Shahrood University of Technology

Iranian Society of Mining Engineering (IRSME)

Journal of Mining and Environment (JME)

journal homepage: www.jme.shahroodut.ac.ir

THOMSON REUTERS

Study on an Online Vibration Measurement System for Seismic Waves Caused by Blasting for Mining in Vietnam

Hieu Dao[1], Thanh Loan Pham[1] and Phi Hung Nguyen[2]

1. Faculty of Electro-mechanics, Hanoi University of Mining and Geology, Hanoi, Vietnam
2. Faculty of Mining, Hanoi University of Mining and Geology, Hanoi, Vietnam

Article Info

Received 1 April 2021
Received in Revised form 24 May 2021
Accepted 12 June 2021
Published online 12 June 2021

DOI:10.22044/jme.2021.10677.2028

Keywords

Blasting, Seismic wave
Vibration measurement
Vibration monitor
Vietnam
Nuibeo coal mine

Abstract

Blasting has become a crucial work in mining operation. However, it produces high-intensity seismic waves which cause some serious troubles such as injure people, fly-rock, cracking, breaking and reducing the lifetime of adjacent buildings. In Vietnam, there have been many conflicts between residents and government about the compensation policy for these damages. The solution is proposed, in which a similar explosion is made and an instantaneous concussion meter is used to record the magnitude of the generated shock wave. The results received from this operation will be used to determine the effects of mining blast. In fact, that is an incorrect method because just by changing the type of explosives, the order, the explosives, etc., the shock wave will be significantly reduced. Nothing is ensured that another explosion causing a shock wave amplitude will not occur in the future. To solve this problem, this paper presents an online seismic wave monitoring system operating 24/24h, to transmit the recorded signal to an independent server located around the boundary of the mine. On the basis of the mechanism of generating explosive waves and the recording mechanism of shock waves, the authors have built a program to store records according to the permissible influence of Vietnam Standard and Circular 32/2019/TT- Vietnam Board of Directors.

1. Introduction

From the physical perspective, it is worth knowing that waves are a type of energy spread. For example, shock waves, caused by the high-speed burning processes of detonation, are compression waves in which the spread of these waves is three-dimensional. The pressure is inversely proportional to the distance from the detonation center as the increase in the distance leads to the rapid decrease in the pressure [29].

The air properties would cause the shock or the steep on the front of this pressure wave during the movement of the front. As consequence, the shock front is moving supersonically with the speed which is faster than the sound speed of the air in front of it and with discontinuities in pressure, density, and particle velocity across the front. [30[36]

The ground vibration intensity is dependent on some factors. The most important factors are the distance from the person or house to the blast and the weight of explosives per delay period. Normally, the longer distance from the blast results in the lower magnitude of the ground vibrations [4].

Ground vibration may cause a bad damage to its surrounding properties as well as substantially bother the local residents. The damaged properties can be caused directly by the movements of ground waves or indirectly through unstable soil or rock conditions in the vicinity of the construction site, such as soil liquefaction and slope failure. Air blast is not mentioned as an important factor which causes damage to structures, however, it can be considered as a main factor which causes a number types of complaints of local population [37-39].

Corresponding author: hunguni@gmail.com (N. Phi Hung).

The object near the explosion point could be torn in the skin and internal organs, causing serious injuries to the parts of the body. For instance, during propagation the shock wave also influences on the gas which causes damage to the lung and the middle ears. Particularly, pathological manifestations could be direct lung injury, tympanic membrane rupture, intestinal contusion and intestinal perforation [9, [23]. The impact level of an explosion on the surrounding environment depends on many factors such as the structure of the soil in the area, the explosive power of each type of explosive used, the placement of the pill ingot, simultaneous blasting or differential blasting and so on [11]. Depending on the specific properties and targets of each explosion, the explosion waves propagating in the soil, water, and air environment also have different amplitudes, levels and frequencies of influence on people, structures, etc. device.[6, 34].

Blasting works cause vibrations which influence on buildings and the internal environment of the building as well [8]. If the building are constructed in the surrounding of quarries, the residents can realize the negative vibrations. However, the intensity of these vibrations can be reduced to the levels that the residents would not perceive such negative impacts inside the building by using a suitable millisecond timing interval. The limitation of the vibration intensity has been defined. For instance, nominative values of the particle velocity and frequency were determined for protection of the building from the vibrations. Hygienic standards for the households were also applied, evaluating the effect of the vibration of humans via the measurement of the vibration acceleration in the building [40]. According to Vietnam standard stated in QCVN 01:2019/BCT, the standards for permissible distances for shock waves are given as follows:

Table 1. Permissible limits of impact of blast waves for blasting

Type and method of blasting	Minimum radius of danger zone (m)	Minimum safe distance, m (for rock splash)
Blast-casting practice in opencast mines	Not less than 200 (2)	≥ 200 (2)
Secondary blasting on surface	Not less than 200	≥ 200
Blasting charge in small hole (d<75mm)	According to design papers or approved construction method, but mandatory, ≥200	≥ 200
Blasting to make small block caving pipe type	According to design papers, but mandatory ≥ 300	≥ 300
Blasting with the explosive charge in large hole (d>75mm)	Not less than 400	≥ 400
Blasting with the large holes which made block caving bag	According to design papers	≥ 50
Secondary blasting excessively large boulders in underground	Not less than 50	≥ 100
Blasting with the small holes which made small block caving bag	According to design papers, but mandatory ≥10 (6)	
Blasting with the large holes which made large block caving bag		≥ 100
Blasting in the exploration activity	According to design papers, but mandatory ≥ 100	≥ 30
Blasting in the small shaft and on the surface	According to design papers, but mandatory ≥ 30	By design (4)

For application regarding engineering, the detail description of blast waves is an essential step of the overall design process. Nevertheless, compared to ideal theoretical formulas, actual explosive events might be significantly sensitive to a variety of parameters and to the basic features of the charge, such as size, type and shape. In this case, the design and research developments are supported by using advanced computer codes. Also, the input parameters and the solving based on presumptions of refined numerical methods are commonly available and modified in the literature for specific structure [4].

The excellent blasting model could have an accurate prediction for the non-ideal detonation behavior of explosives in all rock types and hole conditions. Particularly, the damage, fracture, fragmentation and rock movement in three dimensions would be predicted based on awareness of geological conditions, such as rock structure, water saturation and stresses. It will consist of the fluid dynamics effects of gas ingress into and around cracks and its impact on the dynamics of bulk motion related to muck pile heave [42].

