Investigation into detonation properties of PS-2 ammonium-nitrate-based granulite of different producers

AS Flyagin*, PV Menshikov, and SS Taranzhin
Institute of Mining, Ural Branch, Russian Academy of Sciences, Ekaterinburg, Russia
E-mail: *flyagingdr@mail.ru

Abstract. The comparative test results on PS-2 granulite based on porous ammonium nitrate (PAN) manufactured under TU 7276-004-17131060-2008 of different producers: Sibirsky Delovoy Soyuz Co. (Kemerovo), Akron Co. (Belikiy Novgorod), OHK Uralkhim Co. (Berezniki), NAK Azot Co (Novomoskovsk) are reported in the paper. The relationship of PS-2 granulite detonation velocity in steel pipes of 108 mm in diameter versus the grade of ammonium nitrate used is justified experimentally. DATATRAP II DATA/VOD Recorder is employed in the present research work.

1. Introduction
At present the key mining production challenge deals with reduction in costs of drilling-and-blasting operations. The application of the elementary explosives consisting of ammonium nitrate–diesel fuel (AN–DF) blends such as granulites permits to lower the production cost of blasted rock. Therewith it is necessary to take into account the efficiency of mined ore crushing before further beneficiation operations.

The composition of PAN-based explosives makes it possible to provide higher quality of crushing at compared to the explosive composition based on smooth ammonium nitrate (SAN) as it provides higher blasting efficiency: blasting energy, detonation velocity (DV) thanks to its capacity to withhold diesel fuel in pores of granules, thus this factor is 6% with PAN and 2% with SAN [1].

2. Test results
Institute of Mining UrB RAS (IGD UrB RAS) held the independent comparative tests of PS-2 granulite produced under TU 7276-004-17131060-2008 on porous ammonium nitrate of different producers: Sibirsky Delovoy Soyuz Co. (Kemerovo), Akron Co. (Velikiy Novgorod), OHK Uralkhim Co. (Berezniki), NAK Azot Co. (Novomoskovsk). At the polygon owned by Promgorservis Co. the researchers measured the explosive detonation velocities for PS-2 granulite under TU 7276-004-17131060-2008. These measurements are of prime importance for quality estimation. PS granulite is the elementary composite industrial explosive, it presents the oxygen-balanced mechanical blend of granular porous ammonium nitrate and diesel fuel (DF, other oil product from the TU list for PS granulite) and is manufactured in-situ utilization. The appearance of PS granulite is an oily blend of ammonium nitrate granules of the specific color depending on an oil product used.

The objective of the research paper is to determine detonation characteristics of PS-2 explosive granulite in steel pipes of 2500 mm in length and 108 mm in diameter, 16.5 kg in mass, of density $\rho = 0.733$–$0.775$ g/cm$^3$ and temperature $t = 20^\circ$C used in PAN composition of different producers.
The detonation velocity was determined with the use of DATATRAP II DATA/VOD Recorder under the procedure elaborated at Rock-Breaking Laboratory, IGD UrB RAS [2, 3].

Three 4-charged blastings in total were performed. Each blasting involved 4 steel pipes of 2500 mm in length charged with PS-2 PAN-based granulite of different producers. The charges were placed in the before-prepared trenches banked from two sides. Initiation was carried out by NSI Iskra-Start-V; the priming cartridge was 6ZhV-32 ammonite cartridge of 200 g in mass in combination with NSI Iskra-S-500-12. The information on PAN-based charges of different producers is reported in Table 1.

