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IMPACT OF AVAILABILITY AND UTILISATION OF DRILL RIGS ON PRODUCTION AT KANJOLE MINERALS LIMITED

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Abstract: The availability and the utilisation of drill rigs have great impact on the output of a mine. These can be optimised by reducing the downtimes and operational delays to ensure high availability and utilisation, and consequently higher productivities. In this paper, the causes of the numerous rig breakdowns at Kanjole Minerals Ltd. (KML) were investigated, the availability and utilisation of the rigs were estimated and the impact of the availability and utilisation of the rigs on the mine's production evaluated. Iron ore occurs on five hills at KML. Five drill rigs which are currently in operation at KML were studied in this work. The causes of the rig breakdowns observed include hose burst, overheating, shank adapter breakage and change out, rod breakage, low flushing, percussion and rotation pressures, track removal and breakage and drilling chain breakage. The operating data of the rigs were entered into drill log books during drilling operations. The period of study was from September 2012 to February 2013. The results show that production of the mine is dependent on the average hours used for drilling which is also dependent on the availability and utilisation of the drill rigs. Also, analysis of logged data indicate that the mine does not schedule rigs to undergo regular maintenance. It is therefore recommended that regular maintenance schedules should be prepared for the drill rigs by the mine to minimise the unplanned downtimes of the rigs.
Keywords: Drilling, Drill rigs, Availability, Utilisation, Downtimes, Production.

1 Introduction

Drilling and blasting are major operations in hard rock mining. Blastholes are usually drilledfor the loading of explosives which are fired to fragment the rocks. The principal drilling methods used in mines currently are mechanical methods in which a drill drives cutting tools into the rock by means of static or dynamic forces (Watanable, 2011). These mechanical methods employ drill rigs or rock drills to make the holes into the formation. The output of many industries (including mining) depends on their assets. The current economic conditions, severe global competition, among other factors, has caused mine operators to consider creative and proven methods to determine and improve the efficiency of their equipment to reduce the total production costs (Elevli and Elevli, 2010). The efficiency of the mining equipment is usually measured using parameters such as availability and utilisation.

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These parameters have a great effect on the overall performance of mining equipment such as drill rigs, excavators and dump trucks which are very necessary in the production cycle. It is therefore imperative that availability and utilisation of the equipment be optimised in order to improve productivity of any mining operation. Though much research has been done on the selection of mine equipment, little attention has been given to the measurement of equipment effectiveness. Also, maintenance policies have been implemented to improve equipment (mostly trucks) availability and utilisation (Elevli and Elevli, 2010) but little attention has been paid to the impacts drill rigs' availability and utilisation have on mine production.

Kanjole Minerals Limited (KML) is surface mine in the Western Region of Ghana. It is observed that there are numerous breakdowns of the drill rigs at KML. This causes many problems such as undue delays in blasting times and sleep shots and hence production delays. It also causes low rig availability and this affects the overall output of the mine. The objectives of this paper are to investigate the causes of the numerous rig breakdowns, estimate the availability and utilisation of the various rigs used at KML and evaluate how the availability and utilisation impact production at the mine and suggest ways of improving rig output. This research will therefore, add to the very scarce literature on rig availability and utilisation in the mining industry.

1.1 Drilling System Performance

The efficiency of a modern mining system depends heavily on the productivity and availability of the equipment used to extract the material (Bullock, 2011). According to Pathak (1989), drilling is the process of making a hole into a hard surface (rock mass) with the depth or length of the hole being very large as compared with the diameter. Pathak (1989) further classifies the types of drilling as production, exploration and technical drilling. It is the first stage of the rock fragmentation process. According to Agbeno (2011), the factors that affect the performance of a drilling system are categorised as design or operating variables, uncontrollable/independent variables, drillability factors and service or job factors.

Design or operating variables are factors that are directly linked with the components of the drilling system namely drill (energy source), rod, bit and flushing or circulating fluid. They are usually referred to as controllable factors. They include the piston mass and geometry, impact frequency, rotation speed and feed force of the drill, rod type and geometry, bit diameter, its design and the type of buttons used, and type of flushing fluid used (Agbeno, 2011).All these factors are directly related to the penetration rate and hence the drilling performance.

Independent variables in drilling are rock properties, which are usually characterised by compressive, tensile (indirect), and shear strength measurements (Tuck, 2011). Drillability factors are also termed as rock factors. According to Temeng (2012a), such factors include the physical and mechanical properties of the rock. These include the density, porosity, hardness, moisture content, the state of stress and geological conditions such as bedding planes and fractures.

