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Steam trap control valve for enhancing steam flood performance in an Omani heterogeneous heavy oil field

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ABSTRACT

In this research, a numerical feasibility study of the thermal oil recovery using steam injection has been carried out for a heterogeneous heavy oil field located in southern Oman. There are several technical challenges for designing EOR operation system for oil reservoir with heterogeneous permeability. A numerical simulation of the steam injection has been developed to investigate the optimum heat transfer in the reservoir to reduce the oil viscosity with more efficiency. The CMG STARSTM model was used for the simulation of steam injection operation with the valve control of steam trap subcool in this field. The simulation results showed that the valve control can result in wider and faster temperature transmission and distribution in the reservoir after steam injection. It was also shown that steam trap operation can result in relatively higher oil production and lower required steam temperature. Finally, it was suggested that by setting subcool temperature on 20–30 °C using the valve control, steam injection efficiency can be increased and better SOR (steam oil ratio) and RF (recovery factor) can be achieved.

1. Introduction

Steam flooding is an enhanced oil recovery (EOR) process by which heat is continuously supplied to an oil reservoir through steam injection to make heavy oil easy to flow (Zhu and Liu, 2013). This method was started from 1950's and developed in 1960's, principally in California, where it matured into a proven EOR method later in the early 1970's (Traverse et al., 1982). Steam flooding is the most commonly used EOR method due to the possibility to be applied to a wide variety of reservoirs (van Poollen, 1981). Though being successfully performed worldwide for several decades, there are still problems and challenges associated with its operational mechanisms. The most important technical challenges are to prevent heat loss and make faster and efficient heat transfer and expansion with less steam quantity.

After being injected into the reservoir, the steam loses its heat and changes to water phase. Therefore, four separated zones are available in the reservoir, namely oil bank, hot water bank, solvent bank, and steam zone (Hong, 1994; Bae et al., 2014). Due to gravitational effects and heterogeneity, the steam tends to move towards the upper portion of the reservoir causing it to reach production wells very fast (Bae et al., 2014). In order to achieve commercial operation, preventing steam escape from production wells is recognized as an important issue because it can save energy while maintaining a favorable steam-oil ratio (SOR). To achieve this, valve control of steam trap subcool temperature has been developed for preventing steam withdrawal from the steam zone in the reservoir (Doan et al., 1999).

In this study, numerical simulations by using CMG STARS were carried out to model optimal well arrangements and production scheme for energy saving and efficient steam-EOR in a heterogeneous heavy oil field (19° API) located in southern Oman. In order to achieve better SOR in the production well, the effect of steam trap valve in changing subcool temperature was investigated. It should be noted that the focus of this study is investigating the effectiveness of trap valve control for enhancing steam flood performance from a technical point of view, and cost analysis is not among the objectives. Although, confirming the role of valve control on energy saving can be a positive sign for cost effectiveness; a comprehensive cost-benefit analysis is required in the future studies.

In order to measure the effect of steam trap valve, simulations were carried out with and without trap valve installation. The implementation of trap valve in the simulation is possible through the tools and options provided by the simulation software. Such tools can assume installation of a trap valve by applying controls on the flow rate or pressure of the producer wells. There are many parameters to be controlled in the production wells such as surface

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liquid rate (STL), bottom hole pressure (BHP), surface oil rate (STO), surface water rate (STW), etc.. In this study, we focused on BHP and STL for the base case (field data operation), and for the steam trap control case we used STEMTRAP option of the simulator which is for the steam trapping mode.

1.1. Mechanism of steam trap valve

According to the Fluid Controls Institute (1989) "a steam trap is a self-contained valve that automatically drains the condensate from a steam-containing enclosure while remaining tight to live steam or, if necessary, allowing steam to flow at a controlled or adjusted rate" (Oland, 2001, p. 7). Most steam traps will allow non-condensable gases to pass while remaining tight to live steam by using sensor or balance pressure. Steam-based heating system uses latent heat and transfers it to a given part of the reservoir. After the steam has given up its latent heat, it becomes condensate. Heating efficiency will, therefore, decrease if condensate is not removed as fast as possible. Steam traps are used to ensure that steam is not wasted. The latent heat of the steam needs to be used efficiently with the lowest operating steam temperature that requires a lower reservoir pressure as well (Edmunds and Chhina, 2001). So, the valve provides an essential function to lower the pressure in the reservoir, remove the condensate to avoid early condensation and prevent steam production from the producer without any heat exchange to oil. This process maximizes utilization coefficient of latent heat included in the steam.

