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Full Length Research Paper

Fast incineration assisted importance drainage (FCAGD) process for heavy oil improvement

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"Fast combustion assisted gravity drainage" (FCAGD) process is a novel heavy oil recovery enhancement method which is a specific combination of the two *in-situ* combustion process and steam assisted gravity drainage process. In this paper, the novel FCAGD thermal heavy oil recovery enhancement process has been presented by an improved simulation with an Eclipse500 simulator and has been analytically validated with Visual Basic.net code. As a result, the oil recovery factor of the simulation of the FCAGD process has been increased to about 48%. But, in comparison to its improved one, it is less efficient because as a result of the improved FCAGD process simulation, the oil recovery factor has been increased to about 52% in the reservoir. This novel process can be substituted with other thermal heavy oil recovery enhancement methods under proper technical circumstances with a greater recovery factor of oil produced.

Key words: Fast combustion assisted gravity drainage, improved simulation, thermal heavy oil recovery enhancement methods.

INTRODUCTION

Generally, in thermal heavy oil recovery enhancement methods, the conductive heat transfer to a reservoir of heavy oil can cause the reduction of oil viscosity and density and the increase of its mobility.

In the sample heavy crude oil reservoir, the heavy crude oil properties are such as: API=7.24, Flash point=180 F, pour point=4 centigrade, viscosity=1758 cp, interfacial tension=10 mN/m.

Among the most important thermal heavy oil recovery enhancement methods, it is possible to point out to *In-situ* combustion (ISC) and steam assisted gravity drainage (SAGD) processes. The *In-Situ* Combustion process is a displacement process that oxygen (air) is injected into the reservoir which reacts with the crude oil and forms a high-temperature combustion front which moves ahead through the reservoir. This method can be carried out in different forms based on the available circumstances.

Two main types of oxidation reactions with high and low temperatures are done and each of them will be effective in the whole of the process.

The steam assisted gravity drainage process is done by means of a horizontal injection well above a horizontal production well that a high-temperature steam saturated zone is formed in the heavy oil reservoir. The heat transfer from the injected steam to the reservoir rock and fluid (the original heavy and cold oil) is in the form of conduction.

The reservoir gravity force can cause the drainage of the heated heavy oil with more mobility (the activated oil) accompanied with the produced condensed water (hot water) towards the reservoir bottom and the horizontal production well.

"Fast combustion assisted gravity drainage process" (FCAGD) as a heavy oil recovery enhancement novel method in the world is a specific combination of the two *In-Situ* Combustion process (mostly in terms of the process mechanism and the combustion reactions and also the injected gas type) and the Steam Assisted Gravity Drainage process (mostly in terms of wells configuration) with three parallel and the same depth and

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lateral distance horizontal wells for more recovery factor of oil.

This novel combined process production performance depends on many parameters related to the reservoir and the injection /production wells that must be improved by means of the application of some specific solution ways (improvements).

However, there have been previous researches on heavy oil recovery enhancements of the ISC and SAGD methods.

MATERIALS AND METHODS

Methodology of this research

The FCAGD process is a novel thermal heavy oil recovery enhancement method which is a specific combination of the two *in-situ* combustion process (mostly in terms of the process mechanism and the combustion reactions and the injected gas type) and the steam assisted gravity drainage process (mostly in terms of well configuration). This novel process can be substituted with other thermal heavy oil recovery enhancement methods under proper technical circumstances with a greater recovery factor of oil produced.

This novel FCAGD thermal heavy oil recovery enhancement process has been presented by an improved simulation with an Eclipse500 simulator and has been analytically validated with Visual Basic.net code.

According to the simulation with an Eclipse500 simulator (Figures 1 to 8), the important technical and economical production parameter known as produced oil "recovery factor" has been gained and compared in both the ordinary simulation of the FCAGD process and the improved simulation of the FCAGD process.

As a result, the oil recovery factor of the simulation of the FCAGD process has been gained to about 48%. But, in comparison to its improved one, it is less efficient because as a result of the improved FCAGD process simulation, the oil recovery factor has been increased to about 52% in the reservoir.

