Study of Adsorption and Transport Behavior of Iron Oxide (Fe_2O_3) Nanofluids In Difference Porous Media

By

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is myown except as specified in the references and acknowledgements, and that the original work containedherein have not been undertaken or done by unspecified sources or persons.

HERMAN HARI BIN MATRAJI

ABSTRACT

In order to extract more residual oil in place, understanding the adsorption and transportation of nanoparticles in porous media is critical. Even though there are a lot of studies on nanoparticles application in oil and gas industry but until today, the transport of nanoparticles in porous media for oil recovery has been little investigated. No specific research to investigate the adsorption and transport behavior of iron oxide nanofluids using different porous media. Coreflooding tests are performed to study iron oxide nanofluids particle adsorption onto three different porous media medium - Berea sandstone, glass bead and river sand. By measuring the particle concentration in the effluent by using UV/Vis spectrophotometer, iron oxide nanofluids transport in different core samples was investigated. Particle plugging and changes of core's permeability was observed during the tests by measured pressure drop across the porous medium. The relative concentration of iron oxide for sandstone, glass bead, and river sand were estimated as 30%, 48% and 35% respectively. It was found that sandstone has the lowest permeability compare to other which could lead to higher interactions between moving particles and pore surfaces that promote pore – throat processes e.g. plugging. Iron oxide show the lowest adsorption (0.03 wt %) and transport behavior in the sandstone compare to river sand and glass bead. The pressure drop was observed increase continuously during the coreflood test due to the porous medium permeability change, which means the particle plugging occurred in the porous medium.

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CHAPTER 1
INTRODUCTION

1.1 Project Background

There is considerable evidence indicating that the excessive decline in productivity observed in many producing oil and gas wells results from a reduction in permeability near the well bore arising from an accumulation of fines-i.e., small solid particles of sand and/or clay-which have become entrained in the flowing fluids and transported through the porous formation toward the well.

Nanotechnology has called attention to its potential application in oil and gas industries. Recent research projects have shown that nanotechnology has the potential to solve or manage several problems in the petroleum industries especially in Enhanced Oil Recovery (EOR). According to Mokhatab et al, (2006), nanotechnology could help improve oil and gas production by making it easier to separate oil and gas in the reservoir; for instance, through improved understanding of process at the molecular level.

Transport and adsorption of nanoparticle in the oilfield are very challenging due to the complicated local condition such as high salinity, low permeability, and heterogeneous rock properties. The adsorption of nanoparticle on rock/soil/sediment solid matrix may result in the loss and reduction of their concentration, which may render them less efficient or ineffective in practical treatment. Adsorption of nanoparticle from aqueous solutions in porous media is very important in enhanced oil recovery (EOR) of oil reservoirs because surfactant loss due to adsorption on the reservoir rocks impairs the effectiveness of the chemical solution injected to reduce the oil–water interfacial tension (IFT) and renders the process economically unfeasible (Curbelo et al., 2007).

Other literature devoted to deep-bed filtration has contributed some understanding of the influence of such factors as particle size, fluid velocity, and physical properties of fluids and porous solids on the process. However, there is little research to study the fundamental adsorption and transport behavior in different pore formation. Thus, this paper will present the results of a study on the adsorption and transport behavior of iron oxide nanofluids in different porous media.

1.2 Problem Statement

Although various applications of nanoparticles in the oil and gas industry have been developed, there are a lot of challenges in using nanoparticles in the oilfield due to complicated local conditions such as salinity, permeability and heterogeneous of rock properties. One of the critical issues is the understanding of transport and retention of nanoparticles in the oilfield reservoir.

1.2.1 Problem Identification

Even though there are a lot of studies on nanoparticles application in oil and gas industry but until today, the transport of nanoparticles in porous media for oil recovery has been little investigated.No specific research to investigate the adsorption and transport properties of iron oxide nanofluids using different porous medium.

1.2.2 Significant of the Project

To study the adsorption and transportation behavior of iron oxides nanofluids in different porous media is very important. This is because iron oxide nanoparticles has large surface energy and has possibility to give a good result in EOR.In this project, the coreflood test is used to evaluate iron oxide nanofluids adsorption and transport behavior.

1.3 Objectives

The main objective of this study is to investigate the fundamental adsorption, transport, and retention properties of nanofluids using different porous materials. Iron oxideis chosen to investigate nanofluids adsorption and transportation behavior in different porous samples.

Based on the potential problems that have been identified, three objectives of this project have been developed as shown below:

I. To prepare andcharacterize iron oxide nanoparticles.
II. To study the adsorption and transport behavior of iron oxide nanofluidsin three different porous media through coreflooding test.

1.4 Scope of Study

This scope of project includes:

- The preparation of iron oxide nanofluids by using sol-gel process.
- Iron oxide particle characterization by using XRD and TEM.
- Study of iron oxide nanofluids application in enhances oil recovery through3 corefloodingtest in three different core samples.

1.5 Relevancy and Feasibility

This project is relevant to the oil and gas industry to increase the production of residual oil in place in the reservoir. It can be applied in chemical EOR to reduce the loss of surfactant in reservoir during surfactant flooding. This project is feasible in term of material, time and cost.

CHAPTER 2

LITERATURE REVIEW

2.1 Chemical EOR

In many oil producing regions of the world we have reached the stage where the total rate of production is nearing the decline phase (Hite et. Al., 2005). The older and larger fields face abandonment with 50% of the original oil in place (OOIP) uncovered. This situation provides a major challenge on how to extract more oil economically and delay abandonment. Chemical enhanced oil recovery (EOR) has been a tantalizing possibility for decades, but sustained low prices for much of the 1980’s and 1990’s made the technology too expensive and risky as a commercial proposition (Thomas, 2005).

In summary, Chemical EOR aims to either;

- Increase the capillary number (Nc) to mobilize residual oil, or
- Decrease the mobility ration (M) for better sweep efficiency, or
- Improve conformance in heterogeneous reservoir for better sweep efficiency.