Service or job factors do not have any direct link with the penetration process but may affect the performance of the drilling system. They include factors as the skill of labour, job site and scale of operation, power availability, weather conditions and level of supervision (Agbeno, 2011).

To select the best drilling system for a particular application, the various systems available should be evaluated. The evaluation of the drilling system is carried out using criteria such as energy or power requirement, rate of penetration (drillability), bit wear, cost which includes purchase price, operating and maintenance costs (Agbeno, 2011).

1.2 Availability, Utilisation and Production

Availability: Dhillon (2008) defines availability as the probability that a piece of equipment is functioning satisfactorily at a specified time, when used according to specified conditions, where the total time includes operating time, logistical time, active repair time, and administrative time. Therefore, the equipment availability is simply the proportion of time the equipment is able to be used for its intended purpose. Availability reflects the part of the scheduled hours that the machine is mechanically and electrically ready to be operated. Availability is expressed mathematically as (Rai, 2004):

$$A = \frac{SSH - (MH + BH)}{SSH} \tag{1}$$

where: A is the equipment availability; SSH is the scheduled shift hours; MH is the maintenance hours; BH is the breakdown hours.

The scheduled shift hours is the total time available for the operation of the drill rig during a shift. Such time excludes break times, change over times, safety/production meeting times and other inevitable delays within the shift.

Maintenance hours represent the hours the machine is not available due to planned/preventive maintenance schedule of the machine. This is also known as planned downtime.

Breakdown hours represent the time that the machine is being repaired due to unscheduled breakdowns. This may also be referred to as unplanned downtime.

Utilisation or operational availability: This is the percentage of the available time that the machine is actually operated. It is also referred to as the percentage of the scheduled shift hours (SSH) that the machine does productive work. Events that may lead to the non-utilisation of the machine include dozer works, delays in marking up, operator convenience time, etc. Other factors that may affect the utilisation of the rigs include competency of mine personnel, efficiency of mine plan and support equipment commitment (Temeng, 2012b). Mathematically, utilisation is expressed as (Rai, 2004):

$$\text{Utilisation} = \frac{\text{SSH - (MH + BH + IH)}}{\text{SSH}} \quad (2)$$

IH is the idle hours and represents the hours that the machine is mechanically and electrically ready to be operated but is not utilised due to some of the factors listed earlier on. Fig. 1 is a summary breakdown of the time components that are used in estimating availability and utilisation. In Fig. 1, non-utilisation is broadly grouped into standby and operating delays.

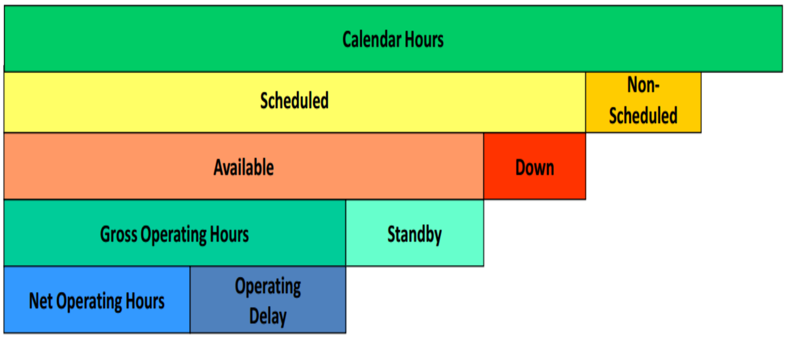

Fig. 1 Detailed Breakdown of Equipment Operating Time (Anon., 2012)

***Production*:** The production of a mine for a particular period is the total amount (tonnage or volume) of material (ore and waste) removed. The unit of measure is cubic meters or tonnes. The availability and utilisation of rigs have great impact on the production of the mine since drilling is the first phase of the rock fragmentation process. Low availability and utilisation will usually lead to few holes being drilled per shift which in turn lead to low volume or tonnage of rock to be blasted (i.e. lower production per shift).

1.3 Mining Operations at KML

KML is located in the Western Region of Ghanaand lies between latitude 4° 00″ to 7° 00″ North and longitude 3° 07″ West and 1° 07″ East (Nyame*et al.*, 1995 and Boye*et al.*, 2011).The ore occurs on five hills namely A, B, C, D and E at KML. The mine is located in the tropical rain forest of Ghana.

