



Sudan University of Science and Technology
College of Petroleum Engineering & Technology
Petroleum Engineering Department



Calculation Rheological Properties of Water Base Mud

Using Marsh Funnel

حساب الخصائص الريولوجية لسائل الحفر ذو الأساس المائي
باستخدام قمع مارش

Project submitted to College of Petroleum Engineering & Technology in partial fulfillment of the requirement for the degree of B.Sc in Petroleum Engineering

Prepared by

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October 2015

Research about:

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الاستهلال

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طه الآية 114

Dedication

We would like to donate this unpretentious effort
To the spirit of **Dr. Mohammed Naeim**

Our Parents;

Who have endless presence and for the never
ending love and encouragement

Our brothers and sisters;

Who sustained us in our life and still

Our teachers;

Who lighted candle in our ways and provided us
with light of knowledge

Finally; our best friend;

Our classmates

Researchers...

Acknowledgement

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First and foremost; the greatest thanking to our supervisor Eng. **Fatima Ahmed Altigan** for her continuous support.... and for her great efforts, she was the best guide and ad monitor....

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Finally; thanking to our teachers, colleagues and workers at college of Petroleum Engineering & Technology for their cooperation.....

ABSTRACT

Rheology is the study of the flow of matter, primarily in a liquid state, but also as 'soft solids' or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force. It applies to substances which have a complex microstructure, such as muds, sludges, suspensions, polymers and other glass formers (*e.g.*, silicates), as well as many foods and additives, bodily fluids (*e.g.*, blood) and other biological materials or other materials which belong to the class of soft matter. In this study, Marsh Funnel is used to determine the rheological properties, namely, apparent viscosity and plastic viscosity of drilling fluid. Funnel drainage volume and corresponding drainage time are two measured variables for this analysis. Drainage volume is used to predict funnel wall shear stress whereas drainage rate is used to estimate funnel wall shear rate. The predicted shear rate is independent of rheological models. Apparent viscosity and plastic viscosity are determined from the funnel consistency plot. Water base mud and the suspension of several drilling fluid additives (*e.g.*, bentonite, barite, caustic soda, soda ash, kcl, pac-lv and flowzan) with practical importance have also been used to determine apparent viscosity and plastic viscosity using the Marsh Funnel readings which were used in a software program named MF system (visual basic) to give the final results. Finally, the Marsh Funnel rheological results are also compared with the 6 Speed viscometer results.

التجريد

الريولوجيا هو دراسة تدفق المادة، في المقام الأول في حالة السيولة ، ولكن يوجد أيضا باسم "المواد الصلبة الناعمة" أو المواد الصلبة في ظل الظروف التي تستجيب مع تدفق البلاستيك بدلا من تشويه مطاطيا ردا على القوة المطبقة عليها. وهو ينطبق على المواد، مثل الأطيان، الحماية، والمعلقات، والبوليمرات وصناعة الزجاج بصورة أخرى (على سبيل المثال، السيليكات)، فضلا عن العديد من الأطعمة والمواد المضافة، سوائل الجسم (مثل الدم) وغيرها من المواد البيولوجية أو غيرها المواد التي تنتمي إلى فئة من المواد الناعمة.

في هذه الدراسة، تم استخدام قمع مارش لتحديد خصائص الانسيابية (التياريه)، وهي اللزوجة الظاهرية واللزوجة البلاستيكية لسائل الحفر. تم قياس حجم التصريف من قمع مارش مقابل وقت التصريف. استخدم حجم التصريف للتنبؤ بإجهاد القص من قمع مارش في حين استخدم معدل التصريف لتقدير معدل القص. معدل القص هو توقع مستقل من النماذج الانسيابية. تم تحديد اللزوجة الظاهرية واللزوجة البلاستيكية من الرسومات. تم استخدام سائل حفر للاساس المائي مع بعض الإضافات (على سبيل المثال، والبنتونايت والباريات، والصودا الكاوية ورماد الصودا) لتحديد اللزوجة الظاهرية واللزوجة من البلاستيكية من قراءات قمع مارش ثم تم إدخال هذه البيانات في البرنامج الحاسوبي المسمى (MF system) بلغة Visual basic. ثم مقارنة النتائج المأخوذة من الجهازين قمع مارش وجهاز 6 speed Viscometer .

