# ILMINITE AND SILICON NANOPARTICLES WATER BASED MUD TO ENHANCING RHEOLOGICAL PROPERTIES AND REDUCING FLUID LOSS PROBLEMS

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# ABSTRACT

Many oil and gas are using barite ($BaSO_4$) to increase the density of drilling to play important roles in drilling operations to suspend cuttings, counter high formation pressure and to ensure wellbore stability. However, this study described the evaluation of an iron-based material, ilmenite ($FeTiO_3$), as an alternative to replace barite in water-based mud. The experiment was carried out at LPLT, HPHT conditions with a varying nano-silica concentration of 0.3wt% and 0.5wt%. At different mud weights, the formulated drilling fluid will be tested for LPLT, HPHT filtrate loss. Nano-silica has been proven in this project to be only effective for fluid loss and improve mud rheology due to the nature of nano-silica as a plugging agent. By adding 0.3 wt%, 0.5wt% silica for ilmenite; the 10-s gel strength, 10-min gel strength and the yield point increased by 23%, 53%, 6% 50%and 77.7% respectively, as compared with the base mud. Whereas, the plastic viscosity and the filtrate volume decreased by 5% and 13% respectively at ambient conditions. The mud cake thickness decreased by 12.6%, 25% and the pH increased by increasing the concertation of silicas. After hot rolling, the 10-s gel strength, 10-min gel strength and the yield point increased by 8.3%, 16.6%, 11%, 22% and 25%,87.8% respectively, whereas, the filtrate volume 0.3wt%, 0.5wt% by 36% 36.6%. the mud cake thickness decreased by 12.6% 25%, pH increased from the findings, it was proven that the combination of ilmenite and silica can enhance the drilling mud rheological properties, reduce fluid loss while maintaining the mud cake thickness, therefore has a great potential as drilling fluid additive.

# ABSTRAK

Banyak minyak dan gas menggunakan barit (BaSO4) untuk meningkatkan ketumpatan penggerudian untuk memainkan peranan penting dalam operasi penggerudian untuk menangguhkan keratan, mengatasi tekanan pembentukan tinggi, dan memastikan kestabilan saluran air. Walau bagaimanapun, kajian ini menggambarkan penilaian bahan berasaskan besi, ilmenite (FeTiO3), sebagai alternatif untuk menggantikan barit dalam lumpur berasaskan air. Eksperimen ini dijalankan pada keadaan LPLT, HPHT dengan kepekatan nano-silika yang berbeza-beza 0.3wt% dan 0.5wt%. Pada berat lumpur yang berbeza, cecair penggerudian yang diformulasikan akan diuji untuk kehilangan LPLT, filtrat HPHT. Nano-silika telah terbukti dalam projek ini hanya berkesan untuk kehilangan cecair dan memperbaiki reologi lumpur kerana sifat nano-silika sebagai agen penyumbat. Dengan menambahkan 0.3 wt%, 0.5wt% silika untuk ilmenite; kekuatan gel 10-s, kekuatan gel 10-minit, dan titik hasil masing-masing meningkat sebanyak 23%, 53%, 6% 50% dan 77.7%, berbanding dengan lumpur dasar. Manakala, kelikatan plastik dan isipadu turas masing-masing menurun sebanyak 5% dan 13% pada keadaan persekitaran. Ketebalan kek lumpur menurun sebanyak 12.6%, 25%, dan pH meningkat dengan meningkatkan konsentrasi silika. Setelah bergolek panas, kekuatan gel 10-s, kekuatan gel 10-minit dan titik hasil masing-masing meningkat sebanyak 8.3%, 16.6%, 11%, 22% dan 25%, 87.8%, sedangkan isipadu filtrat 0.3wt%, 0.5wt% dengan 36% 36.6%. ketebalan kek lumpur menurun sebanyak 12.6% 25%, pH meningkat dari penemuan, terbukti bahawa gabungan ilmenit dan silika dapat meningkatkan sifat reologi lumpur penggerudian, mengurangkan kehilangan bendalir sambil mengekalkan ketebalan kek lumpur, oleh itu mempunyai potensi besar sebagai bahan tambahan cecair penggerudian.