The machines used for drilling at KML are the Atlas Copco self-propelled, self-contained, crawler-mounted drill rigs. The drill pattern used is the staggered hole pattern of 3.5 m × 3.5

m to 5 m × 5 m depending on the rock conditions of the area and the degree of fragmentation required. The hole diameter is 115 mm with an average depth of 10.5 m. During drilling, samples are taken for grade control purposes.

Blasting times at KML are usually between 10:00 am and 5:00 pm on working days. Explosives used at KML for blasting include blend emulsion, 250 g Pentolyte booster, NONEL detonators and initiators which are supplied by MAXAM Ghana Limited. The average density of the blend emulsion is 1.2 g/cc. The final stemming height is 3 m. The NONEL detonators are used for priming and surface connections. Stemming is done using chippings of different sizes.

Materials handling is by the use of hydraulic shovels together with rear dump trucks to match. The mine uses Caterpillar 777, Komatsu and a few Volvo trucks to haul both ore and waste. After loading and hauling the material from the pit, a backhoe is used to clean the bench face to ensure stability.

2. Materials and Methods

Field visits were conducted for data collection and to familiarise with the drilling operations of the mine. Much of the data used is secondary data from the mine. Some primary data about the causes of breakdowns were gathered during field visits. Data for this work were obtained from five blasthole drill rigs used at KML. These includeone Atlas Copco ROC L8 and four Atlas Copco CD-ROC F9 drill rigs. The equipment identification numbers are DRIA 006 for the Atlas Copco ROC L8 and DRIA 009, DRIA 010, DRIA 011 and DRIA 014 for the four Atlas Copco CD-ROC F9 drill rigs. The operating data of the rigs were entered into drill log books during operations. Each rig is assigned a log book to be used for this purpose. This contains data about the operations such as name of operator, rig description, operation times, rig breakdowns, repair times, employee break times, standby times and rig production or meters drilled for the period. The period of data collection was from September 2012 to February 2013. From the data, the availabilities and utilisations of the rigs were computed. The data analysis was done by statistical methods using MS Excel 2013. The company's target for availability and utilisation of the drill rigs are 80% and 90% respectively. The formulae for computing the availability and utilisation are as given in equations (3) and (4) and are based on the terminologies used at the mine:

$$\text{Availability} = \frac{\text{AAT}}{\text{PAT}} \times 100\% \tag{3}$$

$$\text{Utilisation} = \frac{\text{Used Time}}{\text{AAT}} \times 100\% \tag{4}$$

Where PAT stands for Projected Available Time and AAT stands for Actual Available Time.

3. Results and Discussions

This section presents the results of the study, the results for the causes of breakdowns, the availability and utilisation of all the rigs considered in this study and the production results and discussions.

3.1Causes of Rig Breakdowns

The causes of the rig breakdowns observed include hose burst, overheating, shank adapter breakage and change out, drill rods getting stuck in the hole, rod breakage, poor flushing, low percussion and rotation pressures, drilling chain breakage and track removal and breakage.

3.2 Results for Availability and Utilisation of Drill Rigs

Equations (5) and (6) are used in the calculation of the monthly average availability, and utilisation of the drill rigs.

$$\text{Average Availability} = \frac{\sum \text{Monthly Availability}}{\text{Number of Months}} \times 100\% \tag{5}$$

$$\text{Average Utilisation} = \frac{\sum \text{Monthly Utilisation}}{\text{Number of Months}} \times 100\% \tag{6}$$

Using equation (1) to (6) the total and average monthly rig availabilities and utilisationswere calculated. Fig. 2 shows themonthly availabilities and utilisationsof rig DRIA 006 while Figs. 3 to 6 show the monthly availabilities and utilisations of rigs DRIA 009, DRIA 010, DRIA 011 and DRIA 014 respectively.

