Original Article

THERMAL IMPACT ASSESSMENT ON OIL SANDS RESERVOIRS: PETROPHYSICAL BEHAVIOR AND RECOVERY POTENTIAL THROUGH RESERVOIR MODELING

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Abstract: This study investigated the effect of temperature (100°C to 280°C) on the petrophysical properties—permeability and porosity—and recovery potential of a designed oilsand reservoir. Core samples were obtained from Edo State, Nigeria, and subjected to steam injection at varying temperatures. Initial measurements at ambient temperature indicated that the oilsand formation had a porosity of 0.038 and permeability of 0.007 millidarcies (MD). Results show that increasing the formation temperature through steam injection alters the petrophysical properties, leading to a decrease in porosity and an increase in permeability. The enhanced permeability improves the mobility of bitumen, thereby increasing the recovery potential of heavy oil from the reservoir. These findings suggest that thermal stimulation via steam injection is an effective method to enhance the performance of tight oilsand reservoirs.

Keywords: Oilsands, Petrophysical Properties, Tight Reservoir, Steam Injection, Oil Recovery

I. INTRODUCTION

Unconventional reservoirs are reservoirs with tight formations. They are extremely low permeability and porosity formations. These resources have purely a permeability threshold of less than O.IMD and porosity of 1-4% (Meckel & Thomasson, 2008). Unconventional hydrocarbon resources (including tight oil/gas, shale oil/gas and coal bed gas) are becoming a significant component of world energy consumption (Jia et al, 2012; Zou, 2013). They are also fine-grained, organic rich, sedimentary rocks usually shales and similar rock. The shales and rocks are both the source of the reservoir oil and natural gas. The society of petroleum engineers describes “unconventional resources” as petroleum accumulations that are pervasive throughout a large area and are not significantly affected by pressure exerted by water (hydrodynamic influences); they are also called “continuous-type deposits “tight formations.” The unconventional formations may be as porous as other sedimentary reservoir rocks, their extremely small pore sizes and lack of permeability make them relatively resistant to hydrocarbons flow. The lack of permeability means that the oil and gas typically remain in the source rock unless natural or artificial fractures occur. Unconventional reservoirs include reservoirs such as tight-gas sands, gas sands, gas and oil shales, coal bed methane, heavy oil and tar sands, and gas hydrate deposits. Oilsands are either loose sands or partially consolidated stand stone containing a naturally occurring mixture of sand, clay and water, saturated with a dense and extremely viscous form of petroleum technically referred to as bitumen (or colloquially as tar due to its superficially similar appearance) (Ezra, 2011). Petrophysical properties are the properties of a porous media such as porosity, permeability, water saturation, fluid identification, resistivity, particularly in reservoir rock and contained fluids. These properties and their relationship are generally used to identify and assess reservoir rock, source rock and cap rock. No matter what kind of oilsands it is, the bitumen will make a significant contribution to reservoir geomechanical response during thermal stimulation because of its special mechanical behaviors that are sensitive to temperature (Albahlani et al, 2008). The bitumen in virgin reservoir conditions possesses a dramatically high viscosity which indicates a considerable elasticity/viscoelasticity at a low temperature (Behzadfar et al 2013). The injection of steam heats the hydrocarbon in the formation thus lowering its viscosity and vaporizing some of the oil to increase its mobility. The decreased viscosity helps reduce the surface tension, increase the permeability of oil and improve the reservoir seepage conditions (Glatz, 2013).The change in pore volume and permeability is a function of three parameters, Change in mean effective stress, Change in temperature and Shear stress alterations. As temperature increase, the sand structure is expanded. The latter parameter was studied in cold lake as steam is injected into the reservoir and pores are pressurized, the effective stress would be decreased (Scott et al, 1994). In another study, for Clearwater formation in canada, the expansion effect of the steam injection process was transferred to the surface and different areas in the reservoir (walters et al 2000).This is reflected by changing the level of the well which is mostly observed in shallow reservoirs. The shear may be enlarged due to hot fluid injection in cyclic steam injection and permeability change as a function of shear dilation were reported by Wong et al (Wong et al, 2001).Yale et al (2010) confirmed that the most sensible changes occur in relative water permeability and as water is condensed by moving in the front of the hot steam the pressure of the reservoir increases. This mechanism leads to saving the driving energy of the reservoir and supplying it by dilation. This work will analyse the effect of temperature on the petrophysical properties (porosity and pemeability) and recovery potential of the unconventional (oilsand) design reservoir to explore effective ways of bitumen recovery during production.

