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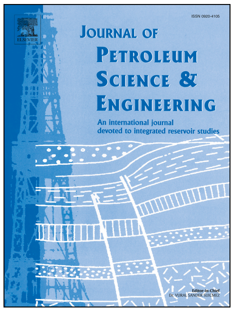

Near-wellbore modeling of a horizontal well with Computational Fluid Dynamics

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Title: Near-wellbore modeling of a horizontal well with Computational Fluid Dynamics

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Abstract: The oil production by horizontal wells is a complex phenomenon that involves flow through the porous reservoir, completion interface and the well itself. Conventional reservoir simulators can hardly resolve the flow through the completion into the wellbore. On the contrary, Computational Fluid Dynamics (CFD) is capable of modeling the complex interaction between the creeping reservoir flow and turbulent well flow for single phases, while capturing both the completion geometry and formation damage. A series of single phase steady-state simulations are undertaken, using such fully coupled three dimensional numerical models, to predict the inflow to the well. The present study considers the applicability of CFD for near-wellbore modeling through benchmark cases with available analytical solutions. Moreover, single phase steady-state numerical investigations are performed on a specific perforated horizontal well producing from the Siri field, offshore Denmark. The performance of the well is investigated with an emphasis on the inflow profile and the productivity index for different formation damage scenarios. A considerable redistribution of the inflow profile were found when the filtrate invasion extended beyond the tip of the perforations.

Keywords: horizontal well productivity, near-wellbore model, inflow performance, reduced order model, numerical model, computational fluid dynamics.

Highlights: Computational Fluid Dynamics (CFD) simulation for modeling well inflow is introduced. Infinite conductivity horizontal wells can be modeled with CFD. The completion geometry can be incorporated into the numerical model. The inflow performance of the horizontal well in Siri field is assessed with CFD. Flow redistribution is observed for formation damage cases.

1. Introduction

Production by horizontal wells is a widely used technology of the upstream oil & gas industry since several decades. The enhanced well-reservoir contact increases the area swept by the well, leading to a rise of inflow performance, thereby horizontal wells perform significantly better in thin reservoirs than vertical wells and reduce problems related with water or gas coning. However, the estimation of the horizontal well productivity is more challenging than the corresponding estimation for vertical wells. The partial penetration of the well into the reservoir, and the finite conductivity of the long wellbore results in a complex well–reservoir interaction that can hardly be captured by conventional analytical methods. Therefore, analytical formulas are only available for simplified problems where the flow in the wellbore is neglected and – in most cases – uniform well pressure assumed(Joshi, 1988), (Giger, et al., 1984), (Renard & Dupuy, 1991). More sophisticated semi-analytical models were developed to overcome the uniform well pressure assumption, by including the pressure loss in the wellbore (Ozkan, et al., 1999). The inflow predicted by such finite conductivity well models reflect the field observations of increased production rate at the heel, where coning is more likely to occur. Nonetheless, when formation heterogeneity or complex well completion is present analytical or semi-analytical solutions are impossible to obtain, numerical methods must be used.

Standard large scale reservoir simulators are extensively used in the industry. However, they often lack the accuracy to resolve the well and the near-wellbore area since the applied Cartesian grid size (50 – 100 m) is two orders of magnitude larger than the diameter of the well. Therefore, the pressure gradients and flow velocities at the vicinity of the well are approximated based on analytical or semi-analytical formulas. Neglecting important near-well physics such as sharp pressure gradients, reservoir inhomogenity or completion geometry. To address this issue methods have been developed to advance the near-well representation by improving the standard Cartesian grid technique. In order to increase the accuracy of the numerical grid's resolution, a local grid refinement (LGR) method was proposed (Heinemann, et al., 1991) using irregular PEBI (perpendicular bisection method) grid. It was proved for vertical wells that the LGR method helps to capture the near-well flow patterns, while the PEBI unstructured grid significantly increases the flexibility of the spatial discretization. A similar unstructured LGR method was presented recently, with upscaling in the near-well area (Karimi-Fard & Durlofsky, 2012). This *expanded well* modeling approach was designed to capture the key near-well

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