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NOMENCLATURE

Q : flow rate (cm³/s)

V : Volume (cm³)

T :Time (s)

Z : liquid height above the capillary section of the funnel, cm

V_o : initial volume of fluid taken in the funnel, cm³

R_l : radius of the cylindrical section, cm

Z_2 : length of conical section of the funnel, cm

Z_2 : length of the capillary section of the funnel, cm

R_o : radius of the funnel at 20 mesh screen, cm

g: acceleration due to gravity, m/s²

ρ : fluid density, kg/m³

:wall shear rate, s⁻¹ $\dot{\gamma}_w$

:wall shear stress (Pa) τ_w

:Apparentviscosity (cp) μ_a

: Plasticviscosity(cp) μ_p

Chapter 1:

INTRODUCTION

Chapter 1

Introduction

The flow properties of the drilling fluid play a vital role in the success of the drilling operation. These properties are primarily responsible for removal of the drill cuttings, but influence drilling progress in many other ways. Unsatisfactory performance can lead to such serious problems as bridging the hole, filling the bottom of the hole with drill cuttings. Reduced penetration rate, hole enlargement, stuck pipe, loss of circulation, and even a blowout. The science of rheology is the study of the deformation of all types of matter. The rheology is interested primarily in the relationship between flow rate and flow pressure and the influence thereon of fluid flow characteristic.

Marsh Funnel is used to determine the rheological properties, namely, yield point, apparent viscosity and plastic viscosity of drilling fluid. Funnel drainage volume and corresponding drainage time are two measured variables for this analysis. Drainage volume is used to predict funnel wall shear stress whereas drainage rate is used to estimate funnel wall shear rate. The predicted shear rate is independent of rheological models. Yield point is calculated from remaining volume of fluid in the funnel at the end of the experiment under no flow condition whereas apparent viscosity and plastic viscosity are determined from the funnel consistency plot. Synthetic crude oil and the suspension of several drilling fluid additives (e.g., bentonite, polyethylene glycol–sodium chloride and polyethylene glycol–sodium chloride–bentonite) with practical importance have also been used to determine yield point, apparent viscosity and plastic viscosity using the Marsh Funnel readings. Finally, the Marsh Funnel rheological results are also compared with the 6-Speed Rotational Viscometer results.

Rheological properties are parameters describe the deformation of fluids and flow of matter . fluid viscosity (apparent viscosity and plastic viscosity), friction pressure losses and annular borehole cleaning. All those properties can be determined by the Marsh funnel and viscometer.

Viscosity is a measure of the resistance of fluid to an applied stress. Viscosity essentially describes a liquids internal resistance to flow and may be thought of as a measure of its internal friction.

The measurement of viscosity is a fairly simple test and the result reported is generally a single number. For the results of a viscosity test to be relevant, they should be compared to the results of tests done at the same temperature. It is normal for fluids to become more viscous at colder temperatures and less viscous at higher temperatures.

Rheology applies to substances that have a complex structure, including: mud's, sludge's, suspensions, polymers, petrochemicals and biological materials. The flow of these complex materials

can't be characterized by a single value of viscosity, instead viscosity changes with changing condition. For example, ketchup's viscosity lowers when it is shaken and corn flour's viscosity increases when is struck.

In practices, rheology is concerned with materials whose properties are between purely elastic material and Newtonian fluids, where mechanical behavior can't be described classic theories.

1.1 Problems Statement :

Generally, the drilling operations must be economic and more effective. Rheogelical properties are consider the main part in drilling fluid.

This properties are determine by using many devises (Marsh Funnel , Viscometer and a lot of modern devices). Viscometer is an accurate device but have some limitations and many failures such as (high cost and sometimes impractical).

1.2 Objectives:

The Objectives of this research can be summarized as follows:

- 1-Find an accurate equation to calculate Rheological prosperities using Marsh funnel
- 2-Build a software program to calculate the Rheological properties from Marsh funnel data.
- 3-Identify the factor to get accurate results.

1.3 Methodology:

Preparation the drilling mud (Gel mud , SILICATE mud) then determine Rheological properties from Marsh funnel and Viscometer and create relationship between the two devices to convert it into equation.

Therefore; designing software to calculate all these properties by sample way, was used language program precisely VISUAL BASIC.

1.4 Thesis Outline:

This study contains five chapters, chapter 2 is about Literature Review and the history Background for the drilling fluid. Then chapter 3 which is about the methodology (materials, procedure, equipment's & device, software). Chapter 4 contains results and discussion. And the last chapter is take the conclusion and our recommendation.

Chapter 2:

Literature Review & Fluid Background

Chapter 2

Literature Review and Fluid Background

Drilling engineering is one of the challenging disciplines in the petroleum industry. Significant advancements have been made in past decades which have allowed the petroleum industry worldwide to economically and successfully exploit underground reserves that were not been possible before. Considerable research studies have been done in drilling fluid technology to understand drilling fluid properties for successful and economical completion of an oil well. The cost of the drilling fluid itself is relatively small, but the maintenance of the right properties while drilling profoundly influence total well costs. American Petroleum Institute has a recommended practice for testing liquid drilling fluid properties; regular interval testing of drilling fluid properties help mud engineers determine proper functioning of drilling fluid.

