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# Temperature field analysis on the highly-deviated wellbore in backwashing condition

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ABSTRACT

Based on the measured borehole trajectory, a prediction model of temperature field of highly-deviated wells in backwashing condition is established. To verify the model, a test instrument to measure the temperature variations in the wellbore is developed and used to measure the temperature of two typical highly-deviated wells in backwashing condition. The comparative analysis shows that the wellbore temperature predicted by the model is close to that measured in field with the relative error less than 8%. The model was further used to analyze the influence of liquid-injection speed and injection time on the temperature distributions of oil pipe, annulus space and radial direction under the backwashing operation with original-temperature and hot washing liquid. It is found that for the backwashing operation with original-temperature washing liquid, the temperature at the lower part of the shaft is most affected by the displacement rate and backwashing time, whereas the curve section and the lower part of the shaft are most affected by the displacement rate and backwashing time in hot washing operation. Along the depth of the borehole, there is a constant temperature section which is almost unaffected by displacement rate and backwashing time. The radial heat transfer analysis shows that the heat exchange range is not large and near the wellbore.

## 1. Introduction

Backwashing operation is widely used in oilfield development with the washing liquid being injected from the annulus and drained out from the oil tube. Due to the structure complexity shown in Fig. 1, the temperature field of a highly-deviated wellbore during backwashing operation is changeable and has a significant effect on the mechanical response of downhole tools, such as tube buckling and packer deblocking. So, it is necessary to analyze the temperature field of the highly-deviated wellbore in the backwashing operation.

The thermal modeling of wellbore heat transmission traces back to the late 1950's, when an analytical model for the calculation of bottom hole temperature in gas wells was presented by Lesem et al. (1957). Subsequently, the studies about the temperature field in the wellbore with injected fluid have been reported gradually.

An approximate solution, neglecting kinetic energy and frictional pressure drop, viewing the flow in the wellbore as a steady-state, non-compressible, and single phase fluid was developed by Ramey (1962) and improved by Willhite (1967). Under the assumption that the vertical temperature gradient is negligibly disturbed by the fluid flow, the Ramey's model has put forward by Beck and Shen (1985). Sagar et al. (1991) calculated the temperature of saturated steam in deviated wells using modified Ramey model. However, the model assumes that the heat transfer in the wellbore is steady state. Similarly, Hagoort (2005) presented a simple and physically analytical solution for the prediction of wellbore temperatures in gas production wells. Shi et al. (2008) proposed an improved numerical simulation method on the Remay's model to calculate the downhole temperature distribution in producing oil wells. A mathematical model to predict thermophysical properties of saturated steam (i.e. steam pressure, temperature and quality) and wellbore heat losses in CDTSIW (concentric dual-tubing steam injection wells) were presented by Hao et al. (2014). Hamid et al. (2014) developed a two-dimensional transient heat conduction model to predict the temperature distribution, average temperatures in the near wellbore region and the cumulative heat flow across the wellbore, during the process of steam circulation in the wellbore. Zhang et al. (2015) established a calculation model of the temperature field distribution of the concentric double-pipe gas injection wellbore that considered the influence of the

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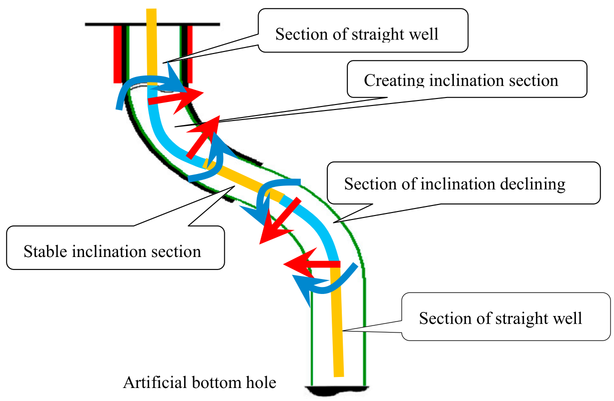