Review of previous methods

(i) Awoleke et al. (2010) have considered the reservoir heterogeneity impact on the ISC process oil recovery factor. In this research, by means of experimental data and different technical analyses, the reservoir heterogeneity impact both in micro and macro scales for the combustion front movement has been identified. As a result, the injected oxygen movement into the reservoir in high permeable zones has been much more better than in low permeable zones.

(ii) Parikshit (2009) has considered the use of a down-hole igniter impact on the ISC method oil recovery factor. As a result, this strategy could be used for wet ISI for more reservoir volumetric sweep efficiency.

(iii) Kristensen et al. (2008) have considered the impact of the ISC process phase behavior modeling on its performance. In this method, a one-dimensional model of sensitivity analysis and numerical methods have been used. As a result, one important and critical condition for the ISC process has been the maintenance of the combustion front with a high temperature. Also any changes in the combustion front phase behavior could bring about either the more growth or the extinction of the process.

(iv) Tavallali et al. (Austria, 2011) have considered the SAGD process with twin horizontal injector and producer wells configuration in the Athabasca McMurray field, Alberta, Canada. As a result, an appropriate well configuration could be a 1:1 horizontal injector and producer well with 5 m vertical distance from each other.

(v) Oskouei (2011) have considered the impact of some formation zones with initial gas saturation on the SAGD process performance in experimental evaluations with physical models. As a result, the existence of some formation zones with initial gas saturation roughly equal to 9% or more could hasten the heat distribution and retard the heat chamber growth of hot steam. So, the case could have a negative impact on the SAGD process performance.

(vi) Farajzadeh et al. (2012) have considered the impact of the use of foam with the injected steam on the SAGD method oil recovery factor. As a result, the case could cause the oil recovery factor to increase up to 30%.

(vii) Dang et al. (2010) have considered the reservoir heterogeneity impact on the SAGD method oil recovery factor. As a result, reservoir heterogeneity and the existence of some thief zones with upper or lower water zones, abundant horizontal fractures and etc… could have negative impacts on the SAGD process performance.

(viii) Thorne and Zhao (2009) have considered the wells flow pressure drops impact on the SAGD method oil recovery factor. As a result, the existence of pressure drop between the twin horizontal injector and producer wells required more steam injection otherwise the oil recovery factor would decrease.

(ix) Yucel and Yannis (2005) have considered the impact of reservoir heterogeneity on the ISC process oil recovery factor. The studies have shown that the existence of reservoir heterogeneity could cause more heat loss, temperature reduction of progressing combustion front in high permeable zones and less sweep efficiency of oil in the reservoir.

DISCUSSION

The novel FCAGD process can be substituted with other thermal heavy oil recovery enhancement methods under proper technical circumstances with a greater recovery factor of oil produced (Rahnema and Mamora, 2010).

Here, this novel FCAGD thermal heavy oil recovery enhancement process has been presented by an improved simulation with an Eclipse500 simulator and has been analytically validated with Visual Basic.net code.

Here, Figure 1 shows the FCAGD process simulation-FOPR, FOIP versus Time graph. Figure 2 shows the Improved FCAGD process simulation-FOPR, FOIP versus Time graph. Figure 3 shows the FCAGD process simulation- wells configuration. Figure 4 shows the FCAGD process simulation-Matrix pressure (psi). Figure 5 shows the FCAGD process simulation-Matrix oil saturation. Figure 6 shows the improved FCAGD process simulation- huff and puff well configuration. Figure 7 shows the improved FCAGD process simulation-Matrix pressure (psi) and at last, Figure 8 shows the improved FCAGD process simulation-Matrix oil saturation.