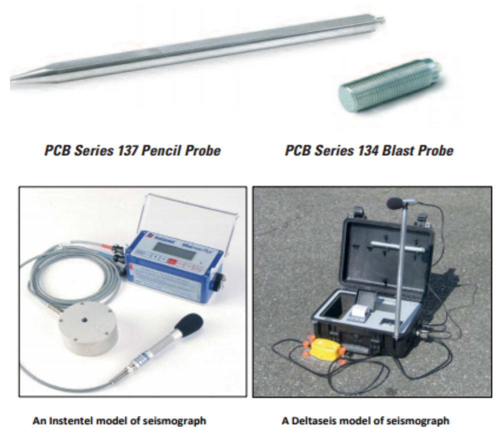
Unfortunately, there is no perfect blasting model. Currently, the available models can perform some of things, however, each shows some limitations and provides just part of the picture. Models can be classified as empirical, analytical, numerical, mechanistic or combinations of these. Empirical computer models are based on the simple fitting of mathematical and/or computational expressions to information that has been attained by observation and/or measurement [43].

These models can commonly be described in a spreadsheet and run on a computer in a few seconds. Analytical models try to make predictions from first principles according to an understanding of the underlying physics of the system or a process that has been transferred into mathematical formulations. These relationships are listed into three ways that (a) are usually few in number, (b) are amenable to computation and (c) are considered good approximations to the theory. Analytical models are not used for dynamic (time-varying) calculations but they often involve iterative procedures to achieve convergence or optimization [45].

Generally, these models can be run on a computer but depending on the fidelity and resolution, they might take a few minutes or even hours to run. Vibration attenuation and scaling constants can be measured only by taking many vibration readings at different scaled distances that can be time-consuming and expensive [27[44].

When monitoring tremors in a large radius around a seismic source to determine a safe radius, the selection of a recording system by seismic recording stations is capable of not only adapting to all terrain conditions but also responding to a wide frequency. There are several systems of seismic recorders commonly found and available today, such as the Blastmate III, Seistronix RAS-24, Terraloc MARK 6, Model 16S 12 and 24 Channel Seismographs, Model 12S12L Channel Seismograph [17 and [45].

(a)



(b)

Figure 1. Seismic wave measuring device. a) Measuring shock waves in the field with the Seistronix RAS-24. b) A kind of shock wave measuring pen

Nowadays, the blasting devices are capable of managing and programming to control separately. Besides, the advanced control methods such as neural networks, artificial intelligence embed on high-speed computers are applied to hand out high precision analyses and predictions [22, [38, [39, [41, [44[43]. The high-tech equipment such as high-speed cameras, measuring and on-site vibration graph indicating instruments are also available for recording and monitoring. All the received information of the equipment will be synthesized and analyzed by using the specialized software. Blast Information Management System (BIMS), a blast management and design software solution from Blasters Tool and Supply Company, allows mining operation to be optimized. This software also provides methods to store, document and retrieve drill and blast related information. The system stores blast details, actual blast parameters, blast pattern, face profile, explosive consumption, charging details, vibration records, photos and videos of the blast. Readily available past data in a logical format and blasting data analysis tools are the key features of this software.

In literature, continuous vibration monitoring and measuring systems have also been developed.

Pinnock and his colleague used micro-seismic sensors to measure the smallest vibrations in order to continuously monitor vibrations. Jinxing Lai used the wireless sensor network to monitor the vibrations in tube caused by blasting [21]. On that basis, the abnormal vibrations will be detected and then a warning will be sent to ensure the safety of the system. The regular vibrations can be studied and analyzed to find the suitable structure for the buildings in order to ensure the safety of the buildings from such vibrations [18].

Recently, several national research projects in Vietnam have applied artificial intelligence (AI) in solving the predictive problems for vibration level. This advanced method ensures that the surrounding areas are safe and the explosion efficiency is increased when blasting occurs. Nguyen et al. have built seismic wave prediction models for blasting in open-pit coal mines, using AI and machine learning algorithms. [12, [19[20, [32 and [33]. Jie Dou, Pham and the research group pointed out some different sampling strategies for predicting landslide susceptibilities are deemed less consequential with deep learning [32]. Bui et al. have stressed the optimization for Spatial Assessment of Landslide Susceptibility [7] and discussed the prediction of ultimate bearing capacity through various novels evolutionary and neural network models [19] and so on.

It is easy to see here that explosion simulation software is not perfect since these results are based on the collected discrete data. So the nature of the real explosion was changed. Then, it will not be possible to fully reflect the explosions of a mining unit in certain time. It makes some explosions with simultaneous explosives exceeding the threshold unrecognized. The effects of these blasting lead to complaints from the local people. Conflicts last for a long time because the testing data is not really reliable. To thoroughly solve this problem, it is necessary to have a system to record blasting waves in real time operating 24/24h. The recorded data is transmitted directly to the server of the local government or a monitoring agency independently. In the condition that, importing equipments are too expensive for state management agencies, the authors have proposed an online monitoring system for vibration caused by blasting in Vietnam. On the basic of principles of shock wave generation from mining blasts, we built an online explosion wave recording system with boundary conditions specified in Vietnam Standard 02/2008 and Circular 32/ 2019/TT-BCT on National technical regulation on safety in production, testing, acceptance, transportation, using, destroying and preservation of explosive precursors.

2. The principle of shock wave formation from mining detonation

Implementation of a mine explosion will cause the vibration around the blastholes and spread to the vicinities. The level of vibration is expressed through the vibration velocity and vibration amplitude of the rock particle. The vibrational velocity referred as particle velocity describes the vibration speed of rock particles around the equilibrium position after the propagation of seismic waves. The movement of the rock from blasting is similar to the movement of the float on top of the water [5]. The unit of particle velocity is m/s or mm/s while the particle velocity is measured by the vibrometer.

The main parameters, that directly affect the seismic wave caused by blasting, are the distance to the detonation point, the amount of explosive and the order of implementation. A lot of research has been carried out to determine the mathematical relationship between vibration level, charge size and distance. In formula (1), A relationship given by Konya and Walter [24] is depicted:

$$v = 100H\left[\frac{d}{W^{\alpha}}\right]^{\beta} \tag{1}$$

where $\boldsymbol{v}$ is predicted particle velocity (mm/s); $\boldsymbol{W}$ is the maximum explosive charge mass per delay (lbs); $\boldsymbol{d}$ is the distance from shot to measured point in 100's of m; $\boldsymbol{H}$ is particle velocity intercept; $\boldsymbol{a}$ is charge mass exponent; $\boldsymbol{b}$ is slope factor exponent.

$\boldsymbol{H}$, $\boldsymbol{a}$ and $\boldsymbol{b}$ are the parameters describing the properties of the explosion area such as topography, rock type, geological structure, thickness of the blasting area and other factors. According to Nichols et al [10], values of 0.5 and -1.6 for α and β, respectively, are acceptable while the value of the parameter $\boldsymbol{H}$ varies significantly depending on the explosion area and other factors [34].

