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Research Paper

Optimization Of Drilling Gas Wells for Improved Hole Quality and Productivity

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ABSTRACT
In a quest to ensure the proper hole cleaning and resultant drilling efficiency, different approaches have explored by research to optimize drilling parameters such as weight on bit (WOB), rotation per minute (RPM), rate of penetration (ROP) and torque. In this study, the focus was the statical regression method to establish the relationships between the drilling parameters and how their relationships with each other affect drilling efficiency, hence optimizing the drilling operation. The drilling parameters were obtained from the secondary sources (selected wells in Niger-Delta Fields) and regression analysis was carried out regression study revealed that WOB has a positive linear relationship with ROP, but Power Setting and tool face angle have a negative linear association. TF Angle showed a curvilinear positive connection with ROP. The analysis determined that the ideal drilling parameters for reaching a maximum ROP of 125.367 ft/hr. are: TF Angle at 180 degrees, Power Setting at 10, WOB at 12 (1000 lbf), Torque at 107.27 ft. lbf, and standpipe revolutions per minute (SRPM) at 8 c/min. The contour plots revealed substantial interaction effects, such as higher ROP at low power settings and increased TF Angle or SRPM. No doubt, this study has shown that statistical modeling could aid in improving hole quality and achieving substantial productivity when the drilling parameters are controlled.

Keyword: *Regression, linear association, tool-face angle, parameters, power setting, contour, Niger-Delta, efficiency.*

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I. Introduction

Reducing non-productive time (NPT) and invisible lost time (ILT) has a direct influence on the bottom line and leads to a faster return on investment. Drilling cost is an important factor in determining the effectiveness of a drilling campaign. This is simply because the success and profitability of an oil and gas drilling operation are determined by the real cost of the well in relation to the price of petroleum products in the oil and gas market. To put it simply, every operator wants to carry out his drilling campaign at the lowest cost per foot possible in order to maximize profits from a drilling effort.

Many studies have been conducted on the optimization of drilling operations. However, the demand for cheaper wells has fueled additional study in this area.A drilling optimization model that could forecast ROP of wells in the same area by comparing their data to Bourgoyne and Young's model was investigated, resulting in iso-ROP and iso-cost graphs for cost-effective drilling [1].

Using a model that establishes an electric potential between the drill bit and the rock could help to reduce bit balling in oil and gas well drilling. According to this model, the rate of penetration (ROP) was doubled when compared to the case when no potential was added [2]. Bode D. *et al*.,[3] explored the difficulties of narrow hole drilling. They presented a report outlining the measures required for safe well control in small diameter wells.

The key challenges in slim hole drilling include a slow rate of penetration for roller cone bits, a significant reduction in bit life due to torsional and axial vibrations, a slow rate of kick detection, borehole instability, inhibited production, loss of ability to effectively transmit weight on a bit in horizontal wells, drill string and tool joint failure, cementing issues, and workover operations [4]. Hareland and Rampersad [5] established a case-specific model for natural diamond bits based on the concept that when weight is added to drilling bits, certain penetration is accomplished that is dependent on scraping action, shape, rock strength, and cutter size. A study was conducted to optimize the string RPM and weight on Bit. This model is formation-specific, and it use several regression techniques to choose the equation parameters that best match the data [6].

The characteristics of the rock being drilled influence how rate of penetration (ROP) responds to variations in drilling parameters. Mineralogy, density, porosity, strength, and permeability are some of the rock attributes he mentioned. He suggested that because the quantities of these attributes are unknown, changes in ROP values may be difficult to interpret [7]. Gjelstad *et al.*, [8] employed the drilling optimization simulator [DROPS] to reduce costs by more than 50% in two North Sea wells.

Drill the Limit Optimization Technique, an alternate planning strategy, was quite successful. It reduced drilling costs by up to 50% and saved time by 15%-70% [9]. Good communication during operations makes advice clear, which reduces downtime. It was advised that, because key judgments are interdisciplinary in nature, a common ground be established for all parties concerned. When this is done, it is possible to affect the unanticipated consequence in real time, rather than waiting for the costly lesson to be learnt [10]. A revolutionary drilling automation and monitoring model was created. The model was called Dillitronics. It optimizes all surface and subsurface drilling data. The model includes methods for controlling stick-slip and increasing ROP by 15%-30% [11]. Drilling optimization was performed using a model based on mechanical specific energy (MSE). The model allows the driller to continuously follow the MSE estimated from surface data as well as other standard mechanical drilling logs [12].