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| | | |
|---|---|---|
| SG | - | Specific gravity |
| YP | - | Yield Point |
| Wt% | - | Weight percent |
| HPHT | - | High pressure High temperature |
| ROT | - | Rate of Penetration |
| LT LP | - | Low temperature Low pressure |
| ppg | - | Pounds per gallon |
| G | - | Gram |
| Ml | - | Millilitre |
| API | - | America Institute of Petroleum |
| WBM | - | Water Based Mud |
| AV | - | Apparent viscosity |
| PV | - | Plastic viscosity |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| % | - | Percentage |
| °C | - | Degree Celsius |
| °F | - | Degree Fahrenheit |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

Drilling fluids perform a variety of functions during the drilling process, including stabilising the wellbore without damaging the formation, keeping formation fluids at bay, clearing cuttings from the bit face, and lubricating the bit and drill-string. Compounds that are dissolved or suspended in drilling fluid to increase its density are known as weight materials. They're used to keep formation pressures in check and protect against the effects of sloughing or heaving shale in stressed areas (M.I. Abdou et al., 2018). Density, or mass per unit volume, is a critical property that distinguishes the effectiveness of various wellbore fluids in achieving these functions. The cuttings must be carried to the surface by a wellbore fluid with sufficient density. Density also helps to keep the borehole stable by increasing the pressure exerted by the wellbore fluid on the formation's surface down hole. Increasing the density of wellbore fluids has long been a goal, and there are a number of approaches available. Adding dissolved salts like sodium chloride, calcium chloride, and calcium bromide to wellbore fluids in the form of aqueous brine is one method. Another approach is to add inert, high-density particulates to wellbore fluids to create a higher-density suspension. Weighting agents are inert, high-density particulates that typically consist of powdered minerals such as barite, calcite, or hematite.

The primary function of weighting materials in drilling fluid is to increase density and, as a result, borehole stability (M.I. Abdou et al., 2018). It also maintains adequate hydrostatic pressure in the hole and reduces fluid loss by forming a thick filter cake on the well's walls. Increased density also increases penetration rate; however, if the density is too high, differential sticking of the drill string can occur. Chemically, barite ($BaSO4$) is inert and insoluble. In silver, zinc, copper, nickel, and lead ores, it occurs as a vein filling and as a gangue mineral (D. Arcos et al., 2008).

The most common weight material for drilling fluids has been barite, which has a specific gravity of 4.2–4.4 and a hardness of 2.3–3.5. The free world's demand is now around 2 million tonnes per year, accounting for about 55% of total barite production (Mohamed Al-Bagoury et al., 2012). Barite, on the other hand, is prone to sagging and requires viscosities and other gellants to keep it suspended. Furthermore, drilled solids that mix with drilling fluid quickly assume the particle size of API-specified barite, reducing solids separation efficiency in shakers and centrifuges. Local materials, such as Malaysian ilmenite ($FeO.TiO_2$), could be investigated to see if they are suitable for use as weighting materials. Ilmenite ($FeO.TiO_2$) is an opaque mineral with a metallic or sub-metallic lustre. Its specific gravity ranges from 4.25 to 4.45 and its hardness ranges from 5 to 6. (Mohs scale). A slight magnetic character easily distinguishes the mineral. It is the primary source of titanium dioxide ($TiO_2$), which is used in drilling fluid as a weighting material. In oil well drilling fluids, local micro-sized ilmenite ore particles are used as a substitute for barite grains. As a high specific gravity iron ore, ilmenite ore was used as an aggregate to improve the mechanical properties of a local concrete mixture used for offshore petroleum pipelines. The rheological properties of each sample were determined at various temperatures (R.B. Watson et al., 2012). Density from a mud balance, viscosity from a viscometer, filtration loss from an API filter press, and gel strength are examples of such properties.

