University of Miskolc

Development of Improved and Low-Cost Drilling Fluids and Cement Slurries in Oil Wells

New Scientific Achievements of PhD Thesis

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ABSTRACT

The aim of the thesis is to develop improved, cost effective and environmentally friendly water-based drilling fluid and cement slurry systems, which have superior rheological and filtration properties and are able to meet the requirements of the drilling operation, using fly ash and rice husk ash. An extensive experimental work was conducted to achieve the relevant goal. To this end, several different types of drilling fluid systems were designed using fly ash and rice husk ash, and their rheological and filtration properties were measured and analyzed at ambient and elevated temperature and potential of differential sticking tendency of the drilling fluid was studied considering the effect of different particle size of fly ash by grinding in a stirred media mill. Subsequently, the cement used in the cementing operation was initially partially replaced by fly ash and rice husk ash, then completely replaced by fly ash by forming geopolymer material to reduce or eliminate the amount of cement required. The performance of the relevant cement slurries has also been analyzed both under ambient conditions and increased temperature as well as when exposed to drilling mud contamination. On the other hand, effect of particle size of fly ash in both driling fluid, cement and geopolymer slurries was examined by conducting the with the different times of grinding process in a thumbling ball mill. In addition, hydraulic performance of the driling fluids formulated with fly ash depending on increasing temperature were calculated by considering parameters cutting carrying index, flow behaviour index and minimum annular velocity required to clean bottom of the well efficiently and rheological model analysis of the fluid was performed.

In conclusion, in the thesis, different types of drilling muds with improved hydraulic performance were developed with fly ash, which is a large amount of industrial waste, and rice husk ash, which also constitutes a large amount of agricultural waste at ambient and elevated temperature. Also, cement and geopolymer with improved rheological and filtration properties were designed by partially changing the amount of cement with fly ash and rice husk ash and completely replacing cement by fly ash, respectively. In addition, it was reveal that particle size of fly plays a great role on the rheological and filtration properties of driling fluid, cement and geopolymer slurries and Herschel-Bulkley model provides the estimation of the rheological parameters of drilling fluid with high accuracy. Consequently, an alternative method was developed for the recycling of fly ash and rice husk ash, as well as contributing to the reduction of drilling costs and environmental problems with the drilling mud and cement slurries developed in this thesis. Also, with the determined Herschel Bulkley model, more accurate assessment of well hydraulic could be achieved. Finally, it worths to be noted that the new comprehensive findings obtained in this thesis can be used as a guide for future studies.

Key words: Drilling fluid, cement, geopolymer, fly ash, rice husk ash, rheology, temperature

1. INTRODUCTION

Drilling fluid and cementing are indispensable components of drilling operations. Drilling fluid plays a vital role in the success of drilling operation and represent 15 to 18% of the total cost of oil well drilling and performs many critical tasks which are essential for efficient drilling process. The main functions fulfilled of drilling fluids include removing drilled cuttings from the hole, controlling subsurface pressure, cooling, and lubricating drilling tools, maintaining

the stability of wellbore, controlling corrosion and suspending drilled cuttings when drilling is paused. Cementing is also one of the most important processes during the drilling and completion of the wells. The primary function is preventing the fluid migrations between the formations and wells to provide full zonal isolation. On the other hand, production of cement needs a large amount of energy and at the end of the cement production a significant amount CO_2 releases to atmosphere. Severe operational difficulties and huge environmental issues as well as high remedy costs could be a result of losing zonal isolation and production of cement.

As it is well known fly ash and rice husk ash have been used at many industries as a useful product, although they are industrial and agriculture wastes, respectively. Research of thesis is to investigate their utilization in drilling industry, since the usage of fly ash and rice husk ash in drilling fluid and oil well cementing has not been studied comprehensively so far. To this end, an extensive experimental work was conducted and general work flow of the thesis was given in Fig.1.

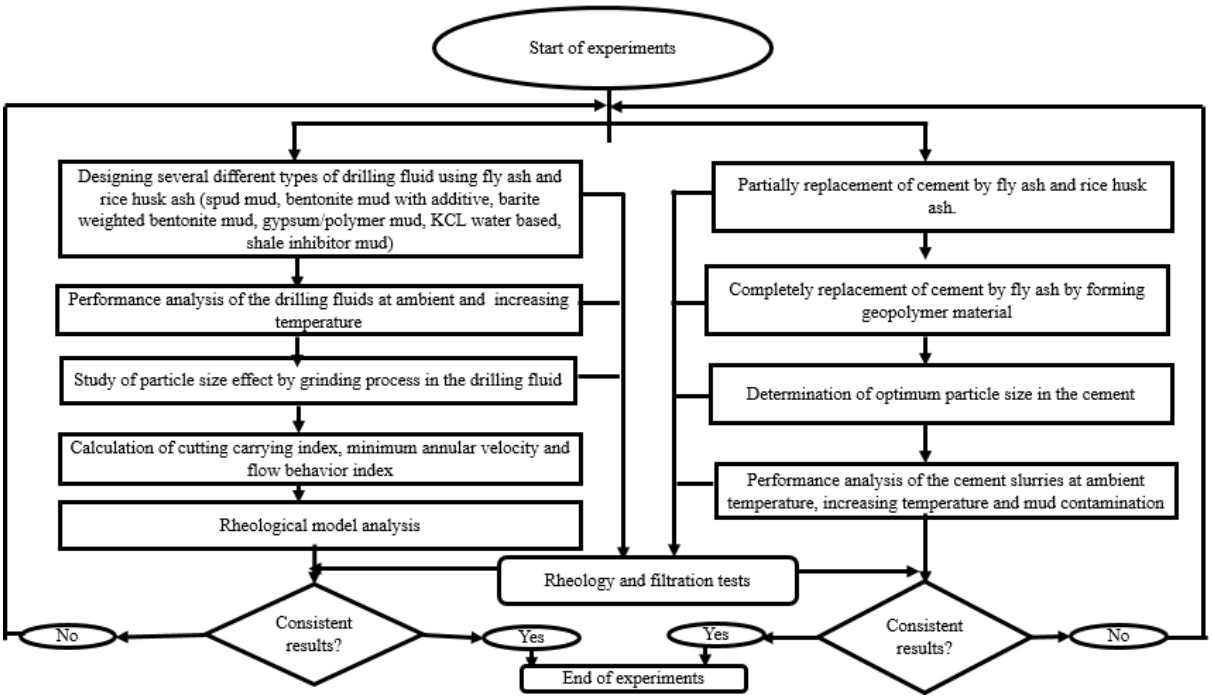

Figure 1. General work flow of the thesis

2. NEW SCIENTIFIC ACHIEVEMENTS

In this section, new scientific results obtained as a result of experimental study and analysis were presented. Theses were listed in the results section in accordance with the order.

2.1 Thesis 1

In this thesis, a gypsum/polymer type drilling fluid system blended with 3.0 wt% content of BFA was developed. This developed mud system exhibited superior rheological and filtration properties compared to reference fluid not composed of fly ash. Results shows adding 3.0 wt% concentration of BFA increased the apparent viscosity, plastic viscosity, yield point and gel strengths (10 seconds and 10 minutes) by 23%, 28%, 9% and 25%, respectively. Filtration test also indicated the fluid loss volume decreased by 23% and mud cake thickness decreased by 75% with addition of 3 wt% concentration of BFA.

Furthermore, based on results, it was proved that type of fly ash plays a crucial role on the properties of gypsum/polymer drilling fluid. While adding the LFA at the same concentration (3.0 wt%) increased the apparent viscosity, plastic viscosity and gel strength by 12%, 21% and 25%, respectively, yield point decreased by 9% and resulted in a reduction in fluid loss by 10% and an increase in mud cake thickness by 150%. Rheological and filtration properties of gypsum/polymer mud formulated with BFA and LFA at the increasin concentration was given in Fig.2. Finally, from this thesis it was concluded that BFA is a promising additive in the usage of gypsum/polymer mud and it would be a welcome development when it was interpreted in proper levels.

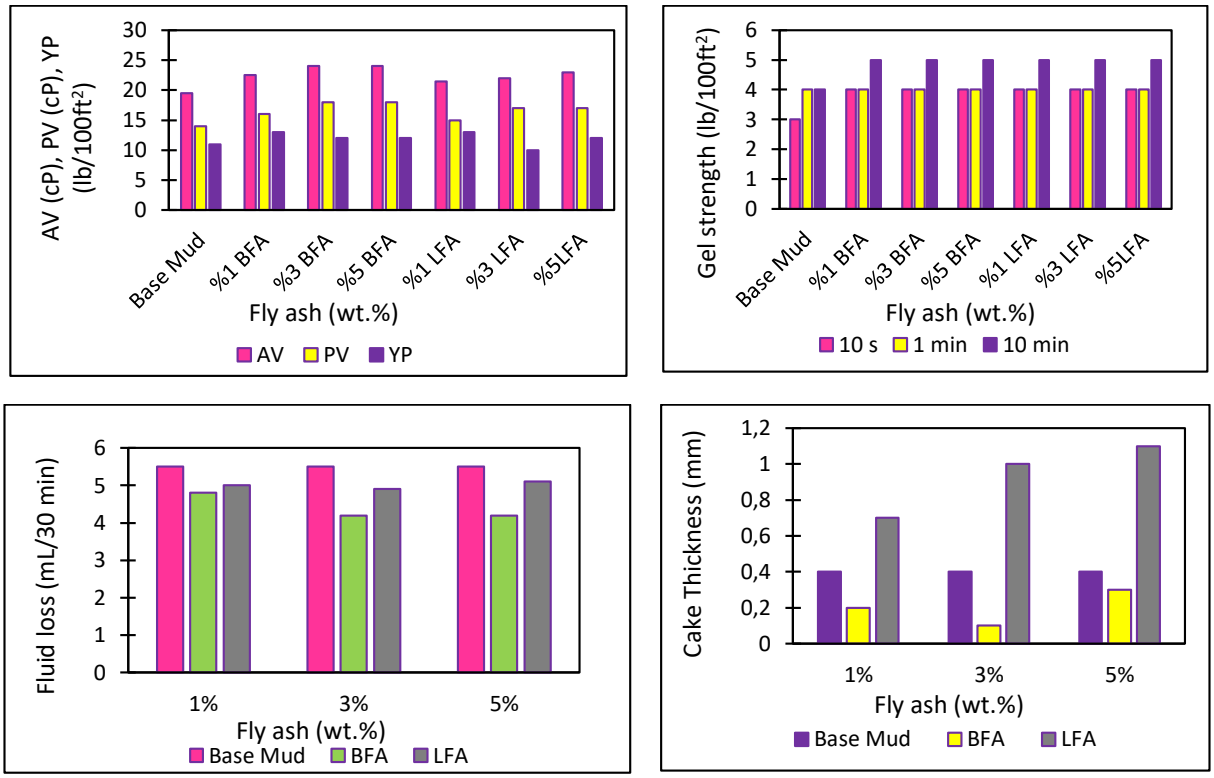

Figure 2. Effect of fly ash type and concentration on the rheological and filtration properties of gypsum/polymer drilling fluid

2.2. Thesis 2

In this thesis, a novel drilling fluid system with the enhanced filtration properies was designed based on spud mud. Developed spud mud incorporated with 7 wt% concentration of BFA exhibited improved filtration properties as well as gel strength without significant variation on apparent viscosity, plastic viscosity and yield point compared to the reference fluid without fly ash. With the forming developed mud system API standard fluid loss and thixotopy of the reference fluid decreased by 22% and 9%, respectively. This developed mud system with BFA could be considered as an alternative mud system to conventional mud for mitigation formation damage of water-based bentonite muds.

