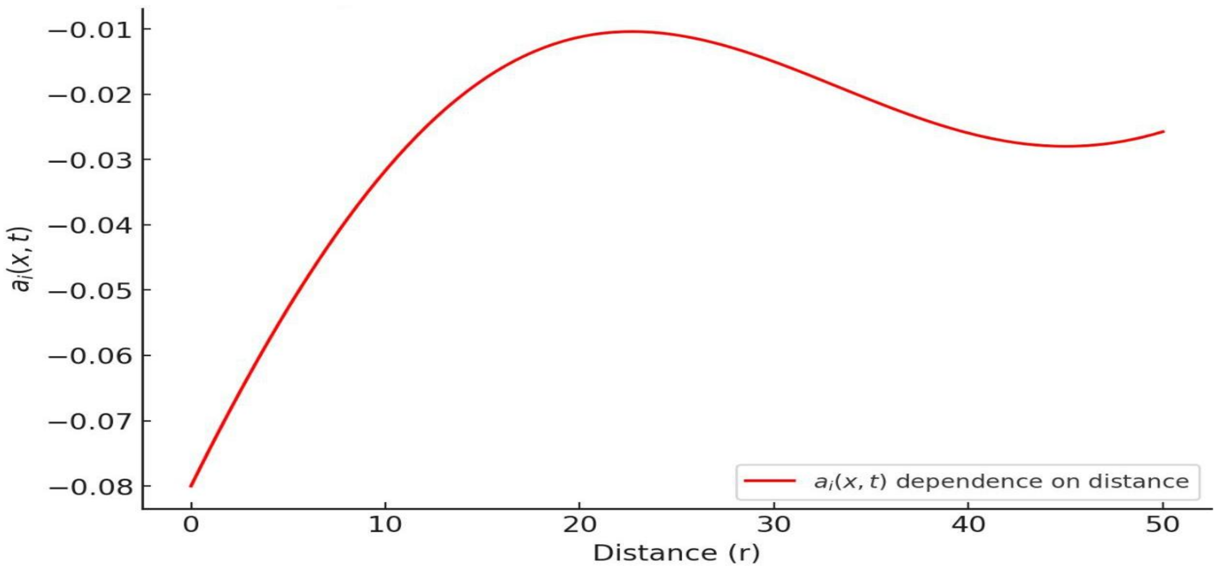

Figure 3. The graph of $a_i(x,t)$ as a function of distance r (with constant time t = 5).

The graph illustrates the attenuation of the signal as the distance increases. In other words, as r becomes larger, the intensity of the signal decreases. This phenomenon is associated with the reduction of seismic wave energy as it propagates over long distances.

These graphs depict the variation of seismic motion depending on time and distance.

Conclusion:

The vibrations generated by an explosion propagate depending on the elastic moduli and density of the rock formations. At greater distances, seismic waves predominantly take on a sinusoidal shape, and their amplitude decreases exponentially. According to the research findings, the time-dependent graph demonstrates the attenuation of seismic vibrations over time within the medium. Meanwhile, the distance-dependent graph examines the reduction of vibrations as they move further from the source.

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