Modification of ANFO detonation parameters by biowaste addition

E Uranchimegi, M Narantsetseg2 and L Purev3
1Blasting research and training center, Mongolian University of Science and Technology Ulaanbaatar, Mongolia  
2Chemical engineering department, School of Applied Science, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia  
3School of geology and mining, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia  
E-mail:narantsetseg0427@gmail.com

Abstract. The present study relates to modification of ammonium nitrate fuel oil mixture. For many years, ammonium nitrate fuel oil has been one of the most popular explosives for use in mining operations. Therefore, it is manufactured and used widely in large volume. Although ammonium nitrate is a relatively strong oxidation agent, it is insufficient to detonate by itself. Therefore, it is generally admixed with liquid fuel such as diesel and various modifiers. Trinitrotoluene (TNT) and metal aluminium are typically used as additive. This paper studies ammonium nitrate fuel oil (ANFO) composition modified by biowaste dung as additive to generate efficient explosion and to result low cost blasting. The experiment results of modified ANFO with biowaste dung as additive illustrate that physical stability and absorption increased by 5% percent compared to regular ANFO. Also was revealed that average detonation brisance increased from 20.5 to 27.5 mm and detonation speed increased from 2300 to 3800 m/s compared to regular ANFO. This modified ANFO is lowered blasting cost from 50 to 150 tugriks per 1kg ANFO compared to aluminium and TNT additives.

1. Introduction
According to statistics, usage of explosives was approximately 69 and 77 million ton in 2014 and 2017 respectively, which reveals evident fact that the market is grown [1]. ANFO compositions are formed of porous ammonium nitrate (AN) prills and diesel oil that is situated within many of the voids of the porous ammonium nitrate prills [2]. In Mining operations, the use of ANFO typically involves drilling a blast hole in the earth that was being mined. Drilling and blasting operations are widely used as rock powdering process in mining industry and road construction projects in Mongolia. In the mining industry, it is vital to define an optimal composition of ANFO which can provide a convenient average detonation brisance [3]. In this study, we are aimed to make an ANFO composition which will be more powerful and cheaper by using a biowaste dung as an additive.

2. Materials and methods
Samples of ANFO with additives and without additives were made in “Monmag” LLC and field tests were conducted on the authorized experimental field of the company “Monmag”. Our new powerful ANFO explosive with biowaste dung were used in blasting work of Tumurtolgoi iron ore open-pit mine. Ammonium nitrate (NH4NO3) is the major oxidation component of the ANFO. The ammonium nitrate (AN) is typically used in the form of prills (spherical or roughly spherical particles up to a few mm in size) that are mixed with liquid fuel to form a suspension. This suspension is then packed into blast holes and ignited by a detonating cord or other means. The resulting explosion produces rock fragmentation and is used in mining and construction applications.
diameter, for example 0.9 to 3.0mm) [4]. In our practice AN is imported both from China and Russia which were compared to physical characteristics and the results are illustrated in table I.

**Table 1. Physical Characteristic Of The Ammonium Nitrate**

| Parameters                        | Standart specific method | Technical requirements | Russian | China |
|-----------------------------------|--------------------------|-------------------------|---------|-------|
| Adsorption ability, no more, %    | MNS 4301:96              | 8.0                     | 8.6     | 13.6  |
| Particle size, 1-4mm, no more, % | MNS 6070:2010            | 95.0                    | 99.9    | 99.9  |
| Moisture, no more, kg/per granule | MNS 4302:96              | 0.4                     | 0.4     | 0.4   |
| Appearance                        | TV 2143-639-00209023-99 | No mechanical impurity  | -       | -     |
| Brittleness, no more, %           | MNS 6071:2010            | 100                     | 100     | 100   |
| Physical fixity, no more, %       | CS 11-0267:2014          | 5                       | 5       | 5     |

The results of physical characteristic are shown that AN imported from both south and north neighbors are met the required standard values. In this study, we used the AN imported from Russia.

3. Results and discussion
The detonation strength of ANFO strongly depends on the characteristics of additives [5]. The technical characteristics of natural biowaste dung are shown in table 2.

**Table 2. Technical Characteristic Of Biowaste Dung**

| Biowaste dung                  | Technical Characteristics |
|--------------------------------|----------------------------|
| Moisture, W^a, %              | Ash, A^d %                 |
| 7.37                          | 16.52                      |
| Volatile compounds, V^daf, %  | 79.27                      |
| Calorific value Q^daf, kcal/kg| 5001.7                     |
| Absorption ability, %         | 100                        |
| Elemental Analysis, %         |                            |
| C^daf                         | H^daf                      |
| 49.50                         | 6.80                       |
| N^daf                         | 2.80                       |
| S^daf                         | 0.40                       |
| O^daf                         | 40.50                      |

According to table 2, dung characterized as follows: moisture less 7.37%, ash content more than 15.31–16.52%, volatile compounds content 61.31–79.27, calorific value 5001.7 kcal/kg. Calorific value is calculated using elemental analysis by the equation: \( Q_0 = 81C + 300H - 26(O - S) \) [6].

Then the ash composition of dung is defined by X-ray fluorescence spectroscopy and is shown in Figure 1.
The ash chemical composition is shown in table 3.

