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# ROCKS FRACTURING WITH EXPLOSIVE-MECHANICAL MEANS

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# РУЙНУВАННЯ ГІРСЬКИХ ПОРІД ВИБУХО-МЕХАНІЧНИМ СПОСОБОМ

*Rocks' elastic properties change under the influence of explosive stressing was showed. Evaluation of elastic properties was carried by ultrasonic waves distribution speed in rock samples. Was established that ultrasonic signal amplitude decrease coefficient 0,6…1,0 demonstrates vertical orientation of technological fracturing. The necessary quantity of explosion stressing (4…6) was determined for specific energy decreasing to drill a well.*

***Keywords:*** *combined fracturing, explosive-mechanical fracturing; rocks weakening; technological fracturing, complex fracturing, specific energy of fracturing.*

*Наведено результати зміни пружних властивостей гірських порід внаслідок впливу вибухових навантажень. Оцінка пружних властивостей проведена за швидкістю розповсюдження ультразвукових хвиль в зразках гірських порід. Визначено, що коефіцієнт зниження амплітуди ультразвукового сигналу 0,6…1,0 свідчить про вертикальну орієнтацію технологічної тріщинуватості. Отримано необхідну кількість вибухових навантажень (4…6) для зниження енергоємності механічного руйнування вибою.*

***Ключові слова:*** *комбіноване руйнування, вибухо – механічне руйнування, послаблення гірських порід, технологічна тріщинуватість, комплексна тріщинуватість, енергоємність руйнування.*

*Приведены результаты изменения упругих свойств горных пород под воздействием взрывных нагружений. Оценка упругих свойств горных пород проведена посредством скорости распространения продольных ультразвуковых волн. Определено, что коэффициент снижения амплитуды ультразвукового сигнала 0,6…1,0 свидетельствует о вертикальной ориентации технологических трещин. Получено необходимое количество взрывных нагружений (4…6) для снижения энергоемкости разрушения забоя.*

***Ключевые слова:*** *комбинированное разрушение, взрыво - механическое разрушение, ослабление горных пород, технологическая трещиноватость, комплексная трещиноватость, энергоемкость разрушения.*

**Problem statement.** For the period of 2014 Ukraine spent 9,6 billion kW·h of electricity to product energy resources and construction materials [1]. With the reason to decrease rocks fracturing specific energy, combinations of mechanical and nonmechanical methods searches are carried out. Relevance of the problem is proved by the regulation of the Cabinet of Ministers of Ukraine of march 1, 2010 year, №243 «On approval of the State target economic energy efficiency program and energy production development from renewable sources and alternative fuels in 2010-2015 years» [2]. The aim of the work is to reduce rocks fracturing specific energy consumption due to technological fractures forming in addition to natural one.

**Experimental part and results obtained.** An explosive – mechanical rocks fracturing method was proposed. The combination of explosive and mechanical (rotating) stressing creates a set of technological and natural fractures in the working face. Thanks to this, strength properties of rocks decrease, causing specific energy of mechanical fracturing to be reduced. To implement explosive-mechanical fracturing it is important to define destructive effect of explosion. An expected effect of explosive fracturing is formation of technological fractures in the working face additionally to the natural one.

Ultrasonic waves speed distribution in rock samples was determined according GOST 21153.7-75. The method of shadow defectoscopy was used. Thus the ultrasonic waves' transducers (radiator and receiver) are on the same acoustic axis on the opposite sides of rock samples. For this reason the measurement results reflect elastic properties for the whole samples' thickness.

For researches the samples of gabbro, granite and sandstone were made. The structure of chosen rocks is granular, thus the direction of explosive influence does not impact destruction nature. According to GOST 30629-99 the mineralogical composition and physico-mechanical properties of rock samples was defined. Gabbro composition: plagioclase (labrador) – 63…65 %; pyroxene – 27…29 %; apatite – 4 %; quartz – 0,5 %. Granite composition: microcline (potassium feldspar) – 35…40 %; amphibole (hornblende) – 20…30 %; plagioclase – 12…15 %; quartz – 16 … 20 %; biotite – 2…3 %. Sandstone consists of quartz-feldspar detrital material (grains size 0,10…0,25 mm), cemented with clay-micaceous and carbonate substance. Chosen rocks are forming strength gradient: from the strongest – gabbro ($\sigma_c$ = 220 MPa) to the least strong – sandstone ($\sigma_c$ = 130 MPa). Fractures volume change was provided by explosion quantity change.