Moreover, from the thesis, it was proved that type of fly ash have a great effect on the properties of spud mud. Although the use of LFA improves the rheology of the fluid, it degrades filtration properties and filter cake thickness dramatically. Rheological and filtration properties of gypsum/polymer mud formulated with BFA and LFA at the increasin concentration was given in Fig.3.

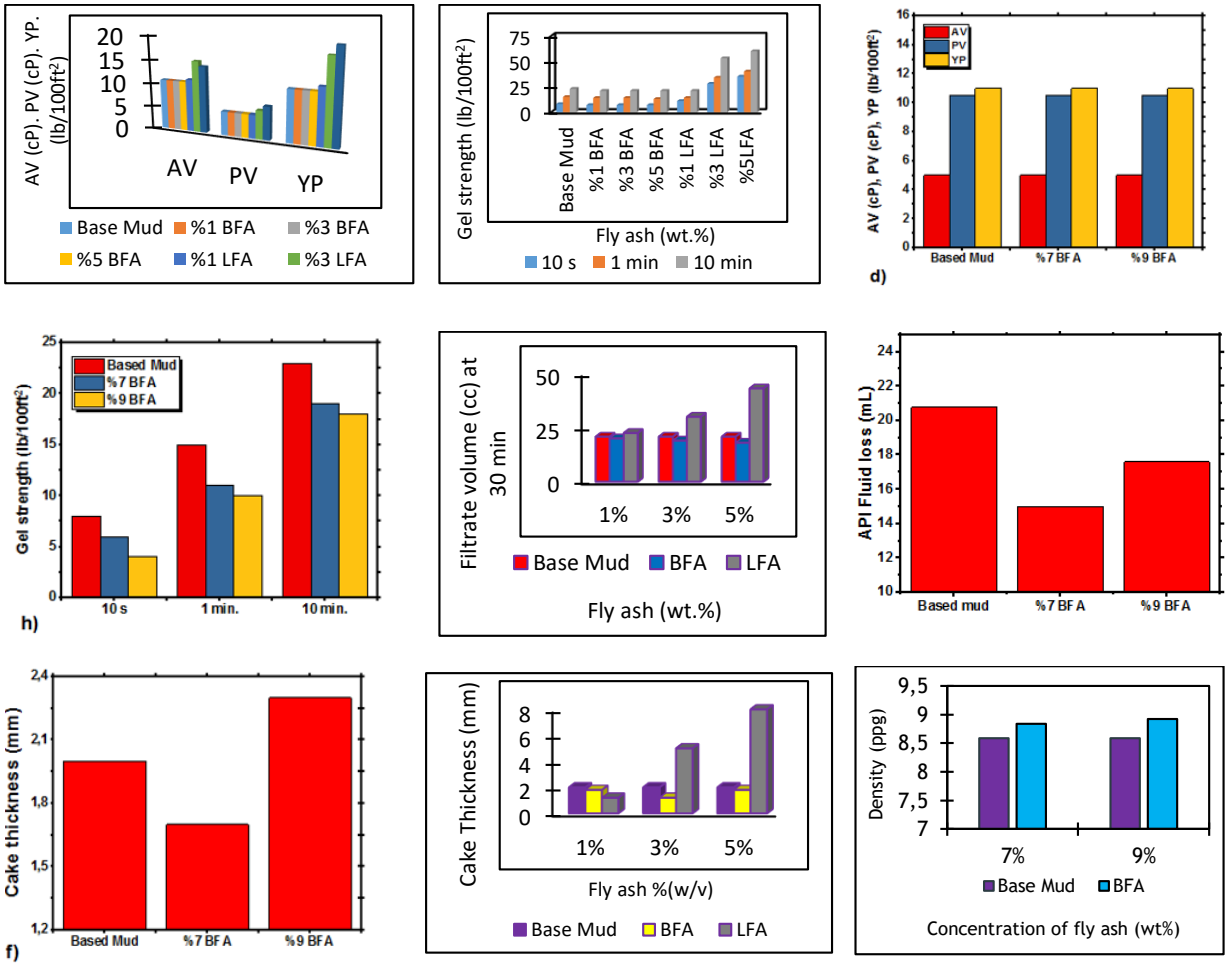

Figure 3. Effect of fly ash type and concentration on the rheological and filtration properties of spud mud

2.3. Thesis 3

In the thesis, effect of grinding of fly ash on the properties of water based driiling fluid was investigated at ambient temperature. Based on the evaluation of results, it was proved that while grinding time of fly ash have no effect on the rheology of shale inhibitor mud, it exhibited a variation on the filtration. shale inhibitor mud incorporated with 9 wt% concentration of sieved fly ash whose a median particle size of 67.89 µm yielded greater apparent viscosity, plastic viscosity, yield point as well as 10 seconds, 1 minute and 10 minutes gel strength than those of shale inhibitor mud blended with ground fly ashes for 30 minutes whose median particle size of fly ash is 18.25 µm, 60 minutes whose mean particle size of fly ash is 13.75 µm and 120 minutes whose median particle size of fly ash is 9.38 µm at the constant concentration. On the other hand, it was reveal that while fluid loss of the fluid increased, mud cake of the fluid decreased with the increasing grinding time. Shale inhibitor mud incorporated with 9 wt% concentration of sieved fly ash showed lower fluid loss and thinner mud cake than those of shale inhibitor mud blended with the ground fly ashes. Fig.4 shows rheological and filtration properties of shale inhibitor mud with different grinding time of fly ash and unground fly ash.

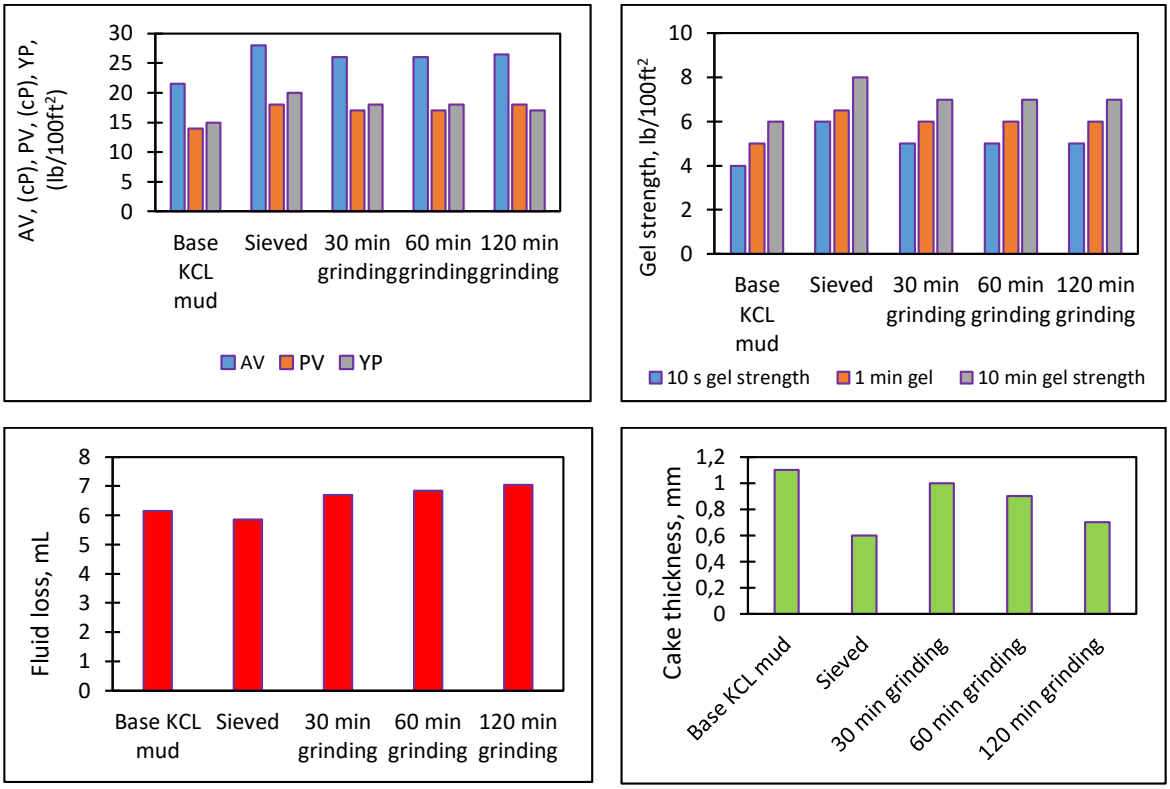

Figure 4. Rheological and filtration properties of shale inhibitor mud with different grinding time of fly ash and unground fly ash

2.4. Thesis 4

In the thesis, two different inhibitive drilling fluid system were developed based on KCl water based mud and shale inhibitor mud with fly ash and rice husk ash considering the rheological and filtration properties.

