



NIGERIAN MINING JOURNAL

ISSN 1117 - 4307



Volume 21

Number 1

October 2023



**A Publication of
NIGERIAN SOCIETY OF MINING ENGINEERS**

NIGERIAN MINING JOURNAL

Volume 21 Number 1 October 2023

Table of Contents

Pages

Title and Author

1 - 10	A Review of the Potential of Natural Gas in Energy Sector Reforms: Case Study, Nigeria Jibril, I. B., Bello, A. & Muhammad A
11 - 19	Optimum Conditions for the Enrichment of Yandoton-Daji Gold Ore, Zamfara State, North Western Nigeria. H. U. Abubakar, R. A. Muriana, A. S. Abdulrahman & E. A. P. Egbe
20 -25	Evaluation and Analysis of Environmental Noise Level at Yassat, Quarry, Ilorin, Nigeria Olatunji K.J., Ogunlola O.A. & Abiola O.
26 - 33	Beneficiation of Mayanchi Gold Ore, Zamfara State, Nigeria Abubakar H. U., Oyeladun O. A. W & Tolu S.
34 - 38	Simulation Study of Oil Viscosity on Polymer Flooding for Oil Recovery: Case Study of Chad/Bornu Oil Fields Jibrin, I. B. Bello A. & Danasabe I. T.
39 - 49	Do Materials Properties have Effects on the Performance and Reliability of Reflectorless Total Station? Adewumi Johnson, Afeni Thomas B. Onifade M. & Adeyemi Adedapo J.
50 - 53	Investigation Into The Causes, Effects And Controls Of Pipe Sticking In Hole Cleaning Adebayo Samuel Ayomide
54 - 57	Reprocessing of Bukuru Cassiterite Tailings to Recover Titanium Oxide and Iron Contents for Metallurgical Applications Akindele U. M, Abubakar H. U & Jibril I. B.
58 - 64	Rate of Penetration Prediction using Mathematical Drilling Models (A Case Study of Niger Delta Formation) Danasabe I. T., Tanko A., & Akindele U. M.
65 - 68	Development of Truck Dispatching Mobile Application in Open Pit Mine: Case Study of Dangote Cement, Obajana, Kogi State Muhammed, K. Salawu O. M & Bida A. D.



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Editor-in-Chief

A. D. Bida

Publisher

Nigerian Society of Mining Engineers (NSME)
NSME Secretariat, Bukuru,
P.M.B. 2036, Jos, Plateau State, Nigeria

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Manuscripts: Manuscripts submitted for publication must represent original contributions and should not have been proposed for publication elsewhere. The papers should be based on original research, innovations and field experience in mineral exploration, mining, mineral processing, extractive metallurgy and equipment maintenance, relevant to the minerals industry. The manuscript must be prepared preferably in Microsoft Word environment, and should be submitted by email to *nigerianminingjournal@gmail.com*

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Unpublished work:

Arubisan, A.P. (2013). *Amelioration of grain size and its effect on iron ore concentrate in Itakpe, West Central Nigeria*. Unpublished M.Tech. Thesis, Federal University of Technology, Minna.

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A Review of the Potential of Natural Gas in Energy Sector Reforms: Case Study, Nigeria

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Abstract

This paper reviews the potential of natural gas in power reforms in Nigeria. The study reveals that, with almost 140 trillion cubic feet of gas, Nigeria ranks as the 7th holder of proven gas reserves in the world and largest in Africa. In energy terms, the reserve of natural gas in Nigeria is at least of the same order as the reserves of the crude oil. About 1000 standard cubic feet of gas is produced in Nigeria in association with a barrel of oil. Therefore, averagely with oil production of 2.2 million barrels per day, about 2.2 billion standard cubic feet of associated gas is produced. Nigeria has not sufficiently explored non associated gas yet, as such, gas reserves are most likely to increase over time and consequently exceed our foreseeable needs. Coal being another source of gas suffers due to its environmental associated hazards (acid rain, gas explosion) and low calorific value. Nuclear energy results in nuclear accidents, hydroelectric power is capital intensive and occupies vast acres of land that could be utilized for agricultural purposes and generates low output. Kainji, Shiroro and Jebba hydroelectric power plants have a combined power output of 1350 mw with a work force of over 3000. Natural gas is a nontoxic, clean source of energy, having a high calorific value and proven to be a more attractive alternative in the energy sector and contributes over 60% of the total output of the national grid.

Keyword: Natural Gas, Associated Gas, Non-Associated Gas, Power, Reforms.

1 Introduction

Energy has a major impact on every aspect of our socio-economic life. It plays a vital role in the economic, social and political development of our nation. Inadequate supply of energy restricts socio-economic activities, limits economic growth and adversely affects the quality of life. Improvements in standards of living are manifested in increased food production, increased industrial output, the provision of efficient transportation, adequate shelter, healthcare and other human services. These will require increased energy consumption. Thus, our future energy requirements will continue to grow with increase in living standards, industrialization and a host of other socio-economic factors (Babanyara and Saleh, 2010).

As the very basis of development, energy use is closely related to the level of productivity in the industry, commerce, agriculture and even in

office activities. Energy consumption per capita is one of the indicators or benchmarks for measuring the standard of living of a people or nation. The unprecedented use of energy which began with the industrial revolution certainly brought about massive increase in productivity and change in lifestyle. Since then energy demand has been in the increase- to produce more products, travel further and faster or to be more comfortable. Physically, energy is defined as the capacity for doing work. The capacities of energy to do work are inherent properties of energy carriers. Although energy cannot be created nor destroyed according to classical thermodynamics, its capacity for doing work can be degraded and destroyed due to system irreversibility in line with the logic of the second law of thermodynamics (Bajaj and Sharma, 2006).

Some of the common energy carriers or sources are coal, petroleum, natural gas, nuclear fuels, biomass. Of all these, the most widely used energy sources are the hydrocarbon

compounds or fossil fuels which account for more than 80% of global primary energy consumption ^[3]. For instance, fossil energies provide about 67% of the energy needed to produce electricity - a veritable and the most terminal form of energy for transmission and distribution for industrial production processes ^[4]. Energy usage has become an important concern in the past years and there has been growth awareness and an increase in taking personal responsibilities in preventing environmental pollution by minimizing energy waste. Energy has been the key to economic development worldwide, but in the way it is sourced, produced and used, two major drawbacks have emerged. First, the overall energy system has been very inefficient. And second, major environmental and social problems, both local and global, have been associated with the energy system ^[5]. Climate change and environmental externalities associated with energy consumption have become a major international issue. It has been observed that among the various sectors contributing to greenhouse gas (GHG) emissions, industrial sector contribution was significant; thus, mitigating GHG emissions from the sector offers one of the best ways of confronting the climate change problem. Energy efficiency is a major key in this regard. An estimated 10-30% reduction can be achieved at little or no cost by improving efficiency of energy use in the industry ^[6].

Although Nigeria is relatively endowed with abundant fossil fuels and other renewable energy sources, the energy situation in the country is yet to be structured and managed in such a way as to ensure sustainable energy development, most especially in the industrial sector. Nigeria as a nation is passing through a serious energy crisis and it has been even more affected not by a lack of energy resources, but

largely due to poor resource and financial management, a crippling dependence on imports particularly second-hand goods built with out-dated, inefficient technology etc ^[7]. As a nation that has limited technological capacity but sees industrialization as constituting a crucial leverage and pre-condition for meaningful development, Nigeria should be wise enough to manage her scarce energy resources judiciously.

The use of energy pervades every aspect of modern society but it is not efficiently used in many industries. In view of the fact that there is an incessant increase in fuel costs, energy efficiency studies are thus rapidly becoming more important. Several millions of dollars can be saved in accumulated energy cost when energy is properly managed. Based on this fact, several researchers have reported on the energy consumption, conservation potential and environmental impact of energy use of different industrial process operations both within and outside Nigeria. Nagesha ^[8] presented the energy consumption pattern in a textile dyeing industrial cluster and environmental implications in terms of emission of GHGs due to energy use. The study identified substantial scope for energy efficiency and analysed energy consumption in the cluster from an economic perspective. All the economic performance indicators adopted in the study seemed to have significant association with energy efficiency in the cluster. Also, it was observed that the small-scale industries which are energy efficient performed better on the economic front and experienced 'higher returns to scale'. The study concluded that the firms in the energy intensive product clusters must aim at enhancing their energy efficiency as it leads to multiple benefits and ensures sustainable development in the long run. Fawkes, investigated energy efficiency in South African Industry. This study showed

that strong incentives exist for energy efficiency improvement in South African industry, in particular, the potential for increasing profit, the need to reduce greenhouse gas (GHG) emissions, the need to maintain economic competitiveness, and the need to delay the cost of new peak-load electricity generation facilities. In their study, Lung et al, investigated the impacts that several emerging technologies have had in the U.S food processing industry. This paper assessed the energy efficiency potential for four of these technologies in the U.S. food processing industry. Based on the assessments of these four emerging and newly commercialized technologies, the potential for energy savings in the U.S. food industry is quite strong. In addition, these technologies have yielded important productivity and other benefits. Depending on the available market portions in which these technologies can be implemented, sector-wide energy savings could range from 1572 GJ and 134 million kWh to 2342 GJ and 186 million kWh. In addition, non-energy benefits such as improved product quality, better production and reduced greenhouse gas emissions are likely. To assessed the energy efficiency in Nigerian Eagle Flour Mills Limited, Ibadan. The study which is limited based on the available years of data collected (1996-2000) analyzed the energy consumption, productivity and efficiency of the company. The results of the study showed that energy is not quite efficiently utilized in this industry because the energy productivity increased substantially from 0.369 MJkg⁻¹ in 1996 to 0.716 MJkg⁻¹ in the year 2000. An average of 47,810.59 GJ of energy was consumed annually within this period with 44.68%, 0.23%, 42.16% and 12.93% of this energy accruing from electricity, lubricants, diesel and petrol, respectively. The average energy productivity, the average intensity of energy and the average cost of energy input per

unit kg are 0.527 MJkg⁻¹, 1.084 GJm⁻² and 28 kobo/kg, respectively. The average value of the normalized performance indicator (NPI) obtained is 0.199 GJm⁻² which indicates substantial energy consumption for the building type. The areas where the industry uses and wastes energy, and where actions for energy conservation can be implemented were identified.

Aderemi, et al, examined the pattern of energy consumption in selected food companies in South-western Nigeria; identified the sources of electrical energy waste and assessed the effectiveness of the strategies for electrical energy savings in the industry. Four sub-sectors of food and drinks industry in the category of Small and Medium Enterprises were examined. They include; beverage, bakery and confectionery, grain mills and storage of cold food products. The study revealed that the pattern of electrical energy consumption in the food companies was mainly from generating set; this was due to either low voltage or epileptic power supply from national grid. Also, the study identified 12 direct sources that lead to electrical energy waste and inefficient energy utilization in the food industry. One of these, among others was the energy loss as a result of worn out or slack / misaligned belts that needed timely replacement or tensioning. Other indirect sources identified include lack of training and retraining of staff, power factor of electrical equipment, and equipment age, among others. A study carried out a comprehensive energy audit of Vitamalt Nigeria Plc, Agbara using portable thermal and electrical instruments with the objective of studying the pattern of energy consumption and identifying the possibilities of saving energy in the plant. A five-year (2000-2004) data on energy consumption of Vitamalt Nigeria Plc was collected and analysed. The study showed that

the Normalized performance indicator (NPI) calculated over the span of five years gave an average of 1.2 GJ/m² indicating a fair range in energy performance level classification (1.0 - 1.2) while significant savings and improvement in energy usage is achievable. The authors concluded that maximizing efficiency of existing system, optimizing energy input requirement and significant capital investment in procuring new energy conserving equipment must be made for the energy performance level to fall into a good range classification (less than 0.8).

The increasing role of energy efficiency as a catalyst for sustainable industrial development is realism in the industrialized countries of the world. In Nigeria the story is different at the moment as the huge benefits derivable from adoption of energy efficiency and conservation measures by industries remain largely untapped due largely to lack of awareness of the economic and social benefits of energy efficiency measures. This, in addition to high incidence of power outages resulting to large scale use of own power generation and lack of investment capital have given rise to high specific energy content of goods produced by industries in Nigeria. The cumulative effect is loss of competitive edge in the global market by these industries and low after- tax returns. This constitutes a major disincentive to investment and sustainable industrial growth. As a matter of utmost importance, industries in Nigeria should take advantage of opportunities in low level, low risk but high worth energy efficient measures that reduces the bottom line of any business enterprise. In so doing, a lead time will be created to pursue high-tech driven production processes that will find support at maturity in an already established energy efficient culture.

As earlier presented of the previous works on energy efficiency in Nigerian industries, none of

these researchers discussed possible ways of achieving sustainable development in Nigeria in perspective of effective utilization of energy in manufacturing industries in the country. Therefore, the prime objectives of this paper are (i) to review energy consumption pattern in Nigeria (ii) to explore the potential sources to increase energy efficiency in industrial sector in Nigeria and (iii) to explore the role of industrial energy use in achieving sustainable development in Nigeria.

Energy Situation in Nigeria

Nigeria has an abundant supply of natural energy sources, both fossil and renewable. Energy plays a double role in Nigeria's economy: as an input into all economic activities and as the mainstay of Nigeria's foreign exchange earnings through the export of crude oil and, more recently, from increasing natural gas exports. Nigeria's economy is heavily dependent on the oil sector and now on gas too, since both together account for 90-95% of export revenues, over 90% of foreign exchange earnings and nearly 80% of government revenues. The majority of Nigeria's exports of crude are destined for markets in the United States and Western Europe with Asia becoming an increasingly important market of late.

The National energy is at present almost entirely dependent on fossil fuels and firewood which are depleting fast. According to Chendo, recent estimates indicated that the reserve for crude oil stood at about 23 billion barrels in 1998, natural gas 4293 billion m³ at the beginning of 1999, made up of 53% associated gas and 47% non-associated gas. Coal and lignite stood at 2.7 billion tones, Tar sands at 31 billion barrels of oil equivalent and large-scale hydropower at 10,000 MW. Table 1 show various conventional and non-conventional energy sources and their estimated reserves in Nigeria.

Table 1. Nigeria's conventional energy resources

Resources	Reserve	Resources in Energy units (billion tonnes)	%Total conventional energy
Crude oil	23 billion barrels	3.128	21.0
Natural gas	4293 billion m ³	3.679	24.8
Coal and lignite	2.7 billion tonnes	1.882	12.7
Tar sands	31 billion barrels of Oil equivalent	4.216	28.4
Hydropower	10, 000MW	1.954(100yrs)	13.1
Total	Conventional/Commercial Energy resources	14.859	100%

Source: Bureau of statistic

Reviewed Methodology

Availability of reliable power supply with considerable access to electricity is going to be the major benchmark for evaluating the performance of the power sectors in the two countries. The performance of the reforms and policies in India and Nigeria are examined according to:

- i) The renewable and renewable energy sources. These sources include fossil fuels (Coal, oil and natural gas), hydro, solar and wind.
- ii) Power generation capacities. This refers to the total power generation capacity of the two countries
- iii) Power transmission capacities and losses. Transmission and distribution (T&D) losses are estimated from the discrepancy between power produced and power sold to the customers assuming no theft of utility occurs.
- iv) Electric power consumption (kWh per capita). This measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants (World Bank, 2011).
- v) Energy efficiency and renewable energy policies. These are policies that promote energy management and effective use of renewable energy sources like solar, wind and biomass.
- vi) Energy sustainability index. Energy

sustainability index published by the World Energy Council compares energy sustainability policies and prospects in many countries. The Index ranks countries according to their capability to provide sustainable energy policies using 3 dimensions of energy dilemma:

Energy security: refers to the effective management of primary energy supply, the ability of participating energy companies to meet current and future demand and the reliability of energy infrastructure

Energy equity: deals with accessibility and affordability of energy supply in the country.

Environmental sustainability: is concerned with the development of energy supply from renewable sources and the achievement of supply and demand-side energy efficiencies.

Countries are awarded a balance score which ranges from A – D for the three competing dimensions of energy dilemma. The balance score demonstrates how well a country manages the trade-offs between the three dimensions. Countries that perform high receive the score AAA while those that do not perform well receive a DDD score.

Performance Analysis

Sources of power generation

India on the other hand has been reported to have 5.48 billion barrels of proven crude oil and

43.8 trillion cubic feet of natural gas reserves at the end of 2012. The country's western offshore holds majority of the reserves and the remaining are in the eastern regions of the country. It was the third largest producer of coal in the world in 2011 and holds the fifth largest coal reserves estimated to be 60.6 billion tons in the world (WEC, 2013). India's deposits of hard coal are located in the eastern part of the country. Eastern states of Chhattisgarh, Jharkhand and Orissa together account for about 64% of India's total coal reserves (EIA, 2014).

The north and north-eastern states of the country are rich in hydropower resources with significant river systems which benefit from energy surpluses in the monsoon period helping the country attain its targets in renewable energy generation (Raj and Ram, 2012). Himalayan rivers, Himachal Pradesh, Jammu and Kashmir and Uttarakhand hold 65 percent of India's small hydropower resources with lowest generation costs.

Large hydro power potential in India is estimated at 148 GW but only about 40 GW out of the total potential capacity has so far been utilized for power generation in the country (Purohit et al. 2013). Similarly, Nigeria, which has tropical climate is blessed with considerable reserves of fossil fuels more especially crude oil and natural gas. According to the US Energy Information Administration, Nigeria is the largest oil and natural gas producer in Africa. It is the ninth largest reserves holder of natural gas in the world and holds the largest natural gas reserves in Africa (WEC, 2013). The country also has abundant renewable energy sources like hydro, wind, solar and biomass mostly found in the northern part of the country. There are over 278 unexploited small hydro sites with total potentials of 3,500 MW but so far less than 30 MW has been utilized (Shaaban and Petirin, 2014).

Table 2. Fossil fuel reserves in India and Nigeria in 2011

Resource type	Total (Global)	India	Nigeria
Crude oil (Million tons)	179,682	0.4%	2.8%
Natural gas (Mtoe)	209,741	0.5%	2.4%
Coal (Mtoe)	891,530	6.8%	0.02%

Sources World Energy

India has good solar radiation within a range of 4 - 7 kWh/m²/day with 250-300 sunny days in a year and an annual average wind speed of 3 – 6 m/s. Nigeria also has solar radiation with a range of 2 – 7 kWh/m²/day and an annual average wind speed of 2 – 4 m/s (Agbetuyiet al. 2012)

4.2 Power generation capacities Power generation using fossil fuels is growing rapidly in India, primarily due to the government's efforts to improve the power supply to meet the growing demand. India is witnessing a

remarkable growth in its power

generation sector due to effective government policies like the Mega Power Policy, Electricity Act 2003, National tariff policy 2006, National Rural Electrification Policies 2006 and the feed-in tariffs policy. The most successful policy that hugely transformed the Indian power sector is the Electricity Act 2003 (Sharma et al. 2013). The most conspicuous features of the Electricity Act 2003 are as follows (Singh and Srivastava, 2004):

Assigned SERCs and CERC as being responsible for licensing, tariff setting, grid rules and access rules

Techno-economic clearance and state licensing for generating stations were abolished,

Provided open access to transmission networks by all distribution companies without any discrimination

Contributed to transparent power trading and creation of a spot market

Called for gradual reduction of subsidies by the government

Stipulated mandatory metering for all consumers to enhance accountability

Provided special provisions for economically weaker people and promoted access to electricity in rural communities

Had provisions for transition from a government-owned monopoly to a privately-owned and competitive industry

Created an efficient and dependable national transmission grid for optimum scheduling and dispatch of electricity among the regional transmission grids. The private sector is encouraged to participate meaningfully in the Indian power sector after the enactment of the Electricity Act 2003. Percentage contribution of the various sectors in hydro power generation in India is shown in Figure 1.

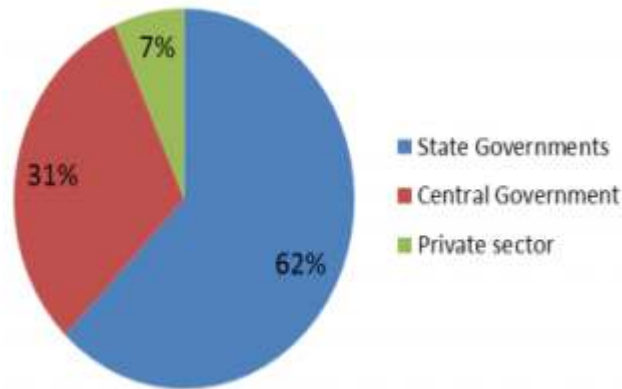


Figure 1. Sector wise installed hydro capacity in India (Sharma et al. 2013)

Figure 1 indicates that state governments in India have the largest share of installed hydro generation capacity compared to both the central government and the private sector. The mega power policy is also having great

impact in the Indian thermal generation sector as it encourages the private sector participation in the construction of mega power plants. In 2014 thermal power contributed 163.3 GW out of the 237 GW total generation capacity in India.

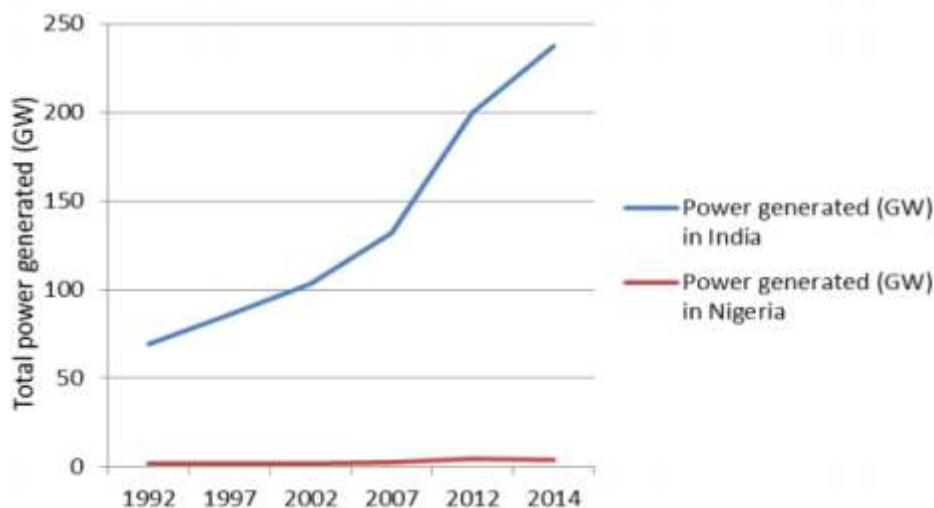


Figure 2. Growth of power generation sectors in India and Nigeria.

Figure 2 indicates that the Indian generation sector witnessed a surge in capacity from 2003 to 2014 with more pronounced growth recorded between 2007 and 2012. Nigeria on the hand witnessed very little additional capacity between 1992 and 2014. The highest peak power generated in the country was 4.5 GW in December 2012. Existing thermal power plants in Nigeria contributed about 72% of the total 3.7 GW of electricity generated in 2014 (MOP, 2014). Despite contributing the highest share in the generation mix, majority of thermal plants in Nigeria operate below 50% of their installed capacity (Aliyu et al. 2013).

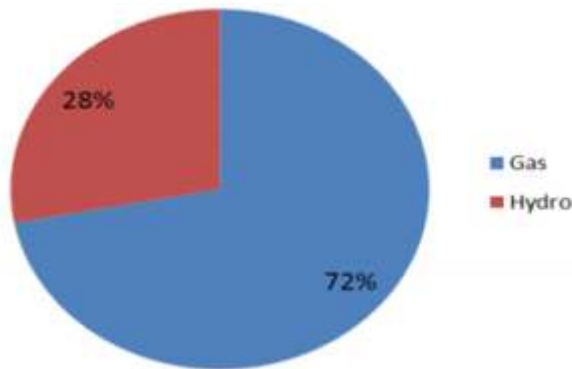


Figure 3. Power Generation mix for Nigeria 2014

Figure 3 indicates that thermal power plants contribute about 72% of the total power generated. The three existing hydroelectric dams in the country (Kainji, Shiroro and Jebba) contributed the remaining 28% of the power generated to the national grid during the same period. Currently there is no grid connected renewable energy generating plant in Nigeria despite the abundant renewable energy sources in the country. The 10 MW Katsina wind farm which is the first renewable energy generating plant initiated by the government in 2009 (Oji et al. 2012). The 10 MW wind farm is still not completed due to inadequate funding by the government.

4.3 Power transmission capacities and losses.

Transmission lines in India are divided into 765 kV lines which have a total length of 32,250 km, 400 kV with 144,819 km and 220 kV transmission lines having a total length of 170,980 km. The country's transmission and distribution (T & D) losses vary from state to state with some states having losses as high as

33% while others have losses around 25%. The average T & D losses in the country currently stand at 23.6% (CEA, 2013).

On the other hand high voltage transmission lines in Nigeria are made up of 132 kV and 330 kV transmission lines. The 330 kV lines have a total length of 5,650 km while the 132 kV lines have 6,687 km making a total of 12,337 km (NDPHC, 2014). Nigeria's T & D losses were rated as one of the highest in Africa with losses reaching up to 35% in 2013 due to the poor state of the power sector (Shaaban and Petirin, 2014).

4.4 Electric power consumption (kWh per capita)

This measures the average electricity use per capita in a country for a specified period which is usually one year. The electricity consumption per capita in India and Nigeria for 2011 is shown in Table 4.

Table 4 Electricity consumption per capita for India and Nigeria

Country	Electric power consumption per capita (kWh/year)
India	684
Nigeria	149

Source: (World Bank, 2013)

Nigeria's electricity consumption per capita in Table 4 implies that its population does not have access to reliable electricity supply. The country's electricity consumption per capita is one of the lowest in the world.

