PLUGGING DUE TO FINES MIGRATION IN SANDPACKS

by

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Abstract

This paper intends to show the plugging problem due to fines migration when sandpacks are used. Plugging causes pore throat blocking which causes permeability to decline.

Sandpacks and glass bead packs were used in the experiments. The porosity and absolute permeability were determined prior to further tests of waterfloods and miscible floods. The permeability profiles over the injection periods were studied. There were plugging by fines in the sandpacks and the severity depends on the sand quality and flowrates. There was no plugging when glass bead packs were used.

Introduction

Many laboratory experiments still use sandpacks or glass bead packs as porous media. These unconsolidated cores are relatively cheap and readily available. But the sandpacks and glass bead packs are not representative of real cores and may be affected by loose fines. This may happen even though the sand has been cleaned and sieved before use.

Fluids moving through the pores encounter some very critical conditions - tortuous paths; rough pore walls with large surface area; and a variety of reactive minerals such as clays, feldspars, micas and iron compounds. These pores provide and ideal medium for both physical entrapment of solids and chemical reactions between invading fluids and the clays or other minerals lining the pores [1,2].

Indications of particle movement that can be observed in the laboratory experiments are:

1. abrupt changes in permeability values when flow through a core was reversed.

2. the discharge of micron-sized fines when fresh water was injected into a clay containing core.

3. lower permeabilities to water in a single phase flow than permeabilities to oil in restored state flow in water sensitive cores.

Laboratory studies have shown that the migration of water-wet fines is triggered by invasion of water that immobilizes them from the water envelope at the pore walls[3]. Pores in the restored state (pores containing a continous oil phase and an interstitial water phase at the pore walls) have the fines trapped in the immobile water. Simultaneous flow of oil and water causes fines to migrate substantial distances. The moving water mobilizes the water-wet fines and the multiphase flow causes localized disturbances that reduces the likelihood of bridging.

At low rates, dispersed fines can gradually align themselves to work their way one by one through the constrictions or can become immobilized in the interstitial water envelope at the pore walls. At high rates, the randomly distributed fines in rapid motion interfere with each other and bridge in a "brush heap". These bridging and non-bridging conditions are illustrated in Figure 1.

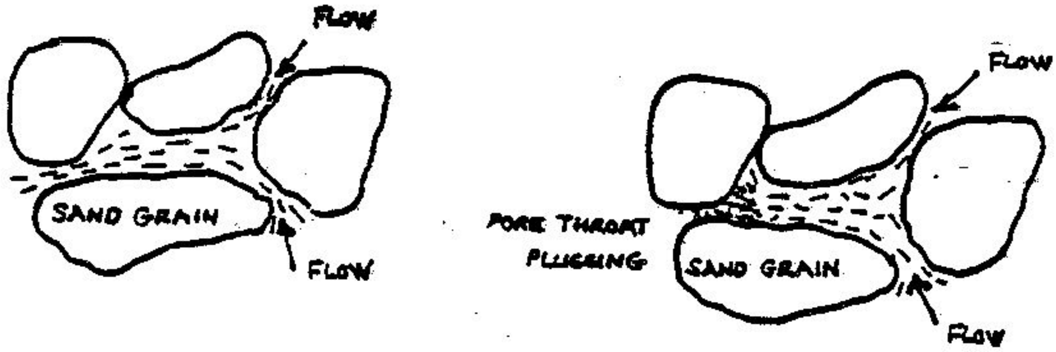

Fig. 1 - Pore throat plugging by fines

Experiments

Experiments to determine the porosity and absolute permeability of sandpacks and glass bead packs were done (3). The purpose was to observe any occurances of permeability reduction due to plugging by fines.

The sands supplied was described as 'cleaned acid washed' with 40 to 100 mesh sand grain size. Uniform size glass beads of 0.3 mm diameter was also used.

The core holder was made of stainless steel. The length was 10 inches and the diameter was 1 inch. The sand or glass beads were packed into the core holder and similar amount (by weight) was put into it every time. The packed materials were supported at both ends by sintered glass disc.

The core holder bulk volume was determined by filling an empty core holder with water. After packing the pack were vacuumed to -16 psig. Then distilled water was injected into the packs to fill the pore volume. The injection was stopped when pressure has reached slightly above zero psig.

The absolute permeability to water was then determined using the Darcy's Equation. The pressure drop across the core was determined by manometer tube filled with distilled water. Water injection was done by ISCO Syringe pump.

