Investigating the Fluid Loss and Rheology of Ordinary Portland Cement Blended with Metakaolin and Sawdust-Ash for Oil Well Cementing

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ORIGINAL RESEARCH

Abstract— Monitoring the fluid loss and rheology performance of slurry is very much essential for Oil well Cementing. Oil well cementing involves placing a special compound of cement grout formulated from constituents with relative weight to that of cement in the annulus between the casing and the adjacent rock formation to strongly join the casing to the formation. This study focused on addressing the challenges usually encountered during deep drilling, especially in a High-Pressure-High Temperature (HPHT) environment; which is mainly the sustenance of wellbore integrity during pumping and service life of a well. In this study, the viability of optimizing fluid loss and rheology performance using Sawdust Ash (SDA) and Metakaolin (MK) as a blend to Ordinary Portland Cement (OPC) was investigated. The Materials for the study were synthesized and characterized based on physical, chemical, and pozzolanic properties. The method adopted involved replacement of (OPC) with Metakaolin for 10%,12.5% and, 15% while SDA at 0%, 5% to modify the properties of ordinary Portland cement. The slurry and mechanical properties were studied based on the mix formulation generated from design of experiment (DOE) using two domains three interactive factors (23) level factorial model following the specifications of API SPEC 10A and 10B. The result obtain showed that Metakaolin blend with OPC alone at 15% was detrimental to rheology performance but incorporating Sawdust Ash up to 10% with Metakaolin at both low and high blend (10% and 15%) improved the fluid loss and rheology performance respectively. It was concluded that an optimal blend of 75%OPC, 15% MK, and 10% SDA is recommended to provide efficient and cheaper oil well cementing material. .

Keywords—Cementing, Fluid loss and Rheology, Metakaolin, Oil well, Sawdust Ash.

1 INTRODUCTION

Cementing operation is the most important, expensive, and most critical process during drilling operations for wellbore completion immediately after casing is installed (Alyooda, 2017). This operation involves placing a special compound of cement grout formulated from different constituents with relative weight to that of cement in the annulus between the casing and the adjacent rock formation and allowed to set, after a few hours or few days, to strongly join the casing to the formation (Silas et al.,2025). The main purpose of cementing is to displace the drilling fluid, isolating the permeable zone, supporting the axial load of the casing string, protecting the casing from corrosion, preventing fluid migration and hindering the escape of oil minerals into rock formation (Dhorgham, 2016). The rheological properties of oil well cement slurries are highly dependent on temperature, water/cement ratio and the type of admixture used. The effects of temperature and chemical admixtures had been reported to have a substantial effect on the flow properties of the slurries (Shahriar and Nehdi 2016). Also, one of the challenges usually encountered during deep drilling, especially in a High-Pressure-High Temperature (HPHT) environment is the sustenance of wellbore integrity in terms of slurry quality for pumping and sustenance over service life of the well. The serviceability is a function of quality wellbore cementing slurry, and well cement sheaths which tends to degrade in a corrosive and high-temperature environment. It is further found that elevated temperatures leads to gradual damage of connections between admixtures and cement paste while causing the generation of minerals with poor structure, resulting in bad mechanical behavior (Nguyen,2021). These backlash leads to increased rate of chemical attacks, formation movements and mechanical failure experienced in many cases of oil wellbore drilling. On the other hand, continuous generation of wastes arising from industrial by-products and agricultural residue like sawdust creates acute environmental problems both in terms of their treatment and disposal; hence creating the need for a cleaner modern means of utilizing these waste materials efficiently (Ubachukwu, and Silas, 2017). Furthermore, the criteria for choosing an oil-well cement slurry for individual wells is based on the physical and performance requirements of the slurry which include the thickening time, rate of fluid loss, amount and rheology of the slurry. These requirements are essential due to the high water-cement ratio of the mixture which is necessary to achieve the desired density, slurry quality, pumpability, and its cake strength with regards to requirements of the American Petroleum Institute (API) Specification (Qosai and Radi, 2018). The requirements and associated risk on failure occurrence have led many oil and gas companies to research for efficient materials for oil well-cementing operations (Efstathios, 2016). According to Oloro (2017), the fluid loss of the cement should be controlled to prevent early dehydration of the slurry causing an artificial premature hardening. Also, higher fluid loss indicates that when cement is pumped into the well, it might require

