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Apparent Viscosity Direct from Marsh Funnel Test

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Abstract

Accurate and simple techniques for measurement of fluid rheological properties are important for field operations in the oil industry. Marsh Funnels are popular quality-control tools used in the field for drilling fluids and they offer a simple, practical alternative to viscosity measurement. In the normal measurements, a single point (drainage time) is used to determine an average viscosity; little additional information is extracted regarding the non-Newtonian behavior of the fluid.

Here, a new model is developed and used to determine the rheological properties of drilling muds and other non-Newtonian fluids using data of fluid density and drainage time collected from a Marsh Funnel as a function of viscosity. The funnel results for viscosity compare favorably to the values obtained from a commonly-used Fann 35 viscometer. Different quantities of bentonite, barite and other additives which have been used to prepare many samples. Empirical equations are obtained

$\mu_{app.} = \rho\ (t - 28)$ and $\mu_{app.} = -0.0118t2 + 1.6175t - 32.168$,

where apparent viscosity ($\mu_{app.}$) in (cp), Marsh funnel time (t) in seconds and the density (ρ) in gm/cm3.

Introduction

Hydrocarbon production uses many fluids that are rheologically complex. Among these is cement, drilling muds, aqueous solutions of water-soluble polymer and of course crude oil itself.

Drilling fluids can be air or water, but most commonly they are “muds” or suspensions of solids in an aqueous or oleic fluid. The solids are suspended with one or more surfactants. The solids are used to provide weight to the mud for pressure control, the main function of muds, but muds also lubricate the drill, carry drilling cuttings to the surface and cool the bit. Most muds are water-based as is the type used in this study. When fresh water is the liquid base, bentonite is the clay used for its superior properties necessary to achieve the goals stated for drilling mud [1]. Water-based fluids are suspensions of weight material in water, but also contain a number of additives to control fluid properties such as rheology, fluid loss, shale inhibition and lubricity. The standard weight material is API barite. There are also non-standard weight materials with considerably finer particle size, which generate low rheology and are used in some high-density and/or slim-hole applications. The liquid phase of drilling fluids generally contains a number of additives to control the various required properties of fluids, including one or more rheology additives to suspend the weight material. Thus, fluid rheology is generated partly by the suspended solids and partly by the rheology additives [2, 3]. Drilling mud exhibits several important rheological properties [4]. The viscosity or consistency index of a mud is a measure of flow resistance. Therefore viscosity should be as small as possible to limit friction pressure. However a certain amount of viscosity is required to improve the solids carrying capacity of the mud. If viscosity is too small, the mud may be unable to suspend drilled solids at the desired pump rate. This requires the pumps to be run faster to continue to circulate drilled solids out of the well. If viscosity is too high, an excessive pump pressure will be required to circulate the mud at the desired rate. Higher than necessary pump pressure is an added strain on the pumps and piping and an added pressure in the bore hole that can lead to well bore stability problems. Non-Newtonian fluids (drilling muds and polymers) may also exhibit a yield stress (or gel strength). For drilling operations, the higher the yield stress the more pump pressure will be required to initiate circulation. The yield stress can also be a desirable property because it will suspend the drilled solids and prevent or slow them from slipping back to the bottom of the hole during periods when there is no circulation. Fluid yield stress in fracturing fluids for example can help carry and suspend proppant, but can also make cleanup difficult [5]. Below the yield stress the material is solid-like and has an infinite viscosity. The solid-like behavior is typically a result of a three-dimensional microstructure at low stresses [6]. Above the yield stress the material deforms as a fluid and the viscosity is a function of shear rate. Many pastes, foodstuffs, gels, and drilling muds have a yield stress. The simplest yield-stress model is the Bingham model, in which the relationship between shear stress and shear rate is linear, with the yield stress defined as the extrapolated *y*-axis intercept [2].