II. Methodology

2.1 Research Design

The data were obtained from the Niger-Delta fields. These data were used to carry out a multiple linear regression analysis. The drilling parameters were optimized using surface response method (RSM).

2.1.1. Multiple Linear Regression Analysis

Based on the Pearson correlation data, a multiple linear regression analysis was carried out to predict the relationship between drilling parameters and ROP. To develop a prediction model for ROP, the coefficients of the independent variables (WOB, RPM, and FR) as well as the intercept will be calculated. The model's goodness of fit was evaluated using the coefficient of determination (R-squared) and other statistical tests such as the F-test and t-test.

2.1.2 Response Surface Methodology (RSM) for Drilling Parameter Optimization

The Response Surface Methodology (RSM) was used to optimize drilling parameters for increased rate of penetration (ROP) in production wells. Minitab statistical software was used to do the entire RSM study. Response Surface Methodology (RSM) is a statistical technique for optimizing operations that examines the correlations between input variables (in this case, drilling parameters) and response variables (ROP).

The fundamental purpose of RSM is to determine the best set of input parameters for maximizing or minimizing the response variable. Contour maps in RSM was used to determine places where the ROP was most effective. These graphical representations showed how the response variable (ROP) varied as the input parameters (WOB, RPM, and FR) change. Response surfaces made it easier to see the interactions and nonlinear relationships between variables. They also allowed for the determination of ideal parameters that result in the highest ROP.

III. Results and Discussion

3.1 Regression Analysis

The model was developed using a second-order model with interaction terms. To avoid overfitting and adding redundant terms to the model, terms that did not help to explaining the variation in the model were removed using backward elimination. Tables 1 to 3 show the regression analysis results, while Figures 1 to 3 illustrate them. Table 1 shows the analysis of variance for the regression model.

Table 1: Analysis of Variance and Regression Model

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	12	28357.5	2363.13	25.67	0.000
Linear	5	12675.4	2535.08	27.54	0.000

TF Angle	1	2262.1	2262.11	24.57	0.000
Power Setting	1	8012.4	8012.38	87.04	0.000
WOB	1	906.1	906.12	9.84	0.003
SRPM	1	2283.0	2282.97	24.80	0.000
Torque	1	1415.0	1414.99	15.37	0.000
Square	2	1403.2	701.61	7.62	0.001
TF Angle*TF Angle	1	287.0	287.01	3.12	0.084
SRPM*SRPM	1	1333.6	1333.61	14.49	0.000
2-Way Interaction	5	7524.9	1504.98	16.35	0.000
TF Angle*Power Setting	1	4140.4	4140.43	44.98	0.000
TF Angle*WOB	1	2201.2	2201.16	23.91	0.000
Power Setting*SRPM	1	4314.0	4313.96	46.87	0.000
Power Setting*Torque	1	2028.5	2028.45	22.04	0.000
SRPM*Torque	1	1655.6	1655.56	17.99	0.000
Error	48	4418.4	92.05		
Lack-of-Fit	26	2393.5	92.06	1.00	0.504
Pure Error	22	2024.9	92.04		
Total	60	32775.9			

Table 2: Rate of Penetration Model Equation

Model Type	Model Equation
Second order regression model with interaction terms	ROP = -172.2 + 0.025 TF Angle + 2.922 Power Setting - 1.017 WOB + 8.97 SRPM- 60.8 Torque + 0.000511 TF Angle*TF Angle - 0.0612 SRPM*SRPM - 0.004283 TF Angle*Power Setting + 0.01472 TF Angle*WOB - 0.05542 Power Setting*SRPM + 0.2298 Power Setting*Torque + 0.587 SRPM*Torque

