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Thermal and Magnetic studies on *Itakpe* Iron Ore Concentrate for Magneto-Rheological Potentials and Applications

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ABSTRACT

This research work show cases the potentials of *Itakpe* Iron concentrate for magneto-rheological abilities. The concentrate was first ball milled to reduce its size and then subjected to low magnetic strength from magnetic bits in-situ the magnetic fluid. It was determined that temperature affected the fluid inversely, as temperature increased at the shear rates from the viscometer and Newtonian viscosity calculated reduced, giving a negative relationship between temperature and Newtonian viscosity as loading remained constant. The magneto viscous property of the fluid was also checked as a magnetic field of different strength was then introduced and the viscosities of the concentration at constant loadings were measured. This gave a linear relationship (i.e increase in magnetic strength led to an increase in viscosity of the ferrofluid). Temperature was varied at 27 ^{o}C room temperature to: 30 ^{o}C, 40 ^{o}C, 50 ^{o}C, 60 ^{o}C and 70 ^{o}C with constant loadings of 10%, 15% and 20% for three different runs using from one to two magnetic bits to increase the magnetic strength. As temperature increases, viscosity reduces even for magnetic fluids. These positive signs of magneto-rheology under low magnetic influence put *Itakpe* Iron concentrate a candidate material for magnetic fluid potential and application in automobile shock absorbers breaks etc.

Keywords: Itakpe iron concentrate, in-situ, magneto-rehology, magnetic bits, temperature

INTRODUCTION

The rates and levels of industrialization in any economy of a country are measures of the production and consumption of iron and steel. They are the most widely used engineering materials for construction, fabrication and production of most items including ships, vehicles, military hardware, etc. This explains why the per capita consumption of steel is an assessing index for development in the economy of any nation. The availability and development of iron and steel sector, is essential for industrial growth, increased engineering capacity and enhancement of technical skills [9, 11].

Magneto-rheological fluids (MR Fluids) consist of 0.03 - 10 micro size magnetic particles suspended in non-magnetic fluids (carrier liquids). They usually respond to external magnetic forces where their rheological properties are altered or controlled. Viscosity is one of the rheological properties that are tuned by the external magnetic effect. The tuning of the physical properties of these MR fluids make them become smart fluids which have found many applications in research areas such as aerospace, bio-engineering, electronic packing sets [10].

The history of MR fluids dates to the 1940s when it was discovered by Jacob Rabinow of the US National Bureau of Standards fluids. Rabinow was inspired by Willis Winslow following a seminar on electro rheological (ER) fluids [9]. A decade later saw MR patents surpassed that of the ERs and by the 1990s MR fluids moved from research and development to industrial application in areas of shock absorbers and polishing machine [3]. In recent times, MR fluids have found applications in automobile and aerospace technology and they possess higher field induced particles than ER fluids, hence the preference for ER fluids [3, 13]

Magnetic fluids can be made into solid structures at room temperature and turned liquid at slightlyelevated temperature when paraffin basedferrofluid is used as the carrier liquid. Heating the fluid and cooling inthe presence of a magnetic field will find application in solid magnetic nanostructuressuch as the gear-like structure [4, 5]. Magneto-rheological applications are generally classified as Shear mode where clutches and breaks are used; flow mode which includes shockabsorbers and damper in medical devices and squeeze mode in vibration isolation systems in artificial limbs [2, 8].

Several studies on magnetic fluid have been carried out with great engineering interest at room temperatures and more focus on the external magnetic field (electromagnets). However, other works have reported findings in small temperature ranges of 40 – 45^{o}C in biomedical applications. This research therefore focuses on the effect of temperature (from room temperature to 70 ^{o}C and Iron concentrate of up to 25%) on permanent magnetic influenced ferrous particles in-situ Motor oil.

Due to the industrial advances made in the last few years have significantly increased the demands for "Magnetic Materials". Among, which the magnetic fluids are smart liquid materials whose properties can be manipulated by applying a magnetic field, unfortunately this technology has not been harnessed in Nigeria, because of low exploration of iron ore and materials to properly make a ferrofluid. Hence, a lot of researches that has been made by research works carried out by researchers and the general progress made in terms of magnetic fluids has smart liquid materials [2-7] and [9-12] respectively are on-going in the field of ferrohydrodynamics because of its wide applications in different fields of which this research work is one of such.