Bourgoyne Jr. (1986) mentioned that drilling fluid is related directly or indirectly to most of drilling problems.

Therefore, the Rheological properties of important to learn characteristics of fluids, the conditions and manner to the particular fluid action of the situation. All that properties can measure by Marsh Funnel.

The Marsh Funnel was invented by Hallan N. Marsh in 1931 . 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.

2.1 Literature Review:

Limited studies have been reported on Rheological analysis using Marsh Funnel. Chandan Guria et al,(2013) in this study, Marsh Funnel is used to determine the rheological properties, namely, yield point, apparent viscosity and plastic of drilling fluid Funnel drainage volume and corresponding drainage time are two measured variables for this analysis. Drainage volume is used to predict funnel wall shear stress whereas drainage rate is used to estimate funnel wall shear rate. The predicted shear rate is independent of rheological models. Synthetic crude oil and the suspension of several drilling

fluid additives with practical importance have also been used to determine yield point, apparent viscosity and plastic viscosity using the Marsh Funnel readings. Finally, the Marsh Funnel rheological results are also compared with the 6-Speed Rotational Viscometer results.

They found that the Rheological results obtained from Marsh Funnel readings are compared with Vann 35 viscometer readings. It is observed that Marsh Funnel and 6-Speed Rotational Viscometer result almost identical yield points for 6.0% and 8.0% (wt/wt) bentonite suspensions as compared to the other suspensions (i.e., synthetic crude, 5.0% bentonite, and PEG based mud).

It is also observed that almost identical values of μ_a and μ_p are obtained for 8.0% (wt/wt) bentonite suspension from both the rheometers whereas relatively higher values of μ_a and μ_p are obtained from funnel prediction for all other suspensions except synthetic crude. An identical apparent viscosity is obtained for synthetic crude oil from both the rheometers whereas lower plastic viscosity is obtained for this crude oil from funnel readings as compared to 6-Speed Rotational Viscometer readings.

(Faleh H. M. Almahdawi et al, 2014) introduced a new model which 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. The accuracy of the work compared to the true data that found from graphs and tables was slightly low, the results from the van viscometer was higher than the result from marsh funnel.

(Mohammed Hatem Mohammed et al, 2014) Published a study called Rheological Properties of Cement-Based Grouts Determined by Different Techniques, and they contain on The rheological properties of cement-based grouts containing talc or palygorskite were investigated for optimizing fluidity and quick strengthening at injection. The fluidity controls the ability of grout to penetrate fractures and can be determined by pipe flow tests, Marsh funnel tests, mini-slump cone tests and rheometer tests. The flow test data converted Marsh flow time into viscosity. The pipe flow tests gave 26.5% higher values than the viscometer for grout with Portland cement and talc, and about 13.7% lower than the viscometer data for the grout with low-pH cement and talc. The big Marsh funnel gave values differing by 5.2% - 5.3% from those of the viscometer for grout with talc and Portland, and Merit 5000 cements. For grout with palygorskite the viscosity was at least twice that of the other grouts. Grout fluidity was positively affected by talc and negatively by palygorskite and early cement hydration.

A recent study by (Britta Schoesser and Markus Thewes, 2015) they presented Marsh Funnel testing for rheology analysis of bentonite slurries for Slurry Shields. This paper was shown. For the face support during slurry shield tunnelling, the rheology of the bentonite suspension has to meet strict requirements. Determination of the rheological properties follows the international standards API 13B and DIN 4126.

On the construction site, simple and robust measurement methods are required for quality control of the suspension parameters during the tunneling process. In comparison to detailed rheological measurements using a viscometer or rheometer, exact determinations of viscosity and yield stress are not possible with a Marsh funnel.

However, by adoption of additional equipment (e.g. a scale with data logging and computer for data processing) the informative value of the standardized Marsh-funnel measurements for tunnelling practice can be increased considerably. Application of this model provides the opportunity to pre-processes the logged data into various information sets. By extending the measurement equipment slightly and adopting the mathematical equations of capillary viscometry, the informative value of a simple and standardized Marsh-funnel measurement provides advanced rheological analysis. Especially the yield point can be determined for certain fluid conditions. Up to now this possibility was only a subject for advanced measurements using a viscometer or rheometer.