4.5 Energy efficiency and renewable energy policies

Energy efficiency policies and laws are adopted as a means to improve power sector performance. Table 5 below lists the energy efficiency policies in India and Nigeria. These laws and policies are necessary in order to minimize greenhouse gas emissions and improve the reliability of electricity supply. Table 5 Energy efficiency policies and laws in India and Nigeria (WEC, 2014)

Table 5. Energy policies in India and Nigeria

Energy efficiency policies and programs	India	Nigeria
National energy agency	●	✖
Ministry or department for energy efficiency	●	✖
Local/regional energy agencies	● ₁	✖ ₂
Dedicated energy efficiency fund	●	✖
Energy efficiency law	●	✖
Energy efficiency law with targets	✖	✖
● - Available ✖ - Not available		

Table 5 indicates that India has more energy efficiency policies and laws compared to Nigeria. The Indian government also established the national mission on enhanced energy efficiency as an initiative aimed at addressing national problems of inefficient energy use. The mission introduced an innovative mechanism called "Perform, Achieve

and Trade" (PAT) mechanism which assigns energy efficiency improvement targets to India's most energy intensive industries (WEC, 2014). Despite having more challenges in its power sector, Nigeria still lags behind India in the promotion and implementation of energy efficiency policies to manage the little power produced.

Table 6 Comparison of Energy trilemma scores of India and Nigeria (WEC, 2014)

Country	Energy Security	Energy equity	Environmental sustainability	Score
India	C	D	D	CDD
Nigeria	A	D	C	ADC

Table 6 indicates that Nigeria performs better in energy security and environmental sustainability due to higher natural gas reserves and lower carbon emission from its power generation sector compared India. Nigeria's weakest performance is in the energy equity which is largely due to its inability to provide reliable power supply to majority of its population. Nigeria ranked 81st in the 2014 global ranking for dilemma index and balanced scores. While India's lowest performance comes from the energy equity and environmental sustainability dimensions which eventually placed it in 122nd position in the 2014 global ranking for trilemma index and balanced scores (WEC, 2014).

Conclusion

Nigerians have been experiencing chronic power shortages despite several reforms implemented by the government. The challenges experienced before the enactment of the ESPR Act 2005 still exist in the power sector despite the huge investments and

reforms implemented to improve the performance of the sector. The average power generated by all the country's power plants was about 3.7 GW in 2014 which is grossly inadequate for Nigeria's population of about 177 million. Major factors that inhibit the development of Nigerian power sector are inconsistency in the implementation of government policies and corruption. On the other hand, India's power sector witnessed massive transformation after the enactment of the Electricity Act 2003. The Electricity Act opened up the generation and the distribution sectors for private sector participation. The mega power policy and the renewable energy policies like the feed-in tariffs have contributed immensely to the growth and development of the Indian power sector. The country's generation capacity was about 100 GW in 2002 which rapidly rose to about 237 GW in 2014. Although its transmission sector is also witnessing remarkable improvements with the adoption of higher transmission voltages up to 765 kV, still its transmission and distribution losses are among the highest in the world. The

country has been taking drastic measures to curb the inefficiencies in the in its power sector by promoting renewable energy generation and energy efficiency policies and laws like the "perform, achieve and trade" mechanism.

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Optimum Conditions for the Enrichment of Yandoton-Daji Gold Ore, Zamfara State, North Western Nigeria.

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Abstract

This research dealt with the enrichment of Yandoton-Daji gold ore. The ore was collected from Bayan Banki Village in Yandoton-Daji, Zamfara State. The optimum criteria for concentration of Yandoton-Daji gold ore was carried using panning method. Three criteria were varied to determine the optimum conditions: particle size, pulp density and swirling time. At 125 μ m, the highest grade was obtained after five runs conducted using various particle sizes. The best pulp density for the panning of the gold ore was found be 20% solid by weight and posted a good grade-recovery combination. The swirling time for the panning process of the gold ore was found to be 20 minutes and has the best grade-recovery combination.

Keywords: Enrichment, Gold ore, gravity separation, optimum conditions.

1.0 Introduction

Nigeria is blessed with variety of minerals, which its occurrence is spread across the country. Okunlola, (2017), reported that, the official current Nigeria's minerals endowment is about forty-four (44) different minerals found in commercial quantities in four hundred and fifty (450) different locations across the country. Nigeria's mineral endowment consist of three broad categories of mineral resources which comprises of high-value commodities like gold, bulk commodities like iron ore and tin, and gemstones (NEITI, 2019). Within the minerals, Government has highlighted a few strategic minerals that have the potential to contribute significantly to the economic development. These include barite, gold, bitumen, iron ore, lead/zinc, coal and limestone (Roadmap MMSD, 2016).

Gold is a chemical element with symbol Au and atomic number of 79. Gold is a dense mineral, soft, shiny, malleable and ductile metal. Pure gold has a bright yellow colour and lustre. According to tradition, it is regarded attractive and does not oxidize in air or water when kept in good condition (Yannopoulos, 2017).

Gold is the element generally accepted by man as a metal. Ancient Egypt was the main gold producing country and maintained that position until 1500 BC. Gold is a metal, which has been valued for a very long time because of its colour,

its occurrence in the native state, and its non-tarnishing properties (Robert *et al*, 2013). Gold has high thermal and electrical conductivities with natural isotope of ¹⁹⁷Au (Yannopoulos, 2017).

The average concentration of gold in the earth's crust is 0.004 g/tonne. A gold deposit becomes interesting for economic exploitation with grades usually above 0.2 g/tonne (Wills, 2006). A rich deposit has gold grades above 10 g/tonne. Gold usually occurs in low concentration and as very fine particles in the earth crust sometimes as fine as 0.001mm. For these reasons, gold ore extracted from the earth crust is very difficult to concentrate. According to Wills, (2006) the purpose of mineral processing is to increase the economic value of an ore. Therefore, it is technologically imperative to process any gold material to increase its economic value.

Gold generally occurs in minute amounts which require large bulk samples to be collected for size analysis especially during percentage weight determination of coarse gold grains. Different physical methods of separation are used for gold concentration most commonly gravity separation (British Geological Survey, 1997).

Gravity separation depends on the difference in specific gravities of minerals. It is one of the oldest techniques for separating minerals. The method does not require much capital and

operating cost. It does not require any chemical or excessive heating during processing, therefore it is environmentally friendly (Falconer, 2003). Gravity separation operations are characterized by processes that allow particles to be held slightly apart so that they can move relative to each other and therefore to separate into layers of dense and light minerals. The mechanism by which this inter-particle spacing is accomplished may be used as a convenient means of classifying gravity concentrators. These concentrators include jigs, shaking table concentrators, heavy media separators, gold pans, spirals, sluices and cyclones (Gupta and Yan, 2006).

Most of the equipment described above have been used for centuries. Many variations of the basic designs have been used throughout the years. Some are more efficient than others. Most have low capacity and do not efficiently recover fine gold. Only the most useful, simple, inexpensive, or easily constructed of these old but practical devices are described.

Gold Pan perhaps the oldest and most widely used gold concentrator is the gold pan. Although available in various shapes and sizes, the standard American gold pan is 15 to 18 inches in diameter at the top and 2 to 2.5 inches in depth, with the sides sloping 30-45 degrees. Gold pans are constructed of metal or plastic and are used in prospecting for gold, for cleaning gold-bearing concentrates, and rarely, for hand working of rich, isolated deposits.

A gold pan concentrates heavy minerals at the bottom while lighter materials are removed at the top. The basic operation of a pan is simple, but experience and skill are needed to process large amounts of material and achieve maximum recovery.

2.0 Materials and Methods

2.1 Sample ore collection and Preparation

Representative samples were obtained from various points around the study area; Bayan Banki Village, Yandoton-Daji, Tsafe Local Government Area of Zamfara State. 500kg of the ore was obtained from five pits along the gold bearing veins, at a depth of about 2m. The sample was collected with the assistance of

Nigerian Geological Survey Agency (NGSA) using GPS at an interval of 20m apart to be able to have a good representative. The collected samples were stored in the sampling bags. Further sampling was carried out using Chute riffle sample division process to adequately obtain a reasonable representative portion for the enrichment process.

2.2. Enrichment of Yandoton-Daji Gold Ore

The ground ore sample was mixed thoroughly with water to form a pulp of 40% solid/water ratio. The concentration of Yandoton-Daji ore to obtain an enriched portion by gravity concentration using panning was carried out using five (5) different particle sizes of 250 μm , 180 μm , 125 μm , 75 μm and 45 μm of the ore respectively. The particle size of the ore was considered as one of the parameters for optimization of the process. Other parameters considered for the optimization involve pulp density that is solid/water ratio of the ore and time of swirling of the ore in the pan when immersed in water for 10 minutes, 15 minutes and 20 minutes. The pan is a light circular dish with a flat bottom and sides that slope out at about 45°.

200g of the ore was subjected to panning to upgrade the ore (100g of ore was supposed to be used for the process as dictated by Gy estimation formula but the process can be done in multiples of hundreds). The pan was first filled halfway with the ground ore material. The pan was then immersed in water and the mixture was thoroughly wetted and stirred. The pan still under the water was swirled gently (combination of shaking and gyration). This allows the heavy particles to settle and the lighter material are brought to the surface. At intervals the pan was tilted and the light surface material is washed off. This process continued until only heavy materials (gold and other heavy minerals) remain in the pan. The panning process requires a lot of patience because it is a slow and tedious process. The collected products that is, the concentrate and tailing were dried in the oven at 105°C.

The operational conditions for the optimized enrichment of Yandoton-Daji ore is given in Table 1

Table 1: Operational conditions for the optimized concentration of Yandoton-Daji Ore

S/No.	Parameter	Test Condition
1.	Particle Size (Nominal) μm	250, 180, 125, 75 and 45
2.	Pulp Density (%)	10, 20 and 30
3.	Swirling Time (minutes)	10, 15 and 20

2.3. Assay of the Concentration

After the concentration, the various concentrates and tailings were analysed to establish the grade (assay value) of the gravity concentration products i.e. (concentrates and tailings). This gave the percentage metal content (percentage gold) in the various products. The entire success of the separation depends on the percentage metal recovered. The fundamental target was to satisfy both the technical and economic objectives; whereas technically the concentrates should meet up with the moisture content, assay-grade and minimum impurities, economically is to concentrate ores using the best combination of unit operations that will give the optimum possible profit margin.

3.0. Results and Discussions

3.1. Enrichment of Yandoton-Daji Gold Ore

Gravity concentration method was carried out on Yandoton-Daji ore to enrich the gold content in the ore thereby reducing the amount of impurities. The concentration method relies on the high density of gold relative to other minerals. Gold has a very high density that is why it is easily separated from other associated lighter mineral particles with gravity method of concentration. According Stamboliadis *et al*, (2002) reported that gold metal can be recovered by gravity concentration which can be attained at relatively lower sizes (250 μm , - 10 μm).

The ore was subjected to panning method of gravity concentration test. This involved set of runs that tested the effects of three criteria in the upgrading of Yandoton-Daji gold ore involving particle size at five levels of significance, pulp density and swirling time at three levels of significance. The results of the experiments showing the gravity concentration products

were presented in tables, showing weights of the concentrates and tailings, the metal assay values in concentrates and tailings and the metal recovery. Ratios of concentration and enrichment ratios were carried out to compliment grade and recovery in establishing the effectiveness and efficiency of the process.

(i) Effect of Particle Size on Gravity Concentration of Yandoton-Daji Ore

The sluice concentrate was subjected to sieve analysis using 250, 180, 125, 75 and 45 μm sieves. The resultant sieve fractions were subjected to panning to upgrade the value of gold in the ore. The result of the experiment showing the assay of the concentration products of the five particle sizes on gravity concentration were presented in Table 2.

Table 2 showed the result of the assay of concentration products of Yandoton-Daji gold ore. From the analysis it was observed that the particle size of 125 μm concentrate has the highest percentage composition of 3.68%Au, followed by the concentrate of 75 μm particle size which has a percentage composition of 1.87%Au, 45 μm particle size concentrate has a percentage composition of 0.91%Au and the least is the concentrate of 180 μm size which has a percentage composition of 0.13%Au. The 250 μm has a trace amount of gold. The percentage composition of gold in the tailings of all sieve sizes is in traces. Therefore, the highest assay value on the concentrate was obtained on 125 μm size which supported the earlier determination made on liberation size of Yandoton-Daji ore at 125 μm . Abdul-Rahman, (2010) stated that ores with fine gold are easily concentrated by gravity concentration. He also reported that combination of the different types of gravity concentration methods improve the metallurgical efficiency of the process.

The efficiency of the concentration process for the five different sizes of the ore was calculated. This involves recoveries, ratios of concentration and enrichment ratios. The results are shown on Table 3.

Table 3 showed the recoveries, ratios of concentration and enrichment ratios of gravity concentration process of Yandoton-Daji ore using panning method. The concentration was

Table 2: Assay of Concentration Products at Various Particle Size

S/N	Elements	250 μm		180 μm		125 μm		75 μm		45 μm	
		C	T	C	T	C	T	C	T	C	T
1	Si	30.36	38.86	31.27	38.93	29.49	36.80	28.92	38.53	28.45	43.42
2	V	0.93	0.00	1.01	0.00	0.18	0.00	7.20	0.00	2.61	0.00
3	Cr	4.05	0.00	5.87	0.00	6.21	0.00	3.10	0.00	5.03	0.00
4	Mn	10.06	0.06	3.11	0.03	2.33	0.08	8.66	0.00	6.94	0.01
5	Fe	9.05	10.38	10.10	11.28	9.20	18.02	1.03	10.03	7.05	1.25
6	Co	1.58	3.42	1.81	2.33	2.01	0.11	2.33	4.66	3.11	10.11
7	Ni	0.88	0.00	1.23	0.00	1.98	0.00	1.83	0.01	3.69	0.04
8	Cu	2.35	1.08	2.38	2.05	4.38	1.01	3.06	0.06	1.25	1.85
9	Nb	1.02	0.19	0.01	1.05	0.03	0.23	0.06	0.88	1.03	1.10
10	Mo	0.01	0.00	0.00	0.04	0.01	0.00	0.02	0.01	0.01	0.08
11	W	0.00	2.04	0.00	2.24	0.00	0.27	0.01	1.22	0.03	1.98
12	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Ca	0.55	2.33	1.20	1.53	0.97	0.01	1.06	0.05	0.01	0.93
15	Mg	0.05	2.12	0.00	1.24	0.00	0.41	0.03	1.06	0.96	2.00
16	K	0.00	0.01	0.00	0.03	0.00	0.01	0.00	0.93	0.06	2.06
17	Ba	3.88	0.81	2.22	0.68	3.22	0.50	4.13	1.02	0.00	0.64
18	Al	5.21	22.60	6.30	21.15	5.49	24.08	3.88	22.12	5.66	19.58
19	Ta	1.86	0.55	0.91	0.31	0.24	0.19	2.11	2.11	2.98	0.63
20	Ti	0.99	11.11	10.31	12.66	0.52	14.17	1.36	11.10	0.94	11.21
21	Zn	10.21	0.93	6.81	1.25	12.26	4.11	9.02	6.21	10.01	0.00
22	Ag	3.08	0.00	7.60	0.00	6.22	0.00	5.81	0.00	4.58	0.00
23	Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Zr	7.43	0.05	0.23	0.00	4.54	0.00	5.11	0.00	6.03	0.00
25	Sn	6.45	3.46	4.56	3.20	7.04	0.00	7.18	1.11	8.66	3.11
26	Au	0.00	0.00	0.13	0.00	3.68	0.00	1.87	0.00	0.91	0.00

conducted on five different sieve sizes. The 250 μm size has a 0% recovery and zero enrichment ratios since the assay value of the concentrate and tailing is zero, the 125 μm particle size has the highest assay level and has the highest gold metal recovery of 81.58%. The ratio of

concentration during the enrichment process was calculated as 8.51 which showed that the process is good for the concentration of the ore at a size of 125 μm and so also the enrichment ratio calculated as 6.94. The gold recovery of 81.58% means that the 81.58% of gold originally in the

Table 3: Panning test results at various particle sizes

Sieve size (Nominal) (μm)	Feed		Products				Recovery %	Ratio of Conc. F/C	Enrichment ratio c/f
	Wt (g)	Au %	Conc.		Tailings				
			Wt (g)	Au %	Wt (g)	Au %			
250	200	0.53	53.67	0.00	146.33	0.00	0	3.72	0
180	200	0.53	40.24	0.13	159.76	0.00	4.78	4.97	0.238
125	200	0.53	23.5	3.68	176.5	0.00	81.58	8.5	6.94
75	200	0.53	33.67	1.87	166.33	0.00	59.40	5.94	3.54
45	200	0.53	18.25	0.91	181.75	0.00	15.67	10.96	1.72

ore is in the concentrate and the remaining 18.42% of gold in the tailing and middling.

(ii) Effects of Pulp Density on Gravity Concentration of Yandoton-Daji Ore

The gravity concentration of the gold ore was carried out using panning by preparing slurry

containing three different pulp densities of about 10, 20 and 30% solids by weight at a constant particle size range of -180+125 μm . The results of the assay of the products of concentration are presented in Table 4.

Table 4: Assay of Concentration Products at Various Pulp Densities

S/No	Elements	Pulp ρ_1		Pulp ρ_2		Pulp ρ_3	
		Concentrate (%)	Tailing (%)	Concentrate (%)	Tailing (%)	Concentrate (%)	Tailing (%)
1	Si	28.12	38.41	28.78	37.27	27.42	34.77
2	V	0.31	0.00	0.24	0.00	0.60	0.00
3	Cr	5.46	0.00	3.88	0.00	5.08	0.00
4	Mn	1.78	1.05	1.68	1.15	3.11	0.10
5	Fe	5.21	8.28	9.61	16.55	4.21	15.75
6	Co	2.16	0.25	10.02	0.43	1.85	0.33
7	Ni	1.66	0.00	2.08	0.03	2.35	0.00
8	Cu	5.20	1.45	4.75	2.11	5.71	2.03
9	Nb	0.04	0.19	0.04	0.16	0.01	0.41
10	Mo	0.02	0.00	0.03	0.00	0.03	0.00
11	W	0.00	0.36	0.00	0.53	0.00	0.31
12	P	0.00	0.00	0.00	0.00	0.00	0.00
13	S	0.00	0.00	0.00	0.00	0.00	0.00
14	Ca	1.04	0.00	1.10	0.00	0.68	0.02
15	Mg	0.00	0.66	0.00	0.25	0.00	0.61
16	K	0.00	0.00	0.00	0.00	0.00	0.03
17	Ba	4.11	0.75	3.50	0.08	4.11	0.75
18	Al	6.60	23.56	4.38	25.11	6.23	22.58
19	Ta	0.34	2.11	0.74	0.23	1.21	1.21
20	Ti	0.75	16.06	1.72	12.28	0.51	16.71
21	Zn	11.38	4.75	10.75	3.05	13.76	4.25
22	Ag	7.11	0.01	5.71	0.01	6.56	0.00
23	Cl	0.00	0.00	0.00	0.00	0.00	0.00
24	Zr	6.71	0.00	4.21	0.65	5.66	0.06
25	Sn	8.65	2.11	6.30	0.11	7.70	0.08
26	Au	3.35	0.00	3.51	0.00	3.21	0.00

Table 4 presented the result of the assay of concentration products of Yandoton-Daji gold ore at various pulp densities and constant feed size of -180+125 μm . From the analysis it was observed that the second slurry containing a pulp density of 20% solid by weight concentrate has the highest percentage composition of 3.51%Au, followed by the concentrate of 10%

solid by weight slurry which has a percentage composition of 3.21%Au. The assay of gold in the tailing is in traces.

The efficiency of the concentration process at various pulp densities and constant size of the ore was calculated. This involves recoveries, ratios of concentration and enrichment ratios. The results are shown on Table 5.

Table 5: Panning test result at various pulp densities

Pulp Density (%)	Feed		Products				Recovery %	Ratio of Concentration F/C	Enrichment ratio c/f
	Wt (g)	Au %	Concentrates Wt (g)	Au %	Tailings Wt (g)	Au %			
10	200	0.53	31.32	3.35	168.68	0.00	99	6.39	6.32
20	200	0.53	29.19	3.51	170.81	0.00	97	6.85	6.62
30	200	0.53	31.41	3.21	168.59	0.00	95	6.37	6.06

Table 5 was a panning test result conducted by varying the pulp densities as 10, 20, and 30% solids by weight respectively. The particle size of -180+125 μm was kept constant during the panning test because the liberation size of the ore was determined as -180+125 μm and during the panning test at various particle size, it was observed that 125 μm nominal size the has the highest recovery of 81.58% and a grade of 3.68%Au. From the result presented in table 3.4 the concentration process at a pulp density of 10% has the highest recovery of 99% at a concentrate grade of 3.35%Au. The concentration with the second pulp density which is 20% solid by weight has recovery of 97% and has the highest concentrate grade of 3.51%Au. This shows that the process with 20% pulp density is good the and so also the enrichment ratio is calculated as 6.62 and ratio of concentration of 6.85. The gold recovery of 97% means that the 97% of gold originally in the ore is in the concentrate and the remaining 3% of gold in the tailing and middling. The result supported that of mindat.org, (2021) which stated that effective recovery and grade of concentrate are best achieved when the pulp density ranges from 10-25% solid by weight. Therefore, the concentration of the gold ore using panning is best achieved using slurry of 20% solid by weight at a particle size range of -180+125 μm .

(iii) Effect of Swirling Time on Gravity Concentration of Yandoton-Daji Ore

The gravity concentration of the Yandoton-Daji ore was carried out using panning by varying the swirling time of the pan containing pulp in water bath. The various swirling time was 10, 15 and 20 minutes. During the process, the particle size range of -180+125 μm and pulp density of 20% solid by weight were kept constant. The assay of the products of concentration are presented in Table 6.

Table 6 presented the result of the assay of concentration products of Yandoton-Daji gold ore at various swirling time and constant feed size of -180+125 μm and pulp density of 20% solid by weight. From the analysis it was observed that the concentrate with swirling time of 20 minutes has the highest percentage composition of 3.71%Au, followed by the concentrate with swirling time of 15 minutes which has a percentage composition of 3.27%Au. The assay of gold in the tailing is in traces.

The efficiency of the concentration process at various swirling time and constant size of the ore feed and constant pulp density was calculated. This involves recoveries, ratios of concentration and enrichment ratios. The results are shown on Table 7

Table 7 presented a panning test result conducted by varying the swirling time as 10, 15, and 20 minutes respectively. The particle size of -180+125 μm and pulp density of 20% solid by weight was kept constant. It was observed that 125 μm nominal size the has the highest recovery of 81.58% and a grade of 3.68%Au and the test at various pulp densities, 20% solid by weight has a good recovery and a the highest concentrate grade. From the result presented in table 3.6, the concentration process at a swirling time of 20 minutes has the highest recovery of 90.2% at a concentrate grade of 3.71%Au. This explains the fact that 90.2% of the gold metal originally in the ore is in the concentrate and the remaining 9.8% of gold in the tailing and middling. The ratio of concentration and enrichment ratio for 15 minutes are 7.76 and 7.00. From the table it was observed that the ratio of concentration decreases with increasing swirling time from 7.76-11.14 while the enrichment ratio increases with increasing swirling time from 6.00-7.00. The second swirling time of 15

Table 6: Assay of Concentration Products at Various Swirling Time

S/N	Elements	St ₁ (10m)		St ₂ (15m)		St ₃ (20m)	
		Concentrate (%)	Tailing (%)	Concentrate (%)	Tailing (%)	Concentrate (%)	Tailing (%)
1	Si	30.11	38.01	32.19	35.89	29.68	39.83
2	V	1.03	0.00	0.08	0.00	0.21	0.00
3	Cr	5.21	0.00	4.65	0.00	5.33	1.23
4	Mn	3.04	1.01	3.11	1.21	2.58	3.58
5	Fe	11.14	16.28	9.65	17.86	8.71	11.56
6	Co	1.25	2.03	1.76	1.11	3.11	0.75
7	Ni	2.02	0.00	0.96	0.07	0.83	0.00
8	Cu	5.33	2.10	2.21	1.62	3.51	2.98
9	Nb	0.01	0.48	0.05	0.38	1.10	0.25
10	Mo	0.00	0.00	0.02	0.01	0.00	0.00
11	W	0.00	0.31	0.00	0.33	0.00	0.31
12	P	0.00	0.00	0.00	0.00	0.00	0.00
13	S	0.00	0.00	0.00	0.00	0.00	0.00
14	Ca	0.65	0.00	0.00	0.01	0.00	0.00
15	Mg	0.00	0.33	0.00	0.61	0.00	0.53
16	K	0.00	0.00	0.00	0.01	0.00	0.02
17	Ba	4.11	0.74	4.11	0.71	2.31	0.63
18	Al	3.80	22.19	6.21	23.61	4.56	16.71
19	Ta	0.30	0.18	0.98	1.10	0.09	0.64
20	Ti	0.66	15.61	1.21	12.23	0.71	15.75
21	Zn	12.40	0.73	11.58	8.61	11.11	5.23
22	Ag	5.77	0.00	3.62	0.00	2.75	0.00
23	Cl	0.00	0.00	0.00	0.00	0.00	0.00
24	Zr	4.21	0.00	5.71	0.00	7.99	0.00
25	Sn	9.58	0.00	8.65	2.63	11.71	0.00
26	Au	3.18	0.00	3.27	0.00	3.71	0.00

Table 7: Panning Test Result at Various Swirling Time

Swirling Time (Minutes)	Feed		Products				Recovery %	Ratio of Conc. F/C	Enrichment ratio c/f
	Wt (g)	Au %	Conc.		Tailings				
			Wt (g)	Au %	Wt (g)	Au %			
10	200	0.53	17.94	3.18	182.06	0.00	53.8	11.14	6.00
15	200	0.53	22.33	3.27	177.67	0.00	68.9	8.96	6.17
20	200	0.53	25.78	3.71	174.22	0.00	90.2	7.76	7.00

minutes has 68.9% recovery at 3.27%Au of concentrate grade and the 10 minutes swirling time has the least recovery and concentrate grade. From the table 3.6 it was observed that effective panning process can be achieved with higher swirling time.