MATERIAL AND EQUIPMENT

Materials used in the course of this work includes motor oil (SAE 40), magnetic stirrer bars, Iron concentrate while equipment/instruments used are weighing balance, thermometer, and ball milling machine, viscometer, and Scanning electron microscope (SEM). The Iron ore concentrate sourced from *Itakpe*mining site was ball milled for 50 hours to reduce its particle size to micro range. SEM Q30 equipment was used to study the morphology. The MR fluids were produced by varying loading of the iron concentrate in the motor oil from 0% to 25% and constant surfactant concentration of 15%. The fluid was then subjected to varying magnetic effect between 0, 1 and 2. Magnetic stirrer bars were dropped into the fluid and temperature varied from 30^{o}C to 70^{o}C. The viscosity readings were then calculated and recorded.

RESULTS AND DISCUSSION

Figures 1 shows the morphology of the ball milled iron concentrate. Particles size distribution varies from about <5 to 100 µm as seen from the scale of the microscopic image. The smaller particles (< 10 µm, circled in red) fall in the range of particles generally used for magneto rheological studies [7]. Figures 2 to 6 show the effect of temperature and loading on magnetic influenced fluid containing the iron concentrate. In Figure 2 where there were no iron concentrate in the oil, the viscosity was affected by the presence of the extra bulk magnet introduced into the solution by the magnetic strip. In Figure 3 where 10% iron concentrate was introduced into the oil, viscosity increased as the number of magnetic bit in the oil increased. This behaviour was consistent at temperature below 40 ^{o}C similar to the behaviour observed in Figure 1. When Iron concentratewas increased to 15 % and 20% (Figure 4 and 5 respectively), the viscosity of the fluid with 2 bits had the highest viscosity until 50 ^{o}C where its viscosity coincided with the viscosity of fluid with one magnetic bit. This can be attributed to the fact that temperature has a prominent role to play against low magnetic effect on magneto viscous fluids [2, 7]. In Figure 6, where the fluids had 25% iron concentrate, there was no convergence of viscosity below 70 ^{o}C although there are signs for it after 70 ^{o}C. The Itakpe iron concentrate shows behaviour for magneto-rheology applications since the effect of temperature on low magnetic influence of permanent magnet in-situ the fluid) is apparent in the samples produced [1] and [13].

