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[VARISTEM STEMMING CAPS]

Report on the testing of the Varistem stemming caps at the SURALCO LLC. Mine sites namely Successor Mines and CBO mining operations.

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List of Abbrevations

Abbrevation	Full name
SM	Successor Mines
CBO	Coermotibo Mining
ROM	Run Off Mine
BAE	Boren Afgedekt Erts (grade control drilling)
ANFO	Amonium Nitrate Fuel Oil
RBS	Relative Bulk Strength
Powergel	Senatel Magnafrac Emulsion gelatin explosive

Project: Varistem Stemming caps test

1. SCOPE

This test is designed to test the effectiveness of the Varistem stemming caps for possible implementation in the Blasting program of both the SM and CBO mining operations. The gains claimed by the Varistem Corporation are an increase in fragmentation, a reduction of flyrock hazard and a reduction of noise and vibration. The improvement on fragmentation will benefit both mining sites as fragmentation influences ROM truck fill factors and also reduce crushing and milling costs. But the reductions in flyrock, noise and vibration are most important for the CBO mining site as the bauxite mines move ever closer to the community areas, hereby disturbing the inhabitant's daily routines.

The main theory behind these stemming caps comes from the fact that an incensement of the confinement of the explosive energy within the borehole, drastic improvements in fragmentation can be achieved. This is caused by the extra time that the explosive force can work on the surrounding material.

The manufacturer claims an increase of 25% in confinement. This claim should exert itself in 2 conclusions namely:

1. That the 25% increase in confinement can lead to a pattern expansion of 25%, resulting in the same fragmentation.
2. Or this fact can be rewritten leading to another fact namely that with the same pattern 25% less explosives is needed to achieve the same results in fragmentation.

The main question that can be asked for this test is: **which configuration of explosives coupled with or without a stemming cap can deliver a more economic blasting configuration?**

This leads to some research questions:

1. Which configuration of products delivers the best economic performance?

2. What are the possible financial gains in implementing the Varistem caps?

3. Is it possible that implementation of these caps open up new reserves closer to the community (applicable for CBO ops.)?

2. METHODS & TECHNIQUES

2.1. SM TEST METHODOLOGY & BLAST PLAN

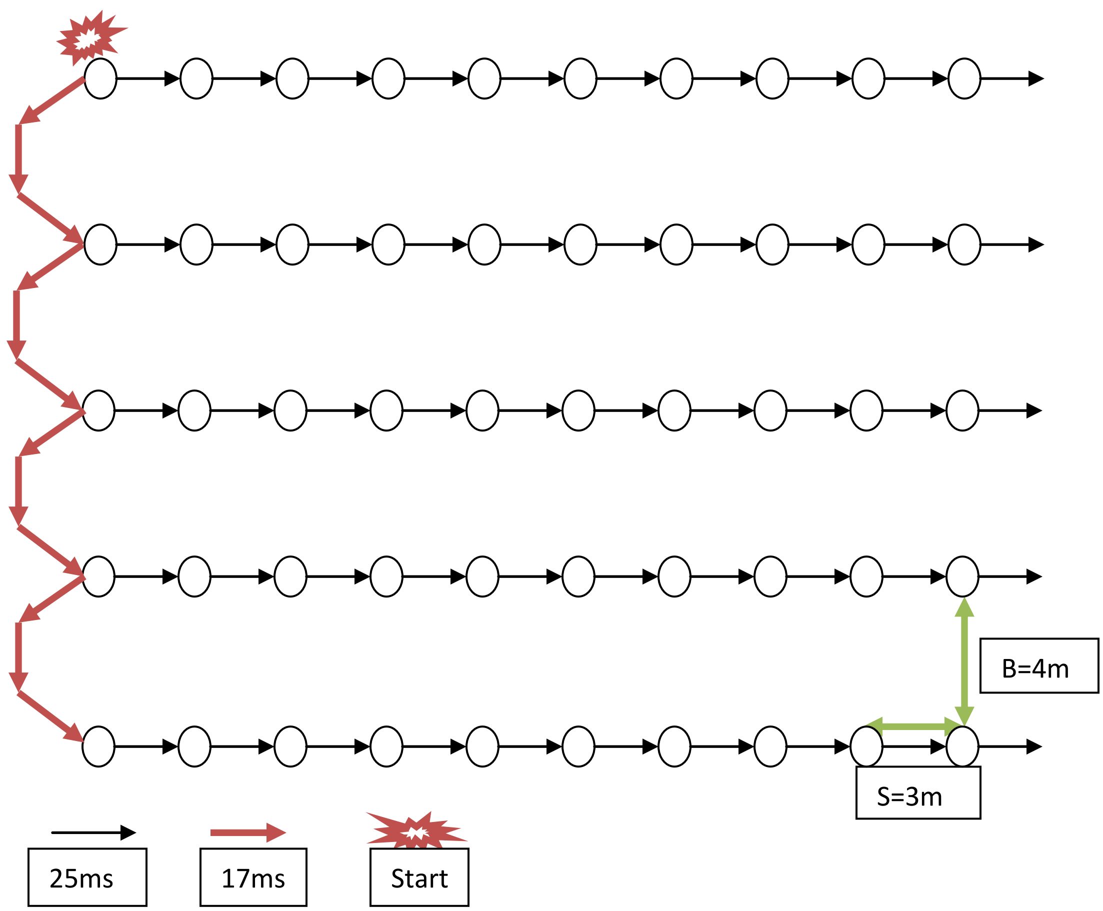
To test the claims of the manufacturer of the Varistem stemming caps a research methodology is required to test various configurations of products within the blast hole.