Table 3: Goodness of Fit for Model

S	R-sq	R-sq(adj)	R-sq(pred)
9.59424	86.52%	83.15%	77.84%

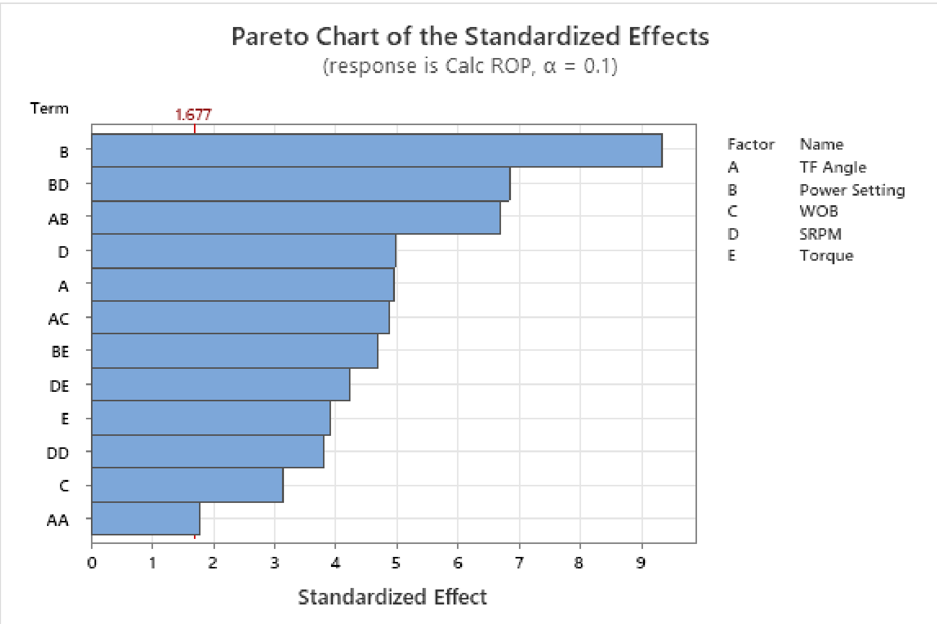

Figure 1: Pareto chart showing the effect size of each of the drilling parameters

