MODELING ASPHALTENE DEPOSITION RELATED DAMAGES THROUGH CORE FLOODING TESTS

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ABSTRACT

Asphaltene deposition and its imposing damages in oil reservoir is an issue for several countries and have strong effect on oil production and its costs during various steps of recovery. Although tests performed by researchers determine the amount of deposition and reduction of permeability, the limits in which asphaltene precipitated in oil or deposited at the pore surface are not clearly determined.

In this paper, series of tests are performed in order to determine the effect of asphaltene deposition on sandstone rock. To generate reliable data on formation permeability damage due to asphaltene deposition, several dynamic displacement tests with oil asphaltene content were conducted in various rates and concentrations.

These laboratory tests have shown evidence of core damage happening under dynamic flowing conditions. Data were plotted in order to determine the effect of permeability reduction with comparison to reference oil permeability where they show a significant permeability reduction after flooding. The results have shown that removal and deposition processes occurred simultaneously and trends were similar to previous works where they track a smooth curve pattern except where removal occurs.

The test results and data used to develop a black model to predict new core flooding results without having expensive and time consuming laboratory tests. As concentration

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increases, at constant rate, more permeability damage occurs, also at constant concentration, as velocity increases, more permeability damage occurs.

INTRODUCTION

Asphaltene precipitation and deposition from hydrocarbon reservoir fluids during petroleum production are serious problems because they can result in plugging of the formation, wellbore and production facilities. Asphaltene precipitation also occurs frequently during enhanced-oil-recovery by gas injection, which impedes the recovery seriously. Iron contaminated acid has recently been found to promote the precipitation of asphaltenes when acidizing certain oil-bearing zones. This can cause severe formation damage. Asphaltene deposition is a function of permeability, flow rate and concentration. Asphaltene deposition could be explained in terms of trapping and mechanical plugging which were sharply dependent on the flow rate. (Ali and Islam, 1997)

EXPERIMENTAL PROCEDURE

The laboratory apparatus used in this research work, conducted in the petroleum research center of Petroleum University of Technology by Rezaian *et al.*, is designed to isolate the effect of asphaltene deposition on core samples through several dynamic displacement tests. This section describes: core sample preparation; the displacing system; the experimental setup and procedures for conducting the dynamic displacement core flood and supplementary experiments.

In this research work five groups of fairly clean sandstone samples are tested. Sandstone is used because of its high permeability and porosity and low adsorption. An increase in length of core samples could supply more pore volume and better understanding of permeability alteration, but some limitations in laboratory apparatuses restricted core samples length to be maximum 8 Cm long (Consisted by two 4Cm cores). Firstly, n-hexane was selected as injection fluid. However, for sandstone cores, with high permeability and porosity it was not suitable because of n-hexane's very low viscosity (0.294 cp) which prevents monitoring the pressure alteration during injection. Besides n-hexane is toxic. Moreover, normal alkane was not a good choice because of their volatility. Normal alkane concentration fluctuates at room temperature, which leads to affect our experiment results. So for injection purpose Gasoil was selected with the density of 0.824 g/Cm^3 and viscosity of 2.67 Cp.

For purpose of deposition of asphaltene on rock surface or porethroat one should be sure that asphaltene particles are not react with fluid, so as it will be mentioned later, fluid filtering was conducted to remove all the impurities and/or components of fluid as much as possible, in addition we must be sure that asphaltene particles are not precipitated from fluid eventually, so the decision was to prepare a pre-separated asphaltene content and using it as the source of concentration change in all the parts of this research work, so here, it was preferred to use n-hexane as solvent because it is the nearest normal alkane to asphaltene bearing-heavy oil that could separate asphaltene from crude oil. The standard procedure of asphaltene separation was conducted including Soxhlet extracting and centrifuging of fluid and then drying.

So with pre-separated asphaltene particles from crude oil, various concentrations of asphaltene bearing-gasoil were prepared in order to conduct various dynamic tests.

After taking the samples from sandstone rock, soxhlet was used to wash them and core were saturated completely by means of vacuum pump, then they were injected into core holder for performing flow tests. Various injection tests were conducted using different samples, injection rates, and concentrations. Permeability was calculated using Darcy's law, and the limitation of it was measured using Q versus pressure difference curve. Also fluid was filtered to eliminate contaminants. Asphaltene was separated and injection process was conducted to find the effect of concentration and rate change on permeability of the cores.

Experimental setup is shown in following figure.

Figure 1- Experimental Setup

EXPERIMENTAL RESULTS

Porous media properties are presented in Table 1, which is a good reference for comparing the results of tests. Note that injecting velocity is varied from 4.5 to 7.5 Cm/Sec and each core sample set is consisted by two core sample placing in a row.

