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Impact of blasting parameters on vibration signal spectrum: Determination and statistical evidence

Ze-wei Wang [a,*], Xi-bing Li [a], Kang Peng [b,a], Jiang-feng Xie [c,a]

[a] School of Resources and Safety Engineering, Central South University, Changsha 410083, China
[b] State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400044, China
[c] LinTung-Yen & LiGuo-Hao Consultants Shanghai Ltd., Shanghai 200135, China

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ABSTRACT

Research on the impact of blasting parameters on vibration signals is of significant value for guiding blast-resistant design. Previous research was primarily aimed at the impact on vibration amplitude in the time domain but rarely focused on energy distribution in the frequency domain (i.e., spectrum). Based on large amounts of blast signals from a series of events, in this study, the primary parameters that affect the vibration spectrum were determined. First, the K-means method was used to cluster all of the signals into six distinct spectrum clusters. The *T* test was then utilized among different clusters, to detect discrepancies in continuous parameters, including total charge, maximum charge, concrete age and distance between the explosion source and measuring point. Meanwhile, a random clustering simulation was conducted to determine whether the other two discrete parameters, i.e., the number of detonator relays and the explosion source location, influence the spectrums of vibration signals. The results show that three of the six parameters studied have a close link to the vibration spectrum, whereas the other three do not. This study also discusses how the parameters impact the occurrence and evolution of vibration signals.

1. Introduction

Vibration hazard, as an inevitable product of blasting, can have a considerable impact on the surrounding environment (Gorgulu et al., 2013). At present, studies on the factors influencing blasting vibration have been mainly aimed at the effect on vibration amplitude, such as peak particle velocity (PPV). Laws regulating blasting practice and scientific research into blast-induced ground vibrations use the PPV values as standard base parameters (Gorgulu et al., 2013). Site-specific empirical models for PPV are commonly used for blast-resistant designs (Amnieh et al., 2012; Xia et al., 2013; Ozer et al., 2013; Khandelwal and Singh, 2013). Related studies have emerged in large numbers in the past decades: on one hand, abundant improved empirical models were constantly proposed (Duvall and Petkof, 1959; Nicholls et al., 1971; Langefors and Kihlström, 1978; Pal Roy, 1991; Dey and Murthy, 2012; Kumar et al., 2014); on the other hand, various modern prediction techniques, such as expert systems (Khandelwal and Singh, 2013), adaptive neuro-fuzzy inference systems (Ataei and Kamali, 2013) and fuzzy logic models (Ghasemi et al., 2013), were developed to improve the prediction of PPV. Also reported was the comparison of intelligence science techniques and empirical methods by Mohamadnejad et al. (2012). Compared with the attention paid to vibration amplitude, research about energy distribution in the frequency domain of blast vibration seems to be rarely reported. However, a shortage of current design code based on ground motion PPV alone has also been reported (Ma et al., 2002), which means that characteristics in the frequency domain should also be considered.

It is well known that blast vibrations induce a resonance in structures if the frequency of the ground vibration matches the natural frequency of the structure (Khandelwal and Singh, 2006) and that structural responses depend on the frequency of ground vibrations. Therefore, knowledge of how blasting parameters impact the frequency of vibration signals seems to be a potential source of guidance for environmentally friendly blast design. Among the few studies related to frequency, most treated the frequency feature of vibration as a single value (Khandelwal and Singh, 2006; Singh, 2002; Kahriman et al., 2006), such as dominant frequency. However, using a single value to represent the features in the frequency domain is definitely too simplified, as

* Corresponding author at: School of Resources and Safety Engineering, Central South University, Lushan South Road, Changsha 410083, China. Tel.: +86 15200858008.
E-mail addresses: wangzw.csu@gmail.com (Z.-w. Wang), xbli@mail.csu.edu.cn (X.-b. Li).

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nonstationary blast-induced vibration contains a wealth of frequency components. For instance, high-frequency ground motion can cause brittle damage to structures (Lu et al., 2001; Wu et al., 2005), which may be ignored as the domain frequency is always much lower. Another example can be seen in BM-RI-8507, which tries to link PPV and dominant frequency to predict vibration damage. The data of the velocity–frequency-damage plots in this report shows sets of different damage levels are mixed together, with their boundaries difficult to determine. This may cause inconvenience in use and over conservative application. One possible reason for this may be the use of single frequency value. Therefore, rather than the dominant frequency value, this study considered the energy distribution in the frequency domain, i.e., the spectrum. Blasting parameters impacting the spectrum of vibration were determined and corresponding statistical evidence was given to begin to determine the relationship between blasting parameters and the vibration spectrum.

