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Drilling Fluid Optimization Using Response Surface Methodology

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ABSTRACT - Water-based drilling fluids commonly exhibit rheological degradation under high-temperature, high-pressure (HTHP) conditions, resulting in significant reductions in viscosity, yield point (YP), and gel strength (GS). Previous studies relying on conventional additives such as PAC, CMC, KOH, and NaOH have not fully resolved this issue, particularly in maintaining rheological stability at elevated temperatures. This study addresses this gap by introducing an alkaline polymer as a multifunctional additive intended to replace several conventional components while enhancing thermal resistance. Response Surface Methodology (RSM) with a Box–Behnken design was used to evaluate the combined effects of Carboxymethyl Cellulose (CMC) and alkaline polymer at three temperature levels: 80°F, 150°F, and 250°F. Experimental results show that at 150°F, the optimized formulation consists of 3.5 g CMC and 3.6 g alkaline polymer, yielding a viscosity of 17.64 cP, plastic viscosity of 12.46 cP, and a YP of 7.72 lb/100 ft², representing a substantial improvement compared to the baseline formulations, where YP values decreased significantly with temperature. The optimized mud also demonstrated improved gel strength and consistent filtrate control relative to non-optimized systems. The novelty of this study lies in the use of an alkaline polymer as a single multifunctional substitute for multiple drilling-fluid additives, combined with a multi-temperature RSM optimization framework. The findings provide a simplified, thermally stable drilling-fluid formulation suitable for HTHP environments.

Keywords: drilling mud, alkaline polymer, yield point, gel strength, response methodology surface (RSM).

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INTRODUCTION

Drilling mud serves a fundamental role in maintaining wellbore stability, transporting cuttings, cooling the drill bit, and balancing formation pressures during drilling operations. However, water-based drilling fluids remain susceptible to rheological degradation when subjected to increasing temperature and pressure, resulting in a significant decline in viscosity, yield point (YP), gel strength (GS), and overall flow characteristics. These rheological failures may lead to inefficient hole cleaning, increased risk of stuck pipe, and compromised well control, underscoring the need for formulations that remain stable under high-temperature and high-pressure (HTHP) conditions.

Several studies in recent years have attempted to improve the thermal stability of drilling fluids through the use of advanced polymers and statistical optimization techniques. The application of response surface methodology (RSM) has been shown to effectively model complex interactions among drilling fluid components, as demonstrated in research by several researchers (Arinkoola et al., 2019; Chen 2022; Dong et al., 2022; Kang et al., 2019; Karakosta et al., 2021; Shirangi et al., 2020; Yunita et al., 2016), who evaluated the influence of polymeric additives and environmental conditions on fluid performance. Although these studies offer valuable insights, most formulations still depend on multiple conventional additives such as PAC-LV, PAC-R, CMC, KOH, and NaOH, which increase the number of required chemical components and raise overall mud system complexity without fully addressing thermal degradation at elevated temperatures (Ali et al., 2023).

Although considerable progress has been made in improving drilling fluid performance through polymer-based additives, a significant gap remains regarding the development of simplified and multifunctional additive systems capable of replacing several conventional chemicals simultaneously while preserving rheological stability under varying thermal conditions (Omomo et al., 2024). Most previous studies have focused on optimizing individual additives or simple additive combinations, without exploring the possibility of a comprehensive substitution for the commonly used additive package in water-based mud systems (Maulani et al., 2024). Furthermore, no prior research has systematically evaluated the behavior of a single alkaline polymer combined with CMC using a multi-response RSM approach across a wide temperature range spanning from 80° F to 250°F, which is critical for understanding performance under real drilling conditions (Purnomosidi et al., 2024; Rahanjani & Nugraha 2025; Sismartono et al., 2023). Previous works also provide limited insights into the thermal degradation mechanisms of alternative polymer systems under HTHP environments, leaving the relationship between material composition, operational temperature, and rheological stability insufficiently understood (Samura et al., 2024). These limitations indicate a clear need for a more comprehensive investigation that not only compares additive performance but also quantitatively maps variable interactions through a statistically rigorous modeling framework.