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secondary cementing. According to Anon (2013), under standard laboratory conditions i.e (6.9 MPa (1 000 psi) filter pressure, a slurry for a squeeze job and primary cement job should give a fluid loss of 50-200 cc (ml) and 250-400 cc (ml) within thirty (30) minutes respectively as reported by Broni-bediako, et al.(2016). Referring the report of Boškovic et al.(2013), filtrate (fluid) loss for class G cement is not precisely defined by API Specification, but recommended that within thirty (30) minutes test period, the fluid loss should be limited up to 1000 cc (ml) for cementing technical casing string, 500 cc (ml) to less or equal to 100 cc (ml) for production casing string and 30-50 cc (ml) for gas wells respectively. On the other hand, the rheology study of the slurry is necessary to properly predict the frictional pressures that will occur while pumping the various fluids in the well. Here, the slurry viscosity is measured using viscometer for different rheology properties including 10seconds and 10 minute gel strength, and plastic viscocity with all reported with the testing temperature range (Shahriar and Nehdi 2016). To solve the above challenges, the modelling and use of pozzolan materials as admixture serve to improve the slurry performance, reduce the quantity of the deleterious calcium hydroxide in the concrete matrix during hydration as well as increase the quantity of the beneficial calcium-silicate-hydrate. This concurrently leads to high strength in early and later age, durability in terms of low porosity, high temperature resistance and good chemical corrosion resistance (Ettu et al., 2016). Qosai, and Radi, 2018 reported that when choosing mineral additives and pozzolan admixtures, great attention is focused on their physical as well as their chemical properties, such as the size and shape of particles, water absorption, active chemical interaction with Portland cement and its micro structure. Ettu et al. (2016) have reported Metakaolin to be an excellent pozzolan when blended in concrete. Nevertheless, it is a high water demanding pozzolan when it comes to oil well-cementing jobs which require the slurry to remain pumpable till it reaches its target depth, hence creating the need for modification of this pozzolan with lesser water demanding one like Sawdust Ash (Silas et al., 2025). The combination of the two pozzolan is a breakthrough in obtaining efficient cementing material thus spurring the study. The objective of the study were meet by employing factorial model of two domain three interactive factor 23 for designing the experimentation as well as analyzing the various properties of the slurry and hardened cubes of ordinary Portland cement blend with metakaolin-sawdust ash cementing material. The study focused on the performance interaction of the blending of Ordinary Portland Cement (OPC) with metakaolin and sawdust ash at 25% OPC cement replacement. The outcome of the hybrid blending allowed the reduction in consumption of OPC, or imported class G and H cement while improving the fluid loss, rheology, and strength and durability performance of the oil well-cemented casing.

2 MATERIALS AND METHODS

2.1 Experimental Materials

The following materials were synthesized, prepared and employed in conformation to the requirements and specifications of the experimental process. Sawdust ash obtained from sawdust in timber market Umuahia as well as kaolin for Metakaolin obtained from Umuariaga Oboro Ikwuano, Abia state; were prepared following standard methods within the specified temperature of calcination and heating time of 90 minutes for Metakaolin before being employed to the experimental module. The cement on the other hand was obtained prepare grade 42.5 OPC class B according to the classifications of (ASTM C150 and API 10A, 2019). The water for the study was clean tap water from the Federal University of Technology Owerri Civil, Chemistry and Petroleum department laboratories respectively; conforming to the standard spelt in EN 196 and API 10A.

2.2 Methods

For this study, two sets (2) of samples were prepared. One set made from factorial model experimental runs as generated in Minitab design of experiment (DOE) for slurry properties of Metakaolin –Sawdust Ash (MKSDA) blended OPC as shown in Table 1 and the other set of control sample containing pure class B cement. N1 to N18 represents the run order for the randomised blended cementing sample from the factorial design, while the C1 and C2 run orders represent the sample with only class B Ordinary Portland Cement (OPC) in accordance to API 10B mix specifications. The experimentation was carried out in phases thus actualizing the objectives of the study as follows. The material preparation and characterization involved the physical, chemical and pozzolan testing of Sawdust -Ash and Metakaolin samples respectively. The slurry characteristic testing followed the formulation and slurry mix design based on pseudo mix ratio generated from two domain three factor (2^3) for two replica and centre points factorial model making up 18 samples per run and two control samples with only Ordinary Portland Cement shown in Table 1.

