Nigerian Journal of Technology (NIJOTECH)
Vol. 41, No. 4, July, 2022, pp.644-650
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
http://dx.doi.org/10.4314/njt.v41i4.2

Comparative Analysis on the Performance of Non-Electronic and Electronic Initiation Systems on Fragmentation Distribution at Gold Fields Ghana Limited-Tarkwa Gold Mine

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Article history: Received 3 February 2022; Revised form 21 June 2022; Accepted 15 July 2022; Available online 10 September 2022

Abstract

The purpose of blasting is to reduce rock mass to acceptable sizes suitable for load and haul operations to satisfy primary crusher requirement. The crusher settings of Gold Fields Ghana Limited require that about 80 percent of every muckpile be less than the size of 240 mm to enable free flow of materials in the crusher. Initiating blast at Gold Fields Ghana Limited is done by the shock tube non-electronic (NONEL) initiation system as well as the electronic initiation system. As a result of findings from previous studies the shock tube non-electronic system is used more often while the electronic initiation system is used at sensitive areas of the mine specifically the Atuabo pit. However, no detailed current study has been carried out to determine which of these initiation systems is more efficient in terms of the cut-off sieve size of the crushing plant. This paper compares the percentage fragmentation sizes of the blasts produced by the initiations systems used at the mine to determine which of the initiation methods produces 80 percent of the muckpile being less than the size of 240 mm; keeping every parameter related to fragmentation constant. The results obtained reveal that initiating with the electronic system increases the percentage of the required sizes above the 80 percent benchmark. About 33.33% of blast initiated by the NONEL system were below the 80 percent. The achievement by the electronic initiation system could be attributed to the higher precision and accuracy of the electronic detonators.

Keywords: Initiation, non-electronic, pyrotechnic, rocks, fragmentation, size distribution.

1.0 INTRODUCTION

Drilling and blasting constitute the fundamental unit operations of hard rock mining. Blasting which is the second phase of these major operations aims to reduce the rocks to acceptable sizes suitable for loading and hauling and to meet crusher requirement. This important stage of the drilling and blasting operations should be carried out in a safe and an economic manner. Initiation of a particular blast can be done using different initiation systems.

Gold Fields Ghana Limited (GFGL) initiates blast using (Non-Electronic) NONEL and electronic initiation systems. The results from [1] suggest that the electronic way of initiation should be used in terms of safety, that is, dealing with air blast and ground vibration. As a result of findings from [1], the mine mostly employs the electronic initiation at sensitive areas of the mine, specifically the Atuabo pit. Alternative evaluation between electronic detonator and pyrotechnic detonator is the rock fragmentation degree attained after the explosion. The results from [2] reveal the outcomes got in surface mining, mainly on the log-linear plot of muck pile; electronic detonator created a decrease in the upper size and the fines. In contrast, the particle size related to electronic detonator, evaluated by [3] and [4] are steadily greater compared with pyrotechnic detonator.

There has not been any study to compare these initiation systems based on size distribution of the fragmented rocks. This study seeks to compare the performance of NONEL and electronic initiation systems in relation to fragmentation size distribution. Therefore, the objective of the paper is to compare the performances of NONEL and electronic initiation systems on fragmentation distribution to determine the impact of the different initiation systems on the size distribution of fragmented rocks at Atuabo pit at Tarkwa, Ghana. Results in [5] determine the precision and accuracy using reliability engineering and conclude that for pyrotechnic initiation, the reliability is poor and close to zero whilst the reliability of electronic initiation yields 0.8647 making the electronic

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sequence arrangement far better than the pyrotechnic sequence arrangement. NONEL detonators use pyrotechnic delay elements and the variation of the actual delay periods is at best approximately 1 percent of the nominal delay. The lack of guaranteed precision common to all pyrotechnic systems enhances the likelihood of negative environmental blasting effects. On the contrary, the negligible variation in the electronic delays mean that the firing pattern will consistently be the same for each blast resulting in uniform blast results.

Electronic detonators are therefore a key tool in establishing control of the blasting process due to their precision delay and consequent ability to ensure sequential firing [6]. Electronic detonators provide unlimited delay times in addition to the increased accuracy over pyrotechnics. One of the advantages of electronics over pyrotechnics is that there is no restriction as to the delay timing of the shot as the detonators are programmed according to the shot design rather than fixed supplied delays [7]. However, [8] postulates that there are no validated prediction models to determine how initiation affects rock fragmentation.