Here, according to the sketched 2D graphs (FOPR, FOIP-Time graphs) and also the Flovis software 3D graphs, the important technical and economical production parameter known as produced oil "recovery factor" has been gained and compared in both the ordinary simulation of the FCAGD process (without the

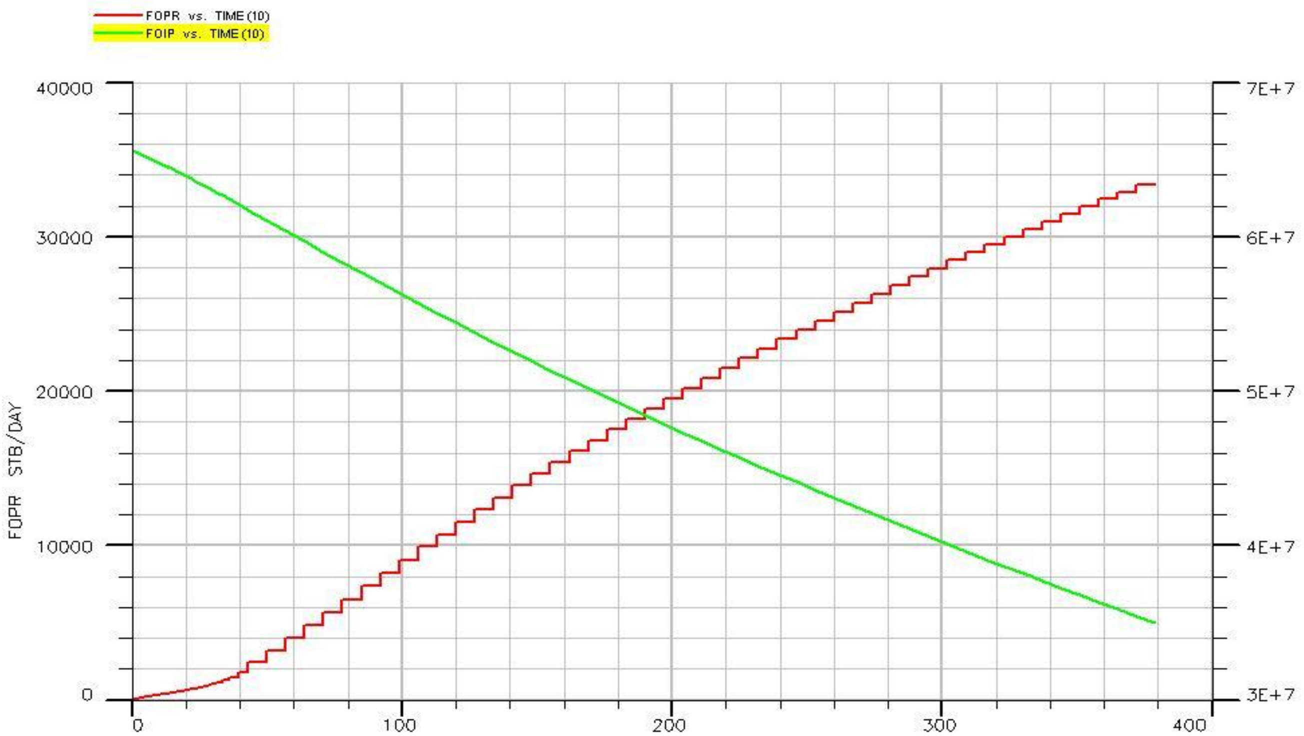

Figure 1. FCAGD process simulation - FOPR, FOIP versus Time Graph.