The number of experimental runs performed for the model development for full factorial design is governed by the Equation (1.0).

$$N = L^K \quad (1)$$

Where K denotes experimental variable referred to as factors

L is the number of domain levels of variables,

N is the total number of experimental runs,

While K can be represented as X_n, X_{n+1}, X_{n+2}…, and X_K regarding various experimental factors Experimental runs based on two (2) levels is attributed to 2^K level domain '-'(-1) to indicate low level and ' + ' (+1) for high level which can be percentage of additive of constituent in an experimental sample or percentage of replacement of constituent in an experimental sample. The model has a high efficiency with correlation coefficient of 99.8%, standard error of 0.1325, and accuracy of 99.8% (Nguyen, Ahn, Le, Lee, 2021). The mathematical model had r repetitions per cell in a completely randomized design according to Equation (2) yielding Equation (3).

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + C_k + AC_{ik} + BC_{jk} + ABC_{ijk} + E_{ijkv} \quad (2)$$

Where $i,j,\ k$ = (0,1) and r = (1,2….,r) repetitions, μ = interactive intercept coefficient while E = experimental error coefficient (Silas et al., 2022).

Thus, for X_1, X_2, and X_3 factors the model becomes

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$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 - b_{123}X_1X_2X_3 + e \quad (3)$$

Where $b0$ corresponds to μ and e corresponding the interactive errors for b_1,b_2 and b_3 factors.

The slurry characteristic testing focusing on the rate of fluid loss and rheology followed the formulation and slurry mix design based on pseudo mix ratio generated from two domain three factor (2^3) for two replica and centre points factorial model making up 18 samples per run and two control samples with only Ordinary Portland Cement shown in Table 1; following the domain of Design of Experiment (DOE) which have various combinations and percentages blend of the Ordinary Portland Cement (OPC) with Metakaolin for 10%,12.5% and, 15% while Sawdust ash at 0%, 5% and 10% which made up for 10 to 25% .The model design allow for slight under use as well as excess dose of the combine percentage blending with Metakaolin and sawdust ash; aligning with the factorial design by Falode, et al.(2013). Water cement ratio W/C was maintained at 0.46 based on API standards API SPEC 10B for all the samples to be mixed as reported by Qosai and Radi,(2018) for Mk dosage below 30%. The formulated samples slurry were tested for various led down simulated fluid loss and rheology test by API 10A (2019) for slurry required to be used in well bore. The study used a total of 360 run samples for both rheology and fluid loss of slurry and mechanical performance testing.

Table 1. Pseudo and actual mix ratio for the slurry formulation generated from Minitab DOE

Std Order	Run Order	OPC	Metakaolin(MK)	Sawdust ash (SDA)	Equivalent OPC (%)	Equivalent MK (%)	Equivalent SDA (%)
11	1	-1	1	-1	90	15	-
3	2	-1	1	-1	90	15	-
9	3	-1	-1	-1	90	10	-
12	4	1	1	-1	75	15	-
16	5	1	1	1	75	15	10
14	6	1	-1	1	75	10	10
10	7	1	-1	-1	75	10	-
2	8	1	-1	-1	75	10	-
15	9	-1	1	1	90	15	10
17	10	0	0	0	82.5	12.5	5
1	11	-1	-1	-1	90	10	-
13	12	-1	-1	1	90	10	10
18	13	0	0	0	82.5	12.5	5
7	14	-1	1	1	90	15	10
8	15	1	1	1	75	15	10
5	16	-1	-1	1	90	10	10
4	17	1	1	-1	75	15	-
6	18	1	-1	1	75	10	15