1.1 Geographical location, Microclimate and Geology of the Mine

Tarkwa is located in south-western Ghana approximately 300 km by road west of Accra, the capital, at latitude 5°15’ N and longitude 2°00’ W. The Tarkwa gold mine is at located 4 km west of the town of Tarkwa with good access roads and an established infrastructure. The mine is served by a main road connecting to the port of Takoradi some 60 km to the south on the Atlantic coast [9].

Figure 1 illustrates the location map of Tarkwa Mine**.** A tropical climate, characterised by two distinct rainy seasons from March to July and September to November exist in the study area. Average annual rainfall near the site is 2 245 mm. Although, there may be minor disruptions to operations during the wet season, there is no operating or long-term constraint on production due to climate [9]. Tarkwa Gold Mine is located at the southern end of the Tarkwa Basin. The north-east trending basin approximately 220 km wide within the West African Craton and is also called the Tarkwa syncline or the Ashanti Belt.

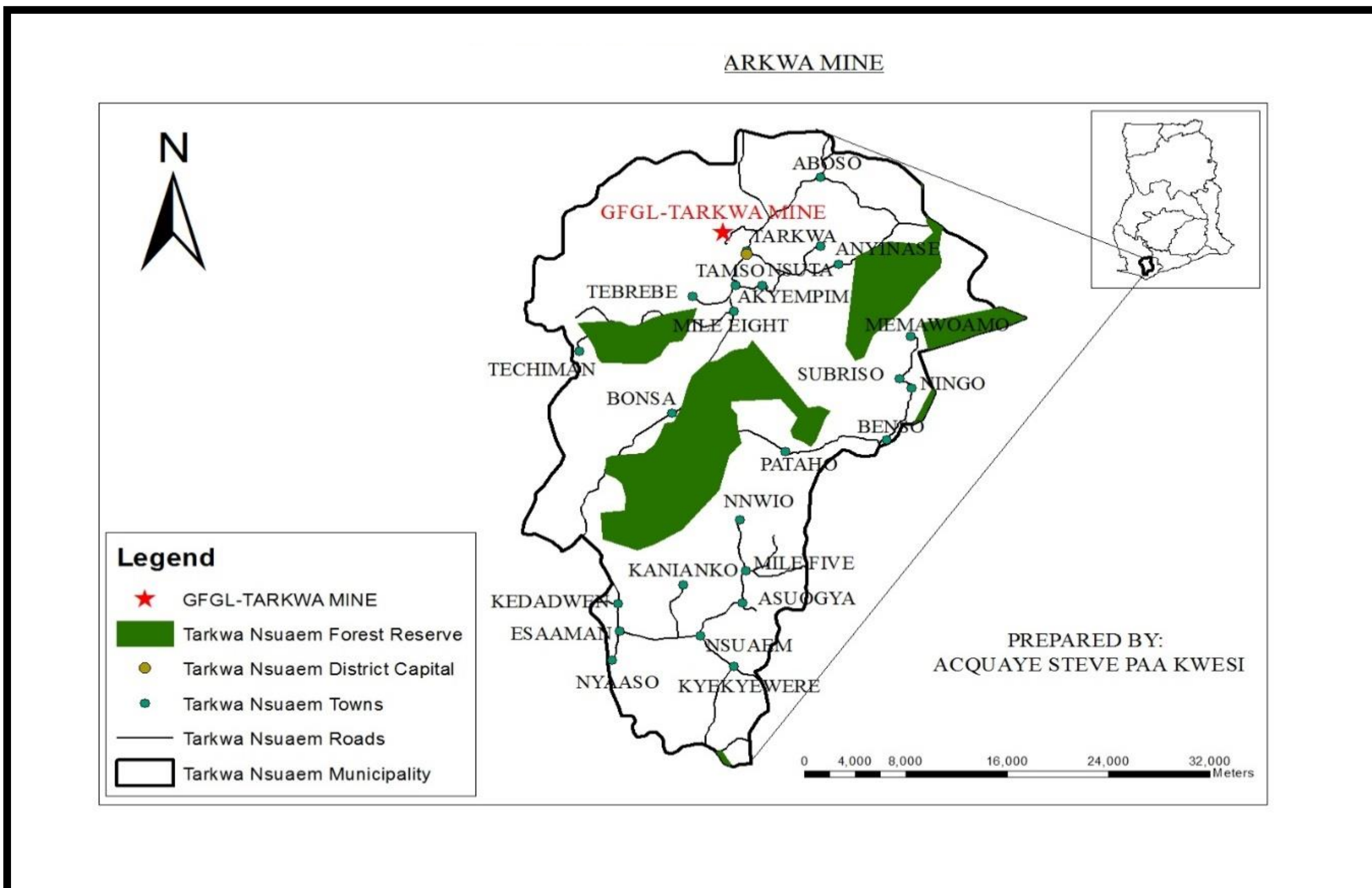

Figure 1: Location Map of Tarkwa Mine [9]