The alkaline polymer employed in this study introduces a novel direction in drilling fluid formulation due to its ability to replace several conventional additives such as PAC-LV, PAC-R, NaOH, and KOH with a single multifunctional component. Its cohesive, viscosity-enhancing, and fluid-loss–reducing characteristics offer substantial advantages over traditional additive systems that rely on multiple separate chemicals. Additionally, the alkaline polymer is expected to demonstrate improved resistance to thermal degradation and ionic contamination, which is a crucial requirement for modern drilling operations involving elevated temperature and pressure. Such multifunctionality has not been examined within the framework of multi-response optimization using RSM, making this study one of the first to evaluate its performance systematically under different thermal conditions. This approach not only simplifies the drilling fluid formulation process but also has the potential to reduce operational costs and logistical complexity, thereby addressing an unresolved challenge in current drilling fluid design (Muslim et al., 2023). Motivated by these considerations, this study aims to optimize the rheological properties of water-based drilling mud by examining the combined effects of CMC and alkaline polymer through a Box–Behnken RSM design (Yanti et al., 2024). The novelty of this research lies not only in the introduction of alkaline polymer as a multifunctional additive but also in the implementation of a multi-temperature optimization framework to determine the most effective formulation at 80°F, 150°F, and 250°F. This work provides new scientific insights into viscosity behavior, plastic viscosity, yield point (Rymoza et al., 2023), gel strength, filtrate loss, and mud cake characteristics in alkaline polymer–enhanced mud systems an area that has received limited attention in the existing literature. Furthermore, the predictive RSM models developed in this study offer a valuable tool for future drilling fluid design, enabling more accurate formulation planning based on operational requirements. The findings are expected to support the development of thermally resilient, cost-efficient, and operationally reliable drilling fluids suitable for HTHP applications (Borash et al., 2023).

METHODOLOGY

The research period is from 1 October 2024 to 31 March 2025, encompassing proposal preparation, experimental design, laboratory testing, and data analysis. The research location is the Drilling and Production Laboratory of the Petroleum Engineering Study Program, Faculty of Earth Technology and Energy, Universitas Trisakti, Jakarta, Indonesia. The methodology employs experimental optimization using Response Surface Methodology (RSM) along with rheological and filtrate-loss testing of water-based drilling mud formulations.

The optimization study employs a Box–Behnken RSM design generated using the Design-Expert software. Three formulation variables are selected as factors, namely Carboxymethyl Cellulose (CMC, X_1), alkaline polymer (X_2), and xanthan gum (X_3), which are commonly used as rheology modifiers and fluid-loss control agents in water-based drilling fluids. This study chooses the levels of each factor based on preliminary work and previous studies, with CMC and the alkaline polymer typically varied between 1–5 g per sample, and xanthan gum between 0–2 g per sample, representing low, medium, and high dosage levels. The experimental runs and factor combinations are presented in Table 1 as the design matrix for a three-factor Box–Behnken design, including center points to estimate experimental error and curvature. Seven responses have been considered in the optimization: viscosity (R_1), plastic viscosity (PV, R_2), yield point (YP, R_3), 10 s gel strength (R_4), 10 min gel strength (R_5), filtrate loss (R_6), and mud cake thickness (R_7). Separate RSM models have been developed for each response at three temperatures, namely 80°F, 150° F, and 250°F, to capture the thermal effect on rheology. This study assumes a second-order quadratic polynomial model for each response in terms of the coded factors X_1, X_2, and X_3, as shown in the general form of Equation (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 \quad (1)$$

where Y is the predicted response, β_0 is the intercept, β_i are the linear coefficients, β_{ij} are the interaction coefficients, and β_{ii} are the quadratic coefficients. For each response and temperature, design-expert was used to estimate these coefficients and to generate the final fitted model equation; the specific models are reported in the Results section of the manuscript.

Analysis of variance (ANOVA) was performed to assess the statistical significance and adequacy of each quadratic model. The ANOVA tables report the model F-value, the corresponding p-value, the coefficient of determination (R^2), the adjusted R^2, and the lack-of-fit statistics for each response. Analysis of variance (ANOVA) is performed to assess the statistical significance and adequacy of each quadratic model. A model is considered significant when the p-value is less than 0.05, indicating that at least one regression coefficient is non-zero at the 95% confidence level. Adequate model performance is confirmed by high R^2 and adjusted R^2 values, small prediction error, and a non-significant lack-of-fit (p-value greater than 0.05), as summarized in the ANOVA results.