Equation (1) shows how the relationship between the distance and the explosive charge mass affects the particle velocity. The parameters ($\boldsymbol{H}, \boldsymbol{a}, \boldsymbol{b}$) are different in each direction of the vibration axis. They are constant for the axial direction (from the measuring point to the blasting point) [4]. In this case, the particle velocity is mainly dependent on two factors which are explosive charge mass and distance to detonation point.

The vibration level of structures can be extrapolated from the vibration level of the ground outside the structures but within the building face towards the blasting area. The distance from the measuring point to the explosive position is not less than 20% of the distance from the explosive position to the construction. The extrapolation is performed according to the formula (2):

$$V = V_0 \times \frac{D_0}{D} \times 1.5 \quad (2)$$

Where $\boldsymbol{V_0}$ is the velocity of the measured element at the placement of the measured device (mm/s); $\boldsymbol{D_0}$ is the distance from the location of the measured device to the blast site (m); $\boldsymbol{D}$ is the distance from blast site to the building (m); $\boldsymbol{V}$ is the elemental oscillation velocity of the structure of the building (mm/s).

According to Konya and Walter [24], the wave propagation speed represents for seismic wave speed which spreads from the explosive position to the measured point on the earth's crust. Its speed varies in the range of between 305 and 6100 m/s depending on the area. In a certain area, this value is almost constant. A delay time between consecutive explosions consequently causes the delay of propagation of seismic wave. The period of time that the waves propagate is very small compared to the delay between consecutive explosions, as the distance between the burst points is short. As a result, the seismic waves cannot be met each other. [25].

The seismic wave propagating from the blasting point is composed of three components: a P wave (pressure wave or longitudinal wave), an S wave (shear wave) and a Rayleigh wave [4, [24 and [26]. The P wave, the main cause affecting the vicinity, gives the highest breaking effect [5] and the propagation velocity of the P wave ($\boldsymbol{V_P}$) is also the greatest [34]. In some cases, $\boldsymbol{V_P = 2V_S}$ ($\boldsymbol{V_S}$ is the propagation velocity of the shear wave). (Figure 2).

The longitudinal wave propagation velocity $\boldsymbol{V_P}$ is influenced by many factors such as: the porosity of rock (or rock density), the compression resistance, the crack, the crack direction, and water retention. Meanwhile, these parameters are closely related, and they affect each other. This makes $\boldsymbol{V_P}$ vary according to a non-linear and non-repeatable rule on different geological areas [4].

Energy, measured by ground vibrations and the maximum particle velocity, is emitted from the detonation point and it spreads in all surrounding directions. If the ground is a homogeneous medium and the energy transmitted in all directions is the same, the vibrations in all directions would be equal. However, in fact, the propagation of vibrations is not ideal due to changes in the earth's structure and changes in the vibrations in different directions. Geological structures, will change the vibration level and frequency. Therefore, choosing the order of the explosion causes the different vibration levels or seismic levels with different directions. [1, [2, [6, [10, [25 and [42].

The size of a blast is not the decisive factor affecting the maximum particle velocity, but the simultaneous explosives mass. To reduce the seismic wave, the explosion is divided into several smaller explosions using the delay time with a difference of 1/1000 s. The alternative way for the reduction of the seismic wave is to arrange the explosion so that the blast wave collides with each other to self-destruct the vibration [11]. An electronic differential detonator with a capability of regulating the delay time provides flexibility when controlling the explosion direction, leading to the reduction of vibrations and the increase of breaking capacity [24, [28 and [35]. However, the implementation process cannot be relied on the theoretical calculation.

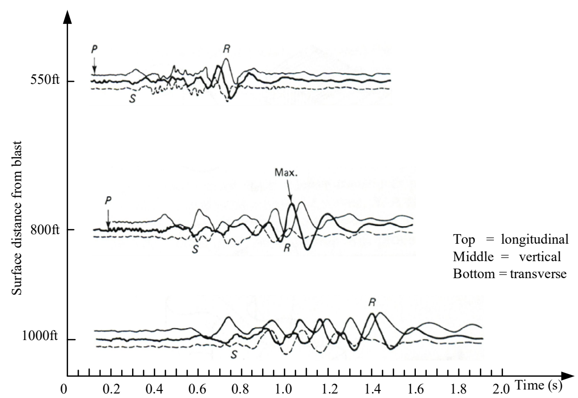


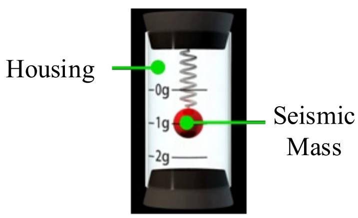
Figure 2. General form of blast vibration time-history records

3. Methods for recording shock waves from mining blast

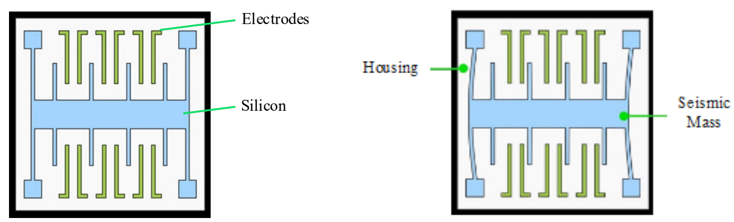
To record shock waves, current devices use a type of sensor called an accelerometer. The accelerometer operates based on the principles that, when the shock wave affects the sensor, the spring of sensor will contract and expand to bring the object to the corresponding position [3]. The recorded displacement of the counterweight will determine the intensity of the shock wave. To make this operation easier, the spring and counterweight are replaced by a thin layer of silicon with condenser plates and integrated as electronic chips. When the sensor chip is subjected to displacement, the silicon layer is deformed (Figure 3b). Two electrodes and the silicon layer form a variable capacitor (Figure 3c). The movement of the silicon will change the balanced potential and causes an electric current to be generated. Measuring the value of this current will determine the moving distance of sensor chip and its displacement acceleration. With a 3-axis accelerometer chip, there will be 3 silicon layers placed in the 3 XYZ directions of the spatial coordinate system. Attaching the sensor to the object, measuring the level of the sensor signal in each direction, and then summing it up will give the object's motion acceleration [46].

When an explosive amount is detonated in the rock, it will create a vibration wave that propagates in the rocky environment around the explosion area. The soil particles vibrate in the space around it and are measured according to the LVT coordinate system (Figure 3d). The LVT coordinate system is an axis system in 3 directions of space, corresponding to the XYZ axis system. Each direction of an axis is responsible for describing the degree of vibration of soil particles in that direction. The total vibration of the particle will be calculated by the formula:

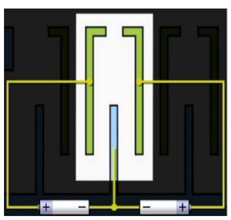
$$\vec{u}=\sqrt{\vec{u}_L+\vec{u}_V+\vec{u}_T} \tag{3}$$



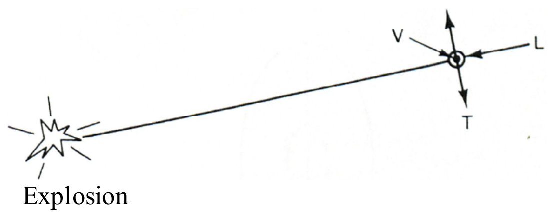
a) Basic principle of accelerometer



b) Displacement of the silicon layer when moving the sensor chip



c) The method of converting the relative displacement level into an electrical signal



d) Location of the shock wave device

Figure 3. The principle of accelerometer

The 3-axis accelerometer chip is fixed to the rock layers subjected to vibration caused by blasting, the XYZ directions of the sensor are set to be similar to the LVT directions.

