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EFFECTS OF GRAIN SIZE AND GRAIN GEOMETRIES ON RESIDUAL OIL SATURATION AFTER WATER FLOODING

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Abstrak. This paper presents an experimental study on the effect of grains size and grain geometry on residual oil saturation after water flooding. Cylindrical sand pack holder (2.5 cm × 30.5 cm) was developed and all variables except grain size and grain geometry were kept constant during the water flood experiment. The flow rates of water flooding process in this experiment were set to 11 ml/min, crude oil as a displaced fluid and NaCl solution (brine) with 20,000 ppm concentration was used as a displacing fluid injected into the sand pack. The result from the first part of the experiment revealed that grain with size from 250 – 500 (μm) produce the highest residual oil saturation, while grain with 1000-2000 (μm) size recovers more oil. Second part of the study show that angular grain geometry with (80% glass bead + 20% sand) produced the highest residual oil saturation, indicating an effect on residual oil saturation due to grain geometry, while percentage of oil recovery varies when there is an increase of percentage of sand in sand pack consist of glass bead. The result of this study showed that grain size and grain geometry have a measurable effect on residual oil saturation after water flooding.

Keywords: Grain size; grain geometries; residual oil saturation

1.0 INTRODUCTION

During the early stages of a water flood in a water wet reservoir system the brine exist as a film around the sand grains and oil fill the remaining pore spaces. At a time intermediate during the flood the oil saturation had been decreased and exists partly as a discontinuous phase in some pore channel but as discontinuous droplets in other channel. At end of flood when the oil has been reduced to a residual oil saturation (S_{or}), the oil exist primarily as discontinuous phase droplets or globules that have been isolated and trapped by the displacing brine. The mobilization of the residual oil in a water wet system requires that the discontinuous globules be connected to form a continuous flow channel that leads to a producing well. The water flooding of oil in oil wet system yields a different fluids distribution at S_{or}. Early in the water flood, the brines from continuous flow paths through the centre portion of some of the pore channel. The brines enter more and more of the pore channel as the water injected. At residual oil saturation, the brine has entered a sufficient number of pore channels to shut of the oil flow. The residual oil exists as a film around the sand grain. In the smaller flow channel, this film may occupy the entire void space.

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Successful operation of enhanced oil recovery schemes requires that methods be developed which can improve the displacement efficiency in the swept zones of an oil reservoir. Evaluation of the mechanisms must be conducted by considering the microscopic flow behavior of the reservoir fluids within the pores that contain them. Water, which is the wetting phase since it tends to coat the matrix, is continuous throughout the rock. As the non-wetting fluid, occupies central portions of the void space of the solid matrix. Prior to production of oil from the formation, the oil phase is mostly continuously connected throughout the rock. In immiscible, a fluid-fluid displacement such as water flooding, the non-wetting oil is pushed through the irregular void geometry of the porous medium. Displacement under these conditions is characterized by movement of an oil bank followed by the commingled flow of both phases. Flow after the passage of the oil bank is followed by breakup and coalescence of oil droplets. Droplets break up whenever their different parts fail to maintain uniform mean curvatures. Some of these droplets or ganglia, under suitable conditions during simultaneous flow of both phases meet with each other and can possibly merge. In a flowing situation, the geometrical configurations of these ganglia are strongly guided by the wettability of the solid matrix or rock and the geometry of individual pores and pore connections. Individual pores of real porous media are non-circular and uneven in cross-section. An oil ganglion flowing through a pore will become entrapped or immobilized whenever the forces available to carry it along in a flood in sufficient to squeeze it through any of the pore exits.

