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Development Status and Prospect of Heavy Oil Thermal Recovery Technology

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Abstract

Our country is rich in heavy oil resources, proven and controlled reserves has reached 16×10^8 t, is the world after the United States, Canada and venezuela's fourth largest producer of heavy oil. It is mainly distributed in shengli, liaohe, he'nan, xinjiang and other oilfields. This paper summarizes the present situation, development trend and applicability of heavy oil thermal recovery technology in the world. Commonly used thermal recovery of heavy oil steam stimulation technology exhibit low recovery efficiency is more and more, but with the constant improvement of the development of heavy oil heat, and the development of new technology of heavy oil is also appear constantly, main performance for thermal recovery technology combined with engineering or chemical technology, such as horizontal well with steam assisted gravity drainage, nano fluid joint displacement to improve recovery factor of heavy oil, etc. It can be seen that the combination of various technologies is the development trend of heavy oil thermal recovery technology in the future.

Keywords

Heavy Oil Thermal Recovery; Technology Status; Technology Outlook.

1. Steam huff and puff

1.1. Steam stimulation supplemented by flue gas

Steam huff and puff as an increasing production technology has been widely used in heavy oil reservoirs. However, with the development of the oil industry, the change of the world oil pattern and the continuous trough of oil prices, the traditional steam huff and puff process also shows its uneconomical, mainly in:(1) Low recovery, mainly depending on natural energy; (2) Steam is generated from the ground and injected into the formation through the wellbore. Due to the condensation of steam, the heat transfer mode changes, which aggravates the loss of heat; (3) The effect of steam huff and puff only has obvious effect on the formation area near the well, but cannot produce obvious effect on the farther formation; (4) Since the operation of steam huff and puff needs to go through three stages of steam injection, soaking and recovery, resulting in longer working cycles, etc.

Bing Wei et al. of Southwest Petroleum University developed heavy oil reservoirs in Northeast China by using N_2 and CO_2 (flue gas) assisted steam stimulation, its use of CO_2 dissolved in heavy oil can reduce viscosity and extract hydrocarbons. N_2 and CO_2 assisted steam injection technology not only combines the mechanism of gas injection and steam injection, but also has a certain synergy, which can further expand the heating volume of steam injection and maintain reservoir pressure, it plays an important role in the development of heavy oil reservoir. Liu Ning et al. from CNPC also applied CO_2-assisted steam huff and puff to the old oilfields with years of steam huff and puff, and achieved good results. The steam injection pressure increased by 1.2 MPa, and SOR decreased from 3.45 to 2.86.[1][2]

Welker and Dunlop studied the expansion and viscosity changes after carbon dioxide dissolution as early as 1963. [3]The results show that the solubility of carbon dioxide in crude

oil is high. At 27 °C and 5.514 MPa, the solubility of carbon dioxide in crude oil can reach 71 m3 / m3. The solubility of carbon dioxide and the volume expansion of crude oil caused by the dissolution of carbon dioxide increase with the increase of pressure and the decrease of temperature. The lower the relative density of crude oil, the higher the solubility of carbon dioxide.

1.2. Steam stimulation in complex structure wells.

Pairwise horizontal well is also a kind of complex structure well, which is often used in horizontal well assisted gravity drainage technology, called SAGD. Using steam as heating medium, oil layers are heated under the action of fluid thermal convection and heat conduction, and heavy oil is exploited by gravity. SAGD has the following characteristics: gravity is the main driving force of crude oil; heated crude oil flows directly into production wells by gravity; high recovery, high cumulative oil-gas ratio, but the conventional SAGD well also has the problems of uneven development of steam chamber and low utilization of horizontal section, so Jiang Yongping carried out the research on the effect of compound huff and puff to improve SAGD. [4]With the combination of high temperature dispersing solvent + nitrogen + steam composite huff and puff technology and SAGD technology, high temperature dispersant has a certain mixing and dispersing effect, which can improve the thermal connectivity between SAGD injection and production wells. As an active macromolecule, it can reduce the interfacial tension, accelerate the flow of heavy oil in the steam chamber and improve the oil displacement efficiency.

2. Steam flooding

Steam flooding refers to the process of continuous steam injection of steam injection wells and continuous production of surrounding oil wells. However, in the process of steam flooding operation, a large amount of steam consumption is often accompanied. In addition, the current steam generators are basically boilers, and the pollution of waste gas and wastewater on the environment cannot be ignored. There are also problems in the development effect, such as gravity overshoot and gas channeling.

2.1. Coupling Low Salinity Water Flooding and Steam Flooding

The purpose of combining low salinity water flooding with steam flooding to improve heavy oil recovery is to combine the advantages of low salinity water (such as changing wettability) and steam (such as reducing oil viscosity), and to minimize the steam problems caused by the density difference between steam and high viscosity oil (such as steam gravity overcoating, channeling and early breakthrough).

Low salinity water and steam can flow in the whole core (or reservoir) at the same time, thereby increasing the vertical sweep coefficient. The results show that due to the effect of steam on reducing residual oil saturation, the wettability change of core with low salinity water + steam flooding is significantly higher than that of core with only low salinity water. Low salinity water is effective in changing sandstone wettability and making sandstone water-wet.[5]

2.2. Chemical Compositions Injection Combined with Cyclic-Steam Stimulation

Co-injection of steam and solvent reduces dependence on steam, which can reduce air pollution caused by excessive use of steam. In addition to the mechanism of steam flooding, the solvent can also improve the solubility to assist oil recovery. Light paraffin, aromatic hydrocarbon, hydrocarbon mixture (such as condensate oil) and some polar components were added into the steam injection. After steam flooding, condensate oil was injected with steam for a period of time, and then steam was injected. In the co-injection process, the solvent is condensed at the

steam-asphalt interface to form a liquid solvent pool, which has the potential to reduce the viscosity of heavy oil to improve the recovery of heavy oil.