2.2 Wettability and Nano-scale

Wettability of reservoir rock plays a vital role in determining the recovery efficiency of the displacement process. Wettability affects both the distribution of hydrocarbon and aqueous phases within the rock matrix and the dynamics of displacement.

Wetting behavior of reservoir rock surface is strongly dependent on adsorption of crude oil components (Cuiec, 1990). At the nano-scale, the pore shape, mineralogy, roughness, water distribution and surface film behavior dominate oil recovery (Morrow, 1990). Because the surface areas are small, measurements can be seriously affected by equilibrium procedures and contaminants that alter adsorption behavior.

EOR is dependent on the processes at the nano-scale in addition to micro and macro scales. Although oil recovery needs to overcome capillary forces it is the boundary conditions (pore geometry and wettability) and effects of instabilities of the associated interfaces that govern the oil displacement at the micro scale. Trapping of oil in water wet systems happens because the viscous/buoyancy forces acting locally cannot overcome the large capillary forces at small pore throats within the rock that exists when the interfacial tension is high.

Wasanet al. (2011) studied the role of disjoining pressure for wetting and spreading of nanofluids on a solid surface. Disjoining pressure is a pressure that arises when two surface layers reciprocally overlap, and is caused by the total effect of forces that are different by nature. Electrostatic forces, the forces of “elastic” resistance of solvated, or adsorbed solvated, films, and the forces of molecular interaction can act as components of the disjoining pressure.

Wasan et al. (2011) reported that the driving force for the spreading of a nanofluid is the structural disjoining pressure direct towards the wedge from the bulk solution. The film tension is high near the vertex, because the particles are structuring in the wedge confinement. As the tension on the film gets bigger towards the top of the wedge, it will cause the nanofluid to spread at the wedge tip. This will improve the dynamic spreading behavior of the nanofluid. Figure 2 shows how nanoparticles structure inside the wedge film, formed between an oil droplet and a solid surface. The result is that the nanoparticles exert a large pressure through the wedge film relative to the bulk solution. This excess pressure, also called disjoining pressure, will separate the two phases from each other.

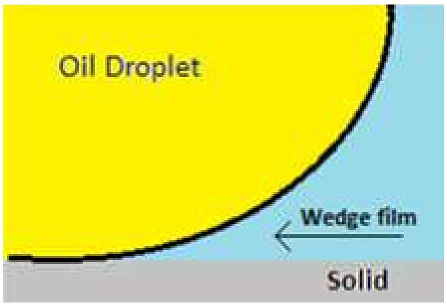


Figure 1: Oil drop placed on a solid surface.

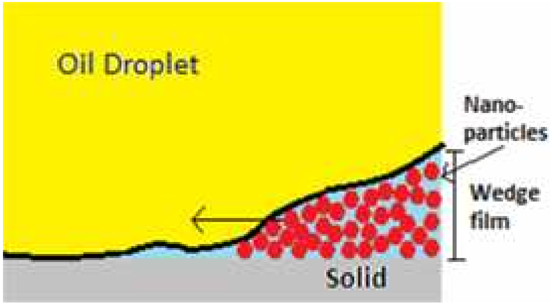


Figure 2: Nanoparticle structuring in the wedge-film, resulting in structural disjoining pressure at the wedge vertex.

2.3 Retention in Porous Media

Porous media is a complex structure of pore bodies and throats covering a range of sizes. Particle retention in porous media has been a concern for many industries, since the transport of particles is limited to the degree to which the particles are retained by the porous medium. Reservoir rocks that bear oil and gas can be severely affected by particle invasion (C. Gao, 2007).

Particle movement in porous media is a very complex process due to complexity and forces controlling solid movement in porous media. Adsorption of particles onto rock surfacebecause of the Brownian motion, and the electrostatic interaction between the migration particles and the solid surface of the pores is one of the mechanisms (C. Gao, 2007). Mechanical entrapment, or deep-bed filtration, in small pores has been recognized as another element of retention (Hao, E et. Al, 1990). The mechanism, also known as straining, leads to blocking of narrow pore throats by larger particles. The evidence for mechanical entrapment is taken to be either that the particle concentration in the effluent does not reach the injected concentration, or that it would do so only after injecting a large volume of particles (Skauge et al, 2010).

The third entrapment mechanism is known as log-jamming. This mechanism is similar to straining, but particles can block pores larger than the particle size. Due to density differences between moving particles and carrying fluid, sedimentation or gravity settling will take place. When pore throats narrows, flow velocity will increase. Water molecules will then accelerate faster than heavier particles, and accumulation will occur. Due to gravity settling the pore throat will gradually be reduced and eventually blocked. The main factors governing the log–jamming effect are particle concentration and effective hydrodynamic size, pore size distribution and flow rate.

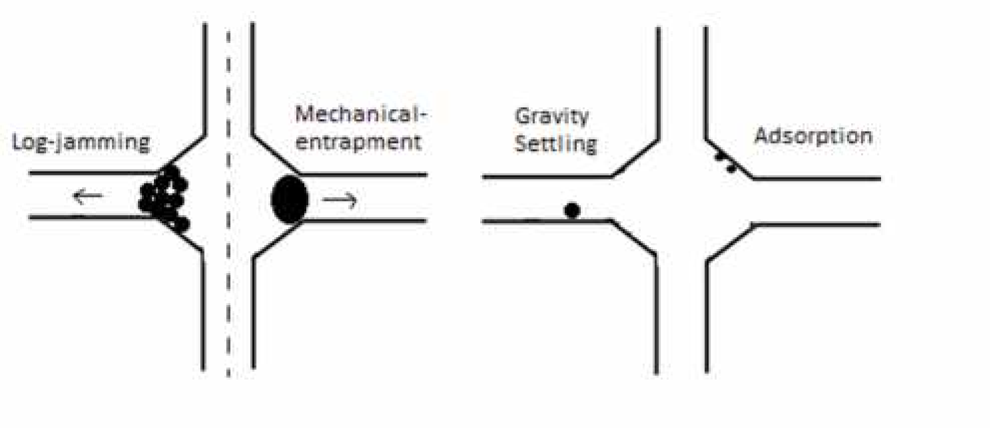


Figure 3: EntrapmentMechanisms –Four different entrapment mechanisms; log-jamming, mechanical entrapment, gravity settling and adsorption.

