UNIVERSITI TEKNOLOGI MARA

The 11th International, Invention, Innovation & Design 2022

INDES 2022

Ushering in the Age of Endemic

THE 11TH INTERNATIONAL INNOVATION, INVENTION & DESIGN COMPETITION INDES 2022

EXTENDED ABSTRACTS BOOK

e ISSN 2756-8733

9 772756 873009

Perpustakaan Negara Malaysia Cataloguing in Publication Data

No e-ISSN: e-ISSN 2756-8733

Cover Design : Nazirul Mubin Mohd Nor
Typesetting : Wan Nurul Fatihah binti Wan Ismail

The 11th International Innovation, Invention and Design Competition 2022

Organised by

Office of Research, Industrial Linkages, Community & Alumni Networking (PJIM&A)
Universiti Teknologi MARA Perak Branch

and

Academy of Language Study
Universiti Teknologi MARA Perak Branch

SYNERGISTIC EFFECT OF POLYACRYLAMIDE (PAM) AND SILICA ON THE RHEOLOGICAL PERFORMANCE OF WATER-BASED DRILLING FLUID AT SPECIFIC TEMPERATURE

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ABSTRACT

The rheological performance of drilling fluid in bored pile operation is the most concerning issue for the geotechnical field. Usually, polymer is a common additive used in a bored pile operation as it works well in operational, environmental, and economic aspects. High molecular weight with good gelling behaviour polyacrylamide (PAM) were used in this study as it is eco-friendly, though it is temperature-sensitive during the drilling operation. Thus, the hybridisation of silica is required in PAM-based drilling fluid. The study investigated the effects of specific temperatures on PAM and modified PAM.

Keyword: *Polyacrylamide, Silica, rheological, viscosity*

1. INTRODUCTION

According to Davoodi et al. (2019), it was expected that the global drilling mud market would reach a value of 12.31 billion by 2019, attributed to its growth rate of 10.3%. Meanwhile, the performance of drilling fluid can affect the overall expenditure. Therefore, drilling fluid formulation is crucial to determine the efficiency of drilling operations, especially to cope with the difficulties related to bore pile stability, pH stability, and thermal stability. With this regard, there has been a special focus on the enhancement of conventional polymer with a potential dopant to overcome the difficulties aforementioned.

In a drilling system, the polymer is always utilized as a rheological modifier, filtration controller, and shale stabiliser. Two types of polymers can be employed in a drilling system: synthetic polymer, and natural polymer. Natural polymers, such as starch, carboxymethyl cellulose, and guar gum are commonly studied in drilling operation as it is low-cost and biodegradable. However, natural polymers have limitations, such as thermal and chemical stability as reported by several researchers (Mohammed, 2018; Nzenguet et al., 2018; Ramasamy & Amanullah, 2020). On the other hand, synthetic polymer garners attention in drilling formulation as it is capable to control the filtration loss and rheological performance of drilling. Many researchers suggested synthetic polymers to be hybridized with some drilling additives to contribute to better or comparable results as the commercial PAM (Davoodi et al., 2019). PAM is selected in this study because it is a commercial alternative to conventional bentonite in the drilling operation. Although it is eco-friendly and inexpensive, it has some

difficulties in terms of bored pile stability, thermal stability, soft toe issue, and others in the geotechnical field. In this study, silica was used to modify PAM to investigate the rheological performance between bare PAM and modified PAM under specific temperatures. Below is a schematic diagram for modifications of PAM.