Formulation of KCl water based mud with 9 wt% concentration of fly ash resulted in an increase in yield point by 27%, in apparent viscosity 25% and in plastic viscosity 21%. On the other hand, formulation of shale inhibitor mud with 12.5 wt% concentration of 100 micron sieved fly ash also resulted in an increase in AV, PV and YP by approximately 35%, 29% and 47%. This mud system reduced the fluid loss of the mud by 10% and the mud cake thickness by 54%.

Developed shale inhibitor mud with 4 wt% concentration of rice husk ash provides an increase in in apparent viscosity by 19%, in plastic viscosity 14% and in yield point by 27%. Moreover, the mud systems decreased the fluid loss and mud cake thickness of the reference fluid by 12% and 63%, respectively.

Developed cost effective mud systems yields an improvement on the performance of drilling operation by increasing cutting carrying capacity, reducing formation damage and the possibility of stuck pipe and associated challenges. Fig.5 shows rheological and filtration properties of shale inhibitor mud and KCI water based mud with fly ash.

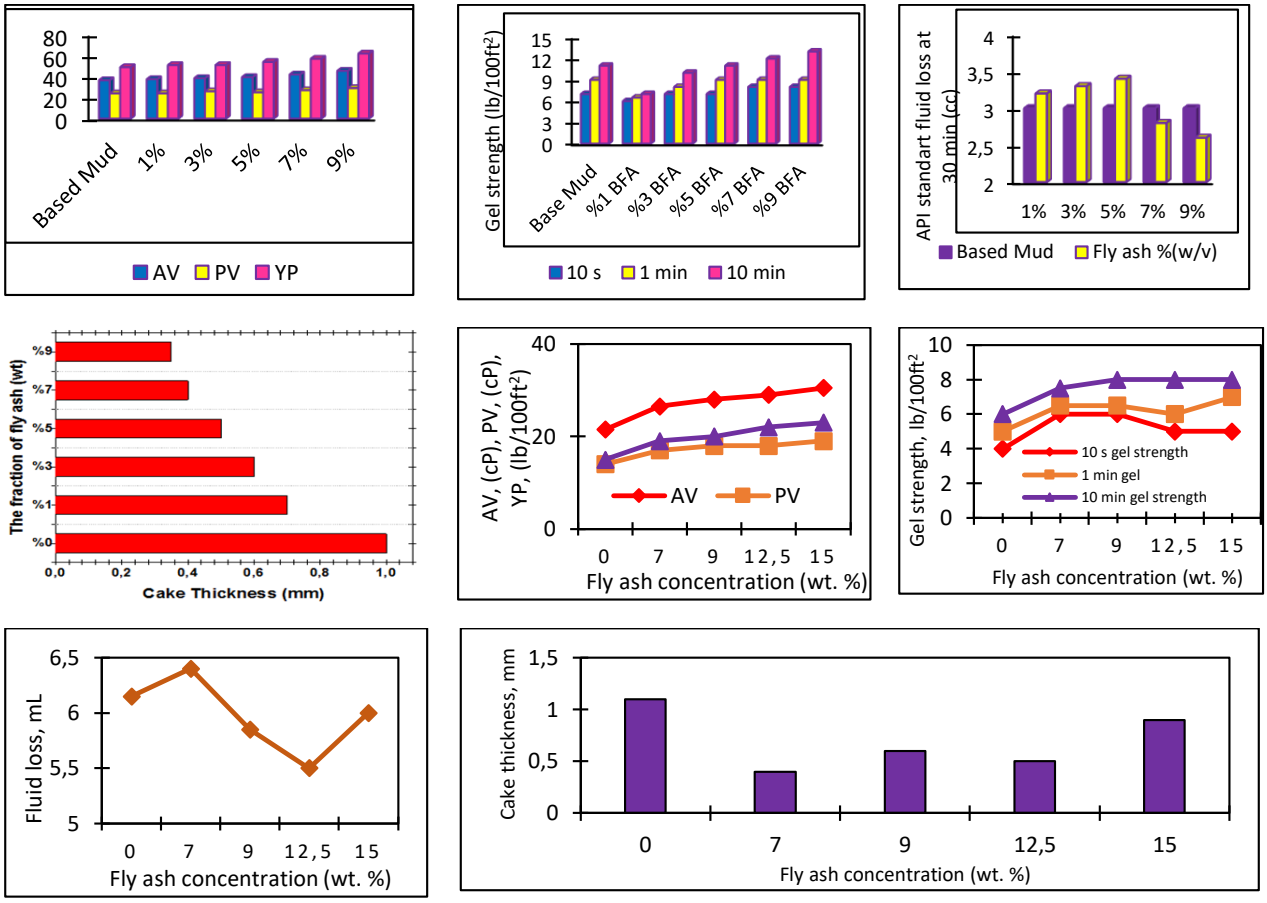

Figure 5. Rheological and filtration properties of shale inhibitor mud and KCI water based mud with fly ash

2.5. Thesis 5

In this thesis, an attempt was made to develop an improved drilling fluid with fly ash based on bentonite mud with additives. In this context, for a better understanding behaviour of bentonite mud driling fluids contains additive with fly ash was further investigated under different conditions. Effect of aging time, bentonite, XG and CMC concentrations on the performance of the fluid was examined.

Based on results, it was concluded that performance of fly ash was improved with aging time of 72 hours and increasing bentonite concentrations. It was proved that driling fluid formed by increased bentonite concentration (from 6 wt% to 8 wt%), incorporated with 4 wt% content of fly ash yielded higher rheological parameters than the other driling fluid system including increased concentration of XG (0.80 g) and CMC (1.3 g) both in absence and presence of 4 wt% concentration of fly ash. Also, the fluid system exhibited the lowest the fluid loss than the other drilling fluid systems. It was concluded that when bentonite concentration increased from 6 wt% to 8 wt% under aging time of 72 hours, AV, PV and YP of bentonite mud containing bentonite (8 wt%), XG (0.5 g), CMC (1.0 g) incorporated with 4 wt% content of fly ash increased by %82, %34, %127 respectively compared with the reference fluid containing 6 wt% concentration of bentonite under 24 hours aging time by keeping other variables constant. And, thixotropy of the reference fluid containing 6 wt% concentration of bentonite decreased by approximately 10% as well. Moreover, fluid loss of the drilling mud decreased by 24% without compromising of the mud cake thickness. Rheological and filtration properties of the developed driling fluid was given in Fig.6.

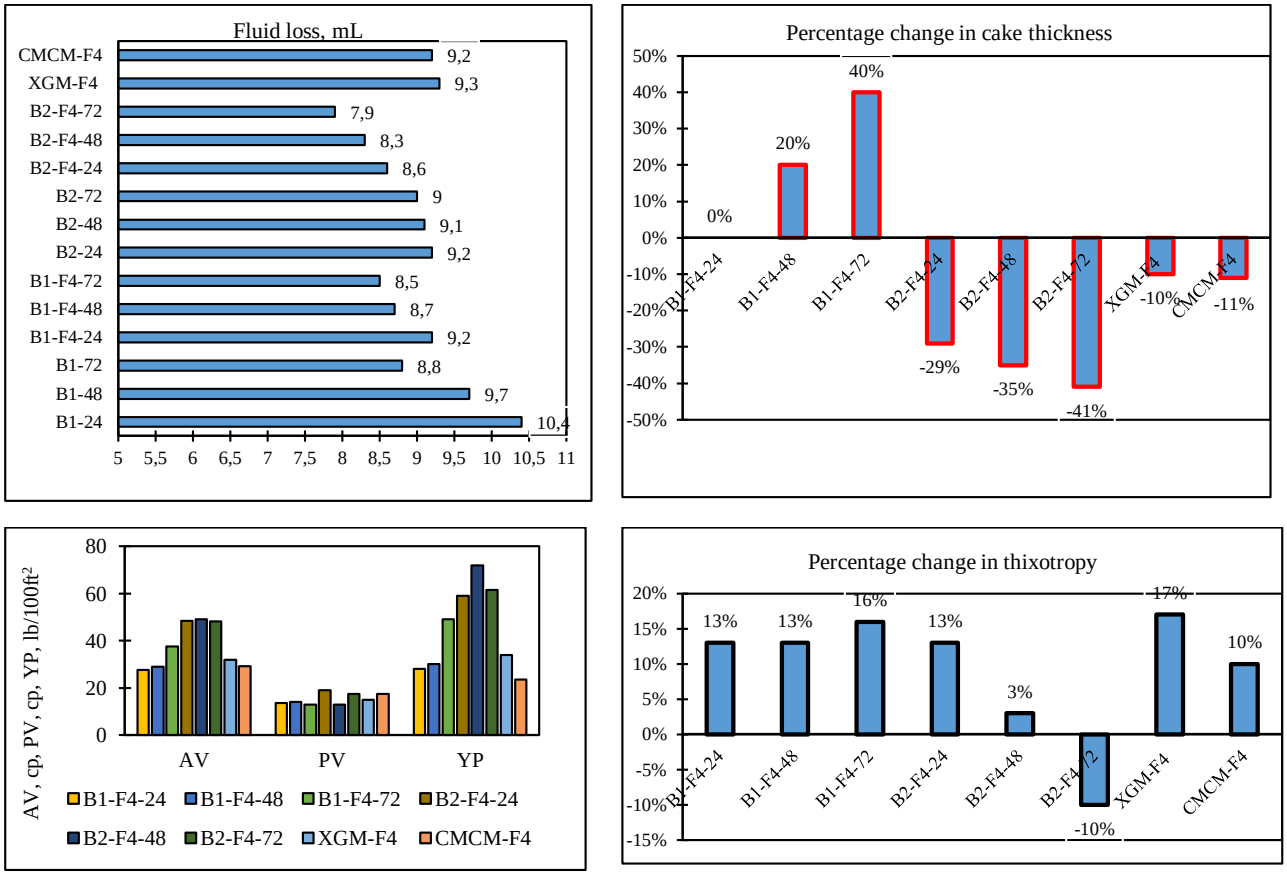

Figure 6. Rheological and filtration properties of the developed driling fluid

2.6. Thesis 6

Based on measurements performed with a Fann Model 21150 Differential Sticking Tester, a novel driling fluid system was developed considering differential sticking coefficient. Based on results, it was reveal that barite weighted bentonite driling fluid system with 0.3 wt% concentration of BFA grinded for two hours with a mean particle size of 0.272 µm decreased the sticking coefficient of driling fluid by 45%. Thereby, this developed system provides a reduction in non-productive time and associated well cost.