2.2.1 Slurries Formulation of OPC blend with Metakaolin and Sawdust Ash

Slurries specific weights were fixed at 1.45-1.87 g/cm3 for the 600 ml slurry sample, according to API 10B recommended specification as reported by Falode et al. (2013). For comparative purposes, one set was formulated with cement and water only while another was formulated with blend of metakaolin (MK) and sawdust ash (SDA) with replacement up to 25% at underuse or excess addition of 5%-10% required by the model. The Preparation of slurry was carried out using Electronic Balance, sieves 850 µm wire cloth sieve (US sieve No. 20), in accordance with the requirements given in ASTM E11 for sieving cement prior to slurry preparation, Mixing Devices with capacity of about 1 L (1 qt) size, bottom-drive, blade-type mixer, with a timing device able to measure both 15 s and 35 s. The mixing device had the capacity to mix cement slurry at 4000 r/min rotational speed, and at 12,000 r/min ±250 r/min rotational speed. The formulation procedure included sieving the samples prior to mixing using a sieve size 0.85mm according to API 10B standards. The temperature of the mix water in the container was maintained within 60s at 23 °C ±1 °C in accordance to API 10A and B specifications. The mix water was weighed directly into a clean cylinder and poured into dry mixing container. The mixing quantities of slurry component for class B followed the specification in Table 2 for different class of oil well cement according to API 10A. The quantities of components based on factorial quantities were used for testing each run sample while maintaining a 0.46 W/C (46%) mix-water percentages for the various samples run following the report by Falode, et al.(2013), (Silas, et al.2022).

Table 2. Slurry mix requirements

Components	Classes A and B (g)	Class C (g)	Classes D and H (g)	Class G (g)
Mix water	355 ±0.5	383 ±0.5	327 ±0.5	349 ±0.5
Cement	772 ±0.5	684 ±0.5	860 ±0.5	792 .5

Source: API specification 10 A (2019)

The quantities of composite cement and mix-water was measured at ±0.5 g based on a calculated slurry volume of 600 ml. The mixing sample was poured into the container with the required mass of mix water, as specified in API 200A and as shown in Table 3, following mix proportions from the Factorial model pseudo mix based on class B cement. The motor is turned on and maintained at 4000 r/min ±250 r/min while the cement sample was added at a uniform rate during no more than 15 s. After 15 s at 4000 r/min ±250 r/min, there was continue mixing at 12,000 r/min ±250 r/min for 35 s ±1 s in conformity to API 10 A and B.

2.2.2 Fluid Loss of Oil Well Cementing Material Containing Metakaolin and Sawdust Ash

The test was designed to measure slurry dehydration during and immediately after cement placement. It is one of durability test parameters as a criterial and check for any given oil or gas well sustainability. Under simulated wellbore conditions, the slurry was tested for filtrate loss across a standardized filter press at differential pressures of 6.9 bars (100 psi). The test duration was 30 minutes and results were quoted as ml/30 min. API fluid-loss rate of 50-100 ml/30 min. (for 0.6 litres of slurry) is satisfactory in most primary cementing. The API fluid loss test was conducted at simulated elevated temperatures and a pressure differential of 100 psi through a 325 mesh screen. The recommended fluid loss values ranges from a maximum of 100 ml to no control. The recommended API fluid loss ranges from 50 to 250 ml for liners and 50 to 200 ml for squeeze cementing. For this study, the slurry was formulated by first measuring out the samples using the electronic weighing balance. Distilled water was measured using a measuring cylinder into the multi mixer cup then gradually the dry cementing material was added to the water in the multi mixer cup with the mud mixer to obtain homogenous mixture for 45 seconds. The formulated cement slurry was placed in the consistometer and conditioned for 20 minutes maintaining a temperature range

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of 45-65°C throughout the test. The filter cell was assembled in the following order; (i) Base cup (ii) Rubber gasket (iii) Screen (iv) A sheet of filter paper and (v) Cell body. The cell of the filter press was filled with the formulated slurry and secure to the base cap by rotating clockwise placed within the frame.

Table 3. Actual Mix Quantity for Slurry Samples

Sample	Mix volume (m^3)	Cement (g)	Metakaolin {MK} (g)	Sawdust ash {SDA} (g)	Water
N_1	0.0006	694.800	54.418	-	372.750
N_2	0.0006	694.800	54.418	-	372.750
N_3	0.0006	694.800	36.278	-	355.00
N_4	0.0006	579.000	54.418	-	319.500
N_5	0.0006	579.000	54.418	19.897	355
N_6	0.0006	579.000	36.278	19.897	337.250
N_7	0.0006	579.000	36.278	-	301.750
N_8	0.0006	579.000	36.278	-	301.750
N_9	0.0006	694.800	54.418	19.897	408.250
N_{10}	0.0006	636.900	45.340	9.93	355.000
N_{11}	0.0006	694.800	36.278		355.000
N_{12}	0.0006	694.800	36.278	19.897	390.500
N_{13}	0.0006	636.900	45.340	9.93	355.000
N_{14}	0.0006	694.800	54.418	19.897	408.250
N_{15}	0.0006	579.000	54.418	19.897	355.000
N_{16}	0.0006	694.800	36.278	19.897	390.500
N_{17}	0.0006	579.000	54.418		319.500
N_{18}	0.0006	579.000	36.278	19.897	337.250
C_1	0.0006	772.000	-	-	355
C_2	0.0006	772.000	-	-	355