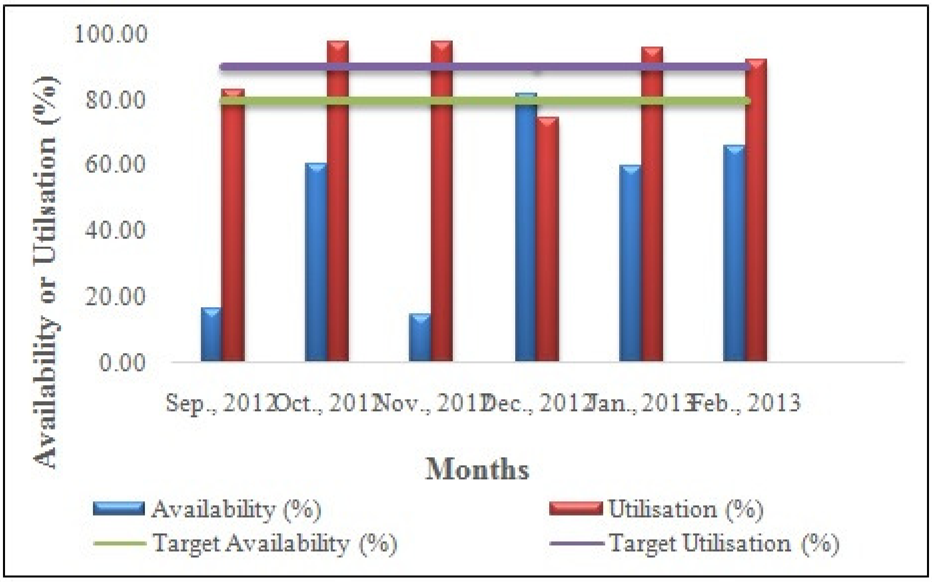

Fig. 2 Monthly Availability and Utilisation for Rig DRIA 006

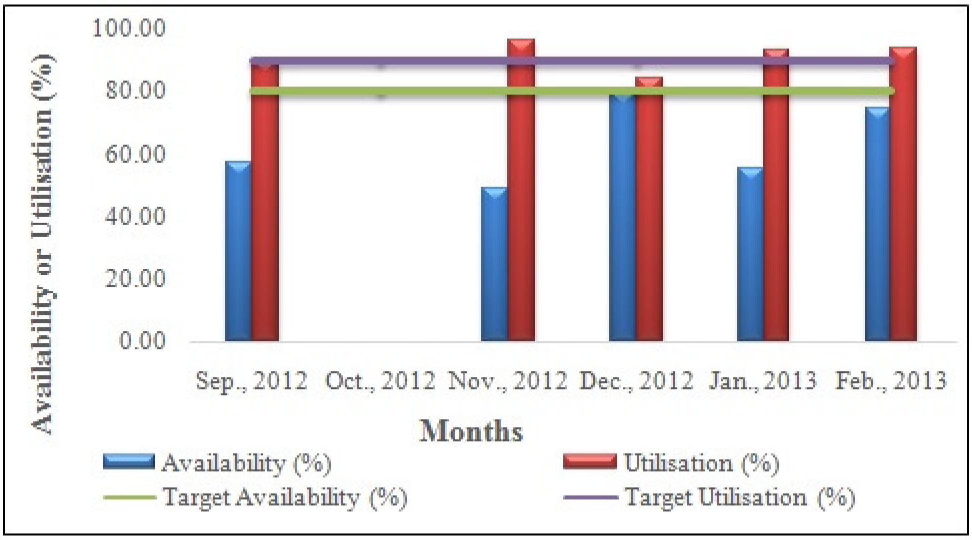

Fig. 3 Monthly Availability and Utilisation for Rig DRIA 009

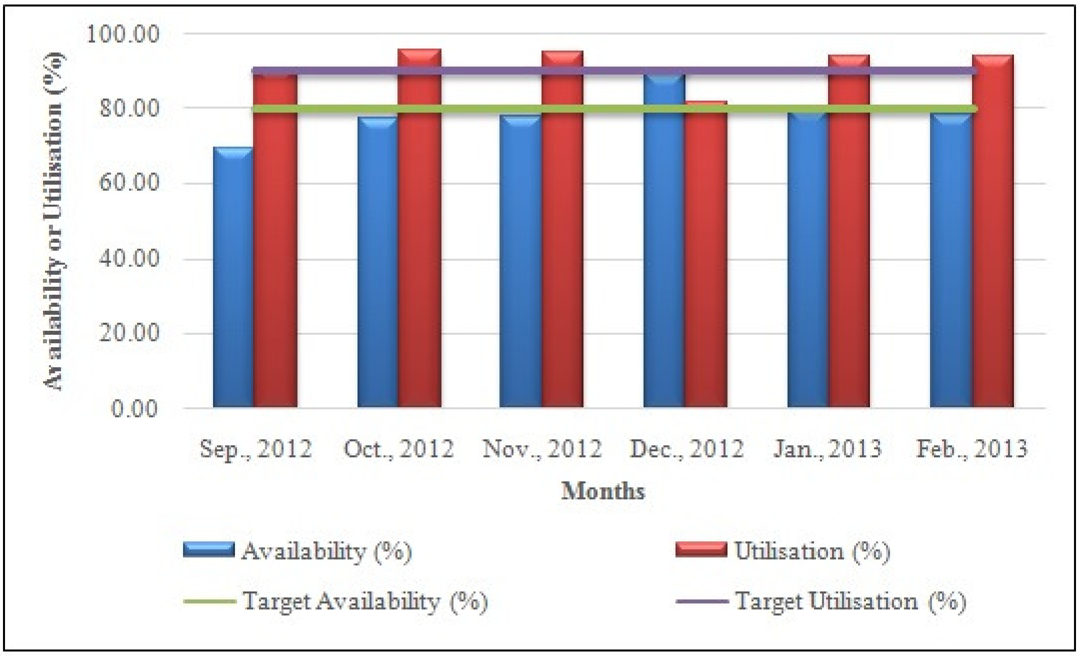

Fig. 4 Monthly Availaility and Utilisation for Rig DRIA 010

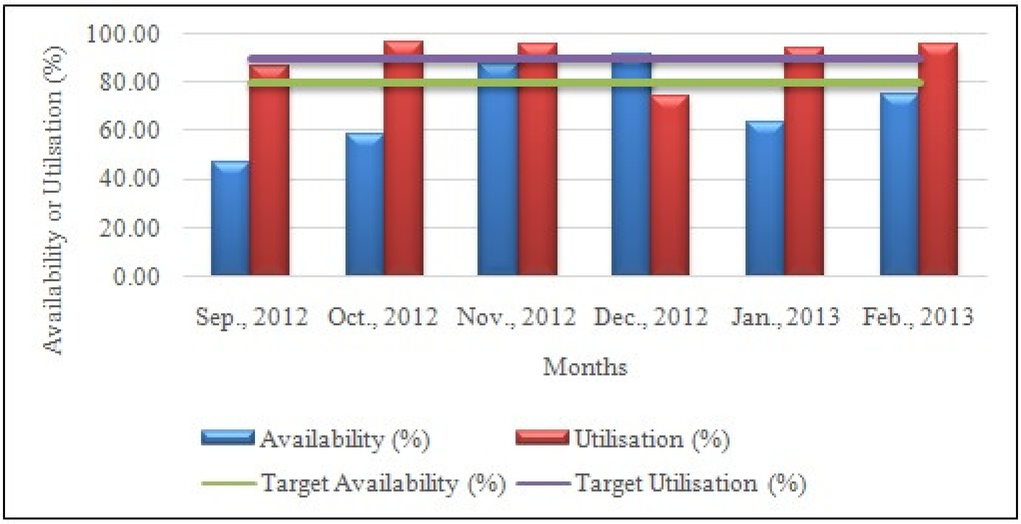

Fig. 5 Monthly Availability and Utilisation for Rig DRIA 011

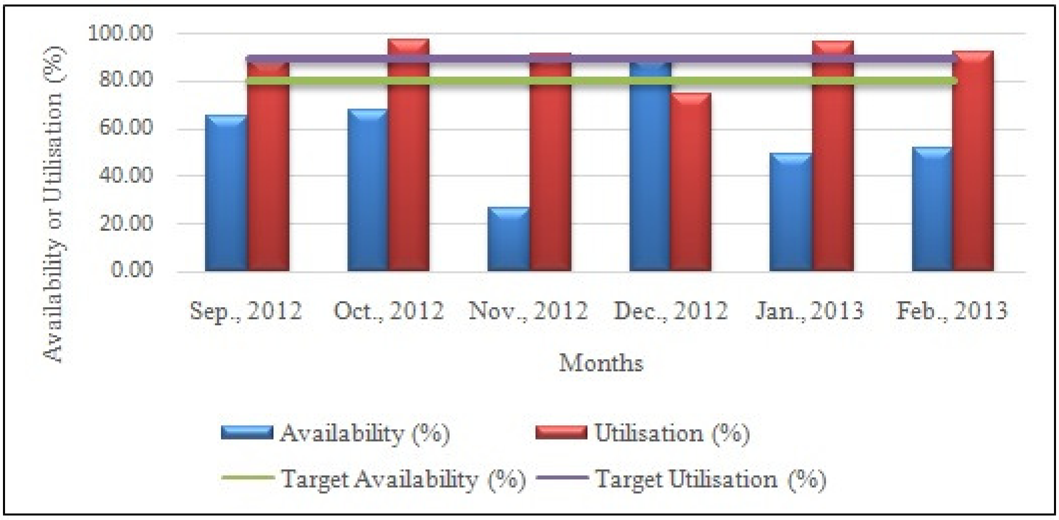

Fig. 6 Monthly Rig Availability and Utilisation for DRIA 014

3.3 Discussion of Availability and Utilisation Results

From Fig. 2, apart from December 2012 when the availability was 81.3%, all the other months had availabilities below the target of 80%. The least utilisations of the rig occurred in September and December 2012 (82.7% and 74% respectively). All other values of utilisation were greater than 90%. The average availability and utilisation were 49.6% and 89.7% respectively. This indicates that the achieved availabilities for most of the months were far below the targeted value. The utilisations, however, exceeded the targeted values in four out of the six months.

From Fig. 3, the availability and utilisation of the Rig DRIA 009 from September, 2012 to February, 2013 were all below the targeted values. In November 2012, January and February, 2013, the achieved utilisations exceeded the target. The other months recorded lower utilisations than targeted values. The rig was not available and hence it was not utilised in October 2012. The average availability and utilisation for Rig DRIA 009 were 52.5% and 76.1% respectively.