Marsh Funnel

The Marsh Funnel was invented by Hallan N. Marsh in 1931 [7]. It is used to measure the time in seconds required to fill a set volume of fluid. (In the United States the volume is one quart.) The flow through the small tip at the end of the funnel is related to the rheological properties of the fluid being measured. The Marsh Funnel "viscosity" is reported as seconds and used as an indicator of the relative consistency of fluids. The more viscous the fluid the longer the time to fill one quart. The calibration for Marsh Funnel time is 28 seconds per quart for fresh water. The standard Marsh Funnel is shown in Fig. 1 . The Marsh Funnel provides a simple and effective tool to determine the relative viscosity of drilling mud. Here, we also use the funnel for additional oilfield fluids.

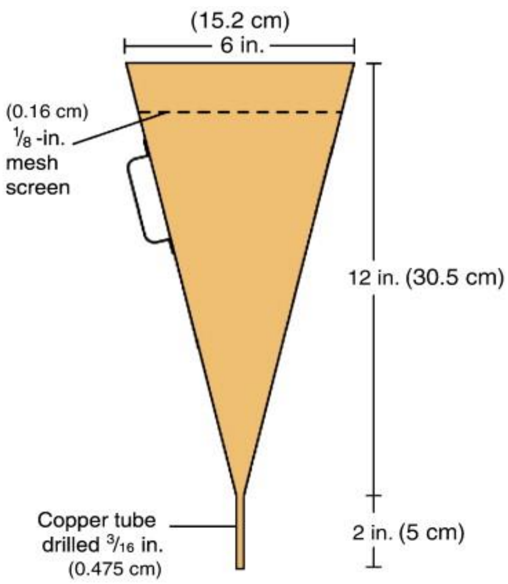

Fig. 1, Standard Marsh Funnel

Figure 1 shows that the height of cone-portion of the funnel is 12 in.

(30.5 cm) and the diameter is 6 in. (15.2 cm). The copper tubing is 2 in. (5.08 cm) in length and has a diameter of 3/ in. (0.48 cm).

Although rheological properties of these fluids can be measured by conventional rheometers, a simple method is often needed. The goal of this work is to develop such a method for determining rheological properties of non-Newtonian fluids using a Marsh Funnel. An experiment consists of filling the funnel to a pre-specified height and measuring the rate at which the test fluid drains.

The flow behaviour of a Marsh funnels is simulated numerically [8]. As a result, his simulation provides a general picture of the meaning of the Marsh funnel time and a correlation enabling this to be converted into a value for effective viscosity of non-Newtonian fluids. The final equation for M.J. Pitt is:

$$\mu_{eff.} = \rho\ (t - 25) \qquad \ldots(1)$$

Where: $\mu_{eff.}$ = effective viscosity (cp); ρ= density (gm/cc); t=time (sec.)

The model presented in this work can estimate the apparent viscosity instead of effective viscosity depends on Pitt's equation in this study we used experimental data instead of numerical simulation.

Fluid Preparation

Many of the fluids used in these experiments must be mixed before testing. The used fluids are water-based fluids. Before adding any solid particles or polymer to the water-based fluids used here, water was adjusted to approximately a pH of 9 by adding droplets of NaOH (sodium hydroxide). For all tests, the fluid was at room temperature (~ 30 °C), the density was measured using a density balance, and the rheology measured using a Fann V. G. 35 viscometer. Fluid was then poured in the Marsh Funnel for the tests.

Different quantities of bentonite, barite and other additives which have been used to prepare samples and the measured values are listed in table 1.

Marsh Funnel Test

After the fluid rheology is measured, the fluid is placed in the Marsh Funnel as shown in table 1.

The Marsh Funnel is designed so that 1500 mL of fluid can be poured into the funnel. A small stopper is placed in the orifice at the bottom to prevent flow out while the fluid is poured into the funnel. Once it reaches the bottom of the screen, this indicates that 1500 mL now rests in the funnel. The purpose of screening is to remove any unmixed solid particles from the rest fluid.

Results and Discussion

After measuring the fluid properties from Lab., an experimental correlation between the apparent viscosity and Marsh time is estimated as:

$$\mu_{app.} = -0.0118t^2 + 1.6175t - 32.168 \quad \ldots(2)$$

as shown in Fig. 2. Also, we investigated that the apparent viscosity is equal to

$$\mu_{app.} = \rho\ (t - 28) \qquad \ldots(3)$$

Depend on Marsh time and density together as shown in Fig. 3.