From all the panning tests using different parameters, it was observed that, there is a high recovery ranging from 81-97% and a very low concentrate grade ranging from 3.51-3.71%Au. This is in accordance with the assertion of Wills, (2006) that in mineral concentration, there is a general inverse relationship between the recovery and the concentrate grade. Usually the lower the concentrate grade the higher the recovery because some of the valuable mineral is lost in producing high grade concentrate. But higher grade concentrate are easier to refine at a lower refining costs. Michael, (1986) declared that the recovery of gold from its ore is the most difficult task in mining operation and the value of gold deposits depend on the amount of gold that can be recovered by existing processes. Abdul-Rahman, (2010) demonstrated the use of Knelson bowl for the recovery of fine gold using gravity concentration and achieved 80% gold recovery which is very close to the result of present research. The result of this research is also close to that Gul *et al*, (2012) who obtained 82g/t Au with 89.9% recovery from ore assaying 6g/t Au by direct flotation. Mendoza, (2014) also had a gold recovery from 40-90% using eco-friendly recovery of gold by flotation-gravity concentration process compared to cyanidation and/or amalgamation process.

4.0 Conclusion

The optimum criteria for concentration of Yandoton-Daji gold ore using panning methods are:

- a. Particle size of 125 μ m, which contain the highest grade value in all the five runs, conducted using various particle sizes. This also provides the best assay grade-recovery value combination among all the five particle sizes.
- b. The best pulp density for the panning of the gold ore is 20% solid by weight and posted a good grade-recovery combination.
- c. The swirling time for the panning process of the gold ore is 20 minutes and has the best grade-recovery combination.

5.0 Acknowledgements

The authors acknowledged Mines Officer of Zamfara, Mr Usiju Lawal, for his assistance during sample collection. Also, the authors appreciate the support given during course of this research work by Department of Mineral and Petroleum Resources Engineering, Kaduna Polytechnic, NGSA and NSRMEA, all in Kaduna.

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Evaluation and Analysis of Environmental Noise Level at Yassat, Quarry, Ilorin, Nigeria

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Abstract

Noise pollution is a challenge in mining industry, it has potential to affect the health of the workers and the neighborhood. The Quarry site studied was Yassat Quarry, Ilorin, Kwara state. The measurement of noise levels was conducted during drilling, blasting, crushing and haulage operation. During the analysis of the result, a corrective calculation formula which accounts for observer and receptor distance was employed. This gave the noise level characteristics of the site. Comparing the noise level of the quarry during drilling, crushing, blasting and haulage operations with the standard regulation limit stated by National Environmental Standard and Regulation Agency (NESREA) (2009), the values are within the standard regulation limit. The noise level of 99.55 dB (A) to 126.6 dB (A) measured average range exceeds the value stated by the environmental regulation for continuous exposure to noise i.e., 88 dB (A). The noise safety of the neighborhood of the quarry based on the standard for quarry location was also evaluated, and at distance stated by the regulation, it is safe. The continuous monitoring of the noise level and the use of personal protective device by the worker are recommended.

Keywords: noise, operations, standard, safety, monitoring.

1.0 Introduction

1.1 Noise Pollution

Noise pollution is a bad incident globally since it is imposed on human society contrary to their desire (Goines and Hagler, 2007). When the noise level goes beyond tolerated levels, it becomes dangerous and can cause hearing disorder, other associated health problems are increasing blood pressure level, sleeplessness, annoyance and shift in threshold temporarily (Aslam et al, 2008).

Noise pollution generated by rock quarries can cause major annoyance, occupational hazards, it may lead to various health problems like hearing impairments, psychological and physiological damages to workers, these negative effects can also affect the residents of neighborhood of the quarries (Ashley, 2004).

1.2 Effects of Noise Pollution

High noise level can adversely affect communication, sleeping, concentration, sensitivity, and efficiency at work. It has been reported that if there is continued exposure to noise levels of great intensity, breakdown

nervously, damages to infrastructure by vibrations, and elevation of human blood pressure can occur (Vivian, 2019).

Naik et al. (2007) said that continuous exposure to noise beyond permissible limit may result into problems of human auditory system for a long time. They itemized the effects as eardrums bursting, permanent loss of hearing, fatigue, irritation, stress, lack of efficiency and becoming unproductive.

1.3 Control of Noise Pollution

Bauer and Baibich (2007) recommended that the appropriate authorities enforce that management and workers of the quarries abide by occupational health and safety regulations. They believed that this action would ensure protection of rights of worker to conducive conditions of working, and environment which is clean and healthy. Wanjiku (2015) mentioned that governments need to make sure that mining environments are studied in detail, and make the public to be aware of laws and regulations guiding mining, to improve safety of lives and properties.

The goal of this study is to evaluate the noise level in the granite quarry, compare with the permissible level and estimate the noise-safe distance from the quarry based on the results obtained.

2.0 Experimental.

Yassat quarry is located at Oke Ose, Ilorin, Ilorin

East Local Government of Kwara State. The site is about six kilometers away from Kwara State Polytechnic permanent site along Old Jebba Road (Figure 1).

The site was visited. Sound level meter Exi-Ech model was used on the site, Figure 2 shows the photograph of the meter.

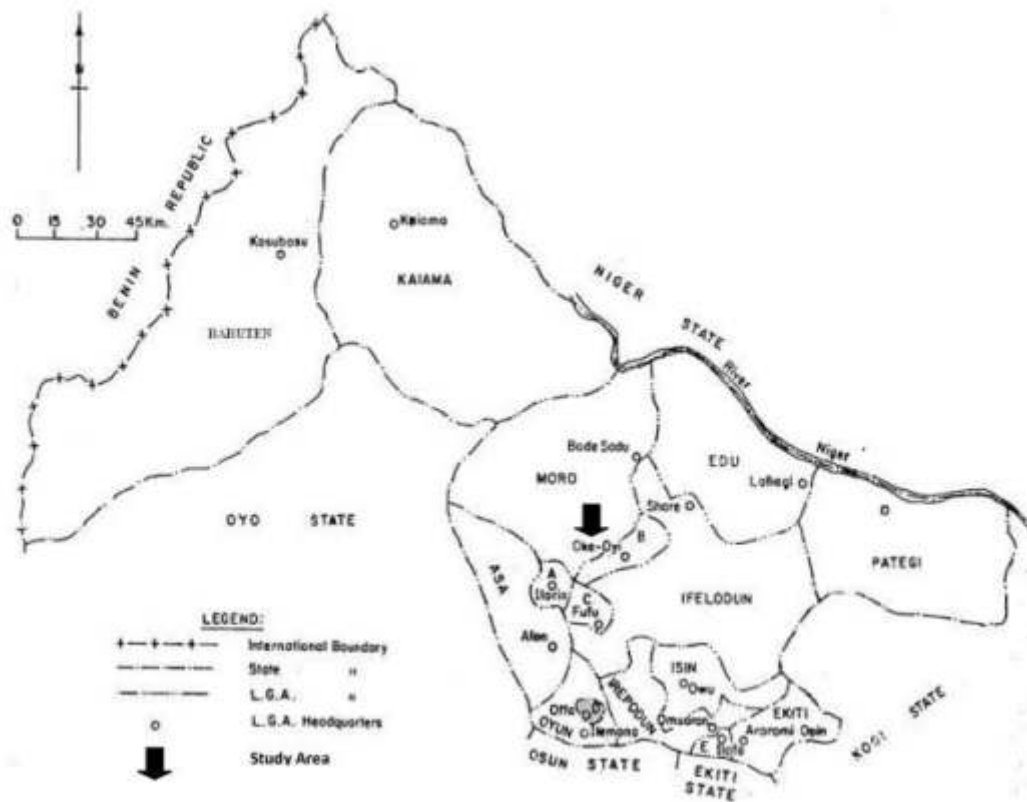


Figure 1: Map of Kwara State, Nigeria showing the studied area.
Source: Kwara State Ministry of Information (2005)

Oral Interview was also conducted and the values obtained was compared with limits set by standard regulations. The noise level readings were taken using sound level meter every thirty (30) seconds in decibels (dB) according to approach used by Akpan and Onnu (2004). It was held in the hand at least one meter (1m) from any reflecting surface.

3.0 Results and Discussion

Table 1 shows that the mean value of noise level during drilling activities is 99.55dB (A), this value is greater than the range of 94.9 to 96.2dBA reported by Gyamfi et. al. (2016) for drilling in quarries in Ghana. This mean value is less than 109dB (A) permitted by National Environmental (Noise Standards and Control)



Figure 2. Sound Level meter

Table 1. The result of noise measurement during drilling at Yassat Quarry, Ilorin

Time (Sec)	Hole 1 (dB)	Hole 2 (dB)	Hole 3 (dB)	Hole 4 (dB)	Hole 5 (dB)	Hole 6 (dB)	Hole 7 (dB)	Hole 8 (dB)	Hole 9 (dB)	Hole 10 (dB)	Hole 11 (dB)	Hole 12 (dB)	Hole 13 (dB)	Hole 14 (dB)	Hole 15 (dB)	Hole 16 (dB)	Hole 17 (dB)	Hole 18 (dB)	Hole 19 (dB)	Hole 20 (dB)
30	101.2	102.5	100.3	102.2	102.0	103.5	100.3	100.2	100.5	102.7	103.4	100.4	102.2	102.1	101.6	102.2	101.7	101.0	100.7	102.0
60	102.2	102.7	100.1	102.5	101.5	102.0	100.0	99.9	101.9	101.3	101.2	100.0	101.0	100.9	101.5	101.2	100.3	100.0	100.1	99.8
90	101.7	97.0	99.6	100.0	99.9	100.5	98.2	98.8	99.8	100.9	100.0	100.2	99.5	98.5	99.2	100.7	100.2	98.1	98.7	98.1
120	100.0	99.0	99.9	100.0	100.0	97.3	99.5	99.9	97.9	98.7	100.1	98.9	100.9	99.0	97.3	101.0	100.0	97.3	98.1	98.2
150	97.7	97.7	98.2	99.6	98.5	97.5	99.3	98.7	97.6	98.0	99.0	97.3	98.3	98.6	98.8	97.2	98.2	98.7	97.1	99.6
180	97.0	98.7	97.3	98.0	97.9	97.0	98.9	98.5	97.3	98.1	98.2	97.5	97.0	97.3	98.7	97.1	98.5	97.0	97.9	97.1
Average	99.55																			
Median	99.55833																			
Standard Deviation	0.458439																			
Mode	99.96666667																			

Regulations (2009). The standard deviation of 0.458439 shows that there is a small variation in the emitted noise levels.

Table 2 shows that the mean value of noise level during crushing activities is 99.7 dB (A). This value is within the values of 99.6 to 102.7 dB A

Table 2. The result of Noise measurement during crushing at Yassat Quarry, Ilorin

Time (Sec)	Range (dB)	Time (sec)	Range (dB)	Time (sec)	Range (dB)	Time (sec)	Range (dB)	Time (sec)	Range (dB)
30	97	750	98.1	1,470	107.7	2,190	98.9	2,910	99.7
60	99.7	780	100.2	1,500	101.2	2,220	97.1	2,940	98.1
90	98.7	10	100.9	1,530	102.2	2,250	98.1	2,970	97.9
120	97.1	40	103.2	1,560	101.7	2,280	99.2	3,000	97.1
150	98.1	870	01.7	1,590	100.0	2,310	98.3	2,310	98.3
180	100.0	900	99.9	1,620	97.7	2,340	99.8	3,060	98.7
210	101.0	930	99.7	1,650	97.0	2,370	99.1	3,090	100.5
240	99.7	960	100.5	1,680	102.5	2,400	98.7	3,120	100.0
270	105.7	990	102.7	1,710	101.7	2,430	102.5	3,150	98.2
300	102.9	1,020	98.3	1,740	97.0	2,460	102.7	3,180	99.5
330	100.0	1,050	101.2	1,770	99.0	2,490	102.4	3,210	101.2
360	105.1	1,080	98.0	1,800	97.7	2,520	97.3	3,240	97.0
390	107.7	1,110	98.7	1,830	98.3	2,550	97.8	3,270	101.7
420	102.5	1,140	99.2	1,860	100.7	2,580	99.9	3,300	102.7
450	102.7	1,170	99.8	1,890	100.1	2,610	101.5	3,330	97.0
480	99.7	1,200	97.0	1,920	99.7	2,640	99.0	3,360	99.0
510	98.5	1,230	99.7	1,950	100.5	2,670	105.4	3,390	97.7
540	102.5	1,260	100.0	1,980	101.2	2,700	107.5	3,420	98.5
570	97.0	1,290	101.0	2,010	99.9	2,730	101.2	3,450	99.4
600	97.3	1,320	105.7	2,040	98.3	2,760	101.0	3,480	99.6
630	98.7	1,350	99.7	2,070	91.5	2,790	99.5	3,510	100.5
660	97.5	1,380	102.9	2,100	98.7	2,820	99.8	3,540	97.0
690	97.0	1,410	100.0	2,130	97.1	2,850	99.0	3,570	97.2
720	97.3	1,440	105.1	2,160	97.9	2,880	98.3	3,600	97.2
Total	2403.4	Total	2413.2	Total	2389.3	Total	2404.0	Total	2375.3
Average	99.03								
Median	99.7								
Standard Deviation	9.269								
Mode	97.0								

which Gyamfi et. al. (2016) reported for crushing in quarries in Ghana. The mean value is less than 109dB (A) permitted by the National Environmental (Noise Standards and Control) Regulations (2009). The standard deviation of 9.269 shows some level of variations in the emitted noise levels.

Table 3 shows that the mean value of noise level during haulage activities is 97.78 dB (A). Anon (2013a) suggested that the noise level measured from equipment, Cat D735 articulated dump truck is 79 dB(A), and noise levels generated by both Cat 950H and Cat 972H wheel loaders are respectively, 111 dB(A) (Anon, 2013b). Anon (2013b) reported that the noise level from Cat

336D is 105 dB(A). Meanwhile, this mean value is less than 109dB permissible by National Environmental Standards Regulation Authority, Noise Standards and Control Regulations (2009). The standard deviation values of 0.89 to 8.94 for the measured noise levels show that there were different levels of variation in the emitted noise levels by the dump trucks.

Table 4 shows that these estimated values for the safe distance is good for the level of operation of the studied quarry, though the value of sound from blasting is slightly elevated.

Tables 5 and 6 show that the levels of noise emitted from the activities in the quarry exceed

Table 3. Noise measurement during haulage operation at Yassat Quarry, Ilorin

Time (Sec)	Haulage 1 (dB)	Haulage 2 (dB)	Haulage 3 (dB)	Haulage 4 (dB)
30	71.5	97.1	98.5	97.9
60	98.7	97.8	98.0	97.5
90	97.1	99.2	97.4	98.9
120	97.9	98.2	99.2	100.9
150	98.1	99.8	100.1	98.5
180	98.3	98.1	99.9	99.3
210	99.7	100.0	99.5	99.7
240	99.2	99.4	99.5	98.2
TOTAL	786.5	789.9	792.1	790.9
Average	95.06	98.7	99.01	98.36
Standard Deviation	8.94	0.98	0.89	1.02

the continuous or intermittent exposure permissible, it is therefore important for the workers and visitors in the quarry to use ear protective devices in the quarry especially during operations.

4.0 Conclusions and Recommendations

Conclusions
Noise from industries and its effects can cause hazards. Hence, noise and vibration monitoring require urgent attention to prevent or mitigate against its effects on both man and environment. The data obtained from drilling, blasting,

crushing, and haulage show that the noise from these operations in Yassat quarry are still relatively within the standard regulation limit for noise set by National Environmental Standard Regulation Authority. The noise level generated is also safe for the neighborhood of the quarry based on the regulation.

Recommendations

The following recommendations are made based on the result obtained from this study. The management of the quarry should continually

Table 4: Estimation of Emitted Noise level at safe distance of quarry by National Environmental Standard Regulation Authority, Quarrying and Blasting Operations Regulations 2013 according to Sengpiel Audio (2022).

Activity	Average Noise Level (dB)	Distance of Estimation (m)	Distance of measurement (m)	Estimated Noise Level (dB)
Drilling	99.55	3000	1	30.00757491
Haulage 1	95.06	3000	1	25.51757491
Haulage 2	98.7	3000	1	29.15757491
Haulage 3	99.01	3000	1	29.46757491
Haulage 4	98.36	3000	1	28.81757491
Blasting	126.6	3000	500	111.036975
Crushing	99.03	3000	1	29.48757491

Table 5. Average Sound Levels of Operations at Yassat Quarry, Ilorin

Operation	Average Sound Level (dB)
Drilling	99.55
Blasting	126.6
Crushing	99.03
Haulage	97.78

Table 6. National Environmental Standard Regulation Authority, Noise Standards and Control Regulations, 2009 Regulation 2 (2) Maximum Permissible Noise Levels (Continuous or intermittent noise) from a factory or workshop

Leq dB (A)	Duration (Daily)	Duration (Weekly)
85	8 Hours	40 Hours
88	4 Hours	20 Hours
91	2 Hours	10 Hours
94	1 Hours	5 Hours
97	30 minutes	2.5 Hours
100	15 minutes	1.25 Hours
106	7.5 minutes	37.5 minutes
109	1.875 minutes	9.375 minutes

enforce strict adherence to safety and preventive measure against noise. She should always make use of the National Environmental Standard and Regulation Enforcement Agency (NESREA). Safety Workshops and enlightenment programs should be organized periodically to educate workers on the need to protect themselves from noise exposure. The workers should use personal protective devices i.e., ear mug while working. The noise level and other environmental indices should be monitored periodically, and regularly, and reported to the appropriate authorities for necessary proper actions.

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Beneficiation of Mayanchi Gold Ore, Zamfara State, Nigeria

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Abstract

The research deals with beneficiation of Mayanchi Gold Ore. The Work involved sample collection and preparation, followed by chemical analysis of the head sample using XRF, mineralogical analysis of the Head sample crushing, grinding, particle sieves size analysis, sluicing and panning were also carried out. The result of XRF analysis revealed that Mayanchi Gold Ore contains; 82.1%SiO₂, 0.8%CaO, 0.045%MnO, 0.0762%CuO, 9.4%Fe₂O₃, 0.015%ZnO, 0.720%PbO, 0.019%Au and among others. The result of XRF analysis for the concentrate revealed the Mayanchi Gold ore contained; SiO₂ in 4.17%, BaO in 5.22%, Al₂O₃ in 3.49%, Cr₂O₃ in 10.0%, MnO in 4.34%, Fe₂O₃ in 6.20%, CO₃O₄ in 2.01%, ZnO in 2.09%, Ag₂O in 16.48%, SnO₂ in 2.02%, Au in 8.70% and among others. It is recommended that future concentration method should be carried out on Mayanchi Gold ore.

Keywords: beneficiation, gold ore, panning, sluicing.

1.0. Introduction

A mineral is a naturally occurring heterogenous solid with a definite chemical composition and a highly ordered atomic arrangement. It is usually formed by inorganic processes; the mineral can either be metallic which can be of economic importance to the development of any nation (Brands, 2003).

The treatment of raw material to improve physical or chemical properties especially beneficiation will enhance the preparation for smelting. Beneficiation is the process where ore is reduced in size (comminution) and gangue separated from the Ore (concentration). Since all gold ore deposits have unique mineralogy, the beneficiation process is specific to each deposit separation of certain mineral can be efficiently achieved by taking advantage of the physical, electrical and magnetic properties (SGS, 2009; Hough, 2007).

1.1. Location and Accessibility

The project site located at Mayanchi Local Area, Zamfara State at latitude 12°16'27.94' and longitude 6° 55'46.74'E about 5km (Figure 1)

1.2 Occurrences of Gold in Nigeria

In Nigeria, gold occurs both as placers (alluvial and eluvia) and primary vein deposits within the schist belts of northwest and southwestern



Figure 1: Satellite Image of Mayanchi town, using Google Earth (2023).

Nigeria. Some of the most important occurrences are at Maru, Anka, Kwaga, Gurmana, Birninoyauri, Okolum Dogon-Daji and Iperindo areas all associated with the schist belts. Personal field observation within the Kushaka schist belt showed that there are several new artisanal workings in places like Gusoro, Zumba, Maitumbi Minna, Pago and Maiwayo village which is almost at the contact between the basement and the Nupe sandstone.

1.3 Method of Determining Gold

1.3.1 Fire Assay of Gold

Fire assay is the industry standard process for obtaining analytical gold and platinum group element data from high grade ores. This method is used in the determination of gold in all sample types including drill core, soil and chip samples,

1.3.2 X-ray Florescence (XRF)

Qualitative analysis involves the identification of the various spectral lines with the elements responsible for them. Both particle and background intensity must be qualitatively compared with that of a standard (of known composition) of the same element makeup. X-rays irradiate a sample and the elements present emit a fluorescent x-ray radiation that is characteristic for those elements. Analyzing crystals are used to disperse the different energies. A detector is used to measure the intensity of the X-rays and wavelength (Anon, 2015).

1.4 Mineral Processing

Mineral processing methods are used to separate valuable mineral or mineral of interest from unwanted ones (gangue). It simply entails unit operation such as comminution, sizing, classification, separation, Concentration, dewatering, tailing disposal. Fundamentally, these operations are aimed at the release (Liberation) of the valuable minerals from their gangue followed by separation of these values from the gangue known as concentration.

Liberation of the valuable minerals from the gangue is accomplished by comminution which involve crushing and if necessary grinding to saw a particle size that the product is a mixture of relatively clean particle of concentrate mineral from gangue, concentration on the other hand employ one or a combination of the following most important physical method (Wills, 2006).

Concentration involves the separation of valuable minerals from the other raw materials received from the grinding mill. In large-scale

operations, this is accomplished by taking advantage of the different properties of the minerals to be separated. These properties can be color (optical sorting), density (gravity separation), magnetic or electric (magnetic and electrostatic separation), and physicochemical (flotation).

1.4.1 Gravity Concentration

Gravity concentration method is separating of minerals of different specific gravity by their relative movement in response to gravity and other force (the resistance to motion offered by a viscous fluid such as water or air). It is important for effective separation that marked density differences exist between the mineral and gangue (Will, 2007, Yaro 1997).

The Principle of Gravity Concentration are as follows:

A Concentration Criterion

Some idea of the amenability of separation of two minerals can be obtained from the concentration criterion, which is usually defined as: The specific gravity of the heavy species minus the density of the suspending fluid, divided by the specific gravity of the light species minus the density of the suspending fluid.

A simple relative density difference criterion known as gravity concentration criterion C has been suggested as a rough measure for the possibility of gravity separation (Abouzeid, 1990).

$$\text{Gravity concentration criterion} = \frac{\rho_h - \rho_f}{\rho_l - \rho_f}$$

Where: ρ_h is density or specific gravity of heavy mineral; ρ_l is density of light mineral and ρ_f is the density of media

According to Vijayendra (2001) if this ratio is negative or a positive number greater than 2.5, separation in water is easy at all sizes down to the finest sands. When the criterion value between 1.75 and 1.50, separation is possible down to 210 μm .

At ratio 1.25, good separation is difficult, below which commercial separations by gravity concentration without differential weight

modification is not possible. The laws of free and hindered settling are also very important in the theory of gravity concentration.

B. Mechanisms of Concentration

The various mechanisms are represented pictorially below:

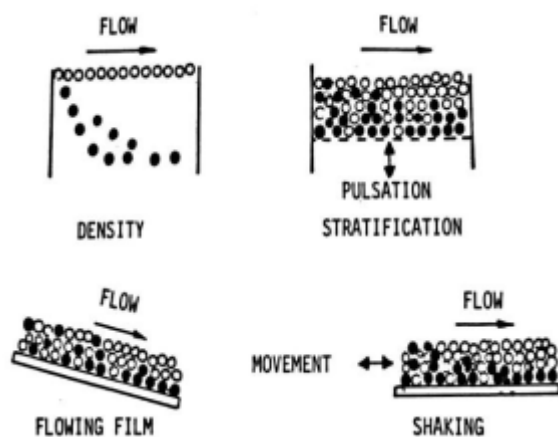


Figure 2: Various Mechanisms of Gravity Concentration

- a. **Density:** The viscous fluid used has a density or apparent density in between that of the minerals to be separated, such that one mineral(s) will have a net positive buoyancy and will float, whilst the other(s) will have a net negative buoyancy and will sink. Into this classification fits heavy medium separation, one of the most important of all gravity concentration processes as well as magnet hydrostatic separation.
- b. **Stratification:** The various mineral constituents are stratified by being subjected to an intermittent fluidization caused by the pulsation of the fluid in a vertical plane. This classification is represented by jigs of which there are a wide range and number.
- c. **Flowing_film:** The various constituents are separated by their relative movement through a stream of slurry which is flowing down a plane by the action of gravity. Flowing film concentration is the oldest process used in gravity concentration and remains of major importance, with such units as the sluice or palong, pinched sluice. Reichert cone, and, by including lateral movement caused by the addition of centrifugal force, the spiral.

- d. **Shaking:** The mineral components are stratified by superimposing on the flowing film, a horizontal shear force, whether it be oscillating as in a shaking table, or orbital, as is the case on the Bartles-Mozley separator or Cross-belt concentrator.

1.4.2. Panning

Gold deposit falls under the placer deposit and its mining comes into the placer mining, thus involve work of excavating and transporting placer gravels and of recovering their contained gold and other valuable mineral, which is usually done by concentrating or washing the gravels in running water (Blerleun. 2000).

1.4.3. Sluicing

Sluice use a near horizontal current of water flowing in a stream to classify mineral grains both by size and gravity.

The stream of water classifies the moving feed so that heavy grains get to the bottom and the light ones remain on top it is usual to insert suitable trap, across the bottom of the sluice so as to retain the heavy grains whereas the current entrains away any light particles (fine or coarse).

A sluice box is an elongated three-sided wooden or metal equipped with riffles and matting, through Which gravel is washed to recover say gold and or other valuable heavy minerals Essentially a sluice inclines trough launder on a net slope through which feed IS washed (sluiced) by a rapid stream of water. The bottom of the trough is roughened by trips or blocks (riffles) fastened in place and so arranged as to maintain spaces between the arrangements of riffles are legion (Brands, 2003).

A Riffles

Are obstructions, placed in the bottom of a sluice box which creates turbulence during hydraulic transportation of valuable minerals and gravel passing over them.