2.4 Formation Fines

Formation fines are defined as loose or unconfined solid particles present in the pore spaces of sandstone formations and the particles are usually smaller than 37 microns, which means the particles small enough to pass through a 400 U.S mesh screen. Formation fines include clay and non-clay particles, and charged as well as non charged particles. These “fines” cab be classified as detrital or authigenic in nature, meaning they were either originally deposited with the rock sediments or were created some time afterwards by weathering effects, respectively. It is formation fines in the authigenic category that usually cause most of the production problems by migrating to the wellbore and sometimes swelling. Examination of well cores with a scanning electron microscope is required to distinguish if the fines are likely to be the migrating variety.

These particles may easily migrate with fluids that flow in sandstone formations. Reservoir fluid velocity increases tremendously as fluid moves from boundaries towards the wellbore. At a critical velocity near the wellbore fines can be picked up into the fluid or gas stream and redeposited near the wellbore. As well production continues, a large quantity of the formation fines can be concentrated in the near wellbore region. Continued fine migration and deposition near the wellbore can result in very high positive skin completions. If the fines migrate into a premium or prepacked screen, the localized plugging and high velocity “hotspot” could ensure, possibly resulting in screen erosion and failure. Different factors such as salinity, flow rates, pH, temperature, residual oil saturation, wettability, oil polarity and fractional flow of oil and water has affects on the acceleration of formation fines migration.

The nanoparticles tested for fines control have significant high surface forces, including van der Waals force and electrostatic forces, to attach the nanoparticles to the surface of proppant during fracturing pumping treatments. When formation fines move through the nanoparticle-treated proppant pack, the surface forces of the nanoparticles attract and retain formation fines, thereby preventing them from moving to the near wellbore region.

CHAPTER 3

METHODOLOGY

3.1 Characterization of Nanoparticles

The iron oxide nanocrystalline powders were synthesis by using the sol-gel method. 50g of iron nitrate was diluted with 1.0M 100ml citric acid solution in aqueous solution at pH 8. The solution was stir continuously by using magnetic stirrer for 4 hours at 60 deg C until it becomes gels. After that, the gels were heated in the drying oven for 24 hours at 110 degC to remove all the impurities until the gels become iron nanocrystalline powders. The nanoparticles were annealed at a temperature of 600^{o}C. Microstructural characterization and crystallographic studies were conducted via Transmission Electron Microscopy (TEM) and X-Ray Diffraction (XRD).

3.2 Porous Media Preparation

Three different porous media: sandstone, glass bead, and river sand were chosen in this experiment. Sandstone and river sand were collected from an outcrop of a local sandstone formation and sand bar near the river. Samples were disintegrated into small pieces by crusher. Rock samples were dried for 24hrs and sieved to obtain particles less than 150nm. The permeability was measured using Darcy’s Law for each of samples before the iron oxide dispersion injection.

3.3 Nanofluid Preparation

Iron Oxide nanoparticles in the form of powder were mechanically mixed in deionized water to form a suspension and stabilized by a small amount of an anionic surfactant, sodium dedocylsulphate (SDS). The amount of nanoparticles to be dispersed in the base fluid was fixed to 0.1 wt% for all samples. The nanoparticles suspensions were further agitated in an ultrasonic bath for 1 hour to reduce nanoparticles agglomeration and ensure longer dispersion of powder particles in aqueous solution.

3.4 Coreflood Experimental Method

A coreflood tests were performed to study iron oxide nanofluids particle adsorption onto three different porous media. An unconsolidated core sample made of sandstone, glass bead, and river sand having an average size measurement of 100-150µm were packed homogeneously and saturated with brine of 30,000 ppm. Pressure measurement was made at a point just upstream of the inlet to the porous medium. Properties of porous medium e.g. permeability, porosity and pore volume were measured at this stage.Iron oxide nanofluid was injected into the porous medium horizontally at a constant flow rate of 3.0 mL/min.

By measuring the particle concentration in the effluent by using UV/Vis spectrophotometer, iron oxide nanofluids transport in different core samples was investigated. Particle plugging and changes of core’s permeability was observed during the tests by measured pressure drop across the porous medium.

3.5 Research Methodology Flow Chart

In order to successfully complete the project, series of steps and procedures are clearly identified. Below is the flow chart which describes and explains the research methodology.