This blast plan will be executed in the KG pit on block Q19BK, which according to BAE drilling has a high iron content, meaning it is one of the toughest bauxites available.

The test blast will consist of 50 holes configured in a 5 X 10 hole rectangular pattern. The spacing between holes is a constant 3m with a burden of 4m. The hole depth will be a consistent 4m.

Between the rows of the blast pattern, stakes will be placed outside of the blast pattern indicating the 2m mark between the burdens of the rows. These halfway stakes will function as a zone of influence limit of each differently configured row.

The blast timing between holes will be 25ms and the delay time between rows will be 51ms. The connections will be made at each rows start.



This will enable us to analyze the fragmentation of each row more accurately, due to the predicted burden movement of each row.

Each row will be differently charged starting with the control row which will be charged without a stemming cap. This row will function as a baseline of the fragmentation that can be achieved without the use of the stemming cap. The holes will be configured as follows:

1. The first row will be charged with two primer bags and two bags of ANFO of 80cm. The ANFO bags will be weighed after filling to determine the charge weight leading to the powder factor. The stemming length will be approximately 1.5m.
2. The second row will be configured with two bags of primer and one bag of ANFO capped with a stemming cap, while the second bag of ANFO will be replaced by an air-filled dummy bag, which will function as an air deck. This dummy bag will be created using the ANFO filling bag and a sealer. The bags will have a functional length of approximately 0.8m. The function of this air deck is to allow more effective expansion of the explosive gases in the borehole. The reason for this air deck is the claim of the manufacturer that the stemming cap increases the confinement of the explosives with 25% meaning that with 25% fewer explosives the same results should be achievable.
3. The third row will be charged with the same configuration as the first row but this time also including the stemming cap. The stemming will be a constant 1.5m. The reason for this configuration is to check the fragmentation created. If a 25% increase in confinement is achieved, the explosives will have successfully achieved excessive fragmentation of 25%.
4. The fourth row will be charged using only primer bags to test the effectiveness of the stemming cap in wet hole blasting conditions. The stemming length will be increased to 2m to compensate for the higher RBS of the primer explosives. 5 bags of primer will be used. A stemming cap will be placed on top of the explosives. The reason for this configuration is the case of fragmentation, if excessive fragmentation is achieved this could lead to a pattern expansion in the Klaverblad mine where wet hole blasting conditions are a common practice meaning a reduction in drilling costs and an increased productivity of the drills. This would be required in the increased ROM for 2011.
5. The fifth row will be charged as the first row and will employ a non-conventional stemming material which should function as an effective stemming cap. The stemming length will be filled with fine-grained sawdust. The reason for utilizing sawdust in this test is a simple investigation of a claim made by N. Mwakipesile during the assistant blasting course. It was claimed that by filling the borehole with sawdust the effective confinement will be increased. The increase in confinement is unknown, hence the reason for this test.