A dry graduated cylinder was placed under the filtrate tube, on the support to receive the filtrate and then the relief valve was shut and pressure applied. This was carried out for 30 minutes during which the relief valve was closed and pressure shut. The filtrate value was determined by the volume of filtrate loss in the graduated cylinder. The filter cell was carefully removed and the filter cake thickness was extracted from the gasket. The API fluid loss was determined using Equation (4) given by API-RP-10B.

$$\text{Fluid Loss} = 2 \times Qt \times \left(\frac{5.477}{\sqrt{T}}\right) \quad (4)$$

Where, Qt is the volume (mL) of filtrate collected at the time, T (mins) is time of the "blowout".

2.2.3 Rheology Testing of Oil Well Cementing Material Containing Metakaolin and Sawdust Ash

The test was carried out to properly predict the frictional pressures that will occur while pumping the various fluids in the well. The rheological properties of the slurries are known to be a function of temperature (Batista, et al.2025). According to Shahriar and Nehdi (2016), the fundamental knowledge of oil well cement slurry rheology is necessary to evaluate the ability to remove mud and optimise slurry placement. Incomplete mud removal can result in poor cement bonding, zone communication and ineffective stimulation treatment (Broni-bediako, Joel, and Ofori-sarpong, 2016). The maximum temperature for the test was limited to about 190 oF (88 oC) (Anon, 2019). The slurry viscosity was measured using viscometer. The slurry sample was first conditioned for 20 minutes in an atmospheric Consistometer before measurements were taken. After mixing and preconditioning, the cement slurry sample was placed in the coaxial cylinder of the viscometer. The temperature of the viscometer was adjusted to the required level, each sample was then subjected to a stepped ramp or steady-state flow and viscosity measurements were taken at 20 different shear rates starting from 5.11 to 511 s-1 after a continuous rotation of 10 s and at each speed corresponding to the 600, 300, 200, 100, 60, 30, dial reading of OFITE model 800 viscometer which house 8 speeds. Readings were taken at ambient conditions and at BHCT; each sample measurements were limited to a maximum speed of 300 rpm. Readings were reported at 200, 100, 60, 30, 6 and 3 rpm following the procedure of API 10B. The 10 seconds and 10 minutes gel shear strength was measured by turning off the motor and turning it on after 10 seconds and 10minutes respectively. Therefore, each test was performed with a new cement slurry at 20 min after mixing. The plastic viscosity and the yield point values were obtained using Equations (5) and (6) respectively as used by (Broni, Joel and Ofori-sarpong 2016, and Anon, 2019).

$$\mu\,(cp) = 1.5(\theta 300 - \theta 100) \quad (5)$$

$$\tau o\,(lb/100ft2) = \theta 300 - \mu p \quad (6)$$

Where $\theta 300$ is 300 rpm dial reading and $\theta 100$ is 100 rpm dial reading.

2.2.4 Compressive Strength of Oil Well Cementing blended with Metakaolin and Sawdust Ash

The compressive strength test gives an indication of the compressive resistance a material have at any instant as well as its ability to sustain drilling well pressure at a given depth. It was carried out according to specifications of API. The cement-slurry mixing operation was carried out in a mixer in accordance with API SPEC 10. In the experiment moulded cubic test-samples with edges of 10.0cm were moulded. The samples were then subjected to a hydrating process (cure) in a thermal bath at 38°C for 8 hours, and 24hours while the temperature was in the range of 28°C - 35°C for 7days, and 28 days. This temperature was chosen to be near to downhole temperatures of oil wells that use the steam injection technique for oil recovery. This technique was used in wells up to 800m depth, approximately, because to greater depths the injected steam loses effectiveness.

