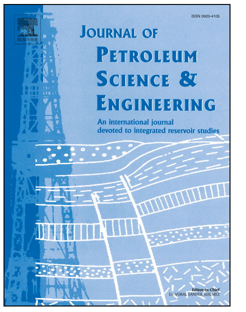
Accepted Manuscript



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PII: S0920-4105(18)30515-1

DOI: 10.1016/j.petrol.2018.06.027

Reference: PETROL 5034

To appear in: *Journal of Petroleum Science and Engineering*

Received Date: 14 January 2018

Revised Date: 9 June 2018

Accepted Date: 9 June 2018

New Analytical Solutions of Wellbore Fluid Temperature Profiles During Drilling, Circulating, and Cementing Operations

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Abstract

Historically, the formulation of the wellbore temperature profiles during drilling, circulating, and cementing operations relied upon the boundary condition or BC at the bottomhole location, wherein the tubular and annular temperatures become equal. This study presents two other formulations to explore alternative to bottomhole BC's that may potentially occur in wellbores.

Application of the energy balance in the wellbore for both forward and reverse circulations underpins all three formulations. The wellbore temperature profiles generated by implementing the energy balance in the system depends on the type of the boundary condition used. Initially, we generated various temperature profiles using these models. In general, we observed that the maximum temperature occurs at the end of the tubular or some distance away from the bottom. For open and cased-hole sections, the difference in heat-transfer coefficients triggers different magnitudes of heat transfer and affects the corresponding temperature profiles.

We compared the performance of our models with those presented in the literature. Thereafter, we sought to validate the models with diverse set of field data. Given the ability of all three models to handle changes in the geothermal gradient due to the characteristics of the sediments, salt domes, and gas hydrates, we explored their performance in situations where there is significant heat transfer. The holistic approach pursued here provided the necessary insights into various temperature profiles in a given situation.

1. Introduction

Although commercial drilling in the US started in the 1920's, the fluid circulation models appeared a few decades later. We note that the earlier analytical models of Edwardson et al. (1962) and Tragesser et al. (1967), although useful to gain a physical understanding of the transient flow problem, are impractical in a field situation because they require a detailed knowledge of the drilling history.

Raymond (1969) presented the first numerical model for computing circulating-fluid temperatures during unsteady and pseudosteady-state conditions to handle multiple casing strings. This approach requires a finite difference solution of the governing equations dealing with the unsteady-state, heat-transfer problem. Subsequently, improvements to this model were presented by Keller et al. (1973), Wooley (1980), and Beirute (1991), among others.

Subsequently, analytical solutions became feasible for less complicated systems, such as that for a single casing string. For example, Holmes and Swift (1970) presented a solution for the steady-state heat transfer in a drillpipe and annulus surrounded by the formation. In contrast, Kabir et al. (1996) and Hasan et al. (1996) obtained solutions for forward and reverse-circulation cases for the variable mud-tank temperature of the circulating fluid. They validated their fluid-temperature model with field data from Holmes and Swift (1970) and Davies et al. (1994).

In the modern era, deeper drilling depths in deviated wellbores and demanding environments, such as that in a deepwater setting present considerable operational challenges. Given the influence of fluid temperature on the fluid properties and the consequent drilling operation itself, one cannot overemphasize the importance of estimating the fluid temperature profiles in both conduits. To that end, Kumar and Samuel (2013) expanded the scope of the previous models by including well deviation and heat generated by wellbore friction. Others studied the drilling fluid temperature profile during the gas-hydrate drilling