However, the term Ashanti Belt is used for the combined Birimian and Tarkwain. The Tarkwa basin rests on a folded and metamorphosed sequence of early Proterozoic age rocks called Birimian [10, 11]. The description of the Tarkwaian stratigraphy is shown in Table 1.

Table 1: Description of the Tarkwaian stratigraphy

Series	Thickness (m)	Lithology
Huni	1 370	Quartzites, minor phyllites
Tarkwa Phyllite	120-400	Chloritic and sericitic
Banket	120-160	Quarzites, grits and conglomerates
Kawere	250-700	Quarzites, grits and conglomerates

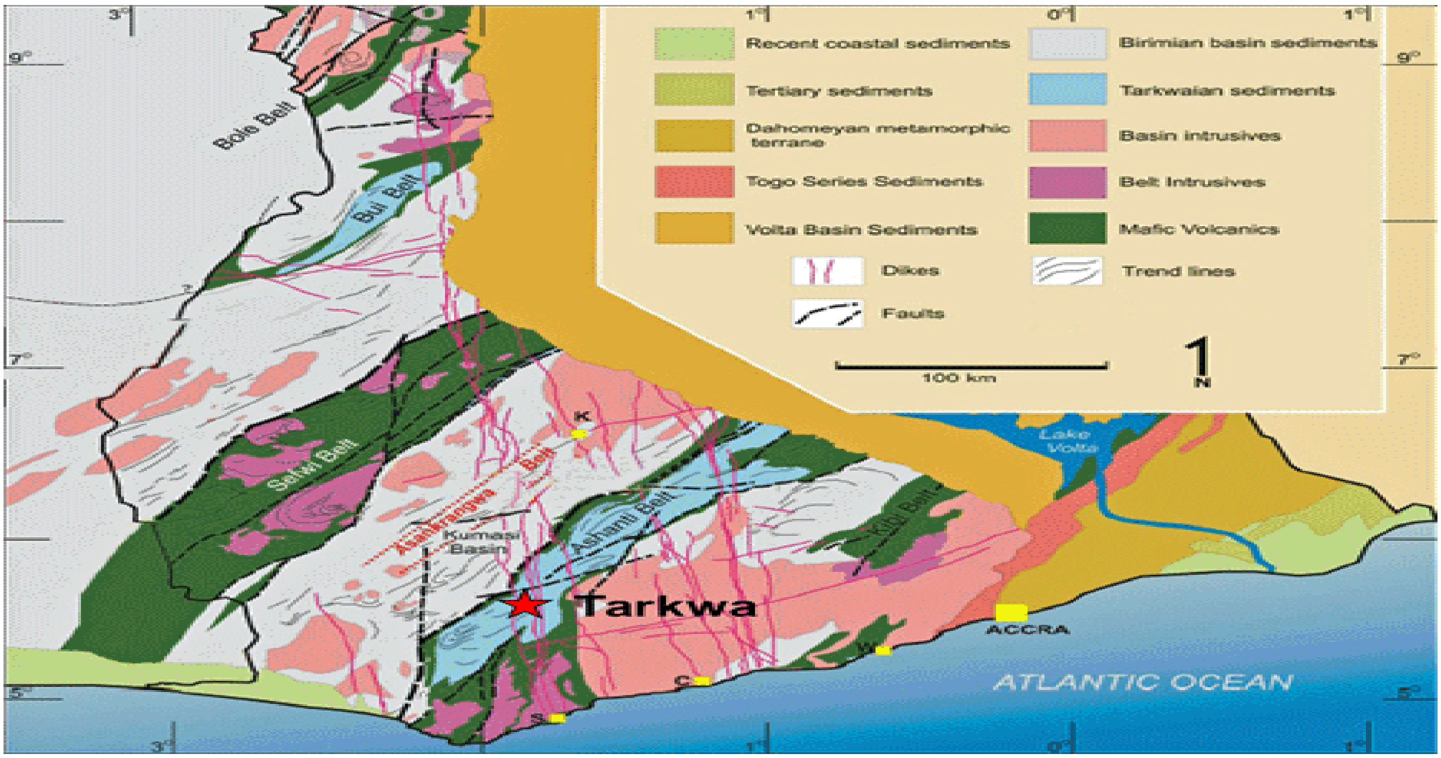

Figure. 2: Geological Map of the Tarkwa Area [9]