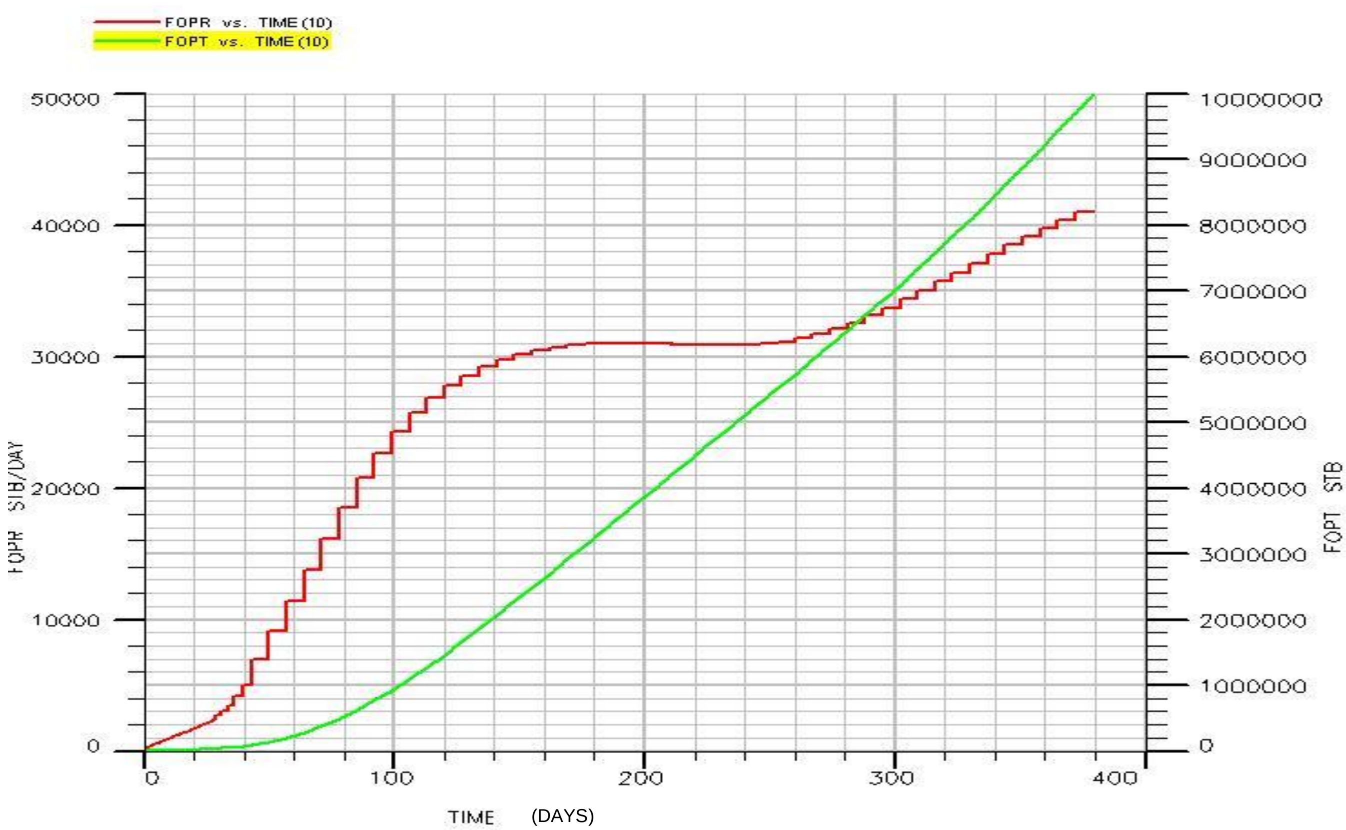

Figure 2**.** Improved FCAGD process simulation - FOPR, FOIP versus Time Graph.