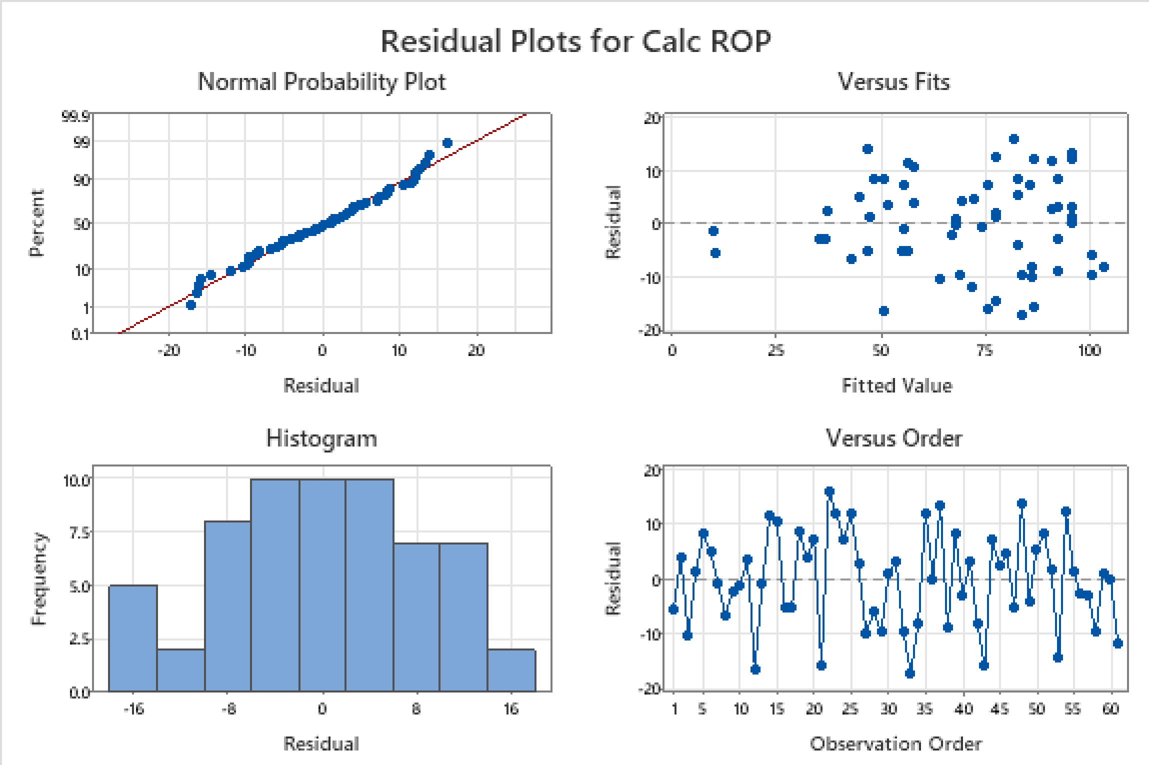

Figure 2: Residual Plots

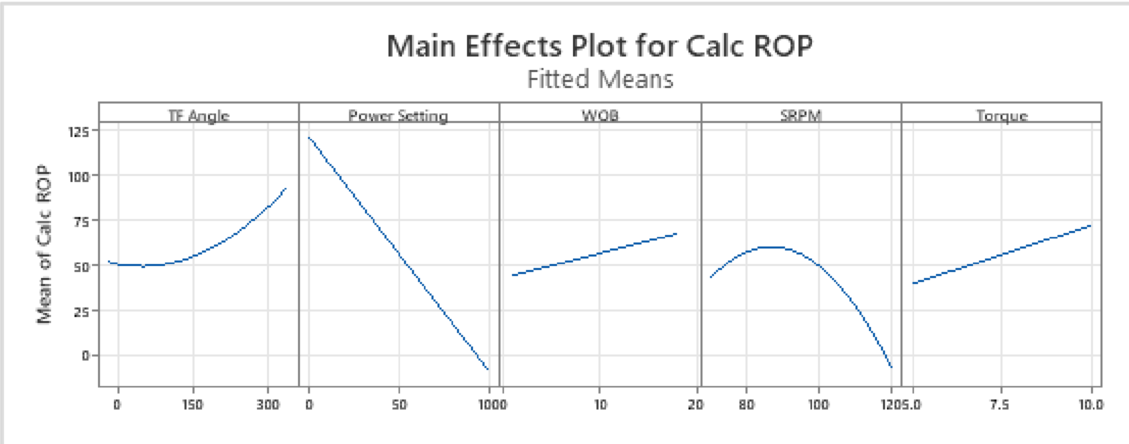

Figure 3: Main Effect plot

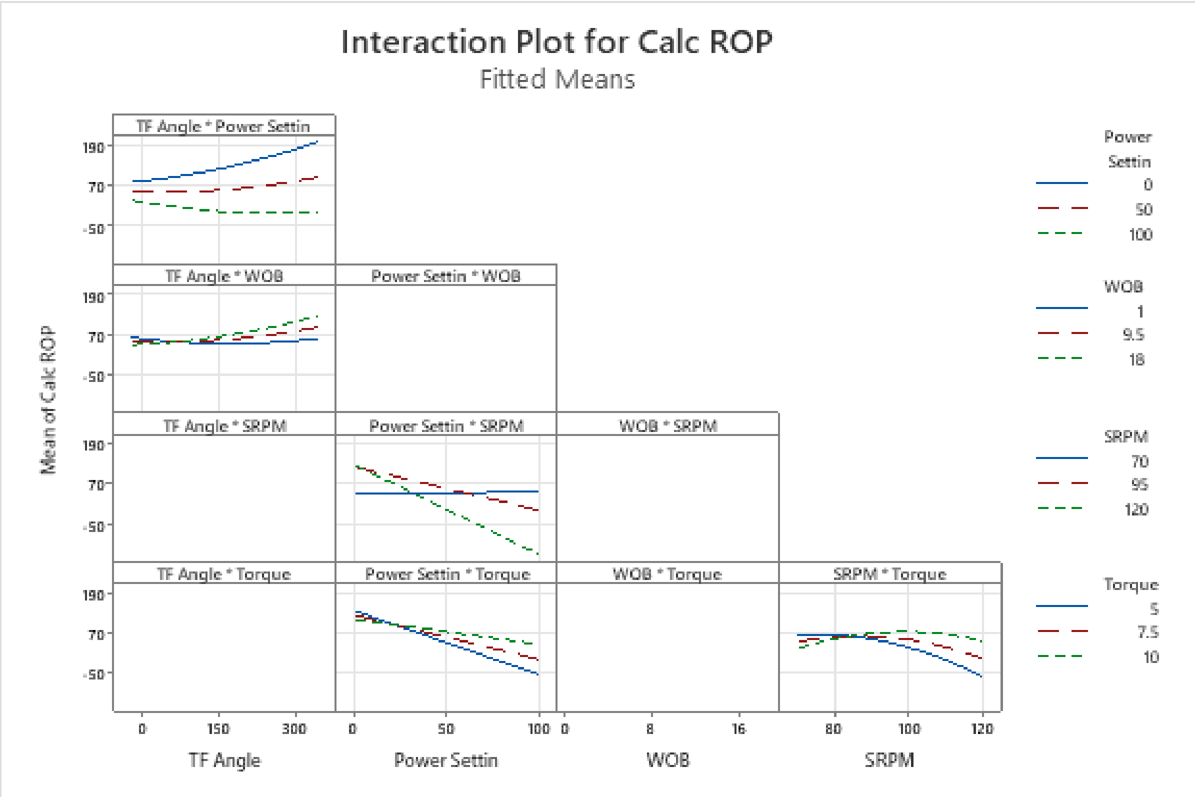

Figure 4: Interaction plots

4.1.4 Optimization of the operating drilling parameters that affect ROP

Response surface approach was used to determine the optimal drilling settings that would result in the highest rate of penetration. Figure 5 shows the response surface methodology's results.

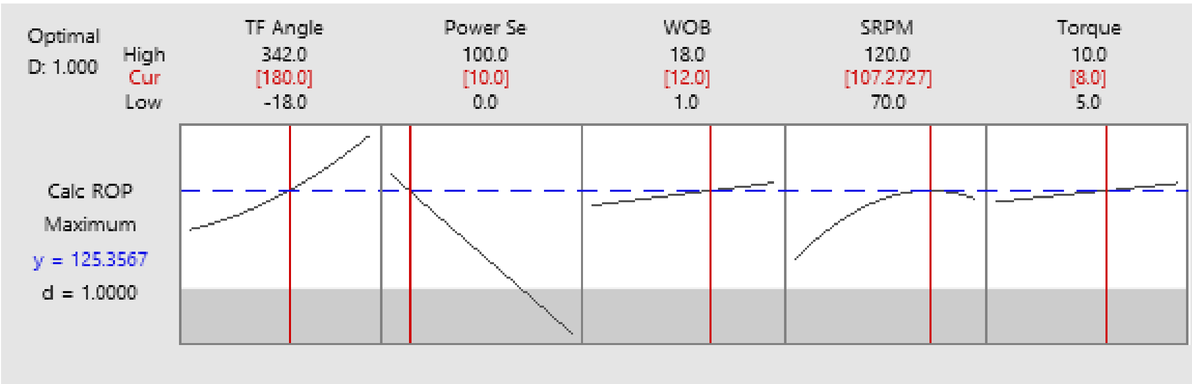

Figure 5: Optimal drilling parameters value to achieve maximum rate of penetration

Table 4: Optimal drilling conditions to achieve maximum rate of penetration

Variable	Setting
TF Angle	180
Power Setting	10
WOB	12
SRPM	107.273
Torque	8

Table 5: Optimum ROP

Response	Fit	SE Fit	95% CI	95% PI
ROP	125.4	11.2	(102.9, 147.8)	(95.8, 154.9)

Table 6: Recommended operating conditions

Drilling Parameters	Values
TF Angle	(-10, 180)
Power Setting	(10, 80)
WOB	(5, 12)
SRPM	(80, 110)
Torque	(5, 8)