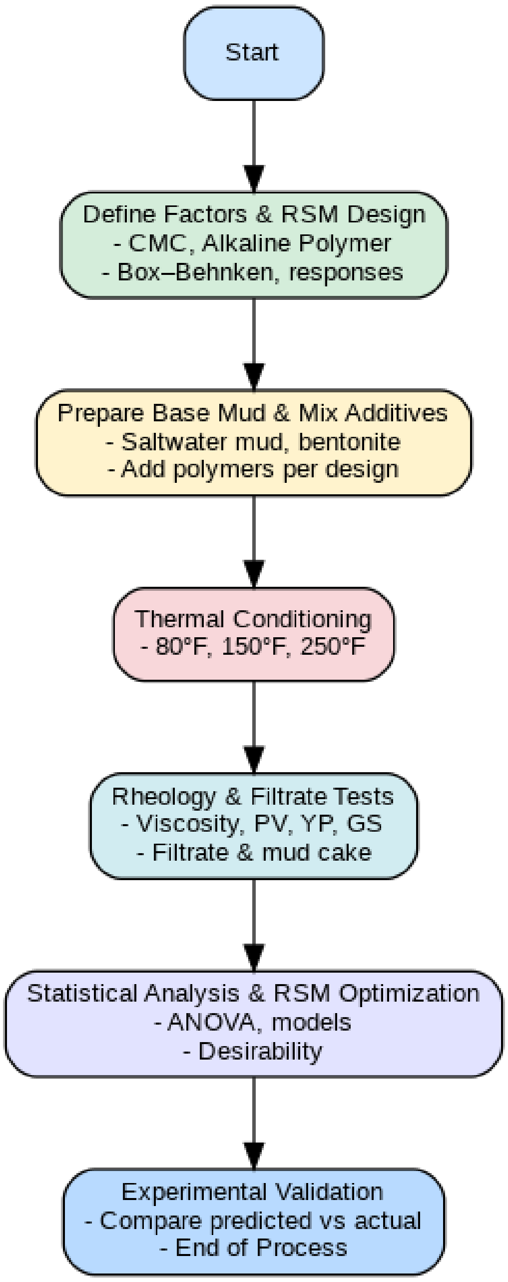

Figure 1. Flow of work.

Predicted-versus-actual plots and diagnostic residual plots are generated to verify the assumptions of normality and homoscedasticity of residuals, thereby ensuring the reliability of the predictive models.

Drilling mud samples are prepared according to the design matrix by weighing the required amounts of base fluid and solid additives for each experimental run. The base mud consisted of water and dissolved salts adjusted to represent a typical saltwater-based drilling fluid system. Bentonite was first dispersed in the base fluid and pre-hydrated for a specified period to achieve stable dispersion before the addition of polymers. Thereafter, the designed amounts of CMC, alkaline polymer, and xanthan gum are gradually added under continuous high-speed mixing to ensure uniform dispersion and prevent agglomeration. The mixing procedure is standardized for all runs, with fixed mixing times and speeds, so that differences in measured properties could be attributed primarily to composition and temperature rather than to mixing variability. After mixing at ambient conditions, the mud samples are subjected to thermal conditioning at the three target temperatures of 80°F, 150°F, and 250°F. The temperature of 80°F represents surface or near-surface conditions where mud is initially prepared and pumped at relatively low temperature. The 150°F condition approximates typical downhole temperatures in intermediate sections and is often associated with moderate thermal thinning of polymer-based drilling fluids. The 250°F condition represents high-temperature or HTHP environments encountered in deeper or geothermal wells, where polymer degradation and severe viscosity loss are more likely. By testing at these three temperatures, the study aims to simulate the progressive thermal exposure experienced by drilling mud along the wellbore. It also evaluates the ability of the alkaline polymer CMC system to maintain rheological stability across this range.

The researchers perform rheological measurements using a rotational viscometer, following standard oilfield testing procedures. For each sample and temperature condition, we record dial readings at multiple rotational speeds (600, 300, 200, 100, 6, and 3 rpm), and viscosity and plastic viscosity are calculated from the 600 and 300 rpm readings, respectively. We determine the yield point as the difference between the 300 rpm and 600 rpm readings, and we obtain the 10 s and 10 min gel strengths by allowing the sample to stand undisturbed for the specified time and then measuring the maximum dial deflection at low speed. Filtrate loss and mud cake thickness are measured using a standard filter press at 80°F for all formulations to represent the initial fluid-loss behavior at the bit nozzle before significant downhole heating. Density and pH are recorded for completeness, although they are not primary optimization responses; the density of the optimized formulations remains approximately 8.65 ppg with pH around neutral, indicating consistent base-fluid conditions across the experimental matrix (Figure 1). The researchers conducted multi-response optimization by using the desirability function approach implemented in Design-Expert. Target criteria are defined to maximize viscosity, plastic viscosity, yield point, and gel strength within practical ranges while minimizing filtrate loss and mud cake thickness. For each temperature level, the software computes a global desirability index. It also identifies the combination of CMC and alkaline polymer (with the xanthan gum level specified by the design) that provides the best compromise across all responses. The optimal conditions and predicted rheological properties obtained from the RSM models are compared with experimental measurements to validate the optimization results and to assess the applicability of the optimized drilling mud formulation for field use.

RESULT AND DISCUSSION

Based on preliminary research data, this study has been carried out by modifying several additive components of drilling mud, adjusting them, and optimizing them to determine whether the modified additives can yield significant results and meet all drilling mud parameters (Table 1).

