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Data Article

Data for analyzing drilling fluid ability to effectively achieve hole cleaning for high shear and low shear rates

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A R T I C L E I N F O

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A B S T R A C T

Rheological models such as Bingham Plastic or Power law models depict fluid behavior with points of the rheological relation which correspond to higher shear rates, but these models are fairly easy to solve for their specific descriptive parameters. Lower rpm (and hence shear rate), could be used to improve the performance and understanding of drilling mud at the lower shear rates prevailing in the wellbore. These data can be utilized in validating these rheological models and the essence of Equivalent Circulating Density (ECD) calculation in analyzing pressure drop in annular hole cleaning.

Specifications Table

Subject area	*Petroleum Engineering*
More specific subject area	*Drilling and Well Engineering*
Type of data	*Table, graph, figure*

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How data was acquired	*Experimental, Field data*
Data format	*Raw, analyzed*
Experimental factors	*The calculation of Equivalent Circulation Density (ECD) is dependent on accurate estimation of the annular pressure losses from the pressure gradient derived using these rheological models.*
Experimental features	*To analyze the various rheological models and attempt to identify an acceptable model for better appreciation of the annular pressure loss. Thus, derive the calculation of ECD while optimizing annular hole cleaning.*
Data source location	*Ota, Ogun State, Nigeria*
Data accessibility	*Data are available within this article*
Related research article	*None*

Value of the data

- The data can be applied in developing and validating a formula that will optimize hole cleaning during drilling operations.
- The data can be used to develop annular pressure loss model.
- The data can be utilized in obtaining direct model for the calculation of Equivalent Circulation Density.
- The data can be used to compare and justify the advantages and disadvantages of existing rheological models.

1. Data

Good hole cleaning practically depends on the type of weighting material and the model applied during drilling operation, [1,2]. The laboratory experiments data for the drilling fluid at different weighting agent concentration and field data are tabulated in Table 1.

Given the data in Table 1, we calculated the pressure gradient, pressure loss and ECD using some rheological models for each of the weighting materials (Tables 2 and 3). Fig. 1 illustrates the effect of Carbonate concentration on mud density while Fig. 2. Illustrate its effect on yield point and plastic viscosity [3,4].

2. Experimental design, materials, and methods

The laboratory work was carried out following the API standard and the materials used are tabulated in Table 4. The rheological tests which is the function of the hole cleaning and their weight properties were carried out using V-G meter and the mud balance as the measuring equipment [6,8].

Given the experimental and field data, the pressure loss and equivalent circulating density was calculated using Bingham Plastic and Power Law models for the calcium carbonates weighting agent [5,7,9].

1. **Bingham Plastic Model**

$$\mu = \theta_{600} - \theta_{300} = 62–47 = 15$$

$$\tau_Y = \theta_{300} - \mu = 47 - 15 = 32$$

Table 1
Mud properties using calcium carbonate as the weighting material and field data.

Activity	Standard	30 g Carbonate	60 g Carbonate	90 g Carbonate	120 g Carbonate
Drilling Mud Experimental Data					
600 rpm	56	62	74	86	106
300 rpm	45	47	53	64	76
200 rpm	39	42	47	51	65
100 rpm	28	30	34	39	43
6 rpm	19	20	26	29	38
3 rpm	15	22	24	32	15
Flow Rate, Q gpm	854	854	854	854	854
Mud Weight, ppg	8.7	9.1	9.4	10.2	10.7
Plastic Viscosity (PV), cP	11	15	21	22	30
Yield Point (YP), lb/100 ft^2	34	32	32	42	46
10 s Gel, lb/100 ft^2	25	21	28	31	43
10 min Gel, lb/100 ft^2	49	43	49	62	78
Well Field Data					
TVD, ft	2056	2056	2056	2056	2056
Length of Drill Collar (L_{DC}), ft	150	150	150	150	150
Length of Drill Pipe (L_{DP}), ft	2074	2074	2074	2074	2074
Length of Casing (L_{Csg}), ft	2156	2156	2156	2156	2156
Hole Internal Diameter, ft	16	16	16	16	16
Drill-pipe Outer Diameter, ft	5.5	5.5	5.5	5.5	5.5
Drill-collar Outer Diameter, ft	7.785	7.785	7.785	7.785	7.785
Casing Internal Diameter, ft	17.570	17.570	17.570	17.570	17.570

Table 2
Calculated data from experimental and field data using Bingham Plastic Model.