B Matting

On the other hand, is the fabric material that

separates the riffles from the sluice floor. The major function of the matting is to provide a secure for fine gained ore-minerals (Brands, 2003).

1.4.4. Flotation

Flotation is a technique in which particles of a single mineral or group of minerals are made to adhere, by the addition of reagents, preferentially to air bubbles.

This technique is chiefly used on base metal ore that is finely disseminated and generally contains small quantities of gold in association with the base metals. Gold is recovered as a byproduct of the base metal recovery although no production information is available specifically for flotation; U.S. Bureau of Mines personnel have suggested that production for smelting may approximate byproduct gold production by the base metal industry. In 1988, smelting recovered 0.67 million troy ounces of gold (11 percent of all domestic gold produced) (U.S. DOI, Bureau of Mines 1990a). Ore is milled and sorted by size in preparation for flotation. The ore is then slurried with chemical reagents of four main groups: collectors (promoters), frothers, activators, and depressants. In a typical operation, the ore slurry and reagents are mixed in a conditional cell so the reagents coat the target mineral. The conditional slurry is pumped to a flotation cell, and air is injected. Air bubbles adhere to the reagents and carry the target mineral to the surface, away from the remaining gangue, for collection. In the flotation technique, the target mineral is not necessarily the precious metal or other value.

1.4.5. Amalgamation

In amalgamation operations, metallic gold is wetted with mercury to form a solution of gold in mercury, referred to as an amalgam, because of its high surface tension. This method of beneficiation is most effective on loose or free coarse gold particles with clean surfaces (U.S. EPA, Office of Water 1982)

1.4.6. Cyanidation

The predominant method used to beneficiate gold ore is cyanidation. This technique uses solutions of sodium or potassium cyanide as lixiviants (leaching agents) to extract precious

metals from the ore. Cyanide heap leaching is a relatively inexpensive method of beneficiating low-grade gold ores while tank leaching is used for higher grade ore. Cyanidation techniques used in the gold industry today include heap or valley fill leaching followed by carbon adsorption (carbon-in-column adsorption), agitation leaching followed by carbon-in-pulp (CIP), or agitated carbon-in-leach (CIL). It is best suited to fine-grain gold in disseminated deposits. Heap or valley fill leaching is generally used to beneficiate ores containing less than 0.04 oz/t. CIP and CIL techniques, commonly referred to as tank or vat methods, are generally used to beneficiate ores containing more than 0.04 oz/t. These gold beneficiation cut-off values are dependent on many factors, including the price of gold and an operation's ability to recover the precious metal (van Zyl *et al*, 1988).

1.5. Uses of Gold

- The most common uses of gold is for making gold jewelry.
- It is also used to make glass that have red or purple colour.
- It is used for electronic products like computers. Telephones, and home appliance, industries medical field etc.

Materials and Methods

2.1. Sample Collection

The Sample was collected by using Non-probability sampling technique at co-ordinate location of latitude 12°16'27.94', longitude 6°55'46.74'E elevation 388m and of 12°01'22.30'N, 6°54'23.40'E elevation 390m. Representative sample weighing 50kg were collected from the site location in lumps size using grab method. This was reduced using sledge hammer, the mixture was pulverized then followed by coning and quartering.

2.2 .Material and Equipment

The material used in carrying out this research work includes: Gold ore sample and water

The equipment used in carrying out this research work includes: Sledge hammer, Laboratory jaw crusher, Pulverizer (grinding machine), Ball mill grinding machine, Sieve,

Sieve shaker, weighing machine and X-Ray fluorescence (XRF) machine

2.3. Sample Preparation

The ore was broken using sledge hammer. The broken ores were fed into laboratory jaw crusher for crushing. The crushed ore was then ground using laboratory ball mill respectively in order to liberate the valuable from their associated gangue. The ore was then mixed thoroughly and sampled using conning and quartering method of sample division in the laboratory to obtain a representative sample of the ore which is analyzed using both XRF and XRD machine.

2.4. Preparation of Sample

2.4.1. Crushing

The ore was broken into the size that could be fed into a jaw crusher using a sledge hammer. Crushing of the ore was carried out in the laboratory jaw crusher

2.4.2. Grinding

After crushing, the samples were taken to pulverizing machine for further reduction of size. Since the size of the crusher is not suitable for the sieves analysis the grinding is carried out in a ball mill. The ball mill was allowed to run for (20) minutes as the mill rotates the ore samples is ground by combined effects of cascading and centrifugal forces.

2.5. Fractional Sieves Size Analysis

The sieves were arranged using the principle of root two sieve section factor with the finest sieve at the bottom and coarsest sieves at the top. 200gm of the ore was introduced into top of the control sieve and the sieve shaker was allowed to for 20minutes, particle size retained on each sieves size was weight and analyzed using X-ray fluorescence (XRF) technique for gold content.

2.6. Chemical Analysis using X-ray Fluorescent (XRF)

The pellet of the sample was loaded in the sample chamber of the spectrometer and voltage (30kV maximum) and a current (1MA maximum) applied to produce the X-rays to excite the sample for a present time (10minutes in this case). The system controlled by a PC, Running the dedicated mini analytic software.

2.7. Sluicing

The grinded ore ($-90 + 75\mu\text{m}$ size range) was mixed thoroughly with water to form a pulp of 40% solid. Sluice box is arrange inclined at 60° degree, then the pulp is poured over flat-bottom troughs, on the surface and lined with a mat with a running water, the lighter particle are washed down and the heavier particle are trap to the mat at the end of the process, the heavier particle (concentrate) trap in the mat are collected and the lighter particle (tailing) which is washed down are also collected, the collected product were dried in the oven at 105°C and analysis using XRF to know the grade of gold.

2.8. Panning

The pan was first filled halfway with the ground ore material. The pan was then immersed in water and the mixture was thoroughly wetted and stirred. Lumps of clay are broken up and large stone are picked out. The pan stay under the water was then given a combination of Shaking and gyratory motion. This allows the heavy particle to settle and bring the lighter material to the surface at interval the pan was stirred and the light surface material is washed off. This process continued until only heavy materials (gold) remain. The collected products concentrate and tailing were dried in the oven at 105°C and were analyzed using XRF to know the grade of gold.

3.0. Results and Discussion

3.1. Results and Discussion

X-Ray Fluorescent (XRF) For the Head Sample.

Table 1: Result of XRF Analysis of Head Sample (Mayanchi gold ore)

Compound (Element)	Percentage (%)	Compound (Element)	Percentage (%)
SiO ₂	82.1	MnO	0.045
Cl	0.835	Fe ₂ O ₃	9.400
K ₂ O	1.8	CuO	0.0762
CaO	1.10	ZnO	0.015
TiO ₂	0.029	Al ₂ O ₃	0.000
V ₂ O ₅	0.023	Rb ₂ O	0.017
Cr ₂ O ₃	0.045	SrO	0.023
ZrO ₂	0.023	In ₂ O ₃	2.9
BaO	0.1	Eu ₂ O ₃	0.31
Re ₂ O ₇	0.039	Ir ₂ O ₇	0.030
AuO	0.019	PbO	0.720

From Table 1, the percentage of elements present in the ore matrix where 0.019% Au, 82.1% SiO₂, which has the highest percentage,

followed by 9.400% Fe₂O₃ and 2.9% In₂O₃ among others. This reveals that Au ore present can be mined which is in line with literature.

3.2. Mineralogical Composition of Mayanchi Gold Ore

Table 2: XRD Result of Mayanchi gold ore.

No	Mineral Name	Compound Name	Crystal System	Chemical Formula
1	Muscovite	Muscovite	Monoclinic	Al ₁₂ FeMn Si ₁₂ K ₄ , NaRbH ₁₆ O ₅
2	Quartz	Quartz	Hexagonal	Si ₃ O ₆



Figure 3: Shows the position of Quartz and muscovite.

Figure 3 shows the result of XRD analysis of the bulk mineral at different particle sizes. In this figure is possible to observe the presence of minerals with low specific mass (2 to 3g/cm³) as

quartz and muscovite. Gold mineral was not detected using XRD because of its low concentration. However, quartz and muscovite are geochemical pathfinder of gold.

3.3. Sieve Assay Analysis of Mayanchi Gold Ore

Table 3: Sieve Analysis

Sieve Size Range (µm)	Weight Retained (g)	Weight retained (%)	Cum% Over Size	Cum % Under Size	Nominal Aperture	Gold content %
+250	19.4	9.72	9.72	90.28	250	0.00
-250+180	36.92	18.46	28.18	71.82	180	0.00
-180+125	43.14	21.57	49.75	50.25	125	0.005
-125+90	48.74	24.37	74.12	25.88	90	0.047
-90+75	39.30	19.65	93.77	6.23	75	0.428
-75	12.64	6.23	100	0	-	0.297



Figure 4: Sieve analysis graph indicating 80% passing

From Table 4, the percentage of elements present in the concentrate sample where 8.70% Au, 16.48% Ag_2O , which has the highest percentage, followed by 6.20% Fe_2O_3 and 4.17% SiO_2 among others.

From Table 5, the percentage of elements present in the tailing sample where 0.002% Au, 66.80% SiO_2 , which has the highest percentage, followed by 18.08% Al_2O_3 and 0.72% Fe_2O_3 among others.

Table 4: Result of XRF Analysis of Concentrate Sample (Mayanchi Gold Ore)

Compound (Element)	Percentage (%)	Compound (Element)	Percentage (%)
SiO_2	4.17	ZrO_2	4.54
V_2O_5	0.18	Cl	1.73
Cr_2O_3	10.0	CaO	0.97
MnO	4.34	BaO	5.22
Fe_2O_3	6.20	Al_2O_3	3.49
CO_3O_4	2.01	Ta_2O_5	3.24
NiO	2.00	TiO_2	0.43
CuO	1.38	ZnO	2.09
Nb_2O_3	0.01	Ag_2O	16.48
MoO_3	0.01	SnO_2	2.02
		AuO	8.70

Table 5: Result of XRF analysis of Tailing Sample (Mayanchi Gold Ore)

Compound (Element)	Percentage (%)	Compound (Element)	Percentage (%)
SiO_2	66.80	WO_3	0.27
V_2O_5	1.00	CaO	0.01
Cr_2O_3	0.00	MgO	0.41
MnO	1.38	K_2O	0.01
Fe_2O_3	0.72	BaO	0.50
CO_3O_4	0.11	Al_2O_3	18.08
NiO	0.00	Ta_2O_5	2.19
CuO	0.23	TiO_2	8.10
Nb_2O_3	0.23	ZnO	0.11

CONCLUSION AND RECOMMENDATIONS

Conclusion

The research concludes that the geochemical analysis of the head sample reveals that Mayanchi Gold Ore contains; 82.1% SiO_2 , 0.8% CaO, 0.045% MnO, 0.0762% CuO,

9.4% Fe_2O_3 , 0.015% ZnO, 0.720% PbO the composition of Au which is the mineral interest is 0.019% Au

The XRD result reveals that presence of quartz and muscovite as the major mineral phases in the ore.

Beneficiation of Mayanchi gold ore using sluicing where the preconcentrated product is used as feed in panning method of gravity concentration. The percentage of gold (Au) in the ore after concentration was found to be 8.70% Au.

Recommendation

Sluicing process followed by panning method of gravity concentration to beneficiate Mayanchi gold ore is recommended. Also recommended is the use of spiral as an alternative method for the concentration of Mayanchi gold ore.

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Simulation Study of Oil Viscosity on Polymer Flooding for Oil Recovery: Case Study of Chad/Bornu Oil Fields

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Abstract

This study aims to investigate the influence of oil viscosity on polymer flooding mechanism in one of the reservoirs of Bornu oil field using simulation model. The polymer flooding simulation is done by coding data of the selected field of study on a note pad and run on an Oil simulator ECLIPSE 100 and designed to investigate the behavior of oil viscosity sensitivity assessments on oil recovery. Results obtained from the simulations indicate that the FOPT, FOE, FCPT and FPR decrease with increase in the oil viscosity. These decreases are attributed to the increase in the mobility ratio between the polymer solution and the oil phase, the viscous forces are dominating, and the polymer solution underruns the oil, forming a so-called "gravity-tongue". The effect results in high proportion of the oil being left as residual oil at the end of the polymer flooding process. This study provides technical support in selecting and optimizing enhanced oil recovery systems for chemical flooding.

Keywords: Polymer flooding, Gravity-Tongue, Viscous Fingering, Oil recovery.

Abbreviations

EOR: Enhanced Oil Recovery
FOPT: Field Oil Production Total
FOE: Field Oil Efficiency
FPR: Field Pressure
FGOR: Field Gas Oil Ratio
FCPR: Field Polymer Production Rate
FCPT: Field Polymer Production Total
FWCT: Field Water Cut

Introduction

EOR technology involves the injection of fluids that are initially not present in the reservoir to increase the recovery of oil from the reservoir that had been by-passed (Silset 2008). EOR uses about 15 different substances that are injected into the reservoir to mobilize substantial amount of oil to the production wells to increase the recovery of oil (Lake 2008; Taber 1997).

These chemicals are aimed at either altering the reservoir forces such as capillary and viscous forces or fluids mobility properties such as viscosity. These forces greatly reduce recovery of oils by reducing mobility of oils due to high viscosities in either heavy or waxy oils and trapping by capillary forces (Dongmei 2007; Lake 2008; Thomas 2008).

The chemical method is divided into three types based on the nature chemical added to the

injected water that is into surfactant flooding, polymer flooding and caustic flooding (Amirbayov 2014). Polymer flooding has been employed successfully in Daqing Oilfield in China for decades; it contributed to the oil recovery of more than 10% of original oil in place (OOIP) after water flooding (Wang et al. 2009).

As mentioned above polymer flooding improves recovery by mobility control and hence this is expressed mathematically using the mobility ratio as shown in the experimentally derived equation below (Dyes 1954).

$$M = \frac{k_w/\mu_w}{k_o/\mu_o}$$

M –Mobility ratio k_w -Effective; permeability of water k_o - Effective; permeability of oil μ_w - Viscosity of water; or the injected phase μ_o - Viscosity of oil

From the equation above when mobility ratio (M) is less than one, it predicts a stable displacement but above one, it predicts high possibility of unstable displacement due to viscous fingering that may arise because of high mobility of injected water.

The viscosity of the polymer solution which is the resistance of the solution to flow, is a key control to sweep efficiency and thus the recovery factor. As such controlling the effect of viscous fingering

of the displacing fluid by piston like displacement mechanism (Abadli 2012; Dongmei 2007). According to Dongmei (2007), the viscosity of polymer solution is controlled by three main factors; (1) the concentration of

the polymer solution, (2) for this given type, the degree of HPAM polymer hydrolysis and (3) the molecular weight of the polymer used which is also specific to a given polymer type and all the three are linearly related as in Figure 1.

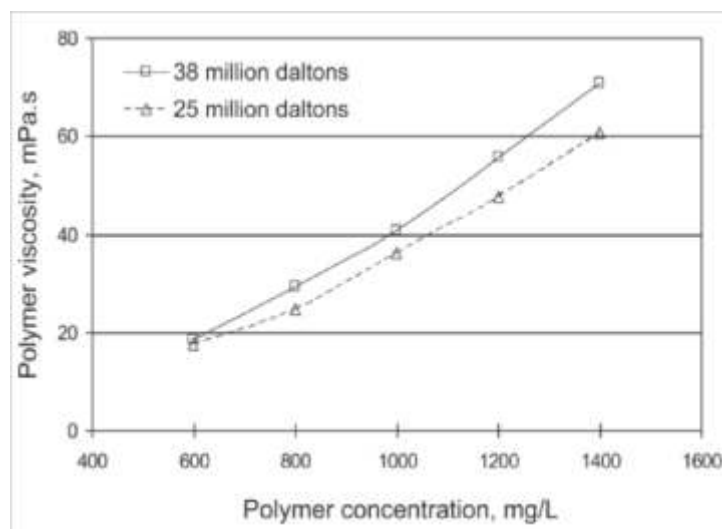


Fig. 1: Variation viscosity with concentration and molecular weight of polymer used in making polymer solution (Dongmei 2007; Gao 2004).

Wax in crudes are high molecular weight, long chain hydrocarbons which maybe straight chain, branched or containing aromatic components that easily crystallize out of solution to form solids in crude at high temperatures for example the anticipated Chad oil Block one exploration area which are waxy having a pour point of 60°C. Waxy crude are widely distributed in the globe and contributes greatly to high viscosity of some crude

Previous studies of waxy crude show that properties such as API gravity, viscosity, molecular weight and wax appearance temperature shows direct linear relationships with wax content which is measured as the percentage weight of wax in the crude (Lalya M. ALghanduri 2010).

Equipment and materials

The material used to conduct simulations in this work is a data from the XXX field in Chad/Borno Basin in a notepad under the different key words which are used for different functions run and Black Oil simulator model **ECLIPSE Software 100**.

The Polymer used is (modified polyacrylamide

GLP-85). It is abbreviated as PAM. This is a polymer ($\text{CH}_2\text{CHCONH}_2$ -) formed from acrylamide subunits. It can be synthesized as a simple linear-chain structure or cross-linked, typically using N,N'methylenebisacrylamide. It is highly water absorbent, forming a soft gel when hydrated, non-biological degraded. The common use of polyacrylamide and its derivatives is in subsurface applications such as Enhanced Oil Recovery. High viscosity aqueous solutions can be generated with low concentrations of polyacrylamide polymers and these can be injected to improve the economics of conventional water flooding and survive high temperature reservoirs. Thus, make it suitable for this project.

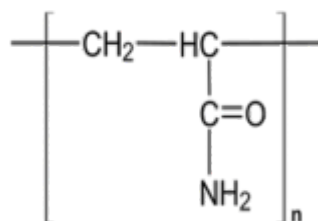


Figure 3: Polyacrylamide (Courtesy en.wikipedia.org)

Experimental Procedures

This involves coding the geophysical, geological, and petroleum engineering data obtained from **Integrated Data Services Limited (IDSL) a Subsidiary of Nigerian National Petroleum Corporation (NNPC) Nigeria** in notepad under the different key words which are used for different functions. The numerical simulation of polymer flooding in Chad oil field is conducted using a Black Oil simulator, **ECLIPSE 100 Reservoir simulator**. This simulator is used to model flow of three phases, oil, water and gas as well as the complex processes of recovery predictions using polymer in a reservoir system.

The model grid is made of a rectangular

coordinate system made up of 36x51x18 cells with dimensions of 110x205x15m but it actually consisted of 17 layers in k-direction since the 1st layer was killed because it has nil porosity thus having 33048 cells in total. The geometry definition is given in a Petrel file name "MODEL_PETREL.GRDECL". Polymer flooding was carried out with assessment to investigate the influence of oil viscosity and polymer flooding on oil recovery efficiency in one of the reservoirs of Bornu oil field using simulation model.

The oil viscosity sensitivity study was carried out by varying in the range 4cp to 20cp as detailed in Table 1 below.

Table 1: Viscosities of oil used in oil viscosity sensitivity assessment

Case	Oil viscosity (cp)
Case 1	4.341
Case 2	10.129
Case 3	20.258

Table 2: Simulation results of all the three cases of the oil viscosity sensitivity

	Oil viscosity (cp)	Mobility Ratio	FOE (%)	FOPT (x10 ⁶ Stm ³)	FCPT (kg)	Maximum FWCT	Maximum FWCT Time (year)
Case 1	4.341	0.182	12.372	4.4082	191060	0.900	18.439
Case 2	10.129	0.426	9.031	3.2143	143053	0.900	20.00
Case 3	20.258	0.851	6.454	2.3061	79408	0872	20.00

Results ad Discussions

From Figure 1 and 2, the FOPT and FOE decreases with increase in the oil viscosity. This decrease in FOPT is attributed to the increase in the mobility ratio between the polymer solution and the oil phase, and tends to resist displacement by the polymer phase as such resulting into unstable polymer flood front causing viscous fingering.

From Figure 3, the FCPT is high and increases more rapidly for low viscosity crude oil than for high viscosity crude. These may be due to high retention and entrapment of polymer by the high viscosity oils since it requires a high driving force for the oil to flow thus leaving substantial amount of polymer being retained in the reservoir.

From Figure 4, despite the fact that low FOE recovery from high viscosity crudes, the FPR

drop remained high enough to still sustain fluid recovery but this was also characterized by gradual average field pressure drop and rise with further increase in oil viscosity.

This result in uneven pressure distribution is as a result of delayed response to flow due to high viscosity of the oil and that the initial pressure applied to the oil is first utilize to overcome flow resistance basically internal forces within the fluid. These could also be due to effects of streamline flow of the injected phase that could be easily achieved when the oil phase has lower oil viscosity as compared with that of high viscosity crude oil as in figure 5 and 6, regions indicated by the Blue Square of layer 4 for figure 5 and 6 respectively.

In figure 5, the streamline flow was more pronounced than for figure 6 at the end of the simulation run.

Conclusions

The main focus is how the polymer reduces the mobility ratio to improve the sweep efficiency and delay the viscous fingering effect. A reservoir model was constructed using Petrel program by Schlumberger that matches a published screening criteria. Following this step, a primary recovery and secondary recovery scenarios were created using Eclipse software by Rock Flow Dynamics. After that, tertiary recovery sensitivity scenarios using polymer flooding were created to inspect each controlling parameter in the polymer properties. From these scenarios, a best-case scenario was determined based on the oil recovery. Thus, increase in oil viscosity decreases the recovery efficiency logarithmically. Therefore, increase in waxy content of oil has similar effect on oil recovery.

At the end of the study, it was determined that it is possible to apply polymer flooding at the specified oil field. It is recommended to conduct lab experiments to back up the results obtained from the simulation software.

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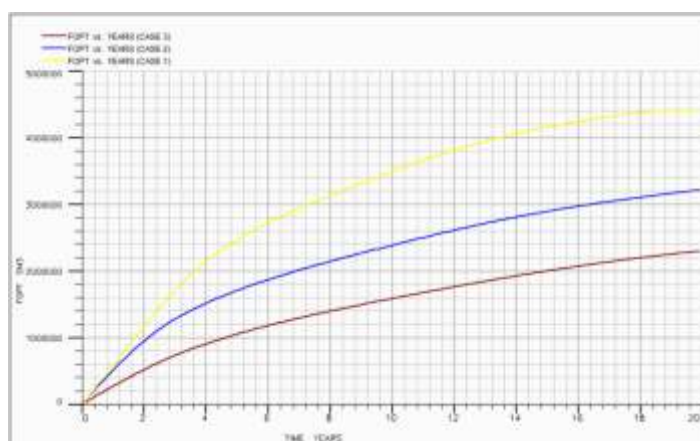


Fig.1: FOPT as a function of time for all the cases of oil viscosity sensitivity studies