It is necessary to understand the pore matrix (geometry of individual pores, pore size distribution, interconnectivity and spatial arrangement of pores) and the interplay of the different forces and phenomena immobilized oil ganglia. It is realized that on a microscopic scale the pore structure most porous media is heterogeneous and random. Even for packs of spheres, regularity in pore shapes would at best be localized. Upon of equal various approaches have been considered previously. For example, multiphase flow phenomena have been studied in non-circular and uneven pores and attempts have been made to study gross behavior within porous media by devising random network or other models which consider the branching and merging of pores. Unfortunately, with all of these processes, several assumptions and realizations such as the shapes of individual pores and the operative forces were necessary. This in turn restricted their utility. Another approach is to consider porous media as granular aggregates. An inclusion of different levels of cementation permits application in situations covering the range from unconsolidated to consolidated media. Although the grains in a typical oil bearing formation might be sub angular or surrounded and would exhibit a size distribution, as a starting point for analysis, they might be considered as aggregates of equal spheres packed in certain well defined geometrical configurations. Approximate analytical expressions for the shape of fluid-fluid interfaces in pore spaces of such aggregates are available for specific cases However; there exists a need for developing a comprehensive model with which one would be able to examine the different aspects of the flow of disconnected oil and oil droplets in porous media. An understanding of the phenomena associated with entrapment and mobilization of entrapped ganglia in well defined geometries and provides a firm basis upon which to generalize to more realistic media. In this research the effect of grain sizes and grain geometry on residual oil saturations after water flooding will be studied to obtain an information and knowledge that involve in the flowing process that occur in the reservoir.

2.0 METHODOLOGY

2.1 Materials and Equipments

The main materials used in this experiment were various size of sand and mixture of glass bead and sand with a certain ratio, brine (NaCl solutions) with concentration 20,000 ppm as a displacing fluid and crude oil as a displaced fluid. Meanwhile the equipment that involved was such as shrinkage pump, sand pack holder and measure cylinder. The sand pack holder comprises, a housing forming an open-ended longitudinal bore where fluid may be injected into the sand sample at one end and discharged from the other ports can be readily accessed. The dimension of sand pack holder is 30.5 cm in length and 2.5 cm in diameter. Both sides were equipped with metal sieve that prevents any sand flow.

2.2 Experimental Procedure

(1) Once it had packed, the weight of model was measured. Then oil was injected until the porous medium fully saturated with the oil. At this time, the S_o value could be determined as 100%. After that, the weight of model within saturated of oil was measured again which then a material balance was performed to determine the pore volume and porosity of the sand pack.

(2) Then about 100 ml of brine was injected through the sand pack to create two phase condition in the model. Total volume of displaced fluid either crude oil or brine was noted to determine S_{oi} and S_{wi}. Besides, the volume of oil trapped in the model and residual oil saturation can be measured. Now the model is ready to be flood.

(3) The imbibitions process was started by injection of brine to the model to displace the residual oil. The experiment was continued until about 0.5 to 2.5 pore volume (PV) brine was injected. The total volumes of fluids that go out from the model were then collected and were measured during this time. All experiments were performed in a horizontal plane and at ambient temperature and pressure.

(4) The volumes of displaced fluid were then calculated to determine S_{or} and S_{wr}. Finally, the percentage of residual oil saturation was determined. Plot the graph

percentage of residual oil saturations S_{or} (%) versus volume of water injected (PV), and oil recovery (%) versus volume of water injected (PV).

2.3 Result and Discussion

Basically the experiments were divided into two parts. In the first experiment sand pack with different sizes of sand were develop to determine the effect of grain sizes on residual oil saturation after water flooding. Secondly sand pack with mixture of sand and glass beads in certain ratio were set to investigate the effect of grain geometries on residual oil saturation after water flooding. The results from the experiment were interpreted base on percentage of residual oil saturation (S_{or}) and Oil recovery. All the data gathered from the experiment is analyzed and discuss in more details in this chapter.