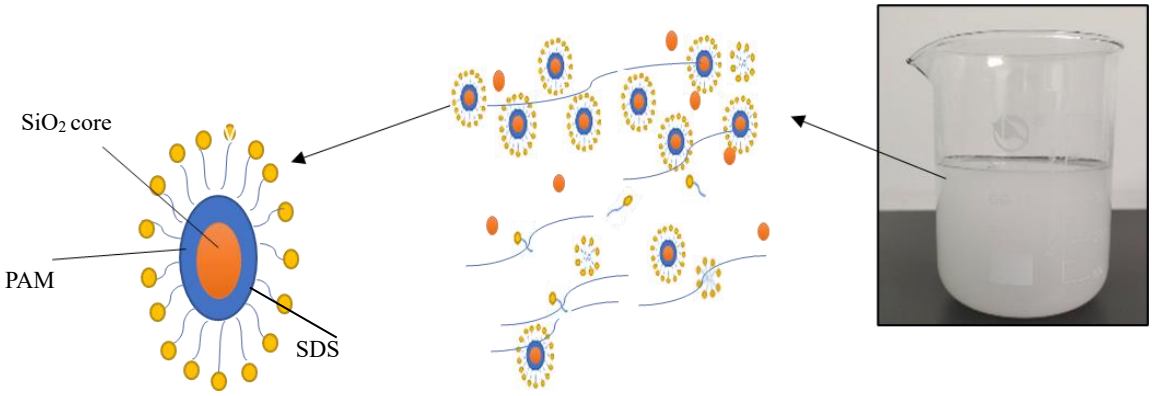

Figure 1 A Surface Modification of PAM (Redrawn from Kumar et al., 2020).

2. METHODOLOGY

PAM was blended with SiO_2 and sodium dodecyl sulphate (SDS) with a specific formulation to form a drilling fluid. Bare PAM was formulated with 1000 ppm PAM only, while modified PAM was formulated with 1000 ppm PAM and a specific concentration of SiO_2 and SDS. The rheological behaviour of drilling fluid was tested via a 6-speed rotational speed viscometer with specific temperatures (ambient (~25°C), and 80 °C). The result obtained compared the rheological profile between bare PAM and modified PAM at ambient temperature to validate the performance after its modification without heating. Subsequently, each product was heated before being tested with a viscometer to validate the thermal stability of each product.

3. FINDINGS

This study has proven that the apparent viscosity and plastic viscosity at ambient temperature (~25 °C) have reduced by 17.68 % and 25.80 %, respectively after modification of PAM using silica. After further heating, modified PAM shows a lower reduction of apparent viscosity and plastic viscosity when compared to bare PAM due to the heating degradation of the polymer, as detailed in Table 1. This means that the modified PAM can withstand thermal stability as its reduction is low.

In summary, the heating temperature can contribute to greater thermal energy of drilling fluid. Low reduction of rheological profile indicates excellent thermal stability of the drilling fluid. This can be explained by the degradation of the polymer. Bare PAM is less viscous than modified PAM after heating at a selected temperature because the binding energy of the bare PAM structure has been destroyed by heating. However, the modified PAM's structure was less damaged by heating as the structure of modified PAM consists of silica, which can

withstand high temperatures. Hence, this invention can be applied in drilling, excavations, and offshore operations.

Rheological aspect	PAM		Modified PAM	
	Ambient	80 °C	Ambient	80 °C
Apparent viscosity	13.12	8.95	10.80	9.75
Plastic viscosity	9.30	4.33	6.90	6.50

Table 1 The Rheological Profile between PAM and Modified PAM at Ambient Temperature and 80 °C.

The cost of modified PAM (RM 10-12/m^3) is cheaper than conventional bentonite (RM 18-25/m^3). Moreover, modified PAM requires less usage (0.5 – 2 kg/m^3) than conventional bentonite (25 – 50 kg/m^3). Next, PAM is a biodegradable material. Regarding health considerations, Silica and SDS pose no safety risks when employed in the modification of PAM, and their utilization is minimal, ranging from 0.1 to 0.5 wt%. The quantity of each component used in the formulation of modified PAM is significantly lower compared to conventional bentonite.

As the utilization of modified PAM at a range of 0.5 to 2 kg/m3 is minimal, the amount of drilling waste generated is reduced compared to conventional bentonite. Additionally, this results in fewer drilling issues such as borehole sticking and soft toe problems, as well as lower energy consumption due to decreased waste production and minimized drilling challenges. Hence, it has a stable rheological performance with good thermal stability as the thermal stability of modified PAM is better than bare PAM.

4. CONCLUSION

In terms of rheological aspect, modified PAM using silica is improved by around 17-25 %. A promising new formulation in drilling technology was studied. This can be further simulated in the pilot scale testing to further improve the technology.

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Tarikh : 20 Januari 2023

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