Fig. 4 shows that the availability of Rig DRIA 010 in December 2012 was 89% which exceeded the target of 80%. However, all the other months recorded lower availabilities than the target. Also apart from December 2012 which recorded the lowest utilisation of 81.9%, the utilisation in all other months exceeded the target utilisation. The average availability and utilisation of the rig were 78.6% and 91.9% respectively. Though the average rig availability is lower than the targeted value, its achieved utilisation figures were relatively higher indicating that during the time that the rig was available, it was well utilised.

From Fig. 5, in November and December 2012, the target availability was exceeded. However, the rig had lower availabilities in the other months compared to the target. Apart from September and December 2012, the rig recorded higher utilisations than the target in the other months. The average availability and utilisation of Rig DRIA 011 were 69.5% and 89.3% respectively. This is an indication that for the period under consideration, the targets for both availability and utilisation were generally not met.

From Fig. 6, the target availability of 80% was exceeded only in December 2012. The availabilities of the rig in the other months were relatively lower than the target. The rig had a good utilisation during the entire period of study with the least utilisation being 74.6% in December. The average availability and utilisation were 58.3% and 90.1% respectively. This shows that even though the average availability was lower than the target, the rig was well utilised for much of the time it was available.

3.4 Mine Production

Mine production refers to the total volume or tonnage of material (ore and waste) moved in a period. Equations (7) and (8) are used in the calculation of the average hours used and production achieved by the drill rigs.

Average Hours Used = Ave. Availability × Ave. Utilisation× Operating Time (T) (7)

Achieved Production = Meters Drilled × S × B× TF (8)

Equation (8) resembles the estimated the annual output of a dragline by Rai (2004) as shown in equation (9).

$$PI = (B/C)\times A\times U\times S\times F\times M\times N_s\times N_h\times N_d\times 3600 \text{ (in million cubic metres)} \quad (9)$$

Where B is dragline bucket capacity (m^3), C is the average total cycle time (s), S is the swell factor, F is the fill factor, M is machine travel and positioning factor, N_s is the number of operating shifts per day, N_h is the number of operating hours per shift and N_d is the number of operating days per year.

In this work, S and B are 4 meach while TF 2.87 t/m^3). Fig. 7 shows the monthly production of the mine during the period of study while Fig. 8 shows the correlation between monthly production and average hours used per month for the period under consideration.