Moreover, it was proved that differential sticking of driling fluid is greatly affected from the changing of particle size of fly ash. It was concluded that as particle size of fly ash decreases, effectiveness of fly ash increases on the reduction of differential sticking. While sticking coefficient of barite weighted bentonite drilling mud decreased by approximately 32% with the introduction of 1.0 wt% concentration of sieved fly ash with a mean particle size of 67.893 µm, it decreased by 25% in presence of 0.25 wt% concentration raw of fly ash with a mean particle size of 84.110 µm. Fig.7 shows effect of fly ash on sticking coefficient and torque of barite-weighted drilling fluid.

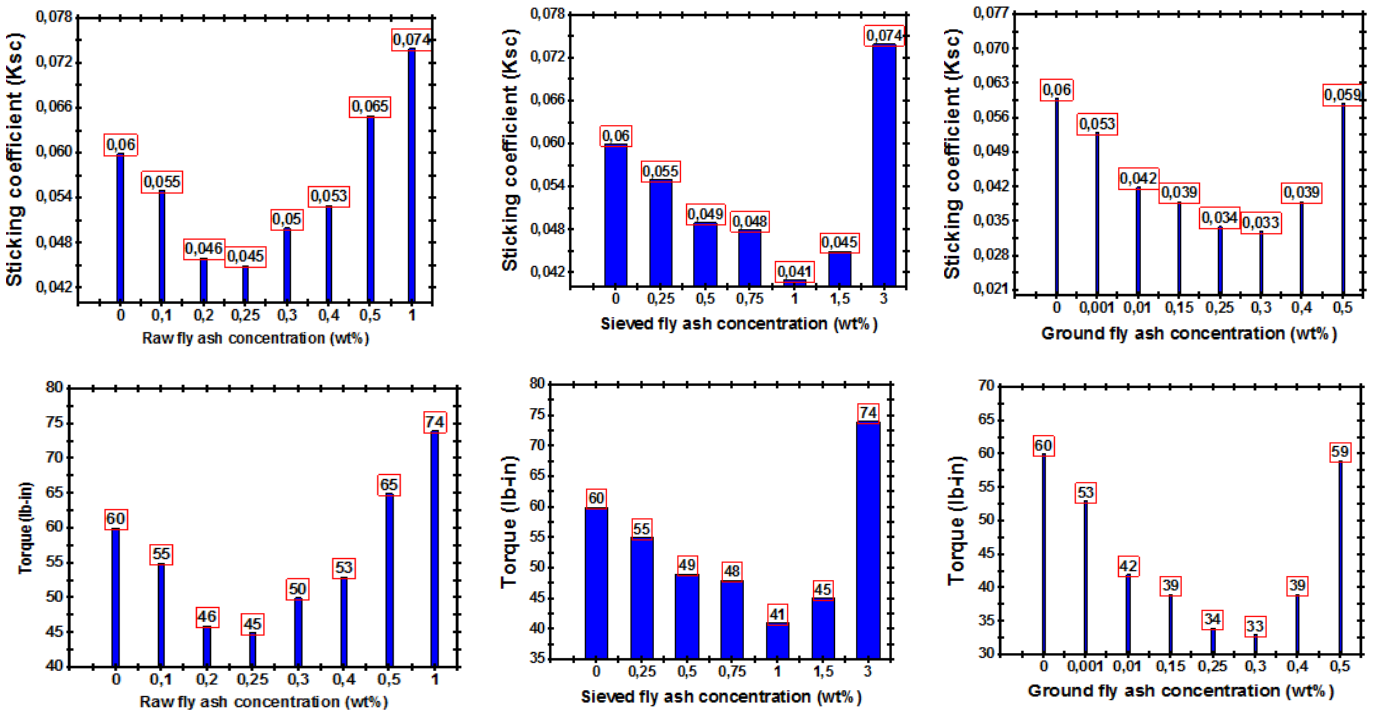

Figure 7. Effect of fly ash on sticking coefficient and torque of barite-weighted drilling fluid.

2.7. Thesis 7

It was reveal that rheological and properties of bentonite mud with XG and CMC were improved depending on concentration of rice husk ash introduced, based on developed drilling fluid systems with 2 wt%, 4 wt%, 7 wt%, 12.5 wt%, and 15 wt% concentration of rice husk ash. While apparent viscosity and yield point of the mud with 15 wt% concentration of rice husk ash increased by 60% and 183%, respectively, thixotropy and plastic viscosity of the fluid decreased by 29% and 63%, respectively, As can be seen in Fig.8.

Moreover, performance of rice husk ash was evaluated based on cutting carrying index, minimum annular velocity needed for the well cleaning efficiently and flow behaviour index of the fluid. Results calculated were given in Table 1. Based on results, it was proved that performance of bentonite mud with XG and CMC in presence of rice husk ash, considering its parametrers that are cutting carrying index (CCI), minimum anular velocity required to clean bottom of the well efficiently (Va) and flow behaviour index (n). Cutting carrying capacity of the reference drilling fluid without rice husk ash increased from 3.183 to 54.700 in presence of 15 wt% concentration rice husk ash. On the other hand, minimum anular velocity required to clean bottom of the well efficiently and flow behaviour index of the reference fluid decreased from 31.412 to 1.828 and 0.419 to 0.087, respectively.

Table 1. CCI, Va and n of water based bentonite mud with additive at different rice husk ash concentrations

Concentration of rice husk ash (wt%)	CCI	Va	n
0	3.183	31.412	0.419
2	5.516	18.126	0.347
4	13.855	7.217	0.230
7	17.103	5.846	0.207
9	5.258	19.015	0.394
12.5	22.101	4.5245	0.210
15	54.700	1.828	0.087

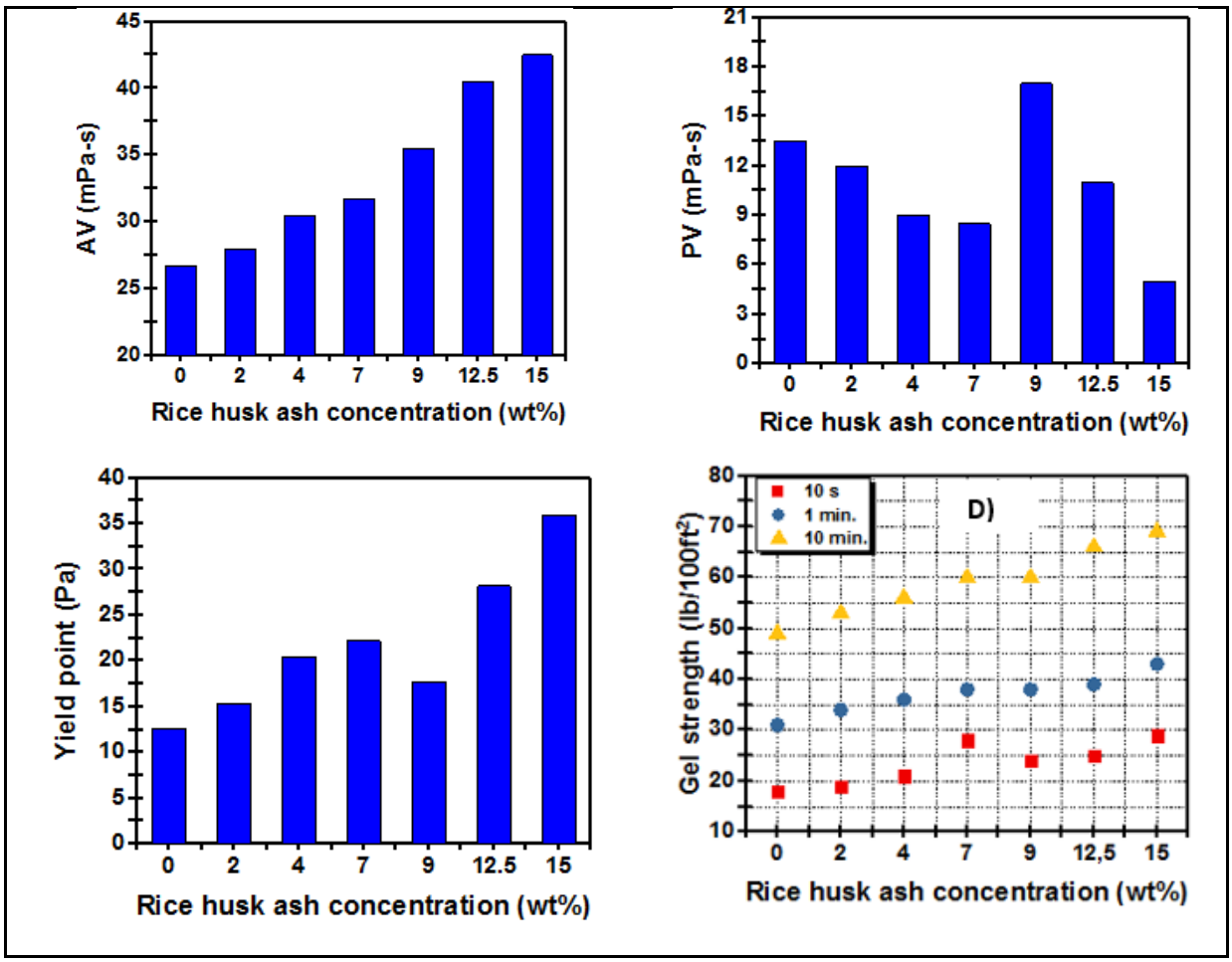

Figure 8. Rheological properties of bentonite mud with additive including rice husk ash

2.8. Thesis 8

In this thesis, possibility of using fly ash and rice husk ash as substitutes in portland cement (P1) slurry was studied experimentally at ambient conditions. Based on results, it was reveal that viscosity of slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement (P1F30R15) is lower than reference slurry without replacement of the ashes up to 300 1/s rotation speed. Moreover, it was concluded that with the developed slurry fluid loss of the reference slurry decreased by 26% and density of portland cement decreased to 14.5 ppg. Rheological properties of portland cement and developed slurries were given in Fig.9. Developed slurry could provide a reduction on pump pressure required and possibility of cracking or channeling in the formation during pumping the cement slurry. Also, the developed slurry prevents premature gelation of the cement composition. Thereby, it can be stated that the system contributes the well cost.