After this step, a sample of each formulation was collected for compressive testing. Using the cement slurry formed from the 18 different experimental runs which were poured under ambient pressure and temperature conditions into the curing chamber. The blended Cement slurry was moulded to cubic moulds with diameter of 10.0 ±0.05 cm; thereafter the moulded samples underwent curing for 8 and 24 hours; 7days and 28days respectively. After the 8 and 24 hours, the compressive strengths of the formulations were measured using a continuous destructive method of determining compressive strength as a function of lad resistance through the measurement failure load of the samples according to API 10A and 10B. A standard destructive process by loading the sample axially until failure were computated using the Equation (7)

$$Fcu = \text{crushing load} / \text{Area of specimen (N/mm2)}. \quad (7)$$

3 Result and Discussion

3.1 Material Characterization

Sawdust ash was physically characterized as less dense of the three cementitious material. Following Table 4 the particle size of Sawdust ash and that of metakaolin have close distribution and comparable to the distribution of fly ash, silica fume, and OPC Type I/II as in the research reported by Ubachukwu and Silas (2017)

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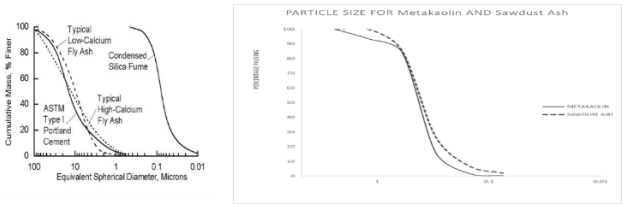

Fig. 1. Particle Size Distribution of Metakaolin and Sawdust Ash as compared to other pozzolan

Table 4. Summary of Physical Characteristics of Sample Material

Description/ Material	Sawdust Ash (SDA)	Metakaolin (MK)	Cement (OPC)
Bulk Density (g/cm³)	0.299	0.547	1.1164
Specific Gravity	1.597	2.064	3.12
Fineness Modulus (%)	3.6	3.726	2

The physical characteristic attribute of the sample material potentially present sawdust-ash as a positive constituent for tail cementing; while metakaolin (MK) makes a positive blending material in both case of lead or tail cementing respectively. The results from the chemical test yields a combine percentage composition of the major oxides including: [Silica (SiO_2), Aluminium Oxide (Al_2O_3), Iron oxide (Fe_2O_3) and Potassium Oxide (K_2O)] as shown in Table 5 for metakaolin to be 84.26% which is more than 70% of combined (SiO_2), (Al_2O_3), (Fe_2O_3) stipulated minimum index as reported by Ettu et al. (2016) thus classifies it as Class N pozzolan according to ASTM C618-15. Sawdust ash for this study had slightly lower composition of about 51%, classifying it as Class F pozzolan in accordance to report of Oladipupu,et al (2018). The pozzolanic activity of metakaolin was paramount as compared to that of sawdust; attributed to the use up of detrimental $Ca(OH)_2$ by production of hydration in the cement matrix by metakaolin as shown in Table 5a and 5b. Hence its potential positive blend in cementing for geothermal and deep well where $Ca(OH)_2$ by product is more.

Table 5a. Summary of Pozzolan test result of MK and SDA Metakaolin

Sample	Duration Of Heating (min)	volume of HCl Used (ml)	Titration Duration (min)
A	16	15.2	10
B	16	11.4	20
C	16	4.8	30
D	16	1.1	40

Table 5b. Summary of Pozzolan test result of SDA SawDust Ash

Sample	volume of H_2SO_4 Used (ml)	Shake/Titration Duration (min)
A	24.6	30
B	11.5	60
C	7.4	90
D	6.0	120

3.2 Slurry fluid loss Experimental Result

Samples blended with sawdust ash in combination with metakaolin kept the fluid loss within the maximum range of 50 to 250ml /30minutes in accordance to API RP-10B. Samples with only metakaolin blend as well as control samples with pure OPC ie C_1 and C_2 had the highest mean fluid loss of (484.970 and 508.645 ml/30min) at 10 and 11minutes blow out compared to other blended samples. The lowest loss was attributed to samples containing sawdust ash at high level (10%); these values placed slurry modified with sawdust ash as an excellent blende for liner cementing while other samples blended with only MK or MKSDA which had loss values within the recommended maximum fluid loss of (250 - 400 cc(ml) where excellent for primary cementing with reference to the report of Broni et al. (2016). Thus, sawdust ash (SDA) blend with metakaolin (MK) is a decent fluid loss and blowout controlling pozzolan reducing the slurry fluid loss by about 57%. the critical region as shown and interaction plot showed in Figure 4 indicates the full effect of sawdust ash in the slurry matrix with MKSDA represented as "BC" and sawdust ash as "C" exceeded the critical margin and had highest interactive effect.