2.2 Drilling Fluids :

The term drilling fluid encompasses all of the compositions used to aid the production and removal of cuttings from a borehole in the earth. This broad definition purposely places no restriction on the type of tools employed nor on the objective. Some specific examples of the application of drilling fluids are: water poured into the hole while boring a foundation footing with an auger, air introduced to blow cuttings from a blast hole, mud made twice as heavy as a water to control tectonic forces in mineral exploration; foam as conveyor of cuttings from a hole being drilled for water in glacial drift; bentonite slurry employed to maintain a stable wall while excavating a cutoff trench; and a mixture of emulsifiers, stabilizers, gallants and sealants in an oil base used to drill for corrosive gases at temperatures above 260 °C. Drilling fluids technology is potentially useful in all types of earth excavation. Drilling Fluid Technology involves the sciences of geology, chemistry, and physics, and the skills and applications of engineering. Its goal is the utilization of available equipment and materials to attain at lowest cost the desired objective of earth excavation.

2.2.1 The Principal Functions:

The rotary drilling process and the principal functions of the drilling fluid are related to the mechanical processes of drilling a hole and to reactions with the formations.

I. Removal of cuttings from the bottom of the hole: One of the most important functions of the drilling fluid is to efficiently remove the freshly drilled cuttings from the bit and transport them in the

annular space between the drill pipe and the hole to the surface where they can be removed. The ability of the fluid to achieve this objective is dependent to a degree on the annular velocity, which is the speed at which the fluid is pumped up the annulus of the well. For the cuttings to move up the well the annular velocity should be greater than the slip velocity.

II. Control subsurface pressures: The formations are composed of solids of varying porosity, where the pores are filled with liquids or gases. The rock and pore fluids are under pressure arising from the rocks overlying them and from movements of the earth's crust. The column of drilling fluid in the hole will exert a hydrostatic pressure proportional to the depth of the hole and the density of the fluid. This pressure is used to control the flow of gas, oil or water from the pores and makes an important contribution to the stability well bore.

III. Isolate the fluids from the formation: Because of safety considerations the hydrostatic pressure exerted by the drilling fluid in the well is usually designed to be greater than the pressure existing in the formation. If this were not so, the well could blowout. If the bit penetrated porous rocks containing gas or hydrocarbons. Under these conditions the drilling fluid will try and penetrate the rock as a whole fluid, or will form filter cakes and the filtrate will penetrate materials have to be incorporated in the drilling fluid to minimize these effects. Whole fluid loss: there may be highly permeable or fractured formations that will allow the entry of whole drilling fluid if there is a pressure imbalance. The solids that are normally in the fluid may not be large enough to bridge the passages and formation sealing agents, commonly called lost circulation materials are added.

IV. Cool and lubricate the bit and drill string: During the drilling operation, a considerable amount of heat is generated by the frictional forces of the rotating bit and drill string. This heat cannot be totally absorbed by the formation and must be conducted away by the drilling fluid. In addition, the current trend towards even deeper and better holes places increased importance on this function. A vast amount of this heat is lost on the surface, with a relatively cool drilling fluid being returned back down the hole.

Lubrication is obtained through the deposition of a slick wall cake and through the use of various specially formulated additives. Additions of diesel or crude oil may also prove beneficial, but this practice is becoming less common due to ecological restrictions.

V. Support part of the weight of the drill and casing string: The natural buoyancy of a drilling fluid aids in supporting part of the weight of the drill string or the casing string. The degree of buoyancy is proportional to the fluid density. Any increase in fluid density creates an increase in the buoyancy factor, and reduces the load on the surface equipment. The importance of this particular function becomes more apparent as depths increase.

VI. Maximize penetration rates: The drilling fluid is so intimately involved in the drilling process that it is inevitable that a wide range of fluid properties will influence the rate of penetration, apart from the mechanical considerations, such as the type of bit weight on the bit and rate of rotation. Fluid properties such as low viscosities at high shear rates, low solids, high fluid loss and lower densities than are required to balance pore pressure, all contribute to faster penetration rates. It can be seen that some of the properties, such as high fluid loss and under balance fluid densities are contradictory to the properties required for a stable hole, and a compromise must be reached.

VII. Control corrosion rates: The fluid should be non-corrosive to the drill pipe casing and drilling equipment. Additives may be used that will specifically give protection, particularly in the highly corrosive environments of hydrogen sulphide and carbon dioxide.

VIII. Protect the formation: The drilling fluid will come into intimate contact with the formations being drilled, If a stable hole is to be obtained, then interactions between the fluid and the formations should be minimal. For example, if a salt section is to be occurring. Some shale formations are sensitive to fresh water and undergo significant changes in mechanical properties that may result in enlarged hole or bore hole collapse. An oil based fluid or an inhibited water based fluid should be used to protect these formations. The porous zones that contain gas or oil should be penetrated with a fluid that will not irreversibly seal the porous passages when the hydrostatic pressure lowered in order to evaluate the zone.