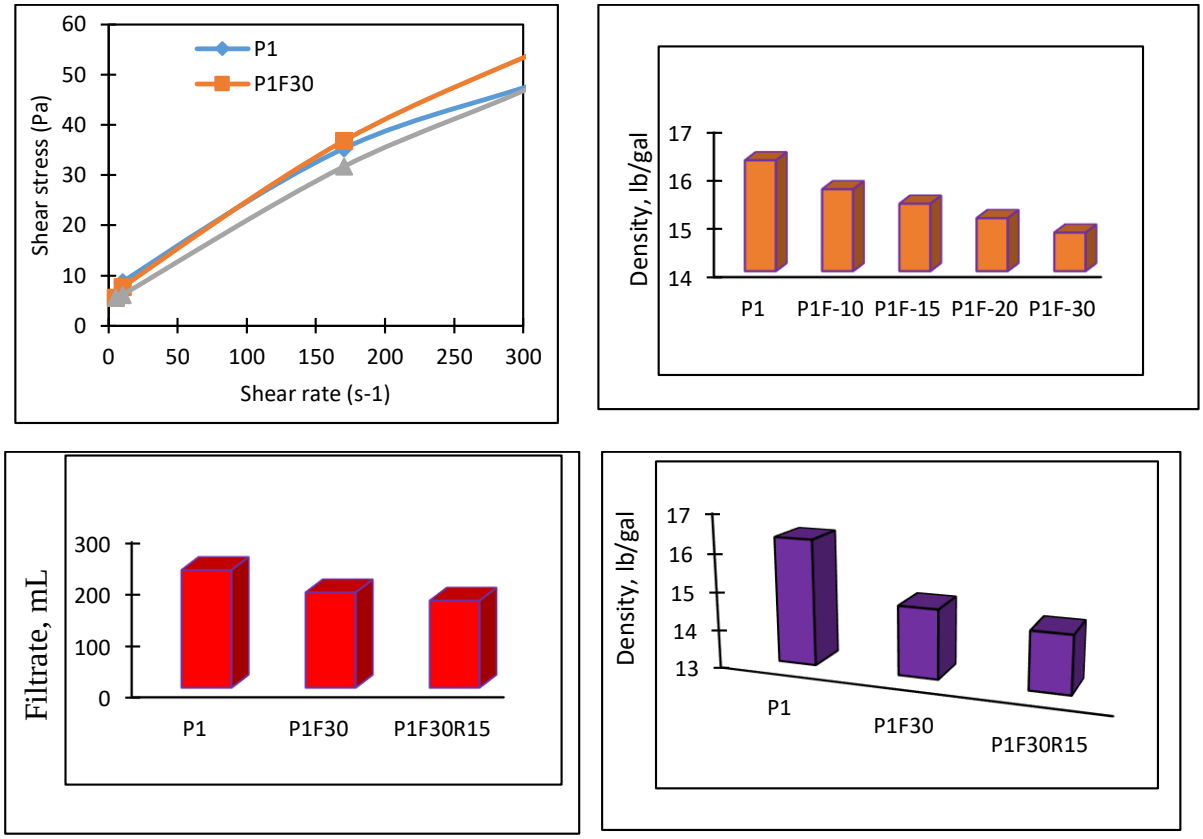

Figure 9. Rheological properties of portland cement and cement replacement by fly ash and rice husk ash slurries

2.9. Thesis 9

In this thesis, stability of the slurry formed by partial replacement of cement with fly ash and rice husk ash was analysed experimantally against to water based inhibitive drilling fluid contamination by comparison with reference portland cement slurry at ambient conditions. P1M5 refers portland cement with the 5 wt% mud contamination and P1M10 refers portland cement with the 10 wt% mud contamination. Also, P1F30R15M-5 donates developed slurry with the 5 wt% mud contamination and P1F30R15M-5 indicates developed slurry with the 10 wt% mud contamination. Based on evaluation of results, it was reveal that viscosity of the slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement decreased in presence of the 5 wt% and 10 wt% dosage of gypsum polymer mud, and rate of the viscosity reduction was lower than reference portland cement slurry. This indicates that developed slurry is more stable than than portland cement slurry under increasing mud contamination. The slurry also exhibited enhanced filtration results and shows lower fluid loss when it exposure to both 5 wt% and 10 wt% concentration of gypsum/polymer mud type contamination by comparison with reference portland cement slurry. Rheological and filtration properties of portland cement and developed slurry under various dosage of water based mud contamination at ambient temperature were presented in Fig.10.

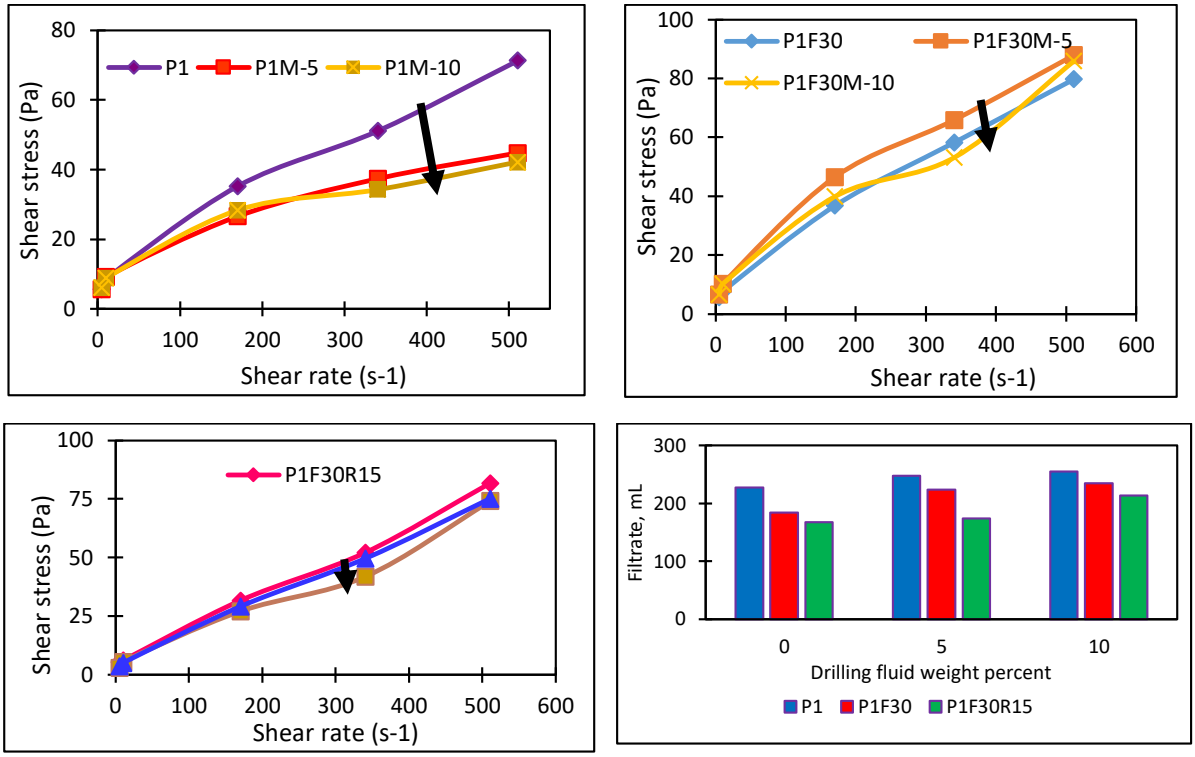

Figure 10. Rheological and filtration properties of portland cement and developed slurry under various dosage of water based mud contamination at ambient temperature

2.10. Thesis 10

In this thesis, effect of particle size of fly ash on the reological and filtration properties of cement slurry was investigated to determine the optimum particle size at ambient conditions. Obtained results were given in Fig.11. Based on the measurement conducted on tumbling laboratory ball mill, Fann-35A viscometer and API standard filter press, it was reveal that particle size of fly ash plays an important role on the properties of cement slurry.

While slurry formed by partial replacement of cement with sieved fly ash yielded lower viscosity than those of slurry formed by partial replacement of cement with ground fly ashes. On the other hand, slurry formed by partial replacement of cement with ground fly ash yielded lower filtration than that of slurry formed by partial replacement of cement with sieved fly ash under the same displacement ratio. From the results, it was concluded that fluid loss of the reference portland cement slurry decreased by 26% with the formulation of slurry formed by partial replacement of cement with fly ash, ground for 120 minutes and D_{50} value is 9.38, in 30% by weight of cement. Moreover, slurry formed by partial replacement of cement with sieved fly ash, D_{50} value is 67.89, in 30% by weight of cement exhibited lower viscosity than those of slurry formed by partial replacement of cement with fly ashes, ground for 120 minutes and D_{50} value is 9.38, and 30 minutes ground and D50 value is 18.25, in 30% by weight of cement.

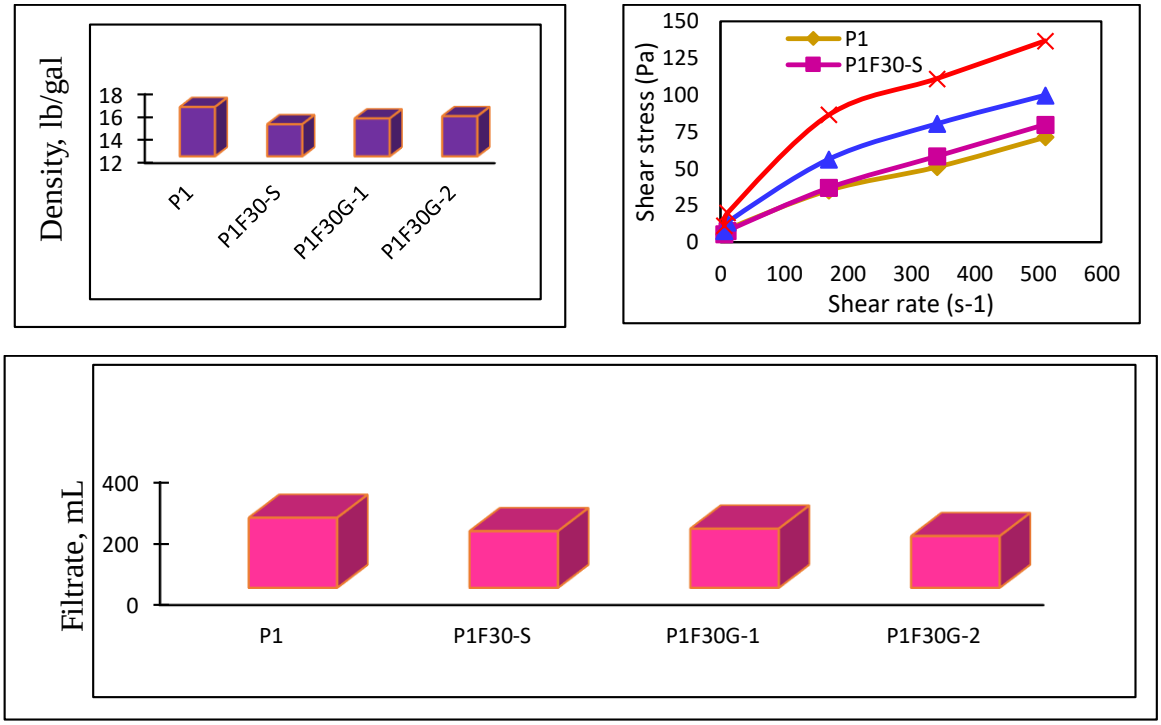

Figure 11. Effect of particle size of fly ash on the reological and filtration properties of portland cement and developed slurries

2.11. Thesis 11

In this thesis, flow behaviour of the slurry formed by partial replacement of cement with fly ash and rice husk ash was investigated experimentally in presence and absence of water based driling fluid at elevated temperature and constant temperature by comparison with reference portland cement slurry.