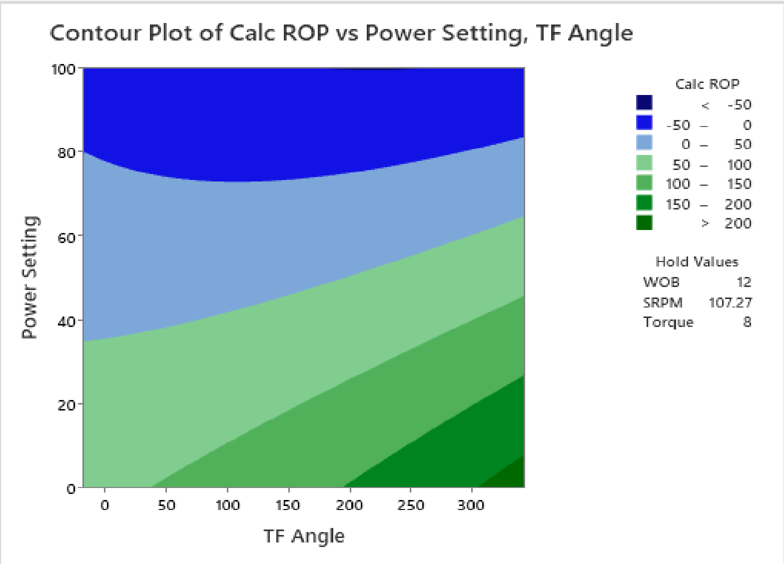

Figure 6: Response surface contour plot for interaction terms Power setting and TF angle