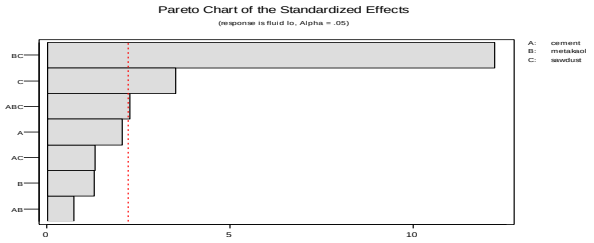

Fig. 4. Interactive Effect Significant Plot for fluid loss of Slurry

3.3 Slurry Rheology Experimental Result

The rheology parameter performance result showed that the blended slurry samples with sawdust ash as well as the control samples have plastic viscosity below 100 mPa.s (cp) compared to the samples N4 and N17 which contain only cement combination of metakaolin at high level (15%) replacement yielding plastic viscosity values (129cp, and 132cp). The result from the gel strength at 10 seconds and 10 minutes as displayed in Figure 5 shows control samples C1and C2 to have lowest value of gel strength compared to other samples. Also, for yield point shear stress, samples with metakaolin (MK) N1,N2,N8, as well as N17 had higher values (76.097, 68.702, 66.078,and 63.454) compared to the samples containing combinations of sawdust ash (SDA) at 10% (N13, N10, N3,N5,N18) (28.865,33.635, 52.481, 57.252, 57.968). Following the various parameter results, it is clearly inferred that metakaolin have negative effect on rheology parameters. Nevertheless, the interactive effect at all levels of the slurry blend combination of metakaolin with sawdust-ash improved the rheological components. Hence, it is a clear indication of the detrimental effect of metakaolin at high level blend (15%) on the cementing slurry in absence of saw dust ash.

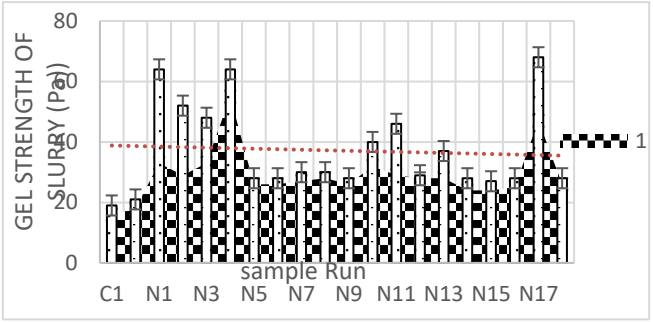

Fig. 5. Gel Strength of Slurry at 10 Seconds and 10 Minutes

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The impact of MKSDA blend for slurry rheology is expressed following the interactive effect on Figure 6, 7, and 8 for plastic viscosity, yield point, 10 seconds gel strength respectively. From the pareto chart it can been seen that sawdust ash had significant influence in theinteraction with OPC and metakaolin. In all three parameters, sawdust ash have the highest effect value followed by the combination between SDA and MK.

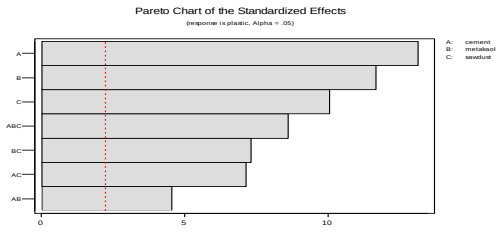


Fig. 6. Pareto and interaction effect Plot of Plastic Viscosity

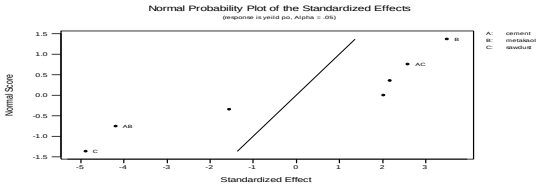


Fig. 7. Pareto and normal probability interaction effect Plot of Yield Point of Shear Stress