According to results reducing speed of ultrasonic waves occurred in following ranges: gabbro – 64…173 m/s, or ≤ 2,0 %; granite – 94…165 m/s, or ≤ 2,5 %; sandstone – 18…346 m/s, or ≤ 8,0 %. Received ranges influenced by consolidated zone crated under fractured zone due to plastic minerals (labrador, microcline) and clay-micaceous substance. Under consolidated zone there is still undamaged zone. Those three zones impacts on ultrasonic waves speed change, where only one has a complex fracturing. For this reason ultrasonic waves' speed reducing in rocks samples does not exceed 8 % and equals 100…340 m/s.

By results of researches the curves of ultrasonic waves speed from explosion quantity dependence was build, figure 1. From received values of wave speed the arithmetic mean (fixed points) was calculated. From the figure 4 it is defined that 4…6 explosion impacts provide the greatest fracturing effect. This value responds for necessary and sufficient quantity of explosions for 10 mm deep rock samples' working face destruction by explosive-mechanical means.

Ultrasonic waves speed dependences from explosion quantity divided on 3 segments. The first segment characterizes by exponential decay with ultrasonic waves speed reducing on 100 m/s for all the samples. The destruction of rocks samples surface with spalling and cracks formation occurs on this segment. Plastic properties of certain minerals are not able to be realized in time because of explosion epicenter proximity. Thus plastic deformations turn into quasiplastic and brittle under the influence of explosion stressing speed ≈ 5 km/s [3]. As a result of explosion the detonation products are forcing into fractures, making them deeper.

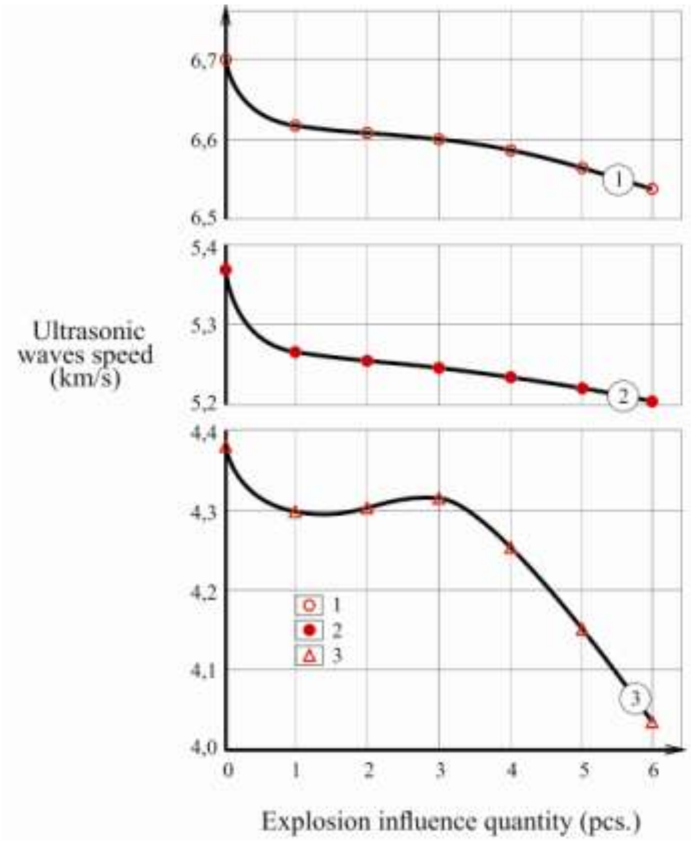


Fig. 1. Ultrasonic waves speed in rocks samples dependence from explosion quantity (1 – gabbro; 2 – granite; 3 - sandstone)

For this reason spalling 0,5mm deep and technological fractures are forming, figure 2, 3. Tangent of decline angle for gabbro and granite samples tg (20º) = 0,36 almost twice less than sandstone’s tg (40º) = 0,84. It indicates that sandstone plastic properties prevail comparing with gabbro and granite because of clay substance.

