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New design for pdc drill bits through a modification in the nozzle angle using computational dynamic fluids

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Abstract

The exploration and exploitation of hydrocarbons forces the oil companies to improve the drilling process, therefore every aspect of this operation that has the opportunity for optimization should be researched. In 2016, Mohamed El Neiri proposed a hybrid drilling technique where the zone located around the bit remains in underbalanced conditions and the rest of the drill string is overbalanced, such conditions requires some modifications in the design of the drill bit. The aim of this project was to modify the nozzle angle of a PDC drill bit in a CAD design tool and to simulate the dynamic behavior of the drilling fluid across the bit, with and without the modifications, with a software tool using CFD techniques to determinate by comparison of the fluid properties, the impact of them.

The simulation consists in three stages: pre-processing, solver and post-processing. During the first phase the adaptation of the geometry, generation of the grid and the insertion of the physical models which characterize properly the system are done. Subsequently, the settings of the solver are set, such as the type of special discretization to finally, in the post-processing validate the results obtained by observation of the response variables profiles. In this study, were used service packs of the commercially software ANSYS®.

For each one of the proposed geometries a differential pressure and velocity analysis were done and this information provided fluid data in some scenarios: when the drilling fluid enters to the nozzle, flows through it and exit as well as it strikes the formation. The results may represent and advance for the sake of the postulates of the hybrid technique. Polycrystalline diamond compact (PDC) drill bit design influences the bit hydraulics and hence the drilling performance. To improve the hydraulics, the fluid flow pattern across the drill bit should be optimized for low pressure drop, low recirculation flow and high velocity. Design of Experiments (DOE) was used to study the effect of various design parameters. Computational Fluid Dynamics (CFD) was used to simulate the fluid flow in the complex geometry of the drill bit. Response Surface Methodology was applied to optimize the design parameters for improved bit hydraulics.

Preliminary simulations were conducted by increasing the complexity to meet the realtime operation. Simulations based on fractional factorial experiment were used to identify the significant factors from the 15 design parameters. The optimum limits of the most significant five factors were identified from simulations based on central composite design (CCD). The optimization procedure was assessed by comparing the optimum design with the original design for Newtonian and Non-Newtonian conditions.

One of the most important concerns in the oil and gas industry is the time and cost associated with drilling wells. The focus of the drilling industry is to minimize the overall drilling cost without compromising the safety and environmental standards. The efficiency of drilling, measured in terms of the Rate of Penetration (ROP), is the most important criteria in the drilling economics as it directly influences the time taken for drilling a well. Based on the relationship between drilling cost and ROP, it had been shown that maximizing the ROP will result in minimizing the drilling cost. The rate of penetration or the drilling performance depends on the lithological characteristics of the formations being drilled, drilling fluid properties, the downward force acting on the drill bit or Weight on Bit (WOB), rotation of the drill bit (RPM) or the combined rotation of drill string and the downhole motor (DHM), and bit hydraulics. Among the above parameters, drill bit hydraulics has been recognized as the major factor influencing the drilling performance.

The purpose of proper hydraulic design of drill bits is to have appropriate conditions of drilling fluid flow rate and bit pressure drop to facilitate the removal of cuttings generated during drilling. Bit hydraulics plays an important role in this process, especially during drilling in sticky or soft formations such as shale plays. Poor hydraulic design causes improper bottomhole cleaning, which may result in balling (the accumulation of cuttings on the bit face) that decreases the ROP, or may halt drilling in severe cases. Drill bit design influences the bit hydraulics in terms of the drilling fluid flow rate and pressure drop across the bit which affects the removal of generated drill cuttings; bottomhole cleaning; reduced chip hold-down pressure and bit cooling as well as power consumption. Some typical problems due to ineffective bit hydraulics are bit balling and pre-mature bit wear due to regrinding of chips. These problems will reflect on the drilling performance and hence increase the drilling cost. Increasing the hydraulic power at the mud pump improved the drilling performance of jet bits.

Drilling operations have a significant effect in oil and gas exploration and production due to its economic reason. Less drilling time can directly lower the overall cost of exploration and production in oil and gas. This project focuses on the hydrodynamics study of a Polycrystalline Diamond Compact

(PDC) drill bit design particularly on nozzle inclination and how it affects the bit hydraulics characteristics of the drilling fluid in the bore hole and around the PDC bit.

Optimizing the hydraulics while drilling is well-known and acknowledged to have significant effect on the overall drilling performance, where good hydraulics provide essential job of removing of drill cuttings to avoid unnecessary mechanical energy loss due to re-work on the produced drill cuttings, cooling of the diamond cutters to prolong the bit life and reduce the potential of bit balling. These factors assist in achieving high ROPs which in turn reduces drilling time thus effectively lowering the cost of a drilling operation. Different types of drilling fluids are also considered in this study as it is also known to have an effect on the drilling hydraulics characteristics. Drilling fluid systems have been continuously modified to aid in bit and drilling performance as well as functioning to maintain the well integrity with its role to provide hydrostatic pressure in the well to prevent collapsing of the well. The main objective of the study is to develop a CFD model in ANSYS Fluent for investigating PDC bit hydrodynamics. Other objectives include investigating the effects of nozzle inclination angle on the drilling fluid flow characteristics around the PDC bit and how different types of drilling fluid influences the PDC bit hydraulics. Drilling simulations models are created using the computer software ANSYS Fluent. Simulations are run using realizable k-epsilon model to correctly simulate the turbulence effect undergone by the fluids around the PDC bit during drilling operations. Several simulations are run with different nozzle inclination angle and types of drilling fluid which have been proven to have significant effect on the flow characteristicaround the PDC bit.