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Modeling Standpipe Pressure Using Multivariable Regression Analysis by Combining Drilling Parameters and a Herschel-Bulkley Model

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Abstract : The aims of this paper are to formulate mathematical expressions that can be used to estimate the standpipe pressure (SPP). The developed formulas take into account the main factors that, directly or indirectly, affect the behavior of SPP values. Fluid rheology and well hydraulics are some of these essential factors. Mud Plastic viscosity, yield point, flow power, consistency index, flow rate, drillstring, and annular geometries are represented by the frictional pressure (Pf), which is one of the input independent parameters and is calculated, in this paper, using Herschel-Bulkley rheological model. Other input independent parameters include the rate of penetration (ROP), applied load or weight on the bit (WOB), bit revolutions per minute (RPM), bit torque (TRQ), and hole inclination and direction coupled in the hole curvature or dogleg (DL). The technique of repeating parameters and Buckingham PI theorem are used to reduce the number of the input independent parameters into the dimensionless revolutions per minute (RPMd), the dimensionless torque (TRQd), and the dogleg, which is already in the dimensionless form of radians. Multivariable linear and polynomial regression technique using PTC Mathcad Prime 4.0 is used to analyze and determine the exact relationships between the dependent parameter, which is SPP, and the remaining three dimensionless groups. Three models proved sufficiently satisfactory to estimate the standpipe pressure: multivariable linear regression model 1 containing three regression coefficients for vertical wells; multivariable linear regression model 2 containing four regression coefficients for deviated wells; and multivariable polynomial quadratic regression model containing six regression coefficients for both vertical and deviated wells. Although that the linear regression model 2 (with four coefficients) is relatively more complex and contains an additional term over the linear regression model 1 (with three coefficients), the former did not really add significant improvements to the later except for some minor values. Thus, the effect of the hole curvature or dogleg is insignificant and can be omitted from the input independent parameters without significant losses of accuracy. The polynomial quadratic regression model is considered the most accurate model due to its relatively higher accuracy for most of the cases. Data of nine wells from the Middle East were used to run the developed models with satisfactory results provided by all of them, even if the multivariable polynomial quadratic regression model gave the best and most accurate results. Development of these models is useful not only to monitor and predict, with accuracy, the values of SPP but also to early control and check for the integrity of the well hydraulics as well as to take the corrective actions should any unexpected problems appear, such as pipe washouts, jet plugging, excessive mud losses, fluid gains, kicks, etc.

Keywords : standpipe, pressure, hydraulics, nondimensionalization, parameters, regression
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