Seismic safety in conducting large-scale blasts

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Abstract. In mining enterprises to prepare hard rocks for excavation a drilling and blasting method is used. With the approach of mining operations to settlements the negative effect of large-scale blasts increases. To assess the level of seismic impact of large-scale blasts the scientific staff of Siberian State Industrial University carried out expertise for coal mines and iron ore enterprises. Determination of the magnitude of surface seismic vibrations caused by mass explosions was performed using seismic receivers, an analog-digital converter with recording on a laptop. The registration results of surface seismic vibrations during production of more than 280 large-scale blasts at 17 mining enterprises in 22 settlements are presented. The maximum velocity values of the Earth’s surface vibrations are determined. The safety evaluation of seismic effect was carried out according to the permissible value of vibration velocity. For cases with exceedence of permissible values recommendations were developed to reduce the level of seismic impact.

1. Introduction

Kuzbass is one of the largest coal basins in the country. In 2016 in Kuzbass 209 million tonnes of coal were produced. This is more than 56% of Russia’s total coal and 80% of coking coal. In Kuzbass 70% of coal is extracted in 80 open pit mines. For overburden operations, while preparing hard rocks for excavation, a drilling and blasting method with large-scale blasts is used. Holes are drilled and charged with explosive. The charge in large-scale blasts reaches 50, 100 and 300 tonnes. The main negative manifestations of large-scale blasts are: a shock air wave, scattering of rock pieces, seismic vibrations and impact on the protected objects, release of toxic gases, dust formation.

To improve the quality and safety of explosion operations in the mining industry, enterprises specializing in explosion operations have been established in Russia and Kuzbass: “Kuzbassvytprom” OJSC, “Vzryvprom Yuga Kuzbassa” OJSC, “Plant Znamya” OJSC, “Nitro-Siberia”, “Azot-Chernigovets” and many others. With the increase in the number of coal mines in Kuzbass and the approach of mining operations to settlements, the negative effect of large-scale blasts is increasing. Residents of settlements that are in close proximity to mining enterprises began to complain about the impact of large-scale blasts on vibrations of houses and sound effects.

To assess the level of seismic impact of large-scale blasts on the protected buildings SibSIU together with the expert organization “Scientific Center of VostNII for Safety in the Mining Industry” OJSC (Russia, Kemerovo) performed expertise for coal mines and iron ore enterprises. Thus, seismic vibrations were registered during the production of more than 280 large-scale blasts at 17 mining enterprises in 22 settlements.

By the request of open pit mines, Open Pit Mine “Bungursky-Severny” OJSC, Open Pit Mine “Berezovsky” OJSC, Open Pit Mine “Korchakolsky” OJSC, UK “Kuzbassrazrezugol”, “Taldinsky
Open Pit Mine”, Open Pit Mine “Stepanovskiy” OJSC, Open Pit Mine “Yuzhny” OJSC, “Open Pit Mine Tomusinsky” the seismic vibrations of the Earth’s surface from large-scale blasts conducted at the enterprises were recorded in the villages of Rassvet, Malinovka, Uspenka, Uchul, Gavrilovka, Novomoskovka, Yasnaya Polyana, Maganak, Matyushino, Pritomsky. Seismic vibrations were recorded at two observation points. They were located at a distance from 300 m to 12 km. The total mass of explosives for a blast was from 3 to 340 tonnes.

2. Methods of research

The generally accepted parameter for estimating the magnitude of seismic action is the speed of soil particles vibrations. The amplitude of vibration speed varies in wide range and depends on the mass of explosive, the distance between the place of blast and the point of registration, design of the charge, scheme of explosion, geological conditions, the direction of the breakage, the presence of free surfaces and stemming.

The problem of negative manifestation of seismic effect caused by the production of large-scale blasts is known for a long time and is relevant to the present day. There is a lot of scientific research on this topic [1 - 3], but, in general, they target the specific conditions of a particular enterprise.

The speed magnitude of seismic vibrations caused by large-scale blasts was determined using seismic receivers SM-3KV, an analog-digital converter (ADC) model E-440 with an option of recording signals to the hard disk of a laptop. The method of recording and processing was developed by the Institute of Dynamics of the Geospheres of the Russian Academy of Sciences [4].