Activity	30 g Carbonate	60 g Carbonate	90 g Carbonate	120 g Carbonate	Standard
Pressure Loss along Drill Pipe in Casing					
Drill-pipe Outer Diameter, ft	5.5	5.5	5.5	5.5	5.5
Casing Internal Diameter, ft	17.570	17.570	17.570	17.570	17.570
Drill-pipe Length, ft	2074	2074	2074	2074	2074
Total Pressure Loss, ΔP, psi	27.760	27.868	36.477	40.056	29.407
Pressure Loss along Drill Pipe in Open Hole					
Drill-pipe Outer Diameter, ft	5.5	5.5	5.5	5.5	5.5
Hole Internal Diameter, ft	16.0	16.0	16.0	16.0	16.0
Length of Drill-pipe, ft	82	82	82	82	82
Total Pressure Loss, ΔP, psi	1.267	1.274	1.665	1.831	1.340
Pressure Loss along Drill Collars					
Drill-collar Outer Diameter, ft	7.785	7.785	7.785	7.785	7.785
Hole Outer Diameter, ft	16.0	16.0	16.0	16.0	16.0
Drill-collar Length, ft	150	150	150	150	150
Total Pressure Loss, ΔP, psi	2.981	3.005	3.922	4.319	3.148
Equivalent Circulating Density	9.40	9.70	10.59	11.13	9.02

a. Pressure Loss along Drill Pipe in CASING

$$V = \frac{q}{2.448(d_2^2 - d_1^2)} = \frac{854}{2.448(17.570^2 - 5.5^2)} = \frac{854}{2.448(278.455)} = \frac{854}{681.6576} = 1.2528 \text{ ft/sec}$$

$$\frac{dP}{dL} = \frac{\mu V}{1000(d^2 - d^1)^2} + \frac{\tau_Y}{200(d^2 - d^1)} = \frac{15 \times 1.2528}{1000(17.570 - 5.5)^2} + \frac{32}{200(17.570 - 5.5)}$$

$$= 0.000128994 + 0.013256007 = 0.013385 \text{ psi/ft}$$

$$\Delta P_{drillpipes\backslash in\backslash casing} = dP/dL \times length\backslash of\backslash drill\backslash pipe\backslash in\backslash casing$$

$$= 0.013385 \times (2074) = 27.76049056 \text{ psi}$$

b. Pressure Loss along Drill Pipe in OPEN HOLE

$$V = \frac{q}{2.448(d_2^2 - d_1^2)} = \frac{854}{2.448(16^2 - 5.5^2)} = \frac{854}{2.448(225.75)} = \frac{854}{552.636} = 1.5453 \text{ ft/sec}$$

$$\frac{dP}{dL} = \frac{\mu V}{1000(d_2 - d_1)^2} + \frac{\tau_Y}{200(d_2 - d_1)} = \frac{15 \times 1.5453}{1000(16 - 5.5)^2} + \frac{32}{200(16 - 5.5)}$$

$$= 0.000210248 + 0.015238095 = 0.015448343$$

$$\Delta P_{drillpipes\backslash in\backslash open\backslash hole} = dP/dL \times length\backslash of\backslash drill\backslash pipe\backslash in\backslash open\backslash hole$$

$$= 0.015448343 \times 82 = 1.266764125 \text{ psi}$$

Table 3
Calculated data from experimental and field data using Power Law Model.

Activity	30 g Carbonate	60 g Carbonate	90 g Carbonate	120 g Carbonate	Standard
Pressure Loss along Drill Pipe in Casing					
Drill-pipe Outer Diameter, ft	5.5	5.5	5.5	5.5	5.5
Casing Internal Diameter, ft	17.570	17.570	17.570	17.570	17.570
Drill-pipe Length, ft	2074	2074	2074	2074	2074
Total Pressure Loss, ΔP, psi	0.134	0.178	0.198	0.243	0.131
Pressure Loss along Drill Pipe in Open Hole					
Drill-pipe Outer Diameter, ft	5.5	5.5	5.5	5.5	5.5
Hole Internal Diameter, ft	16.0	16.0	16.0	16.0	16.0
Length of Drill-pipe, ft	82	82	82	82	82
Total Pressure Loss, ΔP, psi	0.007	0.008	0.009	0.011	0.006
Pressure Loss along Drill Collars					
Drill-collar Outer Diameter, ft	7.785	7.785	7.785	7.785	7.785
Hole Outer Diameter, ft	16.0	16.0	16.0	16.0	16.0
Drill-collar Length, ft	150	150	150	150	150
Total Pressure Loss, ΔP, psi	0.016	0.021	0.023	0.027	0.016
Equivalent Circulating Density	9.10	9.40	10.20	10.70	8.70