Table 1- Sample Properties

Sample	Diameter (mm)	Type	Length (mm)	Porosity (%)
Core Plug Set No. 1	37.42-37.43	Sandstone	43.38-35.1	22-22
Core Plug Set No. 2	37.42-37.42	Sandstone	36-43.73	23-22
Core Plug Set No. 3	37.4-37.42	Sandstone	37.3-44.2	21-23
Core Plug Set No. 4	37.43-37.42	Sandstone	38-43.2	22-22
Core Plug Set No. 5	37.43-37.41	Sandstone	43.2-35.9	22-21
Sample Tested	37.42	Sandstone	80 (2 Plugs)	22

Permeability of cores is presented in Table 2.

Table 2- Permeability of Core Samples

Core Plug Set No.	1	2	3	4	5
Permeability (mD)	39.93	40.63	39.69	40.84	40.32

As mentioned before, pre-separated asphaltene bearing-gasoil was used as displacing fluid. This is a very good method for understanding the effect of rate change and concentration variation where we make the other condition constant. At the end of each test, core sample porosity is measured in order to use in later analysis.

Porosity at the end of each experiment is shown in Table 3:

Table 3- Porosity after Flood

Core Plug Set No.	1	2	3	4	5	Average
Porosity %	17	10	9	12	7	11
Permeability (mD)	14	0.2	0.7	3.7	3.6	4.44

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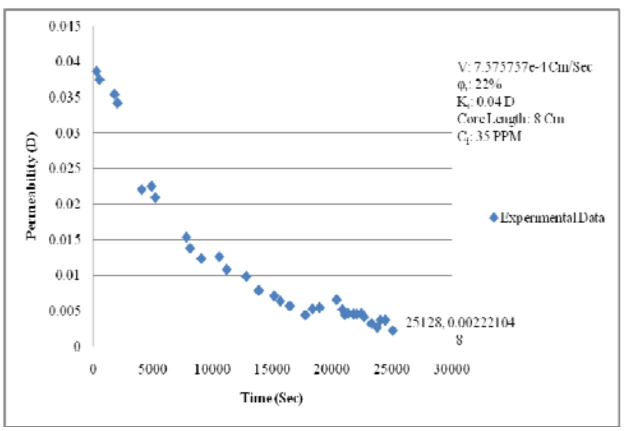

Figure 2- Sample Result of Flooding

DEPOSITION MECHANISM

In a reservoir, any asphaltene precipitation would occur within the pore space as a consequence of destabilizing thermodynamic balance, miscible or immiscible displacement, EOR processes, etc., leading to damage. This stage could be interpreted as disconnecting the resin-asphaltene connection and aggregation of these asphaltene particles, flocculation and as a result, precipitation, in which these precipitated asphaltene particles could deposit on the rock surface, porethroat, etc., by a set of complicated mechanisms like adsorption which is the deposition trigger. To neglect the stage ofprecipitation, which is a very complicated procedure, and just observe the deposition pattern, n-Hexane was used to flocculate asphaltene particles and as a result to precipitate them.

Figure 3- Asphaltene Cake on Injection Side

During the experiments, suspended asphaltene particles are not filtered out at the inlet core face. As shown in Figure 3 there is a thin but distinctive core holder distributor mark made by asplaltene particles on the inlet face of core. The trace of asphaltene throughout the cores, gradually decreasing from the inlet to the outlet, shows that asphaltene particles are deposited throughout the core plugs and results are not affected by filtering process.

The fluctuation at the deposition pattern shows this filtered asphaltene particles do not remain on the rock surface for a long time and they remove accordingly to bridge removal mechanism, where pressure difference decreases and curve shows a path cleaning causing permeability improvement and again pressurizing.

This is not clear that these fluctuations are results of bridging removal at the inlet face solely. These processes could occur within the rock pore space too. To monitor these processes, data point should be selected within very short time intervals, seeking some minor bridge removal, because a very huge pressure drop is a result of bridge removal at the inlet face for very limited pore connection of distributor.

Based on these assumptions, as it is clearly shown in Figure 2, there are some minor pressure drops and consequently permeability improvements which could be interpreted as bridge removal throughout the cores, so one can be sure that the results of experimental work are fairly reliable.

CONCLUSION

Gradual deposition occurs when asphaltene bearing gasoil is injected into core samples due to pore surface blocking, also porethoat blocking by means of bridging is one of dominant mechanisms; so by increasing the time of injection, these bridges will be removed and a fluctuation is observed in permeability curve. As injected pore volume increases, the length of asphaltene penetration increases.

The test results and data used to develop a black model to predict new core flooding results without having expensive and time consuming laboratory tests. As concentration increases, at constant rate, more permeability damage occurs, also at constant concentration, as velocity increases, more permeability damage occurs.

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