2.2. CBO METHODOLOGY

The test at CBO mining operations is designed to measure 2 different aspects of the varistem plugs and one common aspect. The 2 different aspects of the plugs that are to be measured are the flyrock reduction effect (due to the increased confinement) and the noise levels that are produced during the blast, as Peto hill (the location of the test) is located close to the community area of Peto Ondro and is also not situated far from Moengo. The common aspect that will be tested is the fragmentation as an increase in confinement and reduction of noise need to result in more energy being utilized for fragmenting the bauxite.

The test consists of 101 blastholes drilled on the 2 X 2m (B X S) square pattern that is common practice at CBO mining ops. There were 101 varistem plugs available for the test blast, the common hole depth is ± 8-9 ft. The 50 holes are to be charged with 3ft of stemming length and the remainder is to be charged with 5ft of stemming length. The blasting agent is ANFO due to dry borehole conditions; coupled with a ¼ powergel package (see as a 3.5 X 4 inch package) purely for priming purposes (no booster charges are used).

The controls of the test are a best feel of the vibration levels and observing of the blast noise by posting the blast guard in the community area of Peto ondro and the Lijnweg in Moengo (area's that have previously complained).

The ignition sequencing that will be employed by the blasting crew will be the standard sequencing of 25ms between holes and 17ms between rows. The first 5 rows will contain the 5ft stemmed holes and the last will be de 3ft stemmed holes.

2.2.1. Variable and controllable parameters

2.2.2. Instructions for the D&B crew SM

Om de nauwkeurigheid van de test te verbeteren, zij er enkele controls in de procedure gebouwd.

Deze controls dienen om enkele fouten te kunnen elimineren, en bestaan uit:

1. ANFO mixing – Hier voeren wij de ANFo mixing uit 1-2 dagen voor de blast om te kunnen garanderen dat de ANFO zijn maximale potentie haalt. Hier voorkomen we ook de hydration en caking van de ANFO in de zak
2. Voor deze test worden de gaten exact uitgestaked door de survey crew, waardoor er een excate placement is van de gaten. Hierdoor worden afstands fouten geelimineerd.
3. Tijdens het boren moet de diepte van het boorgat gemeten worden, dit gebeurt met behulp van de tamping stick die bij de blast ook gebruikt zal worden. De diepte van het gat moet zo exact als mogelijk 4m zijn. De gaten moeten zo laat als mogelijk geboord worden, uiterlijk 1 dag voor de blast, om de diepte te kunnen garanderen. Voor het laden van de gaten wordt de diepte opniew gechekt en gelogged om de vergelijking te maken.
4. De hardheid van de strata waardoor er geboord wordt moet tijdens het boren gelogd worden per meter geboord om potential weak zones in het blok te kunnen catchen. Deze weak zones kunnen een vertekend beeld vormen bij het uitvoeren van de fragmentatie analyse.
5. De laatste factor waarover niemand een echte control heeft is het weer. De gaten moeten zo droog als mogelijk zijn om de performance van de ANFO te garanderen. Hetgeen ook de reden is dat de gaten zo laat als mogelijk geboord moeten worden.

3. Results Combined SM + CBO

The varistem test was completed as per design criteria with regards to hole depth, stemming length, ANFO freshness and dry boreholes. The test was conducted on a fairly overcastted day, but the rain showers only started 30-45 minutes after the test, meaning a successful post blast examination of the test area could be conducted. The only test that was not conducted was the test using sawdust as a stemming material. This was not used due to the ample lead time for conducting the test. The row that would have contained the sawdust was charged the same way as row number 2. The delay sequence was also changed making effective filming of the blast possible to, between holes 25ms and between rows 51ms for the SM test. The burden and spacing for the SM test was a 4X3m rectangular pattern and for the CBO test a 2X2m square pattern. At CBO the first 50 holes were charged using 3ft of stemming and the remaining 51 holes were charged using 5ft of stemming, this to see the difference of impact that the cap would have on the flyrock hazard, and to see if differing the stemming length would have a significant effect on the fragmentation.

The method utilized to analyze the effects of the varistem caps was a thorough post blast analysis of the fragmentation and also the video imagery of the blast.