IX. Secure maximum hole information: An important objective in drilling a well is to secure the maximum amount of information about the types of formations being penetrated and the fluids or gases in the pores, This information is obtained by analysis of the cuttings, dissolved gases or oil, and by electric logging technology. The cuttings should be well preserved and not disintegrated and should be transported up the hole efficiently, so that the sample is representative of the depth at which it originated should be possible to easily separate and analyses gases or oil dissolved in the fluid. Also the fluid should have a defined receptivity so that satisfactory electric well logs can be obtained.

X. Transmit hydraulic energy to tools and bit: Hydraulic energy provides power to mud motor for bit rotation and for MWD(measurement while drilling and LWD) logging while drilling tools. Hydraulic programs base on bit nozzles sizing for available mud pump horsepower to optimize jet impact at bottom well.

XI. Facilitate cementing and completion: Cementing is critical to effective zone and well completion. During casing run, mud must remain fluid and minimize pressure surges, so fracture induced lost circulation does not occur Mud should have thin, slick filter cake, wellbore with no cuttings, carvings or bridges.

XII. Minimize impact on environment: Mud is, with varying degree, toxic. It is also difficult and expensive to dispose of in an environmentally friendly manner.

2.2.2 Properties of Drilling Fluids:

The large number of functions that have to be performed has inevitably led to the formulation of complex systems, with at least some of the complexity arising from the different environments encountered in various geological situations. The dominant properties that should be controlled follow from the functions of the fluid.

I. Density:

Density of drilling mud is defined as weight per unit volume. It is expressed in field units as pounds per gallon (lb/gal). Density of drilling mud is an important parameter which is controlled during drilling operation. In order to prevent formation fluids to inflow into the well bore and to seal the well bore with a thin, low-permeability filter cake; the density of drilling fluid must exceed the pore pressure of the formation (Darley & Gray, 1988). However, the mud column density should not be high enough to cause formation fracture. Numerous weighing agents can be used to increase mud density to desired value using high specific gravity solid, such as barite, hematite, galena, calcium carbonate, and ilmenite. Barite is most widely used weighing agent. The hydrostatic pressure exerted by a static mud column depends on both the density and the depth. The hydrostatic pressure at depth D , for a column of mud having density (ρ) is derived by using following equation.

II. Viscous or flow properties:

These will depend on the depth of the hole and the annular velocities obtainable. In the upper hole water alone may be sufficient, but at greater depth more viscous fluid are required. Deep wells, angled well, high penetration rates and high temperature gradient all create conditions requiring close attention to the flow properties.

III. Fluid loss control:

This is a fundamental property of the drilling fluid and becomes important when porous formations are being drilled, particularly when those formations may contain gas or water. Special consideration may have to be given to the high temperature and high pressure fluid loss in particular conditions.

IV. Formation protection:

The chemistry and composition of the fluid must be such that there is minimal interaction with the formation. Zones of salt, anhydrite $CaSO_4$, dolomite, limestone, shale and sand may be encountered. Each zone is different in its chemical and mechanical properties and each may require different and special drilling fluid properties.

V. Temperature tolerance:

Temperatures increase with depth quite rapidly in certain areas. The additives and properties must be chosen so that they are stable at the down-hole temperatures.

VI. The other related properties:

The determination of pH value and alkalinity, filtrate analysis, liquids and solids content, methylene blue test for cation exchange capacity and bentonite content, sand content, electrical conductivity, lubricity, electrical stability of emulsions, corrosiveness.

2.2.3 Drilling Fluid Additives:

There are many drilling fluid additives which are used to develop the key properties of the mud.

The variety of fluid additives reflects the complexity of mud systems currently in use. The complexity is also increasing daily as more difficult and encountered.

We shall limit ourselves to the most common types of additives used in water-based and oil-based muds. These are :

- I. Weighting Materials
- II. Viscosifiers
- III. Filtration Control Materials
- IV. Alkalinity and pH Control Materials
- V. Lost Circulation Control Materials

2.2.3.1 Weighting Materials:

I. Barite:

Barite (or barites) is barium sulphate, $BaSO_4$ and it is the most commonly used weighting material in the drilling industry. Barium sulphate has a specific gravity in the range of 4.20- 4.60. The specific gravity of most commercial barite contains impurities including quartz, chert, calcite, anhydrite and

various silicates which lower its specific gravity. It is normally supplied to a specification where the specific gravity is about 4.2.

Barite is preferred to other weighting materials because of its low cost and high purity. Barite is normally used when mud weights in excess of 10 ppg are required. Barite can be used to achieve densities up to pps in both water-based and oil-based muds. However, at very high mud weights (22.0 ppg), the rheological properties of the fluid become extremely difficult to control due to the increased solids content.