From Darcy's Equation:

$$k = \frac{1000\ Q\ L\ u}{A\ P} \qquad \text{........ (1)}$$

where,

k = absolute permeability to water, md
Q = flowrate, ml/sec
L = core length, cm
u = water viscosity, cp
A = core crossection area, sq cm
P = Pressure drop across the pack

By converting pressure drop to water height, h then Equation 1 becomes,

$$k = \frac{1000\ Q\ L\ u}{0.0000967\ A\ h} \qquad \text{........ (2)}$$

where h is the height of water in mm

Seven experimental tests were carried out and in each test the porosity and the absolute permeability were measured. In each run up to 5 pores volumes of water was injected (1 pore volume was equal to 57.0 ml). The tests are given in Table 1.

Table 1 : Experimental tests and descriptions

Test #	Descriptions
1	sandpacks, flowrate 8 ml/hr
2	sandpacks, flowrate 24 ml/hr
3	reused pack # 1, reversed flow direction, flowrate 8 ml/hr
4	sieved sand, flowrate 8 ml/hr
5	acid-washed, sieve, flowrate using brine at 8 ml/hr
6	Glass beads packs (0.3 mm glass beads), flowrate 8 ml/hr
7	Glass beads packs (0.3 mm glass beads), flowrate 24 ml/hr

Table 2 : Porosity and absolute permeability of packs

Test #	Porous media	Treatment	Flowrate ml/hr	Por.	Perm. (D)
1	sands	as received	8	0.39	0.8
2	sands	as received	24	0.39	0.6
3	sands	re-used Pack 1	8	0.39	0.8
4	sands	sieved again	8	0.39	1.0
5	sands	cleaned again	8	0.39	0.8
6	glass beads	as received	8	0.38	2.5
7	glass beads	as received	24	0.38	2.5

Results and Discussion

The porosity and permeability obtained at the end of the injection period from each test are shown in Table 2.

The porosity for all sandpacks was 0.39 and for glass bead packs was 0.38. The absolute permeability of sandpacks range from 0.6 darcy to 1.0 darcy. The lowest permeability was obtained from Test 2 where higher flowrate (24 ml/hr) was used. The highest permeability was obtained from Test 4 where some fines were removed by sieving. The absolute permeability of glass beads packs was 2.5 darcy for Test 6 and Test 7.

However the permeability obtained from all the tests using sandpack was very low when compared to the normal and expected value. Previous works have shown that the absolute permeability of sandpacks is greater than 5 darcy[5]. The very low permeability values obtained were due to plugging by fines. The sand received was actually still containing large amount of fines. This was proven when sieving was done for three hours some fines were successfully removed. However some fines or microfines was still presence in the sand used in the packing. In other words the sieving was not successful to remove all the fines.

The permeability changes with water injection was also observed. This is important in order to observe how the permeability changes as water injection continues. Table 3 gives the absolute permeability profile with volume of water injected.

Table 3 : Permeability profiles over injection volumes

Test #	1	2	3	4	5	6	7
Flowrates, ml/hr	8	24	8	8	8	8	24
	Absolute permeability (Darcy)						
Vol. injected (pore volume)							
0.50	8.0	8.0	1.0	8.0	8.0	3.0	3.0
1.00	6.6	6.5	2.5	5.0	5.0	2.9	2.8
1.50	3.0	3.5	3.5	3.0	3.0	2.8	2.7
2.00	2.0	1.5	4.0	2.0	2.0	2.7	2.6
3.00	1.2	0.8	3.2	1.2	1.3	2.6	2.5
4.00	0.9	0.7	1.4	1.1	1.0	2.5	2.5
5.00	0.9	0.6	0.8	1.0	0.8	2.5	2.5

The plot of absolute permeability profiles over the injection volumes is shown in Figure 2.