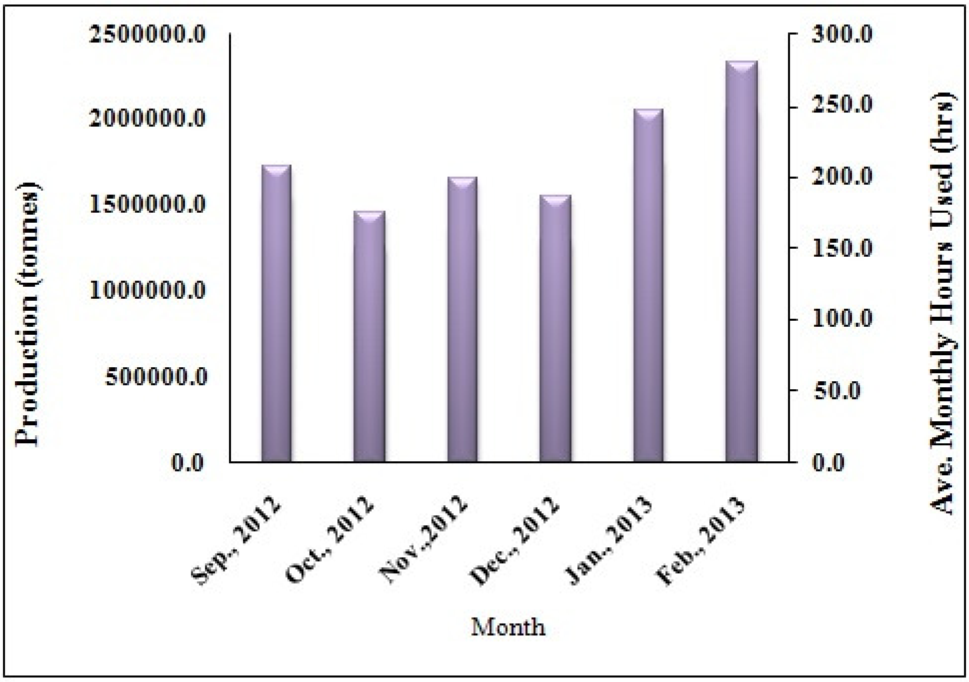

Fig. 7 Monthly Achieved Production

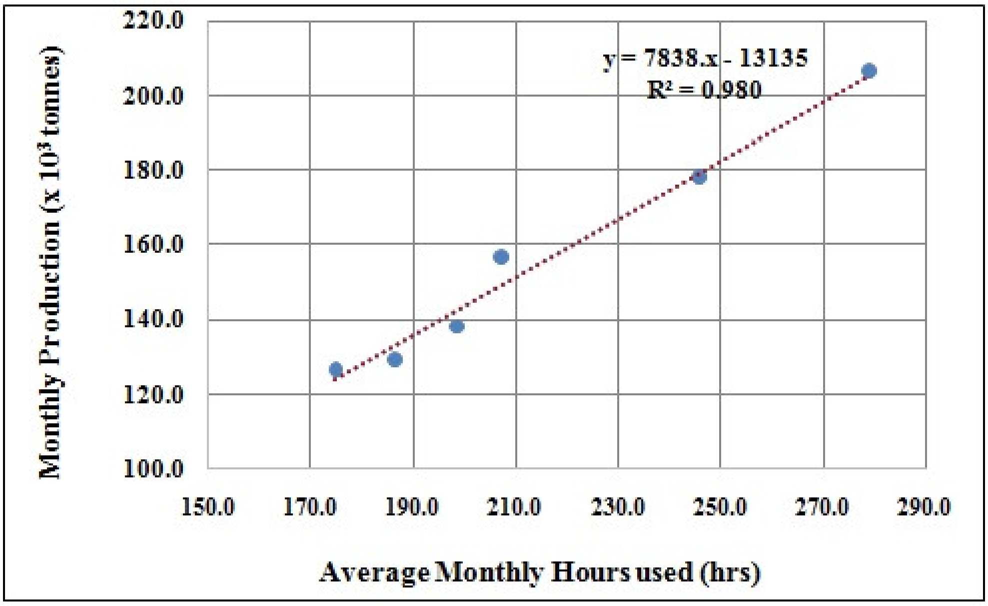

Fig. 8 Correlation of Monthly Hours used and Production

From Fig. 7, it can be seen that the longer the rig is used, the higher the achieved production. Since the average hours used is proportional to the average monthly availability and utilisation, it can be said that the production of the mine is dependent on both the availabilty and utilisation of the drill rig.

Also from Fig. 7, October 2012 recorded the least achieved production (1,264,269.4 tonnes) which corresponds to the least average hours used per month (174.8 hours). Even though October 2012 had a higher availability of 52.8% as compared to September and November 2012 (50.9% and 51.1% respectively), it had the least utilisation of 77.4% and hence the least achieved monthly production.

The average availability of the rigs in February 2013 was lower (67.0%)than that in December 2012 (86.2%). The average utilisation of the rigs was 93.4% in February 2013 and this was higher than that for December 2012 (77.6%). Hence, the highest achieved monthly production of 2,063,415.2 tonnes was recorded in February 2013 confirming that the monthly achieved mine production is dependent on both the availability and utilisation of the drill rigs.