II. Iron Minerals:

Iron ores have specific gravities in excess of 5. They are more erosive than other weighting materials and may contain toxic materials. The mineral Iron comes from several iron ore sources including: hematite/magnetite, ilmenite and The most commonly used iron minerals are:

A- Iron oxides:

Principally hematite, Fe_2O_3 . Hematite can be used to attain densities up to 22 ppg in both water-based and oil-based drilling fluids. Iron oxides have several disadvantages including: magnetic behaviour which influences directional tool and magnetic logs, toxicity and difficulty in controlling mud properties.

B- Iron Carbonate:

Siderite is a naturally occurring ferrous carbonate mineral $FeCO_3$, It has a specific gravity ranging from 3.7 to 3.9. Both water-based and oil-based muds can be successfully weighted with siderite to 19.0 ppg.

C- Ilmenite:

The mineral ilmenite, ferrous titanium oxide $FeTiO_3$, has a specific gravity of 4.60. It is inert but abrasive. Ilmenite can be used to attain densities up to 23.0 ppg in both water-based and oil-based drilling fluids, Ilmenite is the main source of titanium.

III. Calcium Carbonates

Calcium carbonate $CaCO_3$ is one of the most widely used weighting agents in drilling fluids. Its main advantage comes from its ability to react and dissolve hydrochloric acid. Hence any filter cake formed on productive zones thereby enhancing production. It has a specific gravity of 2.60-2.30 which limits the maximum density of the mud to about 12.0 ppg.

IV. Lead Sulphides

Galena (PbS) has a specific gravity of 7.40- 7.70 and can produce mud weights of up to 32 ppg. Galena is expensive and toxic and is used mainly on very high pressure wells.

V. Soluble Salts:

Soluble salts are used to formulate solids free fluids and are used mainly as work over and completion fluid. Depending on the type of salt used, fluid densities ranging from 9.0-21.5 ppg (sg= 1.08-2.58) can be prepared.

2.2.3.2 Viscosifiers:

The ability of drilling mud to suspend drill cuttings and weighting materials depends entirely on its viscosity. Without viscosity, all the weighting material and drill cuttings would settle to the bottom of the hole as soon as circulation is stopped. One can think of viscosity as a structure built within the water or oil phase which suspends solid material. In practice there are many solids which can be used to increase the viscosity of water or increased viscosity of water or oil. The effect of increased viscosity can be felt by the increased resistance to fluid flow; in drilling this would manifest itself by increased pressure losses in the circulating system.

We will begin our discussion of viscosifiers with clay minerals.

1. CLAYS:

Clays are defined as natural, earthy, fine grained materials that develop plasticity when wet. They are formed from the chemical weathering of igneous and metamorphic rocks. The major source of chemical clay is volcanic ash; the glassy component of which readily weathers very readily, usually to bentonite.

A. Bentonite:

This is the most widely used additive in the oil industry. The name, bentonite, is a commercial name used to market a clay product found in the Ford Benton shale in rock Creek, Wyoming, USA. Bentonite is defined as consisting of fine-grained clays that contain not less than 85% Montmorillonite which belongs to the class of clay minerals known as smectites. Bentonite is classified as sodium bentonite or calcium bentonite, depending on the dominant exchangeable cation. In fresh water, sodium bentonite is more reactive than calcium bentonite and hence, in terms of performance, bentonite is classed as "high yield" (Sodium Bentonite) or "low yield" (Calcium Bentonite).

Bentonite is used to build viscosity in water which is required to suspend weighting material and drill cuttings. When clay is dispersed in water, viscosity is developed when the clay plates adsorb water layers on to their structure. Each or several stacked water layers are shared by two clay plates these repeating structures of clay plates and their attached water layers result a viscous structure The

dispersion process will only take place in fresh water. If the clay is used in salt muds it has to be prehydrated in fresh water.

B. Attapulgite:

Attapulgite belongs to a quite different family of the clay minerals, in this family, the tetrahedra in the tetrahedral sheets of atoms do not all point in the same way, but some tetrahedra in the sheets are inverted. Instead of crystallising as platy crystals, attapulgite forms needle-like crystals.

Attapulgite-based muds have excellent viscosity and yield strength and retain properties when mixed with salt water. However, they have disadvantage of suffering high water loss thereby giving poor sealing properties across porous and permeability formation.

C. Organophilic Clay:

Organophilic clay are made from normal clays (bentonite or attapulgite) and organic cations. The organic cations replace the sodium or calcium cations originally present on the clay plates. Organophilic clay can be dispersed in oil to form a viscous structure similar to that built by bentonite in water.

II. Polymers:

Polymers are used for filtration control, viscosity modification, flocculation and shale stabilization. When added to mud, polymers cause little change in the solid content of the mud.

