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Application of optical sensing system in heavy oil recovery

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ABSTRACT

While the heavy oil recovery in China is switching from the traditional Cyclic Steam Stimulation to the more innovative Steam Assisted Gravity Drainage (SAGD), real-time reservoir monitoring system become more and more important for petroleum industries, but tradition electrical systems' performance on spatial resolution are not good enough. In this paper, we present an optical sensing system based on OTDR and corresponding interpretation, which can obtain the real-time temperature profile and its spatial resolution and temperature resolution is much higher than tradition electrical monitoring system. We utilized this system into the heavy oil recovery in Xinjiang oilfield, the experiment result shows that the position of steam cavity leading edge. This system can provide deep insight into the status of oil recovery process and provide basic data for the following operation.

1. Introduction

Since Butler presented the steam assisted gravity drainage (SAGD, Steam Assisted Gravity Drainage) [1,2], SAGD technology has become the most effective production practice of heavy oil and super heavy oil [3–5]. During SAGD development process, the understanding of shape and development characteristics of steam chamber and accurate measurement of steam cavity leading edge distribution and speed are the important basis of successful exploitation [6,7]. Thermocouple is the most commonly used equipment in temperature monitoring for thermal recovery of heavy oil, but it is a single point and discontinuous monitoring, not suitable for real-time and continuous monitoring of steam chamber's development. Optical fiber sensing, which use optic as carrier, optical fiber as media, to sense and transfer the external signal, develops rapidly with the development of optical fiber and optical fiber communication technology. Optical fiber distributed temperature measurement system (DTS, Distributed Temperature Sensing) is a new real-time measurement method of temperature spatial distribution that developed in recent years, it not only has the characteristics of anti-electromagnetic, corrosion resistance, high temperature resistance, also has the advantage of distributed, real-time continuous measurement. DTS is widely used in the production of process monitoring in heavy oil thermal recovery wells [8–11]. In the present paper, distributed temperature sensing system was utilizing into the heavy oil recovery in Xinjiang oilfield. System installation in SAGD production well and observation wells, measuring data and corresponding interpretation achievements was described.

2. Installation of DTS

Xinjiang oilfield SAGD use two horizontal wells for exploitation, the upper horizontal well is gas injector, the other one is production well. During long-term steam flooding, gas injector doesn't take any measures, while production well needs to judge inter well connectivity during

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cyclic preheating stage and usage of horizontal section during production stage according to the temperature profile in production wells, hence long-term monitoring of the temperature profile in production well is very important. In addition, SAGD well group is also surrounded by many observation wells. According to temperature profile in the observation wells, shape and development characteristics of steam chamber can be monitored, and this is helpful for deeply understand the formation process of steam chamber, vertical producing degree and position of planar steam front, and provide the basis for the analysis of reservoir and adjustment of production process.

As shown in Fig. 1, SAGD production well adopts double pipe structure, sensing optical fiber cable enters long tube of production well by binding to coiled tubing, the installation technology includes: preset and installation. Presetting technology mainly includes preset steel wire in shaft, sensing optical fiber cable replace steel wire, and connect pressure sensor to bottom of coiled tubing; installation technology mainly includes installation of coiled tubing, wellhead through and sealing operation, etc. As shown in Fig. 2, in order to accurately reflect steam chamber's position and development characteristics, the technology of embedding hollow rod to casing and mounting the sensing optical fiber cable into hollow rod is used in DTS installation. DTS system conducts real-time monitor to the temperature profile in the well, and describes steam chamber's development characteristics.

3. Experiment

3.1. DTS' application in production well

Temperature profiles of production wells, which measured by DTS system, can effectively determine the connectivity of double horizontal wells during cyclic preheating stage, whether the well has the pump condition, and whether the well can enter the stage of production. Fig 3 is the curve of temperature profiles in production wells of a SAGD well group changing with time, horizontal section is from 405 m to 851 m underground. The cyclic preheating of well group began in 2012 November, the horizontal section connectivity experiment was done in January 20, 2013: production well was soak, and gas injector began steam flooding at two points. According to the whole wellbore temperature data which measured by DTS system, whole horizontal section temperature decreased from 20:00 to 23:00, as a result of heat exchange between borehole and stratum after production well shut down; temperature level of 445 M to 775 m underground in horizontal section obvious rose from 23:30 to 6:00 in the morning, illustrated that thermal connectivity between production well and gas injector had been established after cyclic preheating stage; temperature level in section of 405 m to 445 M and 775 m to 851 m continued to decline, illustrated that thermal connectivity between production well and gas injector hadn't been established. According to thermal connectivity experiment and data measured by DTS system, the connected length of well group is 330 m, the connectivity rate of 74.2%, so this well group has the initial conditions of pumping.

3.2. DTS' application in observation well

The temperature profile of observation wells measured by DTS system, can be used to determine outward expansion and development characteristics in vertical direction of steam chamber at different horizontal section position. Fig. 4 shows the temperature profile of two observation wells A and B which near the SAGD well group during

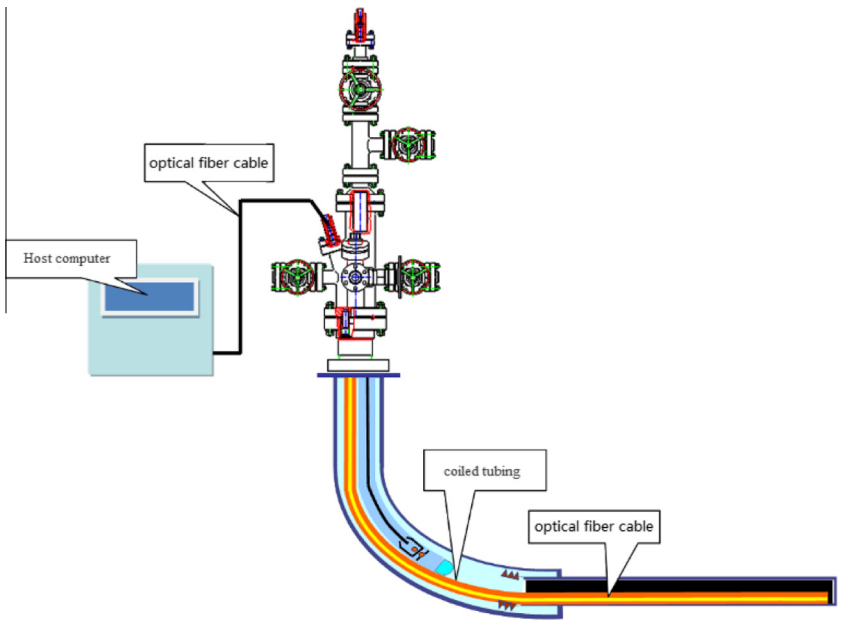

Fig. 1. DTS installation in the SAGD production well.