4. System structure design and programming firmware

4.1. System structure design

By analyzing the solutions and structures of vibration monitoring and measuring systems; finding out the advantages and disadvantages of each structure, the system is the data logger in measuring blasting vibration. In order to be suitable with the conditions in Vietnam, the structure described in Figure 4a. In which, there are a Central Station and some Sensor Station. The Sensor Station is to record vibration data and send it to the center. The Central module not only plays an intermediate role in transmitting data from the vibration measuring station to the cloud, but also stores a database synchronized over time.

The sensor station is built based on the using of a 3-axis accelerometer chip to determine the vibration level of the rock. The sensor is integrated on the electronic circuit. The measured signal from the sensor is sent to FPGA circuits. The signal after processing will be sent to the CPU which is a microprocessor. This microprocessor is responsible for recording, storing, checking and comparing sensor data and coordinating system operations (Figure 4b).

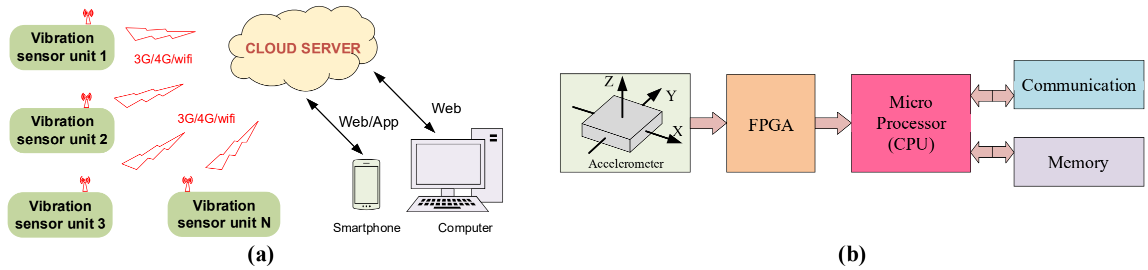


Figure 4. The structure of designed system. a) The structure of blasting vibration monitoring system. b) The structure of Sensor Station with Accelerometer

4.2. Firmware design

CPU controls the measuring device on the basis of pre-programmed firmware. When the amplitude of the signal exceeds the set level, CPU will begin to record all data received in each direction into memory over time. The recording interval can be set from 1-5 seconds. The resolution of the log data is selectable by 0.5 or 1 millisecond. In other words, every 0.5 or 1 millisecond, a set of data in 3 axes is stored in memory. At the end of the data recording process, the CPU determines the synthetic vibration vector from the sensor to find the time and the value when the magnitude of this vector is the largest. All stored data and calculation results are then sent to the storage system on the server (Figure 5a).

On the server, after receiving the data set from the measuring device, thee data will be automatically checked and compared. This aggregated vector value is compared with the allowable limit according to QCVN, from which the management software on the server will automatically send alerts to the app on the user's smartphone and send warning to the registered email (Figure 5b).

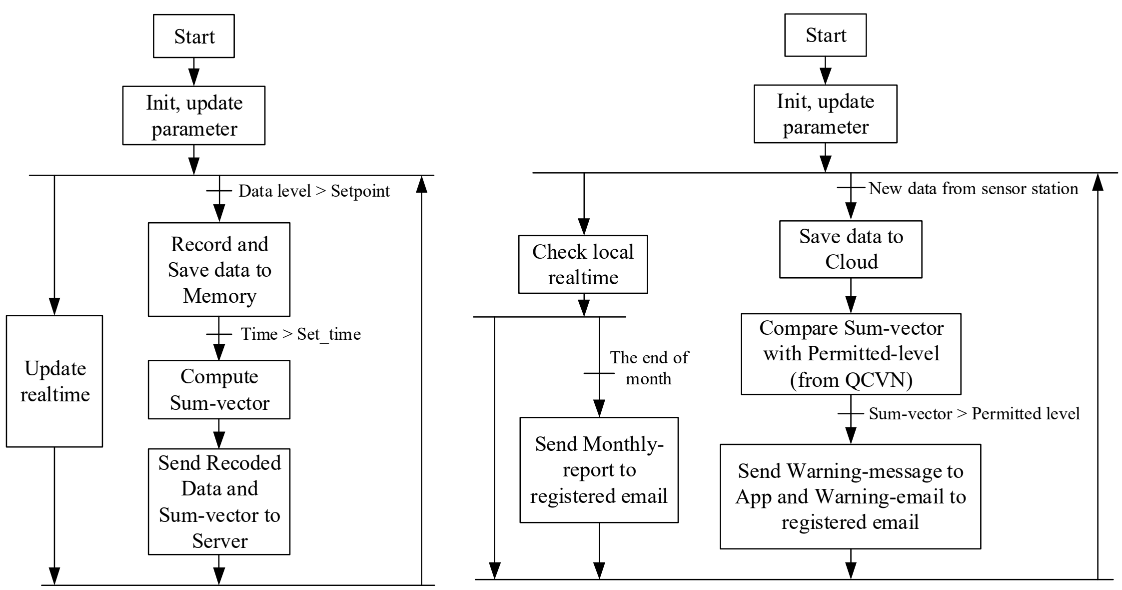
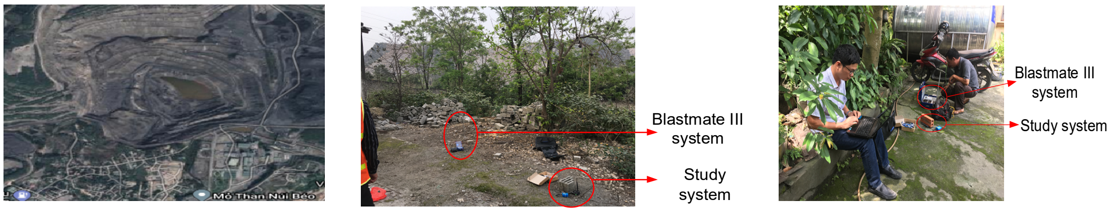


Figure 5. Diagrams describing the operation of the measuring station and the central station, a) State diagram describing the operation of the measuring device (Sensor Station). b) State diagram describing the operation of the management software on the Server (Server Station)

5. Experiment and results

With the proposed system, checking the measuring ability of the vibration measuring station is the most important test. The working ability of system is totally depended on the testing results, which are: the sensitivity and accuracy of sensors; speed of converting, recording and saving measurement data. These results are presented and analyzed in detail in this paper.