The overlying banket series is the main gold bearing unit in the Tarkwaian area and consist of up to 150 m of relatively more mature quartzite and conglomerates. The contact between the hanging wall and footwall of Gold Fields Ghana Limited (GFGL) orebody is structured in such a way that it alternates between Run of Mine (ROM) and waste.

The rocks in the Tarkwa syncline plunge 20 degrees to the North East and the metamorphic grade is generally low but can be locally medium with psammoblastic to lepidodlastic textures. Three types of sedimentary rocks are present in the banket group in the Tarkwa concession area [11]. These are conglomerates, quartzites and phyllites. A number of intrusive igneous rocks cut the sedimentary rocks of the banket group in the Tarkwa concession area [9]. Figure 2 shows the geological map of the Tarkwa area.

2.0 METHODOLOGY

This section describes the field test procedures, observations, and of field data. The tests were carried out using shots from the following pits: Awonaben, Mantraim, Pepe, Akontasi Ridge, Akontasi Underlap and Teberebie.

The mark out crew measured and marked out the floor to be drilled in a staggered pattern for each blast. Drilling was carried out by GFGL drilling crew using Sandvik Pantera DPI 1500i percussive drill with 127 mm diameter bit. After each drilling has been completed, the drilled holes were plugged with plastic cones to prevent materials from falling inside. The designed bench parameters for drilling are provided in Table 2.

Every explosive and accessories required for each blast was supplied by African Explosive Limited (AEL). Blasting activities were carried out by GFGL blasting crew. All the holes were charged using column charge.

Table 2: Designed Drilling Parameters at GFGL.

Bench Parameter	**Recordings**
Burden (m)	4
Spacing (m)	4
Bench Height (m)	9
Sub drill (m)	1.4
Hole length (m)	10.4
Hole inclination (^{0})	90
Hole diameter(mm)	127
Drill pattern	Staggered

Table 3: Designed Blasting Parameters at GFGL

Bench Parameter	**Recording**
Explosive type	ANFO and Emulsion
Density (g/cc)	1.15
Charge length (m)	6.9
Average Charge per hole (kg)	104
Stemming height (m)	3.5
Stemming material (s)	Drilled rock chippings and airbag
NONEL in Hole delay (ms)	500
NONEL Surface delays (ms)	17/25/42/67
Electronic delays (ms)	19/35/55/75

Before the commencement of the charging, the drilled holes were first checked for blockages and presence of water. The designed bench blast parameters for drilling are provided in Table 3.

All shots considered were composed of rock factors ranging from 4.7-5.2 which is approximately 5. NONEL and Electronic initiation systems were used during the blasting operations. For each blasthole a primer was first made with a NONEL Unidet detonator of 500 ms delay and a pentolite 400 g booster. A blend of ANFO and emulsion was used for the column charging. This was pumped from a mobile manufacturing unit into the blasthole through a charging hose to reach the base of the stemming level. After charging, about ten minutes were for allowed degassing of the explosive substance to get the required density. Stemming height was then filled with airbag and drilled rock chippings. After the stemming surface connections were made using surface delays of 17 ms, 25 ms and 42 ms, the entire connection was then connected to a 0 ms delay of multiple lengths to a point where safety of the shot firer is assured. The 0 ms delay was then attached to an electronic detonator which was armed and fired by a bench box.

In electronic initiation system, for each blasthole, a primer was made using a digishot electronic detonator and a pentolite 400 g booster which was lowered to the bottom of the hole. A blend of ANFO and emulsion was used for column charging. This was pumped from a mobile manufacturing unit into the blast hole through charging hose to reach the base of the stemming level. After the charging, ten minutes was allowed for gassing to get the required density. The detonators were tested and given identity with the aid of a tagger. Stemming height was then filled with airbag and drilled rock debris. After the stemming, all the detonators were connected to a harness wire. The harness wire was then connected to a blasting machine which was used for verification and programming of all the detonators to give each detonator the required delay. After programming, the detonators were armed by charging the internal capacitor of each detonator to full firing voltage, after which the blast was then fired using the blasting machine.