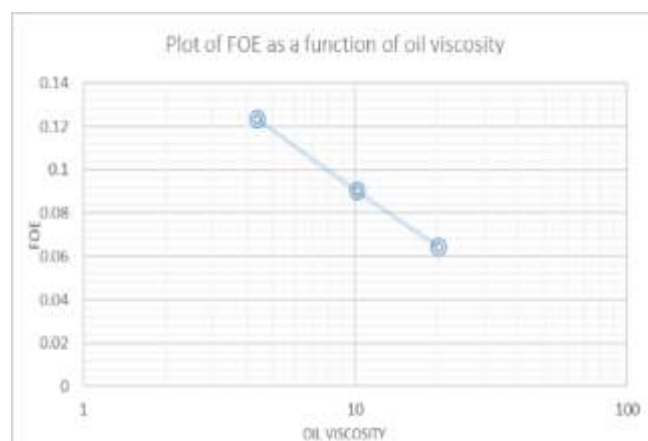


Fig.2: Plot of FOE from simulation against oil viscosity

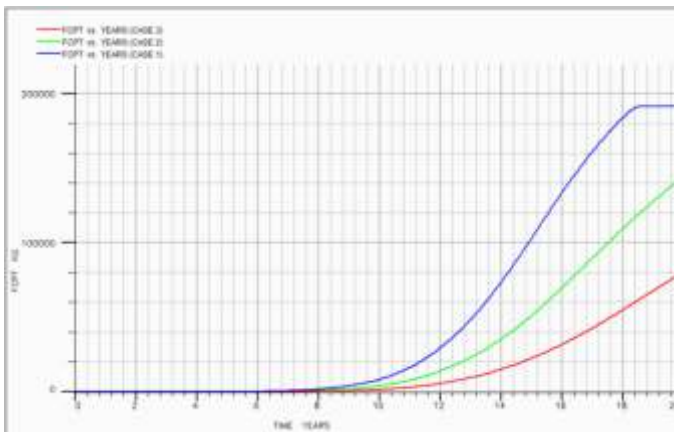


Fig. 3: Plot of FCPT against time for all the three cases sensitivity

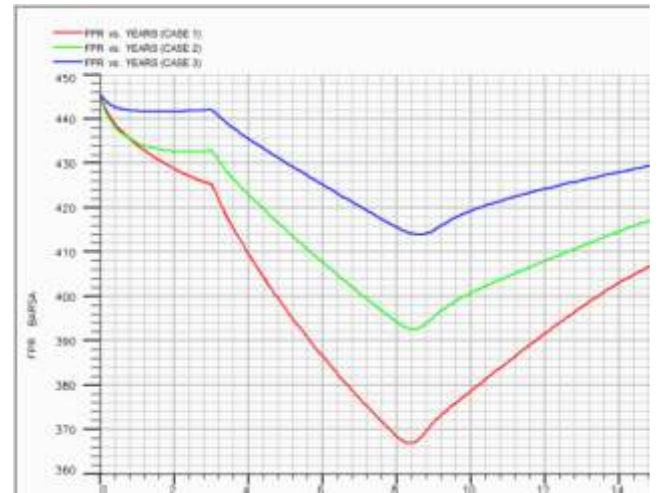


Fig. 4: Plot of FPR as function of time for all the three cases

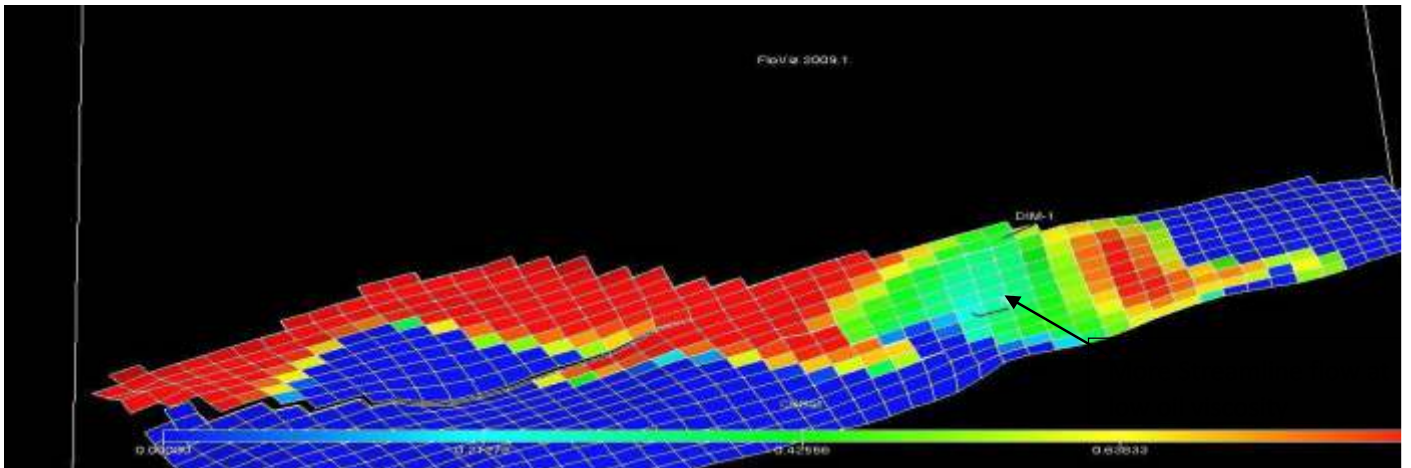


Fig. 5: Floviz image of layer 4 showing effect of streamline flow on FCPT

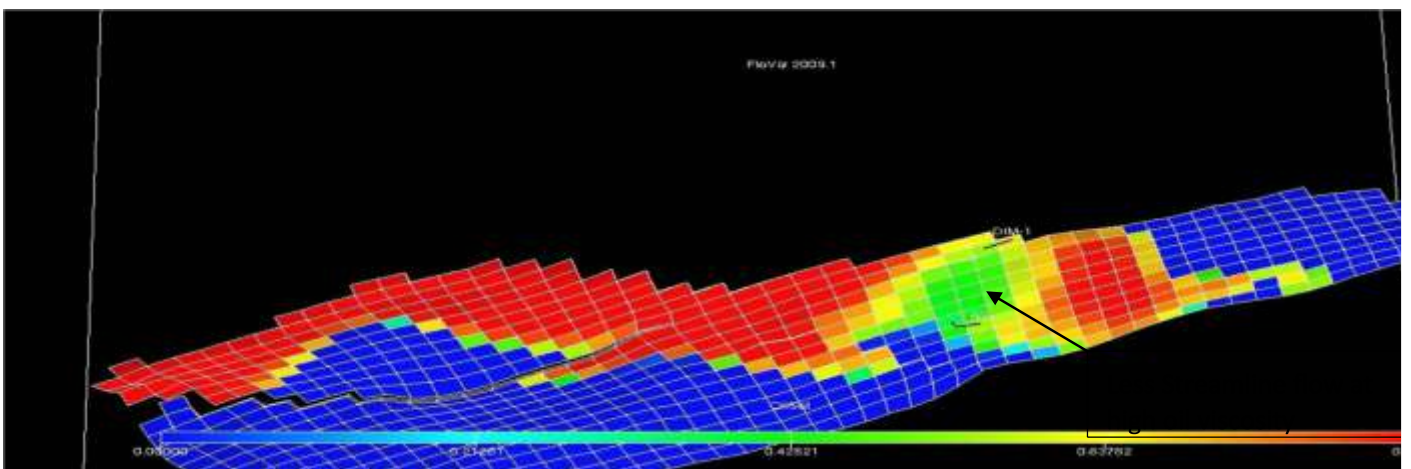


Fig. 6: Floviz image of layer 4 showing effect of streamline flow on FCPT

Do Materials Properties have Effects on the Performance and Reliability of Reflectorless Total Station?

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Abstract

This research studied the effect of selected materials and colours on the performance and reliability of South reflectorless Total Station (NTS 372), especially in relation to the quality of distance measurements. This was done by taking the horizontal distance measurements to the reflector as 'true value' to check the reliability and performance of reflectorless measurements. Pre-laboratory tests (density, hardness, uniaxial compressive strength and mineral compositions) were carried out on the rock samples that were used to replace the reflector during distance measurement with reflectorless mode. The results show that the density ranges between 2.51g/cm³ and 2.77g/cm³, the rebound hardness between 27.5 MPa and 51.0 MPa and the UCS (uniaxial compressive strength) between 46 MPa and 160 MPa. The rock samples used have the following mineral compositions; feldspars, plagioclase, quartz, orthoclase, calcite, dolomite and minor amounts of mafic minerals, such as biotite and hornblende. The analysis of the results of horizontal distance measurements show that all the readings fall within the upper and lower limits of the reflector readings. This shows that materials and colours have little or no effects on the performance of the South reflectorless total station used.

Keyword: Distance Measurement Performance Reflectorless Reliability Total station

1 Introduction

In everyday scientific and professional activity of surveying operation, the surface distance measurements are very important part in applied science for the measurement of a wide range of complex technical projects. The rapid technological development of surveying instruments allows the development of new alternative methods of distance measurements based on the possibility of measurement without using a prism reflector, which is very useful and even necessary in some cases, especially in difficult and complex mine environment or inaccessible mining area (Amann *et al.*, 2001, Fidera *et al.*, 2004, Lambrou and Pantazis, 2006).

Total station has been widely applied in engineering and industrial surveying systems to measure distances and angles automatically (Xia *et al.*, 2006). On a small scale and a local coordinate system, the use of a total station is more superior to other surveying precision and flexibility. The use of total station surveying

instrument for monitoring structural movement with good results have been reported by Radovanovic and Teskey (2001), Hill and Sippel (2002), Zahariadis and Tsakiri (2006), Alade (2018), Eteje, et al., (2018), Zhou, et al., (2020) and Pehlivan (2021). Distance measurement is the most fundamental of all surveying operations. Several methods of distance measurement are available; the preferred method depends on the level of accuracy required in the measurement. Surveyors have used various means to measure distance between two points in the past, such as parts of the human body, pacing, odometer, tachometry (stadia reductions), chains, measuring tapes and electronic distance meter (EDM). However, no matter which method is used, there are only three basic types of distance that can be measured: slope distance, horizontal and vertical distance. The slope distance can be measured directly; the horizontal and vertical distances are not measured directly, but derived from projections on the horizontal or the vertical

planes. The factors that determine which distance is required depend on the purpose of the survey work.

Five (5) successive distance measurements were carried out on different materials. This allows the reflectivity of laser beam when the material is aimed at an angle to be examined. The aim is to compare the value of the measured distance using a prism in each location with the one that was measured in the same position to the surface of each material and calculate their difference. This allows us to examine whether the difference in distance measurement between total station and material target, with and without reflector, is more or less than the permitted 95% confidence level according to the measurement accuracy given by the manufacturers.

2 Materials and methods

Rock samples were collected from three South Western States in Nigeria (Ondo, Ekiti and Oyo State) for laboratory tests. The rock samples were labelled R1 to R9. The rock samples were prepared in the Rock Mechanics Laboratory, Federal University of Technology Akure, Nigeria. The samples were also subjected to petrographic examinations.

(i) Thin section preparation

All the slides prepared from rocks samples as thin sections were studied. This was carried out by using polarizing microscope. A modal

analysis technique was used to determine the mineralogical composition of the rock samples. Three counts at different spots on a slide were taken and all the counts were added together for percentage calculation of each mineral based on the total number of all minerals present.

(ii) Density

Rock samples were weighed and recorded. Water was poured inside the cylinder and the volume were recorded as V_1 (cm³) and the sample was dropped in the water in the cylinder and the volume were recorded as V_2 (cm³). The difference in volume was calculated as $(V_2 - V_1)$ cm³. Density was calculated from Equation 1.

$$\rho = \frac{M}{\Delta V} \left(\frac{\text{g}}{\text{cm}^3} \right) \quad \dots 1$$

Where; ρ is density, M is mass in g and ΔV is the difference between the volumes in cm³.

(iii) Hardness Test

Hardness test was carried out using the Schmidt Hammer of type L for the determination of the hardness of in situ rock. The rebound value of the Schmidt Hammer was used as an index value for the intact strength of rock material. The measured values were arranged in descending order. The UCS values were estimated by using the chart named after International Society of Rock Mechanics (ISRM, 1985) as shown in Figure 1.

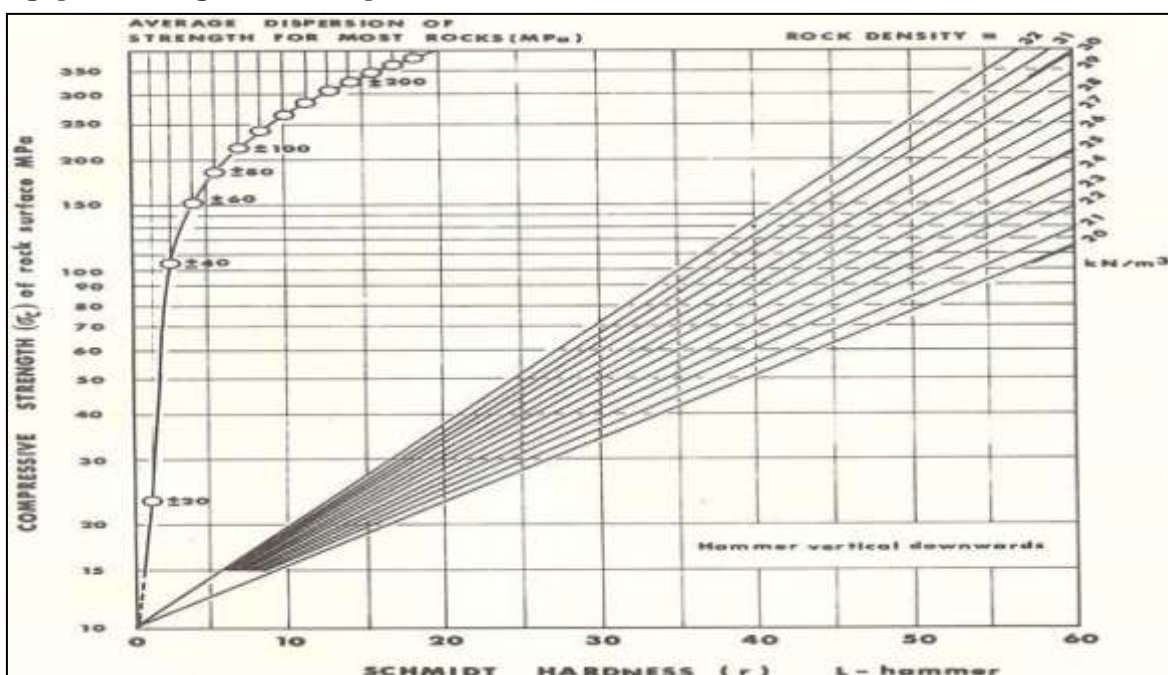


Figure 1: Correlation Chart for Schmidt (L) Hammer, Relating Rock Density, Compressive Strength and Rebound Number (ISRM; Deere and Miller, 1985).

(iv) *Methods of measurement using a total station*

The samples collected were used as a target after they have been processed to slabs of equal sizes. The experiment was carried out between the hours of 6am and 9am for 4 days in order to minimize the effect of atmospheric conditions on the readings. The procedure for each set of measurements is described as follows:

Step 1: The Total station and prism are mounted on a tripod stand. Observations were made to the prism target and the value was recorded.

Step 2: The prism was replaced with the prepared rock samples and materials of

different colours one after the other, while the step 1 is repeated.

Figure 2 shows the sketch of direct observation between the total station and the target. Measurements were taken to the materials at different vertical angles of 30°, 60° and 90° from the total station to the target (this is achieved by adjusting the zenith of the total station telescope to the desired angles i.e. a zenith reading of 90° means the telescope is horizontal, a zenith of 60° means the telescope is elevated 30° above the horizontal e.t.c.). All the targeted materials are placed at the same spot before distance measurements.

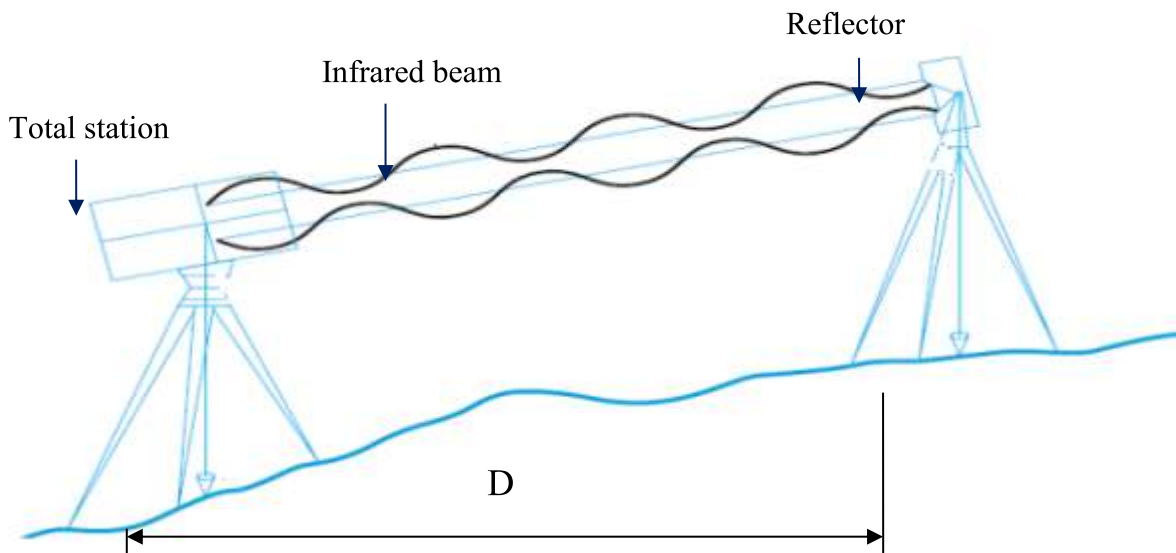


Figure 2: Sketch for direct observation between the total station and the target

The materials used are listed below and are of equal sizes.

(1) Iron; (2) Muscovite; (3) Coal; (4) Light brown Dolostone, R1; (5) Syenite, R2; (6) Limestone, R3; (7) Grey Limestone, R4; (8) Granite, R5; (9) Marble, R6; (10) Grey Limestone, R7; (11) Smoky Quartz, R8; (12) Granodiorite, R9; (13) Concrete; (14) Cement; (15) Pvc; (16) Wood; (17) Tile; (18) Plastic; (19) Glass; (20) Black; (21) Red; (22) Green; (23) Yellow; (24) Blue; and (25) White.

From Equation 2, ΔD is defined as the difference in the distance measurement with or without the use of reflector:

$$\Delta D = \beta_1 - \alpha_1 \quad \dots 2$$

where: β_1 is measurement with reflector and; α_1 is measurement without reflector.

According to the law of transmission errors:

$$\sigma \Delta D = \pm \sqrt{\sigma \beta_1^2 + \sigma \alpha_1^2} \quad \dots 3$$

In order for the difference in length (ΔD) to be eligible, it should be between the time intervals shown in equation 2:

$$z \sigma_{\Delta D} \leq \Delta D \leq z \sigma_{\Delta D} \quad \dots 4$$

Where; z is the critical value for confidence interval, $z = 1.96$ for linear control at 95% confidence level.

Horizontal distance measurements were determined when each of the target was placed at 50m, 100m, 200m, 250m and 300m to the total station. The distance readings were compared with the reflector mode which is considered as 'true distance' readings. Finally, the differences between the two values (i.e.

horizontal distance readings to reflector using infra-red mode and horizontal distance readings to material targets using reflectorless or red laser mode) were recorded for analyses. The lower limit (i.e mean - 3* standard deviation) and upper limit (i.e mean + 3* standard deviation) were determined using

distance measurements to the reflector.

3 Results and Discussion

3.1 Results of Laboratory tests

Table 1 shows the results of the modal analyses obtained from different rock samples and their percentage mineral composition.

Table 1: Result of modal analysis of rock samples (%)

Samples	Dolomite	Calcite	Quartz	Plagioclase	Orthoclase	Biotite	Hornblende	Feldspar
R1	9.8	90.2	0.0	0.0	0.0	0.0	0.0	0.0
R2	0.0	0.0	0.0	27.8	72.22	0.0	0.0	0.0
R3	31.11	68.89	0.0	0.0	0.0	0.0	0.0	0.0
R4	20.31	79.69	0.0	0.0	0.0	0.0	0.0	0.0
R5	0.0	0.0	0.0	20.9	7.4	23.9	25.4	0.0
R6	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
R7	60.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
R8	31.58	21.05	47.37	0.0	0.0	0.0	0.0	0.0
R9	0.0	0.0	55.0	20.0	25.0	0.0	0.0	0.0

From Table 1, samples R 1, R 2, R 3, R 4, R 7 are made up of two minerals each while samples R 5, R 8 and R9 are made up of three minerals each, with varying percentage compositions as shown in the table. Sample R 6 is made up of one

mineral – calcite (with 100% composition). This may be as a result of its weathered nature. Figures 3 to 11 show the photomicrographs of different rock samples.



Figure 3: Photomicrograph of light brown dolostone sample

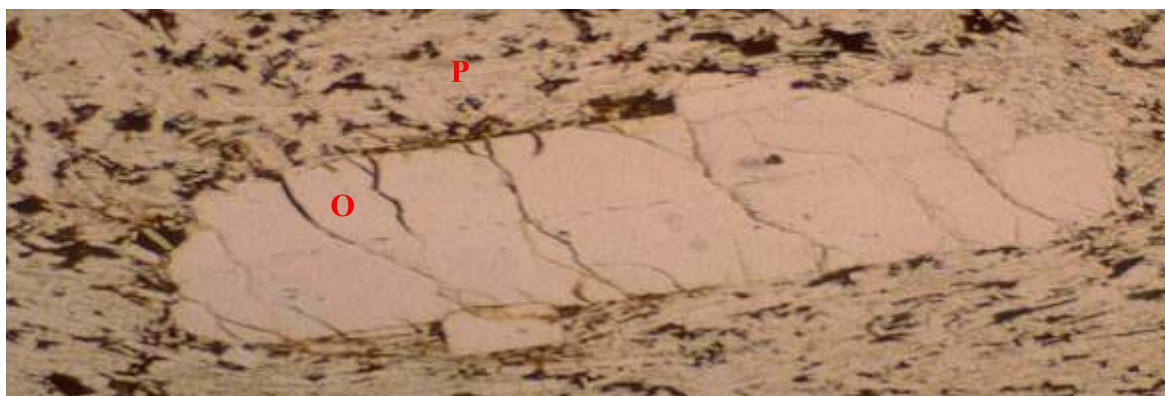


Figure 4: Photomicrograph of syenite sample

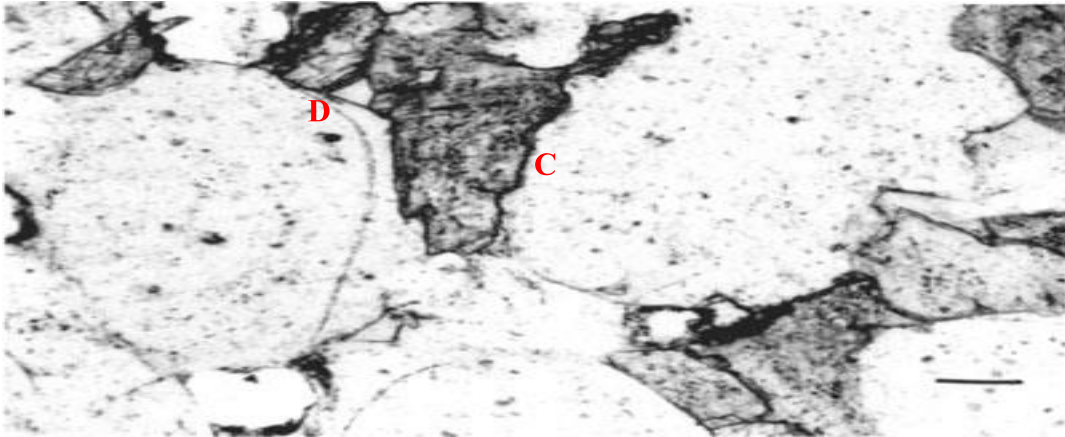


Figure 5: Photomicrograph of limestone sample

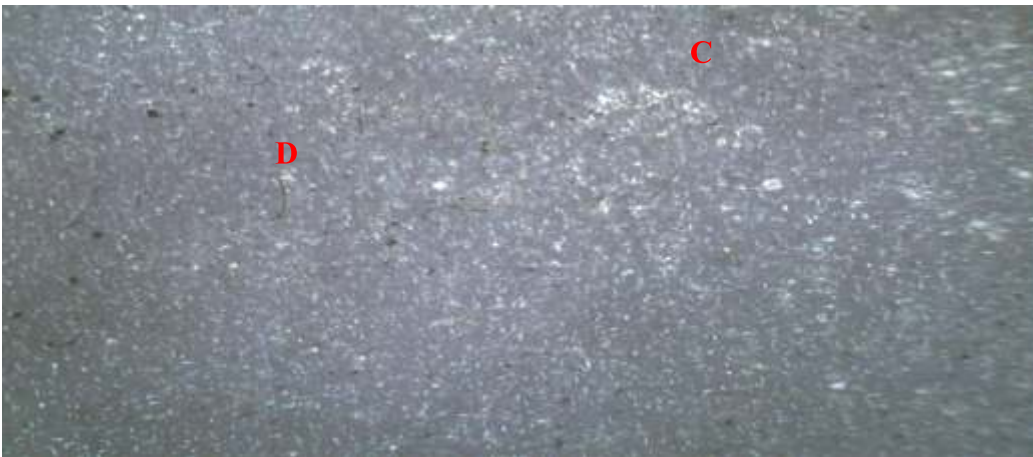


Figure 6: Photomicrograph of grey dolostone sample

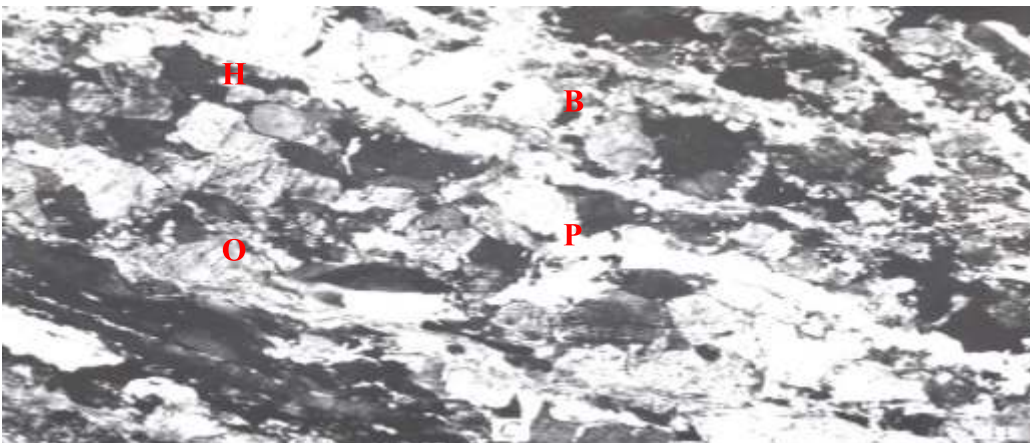


Figure 7: Photomicrograph of granite sample



Figure 8: Photomicrograph of marble sample

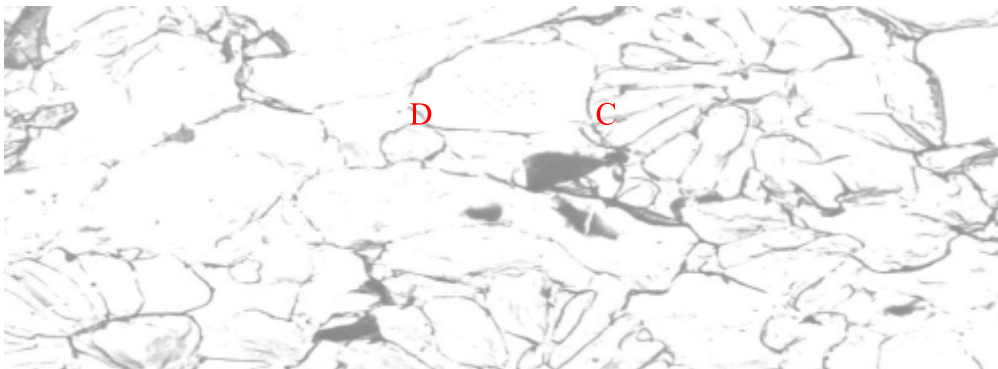


Figure 9: Photomicrograph of glass grey limestone sample

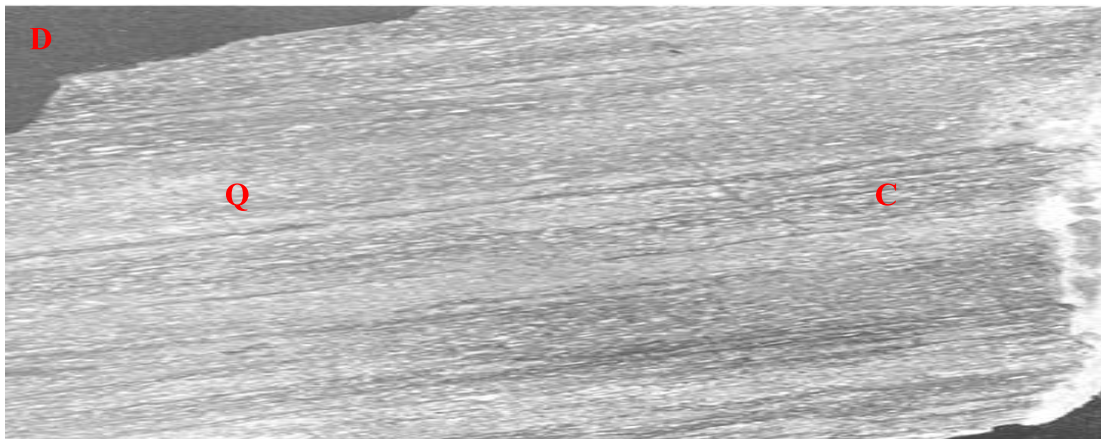


Figure 10: Photomicrograph of smoky quartz sample

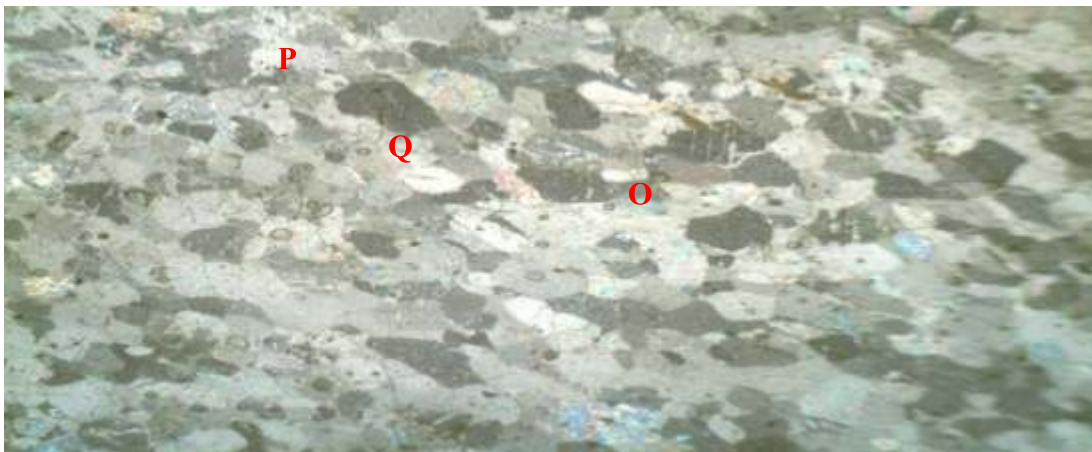


Figure 11: Photomicrograph of granodiorite sample

Figures 3 to 11 show the photomicrograph of the rock samples. Where D is dolomite, C is calcite, P is plagioclase, O is orthoclase, H is hornblend, B is biotite, and Q-is quartz. The main reason for this test is to determine whether the mineral

compositions of these rocks can affect the distance measurement to them using reflectorless mode of the total station. The figures further corroborate the results of modal analysis presented in Table 1.