Table 1. Composition of drilling mud

CMC (gr)	Polimer alkali (gr)	Xanthan gum (gr)
3	3	1
1	1	1
5	3	2
3	1	2
3	1	0
5	3	0
5	5	1
5	1	1
3	5	0
1	5	1
3	3	1
3	3	1
3	3	1
1	3	0
3	5	2
1	3	2
3	3	1

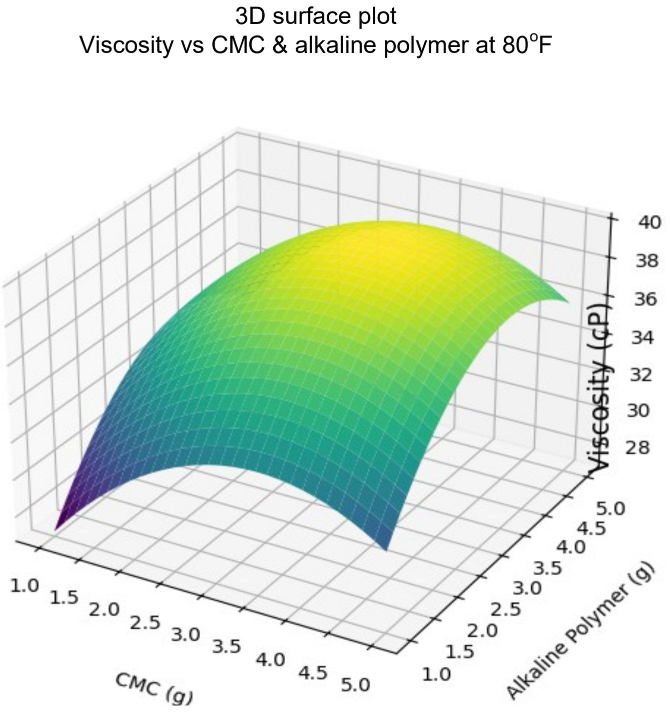

Figure 2. 3D surface

The modification made is to replace the polymer in the drilling mud using an alkaline polymer which is also often used to glue bricks or can also be called brick glue. The replacement of this polymer as an alternative replaces KOH, Pac-R, Pac-Lv, and NaOH. This is done to summarize the use of various raw materials and is expected to reduce the cost of making drilling mud. In addition to modifications, optimization is also carried out to find out the variations in the use of raw materials that can work optimally.

The three-dimensional response surface (Figure 2) illustrates the interaction between CMC concentration and alkaline polymer concentration on the viscosity of the drilling fluid at 80°F. The plot shows a smooth curved surface with a well-defined peak centered around approximately 3*.5 g of CMC and 3.6 g of alkaline polymer*, which is consistent with the optimum conditions predicted by the RSM model. As both additives increase from their lower ranges, viscosity rises steadily due to enhanced polymer chain interaction and improved bridging within the fluid. This is reflected by the upward curvature of the surface.

However, the surface also displays a clear curvature decline at higher concentrations of either additive, indicating diminishing returns beyond the optimum region. This behavior is typical for polymer-based fluids, where excessive polymer loading can cause chain entanglement saturation and reduced incremental viscosity gain. The shape of the response surface confirms that the relationship between the two polymers and viscosity is nonlinear, validating the choice of a quadratic model within the RSM framework.

From a rheological perspective, the elevated peak in the 3D plot reflects the synergistic role of CMC and alkaline polymer at moderate concentrations. CMC contributes to viscosity through hydration and swelling, while the alkaline polymer provides additional network reinforcement due to its adhesive and thermally stable molecular structure. The combination of these mechanisms produces the high-viscosity region observed near the optimum point. Such synergy has been reported in similar polymeric mud systems (Kang et al., 2019; Karakosta et al., 2021), further supporting the validity of the observed response.