A total of 24 shots were considered and after the shot were fired, about twenty minutes were allowed for the blast fumes to clear before the shot firer would proceed with his inspection. before personnel assumed their duties. It was at this time that blastmen took blast photos with the object of reference of 240 mm diameter ball. It was specially placed on that part of the muck pile where there were variations in sizes. This was done to ensure that fair results were generated by the split desktop analyser. At GFGL, it is expected that about 80 percent of the muckpile not fines be less than the ball size of 240 mm to allow for free flow of the material in the crusher based on the primary crusher settings.

An analysis of the muckpile to determine the size distribution is known as fragmentation size analysis. The split desktop analyser software Version 3.0 was used for the analysis. The muck pile image to be analysed was opened on the software using the 'open' tool from the dropped down image menu. The image was delineated using the 'delineate' tool from the dropped down image menu. The image was scaled with respect to the objects of reference as 240 mm using the 'scale' tool and the delineations were then edited. It involved fine filling, mask filling of the objects of reference and using the paint brush and the eraser to correct over delineations and under delineations. Fines were then estimated with the default fine factor. The results were determined by highlighting the image and clicking on the 'show results' tool. An interpolation of the results was done to determine the percentage of material less than that of the object of reference to generate the necessary report.

3.0 RESULTS AND DISCUSSION

The various obtained results are analysed in the Tables 4 to 9 showing percentages used to trace where the 240 mm size will fall.

The results of fragmentation analysis of muckpile from Awonaben pit blast are presented in Table 4. From table 4, the two analyses of the NONEL initiation were below the required 80% passing while electronic initiation analyses exceed the required

The results of fragmentation analyses of muckpiles from Mantraim pit blast are provided in Table 5.

From Table 5 NONEL and electronic initiations produced passes that are above the required 80% passing. There was a maximum of 5% increase with NONEL and 15% increase with electronic initiation.

Table 4: Fragmentation Analysis Results from Awonaben pit blast

Passing (%)		**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99.95**	
ID	NONEL											
N1	Size (mm)	41	71	99	123.	147.	172	208	258	341	403	76
N2		29	54	77	99	120	143	208	257	323	471	77
ID	Electronic											
E1	Size (mm)	24	45	64	83	102	119.	138	161	246	282	89
E2		31	53	73	91	108	126	148	176	224	368	91

Table 5: Fragmentation Analysis Results from Mantraim Pit Blast

Passing (%)		**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99.95**	
ID	NONEL											
N3	Size	42	70	94	117	137	157	181	220-	275	403	84
N4	(mm)	39	66	90	112	132	153	176	206	270	320	85
	Electronic											
E3	Size	28	53	75	98	120	140	163	188	218	355	92
E4	(mm)	15	31	48	66	84	101	119	141	190	285	95

Table 6: Fragmentation Analysis Result from Pepe Cut 7 Pit Blast

Passing (%)		**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99.95**	
ID	NONEL											
N5	Size	15	36	53	85	112	141	174	219	288	447	83
N6	(mm)	47	74	96	115	134	155	193	238	348	554	81
	Electronic											
E5	Size	48	73	94	111	128	145	168	195	238	373	91
E6	(mm)	13	28	43	63	82	101	120	142	174	254	98

Table 7: Results of Fragmentation Analysis from Ridge Cut 7 Pit Blast

Passing (%)		**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99.95**	
ID	NONEL											
N7	Size (mm)	73	105	129	152	172	193	214	238	270	345	80
N8		54	101	121	140	158	177	201	237	297	488	81
ID	Electronic											
E7	Size (mm)	14	33	53	74	98	121	147	182	215	351	92
E8		58	86	109	126	144	163	184	209	243	373	89

Table 8: Fragmentation Analysis Result from Akontasi Underlap Pit Blast

Passing (%)		**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99.95**	
ID	NONEL											
N9	Size	52	81	105	126	145	189	220	275	315	481	74
N10	(mm)	51	82	108	130	151	188	204	250	374	407	78
ID	Electronic											
E9	Size	19.	39	59	79	100	119	139	163	196	357	93
E10	(mm)	32	54	74	93	110	129	152	187	255	471	88

Table 9: Results of Fragmentation Analysis Result from Teberebie Cut 3 Pit Blast

Passing (%)		10	20	30	40	50	60	70	80	90	99.95	
ID	NONEL											
N11	Size	50	80	106	128	148	170	195	229	282	410	82
N12	(mm)	38	68	94	120	144	169	198	225	277	443	83
ID	Electronic											
E11	Size	40	66	89	109	127	145	164	188	222	358	91
E12	(mm)	22	46	68	92	114	135	160	192	245	396	89

The results of Fragmentation analyses of muckpiles from Pepe Cut 7 pit blasts are presented in Table 6.