2. Background

2.1. Case description

The studied vibration signals were obtained from 35 blast events of Shizilong tunnel, which is a 1000 m long double-hole tunnel located at 28.116N, 112.744E (Fig. 1a). The width and height of the tunnel section is 16 m and 10.8 m, and the maximum burial depth is about 124 m. According to the geology report, the surrounding rocks of north side of Shizilong tunnel are silt-slate and metasandstone with occurrence of 342°∠63°, while those of the south side are sandstone and mudstone, with occurrence of 349°∠21°.

Three-bench seven-step excavation method was used in this project, and the heights of the benches were 6.4 m, 2.4 m and 2 m from top to bottom (Fig. 1b). Boreholes were drilled horizontally with depth of 2.5 m. Emulsion explosive was used and the cartridge diameter was 32 mm. Blank column were remained at the bottom of boreholes, and the boreholes were sealed by stemming.

2.2. Blasting parameters

Many factors can affect blasting vibration, including geological structures (Caylak et al., 2014), blast design such as charges per delay, and geometry (USBM RI 8507). In this case, owing to the short period in which the vibration signals were measured (in a few days), the geology of each event can be considered as unchanged. This is also the case in terms of some design parameters, e.g., characteristics of drill holes, type of explosives as well as caps used. Therefore, six primary variable blasting parameters, incorporating aspects of energy, time and distance, were chosen in the study. They are:

ELS – explosion source location;
NRD – the number of relays of detonators;
TC – total charge;

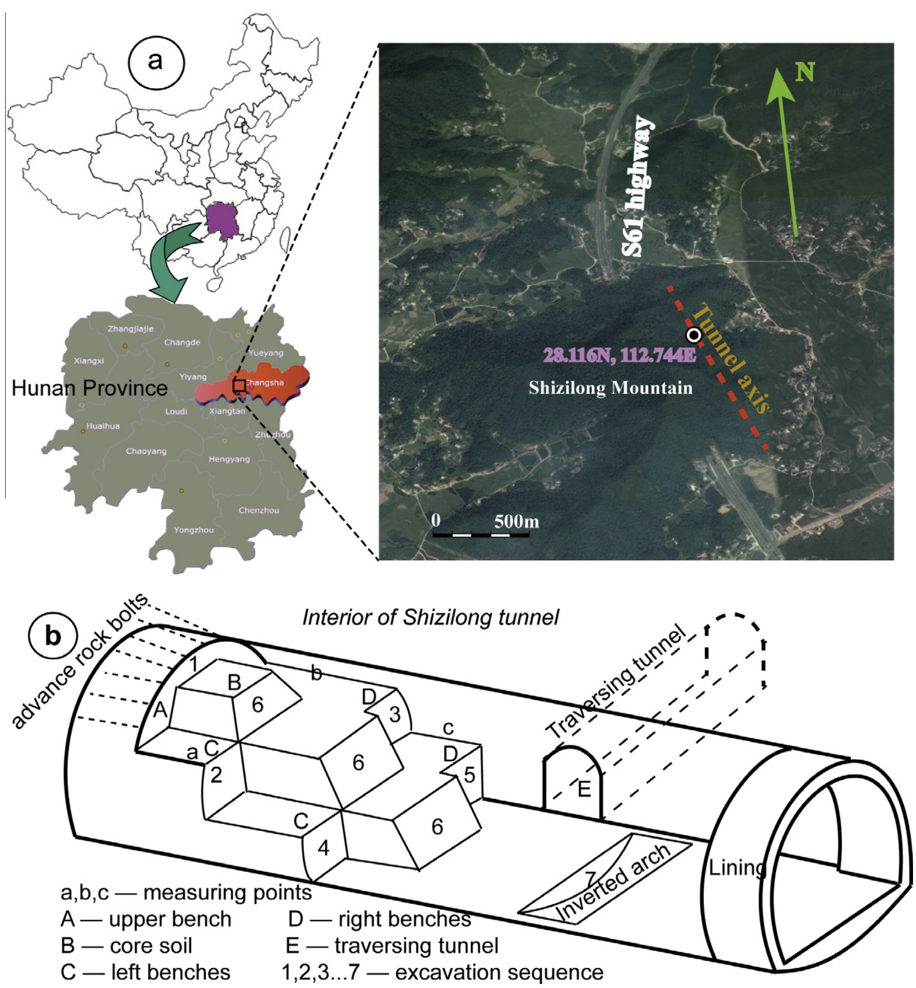

Fig. 1. Description of Shizilong tunnel: a – location; and b – inner structure of the tunnel.