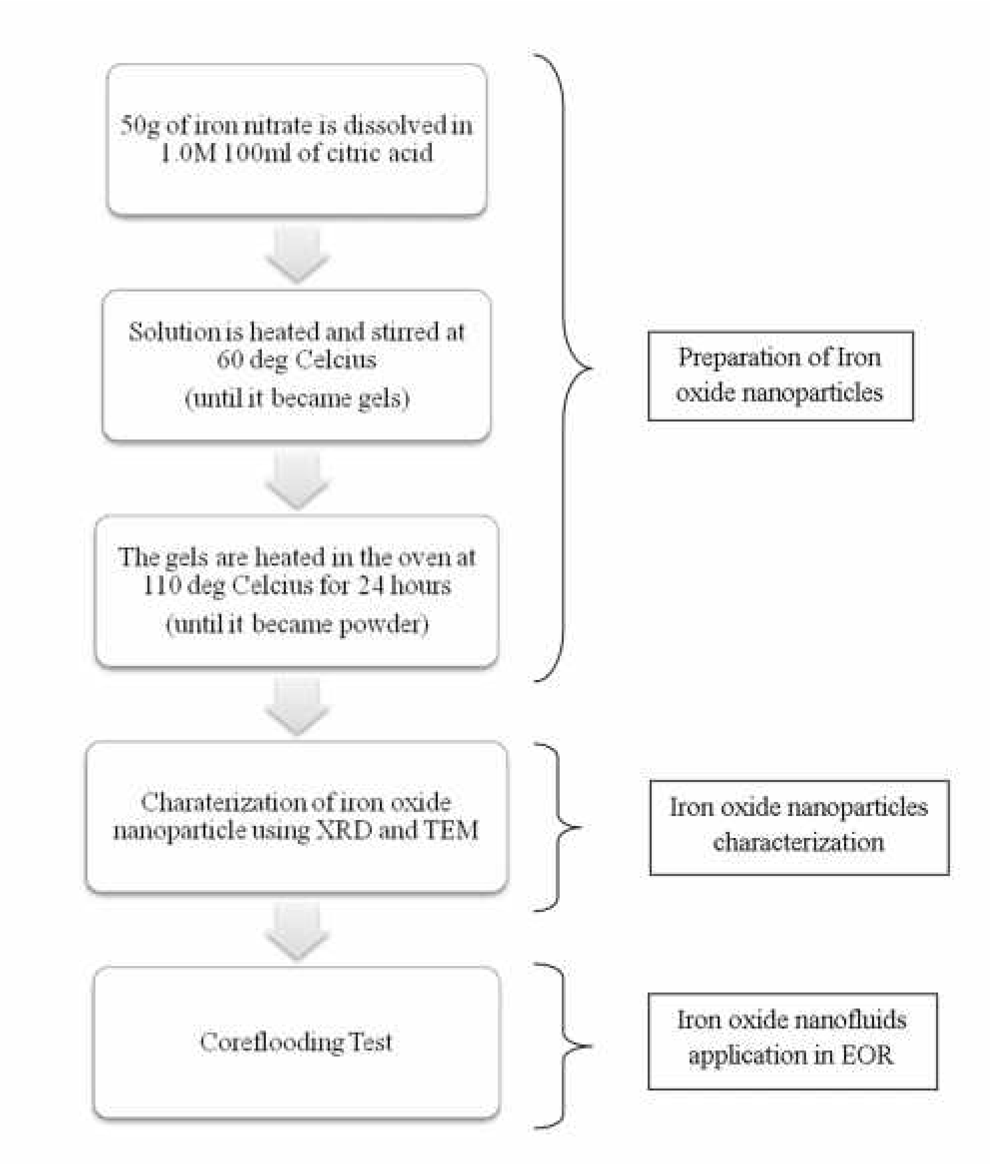
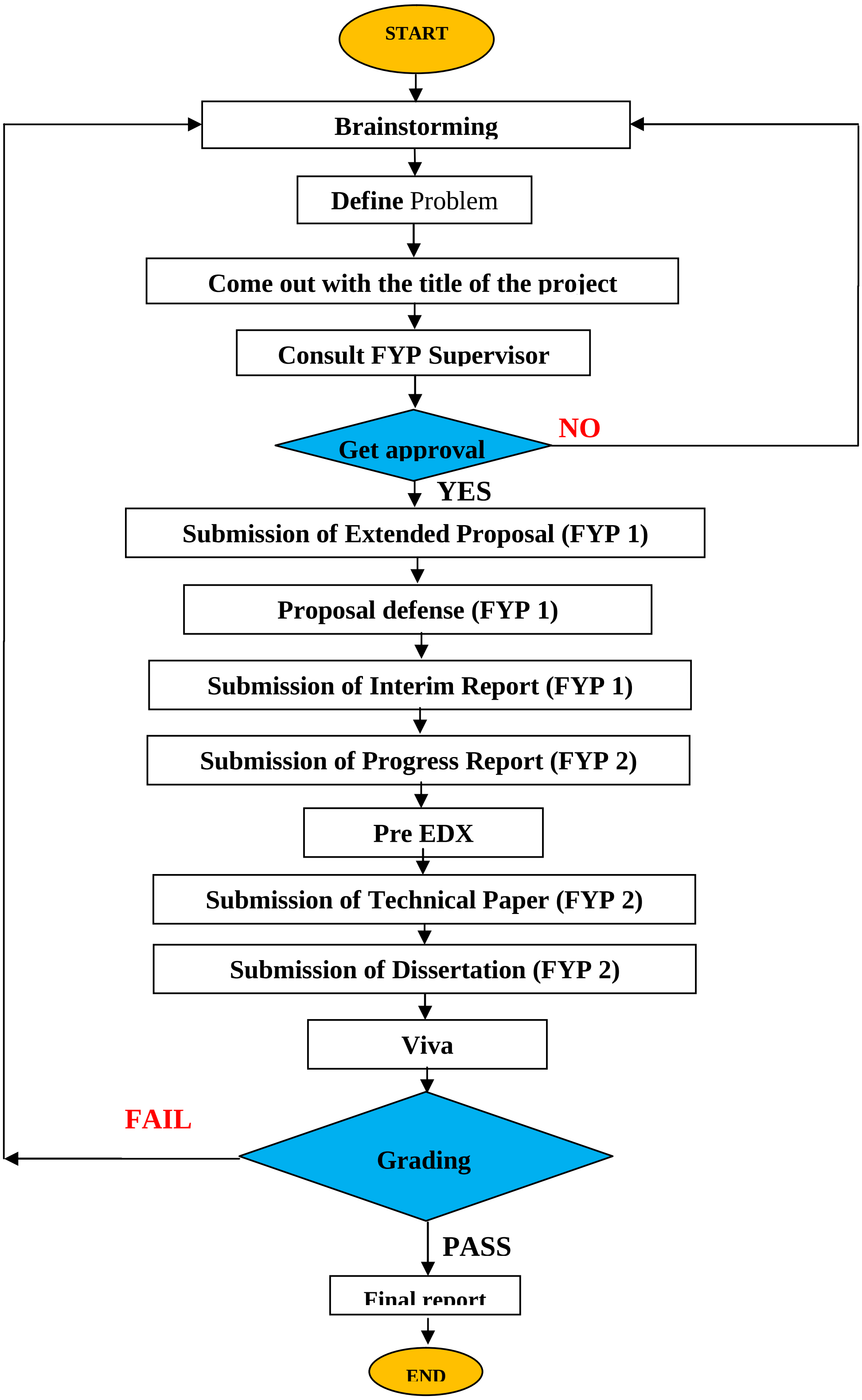


Figure 4: Research Methodology Flow Chart

3.6 Key Milestone

Below is the key milestone starts from the problem of the project until the final report submission.