**Fig. 1.** Sketch of structure of five-section highly-deviated well.

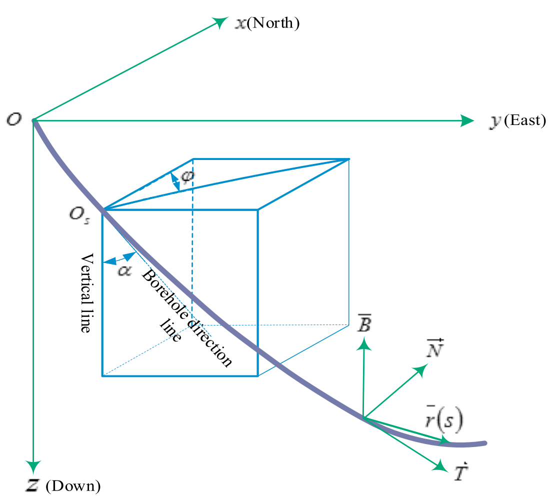


**Fig. 2.** Geometry relationship between 3D well trajectory and coordinate systems.

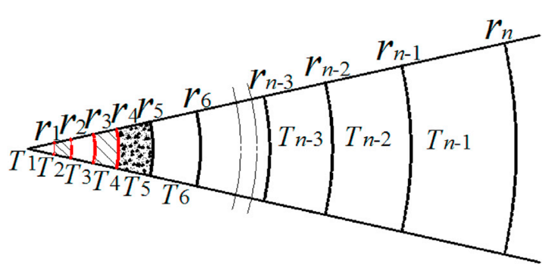


**Fig. 3.** Sketch map of radial unit partition.

wellhead injection parameters and the sizes of inner and outer oil tubes. Guang, 2012 established a mathematical model of the vertical wellbore temperature field by considering the influence of temperature and pressure on the thermophysical parameters. Wang et al. (2016) established a mathematical model for estimating overall heat transfer coefficient and wellbore heat loss, considering the thermal effect of cement sheath during steam injection. The above research is mainly aimed at the temperature field of viscous oil exploitation with steam injection.

A model based on some simplified assumptions was developed by Moss and White (1959) to predict the temperature profile of the injected water in the vertical wellbore. Using numerical solution, Li and Zhu

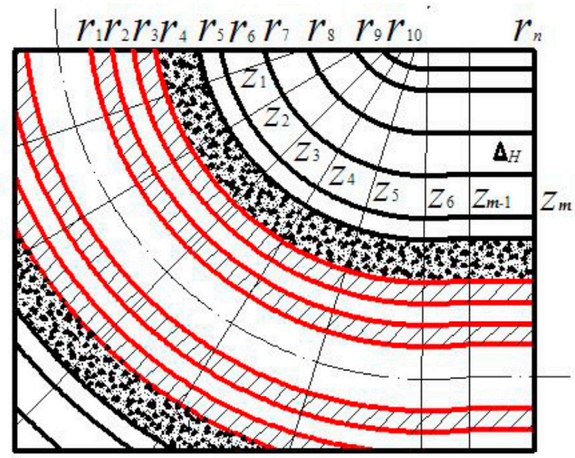


**Fig. 4.** Sketch map of longitudinal unit partition.

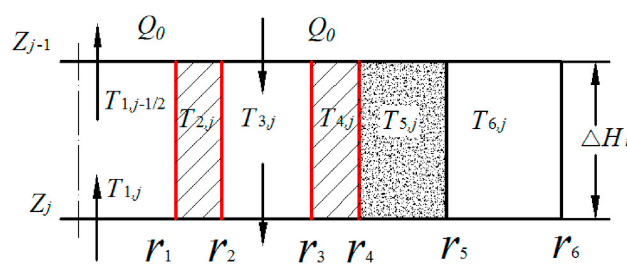


**Fig. 5.** Schematic diagram of heat transfer units in radial direction.

(2010) studied on the horizontal wellbore temperature distribution. Li et al. (2011) presented an analytical model of the temperature field and the calculation formula of the heat transfer coefficient of the wellbore. Ren et al. (2014) established a mathematical model for the downhole temperature field distribution in injection wells and production wells, taking into account the effects of different injection and production parameters (injection speed, injection temperature, injection time, etc.) and formation thickness on the wellbore temperature. Dong et al. (2016) established a prediction model for the temperature field of the whole well. Kan et al. (2016) established a model for the deepwater wellbore heat conduction in the process of testing. Sun et al. (2017) proposed a mathematical model to analyze the flow and heat transfer characteristics of SHS in offshore horizontal wellbores. The downhole temperature distribution's model was given by Du et al. (2017). In the model, a 2-D mathematical model was only considered in water injection condition.

A mathematical model predicting downhole wellbore temperatures in circulation injection was developed by Wooley (1980) to study the influence mechanism of fluid temperature, flow speed, and well depth on wellbore temperature. Lu et al. (1991) established a numerical calculation method for the temperature distribution of vertical wellbore during circulating injection. A temperature field analysis model for in straight well in backcycling killing operation was developed by Li et al. (2009) to analyze the effects of mud displacement, mud specific heat, geothermal gradient, well depth, well killing cycle time and slurry inlet on downhole temperature distribution during circulation. Luan et al. (2012) established three wellbore heat transfer models for closed thermal fluid circulation, considering the influence of the circulating flow speed, circulating medium and tube material property on the wellbore heating effect. Yang et al. (2014), Cai and Duan (2015) developed a temperature field model of horizontal wellbore, the models does not consider the variation of well angle, and the calculation results are also lack of

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