### Table 1. PAN-based charges of different producers

| No. | Blasting date | Producer of ammonia nitrate | Test on complete detonation |
|-----|---------------|-----------------------------|----------------------------|
|     |               | Ø explosive cartridge | ρ, g/cm³ | t, °C | Q, kg | Serial No | Completeness |
| 1   | 11.05.16.     | NAK Azot Co.             | PS-2 granulite | 0.752 | 20   | 16.5   | 1b/b | Complete    |
| 2   | 11.05.16.     | AKRON Co.                | PS-2 granulite | 0.733 | 20   | 16.5   | 2b/b | Complete    |
| 3   | 11.05.16.     | Sibirsky Delovoy Soyuz Co.| PS-2 granulite | 0.775 | 20   | 16.5   | 3b/b | Complete    |
| 4   | 11.05.16.     | OHK Uralkhim Co.         | PS-2 granulite | 0.737 | 20   | 16.5   | 1824 | Complete    |

PS-2 granulite was manufactured in TTT charge-blending machine. The control parameters of PS-2 granulite grade, such as detonation completeness and detonation velocity under polygon conditions were determined in the tests (Tables 2 and 3).

### Table 2. Mass share of components and physicochemical parameters

| No. | Parameter                      | PS-2 granulite |
|-----|--------------------------------|----------------|
|     |                                | TU standard    | Obtained values |
| 1   | Appearance:                    |                |                |
|     | - NAK Azot Co.                 | Fattened blend of granulated ammonia nitrate of specific color depending on the initial oil product used | match |
|     | - Akron Co.                    |                |                |
|     | - Sibirsky Delovoy Soyuz Co.   |                |                |
|     | - OHK Uralkhim Co.             |                |                |
|     | Component composition, %:      |                |                |
|     | - Ammonia nitrate              |                |                |
|     |                                | 94             | match          |
|     | - Diesel fuel                  | 6              |                |
| 2   | Bulk density, g/cm³            |                |                |
|     | - NAK Azot Co.                 | 0.7-0.9        | 0.733-0.775    |
|     | - Akron Co.                    |                |                |
|     | - Sibirsky Delovoy Soyuz Co.   |                |                |
|     | - OHK Uralkhim Co.             |                |                |
| 3   | Detonation                     |                | Complete       |
It is obvious from Table 3 the average velocity is 3450 m/s for Sibirsky Delovoy Soyuz Co., Kemerovo, 3542 m/s for Akron Co. Veliky Novgorod; 3350 m/s for OHK Uralkhim Co., Berezni; 3864 m/s for NAK Azot Co., Novomoskovsk.

Table 3. Detonation velocity of PS-2 granulite in steel pipe of 108 mm in diameter at factual density of 0.733-0.775 g/cm³, m/s

| Blast No. | Ammonia nitrate producer | | | |
|-----------|--------------------------|------------------|------------------|------------------|
|           | NAK Azot Co.             | Akron Co.        | Sibirsky Delovoy Soyuz Co | OHK Uralkhim Co. |
| 1         | 3890                     | 3572             | 3694             | 3365             |
| 2         | 3885                     | 3578             | 3371             | 3388             |
| 3         | 3818                     | 3476             | 3286             | 3296             |

PS-2 PAN-based granulite, produced by NAK Azot Co., Novomoskovsk, has the highest detonation velocity. It is also clear from the graph that the stability of detonation process is specific for PS-2 granulite, manufactured on the base of PAN by NAK Azot Co., Novomoskovsk (Figure 1).

Figure 1. Detonation velocity of PS-2 granulite, based on PAN produced by NAK Azot Co., Novomoskovsk: D = 3818 m/s. Measurement No. 3, Ø = 108 mm, ρ = 0.752 g/cm³, Q = 16.5 kg. Initiation: ammonite cartridge 6ZhV-32, detonator being Iskra-S.

The analysis of the obtained data revealed that PS-2 granulite on the base of PAN produced by NAK Azot Co., Novomoskovsk, is characterized by operation stability and high detonation velocity.

3. Conclusions
It can be concluded that this composition possesses the best explosive characteristics as compared to other compositions and actually improves the rock breaking performance.

The full-scale granulite test procedure, worked out at IGD UrB RAS, incorporates the investigation into the control explosive parameters as well as measurements of granular composition of the blasted rock mass.
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