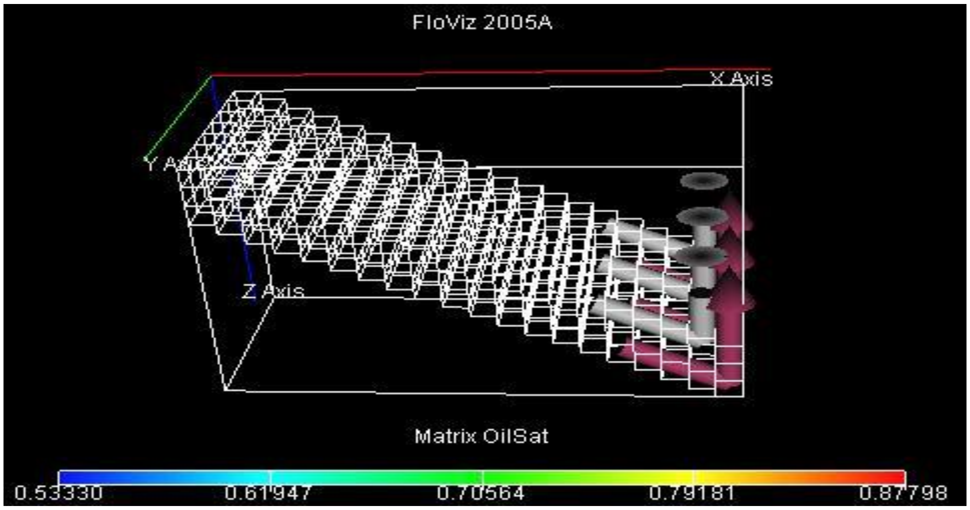

Figure 3**.** FCAGD process simulation – wells configuration.

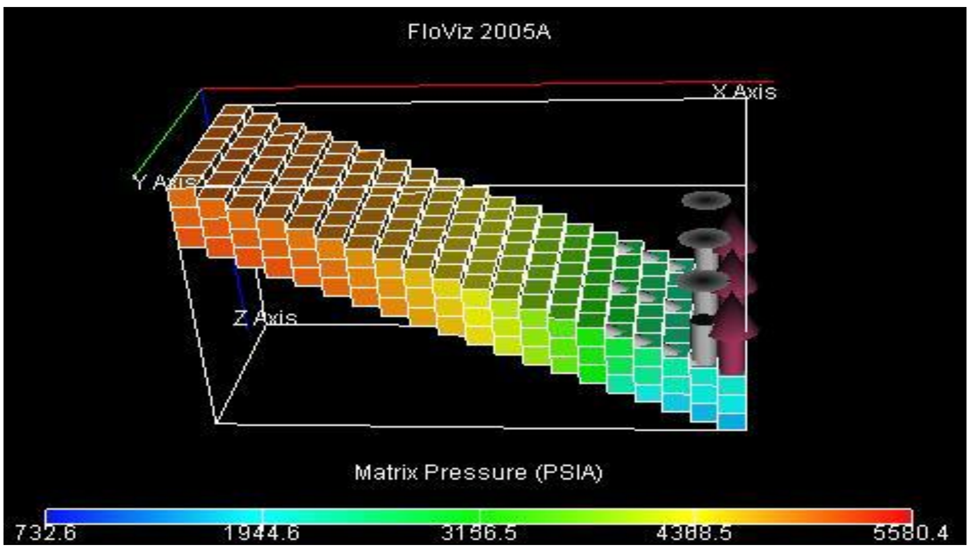

Figure 4**.** FCAGD process simulation – Matrix pressure (psia).

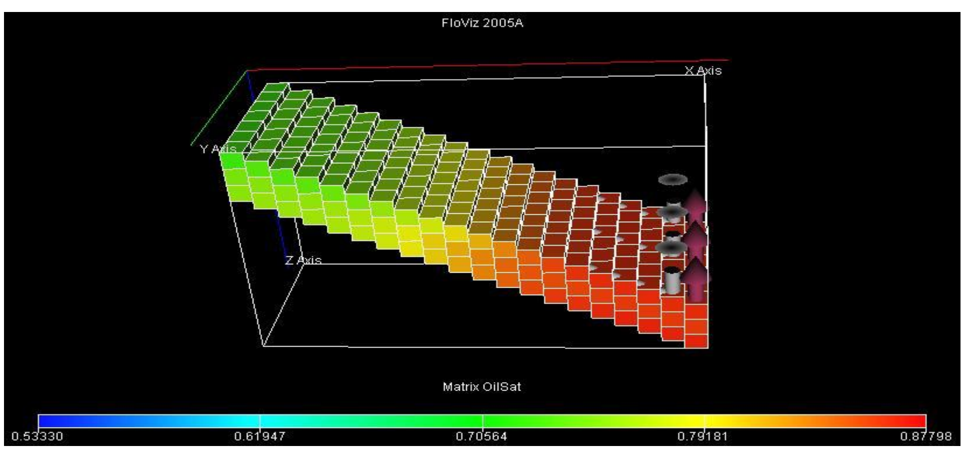

Figure 5**.** FCAGD process simulation – matrix oil saturation.