3.7 Gantt Chart

In order to ensure the project to be completed within the specific time, a schedule has been set up. Specificactivities with proper planning are essential to complete and finish the project. The Gantt chart can be referred to ***Appendix***.

3.8 Tools and Equipment Required

Below are the chemicals and equipmentthat are used to prepare the sample:

- 5g of Iron Nitrate
- 100ml of 1.0M Citric Acid
- Magnetic stirrer
- Hot plate
- Drying Oven
- Furnace

Below are the equipments and tests that are used in the project:

Table 1: Equipment used in the project

Equipment	**Function**
X-Ray Diffraction (XRD)	This test is used to identify crystal structure and physical properties of iron oxide.
Transmission Electron Microscopy (TEM)	This analysis provides fine details of atom of iron oxide such as particles size and microstructure characteristics.
UV/Vis spectrophotometer	It measures the intensity of light passing through a effluent sample, Cand compares it to the intensity of light reflected from a reference sample, Co.

3.9 X-ray diffraction (XRD)

X-ray diffraction is a non-destructive analytical technique which can yield the unique fingerprint of Bragg reflections associated with a crystal structure. A crystal structure can be defined as being built of layers, or planes, which each act as a semi-transparent mirror. X-rays with a wavelength similar to the distances between these planes can be reflected such that the angle of reflection is equal to the angle of incidence. This behavior is called `diffraction´. When the to Bragg´s Law. Peak intensities give information about how much X-ray scattering is contributing to that reflection, for an example, where particular atoms lie in the structure, or how much of a phase is present in a sample. Diffraction pattern analysis allows the identification of phases within a given sample. With that achieved, it may be possible to quantify each phase present, the crystalline of a sample, the crystal structures and their lattice parameters, particle size and strain and all information that can be vital in material characterization and quality control.

Figure 5: XRD equipment

3.10 Transmission Electron Microscope (TEM)

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor such as a CCD camera. TEMs are capable of imaging at a significantly higher resolution than light microscopes, owing to the small de Broglie wavelength of electrons. This enables the instrument's user to examine fine detail—even as small as a single column of atoms, which is thousands of times smaller than the smallest resolvable object in a light microscope. TEM forms a major analysis method in a range of scientific fields, in both physical and biological sciences. TEMs find application in cancer research, virology, materials science as well as pollution, nanotechnology, and semiconductor research.

Figure 6: TEM equipment

3.11 Coreflooding Equipment Set Up

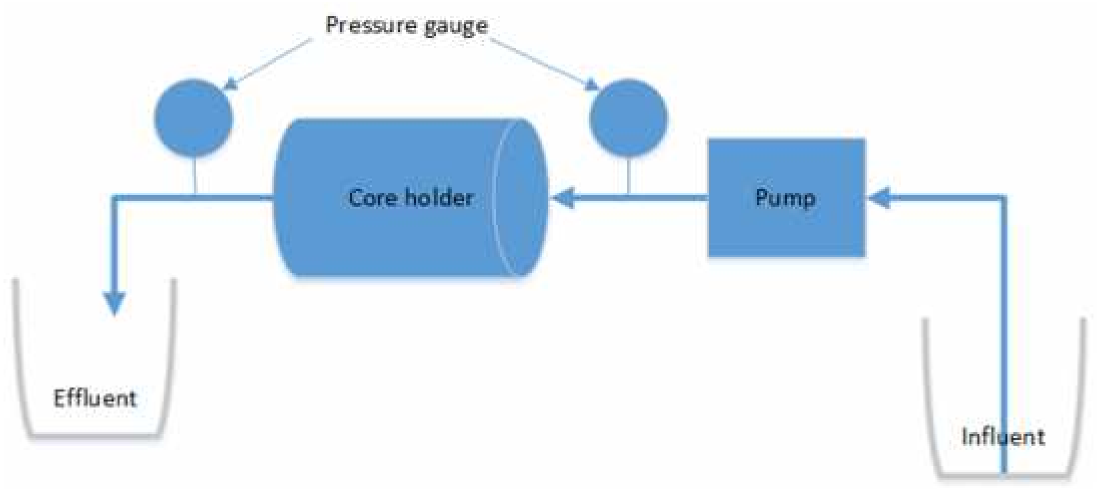


Figure 7: Coreflooding Equipment Set up

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characterization of iron oxide nanoparticles.

Fig. 8 shows TEM images for few samples of Fe_2O_3 nanoparticles which have shown agglomeration on nanoparticles without proper coating or surfactants. Morphology images of Fe_2O_3 depicted hexagonal shape.