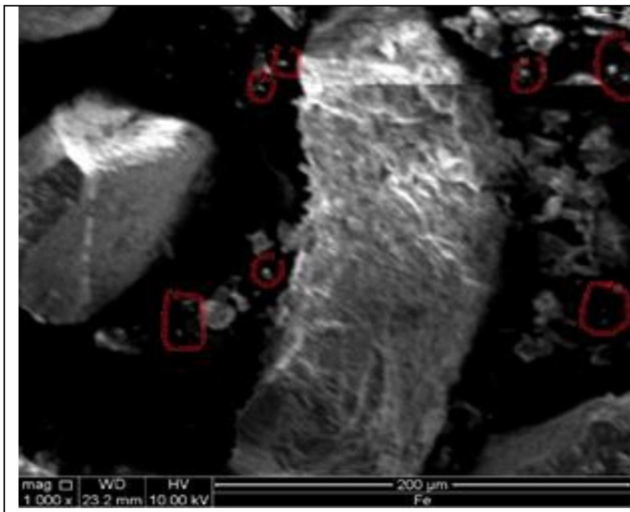

Figure 1: Surface Image of Itakpe Iron Concentrate using the SEMQ30

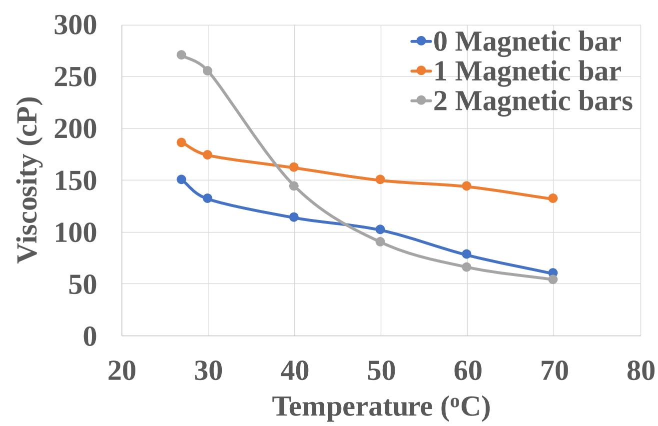

Figure 2: Effect of Temperature on Magnet Influenced Motor Oil

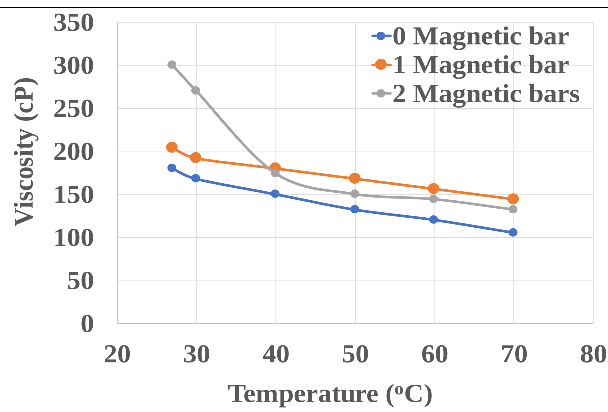

Figure 3: Effect of Temperature on Magnet Influenced 10% Iron concentrate in Motor Oil

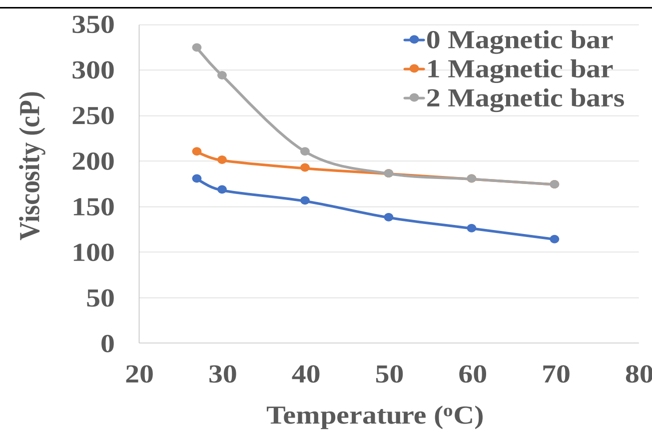

Figure 4: Effect of Temperature on Magnet Influenced 15% Iron concentrate in Motor Oil

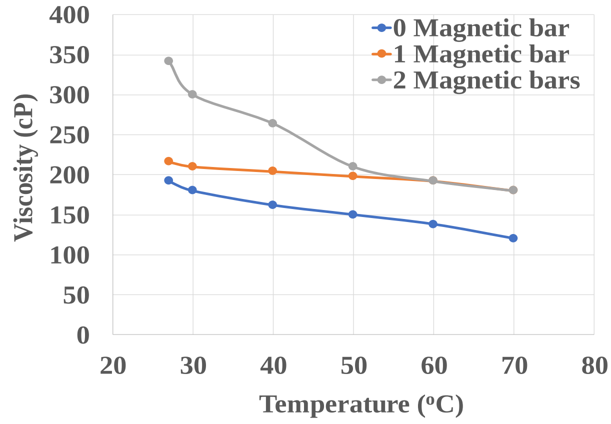

Figure 5: Effect of Temperature on Magnet Influenced 20% Iron concentrate in Motor Oil

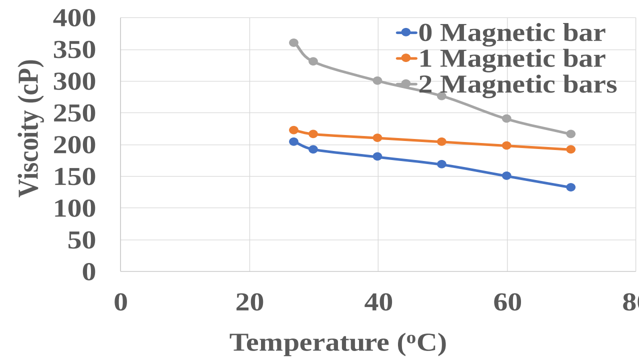

Figure 6: Effect of Temperature on Magnet Influenced 25% Iron concentrate in Motor Oil

CONCLUSIONS

The following conclusions can be drawn from the work:

1. The Iron concentrates although with wide distribution of particle size showed prospects of magneto-rheology.
2. Magneto-rheology increases with Iron concentrate content in the motor oil up to 25%.
3. Temperature has more influence on the viscosity of the fluid when under influence of weak magnetic effect.
4. As the Itakpe iron showed good prospects of magneto-rheology in the magnetic fluid, it should lead to a high capacity utilization and reduce cost of production.

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