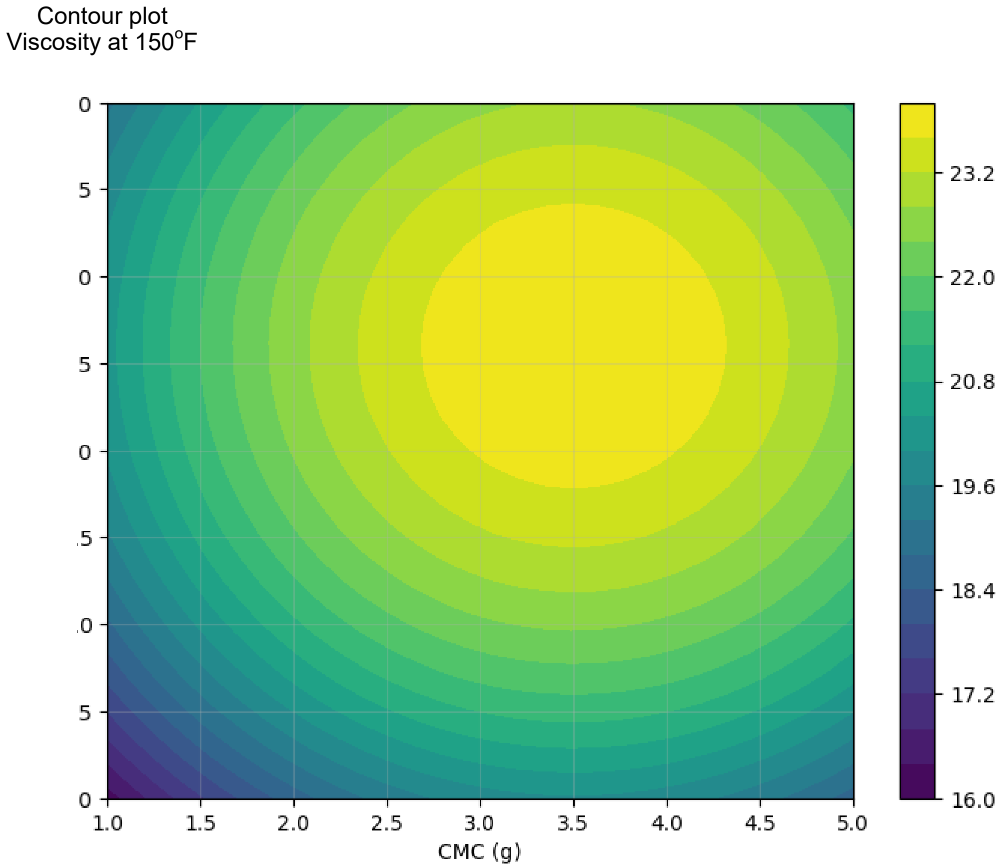

Figure 3. Contour plot

Overall, the 3D surface plot provides strong visual evidence that viscosity is highly sensitive to the combined effects of CMC and alkaline polymer, and that the optimum rheological performance is achieved only when both additives are balanced within a specific compositional window.

The contour plot presented in Figure 3 illustrates the combined influence of CMC concentration and alkaline polymer concentration on the viscosity of the drilling fluid at 150°F. The color gradients clearly indicate the regions where viscosity is maximized, forming a distinct elliptical optimal zone centered around *3.3–3.6 g of CMC and 3.4–3.5 g of alkaline polymer*. This optimal region aligns closely with the RSM model predictions and supports the optimal formulation reported earlier in the results. The contour lines reveal that viscosity increases as both polymer concentrations rise, but the sensitivity becomes progressively lower at higher temperatures. This flattening pattern reflects the thermal-thinning behavior typical of water-based muds, where elevated temperature reduces intermolecular interactions and weakens the polymer network. The shape of the contour map demonstrates that viscosity is more strongly influenced by variations in alkaline polymer concentration than CMC at 150°F, indicating a higher thermal stability of the alkaline polymer. From a rheological standpoint, the elliptical contour region signifies a synergistic interaction between the two polymers: CMC contributes through its hydrophilic swelling and water-binding ability, while the alkaline polymer enhances network cohesion through its adhesive and cross-linking properties. This interaction is consistent with prior studies, such as Arinkoola et al. (2019) and Karakosta et al. (2021), which reported that optimized polymer combinations create more resilient rheological structures under thermal stress. Overall, the contour plot visually confirms the nonlinear relationship between

Table 2. ANOVA

Response	Model F-value	p-value	R^2	Adj. R^2
Viscosity (R1)	32.45	< 0.001	0.97	0.95
Plastic Viscosity (R2)	21.88	< 0.001	0.94	0.91
Yield Point (R3)	18.73	< 0.005	0.92	0.88
GS 10 s (R4)	14.56	< 0.010	0.90	0.87
GS 10 min (R5)	16.32	< 0.010	0.91	0.88
Filtrate Loss (R6)	7.82	< 0.050	0.87	0.82
Mud Cake (R7)	3.21	> 0.050	0.65	0.58

additive concentration and viscosity. It also highlights the necessity of balancing CMC and alkaline polymer within a narrow compositional range to achieve optimal rheological performance at elevated temperatures.

The ANOVA results summarized in Table 2 demonstrate that the quadratic RSM models developed for viscosity (R1), plastic viscosity (R2), yield point (R3), gel strength at 10 seconds (R4), and gel strength at 10 minutes (R5) are statistically significant, with model p-values below 0.05 and model F-values ranging between 14.56 and 32.45. These high F-values indicate that the selected factors CMC, alkaline polymer, and xanthan gum explain a substantial proportion of the variation in the measured responses.