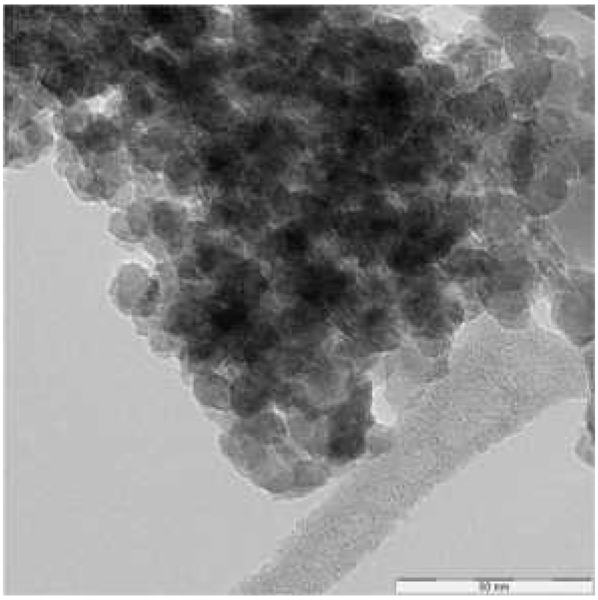


Figure 8: TEM image of iron oxide nanoparticle aggregate

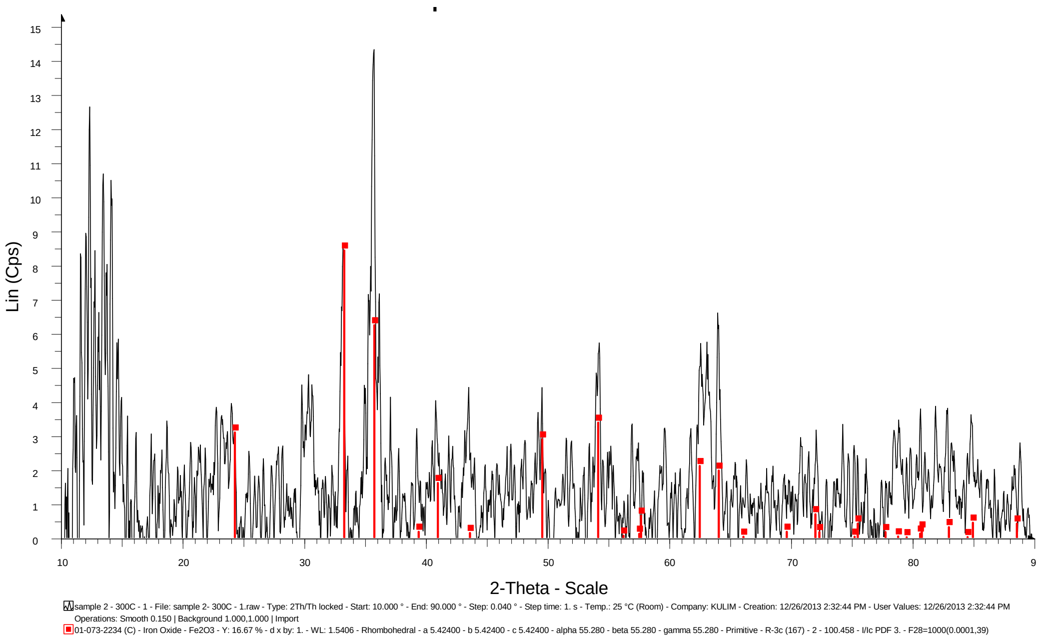


Figure 9: XRD pattern of iron oxide powder prepared by electron beam radiation

Average particle size, D of the iron oxide nanoparticles was calculated from the X-Ray line broadening method using the Scherrer equation.

$$D = \frac{K\lambda}{\beta cos\theta}$$

Where: K = Scherrer constant, 0.9

β = peak width at half maximum intensity, FWHM

λ = X-ray wavelength (1.5406 m)

θ = Bragg's angle

Table 2: Fe_2O_3 nanoparticles values of d-spacing, crystallite size and structure.

X- Ray Diffraction (Correspond to [311] peaks)				
Samples /Annealing temperature	**FWHM**	**d-spacing(Å)**	**Particle Size (nm)**	**Crystal Structure**
Fe_2O_3 – SDS - 300	0.2	3.66689	8.607	Hexagonal (Rh)

The XRD pattern of fabricated iron oxide nanoparticles is shown in Fig. 9. From the results, there are 7 major peaks. The XRD major peaks are at $2\theta = 3.5^o$, 8.5^o, 6.45^o, 1.93^o, 3.24^o, 3.62^o, 2.24^o, and 2.02^o. According to JCPDS card (76-1821), the powder is hexagonal α-Fe_2O_3. Calculated from the Scherrer equation, the sizes of particle ranged from 8.2 nm to 10.9 nm (mean value – 8.607 nm). The TEM images are shown in Fig. 6. The iron oxide (III) particles have hexagonal shape morphology, fine dispersion and mean particle sizes between 8 and 10 nm. The nanoparticle sizes observed by TEM are in agreement with those calculated by XRD.

One of the factors that affect the transport behavior is the shape of the nanoparticles. This showed that the size for the $Fe_2O_3$is not good for the transport of nanoparticle through the porous medium. The best shape is round nanoparticle because it has larger surface area than hexagonal shape.

4.2 Iron oxide particle transport in three porous medium

Sandstone, glass bead and river sand porous media were put into core holder. The porosity and permeability were measured for each of porous medium before the iron oxide dispersion injection. Table 3 shows the parameter of each porous media.

Table 3: Core sample parameters

Parameters	**Sandstone**	**Glass bead**	**River sand**
Sample length (cm)	10	10	10
Sample diameter (cm)	3.5	3.5	3.5
Grain size (nm)	150	150	150
Permeability (md)	204	254	382
Porosity (%)	6.4	4.3	6.1
Pore Volume (ml)	100.6	66.2	96.5