The video imagery has yielded 2 results that are applicable for both the SM and CBO mine sites as the varistem caps were also tested at Peto hill (CBO). These results are that the varistem caps retain the explosive energy within the ground for a longer time resulting in better breakage of the ore, and it reduces the noise and vibration levels significantly. Also the blast guards posted in the community area did not hear or see (flyrock) during the blast. The blaster in charge had to inform them via the CB radio that the blast had already been fired, leading to the conclusion that blasting the ore closer to the community areas is now possible with minimal disturbance of the inhabitants. Localized flyrock was present during the test, but reconfiguring the mining sequence where a free face can be created will resolve this issue.

Both at the CBO and SM mine sites it can be said that blasting with the Varistem caps yielded far better fragmentation results than with regular blasting. This is a direct effect from retaining the explosive energy. One noticeable effect of this analysis is that combining the cap with power gel loaded holes results in relatively poor fragmentation in comparison to ANFO loaded boreholes. This can be backed by the fact that the power gel is a relatively low heave, high velocity emulsion based explosive, relying more on the high detonation velocity to fragment the ore than on the gradual expansion of massive volumes of gas in the case of ANFO.

The test at both mine sites showed significant reductions in flyrock and noise. Vibration levels were not measured, but in comparison to a regular blast the vibrations were significantly reduced (best feel).

These results can be explained with an energy dissipation equation: Total energy (Blast energy) = Fragmentation + Flyrock + Noise + Vibration ($T= a+b+c+d$). As the total energy stays the same in the system, and coupled with the fact that the varistem caps retain the energy much longer within the bore

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hole, and a reduction in noise, flyrock and vibration, most of the blast energy needs to go in the fragmentation.

The biggest restraint for using these stemming caps in our operations is the fact that we don't shoot to the free face, as this would mean casting the bauxite in the mined out areas hereby diluting the ore or jeopardizing mining operations. The heave of the bauxite is mostly caused by the subsequent firing of the blast holes against a choked face. This creates relatively low relief of burden when firing each row. This low burden relief type of shooting will always result in some parts of the muck pile not being fragmented properly. For achieving a significant reduction in flyrock, the blasts for the deposits closer to the community area should be mined in such a fashion that free facing of the benches is possible, hereby enabling sufficient burden relief and preventing choking of the muck pile.

Figure 1: Muckpile of CBO Blast. Maximum boulder size of 50-60 cm, ratio of finely fragmented ore to boulders was 85-15 percent approx. best results achieved with the 5ft stemmed holes.

Figure 2: Muck pile of the SM test, notice the boulders ranging from 80 cm to 40 cm in the row of holes that was loaded with powergel. The finely fragmented ore on the left was the result of a airdeck and ANFO.

4. Conclusions and Recommendations

After having conducted both tests successfully at both the SM and CBO mine sites it can be concluded that with regards to fragmentation, the implementation of the Varistem stemming caps is justified. The implementation of the cap for the reduction of noise and flyrock is also justified for the CBO mine sites however for complete confirmation of the observed levels of noise; a definitive measurement using a decibel meter should be employed. It can also be concluded that the insufficient burden relief during blasting at the CBO mine site is causing most of the flyrock (when using the stemming caps). A change in the mining sequence would enable free facing thus enabling muck pile movement in a horizontal plane instead of vertical.

It was also concluded that even with a pattern expansion at the SM test of 1m extra burden, the fragmentation provided by the ANFO charged holed was more than sufficient, meaning a pattern expansion is justified using the caps which will result in more minable ore with the same amount of meters drilled. The waterlogged holes where powergel needs to be employed, need a stemming increase from 1.6m to 2m for a more effective sealing of the borehole as the RBS of the powergel is 154% of that of ANFO, this explosive relies on high detonation pressure that is caused by high temperature rather than massive volumes of gas to fragment the ore, making the effectiveness of the cap decrease as it is disintegrated faster when using powergel.

The implementation of the cap is justified only if the costs of purchasing the caps is reasonable, the possible gains are stated in the above mentioned conclusions, but the biggest gain that can be achieved with this cap is the gains in reserve at the CBO mine sites, where previously blasting of the ore was deemed impossible due to community issues. The down the line gains of better fragmentation are harder to quantify financially as there are multiple aspects involved e.g. a better fill factor of the ROM and DEL trucks, less secondary breakage costs and less wear on the crushing and grinding circuit. All these parameters are too variable to monitor to justify coupling a financial figure.