3. Combustion in-situ

Fired oil layer, also known as underground combustion method, is different from the former two processes, its heat is produced in the oil layer, so there is no heat loss in the wellbore, but for this relatively new technology, there are still many problems, such as the main fire line control.

Seyedsaeed Mehrabi-Kalajahi et al. applied EPR technology to monitor the ISC process and reservoir temperature in the EOR process, so as to achieve accurate control of the combustion front and ensure that the combustion process is carried out in accordance with the expected direction. In the actual gas injection process, the combustion process will inevitably cause the rise of reservoir temperature. The temperature of combustion front moving direction is higher than other regions. increase of free radical concentration; add is a sign of reservoir temperature rise, EPR technology is used to analyze free radical signals to estimate combustion front.[6]

The in-situ upgrading of crude oil with high S and N content can be realized by burning the oil layer. In the industry, it is difficult to realize the conventional refining processing. In order to study the upgrading potential of Atha-basca supplied by JACOS, I. I. Abu et al. of the University of Calgary carried out the regeneration and reuse of an industrial supported catalyst. Although the HDN activity of the regenerated catalyst is lower than that of the fresh catalyst, the regenerated catalyst is still active and can be reused for in-situ improvement of oil products.[7]

4. The prospect of heavy oil thermal recovery

Through the previous introduction, in the current period of time, the development of heavy oil is still inseparable from steam. The current cost basis of heavy oil projects shows that the energy cost accounts for about 45 % of the unit technical cost and more than 65 % of the operating cost per barrel. In order to reduce the cost of each barrel of oil, some improvement plans for operating costs have been proposed. Therefore, in the field of heavy oil development in the use of steam technology, one of the problems to be solved is the steam cost problem, reducing the steam cost will be one of the future development directions.

4.1. Production of steam by thermal power unit to reduce cost

Through a new cogeneration process, solar energy is used to generate steam, reduce the cost of steam and improve the economic benefits of development. Since renewable energy alone cannot meet all the needs of heavy oil development, the use of cogeneration will be a viable solution to meet the required steam requirements in addition to solar energy and provide the required electricity in addition to solar photovoltaic

The deployment speed of photovoltaic power generation is accelerating, and the global installed capacity has exceeded 500 million kW. At the end of 2020, China ' s installed capacity of photovoltaic power generation has exceeded 250 million kW. Mutual benefits can be achieved through joint development of solar energy and oil.

4.2. Application of complex structure well in heavy oil development

Complex structural wells introduce a new idea through complex well structure. It is not a new method to drive oil to wellbore, but to drill more direction-finding wells, so that they can enter the previously captured crude oil zone, thereby improving the recovery of crude oil. Compared with conventional diameter or even single horizontal well, complex structure well has many advantages:

(1) Under the same wellbore length, drilling and completion costs may be reduced to 60% of the total cost of conventional horizontal wells.

(2) For a certain wellbore length, the contact area with the reservoir is increased, the production capacity and injection capacity are improved, and the flow rate around each wellbore is reduced.

(3) It is possible to drill several lateral boreholes in a main hole at the bottom of the reservoir to maximize the use of gravity.

(4) Several additional boreholes can be drilled at the top of the reservoir to ensure the maximum distance from the bottom water layer.

(5) It is possible to develop a new well distribution system, which combines complex structural wells with the most basic horizontal wells to form a new oil discharge structure.

For example, the exploration and application of Wangjiangtao vertical well assisted double horizontal well SAGD technology in super heavy oil reservoirs in Xinjiang, China, aims to solve the problems caused by interlayer and process conditions, such as uneven utilization of some horizontal sections, uneven development of steam chamber and slow lateral expansion, which limit the increase of oil production.[8]

The basic principle is as follows: the SAGD technology of vertical wells assisted by double horizontal wells refers to the deployment of one or more auxiliary vertical wells above the side of SAGD well group, and the formation of a new cavity through the steam huff and puff of vertical wells. With the expansion of the front edge of the cavity of the vertical wells, it is gradually connected and integrated with the original steam cavity of the double horizontal wells SAGD well group, increasing the volume of the steam cavity. Under the dual effect of gravity and driving force, the oil recovery rate is significantly improved, and the reserves at the unused area are fully utilized.

5. Summary

(1) Composite huff and puff technology will be the development direction of steam huff and puff technology. However, steam huff and puff still have problems to be solved-the heat loss in wellbore.

(2) Many relevant solutions have been proposed by petroleum workers to the problems of steam flooding itself, such as the problem of overpressure. The combination of steam flooding and chemical technology will be the future development trend, which can improve the injection efficiency of steam and the production efficiency of heavy oil.

(3) Fired oil layer is a high-risk process, but because of its unique advantages compared with steam, prompting more oil workers to study, making the fire flooding process gradually mature.

(4) Energy reduction and consumption reduction, the addition of green energy and the application of complex structural wells in heavy oil development will become the development direction of heavy oil thermal recovery technology in the future.

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