Table 2: Pre- test carried out on the rock samples

Rock samples	Minerals present	Density [(g/cm ³)	Equivalent UCS (MPa)	Average rebound hardness value	Distinguishing characteristics	Rock classification* Deere and Miller's /ISRM.
Light brown Dolostone	Calcite and Dolomite	2.75	151	47.5	Coarse grain	High / very high strength
Syenite	Orthoclase, Plagioclase	2.67	152	51.0	Medium to coarse-grained	High / very high strength
Limestone	Calcite and Dolomite	2.56	108	45.5	Medium to coarse-grained	High / very high strength
Grey Dolostone	Calcite and Dolomite	2.51	95	43.5	Medium to fine- grained	Medium / high strength
Granite	Orthoclase, Plagioclase, Quartz, Biotite, Hornblend	2.77	160	49.5	Medium to coarse-grained	High / very high strength
Marble	Calcite	2.71	46	27.5	Coarse-grained	Low / high strength
Grey Limestone	Calcite and Dolomite	2.73	93	41.0	Coarse-grained	Medium / high strength
Smoky Quartz	Orthoclase, Plagioclase Quartz	2.62	110	43.5	Coarse-grained	High / very high strength
Granodiorite	Orthoclase, Plagioclase Quartz	2.69	152	50.0	Medium to coarse-grained	High / very high strength

Table 2 shows provide the results of the minerals, density, UCS, hardness test conducted with the aid of Schmidt hammer using Correlation Chart for Schmidt (L) Hammer, Relating Rock and classified according to Classification Table of Rock Hardness by (Attewell & Farmer, 1976). Density and UCS

were determined from the rebound hardness values using Figure 1. Results of distance measurements to the samples/materials using South Total Station NTS 372 to the various material targets are presented graphically in Figures 12 to 15

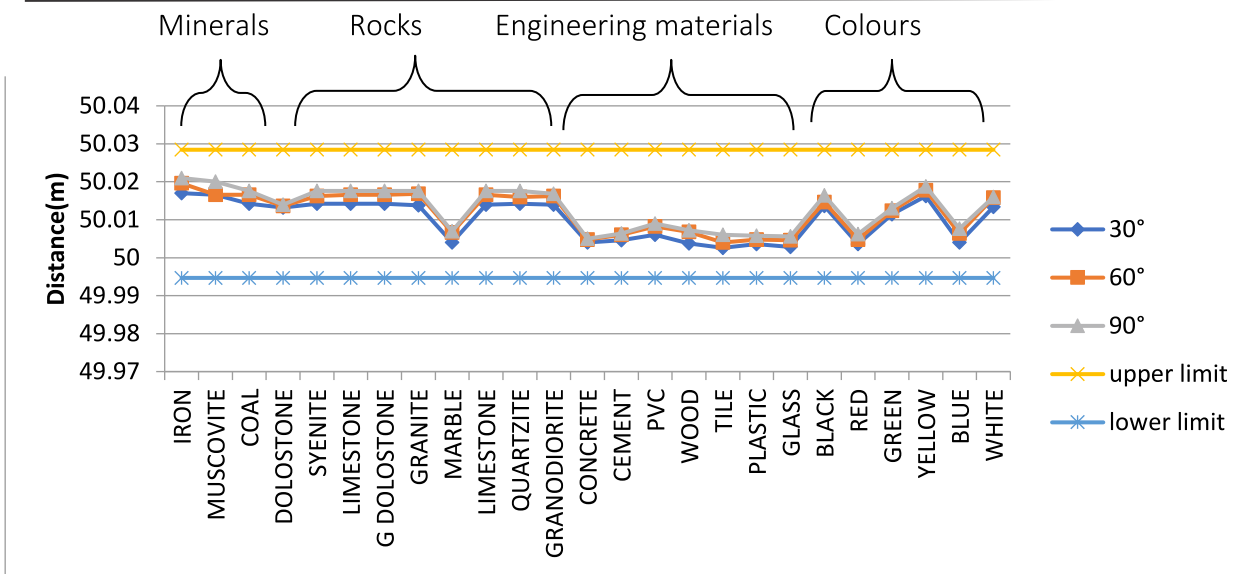


Figure 12: Graphs of HD measurements with NTS- 372 South Total Station at 50m.

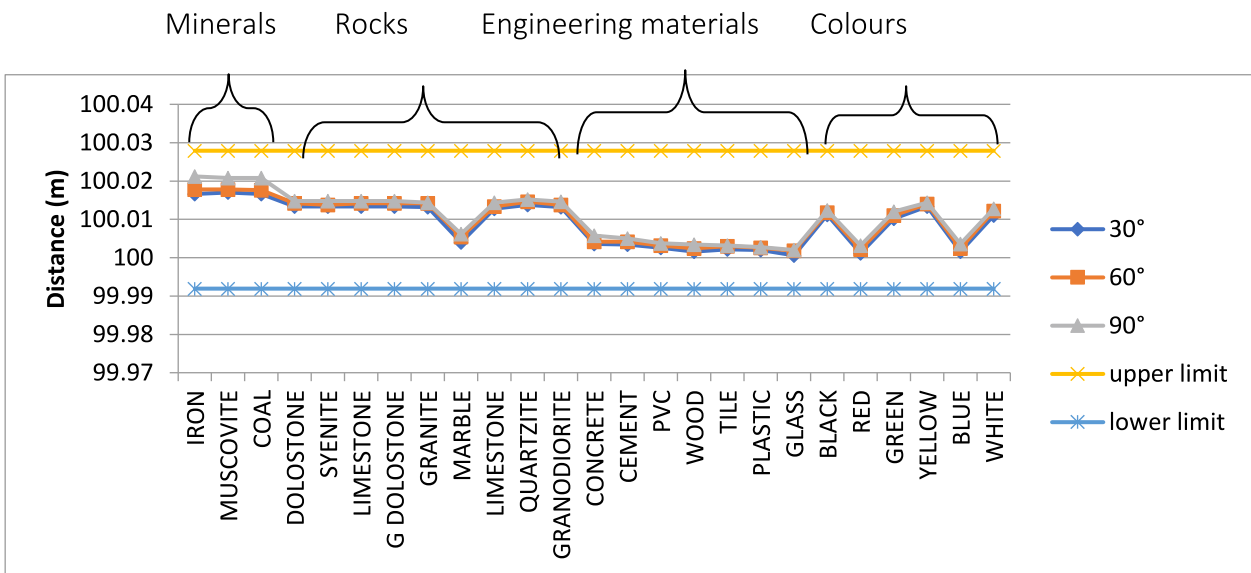


Figure 13: Graphs of HD measurements with NTS- 372 South Total Station at 100m.

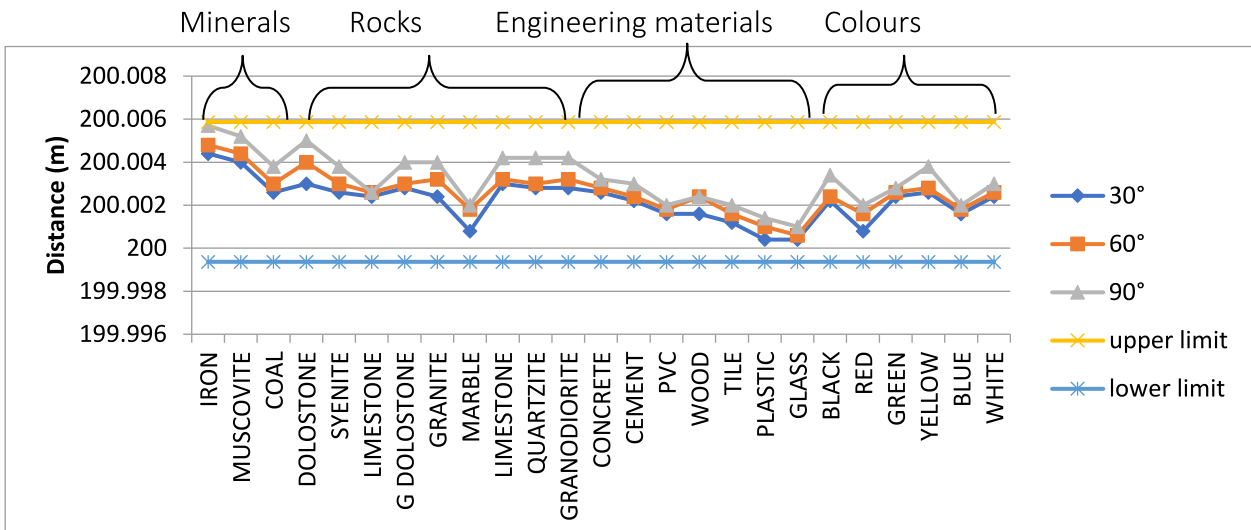


Figure 14: Graphs of HD measurements with NTS- 372 South Total Station at 200m.

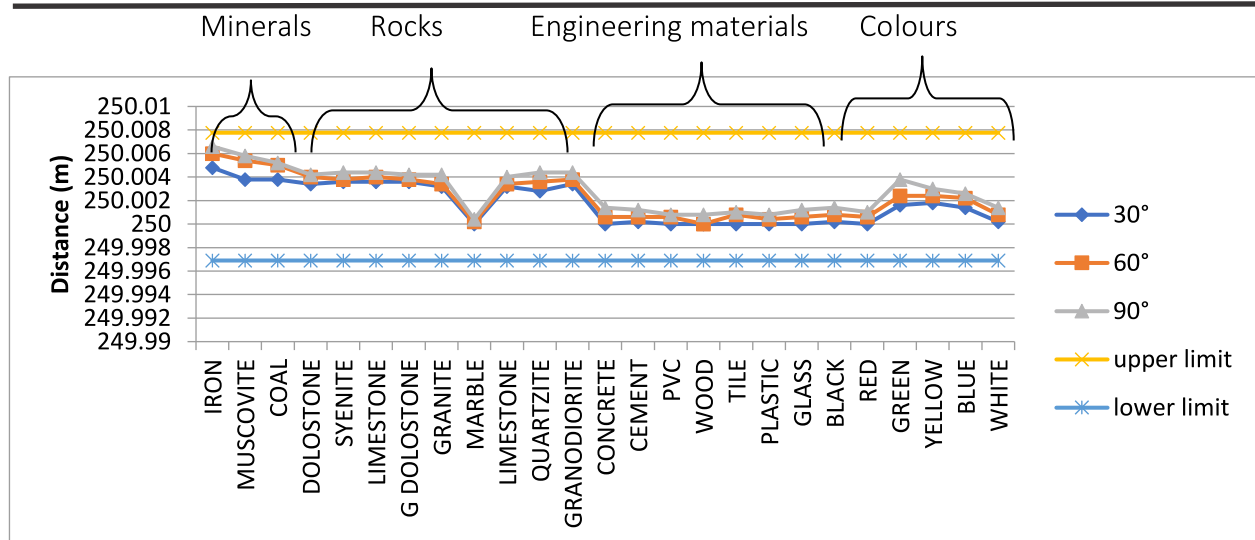


Figure 15: Graphs of HD measurements with NTS- 372 South Total Station at 250m.

The results of HD measurements with NTS – 372 South Total Station at 50m, 100m, 200m and 250 m to various material targets using relectorless mode as presented in Figures 12 to

15 show that all the readings are within the upper and lower limits of HD measured to prism targets using infrared mode.

Table 3: Further analysis on data acquired during HD measurement to establish the performance and reliability of the NTS - 372 South Total Station reflectorless mode.

Distance	50m			100m			200m			250m		
	ΔD , (mm)			ΔD , (mm)			ΔD , (mm)			ΔD , (mm)		
Materials	30 °	60°	90°	30°	60°	90°	30°	60°	90°	30°	60°	90°
IRON	-17	-20	-21.6	-16.6	-17.8	-21.2	-4.4	-4.8	-6	-4.8	-6	-12
MUSCOVITE	-17	-17	-20	-17	-17.8	-20.8	-4	-4.4	-5.2	-3.8	-5.4	-5.8
COAL	-14	-17	-17.6	-16.6	-17.6	-20.8	-2.6	-3	-3.8	-3.8	-5	-5.2
DOLOSTONE	-13	-14	-16.2	-13.4	-14.2	-14.8	-2.2	-4	-3	-3.4	-4	-4.2
SYENITE	-14	-16	-17.2	-13.4	-13.8	-14.8	-2.6	-3	-3.8	-3.6	-3.8	-4.4
LIMESTONE	-14	-17	-17.6	-13.4	-14.2	-14.8	-2.4	-2.6	-2.6	-3.6	-4	-4.4
DOLOSTONE	-14	-17	-17.6	-13.4	-14.2	-14.8	-2.8	-3	-3.6	-3.6	-3.8	-4.2
GRANITE	-14	-17	-17.6	-13.2	-14.2	-14.8	-2.4	-3.2	-4	-3.2	-3.4	-4.2
MARBLE	-0.4	-6.6	-7	-0.4	-5.4	-6.2	-0.8	-1.8	-2	0	-0.2	-0.4
LIMESTONE	-14	-17	-17.6	-12.8	-13.4	-14.4	-3	-3.2	-4.2	-3.2	-3.4	-4
QUARTZITE	-14	-16	-17.6	-13.9	-14.6	-14.2	-2.8	-3	-4.2	-2.8	-3.6	-4.4
GRANODIORITE	-14	-16	-16.8	-13.2	-13.8	-14.6	-2.8	-3.2	-4.2	-3.4	-3.6	-4.4
CONCRETE	-4	-4.6	-5	-3.6	-4.8	-5.8	-2.6	-2.8	-3.2	0	-0.6	-1.4
CEMENT	-4.6	-6	-6.4	-3.4	-4.2	-5	-2.2	-2.4	-3	-0.2	-0.6	-1.2
PVC	-6	-8.2	-9	-2.6	-3.2	-3.8	-1.6	-1.8	-2	0	-0.6	-0.8
WOOD	-3.8	-6.8	-7.2	-1.6	-2.4	-3.4	-1.6	-2.4	-2.4	0	0	-0.8
TILE	-2.6	-4	-6	-2.2	-3	-3.2	-1.2	-1.6	-2	0	-0.8	-1
PLASTIC	-3.6	-4.8	-5.8	-2	-2.6	-2.8	-0.4	-1	-1.4	0	-0.4	-0.8
GLASS	-2.8	-4.6	-5.6	-0.6	-1.8	-2	-0.4	-0.6	-1	0	-0.6	-1.2
BLACK	-14	-15	-16.4	-11.2	-11.8	-12.4	-2.2	-2.4	-3.4	-0.2	-0.8	-1.4
RED	-3.6	-4.8	-6.2	-1.2	-2.2	-3.2	-0.8	-1.6	-2	0	-0.6	-1
GREEN	-11	-12	-1.3	-10.2	-11	-12	-2.4	-2.6	-2.8	-1.6	-2.4	-3.8
YELLOW	-16	-18	-18.8	-13.4	-14	-14.4	-2	-2.8	-3.8	-1.8	-2.4	-3
BLUE	-4	-6.6	-7.6	-1.6	-2.4	-3.6	-1.6	-1.8	-2	-1.4	-2.2	-2.6
WHITE	-13	-16	-16.2	-11	-12.2	-12.8	-2.4	-2.6	-3.2	-0.2	-0.8	-1.4

Table 3 reveals that the impacts were more pronounced at distances of 50m and 100m (as shown in the green highlight). The values obtained are more stable and closer at varying angles. It was found that highly reflective surfaces (such as polished surfaces) from close proximity have effects on the reliability of the resultant measurement. This may be the reason while different surfaces produced varying results with respect to the angle at which the measuring signal strikes the sample surface. Despite the variations, the study indicated that all the readings fall within the upper and lower limits. This is an indication that materials surface and colours have little effects on the performance and reliability of NTS-372 reflectorless total station. This test revealed the reliability and sensitivity of the total station used in the data collection method. It also helped to ascertain how much variation or dispersion is the horizontal distance readings from the average horizontal distance reading (i.e. the mean).

Thus, according to the equation 3, $\sigma\Delta d = \pm 8.043$ mm and finally to accept a measure of confidence level of 95% where $z = 1.96$, $z \cdot \sigma\Delta D = \pm 15.764$ mm, lengths while >250 m, $\sigma\Delta D = \pm 5.8$ mm and $z \cdot \sigma\Delta D = \pm 11.368$ mm.

4 Conclusion

The study observed the effect of different materials surface on the performance of 'South' reflectorless total station. The results obtained indicated that materials and colour of samples displayed variations in their properties. These variations may be due to a number of factors, which include texture, colour, hardness, density, polished surface and mineralogy composition. The modal analysis showed that the rock samples composed of feldspars, plagioclase, quartz (felsic minerals), orthoclase, calcite, dolomite and minor amounts of mafic minerals, such as biotite, hornblende and etc. The results indicated that R6 has low hardness - 27.5 MPa while other rocks samples have medium to high hardness. The results of uniaxial compressive strength tests indicated that R6 has high strength (46 MPa); other rocks samples have high to very high strengths. The results of the analysis show that the value of density ranges

from 2.51g/cm^3 to 2.77g/cm^3 . The results of the horizontal distance measurements to the samples and materials surface revealed that the material properties have little or no effect on the performance and reliability of the reflectorless total station used (NTS-372 South Total Station) since all the horizontal distance readings fall within the upper and lower limits set up.

5 Recommendation

This experiment should be carried out using other brand of reflectorless total stations such as Leica, Tremble etc.

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Pipe Sticking during Hole Cleaning – A Review

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Abstract

Hole cleaning is one of the problems encountered in drilling operation. The challenge encountered in removing cuttings bed during drilling arises because of the interaction of the drilling fluid with cuttings in the cuttings bed to form a cuttings bed gel. When hydrocarbon is to be drilled, then bottom hole cleaning is taken into consideration as poor well hydraulics leads mostly to poor bottom hole cleaning. This paper intensely investigates the critical causes and effects of one of the most prevalent drilling issues caused by differences in pressure and eventually leads to pipe sticking in well drilling and hole cleaning. This study also presents a very simplified method to critically of reducing the chances of pipe getting stuck in drilled holes by the introduction of Nano-particles that alters the mechanical properties of the mud. In addition to the simplified method, Artificial Intelligence and conventional techniques are also discussed which enhances well stability and borehole control.

Key Words: Hole Cleaning, Viscosity, Cuttings, Drill Fluids and Nano-particles.

1.0 Introduction

Over several years oil industry is facing troubles associated with the stuck pipes. Differential pipe sticking is one of the stuck pipe mechanisms with a major impact on drilling efficiency and well costs (Toreifi *et al*, 2017). Stuck pipe is a major cost issue in some drilling in most drilling operations. Differential sticking is, for most drilling organizations, the greatest drilling problem worldwide in terms of time and financial cost. It is a condition, for which the drill string cannot be moved (rotated or pushed up and down) along the axis of the wellbore. Differential sticking typically occurs when high-contact forces caused by low reservoir pressure, high wellbore pressures, or both, are exerted over a sufficiently large area of the drill string. (Islam and Hossain, 2021).

Stuck pipe mechanisms are grouped into either mechanical or differential mechanisms. When a portion of the drill string casing or logging tool is embedded in a hard mud filter cake and held by significant differential pressure. Mechanical sticking of the tube occurs during drilling and is recognized when the lower hole assembly (BHA) cannot be rotated or moved due to hole debris. One of the primary technical issues in the drilling sector has been stuck pipe occurrences, which often result in a large amount of downtime and corrective expenses. The recent increase in drilling activity, shortage of experienced personnel and equipment, and drilling in higher-risks areas have increased the risk of stuck pipe events in all drilling operations (D'Amicis *et al*, 2023)

Poor hole cleaning can lead to drilled cuttings accumulation into the annulus causing stuck pipe. This problem can be more difficult when drilling deviated wells. The cutting beds can form on the low side of the well bore. It is common as rig site practice to pump sweeps and circulate bottom up before tripping out of the hole to avoid such situations. Increased torque and drag are indications of inappropriate hole cleaning and remedial actions have to be taken to remove the cutting beds by pumping sweeps. The sweeps program depends on the type of the well, high viscosity pill can be pumped when drilling vertical wells, whereas low viscosity and high-density pill can be used to clean high deviated wells. The use of pills has to be accompanied by rotating the drill string to create agitation to make cutting beds removal more effective.

The aim of this paper is to investigate the causes, effects, and solutions for differential pressure sticking and stuck pipes in borehole oil and gas drilling operations. Differential pressure sticking and jammed pipes are two of the most common problems encountered during oil and gas well drilling.

2.0 Pipe Sticking in Hole Cleaning

Drilling a well requires a drill string (pipe & collars) to transmit the torque provided at the surface to rotate the bit, and to transmit the weight necessary to drill the formation. The driller and the directional driller steer the well by adjusting the torque, pulling and rotating the drill string. When the drill string is no freer to

move up, down, or rotate as the driller wants it to, the drill pipe is stuck. Sticking can occur while drilling, making a connection, logging, testing, or during any kind of operation which involves leaving the equipment in the hole. (Bargach, 2001)

2.1 Types of Pipe Sticking

2.1.1 Differential Pipe Sticking

Differential pressure pipe sticking occurs when the drill string becomes embedded in a mud solid, filter cake, filter cake, usually across a permeable zone, and is held in place by mud pressure that exceeds the formation pressure. The occurrence of differential sticking can be diagnosed when the drill pipe cannot be rotated or moved up or down but unrestricted mud circulation is still possible. It has a major impact on drilling efficiency and well costs (Gray *et al.*, 1981; Hossain, 2015).

2.1.2 Mechanical Pipe Sticking

The fundamental principle of mechanical pipe sticking are the inadequate removal of drilled cutting from the annulus; borehole instabilities, such as hole caving, sloughing, or collapse, plastic shale or salt sections squeezing (creeping), and key seating.

This mechanism can occur due many reasons;

- Accumulation of drilled cutting
- Borehole instabilities
- Key seating

I. Accumulation of Drilled Cuttings

Poor hole cleaning can lead to drilled cuttings accumulation into the annulus causing stuck pipe. This problem can be more difficult when drilling deviated wells. The cutting beds can form on the low side of the well bore. It is common as rig site practice to pump sweeps and circulate bottom up before tripping out of the hole to avoid such situations. Increased torque and drag are indications of inappropriate hole cleaning and remedial actions have to be taken to remove the cutting beds by pumping sweeps. The sweeps program depends on the type of the well, high viscosity pill can be pumped when drilling vertical wells, whereas low viscosity and high density pill can be used to clean high deviated wells (Rizky *et al.*, 2023)

Borehole Instability

Depending on the weight of the mud and the composition of the mud, the shale can exfoliate or move plastically inward, causing the pipe to

become mechanically stuck. Another type of formation that can flow plastically if the mud weight is not high enough is salt. Also, using a low drilling fluid density can cause the hole to collapse and the tube to stick (Rizky *et al.*, 2023). An increase in pressure and torque are indications about borehole instability.

ii. Key Seating

Key seating is caused by creating a groove into the wall of wellbore when combining the rotation of the drill sting and applying side force on it. The lateral force tends to push the drill string against the wall causing mechanical erosion and creating what is called a key seat. Long bit runs may cause key seats and as good practice to avoid such problem is making wiper trips or using stiffer bottom hole assemblies in order to minimize high dogleg occurrence (Rizky *et al.*, 2023)

2.2 Effects of Pipe Sticking in Hole Cleaning

A stuck pipe can cause breaking or losing a part of the Drill String in the hole. Its result is very expensive. They include:

- Drilling time lost (working on the stuck).
- Cost & time spent on working on the fish (to retrieve the lost part of the Drill String or the Bottom Hole Assembly BHA).
- Loss of pipe in the hole as it is difficult or costly to retrieve it.
- Perform a sidetracking well which is also a waste of time and cost. (Pipe Sticking | Mechanisms, Preventive Actions and Freeing, 2022)

2.3 Primary Causes of Pipe Sticking in Hole

2.3.1 Inadequate Hole Cleaning

If the cuttings are not removed from the well properly, they will settle around the drill string, usually the bottom hole assembly (BHA), causing the drill collars to become stuck. The problem is worse in over gauge sections where the annular velocity is lower. Cuttings will build up and eventually slump in the hole. The cuttings are scraped by the stabilizers and the bit when the BHA is moved up the hole at a connection or a trip out. The over pull will increase until the cuttings will stick the BHA. The hole cleaning differs with the inclination of the hole. The annular velocity required to clean the hole increases with inclination.