2.4 Discussion of Results from Different Grain Sizes Experiments

There were 5 different sand sizes that were used to act as a porous media to represent the reservoir rock. All the result for the first part of the experiment was showed by the graph 4.1 and graph 4.2 that have been plotted used the data collected during the water flooding process. Discussion about the result was conducted for each grain size regarding it effect on residual oil saturation after water flooding

Based on the result presented on the Figure 4.1 and 4.2 it can reveal that the size of grain will effect residual oil saturation and oil recovery. The experiment showed that the smallest grain sizes produce greater residual oil saturation and greater oil

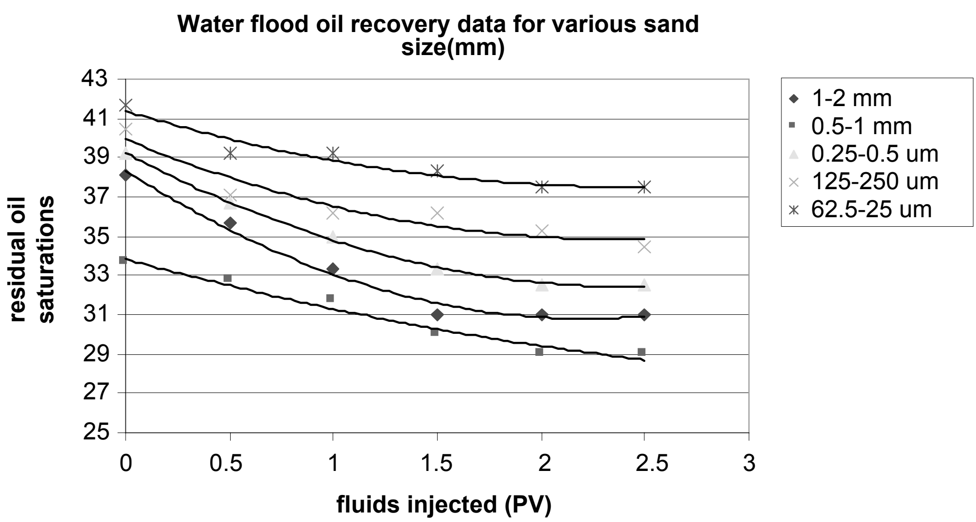

Figure 4.1 Residual Oil Saturation at various water injected in (PV) for different grain size

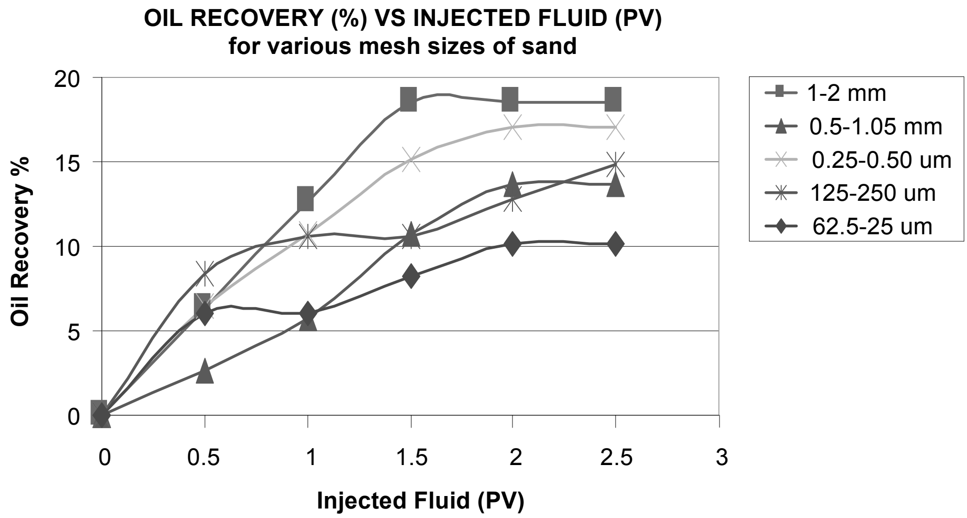

Figure 4.2 Oil Recovery at various water injected in (PV) for different grain size

recovery. Smallest Grain size would have greater surface of area that could trapped the oil. More oil will be trapped between the grain surface and when flood with water, high volume of oil still remain in the sand pack as a residual oil due to the greater resistance that exist in the smaller pore size distribution in the smaller grain size.