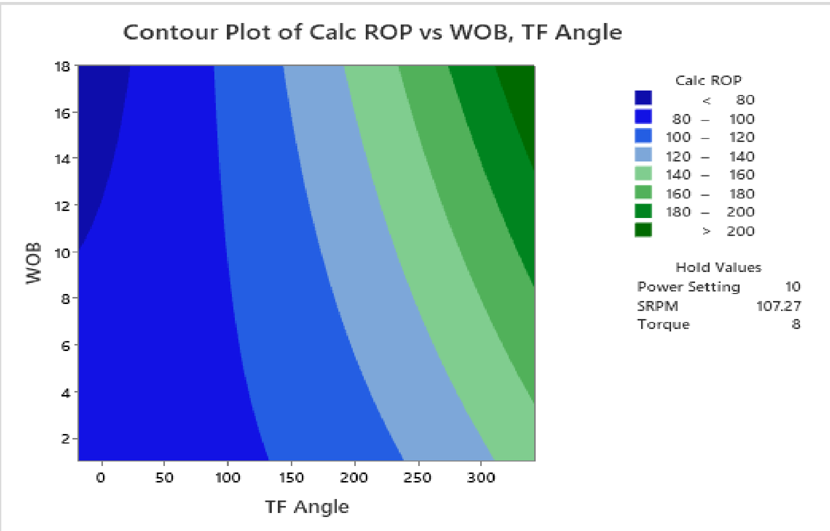

Figure 7: Response surface contour plot for interaction terms WOB and TF angle

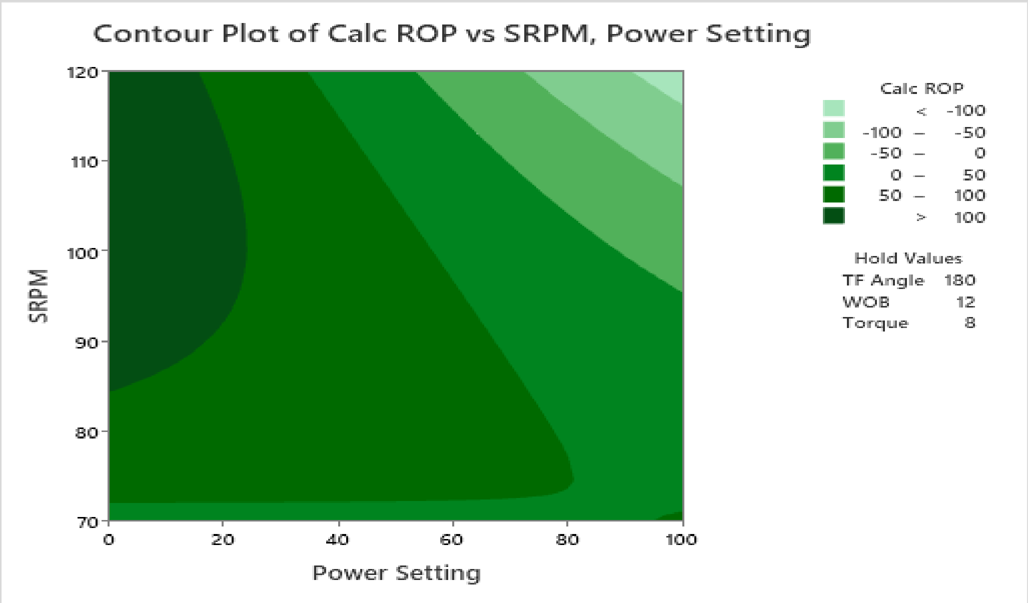

Figure 8: Response surface contour plot for interaction terms Power setting and SRPM

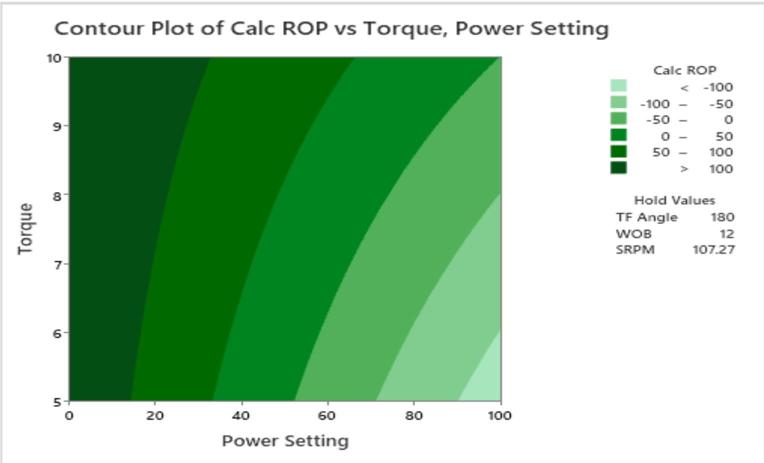

Figure 9: Response surface contour plot for interaction terms Power setting and Torque

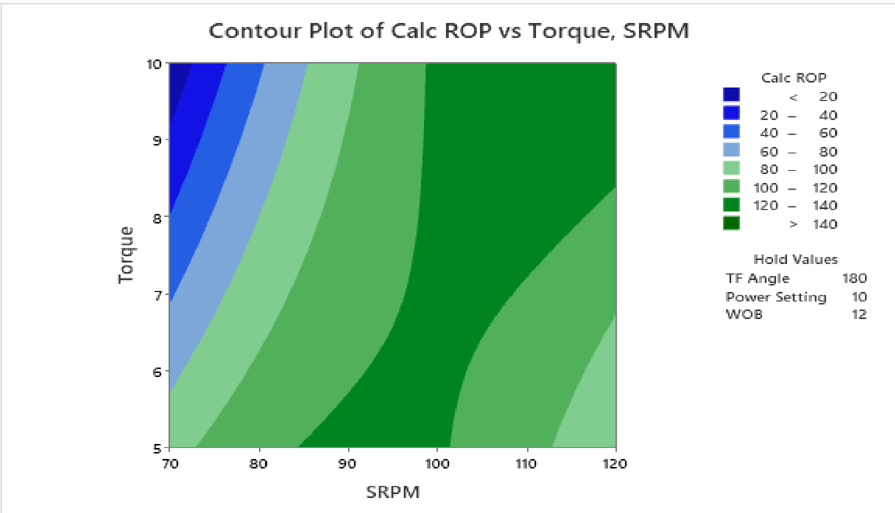

Figure 10: Response surface contour plot for interaction terms Torque and SRPM

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