2.3.2 Chemically Active Formations

Different formations have a different degree of absorbing water. It is thus important for a field engineer to understand the characteristics of the formations that have and will be drilled. Some high clay content rocks absorb water and swell. The amount of swelling varies from highly reactive “gumbo” (fast absorption rate) to shales, which absorb water very slowly. When drilling with water-based mud, the water is absorbed into these types of formations (Commonly shales), causing them to swell and weaken. As a result, chunks of shale will break-off and fall into the borehole. The water-absorbed (hydrated) shale tends to stick to the drill string and accumulate in sufficient quantities to fill the entire annulus around the BHA, causing it to become stuck.

3.0 Methodology

3.1 Methodology of Pipe Sticking Detection

3.1.1 Automation Approach

Careful monitoring of drilling and tripping trends is crucial to a successful drilling operation. The approach discussed in this paper discusses the real time detection of leading signs of stuck pipe incidents using the combination of pattern recognition in the drilling data and the physics of stuck pipe discussed earlier. These include Drilling Automation Approach. The options are to optimize drilling processes actively by controlling mud cake, reducing loss circulation by optimizing drilling fluids, improving hole cleaning efficiency. The automation approach however is consistent of the hardware and software. (Alshaikh et al., 2018)

3.1.2 Statistical Method

The method for warning of pipe sticking during drilling operations based on computing the third order moment, skew, of the stand pipe pressure (SPP) and correlate the skew with the normalized standard deviation of the torque (TRQ) signal has proposed. However, the SPP signal contains information related to the 'mud pressure throughout the entire circulating system. Consequently, increases in the SPP signal may be caused by wellbore mechanics unrelated to poor hole cleaning (e.g. fluctuations in the pressure drop across the mud motor and blocked nozzles in the drill bit (Gulsrud, *et al.* 2009).

3.2 Mitigation Methods

3.2.1 Using Nanoparticles to decrease Differential Pipe Sticking

An important way to reduce the chance of pipe sticking is to use nanoparticles in the excavation mud. This causes some changes in the properties of the mud. These nanoparticles are soot particles that are added to the drilling mud to perform some function. It is known that presence of ordinary materials in drill mud can cause increased viscosity and mud weight. This high mud weight can cause damage to sub-surface formations, plugging of production zones, hole erosion, decreased penetration rate, pipe failures, stuck pipe and lost circulation (BHI, 1998, Reid et al., 2000 and Njobuenwu and Nna, 2005).

In order to decrease probability of stuck pipe we make use of new materials in which do not increase viscosity and mud weight very much. Because as mentioned this increase in viscosity and mud weight may lead to some problems that one of them is stuck pipe. The advantage of carbon black which has Nanometer size particles causes to make a mud cake which is more continues and integrated (it means that mud cake has low permeability). So by having integrated and low permeability mud cake, we have less volume of filtrate and therefore mud cake thickness is less than usual cases.

3.2.2 Artificial Intelligence

This approach uses the combination of automation and human knowledge in mitigating drilling problems has been presented by Sadlier et al. (2013) and Ferreira et al. (2015). The model uses pattern recognition incorporated in an automated decision support tool. This tool provides real-time case-based reasoning to assess the risk and mitigate stuck pipe incidents in collaboration with an expert. The tool uses case-based reasoning (CBR) to match the real-time patterns with historical analogous cases where the same problem occurred. This allows providing automated recommendations for corrective actions based on the recognized patterns and the historical match. The experts are to collaborate in a timely manner with the decision support tool to provide guidance in mitigating the problem. The third approach published in the literature uses analytical models, such as torque and drag, or hydraulics models, in identifying potential drilling problems.

3.2.3 Conventional techniques of removing a stuck pipe

Industry accepted main conventional recovery methods include:

Rapid reduction of hydrostatic pressure through removing drill and mud solids with dedicated mud cleaners and centrifuges, and/or displacing the mud with lighter fluids such as treated water or Diesel, within the limits required for maintaining well control and borehole stability.

Spotting dedicated friction reducing lubricants or pipe release agents around the stuck pipe part, to break down the filter cake reducing the bond between cake and pipe.

4.0 Conclusion

In Conclusion, this work reviewed the causes, effects and controls of pipe sticking during hole cleaning. The study revealed that the transportation of cuttings during hole cleaning is critical in the highly-deviated and horizontal wells, due to the influence of gravity settling. In general, poor hole cleaning may result in stuck pipe, reduced ROP, transient hole blockage leading to lost circulation, excessive drill pipe wear, extra cost for special drilling fluid additives and wastage of time by wiper trip maneuvers. The drilling fluids with high performance and drill-string rotary are beneficial for hole cleaning.

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Reprocessing of Bukuru Cassiterite Tailings to Recover Titanium Oxide and Iron Contents for Metallurgical Applications

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Abstract

In mineral processing, complete separation of valuable minerals is not always attainable; hence the tailings most often contain valuables in them. Reprocessing of such tailings are desirable and may lead to economic results with enhanced techniques. The sample used in this work was sourced from Bukuru, Jos South Local Government Area of Plateau State. The sample prepared and analysed as the head sample revealed the constituents of 27.10%TiO₂, 32.31%Fe₂O₃, 25.1%SiO₂, 1.29%Nb₂O₃ and 1.83%MnO with others in traces such as CuO, ZnO, Ta₂O₅, V₂O₅, PbO etc. Therefore, beneficiation using magnetic separation technique the iron ore and titanium oxide were upgraded to 47.51% Fe₂O₃, recovery of 87.7% and 46.17%TiO₂, recovery of 69% respectively. The results indicated tailings to contain sufficiently high grade of iron ore for the production of pellets that could be utilized for iron and steel making. Titanium on the other hand has inherent properties as well as on the development of new alloys, possess resistance to corrosion. It is therefore recommended that value addition be extended to tailings by exploring its potentials for more economic gain.

Keywords: Reprocessing, tailings, value addition, cassiterite, magnetic separation.

Introduction

Mill tailings which still contain valuable components constitute a potential future resource. New or improved technologies can allow the value contained in tailings, which was lost in earlier processing as discard to be recovered, or commodities considered waste in the past can become valuable in a new economic order. Reducing or eliminating tailings dumps or dams by reprocessing them also reduces the environmental impact of the waste (Wills and Napien-Munn, 2006).

The cost of tailings reprocessing is sometimes lower than that of processing the original ore, because much of the expense has already been met, particularly in mining and comminution. This means that reprocessing is more energy efficient and the prices of products can come down. It also creates jobs, people are employ to collect, sort and work in recycling companies, and also get jobs with business that work with these reprocessing units (European Commission, 2004). Over the last century the volumes of tailings being generated has grown dramatically as the demand for minerals and metals has increased and lower grades of ore are being mined through advances in extraction and processing technology.

A typical instance is the East Rand Gold and Uranium Company (ERGO) which closes its operations in 2005 after 28 years of retreating over 870Mt of the iconic gold dumps of Johannesburg, significantly modifying the skyline of the Golden City and producing 250t of gold in the process. Although gold, tend to dominate the list of tailings reprocessing operations because of the value of the product, there are others, operating and being considered as potential major sources of particular commodities. For example coal has been recovered from tailings in Australia (Clark, 1997), uranium is recovered from copper tailings by the Uranium Corporation of India and copper has been recovered from the Bwana Mkubwa tailings in Zambia, using solvent extraction and electrowinning (Wills and Napien-Munn, 2006).

The magnetic collection of any specific material can be assessed in a straightforward manner in the laboratory. This cursory evaluation will conclusively determine if the material is a candidate for magnetic separation. As a minimum, bench scale magnetic separation testing should be conducted to determine the response of the specific mineral to a magnetic field. The selected mineral must respond appropriately to a magnetic field in order for

magnetic separation to be considered a process option. It is typically the case that the magnetic collection of the mineral is measured as a function of magnetic separation. Several laboratory separators exist for the quantification of magnetic collection of minerals (Andrew et al, 2002).

For all practical purposes magnetic separator selection can be reduced to the decision tree illustrated in Figure 1. The first node indicates

that the mineral will be treated as either a slurry or as dry and free-flowing. The second node indicates the magnetic field magnetic field strength necessary for effective separation (Andrew et al, 2002).

Therefore, findings of this research will be beneficial for detail design for Bukuru cassiterite waste recycling and navigate the area of its metallurgical applications.

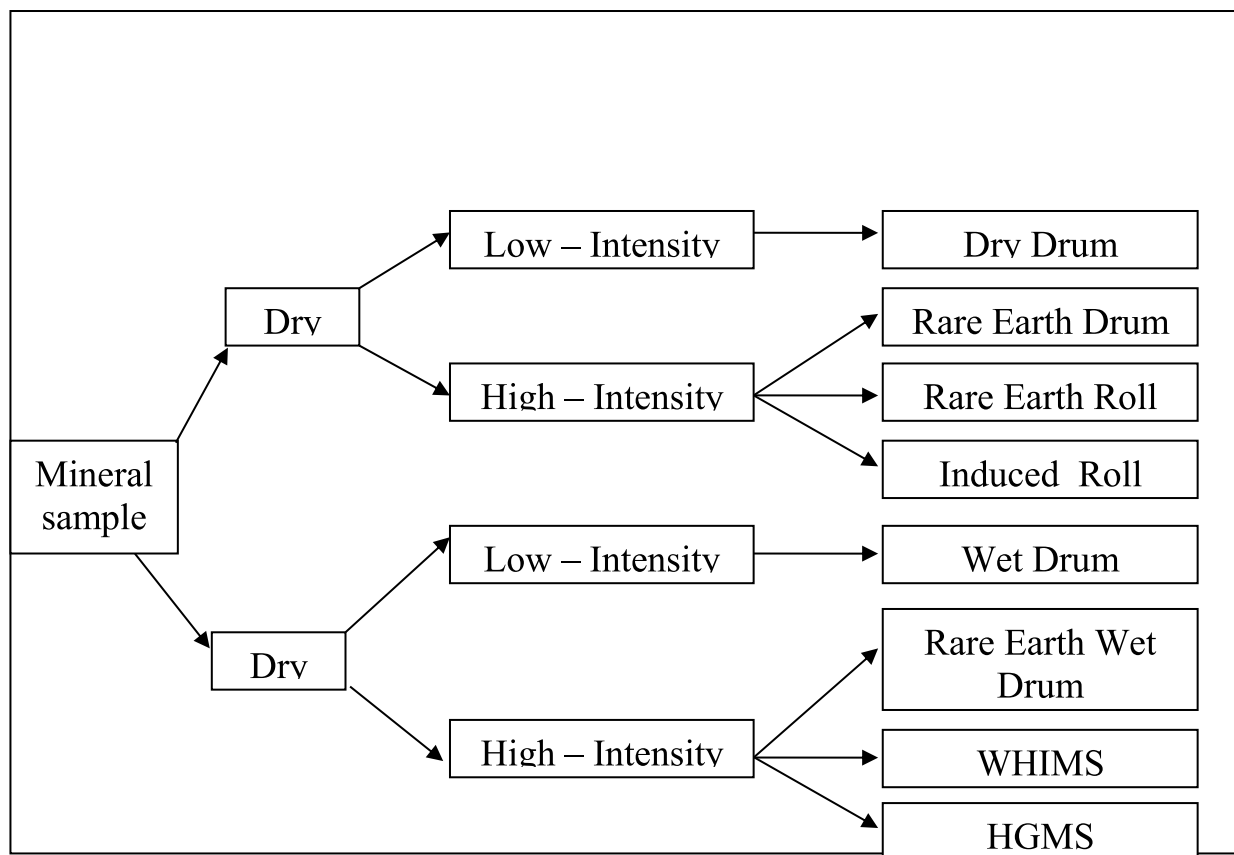


Figure 1: Magnetic Separation Decision Tree (Andrew et al, 2002)

Materials and Methods

Sample Collection

The sample used in this research work was obtained from the main bulk at Bukuru cassiterite tailings dumps area randomly. 50kg of sample collected was taken as representative of the bulk material.

Sample Preparation

The obtained sample from the field further underwent sample division techniques known as coning and quartering in order to have representative and desired quantity (head sample) This was screened by using laboratory

sieve shaker to the range of -355+250µm.

Magnetic Separation

500g sample of the magnetic ore of -355 + 250µm sieve size was subjected to magnetic separation using the magnetic separator, loaded into the machine hopper then passes through the vibrating plate to the rotating drum with vibration feeder controller turned on at 6VF, thereby exposing all the particles before separations. Both the concentrate (magnetic particles) and tailing (non-magnetic particle) collected in different containers. The products then analyzed using XRF.

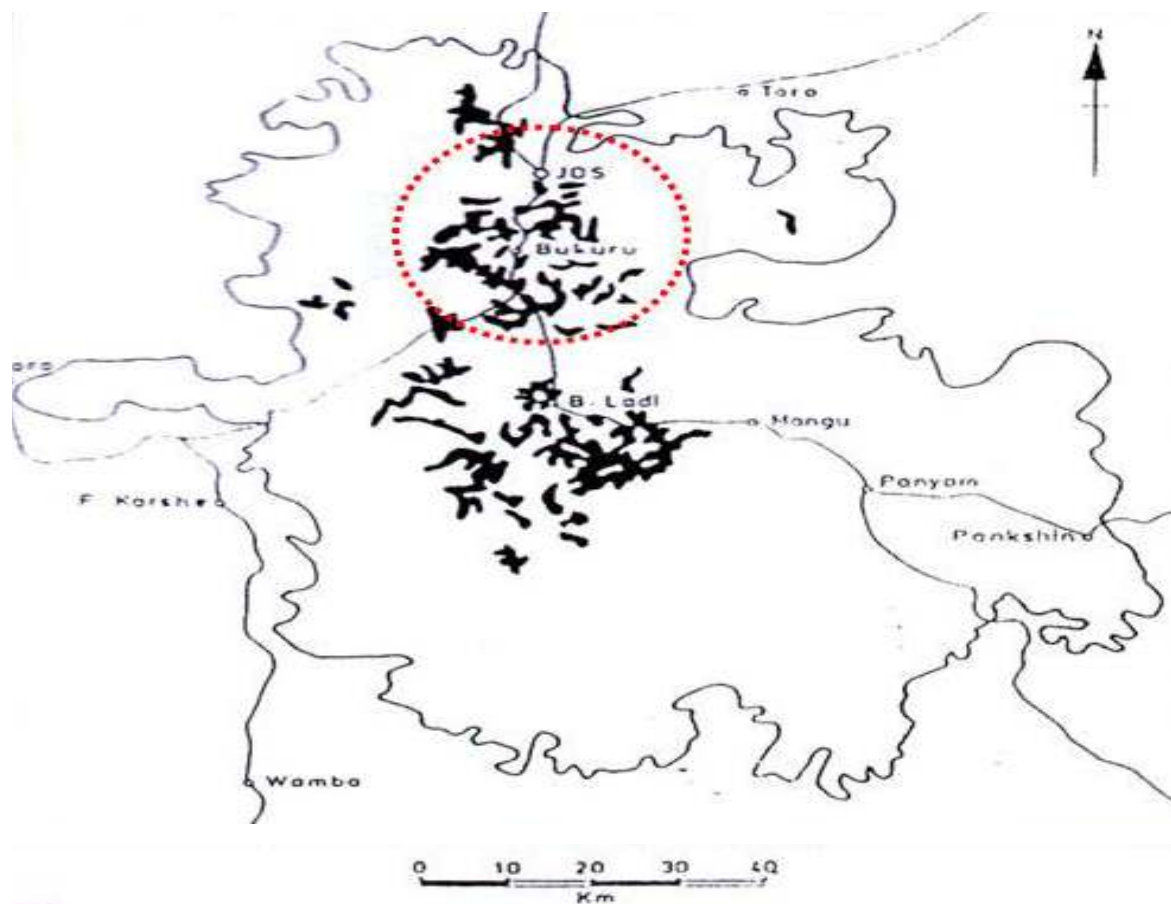


Figure 2: The Mining Areas in Bukuru- Jos. (Jiya and Musa, 2012)

XRF Analysis

The chemical analysis of the sample was carried out on the head sample and the products (Concentrate and tailings), using XRF.

Results and Discussion

The chemical analysis of the dumped resource tailings used as head sample revealed that the resource tailings material contains 25.1% SiO_2 , 1.29% Nb_2O_3 , 32.31% Fe_2O_3 , 27.10% TiO_2 , 1.83% MnO with CuO , ZnO , Ta_2O_5 , V_2O_5 , PbO etc. as trace mineral compounds. Hence, 25.1% SiO_2 , 32.31% Fe_2O_3 , 27.10% TiO_2 as the major components. Therefore, magnetic separation technique was used to recover titanium oxide of 201.73g by weight, while iron oxide weight 298.27g reported as magnetic particles, upgraded to 46.17% TiO_2 and 47.51% Fe_2O_3 respectively. The result reveal that the tailings after reprocessed the grade obtained can be classified as a moderate grade that could be used for metallurgical purposes such as pellets

production required for DRI process of iron and steel making and Blast furnace process route (Abubakar et al, 2009). While on the other hand, titanium has inherent properties on the development of new alloys that pose resistance to corrosion.

Conclusion

Cassiterite tailings was sourced from Bukuru tailings dumps, Jos South Local Government Area of Plateau State. The tailings analyzed and the contents revealed 32.31% Fe_2O_3 and 27.10% TiO_2 . After successful beneficiation by magnetic separation technique the iron ore and titanium oxide were upgraded to 47.51% Fe_2O_3 , recovery of 87.7% and 46.17% TiO_2 , recovery of 69% respectively.

The government needs to be aware that, other more advanced countries have most times taken advantage of our ignorance to short-change the country and reap more value for a mineral that must have been sold as one

component mineral, but with trace elements even of more tremendous value than the main minerals.

Recommendation

It is therefore recommended that value addition be extended to tailings by exploring its potentials for more economic gain.

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Rate of Penetration Prediction using Mathematical Drilling Models (A Case Study of Niger Delta Formation)

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Abstract

The rate of penetration (ROP) prediction is one of the most important factors in improving drilling efficiency and minimizing drilling cost. Mathematical drilling models provide a technique to predict and control drilling process. The prediction of rate of penetration using well data from an exploratory well in Niger Delta has been conducted. Three models were assessed with various degrees of precision. The predictive accuracy of the models was confirmed by comparison with actual ROP data and calculation of Mean Absolute Percentage Errors. The B & Y's model presented the best matches with the actual ROP data in comparison to the other two models used in the study, with a Mean Absolute Percentage Error of 25%. The Bingham's model, followed closely with good matches with the actual ROP data with a Mean Absolute Percentage Error of 35%. Conversely, Maurer's model showed a great degree of discrepancy with the actual data by over-predicting the ROP across the total well depth, thereby yielding a Mean Absolute Percentage Error of 3188%. The outcome shows that B & Y is the best model for ROP prediction in the Niger Delta sedimentary basin going by its low Mean Absolute Percentage Error while Maurer's model is the least accurate. The model can forecast ROP as a function of several drilling parameters such as WOB, RPM, Mud weight, SSP, Torque, flow rate etc. with a sufficient precision.

Keywords: Drilling Efficiency; Rate of Penetration; Burgoyne and Young Model; Exploratory Well; Maurer's model; Bingham's model; Maurer's model.

1.0 Introduction

Rate of penetration (ROP) is the speed at which the drill progresses to the ground layers, which is usually expressed in units of feet per hour (Al-Abduljabbar, et al., 2018). ROP prediction before drilling provides a means of improving overall drilling efficiency, minimization of drilling time and by extension reduction of drilling cost. Several models are applied in the oil and gas industry today, however most of these models contain inadequate drilling parameters leading to inaccurate predictions of penetration rates.

In order to drill a well, three factors have to be established together. Weight on Bit(WOB), Rotation Per Minute(RPM), Torque(T) on First of all, a certain load has to be applied on the bit, and this is known as the WOB. WOB can be achieved by the rig hoisting system by slacking some weight of the drill string against the hole being drilled. The drill string rotation speed by the rig rotary equipment, such as the top drive or the kelly in older rigs, is measured in RPM. The action of WOB and drill string rotation generates a torque (T) as a result of the interaction between

the drilling bit and the drilled formation in addition to friction with the wellbore wall. Finally, a drilling fluid has to be circulated within the wellbore and using the rig circulating system to clean the wellbore and cool the drill bit at circulation rate (Q). Surface pressure is generated at the stand pipe against any pressure losses during the mud circulation (friction, hydrostatic, drill bit nozzles ΔP , etc.). This pressure is known as stand pipe pressure (SPP). The combination of many drilling parameters, such as WOB, drill-string rotation, torque, mud circulation rate (Q), bit type, and bit hydraulics, defines the performance of the drilling operation. Usually, the main objective of a successful drilling operation is to improve efficiency of these parameter by increasing ROP and make the operation cost-effective.

The high costs of drilling operations have led to a significant focus on the reduction in operation time and spending costs (Abbas *et al.*, 2019). The rate of penetration (ROP) is significant in improving the drilling process of a well so that it can be accurately estimated to provide better

planning of future well drilling and drastically minimize the additional costs.

2.0 Mathematical Drilling Models

Mathematical drilling models provide method to predict and control drilling process and minimize drilling cost. Drilling models also provide a means of recognizing unusual effect when the observed but performance deviate from prediction rate, (Malik, 2017). Some of these models are Burgoyne and Young (B&Y), Mechanical Specific Energy (M.S.E), D-exponent, modified D-exponent, Cunningham, Maurer, Bingham, Moore, Warren Motahari etc.

2.1 Burgoyne and Young (B&Y) Drilling Models

B&Y drilling model is the most complete mathematical that has been used for rolling cutter bit. In 1973, B&Y suggested a drilling model considering the effect of several drilling variables on the rate of penetration. (Eten, 2015).

D = true vertical well depth [ft]

gp = Pore pressure gradient [lbm/gal]

ρc = equivalent circulating density

$\left(\frac{w}{db}\right)_t$ = threshold bit weight per inch of bit diameter at which the bit begin to drill 1000lbf/inch

h = fractional tool dullness

f_j = hydraulic impact force beneath the bit force beneath the bit lbf

a_1 to a_8 = constant that must be chosen base on local drilling conditions

f_1 function represent the effect of formation strength and bit type on penetration rate.

f_2 = function accounts the rock strength increase due to normal compaction with depth.

f_3 function model effect of under compaction experienced in abnormal pressure formation.

f_4 = function model the effect of bit weight and rotary speed on penetration rate.

f_5 & f_6 = function model the effect on bit WOB & RPM on penetration rate.

f_7 = function models the effect tooth wear.

f_8 = function models the effect of bit hydraulics on penetration rate.

h = fractional tool dullness

F_j = hydraulic impact force beneath the bit force beneath the bit lbf

The constant a_1 through a_8 can be computed using past drilling data obtained in the area when drilling data is available.

2.2 Bingham Model

The Bingham model is one of the early models. Based on laboratory studies, the following mathematical equation was proposed. This simplistic model ignores the depth of the formation and assumes that the threshold bit

In this model the effect of the parameters such as WOB, RPM, Bit tooth wear and other assumed to be independent of one another. (Eten, 2015).

$$R = (f_1)(f_2)(f_3)(f_4) \dots (f_n) \quad \dots 1$$

$$f_1 = e^{2.303a_1} = k \quad \dots 2$$

$$f_2 = e^{2.303a_2(10000-D)} \quad \dots 3$$

$$f_3 = e^{2.303a_3D^{0.69(gp-9.0)}} \quad \dots 4$$

$$f_4 = e^{2.303a_4D(gp-pc)} \quad \dots 5$$

$$f_5 = \left[\frac{\left(\frac{w}{db}\right) - \left(\frac{w}{db}\right)_t}{4 - \left(\frac{w}{db}\right)_t} \right]^{a_5} \quad \dots 6$$

$$f_6 = \left(\frac{N}{60} \right)^{a_6} \quad \dots 7$$

$$f_7 = e^{-a_7h} \quad \dots 8$$

$$f_8 = \left(\frac{F_j}{1000} \right)^{a_8} \quad \dots 9$$

weight is negligible. As a result, the ROP predictions are frequently unreliable. ROP is a function of the applied WOB, bit size, and rotational speed, according to the Bingham model. Mathematically:

$$ROP = K \left[\frac{WOB}{Db} \right]^a N \quad \dots 10$$

where,

'k' is the proportionality constant that accounts for formation strength.

'a' is the bit weight exponent.

'WOB' is the applied weight on bit.

'Db' is the bit diameter and

'N' is the rotary speed.

Notice that the value of both 'k' and 'a' varies from one field to another. Hence, they must be determined empirically using multiple regression and curve fitting. The values of 'K' and 'a' are 0.18 and 0.38.

2.3 Maurer Model

Maurer devised his "perfect-cleaning hypothesis" of rotary drilling in 1962, which he used to forecast the ROP while utilizing roller cone bits. This model assumes flawless drilling cleaning, that is, that all drilling cuttings are eliminated between tooth bits. Maurer developed a model that is based on two observations.