2.5 Discussion of Result from Different Grain Geometries Experiment

The mixture of glass bead and sand at 5 certain ratio numbers were tested in this experiment. Each of them was act as reservoir rock at a various mixture. Definitely oil recovery percentage for 100 % glass bead will different if they were interfering by sand. All the result for the second part of the experiment was showed by the graph 4.3 and graph 4.4 that have been plotted used the data collected during the water flooding process. Discussion about the result was conducted for each grain geometry regarding it effect on residual oil saturation after water flooding

Based on the result presented on the Figure 4.3 and 4.4 it can reveal that the geomety of grain will effect residual oil saturation and oil recovery. The experiment showed that the spherical grain geometry produce greater residual oil saturation but angular grain geometry indicates greater oil recovery if compared to spherical grain geometry. The angular geometry provided irregular pore shape which tends to give more oil entrapment in the sand pack.

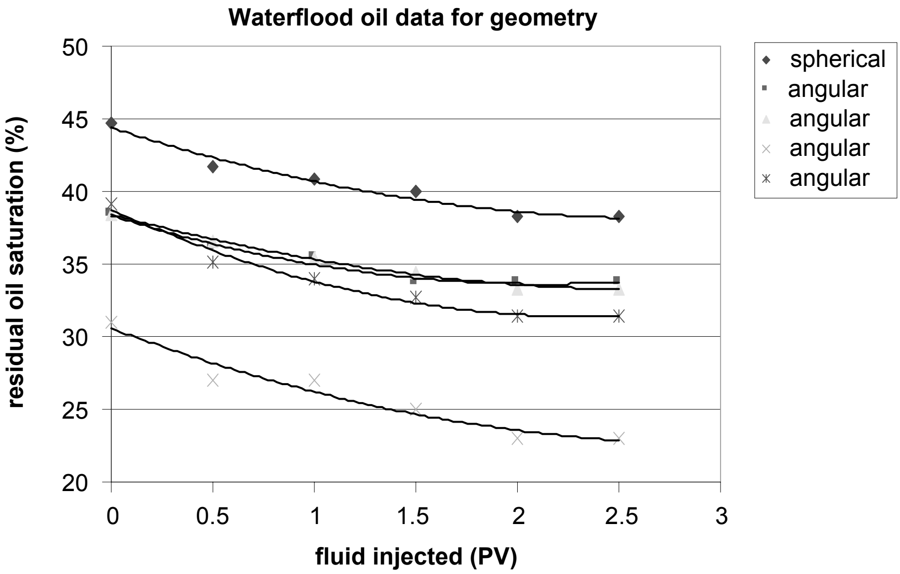

Figure 4.3 Residual Oil Saturation at various water injected in (PV) for different grain geometries