Table 2 shows the results of viscosity which show all calculations to determine the viscosity from observed equations. In addition, the accuracy of the present work compared to the true data.

Table 1, Fluid properties from Lab

No.	Marsh time (second)	Density (gm/cm^3)	app viscosity from lab. (true value); cp
1	40.15	1.025	11.5
2	36.8	1.032	10
3	35.14	1.045	10
4	34.58	1.05	10.25
5	34	1.053	10.75
6	44.6	1.03	15
7	44.4	1.04	15
8	43.21	1.05	15
9	42.03	1.05	15.25
10	40.9	1.051	15.75
11	55	1.03	20.5
12	55.6	1.035	20
13	49.88	1.04	20.5
14	49.13	1.047	21
15	49	1.049	21
16	45	1.02	14.5
17	40	1.035	11.5
18	39	1.04	10.5
19	38	1.053	11
20	36.2	1.06	11
21	36	1.1	10
22	36.2	1.1	10.5
23	45	1.035	22.5
24	46.76	1.043	17.5
25	42.08	1.06	15
26	39.63	1.079	13
27	38.53	1.098	11.5
28	38	1.15	10.5
29	59.11	1.03	19.5
30	43.78	1.035	15.5
31	41.67	1.055	15
32	40.79	1.08	13.5
33	39.78	1.09	13.5
34	38	1.11	12.5

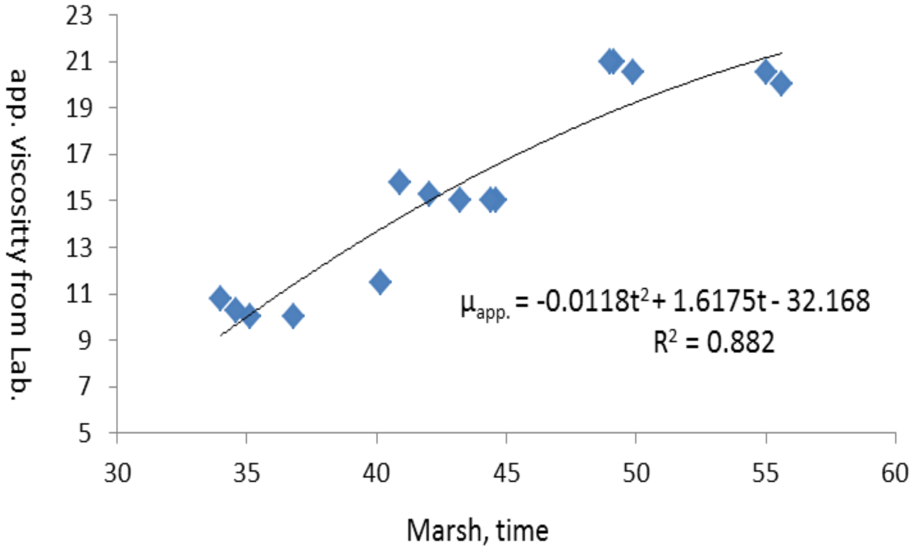

Fig. 2, The relationship between true app. viscosity (cp) Vs. Marsh funnel time(sec.)