Sandstone Coreflood

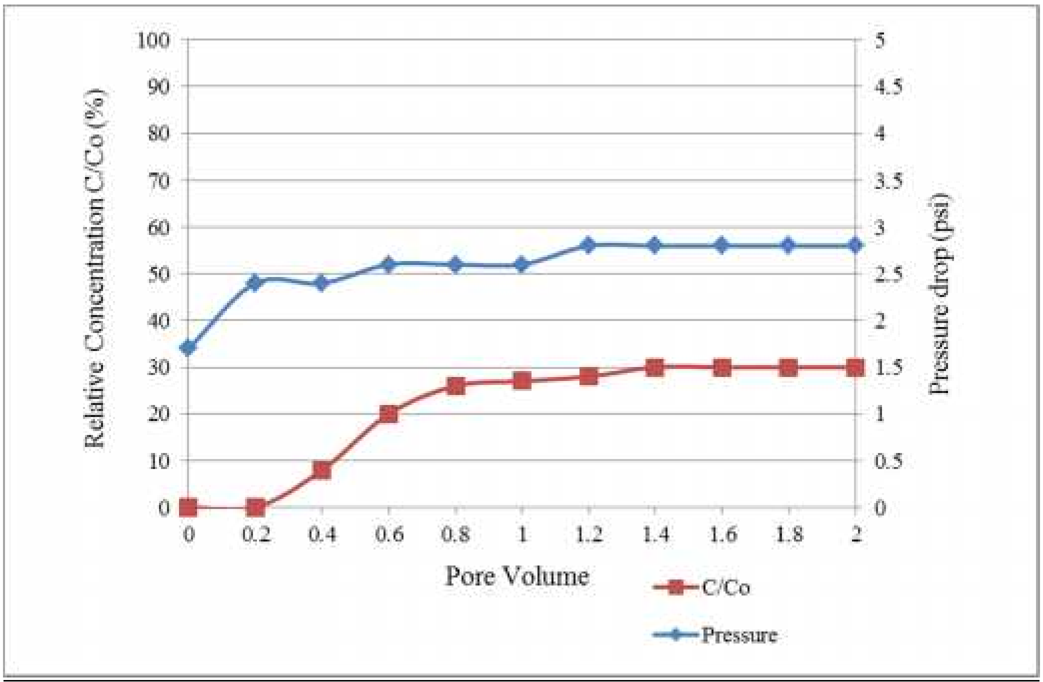


Figure 10: Effluent concentration and pressure drop change with injected volume (sandstone)

The first coreflood was performed in sandstone with permeability of 204 md. Before injection of iron oxide dispersion, the porous media was flooded with brine. The nanoparticle dispersion (0.1%wt) was injectedat a flow rate of 1.0ml/min. Two PV of iron oxide dispersion were injected. Fig. 10 shows the changes of nanoparticle concentration different in the effluent samples and pressure drop across the porous media with the injection volume for sandstone.

The beginning of breakthrough for the nanoparticles was observed at 0.4 PV injections. As 2 PV were injected, the particle relative concentration reach 30% of the original nanoparticle concentration. The small adsorption of iron oxide nanoparticle onto the sandstone is probably due to the particle high surface energy and the clay in the sandstone. Fig. 10 also displays the change of pressure drop across the porous media during the coreflood. The pressure drop was observed increase continuously during the coreflood test. The increase of the pressure drop is probably due to the porous medium permeability change, which means the particle plugging occurred in the porous medium. The alteration of the porous permeability could contribute to changes in the pore structure in the core. Sandstone has the low permeability which could lead to higher interactions between moving particles and pore surfaces that promote pore – throat processes e.g. plugging.

Glass bead Coreflood

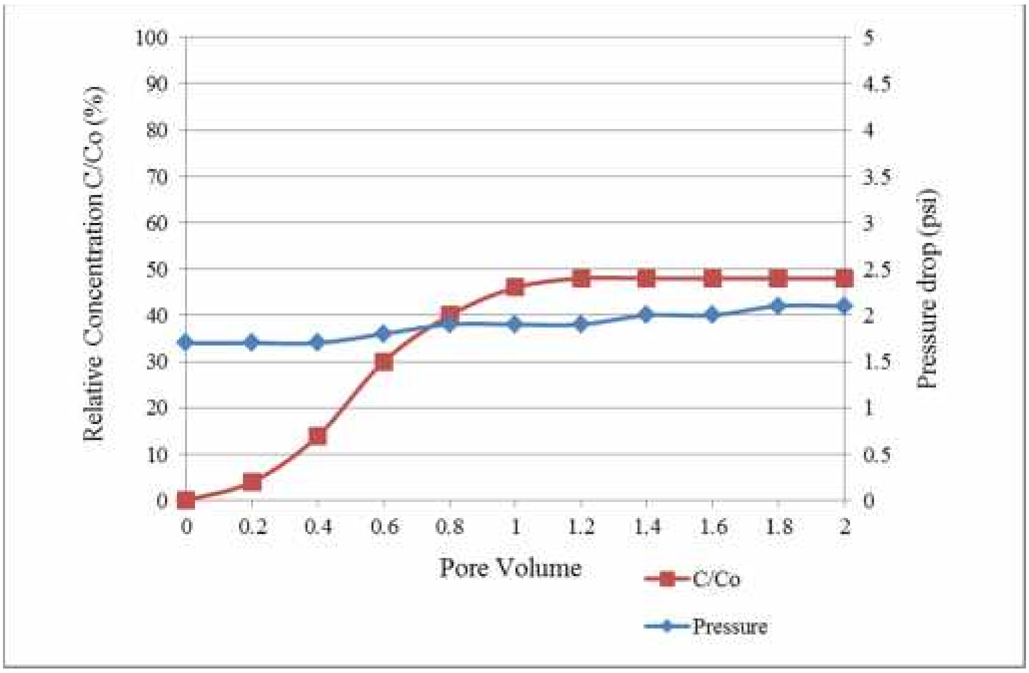


Figure 11: Effluent concentration and pressure drop change with injected volume (glass bead)

The second coreflood was performed with glass bead, which having permeability 340 md. Fig. 11 shows the results of the concentration different and pressure drop change with the injection volume. The coreflood test in the glass bead also was performed with injection of 2 PV iron oxide nanofluids dispersion. The results indicated that the particle breakthrough started after 0.2 PV particle dispersions were injected, which a little faster than the sandstone. The high particle recovery is due to the low adsorption capacity in glass bead. However, there was no evidence of alteration of porous permeability or core plugging by the iron oxide nanoparticle.