Both initiation systems produced passes above the required 80%. The maximum increase was 3% and 18% with NONEL and electronic initiations respectively. The results of the fragmentation of muckpiles from Ridge Cut 7 pit blast are presented in Table 7.

Both initiation systems produced passes above the required 80%. The maximum increase was 1% and 12% with NONEL and electronic initiations respectively. The results of fragmentation analyses of muckpiles from Akontasi Underlap are shown in Table 8.

The two muckpiles analysed for NONEL were below the required pass of 80%. Muckpile analysed for electronic initiation exceeded the required percentage passing. The results of fragmentation analyses of muckpiles from Teberebie Cut 3 are provided in Table 9.

Both initiation systems produced passes above the required 80%. The maximum increase was 3% and 11% with NONEL and electronic initiations respectively. Figure 3 shows a graph of percentage pass against size of NONEL and electronic initiations. All figure 3 in red coloured bars represent the amount as muckpile in percentages lesser than the ball size but not fines as required corroborating with [2].

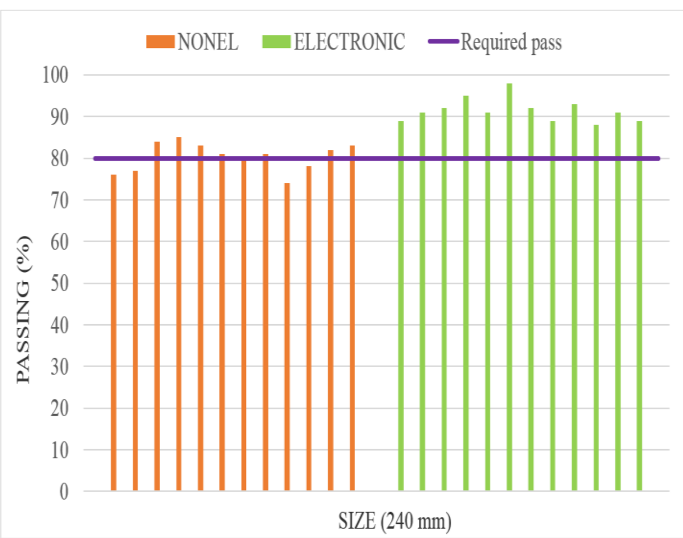

Figure. 3: Graph of percentage passing (%) Versus 240 mm size of NONEL and electronic

It was observed that from all the shots that were considered for this study, those that were initiated with electronic detonators gave a better percentage pass than those that were initiated by NONEL. About 33% of the shots that were initiated by NONEL did not meet the required percentage passing. This will hinder the smooth running of the primary crusher. All shots initiated by electronic exceeded the required pass. The electronic detonators provide more accurate timing than the orthodox pyrotechnic detonators which depend on the burning speed of a pyrotechnic arrangement. The timing exactitude capability of the electronic detonator permits for more effective submission of explosive energy and enhanced muck size regularity [12]

NONEL detonators use pyrotechnic delay elements and the variation of the actual delay periods is at best approximately 1 percent the nominal delay. The lack of guaranteed precision common to all pyrotechnic systems enhances the likelihood of negative environmental blasting effects. On the contrary, the negligible variation in the electronic delays mean that the firing pattern will consistently be the same for each blast resulting in uniform blast results.

Electronic detonators provide unlimited delay times in addition to the increased accuracy over pyrotechnics. One of the advantages of electronics over pyrotechnics is that there is no restriction as to the delay timing of the shot as the detonators are programmed according to the shot design rather than fixed supplied delays [7]. Electronic initiation should be done more often taken into consideration the adverse effect of poor fragmentation after blasting on other sub-systems of mining such as loading and hauling and crushing.

4.0 CONCLUSIONS

It can therefore be concluded that:

i. The timing precision capability of the electronic detonator permits for more effective submission of explosive energy and enhanced muck size regularity and improved fragmentation distribution.

ii. Electronic initiation contributes to more than 80 percent passing of the muckpiles that flow through the primary crusher as required.

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