Developed slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement showed the superior rheology results than reference portland cement slurry both in presence and absence of drilling mud at elevated temperature. While viscosity of the portland cement slurry increses with the increasing temperature, viscosity of the slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement decreases with the increasing temperature, as can be seen in Fig.12.

From the evaluation of results, it was proved that slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement yielded better mud contamination resistance than reference portland cement. While viscosity of the portland cement slurry increases when it exposed to 5 wt% and 10 wt% (by weight of cement) gypsum/polymer type water based drilling fluid contamination under increasing temperatures (80-125 (°F), as can be seen in Fig.13.

Based on results, it was found that developed slurry formed by partial replacement of cement with fly ash in 30% and rice husk ash in 15% by weight of cement showed lower viscosity than reference portland cement slurry up 150 rpm at constant temperatures (80-125 (°F), as can be seen in Fig.14. Moreover, it was concluded that rheology of the developed system enhanced with the increasing mud contamination and temperature. The slurry demonstrated lower viscosity than reference portland cement when it exposed to 10 wt% gypsum/polymer water based drilling fluid under constant temperature of 125 °F, as can be seen in Fig.15.

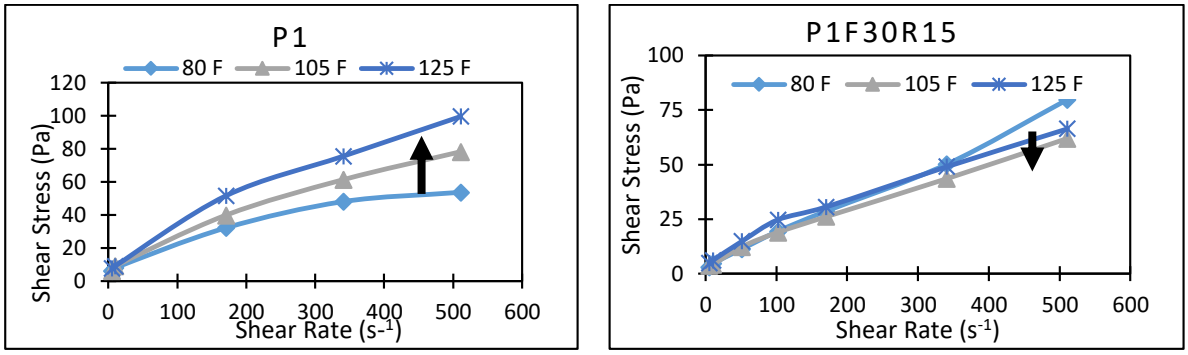

Figure 12. Rheological properties of portland cement and developed slurries at elevated temperatures

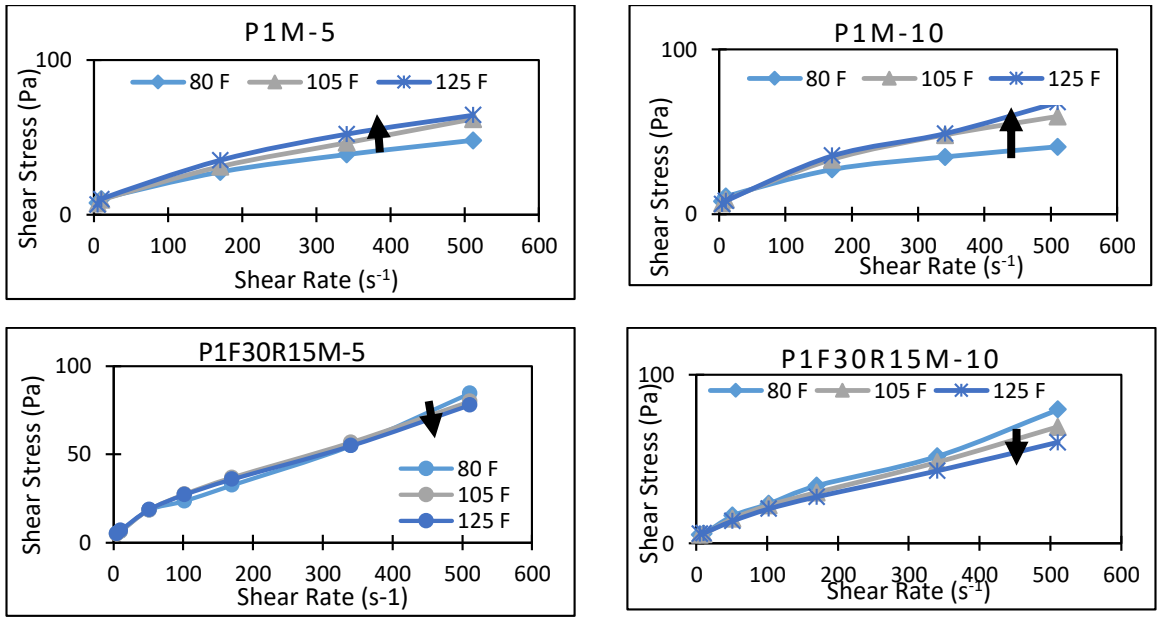

Figure 13. Rheological properties of portland cement and developed slurries with various dosages of water based drilling mud at elevated temperatures

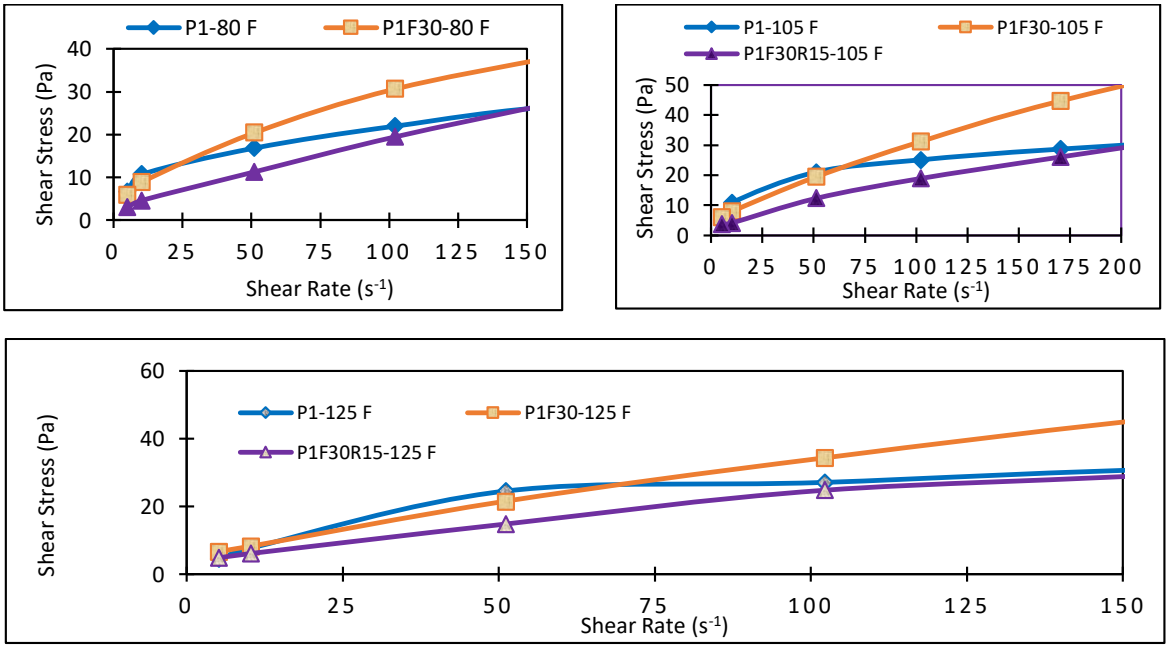

Figure 14. Rheological properties of portland cement and developed slurries at constant temperatures