Polymers are chemicals consisting of chain made up of many repeated small units called monomers. Polymers are formed from monomers by a process called polymerization. The repeating units (monomers) that make up the polymers may be the same, or two more monomers may be combined to form copolymers. Structurally, the polymer may be linear or branched and these structures, either linear, branched, or both, may be cross-linked, i.e. tied together by covalent bonds.

2.2.4 Types of Drilling Fluids:

Many types of drilling fluids are used in industry. Major categories include air, water and oil base fluids. Each has many subcategories based on purpose, additives, or clay states.

Rheology is the study of the deformation of fluids and flow of matter. Its importance is recognised in the analysis of fluid flow velocity profiles, fluid viscosity (marsh funnel viscosity, apparent viscosity and plastic viscosity), friction pressure losses and annular borehole cleaning.

Rheological properties are basis for all analysis of well bore hydraulics and to assess the functionality of the mud system. Rheological characteristics of drilling mud also include yield point and gel strength. Rheological properties (such as density, viscosity, gel strength etc.) are tested throughout the drilling operations. It is critical to control and maintain rheological properties as a failure to do so

can result in financial and loss of time, and in extreme cases, it could result in the abandonment of the well (Darley & Gray, 1988). Besides rheological other tests such as filtration tests, pH, chemical analysis (alkalinity and lime content, chloride, calcium, etc.), resistivity are conducted throughout drilling process.

2.2.4.1 Water based Mud's:

Physical and chemical properties of the drilling fluids largely depend on the type of solids in the mud. These solids are categorized as either active or inactive solids. The active solids are those that react with water phase and the dissolved chemicals. On the other hand, the inactive solids are those that do not react with the water and chemical to a significant degree (Bourgoyne Jr, Millheim, Chenevert, & Young Jr., 1986; Azar& Samuel, 2007). Some examples of the inactive solids include - Barite and Hematite, these are added to drilling fluids as weighing agents.

Water based mud's consist of four basic phases:

- A- Water.
- B- Active colloidal solids.
- C- Inert solids
- D- Chemicals

Water is the continuous phase of any waer-based-mud. Primary function of the continuous phase is to provide the initial viscosity which can be modified to obtain any desirable rheological properties. The second function of the continuous phase is to suspend the reactive colloidal solids, such as bentonite, inert solids such as barite. Water also acts as a medium for transferring the surface available hydraulic horsepower to the bit on the bottom of the hole .water is also a solution medium for all conditioning chemicals which are added to the drilling fluid. In water based muds , clay is added to increase density, viscosity, gel strength and yield point, and to decrease fluid loss.clay used in water based drilling fluids are maily in three groups :

- A. Montmorillonits (bentonite)
- B. Kaolinites
- C. Illites

Types of Water Based Muds:

A. Clear water: Fresh water and s brine can be used to drill hard formations, and near normally pressured formations. This mud is made by pumping water down to the hole during drilling and letting it

react with formations containing clays or shale. The water dissolves the clays and returns to the surface as mud. This mud is characterized by its high solids content and a high filter loss resulting in a thick filter cake.

B. Calcium Mud's: Calcium mud's are superior to fresh water s when drilling massive sections of gypsum and anhydrite as they are susceptible to calcium contamination. When calcium is added to a suspension of water and bentonite, the calcium cations will replace the sodium cations on the clay plates. when calcium mud comes into contact with shaly formations, the swelling of shale is greatly reduced in the presence of calcium cations. The major advantage of calcium mud is their ability to tolerate a high concentration of drilled solids without these affecting the viscosity of mud. Calcium mud's are classified according to the percentage of soluble calcium in the mud.

1- Lime Mud which contains up to 120 ppm of soluble calcium and it is prepared by mixing bentonite, lime($\text{Ca}(\text{OH})_2$), thinner, caustic s and filtration control agent.

2- Gyp Mud which contains up to 1200 ppm of soluble calcium is similar to lime mud except that the lime is replaced by gypsum and they have higher temperature stability.

C. Lignosulphonate Mud:

This mud type is considered to be suitable when:

- I. high mud densities are required.
- II. working under moderately high temperatures.
- III. high tolerance for contamination by drilled solid.
- low filter loss is required.

This type of mud consists of fresh water or salt water, bentonite, ferrochrome lignosulphonate , caustic soda, CMC or stabilized starch. It is not suitable for drilling shale sections due to adsorption of water.

D. KCl Polymer Mud:

The basic components of KCl polymer mud's are:

- I. fresh water or sea water
- II. KCl
- III. inhibiting polymer
- IV. viscosity building polymer
- V. stabilized starch or CMC
- VI. caustic soda
- VII. Lubricants properties.

This mud is suitable for drilling shale sections due to its superior sloughing inhibition properties. It is also suitable for drilling potentially productive sands.