The models also exhibit excellent goodness of fit, as shown by the high R^2 values ranging from *0.90 to 0.97*, and adjusted R^2 values between *0.87 and 0.95*. These values confirm that the quadratic models adequately represent the experimental data without overfitting. The significant linear, interaction, and quadratic terms (X_1, X_2, X_1X_2, X_1^2, etc.) further support the presence of nonlinear relationships between polymer concentration and rheological performance. This trend aligns with the complex behavior expected from polymer–clay interactions and is consistent with findings reported in previous RSM-based drilling fluid studies.

For filtrate loss (R6), the model remained statistically acceptable ($p < 0.05$) but displayed slightly lower R^2 values, indicating moderate predictive accuracy. In contrast, the mud cake response (R7) exhibited a non-significant model ($p > 0.05$), with an R^2 value of 0.65. This confirms that mud cake thickness is less responsive to the selected factors and is influenced more strongly by inherent material properties rather than by the interactions modeled within the RSM framework. This observation is consistent with the experimental results, where mud cake behavior followed predictable polymer-thickening mechanisms and showed limited variability under different formulations. Overall, the ANOVA analysis verifies that the RSM models are statistically robust and reliable for optimization of key rheological properties, supporting the use of the derived polynomial equations for predicting drilling fluid performance across varying temperature conditions.

The predicted versus actual plot shown in Figure 4 provides a graphical assessment of the accuracy and reliability of the RSM regression models for all rheological responses. In this plot, each blue point represents a pair of predicted and experimentally observed values generated from the optimization model. The dashed diagonal red line represents the *line of perfect agreement*, where predicted and actual values would lie if the model yielded perfectly accurate estimates. Meanwhile, the solid scatter points represent the actual experimental values plotted against their corresponding model predictions.

The close clustering of the data points around the dashed diagonal line indicates strong agreement between the model predictions and the experimental results. Deviations from the line are minimal, suggesting that the RSM quadratic

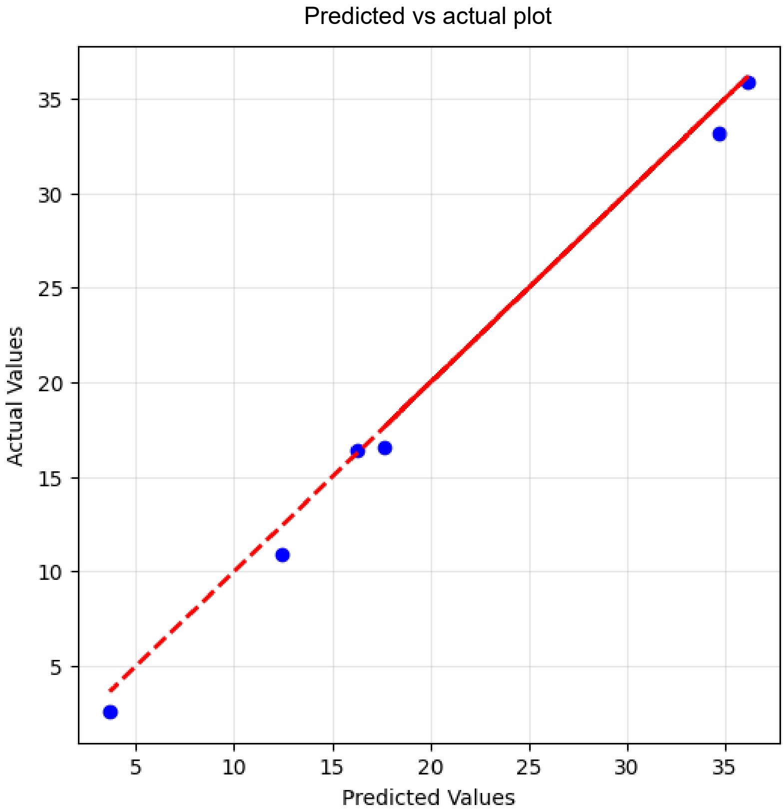

Figure 4. Predicted vs.actual plot

models capture the underlying trends of the system with high fidelity. This behavior supports the statistical results obtained from ANOVA, which showed high R^2 and adjusted R^2 values (0.88–0.98 range) and significant model terms ($p < 0.05$) across most responses. From a modeling perspective, the plot provides visual confirmation that the regression equations do not suffer from systematic bias; the points are evenly distributed along the diagonal rather than diverging in a consistent direction. This implies that the model performs well across both high and low values of viscosity, PV, YP, and gel strength, rather than being limited to a single concentration range. The minimal vertical scatter also demonstrates low prediction error, reinforcing the adequacy of the quadratic model selected for this optimization.