In order to get the correlation and assessment basis, the test are made simultaneously for both the researched equipment and the Blastmate III device, one of the leading equipment in the world in the field of vibration measurement. The probes are placed side-by-side to simultaneously measure vibrations. After testing in laboratory, the device was tested at the resident's houses affected by blasting activities, nearby NuiBeo coal mine (Figure 6). The Blastmate III device used in the test, owned by the Center of Mines and Mechanics, University of Mining and Geology, has been calibrated to meet the need of blasting vibration measuring and monitoring requirements.



(a) (b) (c)

Figure 6. Practical test at places nearby Nui Beo coal mines. a) Nui Beo coal mine, Quang Ninh Vietnam. b) Field application (includes Blastmate III and researched equipment). c) The actual test site at the houses located next to the Nui Beo coal mines

Before the blasting took place, the two systems were located at the same location near the mine. The two sensors are placed close to each other, the distance is negligible to ensure that the obtained vibration data is as similar as possible (Figurer 6b and 6c). The XYZ axes of the accelerometer are set to correspond to the LVT axes specified by the Blastmate III (Y⇔L; X⇔V; Z⇔). The vibration data are recorded together are used as objects for comparison.

To get an exact comparison, the Matlab 2013 software is used to analyze the data obtained on both devices. The amplitude as well as the frequency of the vibration along each axis are different. Each data set is fully analyzed in three axes (Figure 7). The graphs are divided into two groups. That are Amplitude graphs over frequency and Amplitude graphs over time. In which, the red lines are the vibration characteristics obtained by dedicated Blastmate III devive; the blue lines are the vibration characteristics obtained by the reaseach system; and the green lines show the time when the total vibration vector is maximum.

In Figure 7, amplitude graphs show the vibration level of rock over time with abscissa and ordinate represent the time (milisecond) and the velocity of vibration (mm), respectively. Frequency graphs are the characteristics of the frequeny spectrum with abscissa and ordinate represent the frequency (Hz) and the degree of vibration (mm), respectively. From these properties, times and frequencies at which the vibration level in each direction and the synthetic vibration level reach the peak are determined.

Figure 7 shows vibration measurement results for two different blast. Both explosions belong to the group of large borehole blasting in open pit mine. For these explosions types, the Vietnam standard 01/2019BCT stipulates: the minimum safe distance is 200 metre; the maximun of total vibration vector is 25.4 mm/s [31]. The first explosion was done at 11:30 a.m on August 8, 2019 with the distance from the explosion point to mesuaring point is 420 metre. The max total vector was recorded at 400ms (mili second) from the time the machine start recording. Its value is 3.214 mm/s. The second was done at 11:45 a.m on November 5, 2019 with the distance from the explosion point to mesuaring point is 515 metre. The max total vector was recorded at 450ms (mili seconds) from the time the machine start recording. Its value is 3.478 mm/s. All values are within the Vietnam standard limit. If there is an impact claim at this time, extracting the blasting data can prove the right or wrong between the mine and the claimant.

The data in measurement station sent to the cloud server is shown on website and mobile app (Figure 8)

From the testing process and the analysis results shown in Figure 7, the Frequency and Amplitude waveforms of the study device is similar to the actual specialized equipment but there are some different. Practice shows that, measurement results are still different even when we use the same specialized devices placed next to each other. The reason may be is the difference in the transmission of vibration signal to the devices. Thus, this study system can be applied to the actual production. It is a tool to monitor mining activities in the territory of Vietnam.

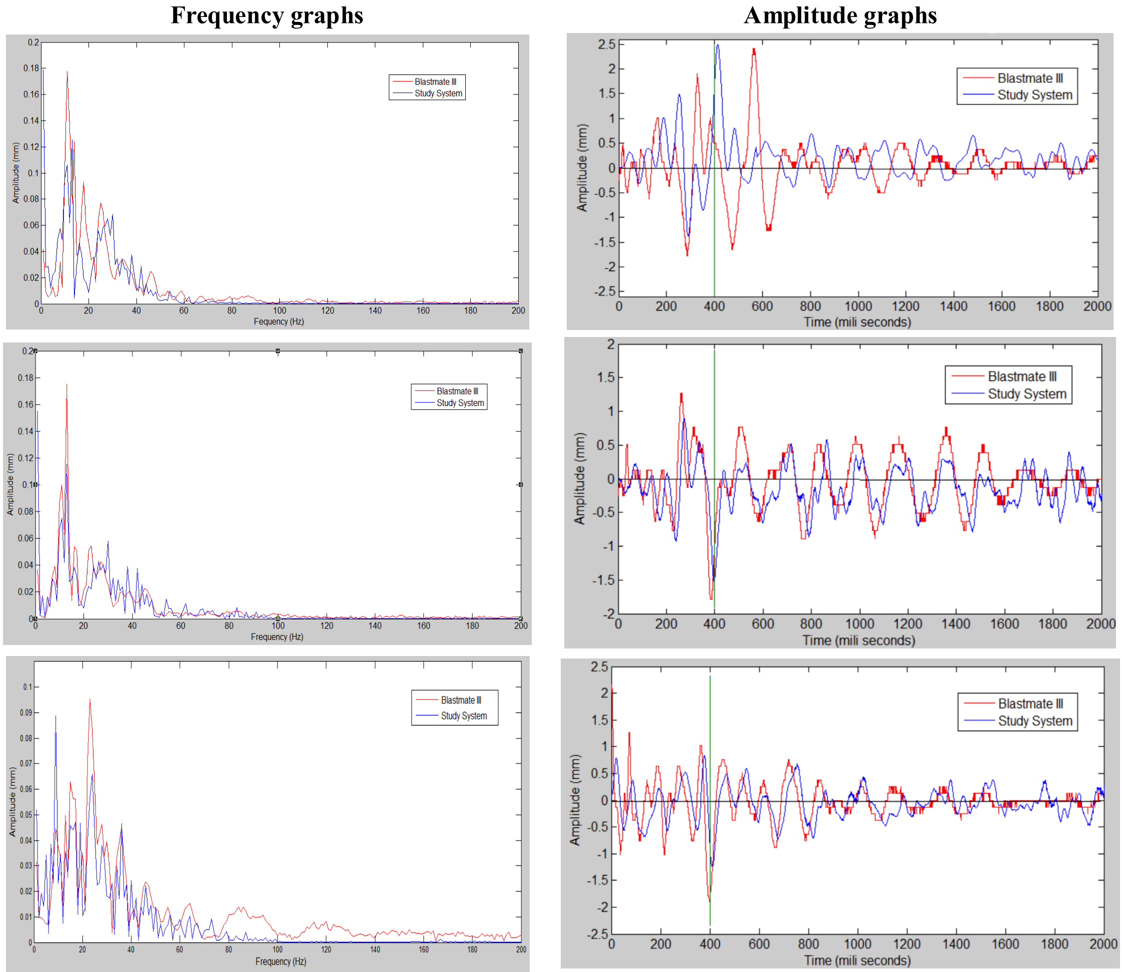


Figure 7a. Explosion: 216kg; 18 holes; 12 Kg/hole; Used delay-time over row, over hole; Distance from measured point to blast point: 420m

6. Conclusions

The results received in the laboratory and in the field of the researched machine are similar to that of the Blastmate III meter. This shows that the proposed device can be manufactured and widely applied in the practice of mining operation and management in Vietnam.