Many studies have been carried out in order to introduce iron-based materials such as ilmenite, hematite, and others as drilling weighting materials. Ilmenite has advantages as a weighting material, such as a high specific gravity, acid solubility, and the availability of large mineral deposits. Despite the higher yield point and gel strength observed, Malaysian ilmenite has a promising future as a weighting agent in drilling fluids, as these issues can be overcome by increasing the lignosulfonate concentration. There was no evidence of lignosulfonate incompatibility in the mud system (Idris et al., 1994). ilmenite has a lower tendency to be ground down to finer materials and requires less fluid dilution, it is better suited to be reused. The performance of ilmenite as a weighting material in water-based drilling fluid was confirmed by laboratory experiments and field trials to be fully equal to, and in some cases better than, barite. A small amount of ilmenite could make the same amount of mud as barite, resulting in lower solids content (Ismail et al., 1999). Ilmenite was found to have less fluid loss than barite, which could help to reduce formation damage. On balance, ilmenite was found to be more suitable for use in drilling fluids than barite (Saasen et al, 2001). When ilmenite was used as an additive, the drilling fluids lasted longer and required less dilution (Elkatatny et al., 2013). There are numerous examples of ilmenite (SG = 4.9) being used in the field. When compared to commercial grade barite (SG = 4.2), this mineral has a higher density, which helps to reduce the solids content of drilling fluids and reduces the impact of the weighting material on fluid rheology (Saasen et al., 2001; Bizanti et al., 1988; Scharf and Watts, 1984). Improvements in rate of penetration (ROP), solid tolerance, and the need for dilution are also reported, all of which help to lower the overall cost of drilling (Scharf and Watts, 1984). As a result, ilmenite is being investigated in this project as a possible replacement for barite as a weighting agent in water-based mud.

Ilmenite, an iron-based material (Gribbel and Hall, 1985), has the potential to be used as a weighting material in drilling fluids that are based on water. A series of laboratory tests were used to assess the performance of ilmenite. The investigation looked into mud weight density, rheological properties, fluid loss, and solid content, all of which were outlined in the API specifications. The results of the ilmenite were then compared to the performance of commercial barite. Barite (barium sulphate, $BaSO_4$) is an industrial mineral that is primarily used in oil and gas well drilling. Baryte or barytes are other names for the mineral commodity. Barite (barium sulphate, $BaSO_4$) has a specific gravity of (4.2–4.5) and contains 58.8 percent barium. Because other minerals such as quartz, chert, calcite, anhydrite, celestite, and various silicates are present in commercial barite, it has a lower specific gravity. It also usually contains a number of iron minerals, some of which can raise the product's average specific gravity. Barite is practically insoluble in water and does not react with other mud constituents (Dhorgham et al., 2017). It's an important component of drilling mud, which is the fluid pumped into an oil or gas well to lubricate the bit and drill stem, remove rock chips, prevent well collapse, and prevent blowouts if overpressure strata are encountered. Barite has an unusual combination of properties, including high density, softness, and chemical inertness, making it ideal for this application. The petroleum industry uses the vast majority of the barite mined as a weighting material in the formulation of drilling mud. Barite raises the drilling mud's hydrostatic pressure, allowing it to compensate for high-pressure zones encountered during drilling. The mineral's softness also prevents it from damaging drilling tools and allows it to act as a lubricant during drilling. Specifications for the use of barite in drilling mud have been established by the American Petroleum Institute (API) (Dhorgham et al., 2017).

## 1.2 Problem Statement

One of the most pressing issues facing drillers in the oil and gas industry is how to develop a smart, cost-effective, and environmentally friendly WBM that can ensure mud rheological properties stability at high pressure high temperature (HPHT) and low pressure, low temperature (LPLT) conditions. Drilling operations at high pressures and temperatures (HPHT) are extremely difficult. In terms of drilling fluid, designed mud weight in HPHT wells must be higher, and narrow mud windows must be precisely controlled. High solid loading and barite sag will be challenges as a result of this requirement. Low rate of penetration is caused by high solids loading, which results in higher pressures and rock incompetency at deeper depths (ROP). Apart from that, at high-pressure high-temperature (HPHT) conditions, the mud system degrades and becomes unstable, resulting in mud fluid loss. Fluid loss occurs when mud cake is unable to form on the formation's walls, resulting in a decrease in hydrostatic pressure in the wellbore and the possibility of a kick. As a result, the oil and gas industry require effective fluid loss control agents, rheology modifiers, and weighing agents to improve current conventional mud systems. Since 2009, the price of API grade barite has risen significantly (Al-Bagoury, 2014). Increased consumption and dwindling quality barite reserves are the primary causes of price increases and supply shortages. As a result, ilmenite, an alternative mineral that can be used to change the density of drilling fluid, has become desirable.