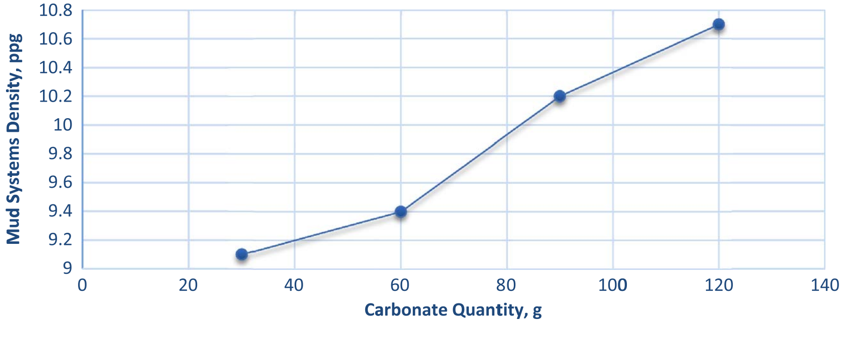

Fig. 1. Effect of carbonate weighting agent concentration on mud system density.

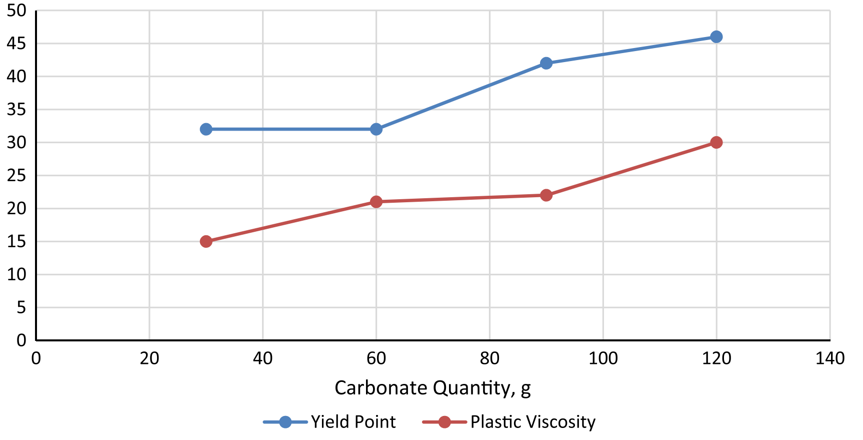

Fig. 2. Effect of carbonate weighting agent concentration on Mud System Yield Point and *Plastic Viscosity*.

Table 4
Materials and additives used in formulating the water based muds (WBM).

Product name	Mixing order & time	Brand name	Product specific gravity	Product concentration field barrel		Product concentration lab barrel	
	Min			Lbs/Bbl	Gals/Bbl	Grams	Mils
WATER	0	Water	1	251.00		251.00	342.94
Viscosifier 2	2		1.5	1.50		1.50	1.00
Fluid loss Additive 1	1	LV	2	0.15		1.25	1.25
Alkalinity		Soda Ash	2.5	0.25		0.25	0.10
NACL	2	NACL	3.31	14.54		14.54	4.37
Other	1	Caustic Soda	2.13	0.25		0.25	0.12
Other	2	X-CIDE 102	1.07	0.25		0.25	0.23
							350.01

c. Pressure Loss along Drill Collar

$$V = \frac{q}{2.448(d^{22} - d^{12})} = \frac{854}{2.448(16^2 - 7.875^2)} = \frac{854}{2.448(256 - 62.015625)} = 1.7854$$

$$\frac{dP}{dL} = \frac{\mu V}{1000(d_2 - d_1)^2} + \frac{\tau_Y}{200(d_2 - d_1)} = \frac{15 \times 1.7854}{1000(16 - 7.785)^2} + \frac{32}{200(16 - 7.785)}$$
$$= 0.000396837 + 0.019476567 = 0.019873404 \text{ psi/ft}$$

$$\Delta P_{\text{drillcollar}} = \frac{\text{dP}}{\text{dL}} \times \text{length\of\drill\collar} = 0.019873404 \times 150 = 2.981010597 \text{ psi}$$

$$\textbf{Total\Pressure\Loss } \Delta\text{P} = \Delta\text{P}_{\text{drillpipes\in\casing}} + \Delta\text{P}_{\text{drillpipes\in\open\hole}} + \Delta\text{P}_{\text{drillcollar}}$$
$$= 27.76049056 + 1.266764125 + 2.981010597 = 32.00826597 \text{ psi}$$

$$ECD = MW + \frac{\Delta P}{0.052 \quad TVD} = 10.33 + \frac{32.00826597}{0.052 \times 2074} = 9.1 + 0.30 = 9.40 \text{ lbm/ft}^3$$