The data that the system can record in real time, including amplitude and frequency, is stored in the cloud. It is an important evidence to resolve long-standing complaints between residents and miners, and is a significant tool for the government to manage and monitor the scale of mining blasts according to Vietnamese standards 01:2019/BCT. Besides, data is also an essential document for mining engineers to adjust the amount of materials, means and methods of explosion to match the conditions of stratigraphic structure, regional infrastructure architecture, etc.

When applied over the entire territory of Vietnam, the collected data play an important role in researching and developing of modern technologies such as artificial intelligence AI, machine learning... in the field of mining, manufacture of explosives, explosive materials. The data is also a necessary database in the planning for development of mineral areas and environmental protection for state management agencies in Vietnam. In the further, this system is a premise that can be developed into other fields such as weather forecast, landslide warning, environment monitoring and so on.

Author Contributions: This is a collaborative research project between mining experts and automation experts. In which, Hieu Dao is responsible for building, manufacturing, and testing equipment according to blasting conditions and law regulations in Vietnam; Hung Phi – Nguyen developed the overview assessment and the researched the basis of seismic wave generation from mining and blasting activities; Thanh Loan Pham is responsible for building a centralized management and monitoring system via the internet as well as building application software for smartphones based on the Android platform. All authors read and approved the final manuscript.

Funding: This research received no external funding

Frequency graphs **Amplitude graphs**

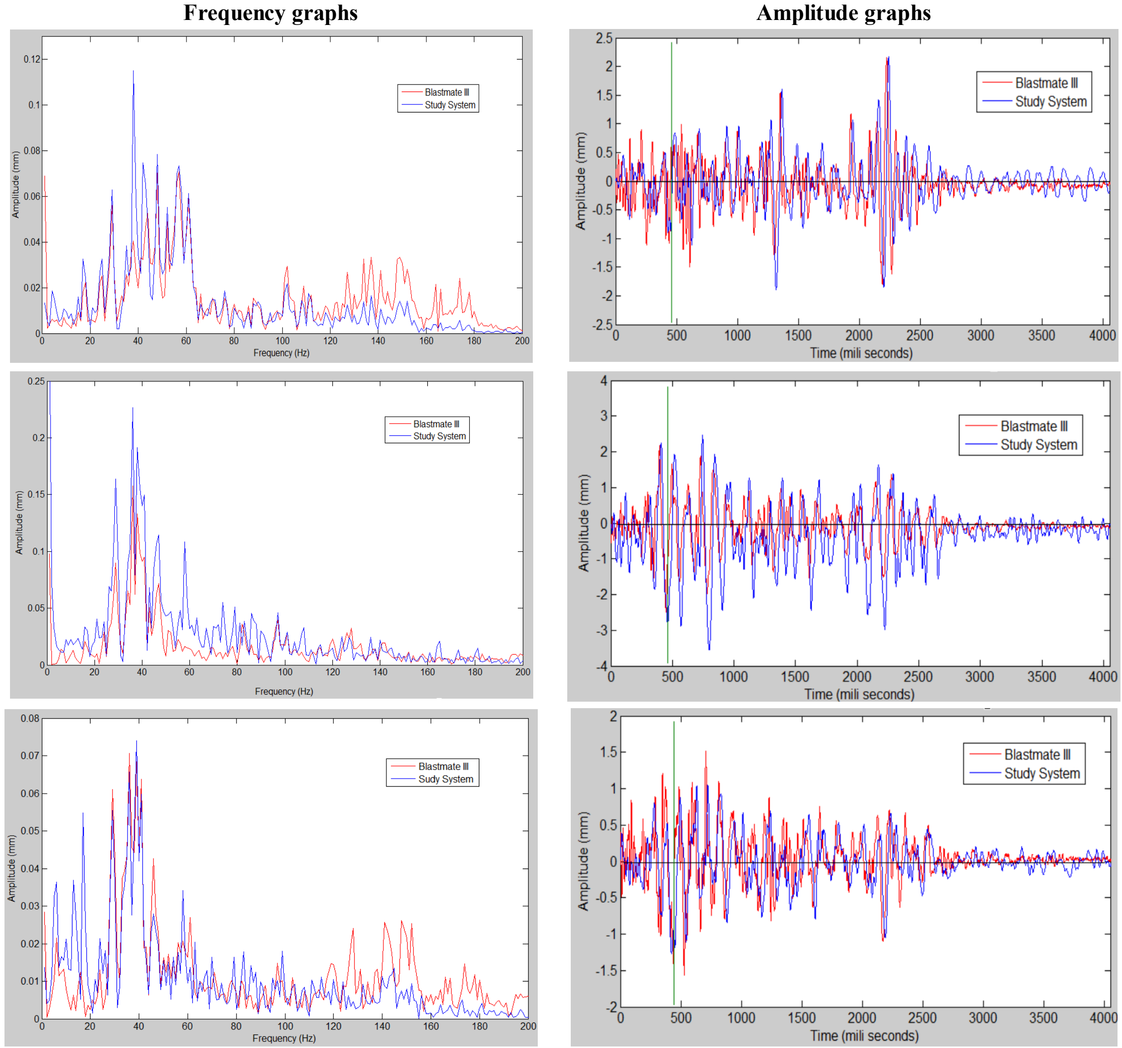


Figure 7b) Explosion: 12 ton; 200 holes; 60 Kg/hole; Used delay-time over row, over hole; Distance from measured point to blast point: 515m