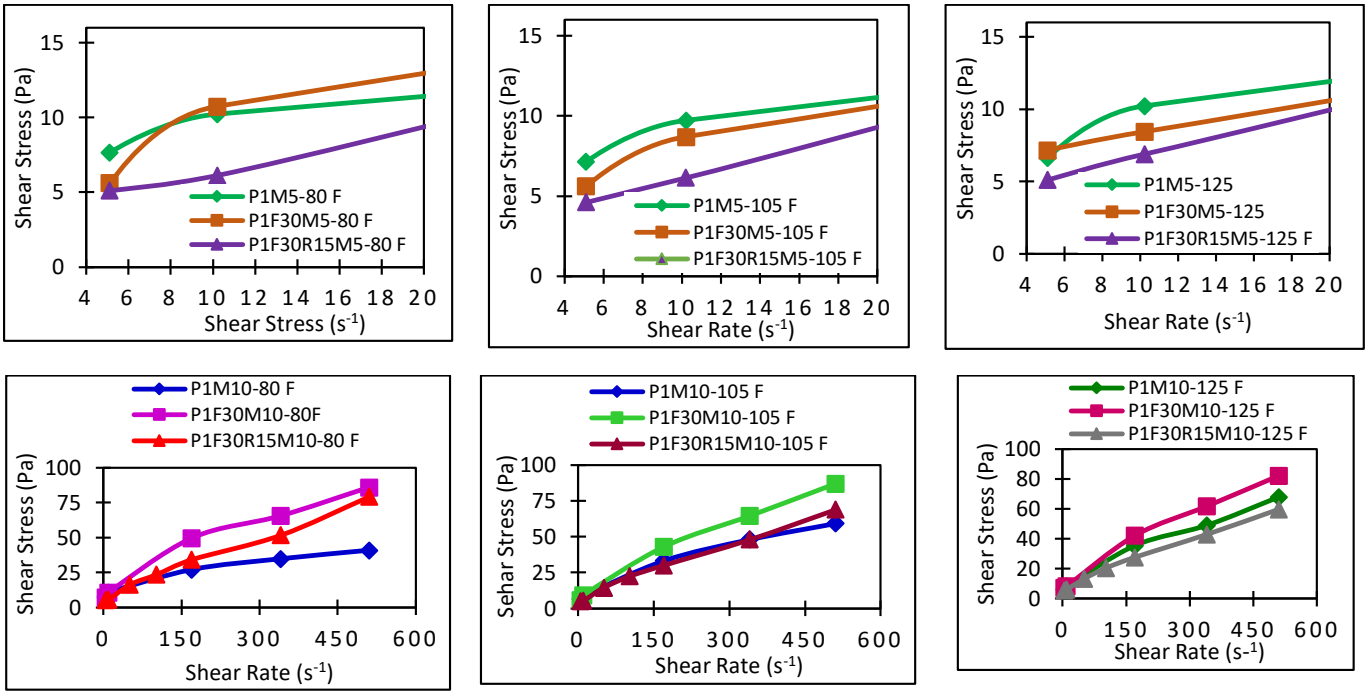

Figure 15. Rheological properties of portland cement and developed slurries under various of mud contamination at constant temperatures

2.12. Thesis 12

In this thesis, a novel geopolymer hybride slurry was developed based on fly ash for oil and gas wells. In order to design geopolymer slurry, firstly, optimum particle size of fly ash was determined. To this end, fly ash was grinded in a a tumbling laboratory ball mill a dry mode for the duration of 30 minutes, 60 minutes and 120 minutes. Then, optimum liquid/solid ratio (L/S) was determined by analysisng four different ratio results. Finally, mud to cement conversion technology was applied on the slurries. Geopolymer and cement slurries were replaced with the real field gyprum/polymer mud by volume and behaviour of the slurries was analysed at both ambient and elevated temperature by conducting rheological and filtration tests. Flow chart for the develepment of hybride geopolymer slurry can be seen in Fig.16.

Based on evaluation of results, geopolymer formed by 12 Molar NaOH (25%), Water glass (75%), 50/50 alkaline activator/120 minutes ground fly ash and gypsum/polymer type water based drilling fluid showed higher mud contamination resistant at ambient temperature and 125 °F temperature. Moreover, the develeoped geopolymer hybride possess much lower fluid loss than reference traditional portland cement slurry.

The developed geopolymer not only improves its pumpability by providing low viscosity, but also contributes on the enhancement of fluid loss. Thereby, the geopolymer hybride ensures that required pump power to pump the slurry and possibility of crack or channel formation in the cement is reduced. Also, with the forming geopolymer hybride by inroducing the mud to alkaline activated fly ash slurry, a recycle method was obtained for disposal of spent mud. Thus, the developed hybrid geopolymer also helps to reduce the total drilling cost.

From the results, it was proved that as particle size of fly ash decreases viscosity and fluid loss of the geopolymer decreases. Geopolymer formed by 12 Molar NaOH (25%), Water glass

(75%), ratio of alkaline activator/120 minutes ground fly ash (45/55) showed the lowest viscosity and filtration than those of geopolymer formed by sieved, 30 minutes and 60 minutes ground fly ash when all other parameters were held constant.

Moreover, it was reveal that geopolymer formed by 12 Molar NaOH (25%), Water glass (75%) and alkaline activator/120 minutes ground fly ash ratio of 50/50 exhibited lower viscosity than those of geopolymer with alkaline activator/120 minutes ground fly ash ratio of 45/55, 42.5/57.5 and 47.5/52.5 keeping all other variables constant.

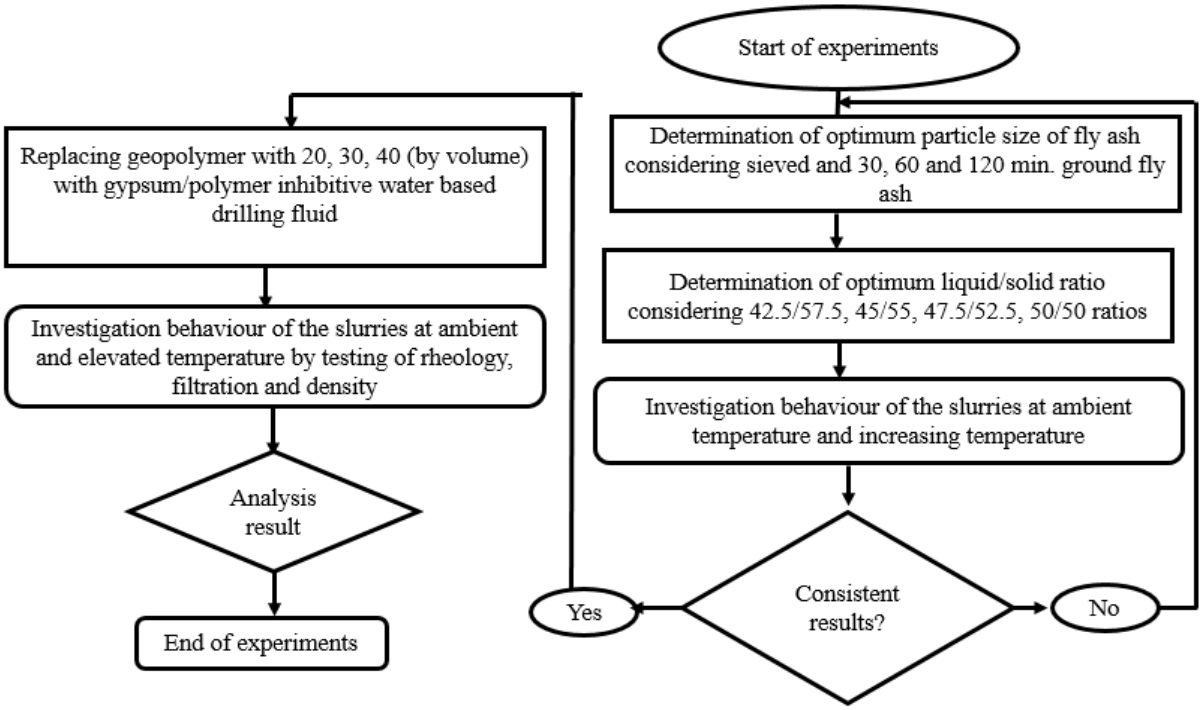

Figure 16. Work flow for the develepment of hybride geopolymer slurry

2.13. Thesis 13

In the thesis, drilling fluid system with improved drilling performance was developed with fly ash under increasing temperature taking into account parameters of cutting carrying index, flow behavior index and minimum annular velocity required to clean bottom of the well efficiently.

Based on data obtained by measurements performed with a Fann model 50 SL rheometer, it was reveal that shale inhibitor mud incorporated with 9 wt% concentration of fly ash increased cutting carrying index of the reference fluid not containing fly ash from 0.794 to 0.813, from 0.459 to 0.620, from 0.202 to 0.410 under 30°C, 40°C and 50°C temperatures, respectively. In addition, with the improved driling fluid system, minimum annular velocity required to clean bottom of the well efficiently decreased from 125.848 ft/min to 122.968 ft/min, from 217.536 ft/min to 161.235 ft/min, from 493.834 ft/min to 243.585 ft/min under 30°C, 40°C and 50°C temperatures, respectively. On the other hand, developing the driling fluid system ensured to decrease flow behaviour of the index from 0.544 to 0.555, from 0.592 to 0.565, from 0.688 to 0.606 for 30°C, 40°C and 50°C temperatures, respectively. Obtained results can be seen in Fig.17. With this developed system, the performance of the drilling operation is improved and it also contributes to the reduction of the total well cost.

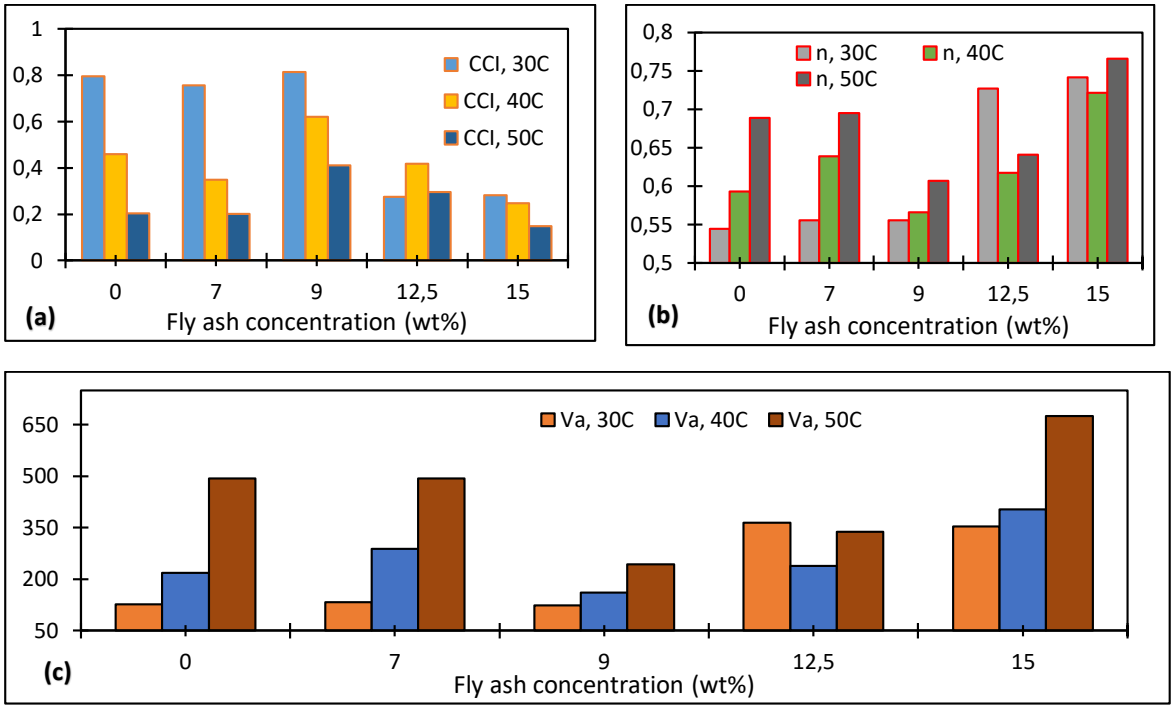

Figure 17. Hydrolic parameters of the water based drilling fluids under increasing temperature, cutting carrying index (a), flow behaviour index (b), minimum annular velocity required to clean the well (c)