Calculation of safe distances for buildings and structures is carried out according to the formulas given in the Safety Rules for Explosion Works [5]. The calculation is carried out taking into account the characteristics of the ground in the base of the object, its design features, the mass of explosives in the blast and the number of groups of simultaneously exploded charges.

The permissible speed of soil vibrations at the base of protected structures is regulated by the normative document RTM 36.22.91 [6]. The permissible speed of soil vibrations is determined depending on the class of responsibility of the protected structures, the type of construction of the facilities, their technical condition and soil properties at the base of the protected structures. The classes of responsibility for buildings and structures are regulated by the normative document of SNiP 2.01.07-85 [7]. The soil group is determined according to GOST 25100-95 [8].

3. Results and discussion

The performed analysis of measurements results of seismic impact shows that in most cases, when large-scale blasts were conducted, the vibrations of the Earth’s surface did not exceed the permissible values (by ten or more times) [9 - 11].

However, there were abnormal manifestations of this impact, for example, in the residential sector of town Pritomsky in Mezhdurechensk and in Tashtagol. The territory with the protected buildings and facilities of the village is located at a distance less than one kilometer from the hazardous production enterprise – the mining take of Open Pit Mine “Tomusinsky” OJSC.

Figure 1 shows the speed seismogram of surface seismic vibrations in the settlement Pritomsky at the address 39 Lunacharskogo Street from the large-scale blast on September 7, 2010 in the open pit mine Tomusinsky from explosive charges 252 801 kg. The speed magnitude of seismic vibration exceeded the selected scale of measurements and by the extrapolation method is 3 cm/s, with a permissible value of 2 cm/s.

Figure 2 shows the speed seismogram of surface seismic vibrations from a large-scale blast on April 02, 2017, with a charge of explosive mass 178 000 kg for the collapse of the eastern section of block No. 6 on the level (-280) ... (-210) m at the mine in Tashtagol of Mountain Shoriya branch of Evrazruda OJSC in the observation point School No. 1. The maximum values of seismic vibrations speed of the Earth’s surface in the observation point at School No. 1 were 1.7; 1.6 and 1.9 cm/s and the horizontal component perpendicular to the direction of the mass large-scale blast exceeded the maximum permissible value of 1 cm/s by 1.9 times.
Figure 1. Speed seismogram of surface seismic vibrations in the settlement Pritomsky at the address 39 Lunacharsky Street.

To reduce the level of seismic impact it is recommended to reduce the blast charge, in the delay, to increase the delay time and the number of delays.

Figure 2. Speed seismogram of surface seismic vibrations caused by the large-scale blast on April 02, 2017 in the observation point School No. 1.

4. Conclusions
In the period from 2010 to 2017 450 registrations of seismic vibrations were performed during the production of 281 large-scale blasts at 16 mining enterprises in 22 settlements. The distance to the registration points was from 500 to 12 km. The mass of explosives varied from 3 to 340 tonnes. The speed maximum values of seismic vibration of the Earth’s surface, basically, did not exceed the maximum permissible values. The general regularities of decrease in the vibrations speed with increase in the distances to protected objects are confirmed. In four cases, exceedance of the maximum permissible values was recorded (Pritomsky, Tashtagol). On these cases recommendations were given.

References
[1] Bogatsky V F and Pergament V Kh 1978 *Seismic Safety during Blasting Operations* (Moscow: Nedra) 1978 p 128
[2] Kutuzov B N 2009 *Safety of Blasting in Mining and Industry* (Moscow: Gornaya Kniga, MSMU) p 670
[3] Mironov P S et al 1972 *Development of the Theory and Practice of Explosives* 71/28
[4] Eremenko A A et al 2005 *Bulletin of the RANS, West-Siberian Branch* 7 148–58
[5] Safety Rules for Blasting Approved by the Order of Rostekhnadzor No. 605 of December 16 2013
[6] Glozman L M et al 1982 *RTM 36.22.91* (Moscow: Nedra)
[7] SNiP 2.01.07-85. *Loads and Impacts*
[8] State Standard 25100-95. *Soils. Classification*
[9] Mashukov I V 2014 *Information-analytical Bulletin on Mining* 4 216–21
[10] Domanov V P and Mashukov I V 2013 *Bulletin of Scientific Center for Safety in the Coal Industry* 1-1 60–4
[11] Mashukov I V et al 2013 *Bulletin of Scientific Center for Safety in the Coal Industry* 1-2 16–21