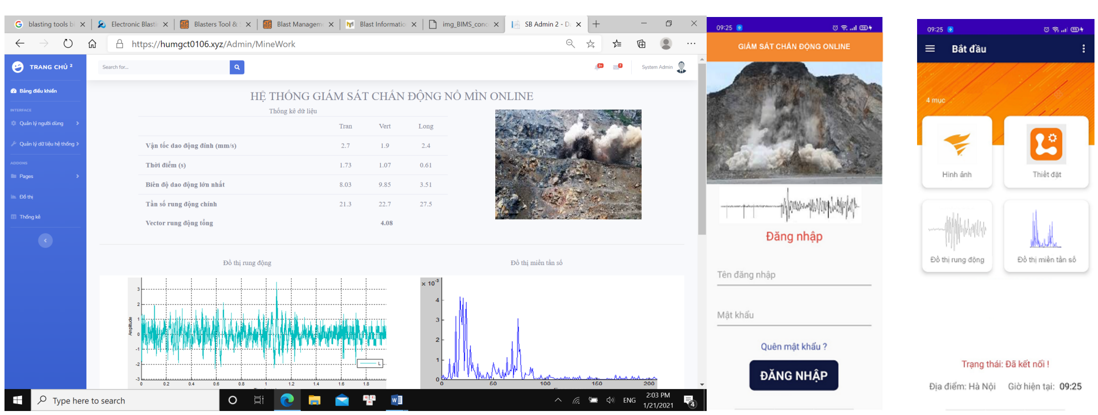


Figure 8. The resulting image on websites and android smartphones.

References

[1]. Sayadi, A., Monjezi, M., Talebi, N. and Khandelwal, M. (2013). A comparative study on the application of various artificial neural networks to simultaneous prediction of rock fragmentation and backbreak. Journal of Rock Mechanics and Geotechnical Engineering. 5 (4): 318-324.

[2]. Alan B. Richards. and Adrian J. Moore. (2009). Blasting Technology: Mesurement- Assessment- Control. A lecture of blast vibration course by TERROCK Consulting Engineers, Astralia. 87 pages.

[3]. Feher, J., Cambal, J., Pandula, B., Kondela, J., Sofranko, M., Mudarri, T. and Buchla, I. (2021). Research of the Technical Seismicity Due to Blasting Works in Quarries and Their Impact on the Environment and Population. Applied Sciences. 11 (5): 2118.

[4]. Needham, C.E. (2018). Blast wave propagation. In Blast Waves (pp. 97-120). Springer, Cham.

[5]. DOWDING, C.H. (2016). Blast Vibration Monitoring for Engineering. Excavation, Support and Monitoring: Volume 4, 111.

[6]. Siskind, D.E. (1980). Structure response and damage produced by airblast from surface mining (Vol. 8485). US Department of the Interior, Bureau of Mines.

[7]. Bui, D.T., Moayedi, H., Kalantar, B., Osouli, A., Pradhan, B., Nguyen, H. and Rashid, A.S.A. (2019). A novel swarm intelligence—Harris hawks optimization for spatial assessment of landslide susceptibility. Sensors. 19 (16): 3590.

[8]. Cullis, I.G. (2001). Blast waves and how they interact with structures. BMJ Military Health. 147 (1): 16-26.

[9]. Yang, C., Dong-Hai, Z., Ling-Ying, L., Yong-Hui, Y., Yang, W., Li-Wei, Z. and Jia-Ke, C. (2019). Simulation of blast lung injury induced by shock waves of five distances based on finite element modeling of a three-dimensional rat. Scientific reports. 9 (1): 1-13.

[10]. Nicholls, H.R. (1971). Blasting vibrations and their effects on structures (No. 656-660). US Department of the Interior, Bureau of Mines.

[11]. Ho Si Giao, Đam Trong Thang, Le Van Quyen, Hoang Tuan Chung. (2010). Chemical explosions: Theory and Practice. Science and technology Publishing, 2010.

[12]. Hossein Moayed, Ahmad Safuan A Rashid, Mohammed Abdullahi Muazu, Hoang Nguyen, Xuan-Nam Bui. and Dieu Tien Bui. (2019). Prediction of ultimate bearing capacity through various novel evolutionary and neural network models. Engineering with Computers, DOI: 10.1007/s00366-019-00723-2, 2019.

[13]. http:// baoquangninh.com.vn/chinh-tri/tin-tuc/200712/anh-huong-lon-den-doi-song-nhan-dan-210338.

[14]. http:// nhandan.com.vn/dieu-tra-qua-thu-ban-doc/no-min-khai-thac-da-gay-hu-hai-nha-dan-246006.

[15]. http:// nongnghiep.vn/no-min-lam-nut-nha-dan-o-quang-ninh-ai-chiu-trach-nhiem-d246363.html.

[16]. http:// thanhnien.vn/doi-song/no-min-khai-thac-da-lam-nut-nha-dan-1121731.html.

[17]. Pinnock, I., Collins, D.S., Toya, Y. and Hosseini, Z. (2015, September). The use of microseismic acquisition for vibration monitoring applications. In Proceedings of the Ninth Symposium on Field Measurements in Geomechanics (pp. 581-587). Australian Centre for Geomechanics.

[18]. Wang, I.T. (2019). Field Experiments and Numerical Analysis of the Ground Vibration Isolation of Shock Wave Propagation under Explosion Shock Loading. Vibration. 2 (4): 300-310.

[19]. Zhou, J., Qiu, Y., Zhu, S., Armaghani, D.J., Li, C., Nguyen, H. and Yagiz, S. (2021). Optimization of support vector machine through the use of metaheuristic algorithms in forecasting TBM advance rate. Engineering Applications of Artificial Intelligence. 97: 104015.

[20]. Dou, J., Yunus, A.P., Merghadi, A., Shirzadi, A., Nguyen, H., Hussain, Y. and Yamagishi, H. (2020). Different sampling strategies for predicting landslide susceptibilities are deemed less consequential with deep learning. Science of the total environment. 720; 137320.

[21]. Lai, J., Fan, H., Chen, J., Qiu, J. and Wang, K. (2015). Blasting vibration monitoring of undercrossing railway tunnel using wireless sensor network. International Journal of Distributed Sensor Networks. 11 (6): 703980.

[22]. Lizarazo-Marriaga, J., Vargas, C.A. and Tiria, L. (2018). A new approach to predict local site effects related to blast-induced ground vibrations. Journal of Geophysics and Engineering. 15 (5): 1843-1850.

[23]. Kevin, C., van Doormaal, A., Haberacker, C., Hüsken, G., Larcher, M., Saarenheimo, A. and Valsamos, G. (2013). Resistance of structures to explosion effects. Review report of testing methods. Ispra: European Commission-Joint Research Centre.

[24]. Konya, C.J. and Walter, E.J. (1991). Rock blasting and overbreak control (No. FHWA-HI-92-001; NHI-13211). United States. Federal Highway Administration.

[25]. Langefors U, Kihlstrom B. (1978). The Modern Technique of Rock Blasting. A Halsted press book, John Wiley & Sons. New York- London- Sydney-Toronto. 440 pages.

[26]. Langefors, U. (1958). Ground vibrations in blasting. Water power.

[27]. Figuli, L., Cekerevac, D., Bedon, C. and Leitner, B. (2020). Numerical Analysis of the Blast Wave Propagation due to Various Explosive Charges. Advances in Civil Engineering, 2020.