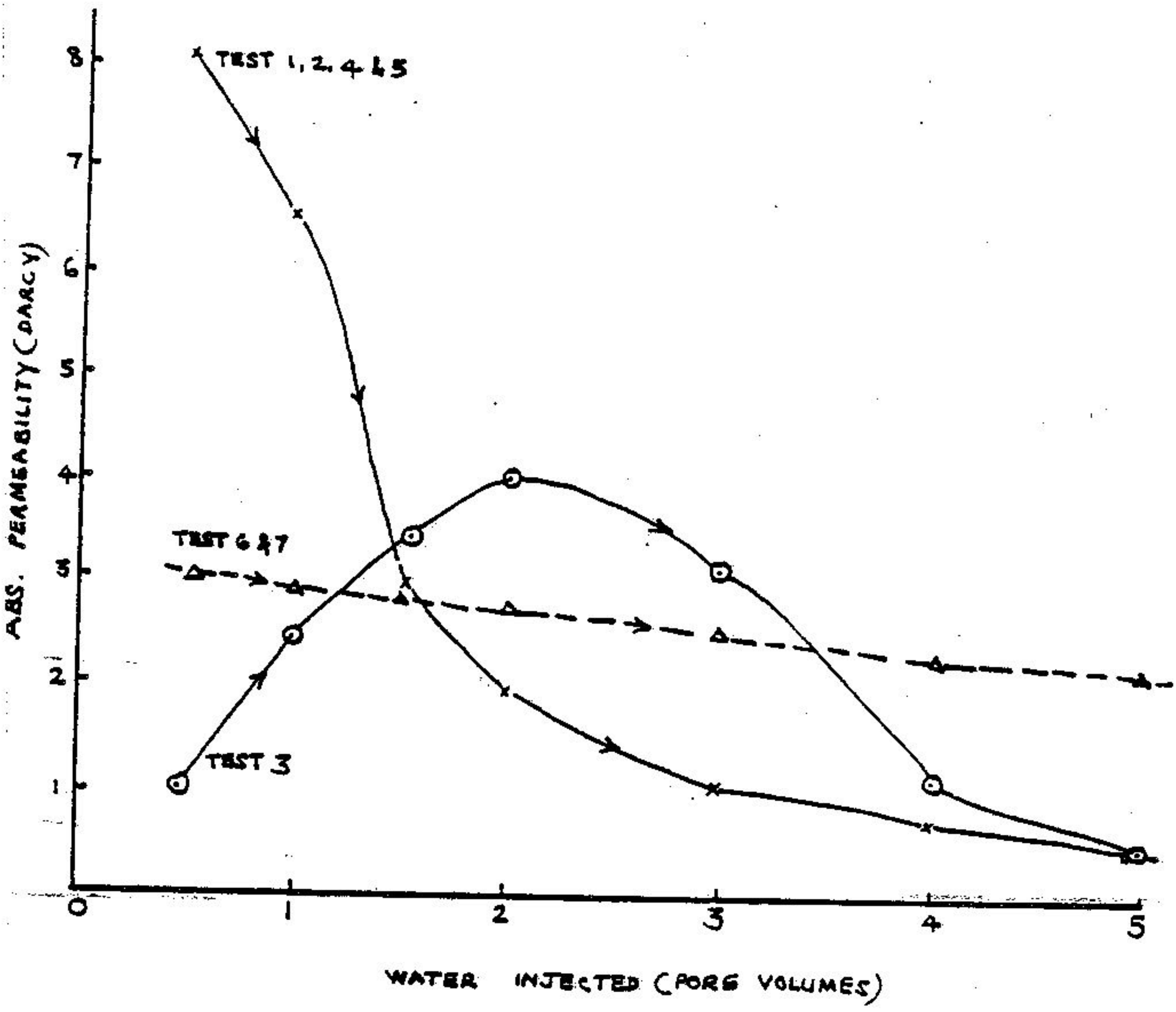

Fig. 2 - Permeability profiles over injection volumes

In Test 3, pack from Test 1 which had final permeability of 0.8 darcy was used again. This time water was injected from the reverse direction. The objective was to see if the original permeability of 8.0 darcy can be recovered by re-opening the plugs. The results show the original permeability was partially recovered (up to 4.0 darcy) but after 5 pore volume of water injection plugging re-occured and the permeability was back to 0.8 darcy.

In Test 5, the sand was sieved, washed with acid and dried before being packed. This time brine was used as the injected liquid. The idea was to make sure the sand is clean and free of any clay materials and fines. The final permeability obtained was slightly higher, that was 1.0 darcy. This shows that the treatment of sand was not effective to remove the fines.

In order to test the hypothesis of fines causing the plugging, glass beads of uniform size were used. Test 6 and Test 7 used glass beads of 0.3 mm diameter size. The permeability obtained started at 3.0 darcy and became stable at 2.5 darcy. The was no great permeability reduction like what happened in sandpacks. In glass bead packs there was no fines presence that can cause plugging.

From the permeability profiles shown in Figure 2, we can see in Tests 1, 2, 4 and 5 that permeability decreases steeply between initial injection to 2 pore volumes injected. After that the permeability decline is gradual until it reaches the final value at about 3 pore volumes injection. Tests also show that plugging is achieved earlier when injection rate is faster (compare Test 1 with Test 2).

Many laboratory experiments are still using sandpacks or glass beads as unconsolidated cores. There are two main reasons for this. One is availability of the material and the other is the low cost when compared to using berea or restored cores.

This work has shown that sandpack cannot be used unless it is completely free of fines, otherwise the permeability obtained is unstable and very low. Glass beads are better alternative but are more expensive.

Conclusions

The conclusions from the study are:

1. The permeability of sandpacks is reduced greatly because of plugging by microfines.

2. Sieving can not remove all the fines.

3. Flowrate affects the time of plugging formation. Fines migration and plugging occurs faster at higher flowrates.

4. Glass beads are better than sands as packing material because it does not contain fines.

Nomenclature

Por = porosity, fraction
Perm = absolute permeability, darcy

References

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