2.14. Thesis 14

In the thesis, rheological model analysis of the drilling fluid system with improved drilling performance was conducted to determine relationship between shear stress and shear rate mathematical under different temperatures by comparing the traditional bingham plastic, power law and herschel bulkly rheological models. Based on data obtained by measurements performed with a Fann model 50 SL rheometer, it was concluded that Herschel Bulkley model showed superior results than the Power Law and Bingham Plastic rheological models for 86°F, 104°F and 122°F temperatures. Employment of the Herschel Bulkley model in the estimation of changes of shear stress depending on shear stress which can occur during driling for 86°F, 104°F and 122°F temperatures provides more accurate assessment of well hydraulics.

3. CONCLUSIONS

In the thesis, different types of drilling fluids with improved hydraulic performance were developed with fly ash, which is a large amount of industrial waste, and rice husk ash, which also constitutes a large amount of agricultural waste at ambient and elevated temperature. In addition, cement slurry and hybride geopolymer slurry with improved rheological and filtration properties were designed by partially changing the amount of cement with fly ash and rice husk ash and completely replacement of cement by fly ash, respectively to reduce and eliminate cement amount needed. Lastly, for a better understanding rheological behaviour of drilling fluids and their wellbore hydraulic performance rheological model analysis was performed. Consequently, an alternative method was developed for the recycling of fly ash and rice husk ash, as well as contributing to the reduction of drilling costs and environmental problems with the drilling mud and cement slurries developed in this thesis. Also, with the rheological model

analysis more accurate assessment of well hydraulic was achieved. It worths to be noted that the new comprehensive findings obtained in this thesis can be used as a guide for future studies.

4. LIST OF RELATED PUBLICATIONS AND PRESENTATIONS

4.1 Journal articles

1. Avci, E., 2018. Effect of Salinity on Flow Properties of Drilling Fluids: An Experimental Approach. Petroleum and Coal 60(2): 232-235. Slovakia.

2. Avci, E. (2018). An Artificial Neural Network Approach for the prediction of Water-Based Drilling Fluid Rheological Behaviour. International Advanced Researches and Engineering Journal, 2(2), 124-131. Turkey.

3. Avci, E., Szabo, T., Federer, G., (2019). The rheological performance of fly ash in inhibitive water-based drilling fluids. Petroleum and Coal 61(6): 1307-1313. Slovakia.

4. Fliss, M., Szabo, T., Avci, E., (2019). Effect of micro-sized fly ash on the rheological and filtration properties of water-based muds. Petroleum and Coal 61(6): 1361-1364. Slovakia.

5. Avci, E., Mert, B. A. (2019). The Rheology and Performance of Geothermal Spring Water-Based Drilling Fluids. Geofluids.

6. Yucel, A., Sezer, S., Birhanli, E., Ekinci, T., Yalman, E., & Depci, T. (2020). Synthesis and characterization of whitlockite from sea urchin skeleton and investigation of antibacterial activity. Ceramics International.

7. Yalman. E., Federer-Kovacs. G., Depci. T. (2021). Effect of Two Types of Fly Ash on Rheological and Filtration Properties of Water-Based Drilling Mud. Natural and Engineering Sciences. 6(3), 223-236.

8. Yalman, E., Federer. G., Depci. T. (2021). Cost Analysis of Inhibitive Drilling Fluids. International Journal of Energy Studies. 6(2), 149-168.

9. Yalman, E., Depci, T., Federer-Kovacs. G., & Al Khalaf. H. (2021). A New Eco-Friendly and Low Cost Additive in Water-Based Drilling Fluids. Rudarsko-geološko-naftni zbornik. 36(5), 1-12.

10. Yalman. E., Federer, G., Depci. T. (2022). Development of Water-Based Drilling Fluid in Mitigation of Differential Sticking Tendency. Rudarsko-geološko-naftni zbornik (The Mining-Geology-Petroleum Engineering Bulletin).

11. Yalman, E., Federer-Kovacs, G., Depci, T., Al Khalaf, H., Aylikci, V., Aydin, M. G. (2022). Development of novel inhibitive water-based drilling muds for oil and gas field applications. Journal of Petroleum Science and Engineering, 210, 109907.

12. Yalman, E., Federer-Kovacs, G., Depci, T. (2022). A New Insight into Formulation Approach for Water Based Drilling Fluids. Petroleum and Coal.

13. Federer, G.K., Al-Khalaf, H., Yalman, E., Nagham. A.-H. M. (2020). API cement behavior under thermal conditions part II. 275 °C test. Műszakı Földtudományı Közlemények. 89(2). 189–202.

14. Federer, G.K., Al-Khalaf, H., Yalman, E., Nagham. A.-H. M. (2020). API cement behavior under thermal conditions part I.120 °C test. Műszakı Földtudományı Közlemények. 89(2). 176–188.

15. Federer, G.K., Al-Khalaf, H., Yalman, E., Nagham. A. M. (2020). Causes and mitigation of trapped annular pressure. Műszakı Földtudományı Közlemények. 89(2). 164–175.

4.2. Book Chapter

1. Federer-Kovacs, G., Al Khalaf, H., Yalman E., Al-Haj Mohammed, N. Depci, T. Reasons and resolutions of trapped annular pressure. Engineering and Architecture Sciences Theory, Current Researches and New Trends 2021, Stamparija IVPE.

4.3. Proceedings of international conferences

1. Avci, E., Mert, B.A. (2016). An Experimental Investigation of the Rheological Properties of the Geothermal Water Based Drilling Muds, International Conference on Engineering and Natural Sciences, Sarajevo/Bosna and Herzegovina.

2. Mert, B.A., Avci, E. (2016). The Development of Well Information System Using Gis: A Case Study of the Bati Raman Oil Field in Turkey, International Conference on Engineering and Natural Sciences, Sarajevo/Bosna and Herzegovina.

3. Mert, B.A., Avci, E. (2017). Evaluation of the Environmental Impact of Geothermal Drilling Mud Wastes, International Congress on New Trends in Science, Engineering and Technology, Barcelona/Spain.

4. Mert, B.A., Avci, E. (2017). Experimental Investigation of the Influence of Polymer Additives on Flow Properties of the Water-Based Bentonite Mud, International Multidisciplinary Congress of Eurasian, Rome/Italy.

5. Mert, B.A., Avci, E. (2017). Reflections of the Legal Regulations on Geothermal Activities in Turkey, International Multidisciplinary Congress of Eurasian, Rome/Italy.

6. Avci, E. (2017). An Experimental Investigation of the Effect of Seawater on Rheological Properties of Drilling Fluids, International Iskenderun Bay Symposium, Hatay/Turkey.

7. Avci, E. (2017). Investigation of Shear Rate-Shear Stress Relation in Polymer Based Drilling Fluids, International Advanced Researches and Engineering Congress, Osmaniye/Turkey.

8. Avci, E., Demir, M.H. (2017). Estimation of Shear Stress in Water-Based Drilling Fluids Using Artificial Neural Network, International Advanced Researches and Engineering Congress, Osmaniye/Turkey.

9. Duren, O., Yalman, E., Aydin, M. G., Depci, T. (2021). An Investigation of Sodium Polyacrylate Effect on Water Based Drilling Fluid, 6Th International Congress on Engineering and Technology Management.

10. Depci, T., Onal, Y., Aydemir, R., Yalman, E., Aydin, M. G. (2021). Investigation of the Biomass Properties of Algae Growing in Iskenderun Bay, International Congress on Sciences and Engineering for Sustainability.

4.4. Conference Presentations

1. Avcı, E., Mert, B.A. (2016) “An Experimental Investigation of the Rheological Properties of the Geothermal Water Based Drilling Muds”, International Conference on Engineering and Natural Sciences, Sarajevo/Bosna and Herzegovina.

2. Mert, B.A., Avcı, E. (2016) "The Development of Well Information System Using Gis: A Case Study of the Bati Raman Oil Field in Turkey", International Conference on Engineering and Natural Sciences, Sarajevo/Bosna and Herzegovina.

3. Mert, B.A., Avcı, E. (2017) "Evaluation of the Environmental Impact of Geothermal Drilling Mud Wastes", International Congress on New Trends in Science, Engineering and Technology, Barcelona/Spain.

4. Mert, B.A., Avcı, E. (2017) "Experimental Investigation of the Influence of Polymer Additives on Flow Properties of the Water-Based Bentonite Mud", International Multidisciplinary Congress of Eurasian, Rome/Italy.

5. Mert, B.A., Avcı, E. (2017) "Reflections of the Legal Regulations on Geothermal Activities in Turkey" International Multidisciplinary Congress of Eurasian, Rome/Italy.

6. Avcı, E. (2017) "An Experimental Investigation of the Effect of Seawater on Rheological Properties of Drilling Fluids", International Iskenderun Bay Symposium, Hatay/Turkey.

7. Avcı, E. (2017) "Investigation of Shear Rate-Shear Stress Relation in Polymer Based Drilling Fluids", International Advanced Researches and Engineering Congress, Osmaniye/Turkey.

8. Avcı, E., Demir, M.H. (2017) "Estimation of Shear Stress in Water-Based Drilling Fluids Using Artificial Neural Network", International Advanced Researches and Engineering Congress, Osmaniye/Turkey.

9. Yalman, E., Federer, G., (2021) "Effect of fly ash on the differential sticking", Earth science PhD forum, Miskolc, Hungary.