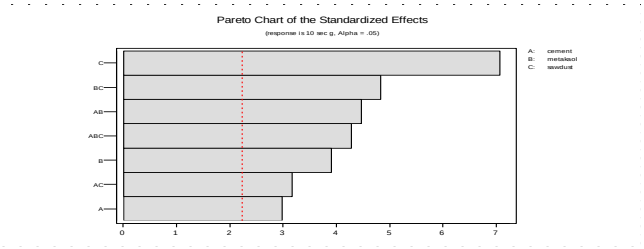
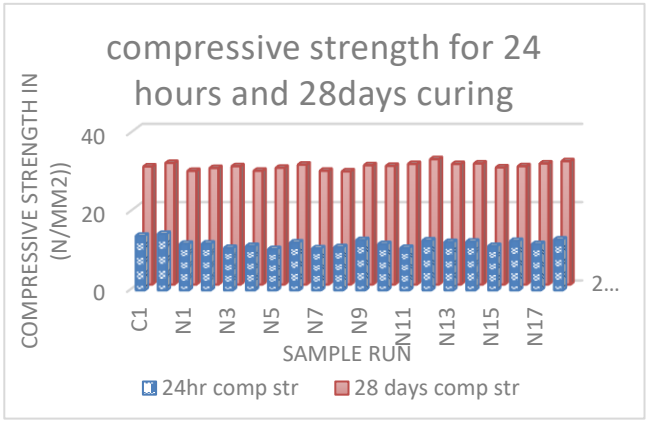


Fig. 8. Pareto Interaction Effect Plot for 10 Seconds Gel StrengthStrength

3.4 Compressive Strength of the MKSDA Blended Cement Experimental Result

From Figure 9 it is clear that the control samples C1 and C2 which contain only class B cement had the heights value of early strength after 24 hours of curing (13.9 and 14.4 N/mm2). The lowest values of strength or in other words samples with highest strength reduction where sample N5 (10.5N/mm2), sample N7 (10.7N/mm2), and N11 (10.8N/mm2) which had about 27.08% reduction in strength. These samples (N5 and N7) were samples of MKSDA blended with OPC up to 75% whereas samples at lower level class B OPC (70%), and with a high level blend of metakaolin (15%) and sawdust ash (10%) showed lower level of strength reduction at 24 hours curing period. After 28 days curing, the samples showed a progressive increase in strength for control and all blended samples with higher values for samples formulated with high level sawdust ash and metakaolin blend (10% and 15%) at 75%OPC. sawdust ash shows more influence in improving the strength at 28days when in high level blend with metakaolin at all levels of OPC incorporation. This could be attributed to the pozzollan filler tendency of the two combined materials in the micro matrix of the cemented cake and production of more calcium silicate hydrate (C-S-H) from reaction of the two pozzolans with the calcium hydroxide by product of OPC hydration. This results to progressive strength



increment as the age of the cement sheath increases based on the report by Ettu et al.(2016).

Fig. 9. Compressive Strength of Samples after 24 Hours and 28 Days Curing

4 Conclusion

Oil well cementing is a crucial process of drilling completion operation. The major influencing attribute for an oil well cementing material is basically its slurry properties as well as its influence on the well strength and durability. Based on the various factorial output focusing mainly on fluid loss and rheology showed that sample blend of (75%OPC, 10%MK, 10% SDA), had optimal performance with respect to both slurry and mechanical properties necessary to maintain excellent cementing process of new well as well as the integrity of the well over a longer period of its service life.

Sawdust Ash served as restrictive constituent and modifying pozzolan in controlling the detrimental effect of Metakaolin which is a more active pozzolan when in excess or alone in the replacement blend. Also Ordinary Portland Cement (OPC) blend of Metakolin and Sawdust Ash fine granule is recommended in addressing excessive fluid loss and water pocket formation as a durability check in cementing slurry paramount in geothermal and gas filled oil well prone to catastrophic failures.

Therefore, the blend of OPC, Metakolin and Sawdust ash is as an environmentally friendly material in addressing the impact of imported oil well cement dependency, pollution and reducing global carbon foot print. Further studies and research are recommended into other forms of pozzolan to ascertain its effect when blended for oil well cementing.

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