Fig. 1 illustrates a schematic diagram of a steam trap valve. The valve contains a floating trap ball. When the condensate liquid fills the body of the valve the ball floats on the liquid. The floating ball is connected to the valve gate by an iron rod in order to open the valve gate when the ball floats upward. On the other hand, when the level of the condensate is low, it means the valve is filled with steam. The steam pushes the ball down and the gate will be closed. Furthermore, the valve can allow the steam to flow by a controlled or adjusted rate. The temperature control of the valve that is important for heavy oil production is also possible using temperature sensors. The temperature control prevents the possibility of overheating the heavy oil (Risko, 2011).

2. Steam trap valve for Omani heavy oil fields

2.1. Heavy oil development in Oman

Oman heavily relies on oil revenues to drive economic growth and finance its imports and social welfare. The country is not, however, a member of the OPEC (Organization of the Petroleum Exporting Countries), and therefore is not obliged to follow a production quota (Rammadhan and Naseeb, 2008). As the largest oil producer in the Middle East outside of OPEC, Oman has had many years of experience of light oil production; however the number of light oil fields is reducing in this country, leading to increasing demands for heavier oil production using new EOR techniques and methods. The necessity of testing new EOR methods is being felt particularly after the recent estimations showing that in a few decades almost half of oil production in the region will be from heavy oil fields (Aalund, 1998). Currently, several EOR methods are being used in heavy oil fields in Oman as explained below:

2.1.1. Polymer flooding

Polymer flooding is a chemical EOR method that uses water-soluble polymers to improve displacement efficiency and sweep efficiency (Shedid, 2006). This method is being implemented in Marmul field in south of Oman which contains extreme heavy crude oil with very high viscosity. A pilot project with promising results was carried out in 1986 (Koning et al., 1988) without further expansion due to the low oil price. In 2010, phase 1 of a large-scale polymer flooding was started in this field with 27 wells and a processing plant (Sheng, 2013). The project is ongoing and its phase 2 and 3 is under planning by PDO with an estimated $1 billion capital expenditure (http://www.pdo.co.om). In 2012, Marmul project produced approximately 75,000 bbl/d (EIA, 2013).

2.1.2. Miscible gas injection

The use of miscible gas flooding as an EOR method is increasing rapidly (Edalat et al., 2007). It involves injecting gas, often toxic, that dissolves in the oil for obtaining higher flow rates. The objective of this method is improving local displacement efficiency and reducing residual oil saturation below the levels normally achieved by water flooding (Teletzke et al., 2005). In Oman, miscible gas injection has been applied in Harweel oil field in the far south of the country which resulted in an additional 40,000 bbl/day production (Denney, 2012).

2.1.3. Steam injection

As explained in the previous sections, thermal EOR includes the injection of steam to increase the flow of heavier oil to the well. Thermal methods at Mukhaizna, Marmul, Amal-East, Amal-West, and Qarn Alam fields, among others are implemented. Mukhaizna has already increased the production to 50,000 bbl/day (Shibulal et al., 2014). It is also estimated that this method will increase production at Qarn Alam up to 40,000 bbl/d by 2015 and at both Amal-East and Amal-West up to 23,000 bbl/day by 2018 (EIA, 2013).

2.2. Benefits of steam trap control

In Oman, steam injection is being used in heterogeneous sandstone reservoir fields such as Mukhaizna heavy oil field using SAGD process. SAGD process typically uses one horizontal injector and one horizontal producer and they are drilled parallel to each other. In Mukhaizna, however, a modified SAGD process with three vertical injectors and one horizontal injector is being used. The heterogeneity of the reservoir has a major impact on the movement of the steam from each injector. This requires more efficient design of the steam injectors and producer wells. In Mukhaizna field in particular, it is not possible to use Limited-entry perforations (LEPs) due to the geologic heterogeneity. Instead, flexible vertical injectors that can be adopted to optimize local pattern performance are being used. For steam control orifices are being changed once exposing to high temperatures without pulling the tubing out of the well, and the size of the orifice is being changed depending on the required amount of steam at each zone (Malik et al., 2011). There is possibility that steam control in such type of heterogeneous reservoir can be handled more efficiently by using steam trap valve. The idea is that by installing steam trap valve in the

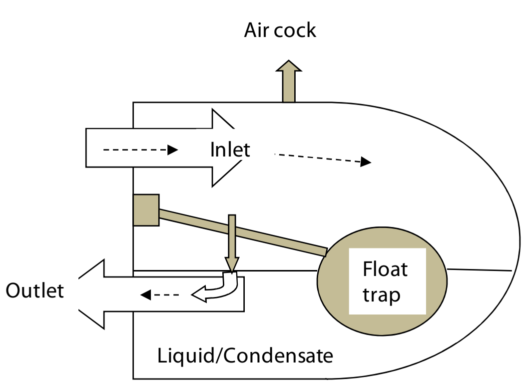

Fig. 1. Schematic diagram of steam trap valve.