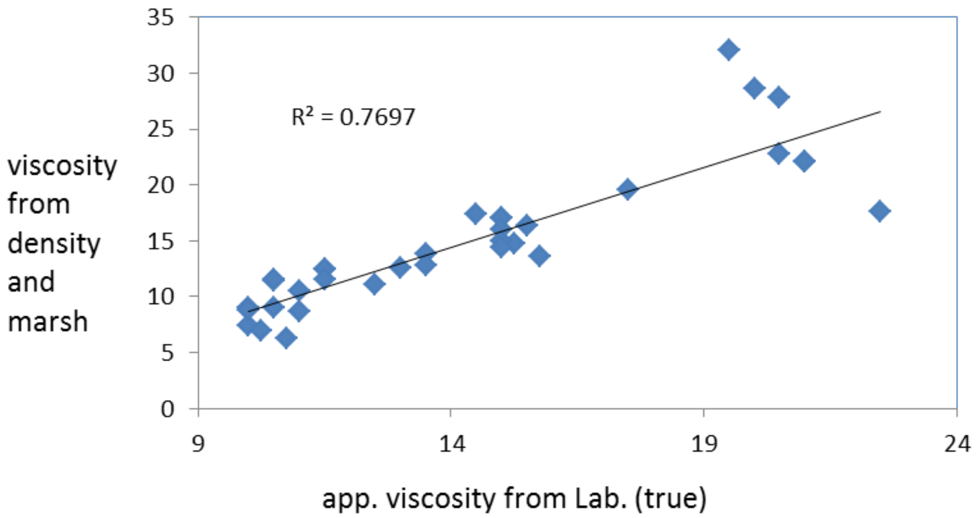

Fig. 3, The relationship between true app. viscosity (cp) Vs.. μ_{app} from equation (3)

Table 2, Apparent Viscosity Calculations

N	Marsh time	density	app viscosity from lab	Vis.= den. (t-28)	app. Viscosity from time only	Vis.= den. (t-25)
1	40.15	1.025	11.5	12.45375	12.96296666	15.52875
2	36.8	1.032	10	9.0816	11.20376633	12.1776
3	35.14	1.045	10	7.4613	10.37067288	10.5963
4	34.58	1.05	10.25	6.909	10.09549982	10.059
5	34	1.053	10.75	6.318	9.813648558	9.477
6	44.6	1.03	15	17.098	15.45686264	20.188
7	44.4	1.04	15	17.056	15.34100763	20.176
8	43.21	1.05	15	15.9705	14.65894974	19.1205
9	42.03	1.05	15.25	14.7315	13.99500999	17.8815
10	40.9	1.051	15.75	13.5579	13.37086832	16.7109
11	55	1.03	20.5	27.81	21.95340737	30.9
12	55.6	1.035	20	28.566	22.35578865	31.671
13	49.88	1.04	20.5	22.7552	18.64076205	25.8752
14	49.13	1.047	21	22.12311	18.17394784	25.26411
15	49	1.049	21	22.029	18.09351863	25.176
16	45	1.02	14.5	17.34	15.68962422	20.4
17	40	1.035	11.5	12.42	12.88199777	15.525
18	39	1.04	10.5	11.44	12.34744062	14.56
19	38	1.053	11	10.53	11.822043	13.689
20	36.2	1.06	11	8.692	10.89965975	11.872
21	36	1.1	10	8.8	10.79904076	12.1
22	36.2	1.1	10.5	9.02	10.89965975	12.32
23	45	1.035	22.5	17.595	15.68962422	20.7
24	46.76	1.043	17.5	19.56668	16.73033785	22.69568
25	42.08	1.06	15	14.9248	14.02289131	18.1048
26	39.63	1.079	13	12.54877	12.6831489	15.78577
27	38.53	1.098	11.5	11.56194	12.09935823	14.85594
28	38	1.15	10.5	11.5	11.822043	14.95
29	59.11	1.03	19.5	32.0433	24.76824529	35.1333
30	43.78	1.035	15.5	16.3323	14.98409134	19.4373
31	41.67	1.055	15	14.42185	13.79492469	17.58685
32	40.79	1.08	13.5	13.8132	13.31072456	17.0532
33	39.78	1.09	13.5	12.8402	12.76361318	16.1102
34	38	1.11	12.5	11.1	11.822043	14.43