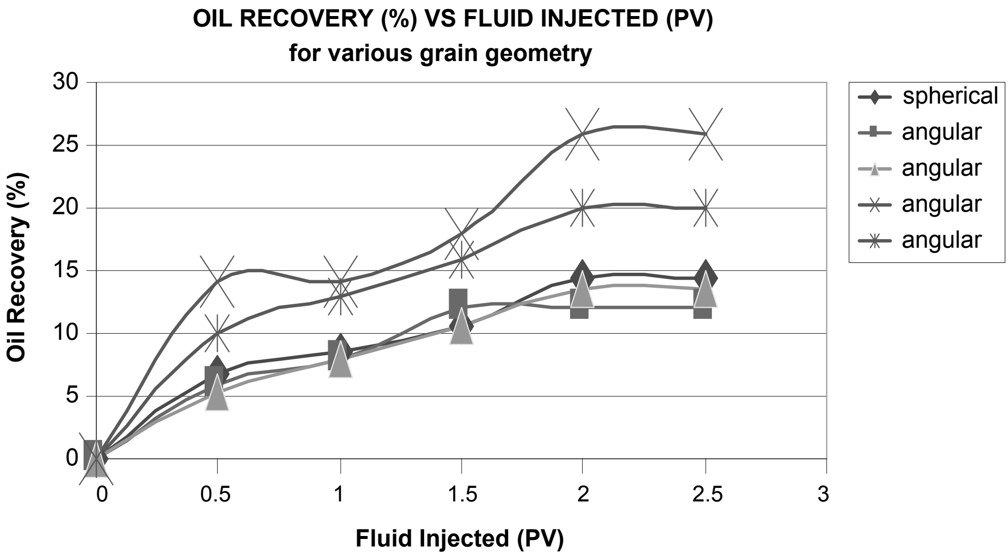

Figure 4.4 Oil Recovery at various water injected in (PV) for different grain geometries

3.0 CONCLUSIONS

Grain sizes and grain geometry can be considered as an important factor that can effect on residual oil saturation after water flooding. The result show that oil recovery increased when grain sized increased and angular geometry of media indicated better oil recovery result.

The following conclusion has been drawn from the data obtained during the investigation:

(1) A trend of higher residual oil saturation encountered when the finer grain sand were employed.
(2) Greater oil recovery was encountered with larger grains sizes than with smaller grains sizes.
(3) The uniform and spherical grain geometry had higher residual oil saturation than the angular geometry.
(4) Angular geometry had higher water saturation than the spherical geometry therefore angular geometry gave higher oil recovery.

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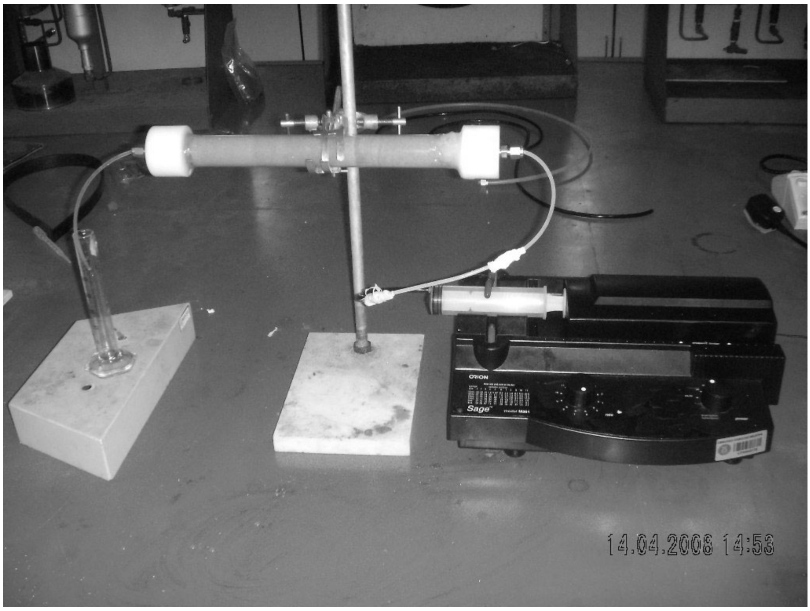
APPENDIX



Appendix 1 Experimental Construction and Design

Parameter Calculation

Pore Volume (PV)

$$PV = \frac{\text{Saturated Weight (g) - Dry Weight (g)}}{\rho \text{ Oil}}$$

$$= \frac{418.1 - 399.2}{0.82\text{g/ml}}$$

$$= 22.93$$

Porosity (Φ)

Φ = Pore Volume (PV) / Bulk Volume (Vb)
= (PV / Ah) * 100
= (22.93 / 154.44) * 100
= 14.85

Residual Oil Saturation (S_{or}) and Water Residual (S_{wr}).

S_{or} = (Voi – Vop) / PV

$$= \frac{100-(73+5)}{22.93}$$

= 52.33 in percent

$S_{wr} = 1 - S_{or}$

= 1-0.5233

= 0.4767

Oil Recovery (%)

$$\text{Oil recovery} = \frac{(1-S_{wi}-S_{or})}{(1-S_{wi})} * 100$$

$$= \frac{(1-0.619-0.31)}{(1-0.619)} * 100$$

$$= 18.42$$