II. MATERIALS AND METHOD

The following materials were used for the experiment; core, crucible, weighing balance, tong, spatula, core holder, cement, soil, water, meter rule, measuring cylinder, stop watch, darcy flow line, beaker. Core samples were collected from Edo state in Nigeria. Steam at temperatures ranging from 100^{o}C to 280^{o}C was used to investigate the effect of temperature on its petrophyscial properties. Sieve analysis of the core sample was conducted, the porosity and permeability of the sample was also determined at ambient temperature to be 0.038 and 0.007MD respectively.

2.1 Procedure for Sieve Analysis

- ❖ A total of 100g of a dry sample (core) was measured.
- ❖ It was poured into the mesh from the top
- ❖ The mesh container was shaken for 10-20mins to allow each mesh size pass through and settle
- ❖ The weight of the residue contained in each mesh size was measured

2.2 Procedure for Porosity Determination

- 29ml (bulk volume, V_b) of core sample was measured in to beaker 1
- 50ml of water was added into beaker 2 at water level A
- The core sample was emptied into beaker 2 from beaker 1 with water level B. V_B 69ml and allowed to soak for 24 hours
- After 24 hours, water level in the beaker reduced to level C i.e V_C = 67.9ml as presented in figure 1

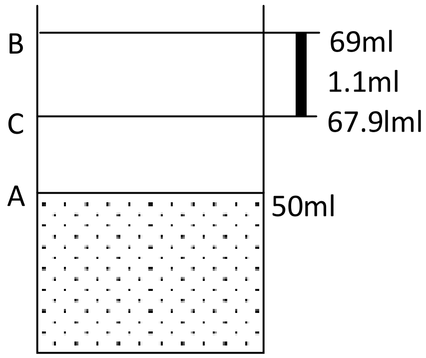

Figure 1: Determining Porosity

$$\text{Porosity} = \frac{V_P}{V_b} \qquad (1)$$

V_P □ V_B □V_C □ □V (2)

V_B = Volume of sample immediately immersed in water,

V_C = Volume immersed in water for 24hours

V_P = Pore Volume, V_b = Bulk Volume, Δv = Change in volume

The value of porosity was obtained as 0.038

2.3 Procedure for Permeability Test.

- The core obtained was fixed in a core holder
- A meter rule was used to measure the thickness and diameter of the core and it was placed in the darcy flow line and closed.
- The inlet valve was opened to allow flow through the darcy flow line, while the outlet valve was closed at a particular reference time of 2 minutes
- The valve inlet and outlet pressure P_1 and P_2 were read and recorded at the time duration
- The outlet valve was opened at intervals to receive volume of requite expelled. These procedure was repeated after steam at different temperatures was acted upon (passed through) the core samples under pressure.

III. RESULTS AND DISCUSSION

The sieve analysis carried out is presented in Table 1

Table 1: Sieve Analysis

Sizes	Weight Retained	% Retained	Average Retained
5.0mm	0.036	0.36	0.33
4.0mm	0.67	0.67	0.51
2.80mm	0.62	0.63	0.65
35 micros	2.29	2.29	1.46
850um	5.90	5.92	4.10
32 um	89.90	90.13	48.02

Total weight of mesh = 99.74g

Weight of sample poured into mesh = 100g

3.1 Effect of Temperature on Porosity

The result obtained shows that porosity of the formation increase with an increase in the temperature of the injected steam as presented in figure 1. Further increase, decreases the porosity which is due to failing (crushing) of the oilsand (sand grains) due to induced stresses associated with the injection of steam. Samples analyzed after production were seen to be smaller which revealed that the sand grains were crushed.