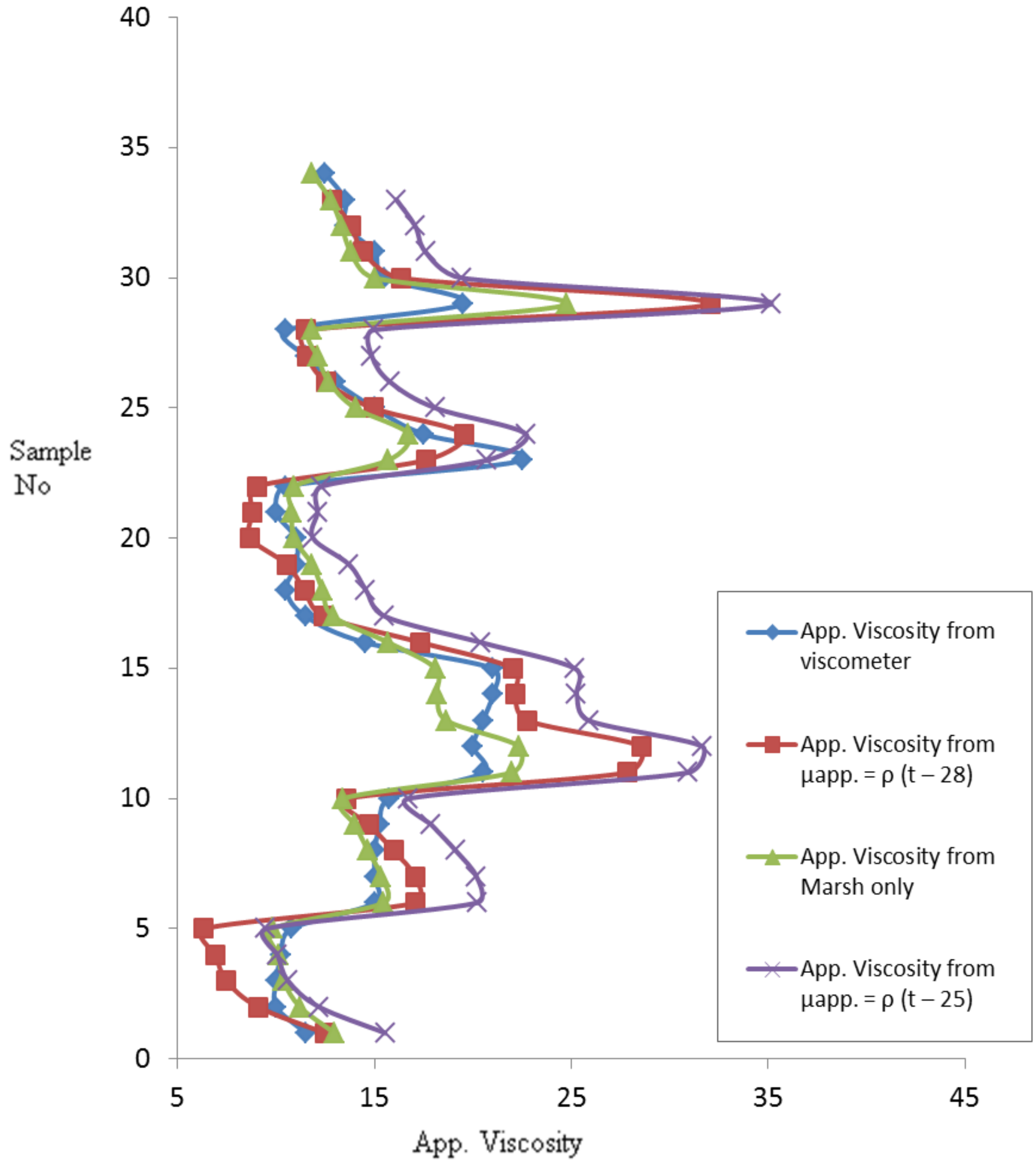

Fig. 4, App. Viscosity from different methods

Conclusions:

A clear relationship between the Marsh Funnel viscosity (t) and the apparent viscosity was obtained through this study, as well as, an equation correlating the apparent viscosity to both density and Marsh Funnel viscosity (t) is presented.

The comparison between the obtained equation 3 and the equation given by M. J. Pitt equation 1 show that constant (28) is more accurate and appropriate than constant (25) given by the same author. (see table 2)

Figure 4 Shows that the relationship No. 2 is more accurate and it can be recommended for use as a relationship between the apparent viscosity measured from the device (multi-speed viscometer) and the viscosity values measured as time from Marsh Funnel. (see table 2)

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