During samples’ surface destruction (the first segment) under the complex fracturing there is a consolidation kernel is forming. The second segment from 1 to 3 explosive stressing confirms this. Thus for gabbro and granite samples the curve falling continues, but more flat with a tangent of angle tg (85º) = 11,43.

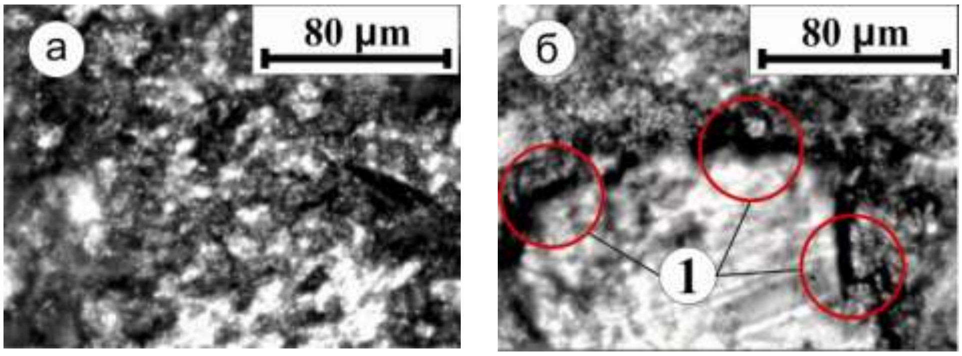


Fig. 2. Gabbro sample surface:

a – before explosive influences; b – after explosive influences – fractures 1

With labrador and microcline compression their tension increases and when achieves compressive strength limit of 120…170 MPa [4] they start to destruct. The level of complex fracturing increases and it is confirmed by the third segment, where curve falling occurs. For gabbro and granite falling angles almost equal with tangent of angle tg (76º) = 4,00 and tg (84º)= 6,31. Kaolinite (the main mineral of sandstone's clay substance) strength limit does not exceed 60 MPa [4]. For this reason the third segment for sandstone is falling with tangent of angle tg (37º) = 0,75 because of technological fractures appearance, figure 4.

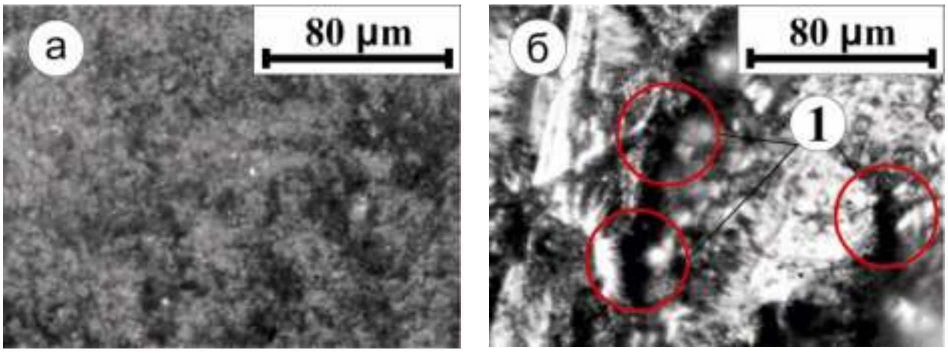


Fig. 3. Granite sample surface:

a - before explosive influences; b – after explosive influences – fractures 1

Consolidation is explained by plastic minerals presence in the rocks samples composition: gabbro – plagioclase; granite – microcline. Plastic clay substance presence and porosity of 3 % in sandstone structure caused more intensive consolidation. This process is proved by curve rising with tangent of angle tg (73º) = 3,27. Adequacy of such behavior confirmed by research [5], where transition from brittle to plastic deformation with tension increasing was recorded for sandstone.