From previous study, Rae et al. (2001) stated that barite was one of the most significant potential pollution sources. It contains heavy metals such as lead, cadmium, mercury, and arsenic, which can dissolve into the sea during mud or cutting discharge. They claimed that ilmenite had a lower concentration of heavy toxic metals than barite and that the heavy metals in ilmenite had a lower bioavailability. Ilmenite is also said to have a higher rate of penetration (ROP), is more solid tolerant, and requires less dilution, all of which contribute to lower drilling costs (Scharf and Watts, 1984).

However, increased settlement rate is a disadvantage of higher density, which can be mitigated by reducing bulk (Walker, 1983). As a result, ilmenite is being studied in this project as a possible substitute for barite in water-based mud additives. When designing and planning for cost-effective drilling operations involving nanoparticles, modelling the rheological and fluid loss behaviour of nanoparticle-enhanced drilling muds is crucial (Vryzas and Kelessidis, 2017). In this study, barite is replaced by ilmenite as a weighting material, with fluid loss control agents of SiO2 (silicon dioxide).

## 1.3 Propose Solution

Ilmenite and silicon dioxide have been combined to produce a more continuous and integrated mud cake. As a result of the integrated (low permeability and low porosity) mud cake, less filtrate enters the formation, resulting in a thinner mud cake than in normal cases. With the drilling fluid flowing at a constrained rate, the consistent particle size distribution provides a better compaction medium. A thinner mud cake also reduces the chance of fluid loss. The viscosity and other properties of the drilling fluid are unaffected by the addition of Silicon nanoparticles.

## 1.4 Research Objectives

In order to fulfil the aim of this study, there are two objectives needed to be achieved, namely:

1. To investigate rheological properties of ilmenite as weighting material in water-based mud in comparison with the conventional drilling with barite.

2. To compare the performance of water-based drilling fluid with ilmenite, silicon nanoparticle ($SiO_2$) against the formulation of water-based mud (WBM) with barite, silicon nanoparticle $SiO_2$ for fluid lost.

## 1.5 Scope of Study

1. Assessing ilmenite efficiency through a variety of laboratory tests such as mud density, rheological property and fluid loss are parameters in the research that will be mentioned according to the API specifications.

2. Preparing the WBM as the continuous phase with a nano-bentonite mud, which included fresh water, xanthan gum, starch, KOH, would initially be processed as per field formulation.

3. Placing separately the weighting material (ilmenite and barite) in mud, forming the desired mud weight of 10-15 ppg.

4. Preparing Six (06) types of mud sample with respective weighting materials will be prepare:

   i. WBM + barite
   ii. WBM + barite + $SiO_2$ (0.3wt%)
   iii. WBM + barite + $SiO_2$ (0.5wt%)
   iv. WBM +ilmenite
   v. WBM+ ilmenite + $SiO_2$ (0.3wt%)
   vi. WBM+ ilmenite + $SiO_2$ (0.5wt%)

5. Determining the mud properties using the conventional mud balance while the rheological properties such as viscosity, yield point, and gel strength, were measured via the viscometer.

6. Comparing on the fluid loss by the mud samples will be measured using a filter press, with the volume or filtrate collected against time being the data collected from this experiment.

## 1.6 Significance of Study

Despite extensive research into the use of ilmenite as a weighting agent for drilling fluids in water-based mud, more progress is needed. The goal of this project is to find rheological properties for drilling fluid that will maximise mud density, rheological properties, and fluid loss problems. The significant and positive characteristics of Malaysian ilmenite will improve the properties of the WBM formulation. As a result, prepare a mud with all of the required properties for the drilling operation.

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