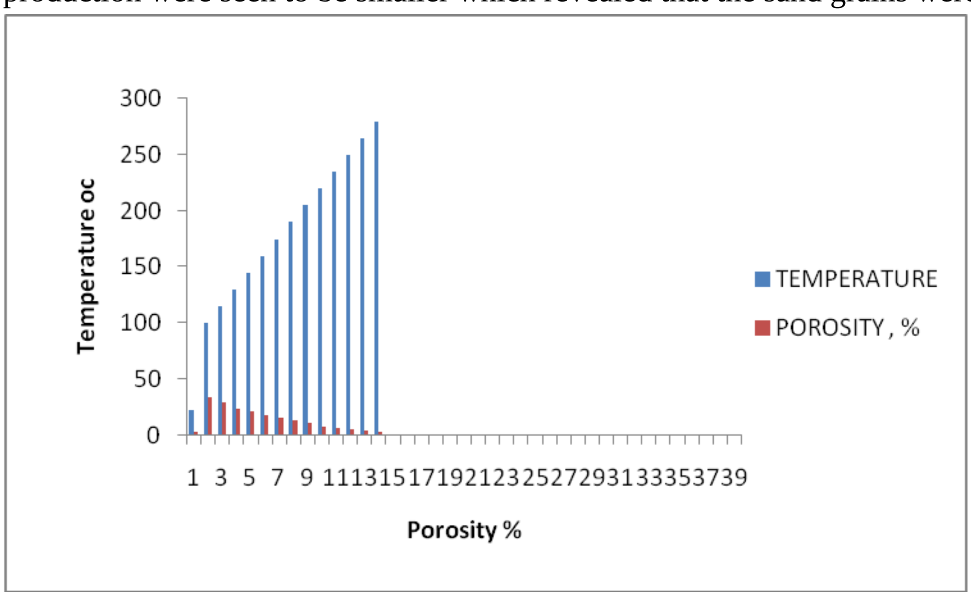

Figure 1: Effect of Temperature on Porosity

3.2 Effect of Temperature on Permeability

The result obtained Shows a consistent increase in the permeability of the formation with an increase in temperature which makes the hydrocarbon (bitumen) flow easily, there by producing more hydrocarbon (bitumen) as presented in figure 2.This is as a result of the intermolecular forces being weakened by increasing thermal energy. Thermal expansion occurs when oil sands are heated. The expansion of sand fluids and solid will reduce the effective stress or reduce contact pressure and this will increase permeability. This expansion of pore volume known as dilation makes neighboring sand grains move past each other on the action of shear stresses which generates micro fractures in the formation creating more spaces thereby increasing permeability.

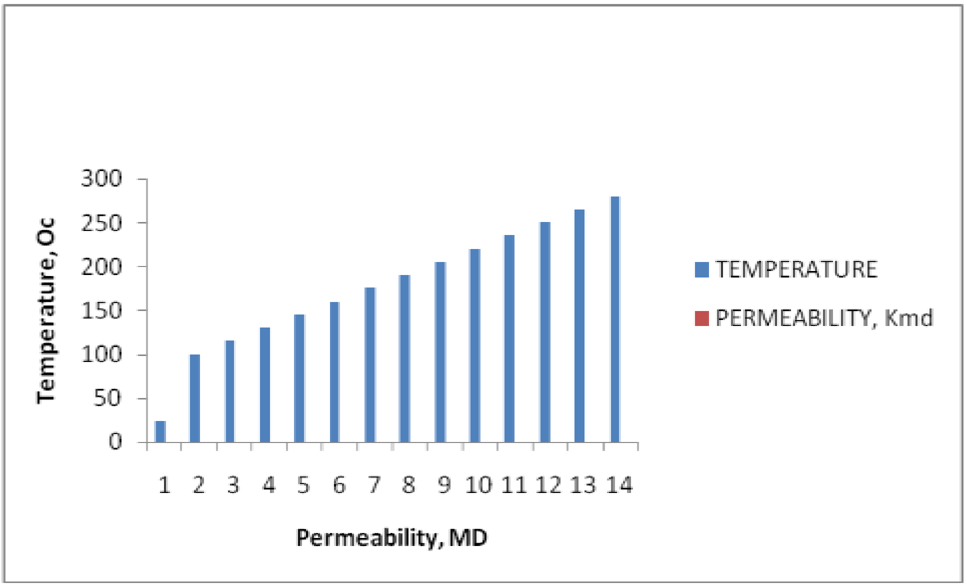

Figure 2: Effect of Temperature on Permeability

3.3 Effect of Temperature and Porosity on Recovery

Figure 3 shows an increase in temperature caused an increase in porosity of the formation and a subsequent increase in recovery. Further increase in temperature resulted in a decrease in the porosity of the formation. Irrespective of the decrease in the porosity of the formation, an increase in recovery is still evident. This increase is associated with a reduction in the viscosity of bitumen and increase in permeability.