River sand Coreflood

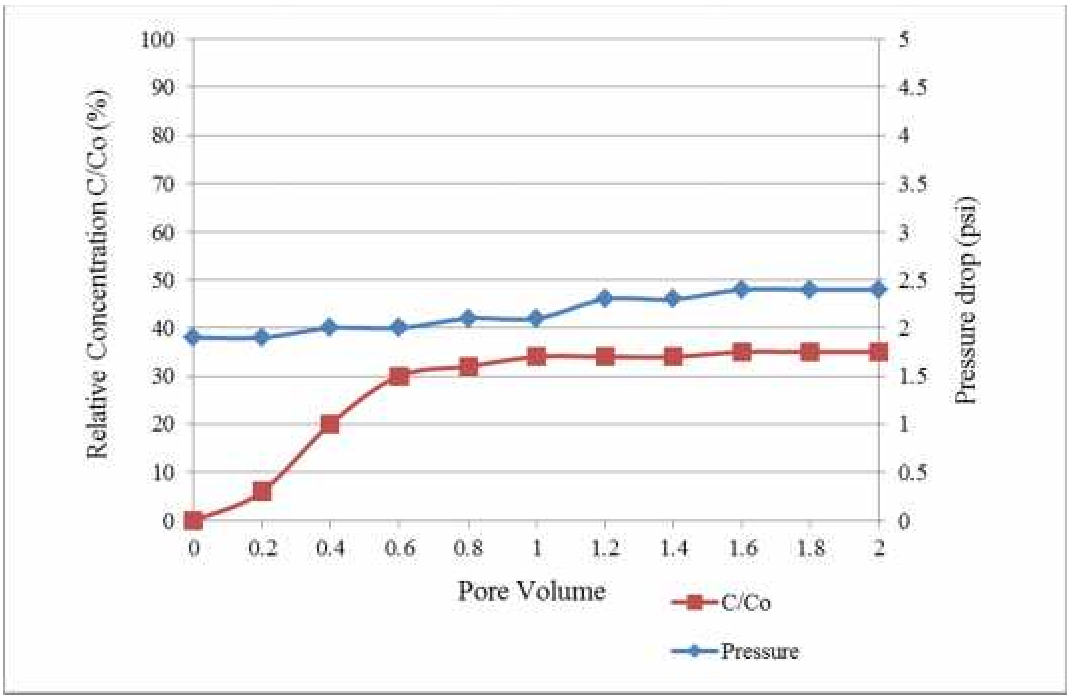


Figure 12: Effluent concentration and pressure drop change with injected volume (river sand)

Fig. 12 shows the results of the concentration and pressure drop change with injection volume for river sand. The results indicated that the particle breakthrough started after 0.2PV nanoparticle dispersion was injected. After 2 PV nanoparticles dispersion was injected, the relative concentration was calculated as 35%. The low adsorption of iron oxide nanoparticles onto river sand was probably due to low electrostatic force between the iron oxide nanoparticle and the river sand surface. Pressure drop across the core was observed to change slightly during the coreflood test. Thus, it can conclude that although a few nanoparticles were adsorbed in the core, the permeability of the core was not altered.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this study, it was found that morphology image of Fe_2O_3 depicted hexagonal shape and calculated particle size is 8.607 nm. The relative concentration of iron oxide for sandstone, glass bead, and river sand were estimated as 30%, 48% and 35% respectively. Iron oxide show the lowest adsorption (0.03 wt %) and transport behaviour in the sandstone compare to river sand and glass bead. Sandstone has the lowest permeability compare to other which could lead to higher interactions between moving particles and pore surfaces that promote pore – throat processes e.g. plugging. The pressure drop was observed increase continuously during the coreflood test due to the porous medium permeability change, which means the particle plugging occurred in the porous medium. The alteration of the porous permeability could contribute to changes in the pore structure in the core.

5.2 Future Direction

The objective of the nanofluid research is to develop new nanofluids synthesis methods, obtain comprehensive experimental data and appropriate theoretical models. Then, these data and model can be used to guide the production of nanofluids for different applications. Although the use of iron oxide nanofluids in a wide variety of applications has a brilliant future, there are still several important properties to be observed to understand process at detailed atomic leveled such as size of dispersed iron oxide nanoparticles, particle agglomeration and coagulation, thermal conductivity of iron oxide nanofluids, and surface properties of iron oxide nanofluids.

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Appendix

Title : Study of Adsorption and Transportation Behavior of Iron Oxide Nanofluids in Different Porous Media
Department : Petroleum Engineering

FYP 1

ASPECTS	ACTIVITIES	WEEK														
		1	2	3	4	5	6	7		8	9	10	11	12	13	14
Experiment	Preliminary Research Work	🟦	🟦	🟦	🟦	🟦	🟦	🟦	**MID-SEM BREAK**							
	Synthesized iron oxide nanoparticles				🟦	🟦	🟦	🟦								
	Characterization using XRD and TEM												🟦	🟦	🟦	🟦
Documentation (FYP 1)	Selection of Project Topic	🟦	🟦													
	Preliminary Research Work		🟦	🟦	🟦	🟦	🟦									
	Submission of Extended Proposal Defence							🟦								
	Proposal Defence									🟦	🟦					
	Project work continues											🟦	🟦	🟦		
	Submission of Interim Draft Report														🟦	
	Submission of Interim Report															🟦

Appendix

FYP 2

ASPECTS	ACTIVITIES	WEEK															
		1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
Experiment	Preparation of Nanofluids	■	■						**MID-SEM BREAK**								
	IFT measurement				■	■											
	Coreflooding Test						■	■									
	Analyse Data									■	■	■					
Documentation (FYP 2)	Project Work Continue	■	■	■	■	■	■	■									
	Submission of project report									■							
	Project work continue									■	■	■	■	■			
	Pre-EDX												■				
	Submission of Draft Report													■			
	Submission of Dissertation														■		
	Submission of Technical Paper														■		
	Oral Presentation															■	
	Submission of Project Dissertation (Hard Bound)																■

Approved by:

Dr. Beh Hoe Guan

Prepared by:

Herman Hari Matraji

Appendix

Preparation of iron oxide nanoparticle

Coreflooding equipment set up