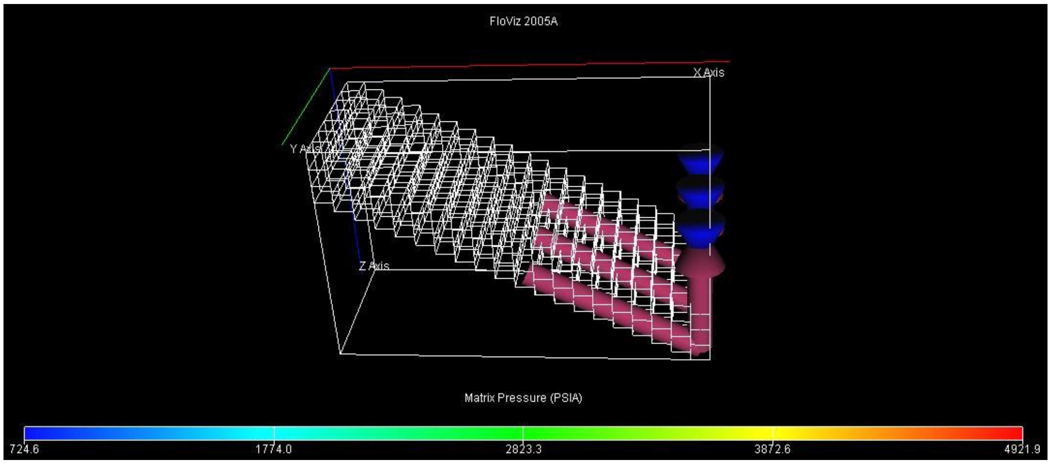

Figure 6**.** Improved FCAGD process simulation – huff and puff well configuration.

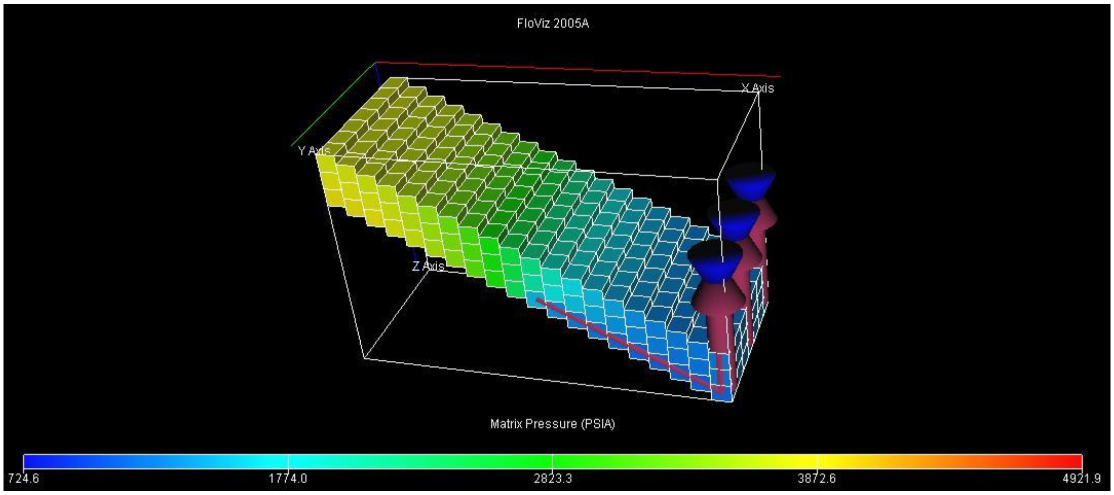

Figure 7**.** Improved FCAGD process simulation – Matrix pressure (psia).