[28]. Cardu, M., Giraudi, A. and Oreste, P. (2013). A review of the benefits of electronic detonators. Rem: Revista Escola de Minas. 66 (3): 375-382.

[29]. Ivančo, M., Erdélyiová, R. and Figuli, L. (2019). Simulation of detonation and blast waves propagation. Transportation Research Procedia. 40: 1356-1363.

[30]. Aloui, M., Bleuzen, Y., Essefi, E. and Abbes, C. (2016). Ground vibrations and air blast effects induced by blasting in open pit mines: Case of Metlaoui Mining Basin, South western Tunisia. Journal of Geology and Geophysics. 5 (3).

[31]. National technical regulation on safety in the process of producing, testing, performing check and acceptance, storage, transportation, use, disposal of industrial explosive materials and storage of explosive precursor. QCVN 01:2019/BCT, 21/1/2019.

[32]. Nguyen, H., Bui, X.N., Tran, Q.H., Van Hoa, P., Nguyen, D.A., Le, Q.T. and Moayedi, H. (2020). A comparative study of empirical and ensemble machine learning algorithms in predicting air over-pressure in open-pit coal mine. Acta Geophysica. 68 (2): 325-336.

[33]. Bui, X.N., Nguyen, H., Le, H. A., Bui, H.B. and Do, N.H. (2020). Prediction of blast-induced air over-pressure in open-pit mine: assessment of different artificial intelligence techniques. Natural Resources Research. 29 (2): 571-591.

[34]. Barton, N.R. (2007, June). Linking seismic velocity to rock quality Q and to seismic quality Q in the near-surface. In 69th EAGE Conference and Exhibition incorporating SPE EUROPEC 2007 (pp. cp-27). European Association of Geoscientists & Engineers.

[35]. ORICA Mining Services. Initiation-Systems. European Shotfirer Standard Education for Enhanced Mobility, a lecture by ORICA Mining Services Germany. 156 pages.

[36]. Walter, P.L. (2004). Introduction to Air Blast Measurements-Part III: Guaranteeing that Validated Pressure Measurements are Acquired. PCB Piezotronics Inc, 1-3.

[37]. Dzwilewski, P.D. and Fenton, G. (2003). Shock wave/sound propagation modeling results for calculating marine protected species impact zones during explosive removal of offshore structures. US Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

[38]. Richards, A.B. (2008). Blast vibration wavefront reinforcement model. Mining Technology. 117 (4): 161-167.

[39]. Kostić, S., Vasović, N., Franović, I., Samčović, A. and Todorović, K. (2014, November). Assessment of blast induced ground vibrations by artificial neural network. In 12th Symposium on Neural Network Applications in Electrical Engineering (NEUREL) (pp. 55-60). IEEE.

[40]. Cho, S.H. and Kaneko, K. (2004). Rock fragmentation control in blasting. Materials transactions, 45(5), 1722-1730.

[41]. Diersen, S., Lee, E.J., Spears, D., Chen, P. and Wang, L. (2011). Classification of seismic windows using artificial neural networks. Procedia computer science, 4, 1572-1581.

[42]. Northwood, T.D., Crawford, R. and Edwards, A.T. (1963). Blasting vibrations and building damage (pp. 973-978). Ottawa, Canada: National Research Council of Canada.

[43]. Taylor, D.L. and Firth, I.R. (2003). Utilization of blast movement measurements in grade control. Application of Computers and Operations Research in the Minerals Industry, 243-247.

[44]. Sastry, V.R. and Chandra, G.R. (2016, August). Signal processing computation based seismic energy estimation of blast induced ground vibration waves. In 2016 IEEE Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER) (pp. 216-220). IEEE.

[45]. Vu Trong Tan, Nguyen Ngoc Thu, Vo T.H Quyen. (2011). Measurement of vibrations in environmental management by seismic machines. Vietnam Jounal of earth science. 33 (2): [CĐ], 224-230, 2011

[46]. Bilbrough, N.R. (2014). The FDA, congress, and mobile health apps: lessons from DSHEA and the regulation of dietary supplements. Md. L. Rev. 74: 921.

مطالعه سیستم اندازه گیری ارتعاش آنلاین موج‌های لرزه‌ای ناشی از انفجار معدن در ویتنام

هیو دائو[۱]، سان لون فام[۱] و فی هونگ نگویان[۲]

۱- دانشکده الکترو مکانیک، دانشگاه معدن و زمین شناسی هانوی، هانوی، ویتنام
۲- دانشکده معدن، دانشگاه معدن و زمین شناسی هانوی، هانوی، ویتنام

ارسال ۲۰۲۱/۰۴/۰۱، پذیرش ۲۰۲۱/۰۶/۱۲

* نویسنده مسئول مکاتبات: hunguni@gmail.com

چکیده:

آتشکاری به یک کار اساسی در عملیات استخراج معدن تبدیل شده است. با این حال آتشکاری، امواج لرزه‌ای با شدت بالا ایجاد می‌کند که موجب برخی از مشکلات جدی از جمله زخمی شدن مردم، پرتاب سنگ، ترک خوردگی، شکستن و کاهش طول عمر ساختمان‌های مجاور می‌شود. در ویتنام، در مورد سیاست جبران این خسارات، اختلافات زیادی بین ساکنان و دولت وجود داشته است. این راه حل پیشنهاد شده است، که در آن یک انفجار مشابه ایجاد می‌شود و یک ضربه گیر متناوب برای ثبت میزان شدت موج تولید شده استفاده می‌شود. نتایج بدست آمده از این آزمایش برای تخمین اثرات ناشی از آتشکاری در معادن استفاده شده است. در حقیقت این یک روش نادرست است زیرا فقط با تغییر مواد منفجره، ترتیب انفجار و غیره، موج ضربه به طور قابل توجهی کاهش می‌یابد. هیچ چیز تضمین نمی‌کند که در آینده انفجار دیگری که باعث ایجاد دامنه موج می‌شود رخ ندهد. برای حل این مشکل، این مقاله یک سیستم مانیتورینگ موج لرزه‌ای آنلاین با کار ۲۴ بار در ۲۴ ساعته برای انتقال سیگنال ضبط شده به یک سرور مستقل واقع در اطراف مرز معدن ارائه می‌دهد. بر اساس مکانیسم تولید امواج انفجاری و مکانیسم ضبط امواج شوک، نویسندگان برنامه‌ای را برای ذخیره سوابق با توجه به تأثیر مجاز استاندارد ویتنام و بخشنامه TT-/2019/32 هیئت مدیره ویتنام ساخته‌اند.

کلمات کلیدی: آتشکاری، موج لرزه ای، اندازه گیری ارتعاش، مانیتور ارتعاش، ویتنام، معدن ذغال سنگ نویبئو.