**Table 3. Ash composition of dung.**

| Composition of Ash, %  | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO   | MgO   | K$_2$O | Na$_2$O |
|------------------------|---------|-------------|-------------|-------|-------|-------|-------|
|                        | 49.70   | 49.70       | 2.81        | 19.1  | 19.10 | 2.93  | 4.92  |

| Composition of ash, %  | Mn$_2$O$_3$ | P$_2$O$_5$ | TiO$_2$ | CuO  | ZnO  | SrO  |
|------------------------|-------------|-----------|--------|------|------|------|
|                        | 4.92        | 4.99      | 0.45   | 0.01 | 0.01 | 0.04 |

The results of ash chemical composition of dung show that the ash has a comparably high content of silica, aluminum, iron, sulfur, potassium, calcium than content of titan, copper, zinc, zircon, manganese oxides.

Then was studied chemical composition of ANFO. The AN, diesel fuel and modifier dung mixed at specific ratios in order to control oxygen balance and to cause the most efficie
ent explosion possible. Mainly the weight ratio AN: diesel fuel is used 94:6 [7]. However, in our case we used modifier-biowaste dung in composition of ANFO and optimal ratio with combustion additive was determined and it is illustrated in table 4.

**Table 4. Optimal weight ratio of the components of ANFO**

| № | Chemical Composition of modified ANFO (AN: diesel fuel: dung) | Absorption ability, $C_{ab}$, (%) | Physical stability ability, $C_{st}$, (%) |
|---|-------------------------------------------------------------|-----------------------------------|-----------------------------------------|
| 1 | 90:5:5                                                      | 5                                 | 5                                       |
| 2 | 94:5.5:0.5                                                  | 4.58                              | 4.91                                    |
| 3 | 93:5:2                                                      | 4.87                              | 4.74                                    |
| 4 | 93:3.5:3.5                                                  | 4.15                              | 4.29                                    |
| 5 | 95:2.5:2.5                                                  | 4.5                               | 5                                       |

From the results, can be seen the optimal composition ratio determined to be AN: diesel fuel: dung is 90:5:5. This ratio shows higher absorption and physical stabilities.

Then we compared explosive efficient of ANFO compositions modified with additive and the regular one and explosives characteristics are illustrated in table 5.
From the experiment results, it is evident that the modified ANFO shows the increase in detonation speed from 2300 to 3800 m/c, brisance from 20.5 to 27.5 compared to regular ANFO.

Then were done field experiments using modified ANFO with optimal composition ratio of such as AN: diesel fuel: dung (90:5:5) and regular ANFO to compare their detonation characteristics at of Tumurtolgoi’s iron ore open pit mine. Produced blast characteristics are illustrated in table 6.

Table 6. Blasting Characteristics of ANFO In Open Pit Mine

| №  | Main parameters              | Regular ANFO | ANFO With Dung Additive |
|----|------------------------------|--------------|--------------------------|
| 1  | Hole diameter (mm)           | Soil 165     | Soil 165                 |
|    |                              | Ore 165      | Ore 165                  |
| 2  | Rock hardness (f)            | 10           | 13                       |
|    |                              | 10           | 13                       |
| 3  | Drilling depth (m)           | 999.5        | 77.5                     |
|    |                              | 822.5        | 47.5                     |
| 4  | Amount of holes (quantum)    | 230          | 17                       |
|    |                              | 185          | 10                       |
| 5  | Blasting volume (m³)         | 24987.5      | 1550                     |
|    |                              | 20562.5      | 1187.5                   |
| 6  | Sum of explosive (Kg)        | 10000        | 1040                     |
|    |                              | 7960         | 480                      |
| 7  | Specific consumption of explosive (kg/m³) | 0.56 | 0.68 | 0.4 | 0.55 |
| 8  | Yield of oversized rocks (%) | -            | 5                        |

From the results of detonation experiments, it is suitable to use the modified ANFO in ore mines, according, to the following characteristics: specific consumption of explosive declined from 0.68 to 0.55 kg/m³, yield of oversized rock declined from 5 to 3% compared to regular ANFO.

Lastly, we calculated the prime price of ANFO with dung comparing to ANFO with aluminum and with TNT (2,4,6-trinitrotoluene) additives and results are illustrated in table 7.
Table 7. Calculation of The Prime Cost of 1Kg ANFO.

| Explosives                  | Modified ANFO | ANFO with aluminum additive | ANFO with TNT additive |
|-----------------------------|---------------|-----------------------------|------------------------|
| Prime cost Mongolian currency (tugrik) | 1300           | 1350                        | 1450                   |
| Difference in prime cost (%) | -              | 3.7                         | 10.34                  |
| Difference in tugrik (tugrik) | -              | 50                          | 150                    |

The results show that the modified ANFO by biowaste is affordable /cheaper/ than explosives with aluminum additive in 3.7% and with TNT additive in 10.34%, that means cheaper on 50 and 150 tugriks /Mongolian national currency/ per 1 kg ANFO in case of aluminum and TNT additives respectively.

4. Conclusion
1. A complete reference should provide the reader with enough information to locate the article concerned, whether published in print or electronic form, and should, depending on the type of reference, consist of: From the experiments of ANFO composition with biowaste additive was determined the optimal weight ratio $\text{NH}_4\text{NO}_3$ : diesel fuel : biowaste to be 90:5:5.
2. Was defined that the uses in ore mines of the modified ANFO by biowaste effect in growth of physical stability, results in detonation speed from 2300 to 3800 m/s, brisance increased from 20.5 to 27.5mm and explosives power increased on 26.31%.
3. Was determined that specific combustion of explosive declined from 0.68 to 0.55 kg/m$^3$ and yield of oversized rock declined from 5 to 3% when used modified ANFO in iron ore open-pit mine compared to regular ANFO.
4. Was found that the uses of modified ANFO saved 50 to 150 tugriks per 1kg compared to ANFO with aluminum and ANFO with TNT additives.

References
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