From Fig. 8, the Y represents the monthly production while X represents the the hours used for drilling per month. The correlation model between monthly production and monthly hours used for drilling is given by equation (10):

$$Y = 7838.9X - 131353 \quad (10)$$

This model indicates that the monthly production is very strongly directly related to the hours used for drilling as R^2 = 98.03%. This means that the higher the hours used in drilling, the higher the production achieved. The average hours used for drilling is dependent on the availability and utilisation of the rig. This indicates that the availability and utilisation impact production. It is therefore evident that to improve the productivity of the mine, the availability and utilisation of the rigs need to be maximised.

4. Conclusions

From the study, the following conclusions can be drawn:

- The causes of the rig breakdowns observed include hose burst, overheating, shank adapter breakage and change out, drill rods getting stuck in the hole, rod breakage, poor flushing, low percussion and rotation pressures, drilling chain breakage and track removal and breakage.
- The availability and utilisation of the rigs used at KML have been estimated. The estimated values indicate that the availabilities of the rigs were generally lower than the target (80%) for most of the months while the utilisations of the rigs were higher (mostly above the target of 90%). This indicates that during the times that the rigs were available, they were also well utilised. It is also an indication that machine downtimes were very low.
- The regression analysis show that there is a very strong correlations between average hours used for drilling and the mine production (R^2 = 98.03%). Since the hours used for

drilling depend on the availabilities and utilisations of the rigs, then the production can be said to be strongly related to these parameters.

5. Recommendation

It is recommended that the availability of the machines be improved through strict adherence to preventive maintenance schedules to reduce machine downtimes.

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References

[1] Agbeno, S.K. (2011), "Ground Fragmentation", *Unpublished BSc. Lecture Notes*, University of Mines and Technology, Tarkwa, 111 pp.

[2] Anon. (2012), *CIM Mining Standards and Guidelines Committee*, Report of Committee Meeting, 49 pp.

[3] Boye, C.B., Yakubu, I., and Pokperlaar, D.S. (2011), "Spatio-Temporal Variability of Rainfall Distribution in the Western Region of Ghana", *Research Journal of Environmental and Earth Sciences*, Vol. 3, No. 4, pp. 393 - 399.

[4] Bullock, R.L. (2011), "Subsurface Mine Development", In Chap. 12.5 of *SME Mining Engineering Handbook*, Darling, P. (ed.), 3rd edition, SME, Port City Press Inc., pp. 1203 – 1221.

[5] Dhillon, B.S. (2008), Mining Equipment Reliability, Maintainability and Safety, *Springer-Verlag*, London, 209 pp.

[6] Elevli, S. and Elevli, B. (2010), "Performance Measurement of Mining Equipment by Utilising OEE", *Acta Montanistica Slovaca*, Rocnik 15, Cisio 2, pp. 95 – 101.

[7] Nyame, F.K., Kase, K. and Yamamoto, M. (1995), "Occurrence and Composition of Manganese Oxide Minerals from the Nsuta Manganese Deposit, Western Region", *Earth Science Reports*, Vol. 2, No. 1, pp. 71 – 80.

[8] Pathak, K. (1989), Introduction to Drilling Technology for Surface Mining, *Unpublished Lecture Notes*, Indian Institute of Technology, Kharagpur, 37 pp.

[9] Rai, P. (2004), "Performance Assessment of Draglines in Opencast Mines", *Indian Journal of Engineering and Materials Sciences*, Vol. 11, pp. 493 – 498.

[10] Temeng, V.A. (2012a), "Surface Mining Systems", *Unpublished BSc. Lecture Notes*, University of Mines and Technology, Tarkwa, 99 pp.

[11] Temeng, V.A. (2012b), “Materials Handling”, *Unpublished BSc. Lecture Notes*, University of Mines and Technology, Tarkwa, 160 pp.

[12] Tuck, M.A. (2011), “Underground Horizontal and Inclined Development Methods”, In Chap. 12.4 of *SME Mining Engineering Handbook*, Darling, P. (ed.), 3rd edition, SME, Port City Press Inc., pp. 1179 – 1202.

[13] Watanable, H. (2011), “Civil Engineering - Drlling Machines”, *UNESCO – EOLSS Sample Chapters*, Tokyo, Japan, 8 pp.