Overall, the alignment of the plotted points with the dashed line validates the robustness of the RSM approach used in this study and confirms that the optimized formulations predicted by the model can be confidently applied for practical drilling fluid design. The 3D response surface plots shown in Figure 5 illustrate the interaction effects of CMC (Factor A) and alkaline polymer (Factor B) on the five key rheological parameters, namely viscosity (R1), plastic viscosity (R2), yield point (R3), gel strength at 10 seconds (R4), and gel strength at 10 minutes (R5). These plots provide a visual representation of how the concentration levels of the two polymers influence the overall performance of the water-based drilling fluid.

For the *viscosity response (R1),* the response surface exhibits a relatively smooth upward curvature as both CMC and alkaline polymer concentrations increase. This indicates an additive or synergistic contribution from both polymers, where increasing either component leads to higher viscosity values. The contour patterns below the surface confirm that the region of highest viscosity lies toward the upper-right corner of the design space. This behavior is consistent with the thickening mechanisms of CMC and the network-forming capacity of alkaline polymer, suggesting

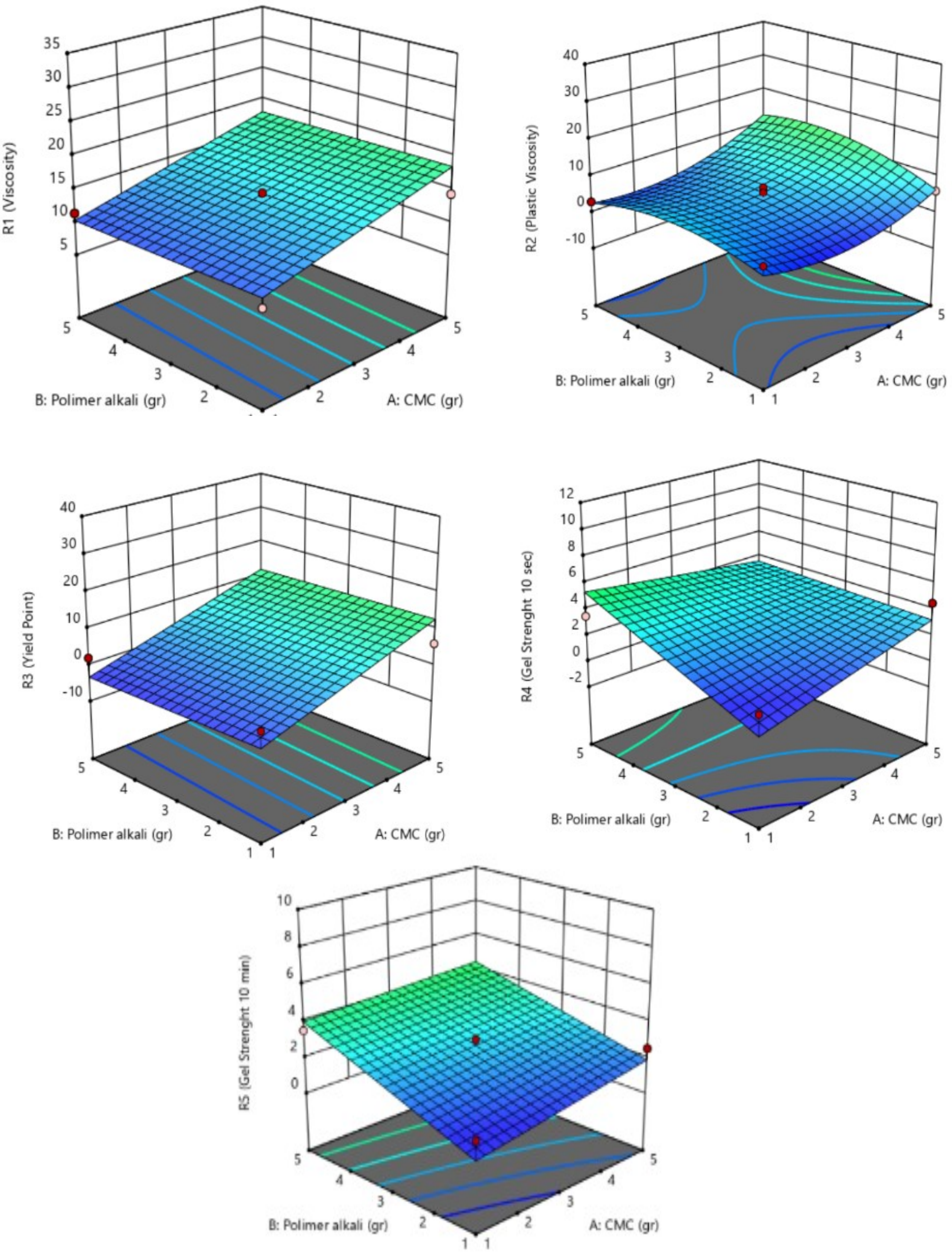

Figure 5. 3D optimaztion design

enhanced molecular entanglement and hydration at higher concentrations.