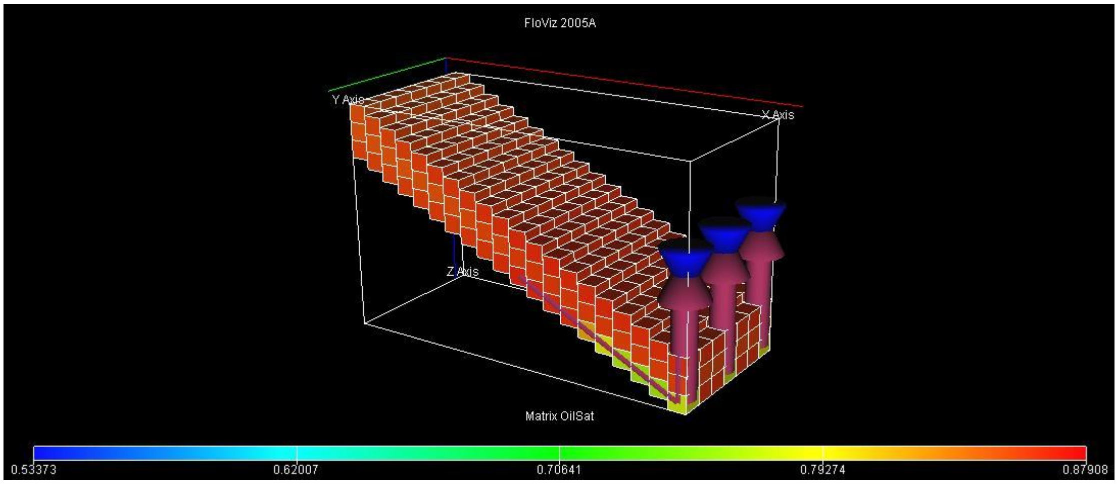

Figure 8**.** Improved FCAGD process simulation – matrix oil saturation.

improvements such as: increase in wells lengths and diameters and vertical distance, or use of "water alternating oxygen injection" for a better combustion quality through the horizontal wells and etc…) and the improved simulation of the FCAGD process.

As a result and as shown in the related graphs, the oil recovery factor of the simulation of the FCAGD process has been gained to about 48%. But, in comparison to its improved one, it is less efficient because as a result of the improved FCAGD process simulation, the oil recovery factor has been increased to about 52% in the reservoir. Some of the important formulas which could be effective to validate the thermal simulation are expressed as below:

A) Conductive heat transfer:

$$Q = (T_1 - T_2) / (L / KA) \quad (1)$$

B) Convective heat transfer:

$$Q = (T_{surf} - T_{envr}) / (1/h_{conv} A_{surf}) \quad (2)$$

C) SAGD thermal process mechanisms:

$$q = 2L\sqrt{(\phi K g \alpha \Delta S_O h) / (m \nu_s)} \quad (3)$$

D) ISC thermal process mechanisms (Fuel (coke) amount):

$$C_m = \frac{V_g}{CV_b}\left[4C_N + 2C_{O2} + 4C_{O2} + 8C_{O2} + 10C_{CO} + C_{N2} \right] \quad (4)$$

E) ISC thermal process mechanisms (Combustion heat): It is shown that the gravity force has a positive impact on production but the capillary and viscous forces have negative impacts on production.

Conclusions

1. In thermal heavy oil recovery enhancement methods, the heat transfer to reservoir heavy oil can result in the reduction of oil viscosity and density and also the increase in its mobility for more recovery factor.
2. The FCAGD process is a novel thermal heavy oil recovery enhancement method which is a specific combination of the two *in-situ* combustion processes (mostly in terms of the process mechanism and the combustion reactions and the injected gas type) and the Steam Assisted Gravity Drainage process (mostly in terms of well configuration). This novel process can be substituted with other thermal heavy oil recovery enhancement methods under proper technical circumstances with a greater recovery factor of oil produced.
3. This novel FCAGD thermal heavy oil recovery enhancement process has been presented by an improved simulation with an Eclipse500 simulator and has been analytically validated with Visual Basic.net code.
4. The recovery factor of the ordinary simulation of the FCAGD process (without the mentioned improvements) has been gained to about 48%. But, in comparison to its improved one, it is less efficient because as a result of the improved FCAGD process simulation, the oil recovery factor has been increased to about 52% in the reservoir.

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