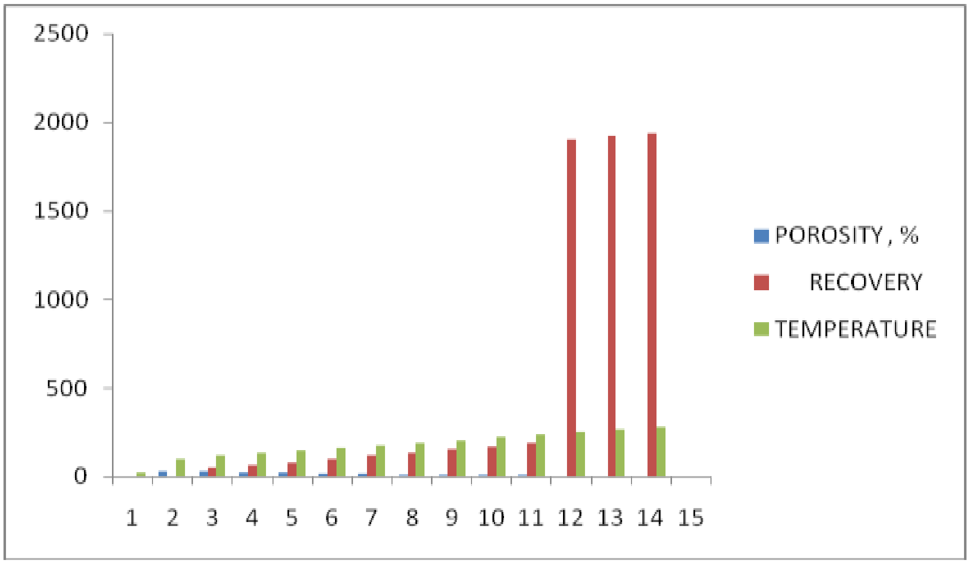

Figure 3: Effect of Temperature and Porosity on Recovery

3.4 Effect of Temperature and Permeability on Recovery

Figure 4 reveals that an increase in temperature resulted in a corresponding increase in the permeability of the formation and consequently an increase in recovery. This increase in permeability is associated with the expansion of oil sand fluid and solid by thermal energy.

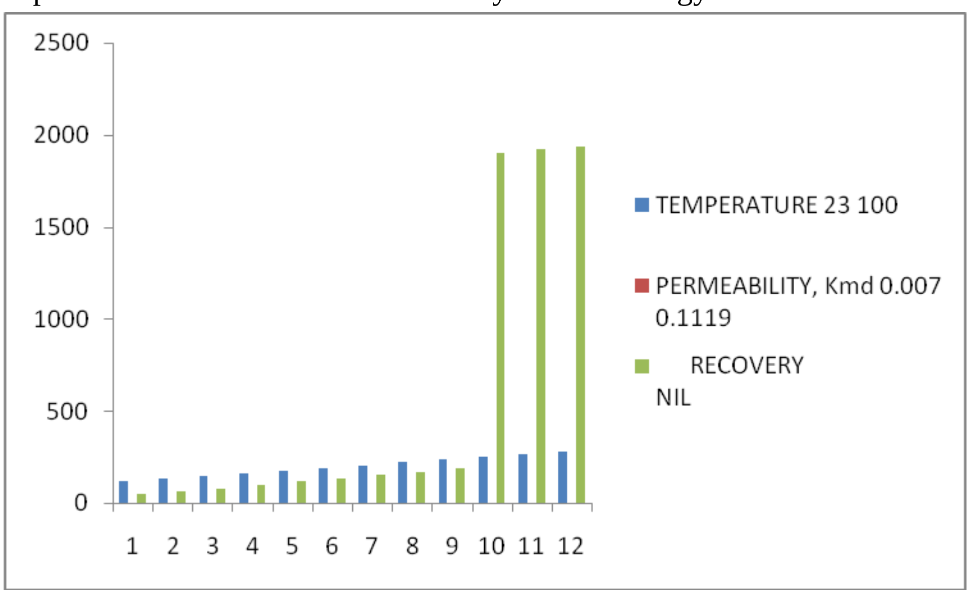

Figure 4: Effect of Temperature and Permeability on Recovery

IV. CONCLUSION

In this study, an unconventional reservoir (oil sands) was designed with steam injection to enhance the porosity and permeability to increase the recovery potential of the system. Increase in the temperature of the system from the steam injection increases the permeability and reduces the viscosity of the heavy oil (oil sands) and enhances the recovery of the heavy oil. A decrease in porosity was observed at a higher temperature but does not reduce the recovery potential of the oil sands as recovery kept improving as viscosity reduces. This confirms the work of other researchers that unconventional hydrocarbon can be produce at a high quantity if the right technique and approach is adopted. Steam injection has proven to increase recovery from unconventional source.

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