- The crater volume (Vc) is proportional to the square of the depth of penetration (X) for craters made by wedge-shaped chisels: $Vc \propto X^2$.
- The depth of penetration (X) is inversely

proportional to the drill ability strength of the rock (S) if constant force is applied on the tooth: $X \propto 1/S$.

$$R = K \frac{N * (W - W_o)^2}{D^2 * S^2} \quad \dots 11$$

$$K = \left[\frac{R}{\left(\frac{N * (W - W_o)}{D_b^2 + S^2} \right)} \right] \quad \dots 12$$

3.0 Methodology

Rate of penetration prediction was executed in this research using three (3) selected mathematical drilling models which include: Burgoyne and Young, Maurer, and Bingham, drilling models. Two (2) well data in Niger Delta Basin were collected from Nigeria Petroleum Development Company (NPDC), a subsidiary of Nigeria National Petroleum Company (NNPC) in year 2020. The data majorly consisted of drilling parameters such as well depth, rate of penetration, weight on bit, flow rate, rotation per minute, torque, bit diameter, stand pipe pressure, etc. These parameters are analyzed using the above-mentioned selected models. Well depth from 1000ft to 9000ft at 200ft interval was selected for this analysis for both Wells. The tools used for the research were Microsoft office Excel and Statistical Package for Social Science (SPSS).

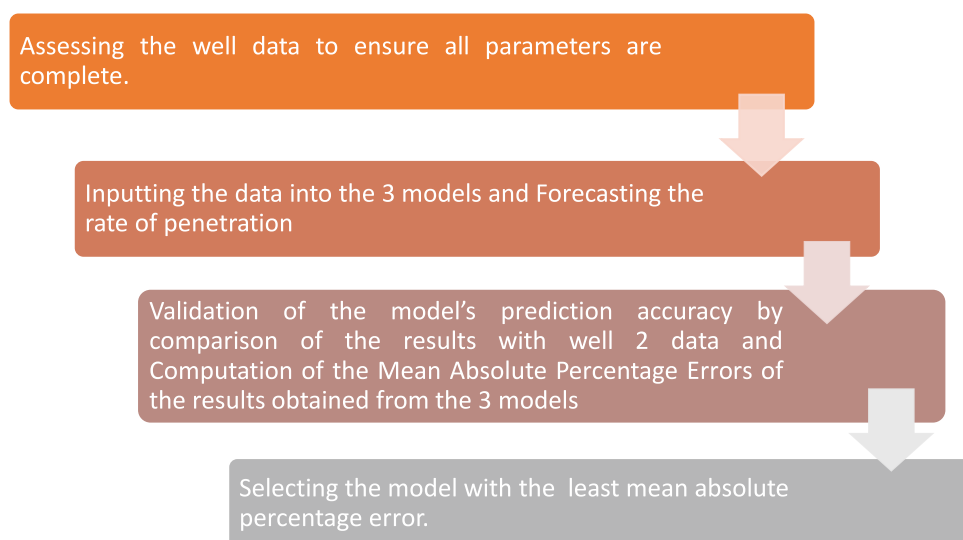


Figure 1: Schematic steps for the work

3.1 ROP Modeling

a. B & Y Model

In this model there are some unknown parameters co-efficient which must be determined based on past drilling data obtained from a field in order to determine the unknown parameters, a linear regression technique will be applied which as follows.

$$Y = \alpha_0 + \alpha_1\beta_1 + \alpha_2\beta_2 + \alpha_3\beta_3 + \alpha_4\beta_4 + \alpha_5\beta_5 + \alpha_n\beta_n \quad \dots 13$$

Where Y is the dependent variable, α_0 is the intercept term and the regression co-efficient $\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n$ are the analogues of the shape of linear regression.

From the above equation Y is the ROP; relevant drilling parameters will make up the regression

$$ROP = \alpha_0 + \alpha_1WOB + \alpha_2FR + \alpha_3RPM + \alpha_4TRQ + \alpha_5Bd + \alpha_6SSP \quad \dots 14$$

Table 1: Coefficients to be employed in the work

coefficients	α_0	α_1	α_2	α_3	α_4	α_5	α_6
B & Y	309.5	0.036	-0.002	0.212	0.017	-4.891	-0.108

Table 1 shows the generated coefficient from Statistical Package for Social Sciences Software (IBM, SPSS Version 26) for both initial B & Y regression analysis.

a. Maurer Model

Drilling parameter from well 1 [ROP, WOB, bit D_b , RPM] are applied into equation [11] to obtained K value at each selected depth. The values obtained are then substituted back into Maurer's equation to predict new ROP using well 2 drilling parameters

$$R = K \frac{N * (W - W_o)^2}{D^2 * S^2}$$

$$K = \left[\frac{R}{\left(\frac{N * (W - W_o)}{D_b^2 + S^2} \right)} \right]$$

W_o = threshold bit weight (1klb)

S = compressive strength of the rock (assumed to be 35% of Mechanical specific efficiency)

variable [β_1, β_n].

α_0 to α_n Co-efficient will be determined by using a software called statistical package for social science (SPSS Software). This SPSS software will perform the regression analysis after all the relevant drilling parameters has been uploaded in it and run.

The analysis will then provide an output compute data. The generated output data are now co-efficient of interest. The first value generated will be α_0 while the values after this are the coefficients i.e. (α_1 to α_n). These values are to be multiply with this regression variable according to their order which is given as follows:

W = bit weight

K = constant of Proportionality

D_b = bit diameter

N = rotary speed

a. Bingham Model

Drilling parameter from well 1 [ROP, WOB, bit D_b , RPM] are applied into equation [10]

Which is as follows equation is as follows:

$$R = K * \left(\frac{W}{D} \right)^a * N$$

$$K = \frac{R}{\left(\frac{W}{D_b} \right)^a * N}$$

a is taken as $2.60 * 10^{-17}$

3.2 Prediction Accuracy

The prediction accuracies of the three models would be ascertained by computing the percentage errors at each selected depth using the formula below

$$PercentageError = \frac{PredictedROP - ActualROP}{ActualROP} * 100\% \quad \dots 15$$

While the average percentage error was also calculated using the formula below.

$$\text{AveragePercentageError} = \frac{\sum \left(\frac{\text{PredictedROP} - \text{ActualROP}}{\text{ActualROP}} \right)}{N} * 100\% \quad \dots 16$$

The above error calculation will be conducted for the three (3) selected models used for ROP prediction using Microsoft excel.

4.0 Results and Discussion

The outcome of the penetration rate prediction in the study area using the three (3) models are presented below in Table 1 and Figure 2 respectively. By using the data obtained from wells 1 and 2, the penetration rates were predicted using Microsoft excel. The predicted penetration rates were then compared with the actual ROPs at various depths to ascertain the accuracy of the models. Afterwards, a statistical analysis of the results was conducted by calculating the Mean Absolute Percentage Error of the results obtained from the models which

was used as the ultimate index to further rank the models in terms of their accuracy. The model with the least percentage error was chosen as the best.

Comparison was made between the actual ROP and predicted ROP. The actual ROP was the ROP contained in the original well Delta (Well 1 Data) while the predicted ROP was the ROP calculated using the three (3) selected models.

The comparison was done between well depths of 1000ft to 9000ft at 200ft depth interval.

Percentage error at each depth interval was calculated for the three (3) selected models and finally the mean absolute percentage error of each model was also calculated.

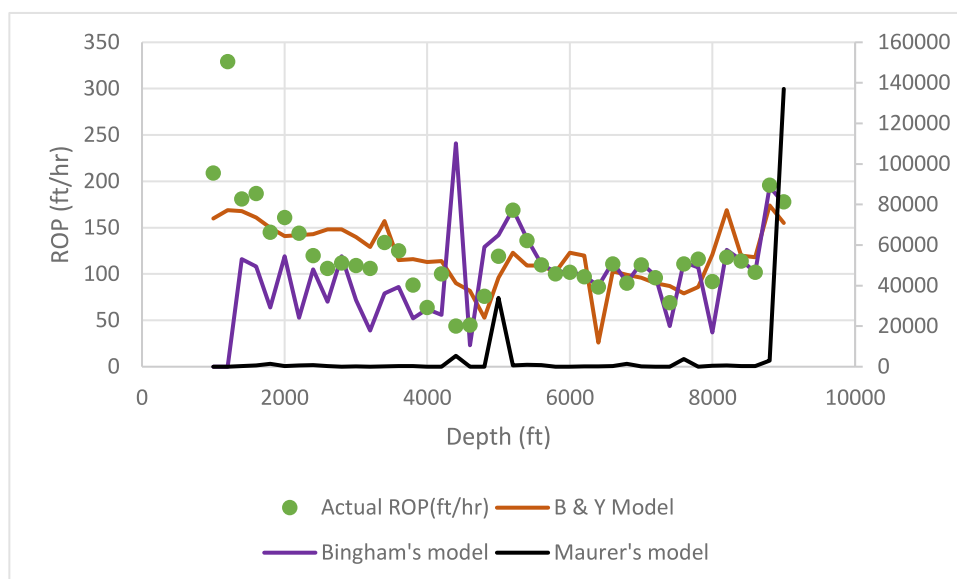


Figure 2: Actual & Predicted ROP vs. Well Depth

The graph of ROP was plotted against well depth, depth on the horizontal axis in feet (ft.) and ROP on the vertical axis in feet per hour (ft./hr) on the vertical axis. The vertical axis of the graph was plotted using two (2) scales values, one on the left and the other on the right-side axis. The left side scale was plotted using the predicted ROP values from the two selected models (B&Y, Bingham and the actual ROP) while the right-

side scale was plotted using the Maurer's predicted ROP values as it couldn't fit into other scale.

From the graph, the actual ROP was considered as the reference plot represented by green dotted points. Meanwhile, the predicted ROP were represented by lines of various colors such as black (Maurer's model), purple (Bingham) and brown (B&Y).

Table 1: Predicted ROP using Three (3) Models

Depth (ft.)	Actual ROP (ft/hr)	B & Y Model	% Error	Maurer's model	% Error	Bingham's model	% Error
1000	209	160	23%	0	100%	0	100%
1200	329	169	49%	0	100%	0	100%
1400	181	168	7%	380	110%	116	36%
1600	187	161	14%	663	255%	108	42%
1800	145	150	3%	1419	878%	64	56%
2000	161	141	12%	364	126%	119	26%
2200	144	142	1%	671	366%	53	63%
2400	120	143	20%	758	532%	105	13%
2600	106	148	39%	364	243%	70	34%
2800	112	148	33%	36	68%	119	6%
3000	109	140	28%	82	25%	72	34%
3200	106	129	22%	39	63%	39	63%
3400	134	157	17%	213	59%	79	41%
3600	125	115	8%	278	122%	86	31%
3800	88	116	31%	370	320%	52	41%
4000	64	113	76%	45	30%	62	3%
4200	100	114	14%	1.3	99%	56	44%
4400	44	90	108%	5390	12288%	241	453%
4600	45	82	80%	21	53%	23	50%
4800	76	53	30%	66	13%	129	70%
5000	119	96	19%	33909	28350%	142	19%
5200	169	123	27%	662	292%	170	1%
5400	136	109	20%	981	622%	138	1%
5600	110	109	1%	794	622%	111	1%
5800	100	102	2%	14	86%	102	2%
6000	102	123	20%	43	58%	103	1%
6200	97	120	24%	90	7%	98	1%
6400	86	26	69%	83	3%	87	1%
6600	111	103	7%	298	169%	113	2%
6800	90	99	10%	1443	1503%	91	1%
7000	110	96	12%	76	31%	112	2%
7200	96	90	6%	37	61%	98	2%
7400	69	87	26%	54	22%	44	36%
7600	111	79	29%	3770	3296%	113	2%
7800	116	86	26%	1	99%	107	8%
8000	92	121	31%	531	477%	37	59%
8200	118	169	43%	696	490%	126	7%
8400	114	120	5%	312	174%	115	1%
8600	102	118	16%	335	228%	102	0%
8800	196	174	11%	2917	1388%	194	1%
9000	178	155	13%	137009	76872%	176	1%
		MAPE	25%		3188%		35%

The B&Y line seems to correlate closely with the actual ROP values in many sections of the well, which implies that this model performed effectively. The model yielded a Mean Absolute Percentage Error of 25%.

The Bingham's model similarly yielded close matches with the actual ROP values across several sections of the well although not as closely matched as the B & Y's model. The model yielded a Mean Absolute percentage error of 35%.

The least performed model from the above analyses was Maurer which yielded A mean Absolute Percentage Error of 3188%.

5.0 Conclusion

The prediction of rate of penetration using well data from an exploratory well in Niger Delta has been carried out. Three models were appraised with various degrees of accuracy. The predictive accuracy of the models was validated by comparison with actual ROP data and computation of Mean Absolute Percentage Errors. The B & Y's model gave the best correlations with the actual ROP data in comparison to the other two models used in the study, with a Mean Absolute Percentage Error of 25%. The Bingham's model, followed closely with good matches with the actual ROP data with a Mean Absolute Percentage Error of 35%. However, Maurer's model showed a great degree of inconsistency with the actual data by over-predicting the ROP across the total well depth, thereby yielding a Mean Absolute

Percentage Error of 3188%.

The result shows that B & Y is the best model for ROP prediction in the Niger Delta sedimentary basin going by its low Mean Absolute Percentage Error while Maurer's model is the least accurate.

Recommendation

The result implies that the B & Y model can estimate ROP as a function of several drilling parameters such as WOB, RPM, Mud weight, SSP, Torque, flow rate etc. with a reasonable accuracy. By and large The result can also provide a guide for next drilling operation near the drilled wells within the Niger Delta basin and the predicted values can be used as a reference to obtain optimum drilling performance and therefore reduce cost and time of drilling operation.

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Development of Truck Dispatching Mobile Application in Open Pit Mine: Case Study of Dangote Cement, Obajana, Kogi State

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Abstract

Truck haulage nowadays is the most common means which is used for moving ore/waste in open-pit mining operations. It is usually the costliest unit operation in a truck-shovel open pit mining. This study developed a truck-dispatch mobile app using General Purpose Simulation System (GPSS) software for a hypothetical medium-sized open pit mine consisting of several production faces and dump locations. Truck dispatching systems were examined and it was discovered that they offered the potential for improving the performance of open pit haulage systems. A dispatching system in any mine can give operational increase in production by minimizing waiting times and increasing productivity. Other beneficial advantages can also be obtained through good monitoring and optimal routing. Thus, the application program developed is structured on the dispatch of the fleet management and the monitoring and recording of cycle times of the fleet.

Keywords: Fleet management, dispatch, cycle time, open-pit, truck-dispatch mobile App.

Introduction

The advent of technology has made it easy for tasks to be executed efficiently with less labour. It is apparent that technology has taken over all the sections of labour with the development of artificial intelligence. Hence, human labour demand will diminish drastically eliminating human errors and improving accuracy in production. Mining industry is indisputably an industry with tedious labour and hazardous working conditions in ancient times when the equipment available for production are pick axe and hammer which give rise to the symbol of the profession. Technology era has cause a tremendous change in the industry with the invention of several working tools and modification of existing ones leading to different mining methods being unveiled frequently with less tedious labour and effective safety regulations and practices to prevent or minimize accidents in the mine. There are several methods of mining and the common one is the open pit mining adopted in extracting industrial minerals and aggregate stones.

In open pit mining, transportation is very significant in the operation of the mine. According to Beaulieu and Gamache (2006), transportation accounts for 50% of the cost of production in an open pit mine, making it the most crucial unit in the mine. Dangote Cement Plc located at Obajana in Kogi State, a typical modern open pit mine in Nigeria, is the case study used to examine the method employed in dispatching trucks. Open pit mining

method is employed for the extraction of the limestone from the quarry site after which the run-off- mine is then transported by dump trucks to the crushing sites. The crushed limestone is then transported via a 7.5km conveyor belt to the processing plant located at Obajana. The plant is supported by a fleet of 2,370 trucks (Victor et. al, 2015). The mine located at Oyo-Iwa runs three pits with a total of 17 dump trucks and three crushing units. The crushers are: Hazemag which is designed for crushing limestone with a capacity of 2000 t/hr; Bedeschi which is designed for crushing additives (laterite and clay) with a capacity of 400 t/hr; and Thyssenkrupp which is designed for crushing all the raw materials with a crushing capacity of 1750 t/hr.

The dump trucks used in the site varies in size and tonnage, the four types of dump trucks employed in the sites are:

- i. Kumatsu (100 tons) capacity.
- ii. Terex (100 tons) capacity.
- iii. Cat 777E (100 tons) capacity.
- iv. Cat 773E (60 tons) capacity.

1.1 Truck Dispatching System

Fleet management system in open pit mines consist essentially of systems that can dispatch trucks, shovels, crushers, waste dumps or stockpiles and when these trucks reach the service point of loading or dumping, decisions made are based on both the state of the equipment and the state of haulage network

(Beaulieu and Gamache, 2006). It is in this context that truck dispatching system becomes important as they can increase the production of the current hauling fleet or achieve the production target using a smaller number of trucks. This may be achieved through a careful analysis of the shovel and truck scheduling in real-time and the consequent choice of the optimum assignment of the trucks allowing increased hauling fleet utilization and reduced operational delays.

1.1.1 Types of Truck Dispatching System

Truck dispatching systems are classified into three categories, namely:

(a) Manual dispatching system: in this type, the pit supervisors gather data from the field by listening to the voice radio and by visual observation. The trucks are assigned to a particular shovel and dump point at the beginning of the shift, changing the circuit according to the dispatcher's best judgement of the situation (Mueller, 1977).

(b) Semi-Automated Dispatch system: in this system, the computer is programmed to aid the dispatcher in the decision making process for assigning the trucks. A digital computer is used to record the status of equipment and the location of trucks which make up the haulage fleet. The computer is also used to assist the dispatcher to assign the trucks to shovels according to the dispatching strategy applied (Hodson and Baker, 1985).

(c) Automated dispatching system: It enable the computer to make the necessary decisions for dispatching truck without any intervention by human dispatcher. Truck locations are detected by sensors and sent to the computer, which calculate the destination for truck allocations using the chosen dispatching strategy applied as in semi-automated dispatching system. The assignments are sent directly to the LCD display mounted in truck's cabin or in a central location where trucks ply (Necmettin, 2004).

1.2 Previous Work on Computer Truck Dispatching

One of the first documented application of computer aided dispatching was in the United States at the Cyprus Pima Dispatch Board (Mueller, 1977). It was an analog computer

which helped dispatchers at the Cyprus Pima mine located south of Tucson to make more consistent decisions. It helped miners increased truck productivity by 10-15%. Although, the analog nature of the system was inadequate as the involvement of the dispatcher was needed to perform certain operation.

The first of such system, DISPATCH, was created by modular Mining Systems Inc. of Tucson. One highly documented installation of the system is at the Phelps Dodge Tyrone open pit copper mine, located in southwestern New Mexico. Major innovations attributed to DISPATCH include a fully integrated hardware system in which the dispatcher need not intervene under ordinary circumstances; a truly rigorous dispatching algorithm based on linear programming; and a very complete automatic data acquisition system. The system, installed in 1980 tracks trucks with the aid of operator data input and generates all assignment including those for truck refueling and services. The dispatching algorithm is called upon to determine the optimal haul route network whenever a shovel is disabled or activated. System benefits include 14% Mine productivity gain, resulting in reduced equipment requirements, alerting the dispatcher to developing potential problems in the equipment; nearly eliminating misrouted trucks; and the exceptional at automatically generated (Clevenger, 1983).

The second system, DATA RANGER, was developed under a partnership between Motorola and Pathfinder systems. One of its applications at the Reserve taconite mine in northern Minnesota has been documented (Weed, 1983). The automatic system was brought on line in April of 1982.

All transactions, including location detecting, dispatching and communications with equipment operators are performed automatically through an integrated hardware system. Other features include a sophisticated dispatching algorithm which takes all of the following into account; equipment pools; available haul routes, truck/shovel Matching and equipment delays. In addition, the following user controlled dispatching criteria can be implemented: desired shovel utilization,

minimizing the cost of cross dispatching, or tire ton miles/hour management.

2 Materials and Methods Used

The mobile application is designed using a GPSS software called 'MIT App Inventor.' The software enables the design of a mobile application using a browser connected to an android phone via scan or code as guide to achieve the intended design.

The software menu are employed to build a desirous interface(s). MIT Software Inventor is a user-friendly visual programming platform that enables one to create completely functioning applications for smart phones and tablets. The MIT Application Inventor Components are located on the left-hand side of the Designer Window under the title Palette. Components are the basic elements to make apps on an Android

phone or iPhone. Some components are very simple, like a Label component, which just shows text on the screen, or a Button component that initiate an action.

Other components are more elaborate: a drawing Canvas that can hold still images or animations, an Accelerometer sensor that works like a Wii controller and detects when you move or shake the phone, components that send text messages, components that play music and video, and components that get information from Web sites.

To use a component in your app, you need to click and drag it onto the viewer in the middle of the Designer. When you add a component to the Viewer, it will also appear in the components list on the right-hand side of the Viewer and as well reflect on the connected mobile device.

Table 1: Cycle time of selected trucks.

Truck ID& Capacity	Load Time	Haul Time	Dump Time	Return Time
TR100-1 (100 tonnes)	3.32	3.05	0.47	2.13
TR100-2 (100 tonnes)	5.20	3.10	0.42	2.22
TR100-3 (100 tonnes)	4.00	3.10	0.45	2
TR100-4 (100 tonnes)	5.15	2.30	0.50	2.10
TR100-5 (100 tonnes)	5.25	2.55	0.44	2.32
TR100-6 (100 tonnes)	5.12	3.20	0.46	2.30
TR100-7 (100 tonnes)	5.23	3.14	0.42	2.35
TR100-8 (100 tonnes)	5.20	2.43	0.45	2.17
TR100-9 (100 tonnes)	5.39	3.56	0.43	2.17

3 Results

In this study, manual dispatching method was adopted to obtain cycle time data of selected nine trucks with same capacity but different loading point. Table 1 shows the variability of time taken to complete a trip by the trucks. Figures 1 and 2 show the images of four screens in the mobile app, namely: the admin screen, the pit screen, the demo screen and the navigation screen respectively. The admin screen gives access to the dispatcher to modify dispatch information of the trucks, monitor the activities of the trucks and access all the working faces in the mine. The pit screen duplicates the function of the admin screen except for the access to change dispatch information to the trucks. This interface is designed for a mine with more than one dispatcher. Demo screen interface is

designed to be accessible by the trucks operators in sending cycle time data to the dispatch room and to also gain dispatch information on where and what to load. Navigation screen is a short cut to enable easy access to all the features of the application on a mobile device.

3.1 Discussion

The application features designed to solve the system challenges of keeping track of truck cycle time was achievable as seen on the truck status screen automated to receive cycle time update from the demo screen. The application is susceptible to adopt any heuristic dispatch system depending on the usage requirement. The mobile application is user friendly and easy to operate.

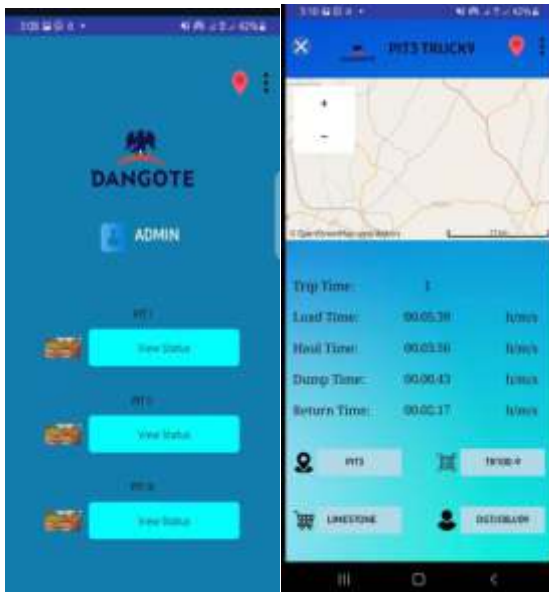


Figure 1: Images of Mobile Application screens.

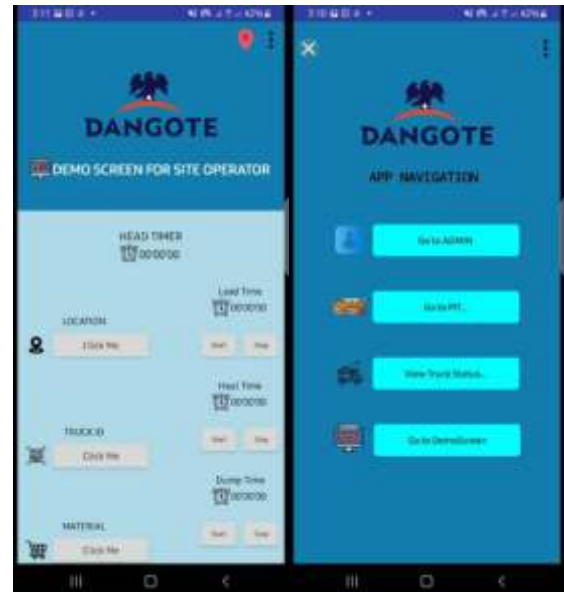


Figure 2: Images of 'Demo' screen and 'Navigation' screen.

4 Conclusions

At the end of the research work, effort was made to realize the intended objectives of how to minimize cost of production in a mine. The development of a truck dispatch mobile application is in the quest to solve the problem of ineffective management of a mine fleet by using the fixed truck assignment dispatch strategy to control trucks and monitor each truck during operations. The "TRUCKit" mobile application as designed will archive operation records of all the fleet facilities put into use in the mine. Data generated will be stored in the dispatch room server. These data could be analyzed using data mining techniques to assist the decision makers in increasing the productivity as well as utilization.

Acknowledgements

The authors heartfelt gratitude goes to the management and staff of Dangote Cement Plc for their support and cooperation especially Engr. Isaac Salifu for his time and effort. All the authors whose works have been used as references are equally acknowledged and appreciated.

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