According to ultrasonic waves speed values in rocks samples without technological fracturing the level of elastic anisotropy was calculated. Thus the values of elastic anisotropy for gabbro is 0,45 %, for granite – 0,15 %, for sandstone – 1,1 %. The values of the sandstone samples are twice bigger than for gabbro and granite because of visible cracks and plastic clay substance presence. In general received values indicate about uniformity and integrity of the samples.

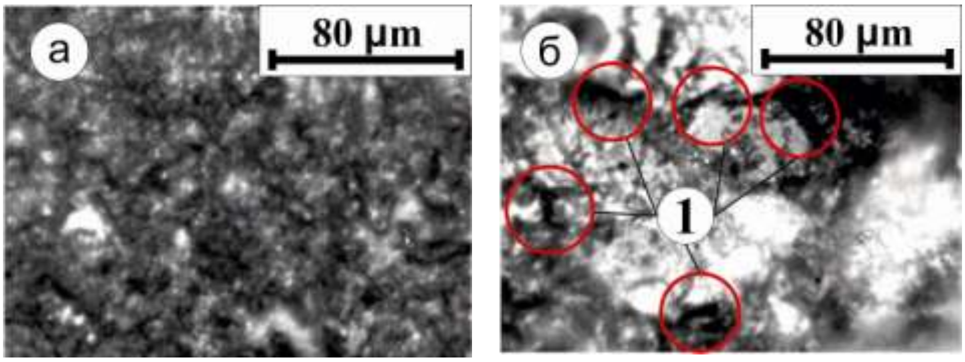


Fig. 4. Sandstone sample surface:

a - before explosive influences; b – after explosive influences - fractures 1.

During the ultrasonic waves speed measurements it was fixed that signal amplitude reduced from 14,0 to 8,0 dB. According to [6] coefficient of signal attenuation from 0,6 to 1,0 says about fractures presence with angles of 50º …90º. Those cracks can be considered as vertical one. Vertical crack are good to force detonation products inside pressing on their open faces. This process leads to technological fracturing deepening and development. Relief with hollows and roughness appears on the surface. Cutters of the explosive-mechanical action cutting tool can cling for such cleavages, making it easier to drill.

## Conclusions

1. An exponential decay of the ultrasonic waves speed with explosion quantity was fixed in ranges: for gabbro 64…173 m/s, or ≤ 2,0 %; for granite 94…165 m/s, or ≤ 2,5 %; for sandstone 18…346 m/s, or ≤ 8,0 %.
2. It was defined that ultrasonic signal amplitude change from 14,0 to 8,0 dB indicates about vertical technological fracturing presence with angels of 50º...90º.
3. The minimal quantity of explosions (4…6) was determined for specific energy decreasing to drill a well.

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## ДОСЛІДЖЕННЯ СЕЙСМІЧНОГО ВПЛИВУ МАСОВИХ ВИБУХІВ НА КОЩІЇВСЬКОМУ ГРАНІТНОМУ КАР'ЄРІ

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## RESEARCH OF SEISMIC MASS EXPLOSIONS ON KOSCHIYIV'S GRANITE QUARRY

*В роботі обґрунтовані методи зниження сейсмічного впливу підривних робіт у кар'єрі, розташованого поблизу об'єктів, які мають важливе загальногосподарське значення. Розраховані параметри буровибухових робіт для забезпечення сейсмостійкості охоронних об'єктів.*

***Ключові слова:*** *сейсмічна хвиля, сейсмостійкість, вибухові роботи, заряд, вибухова речовина.*

*В работе обоснованы методы снижения сейсмического воздействия взрывных работ в карьере, расположенного вблизи объектов, которые имеют важное общехозяйственное значение. Рассчитаны параметры буровзрывных работ для обеспечения сейсмоустойчивости охраняемых объектов.*

***Ключевые слова:*** *сейсмическая волна, сейсмоустойчивость, взрывные работы, заряд, взрывчатое вещество.*

*Methods of decreasing the seismic effects of blasting operations in the quarry, which is located near the facilities which are important general economic value, were substantiated in the work. The parameters of drilling and blasting to ensure seismic stability of security facilities were designed.*

***Keywords:*** *seismic wave, seismic resistance, blasting, charge, explosive.*