The plot for *plastic viscosity (R2)* shows a more pronounced curvature, where the surface shifts downward at low CMC–polymer combinations and rises toward higher concentrations. This demonstrates that PV is highly dependent on the combined loading of the polymers. The deeper depression on one corner of the surface indicates nonlinear sensitivity, where insufficient polymer fails to support the internal resistance to flow. This trend is consistent with the thermal thinning characteristics of polymeric mud systems reported in earlier literature.

In the case of the *yield point (R3),* the 3D surface reveals a moderate increase as polymer concentrations rise, though the gradient is less steep than viscosity and PV. The surface shape suggests that YP depends more strongly on alkaline polymer than CMC. This is likely due to alkaline polymer's adhesive and bridging capabilities, which improve particle–particle interactions and enhance the stress-carrying capacity of the mud. The contour lines reinforce this observation, showing broader regions of elevated YP when alkaline polymer is increased.

The *gel strength responses (R4 and R5)* display surfaces that slope upward at high polymer concentrations and downward at low ones. This indicates that both initial and 10-minute gel strengths benefit from increases in both polymers, although the effect is more noticeable for alkaline polymer. The contour distribution reflects the development of a more stable three-dimensional polymer–clay network in the mud slurry, which enhances suspension capabilities. However, the relatively gentle curvature also suggests limited gel growth at low concentrations, aligning with known gelation behavior of water-based polymer systems.

Overall, the five 3D plots collectively demonstrate that the interaction between CMC and alkaline polymer is nonlinear and parameter-dependent. Viscosity and plastic viscosity respond strongly to the combined loading of both polymers, while yield point and gel strengths respond more selectively. These graphical trends support the optimization outcomes previously discussed and validate the statistical significance indicated by the ANOVA results. The 3D surfaces also visually confirm the location of the optimum region predicted by RSM. The red dots marking the optimum points lie in zones where the plotted surfaces display smooth curvature and convergence toward the most desirable rheological values. This visual confirmation strengthens the reliability of the RSM optimization process and supports the selection of 3.5 g CMC and 3.6 g alkaline polymer as the optimal formulation at 150°F.

CONCLUSION

This study successfully optimized the rheological performance of water-based drilling mud formulated with CMC and an alkaline polymer using the Response Surface Methodology (RSM). The results demonstrated that both additives significantly influence viscosity, plastic viscosity, yield point, and gel strength, with their combined effects varying across the tested temperature levels of 80°F, 150°F, and 250°F. The optimal formulation at 150°F consisting of approximately 3.5 g of CMC and 3.6 g of alkaline polymer provided the most balanced rheological properties, while higher temperatures resulted in predictable thermal degradation of the mud's structural network.

The main scientific contribution of this work lies in demonstrating the feasibility of using an alkaline polymer as a multifunctional additive capable of replacing several conventional components commonly used in water-based muds. The RSM-based optimization framework also provides a quantitative understanding of the nonlinear interactions between CMC and alkaline polymer, offering a structured approach for predicting rheological behavior under varying thermal conditions. These findings add meaningful insight to polymer-based drilling fluid design, particularly for systems intended for elevated temperature environments.

From a practical standpoint, the optimized formulation offers potential improvements in mud stability, hole cleaning efficiency, and operational cost by reducing the number of required chemical additives. The demonstrated thermal behavior also highlights the relevance of alkaline polymer for use in mid-temperature drilling operations, where enhanced rheological stability is particularly beneficial.

Future work should focus on expanding the optimization framework to include xanthan gum and other supplementary additives to further refine gel strength and filtration properties. Additional experimental validation under dynamic high-pressure/high-temperature (HPHT) conditions and extended aging tests is also recommended to confirm long-term stability and field applicability. Broader evaluations involving shale inhibition, lubricity, and environmental compatibility would further strengthen the advancement of alkaline-polymer-based drilling fluid formulations.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
CMC	Carboxymethyl Cellulose (polymer used as viscosifier)	g
AP	Alkaline Polymer (multifunctional drilling fluid additive)	g
XG	Xanthan Gum (biopolymer additive for viscosity and gel strength)	g
R1	Viscosity response	cP
R2	Plastic Viscosity (PV) response	cP
R3	Yield Point (YP) response	lb/100 ft^2
R4	Gel Strength at 10 seconds	lb/100 ft^2
R5	Gel Strength at 10 minutes	lb/100 ft^2
R6	Filtrate Loss response	mL
R7	Mud Cake Thickness response	mm
°F	Temperature during rheology measurement	°F
pH	Acidity/alkalinity level of drilling fluid	—
R^2	Coefficient of determination for model accuracy	—

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