2. **Power Law Model**

$$n_a = 0.657\ \log(\theta_{100} - \Theta_3) = 0.657 log\left(\frac{30}{15}\right) = 0.657 log\ 0.2 = 0.657 \times 0.3010 = 0.1978$$

$$K_a = \frac{5.11 \times \Theta_3}{5.11^{\text{na}}} = \frac{5.11 \times 15}{5.11^{0.1978}} = \frac{76.65}{1.3807} = 55.5141$$

a. Pressure Loss along Drill Pipe in CASING

$$V = \frac{q}{2.448\ (d_2^2 - d_1^2)} = \frac{854}{2.448(17.570^2 - 5.5^2)} = \frac{854}{2.448(278.455)} = \frac{854}{681.6576} = 1.2528$$

$$\frac{dP}{dL} = \frac{KV^{\text{n}}\left(\frac{(2+\frac{1}{n})}{0.0208}\right)\text{n}}{144{,}000(d-d)^{1+\text{n}}} = 55.5141 \times (1.2528^{0.1978})\left[\frac{2 + \frac{1}{0.1978}}{\frac{0.0208}{144{,}000(17{,}570 - 5.5)^{1.1978}}}\right]^{0.1978}$$

$$= \frac{55.5141 \times 1.0458820837308 \times 3.16574213831685}{144,00 \times 19.75348705322220} = \frac{183.7550233}{2844502.136}$$

$$= 0.0000646001\ \text{psi/ft}$$

$$\Delta \text{P}_{\text{drillpipes in casing}} = \text{dP/dL} \times \text{length of drill pipe in casing} = 0.0000646001 \times 2074 = 0.133980535\ \text{psi}$$

b. Pressure Loss along Drill Pipe in OPEN HOLE

$$V = \frac{q}{2.448\ (d_2^2 - d_1^2)} = \frac{854}{2.448(16^2 - 5.5^2)} = \frac{854}{2.448(256 - 30.25)} = \frac{854}{2.448 \times 225.75} = 1.5453$$

$$\frac{dP}{dL} = \frac{KV^{\text{n}}\left(\frac{(2+\frac{1}{n})}{0.0208}\right)\text{n}}{144{,}000(d-d)^{1+\text{n}}} = 55.5141 \times (1.5453^{0.1978})\left[\frac{2 + \frac{1}{0.1978}}{\frac{0.0208}{144{,}000(16 - 55)^{1.1978}}}\right]^{0.1978}$$

$$= \frac{55.5141 \times 1.08989207762134 \times 3.16574213831685}{144,00 \times 16.7169389342758} = \frac{191.5411273}{2407239.207}$$

$$= 0.0000795688\ \text{psi/ft}$$

$$\Delta \text{P}_{\text{drillpipes in open hole}} = \text{dP/dL} \times \text{length of drill pipe in open hole} = 0.0000795688 \times 82 = 0.006524641\ \text{psi}$$

c. Pressure Loss along Drill Collar

$$V = \frac{q}{2.448\ (d_2^2 - d_1^2)} = \frac{854}{2.448(16^2 - 7.785^2)} = \frac{854}{2.448(195.393775)}$$

$$= \frac{854}{478.3239612} = 1.7854\ \frac{dP}{dL} = \frac{KV^{\text{n}}\left(\frac{(2+\frac{1}{n})}{0.0208}\right)\text{n}}{144,000(d_2 - d_1)^{1+\text{n}}}$$

$$= 55.5141 \times (1.7854^{0.1978})\left[\frac{2 + \frac{1}{0.1978}}{\frac{0.0208}{144{,}000(16 - 7.785)^{1.1978}}}\right]^{0.1978}$$

$$= \frac{55.5141 \times 1.12146949399352 \times 3.16574213831685}{144,00 \times 12.4593573139003} = \frac{478.3239612}{1794147.453}$$

$$= 0.000108852\ \text{psi/ft}\Delta \text{P}_{\text{drillpipes in drill collar}} = \text{dP/dL} \times \text{length of drill collar} = 0.000108852 \times 150 = 0.016477796\ \text{psi}$$

Total Pressure Loss $\Delta \mathbf{P}$ $= \Delta \text{P}_{\text{drillpipes in casing}} + \Delta \text{P}_{\text{drillpipes in open hole}} + \Delta \text{P}_{\text{drillcollar}} = 0.133980535 + 0.006524641 + 0.016477796 = 0.156982973\ \text{psi}$

$$ECD = MW + \frac{\Delta P}{0.052\,TVD} = 9.1 + \frac{0.15682973}{0.052 \times 2074} = 9.10\ \text{lbm/ft}^3$$

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Transparency document. Supporting information

Transparency data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.06.007.

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