The advantages of this type of mud are:

- higher shear thinning
- high true yield strength
- improve bore hole stability
- good bit hydraulics and reduced circulating pressure losses.

The disadvantage is their instability at temperatures above 250°F.

2.2.4.2 Oil Based Mud's :

Oil based mud's has been defined as a system the continuous or external phase of which is any suitable oil. At the present time, there are two mud systems the external phase of which is oil, i.e., true oil mud and invert emulsion mud's. True oil mud system consist of the following components:

- Suitable oil
- Asphalt
- Water
- Emulsifiers
- Surfactants
- Calcium hydroxide
- Weighting materials
- other chemical additives

Among all of these, only oil and asphalt are necessary for the proper functioning of oil muds.

The others are only used for the purpose of enhancing and stabilizing rheological properties and plastering characteristics. Different types of oils have been used as the continuous phase in oil mud The following commonly available oils have gained widespread acceptance:

- Lease crude oil
- Refined oils

The following specifications are used as guidelines for the selection of oil:

- Specific weight(API gravity)
- For viscosity purposes.

Aniline point= A measure for the aromatic content of the (flash point) is the temperature at which oil vapor ignites upon passing flame over the hot oil.

(Fire point) is the temperature at which continuous fire is sustained over the oil surface when flame is passed over it. Although presence of water is not required in oil mud some water is generally added to

react with chemical additives in order to enhance the rheological properties and plastering characteristics of oil. A number of bodying agents have been used in oil mud's to achieve the desired rheological and filtration loss characteristics. Bodying agents can be classified into two groups:

- Colloidal size materials

- High molecular weight metal soap

Asphalts which are Colloidal size organophilic materials are used in oil mud have to impart required properties and control fluid loss, mainly through their absorptive characteristics. Asphalt work with the same principle as clays in water-based mud's.

Heavy metal soaps of fatty acids(emulsifiers) are added to the oil mud's in order to emulsify the water in oil. The functions of emulsifiers in oil mud's are as follows:

- Imparting weak gel strength to oil mud's because gel strength is necessary for suspension of weighting materials.

- Emulsification of any water picked up during drilling operation.

- Controlling the tightness of any water emulsion resulting from water contamination, thus, controlling fluid loss.

2.2.4.3 Aerated Mud's:

Interest in under balanced drilling is increasing worldwide. In under balanced drilling operations, pressure of the drilling fluid in the borehole is intentionally maintained below the formation pore fluid pressure, in the open hole section of the well. As a result formation fluids flow into the well when a permeable formation is penetrated during under balanced drilling .

Usually, aerated fluids are used in under balanced drilling operations. Most frequently used aerated fluids are air-liquid mixtures, foams, mist and gas.

2.2.5 Viscosity Measurements:

The Marsh funnel is a simple device for measuring viscosity by observing the time it takes a known volume of liquid to flow from a cone through a short tube. It is standardized for use by mud engineers to check the quality of drilling mud. Other cones with different geometries and orifice arrangements are called flow cones, but have the same operating principle.

In use, the funnel held vertically with the end of the tube closed by a finger .The liquid to be measured is poured through the mesh to remove any particles which might block the tube.

When the fluid level reaches the mesh, the amount in side equal to rated volume. To take the measurement, the finger is released as a stop clock is started, an the liquid is allowed to run into a measuring container. The time in seconds is recorded as a measure of the viscosity.

Based on a method published by (HN Marsh ,1931) a Marsh cone a flow cone with an aspect ratio of 2:1 and a working volume of at least a liter. A Marsh funnel is a Marsh cone with a particular orifice and a working volume of 1.5 liters. It consists of a cone 6 inches (152 mm) across and 12 inches in height (305 mm) to the apex of which is fixed a tube 2 inches (508 mm) long and 3/16 inch(4.76 mm) internal diameter. A 10 mesh screen i fixed near the top across half the cone.

In American practice (and most of the oil industry) the volume collected is a quart. if water is used ,the time should be 26+/-0.5 seconds. If the time is less than this the tube probably enlarged by erosion, if more it may be blocked or damaged, and the funnel should be replaced in some companies, and Europe in particular, the volume collected is a liter, for which the water funnel time should be 28 seconds. Marsh himself collected 0.50 liter for which the time was 18.5 seconds.

The Marsh funnel time is often referred to as the Marsh funnel viscosity, and represented by the abbreviation MF The unit (seconds) is often omitted Formally, the volume should also be stated. The (quart) Marsh funnel time for typical drilling mud's is 34 to 50 seconds, though mud mixtures to cope with some geological conditions may have a time of 100 or more seconds. While the most common use is for drilling muds, which are Newtonian fluids, the Marsh funnel is not a rheometer, because it only provides one measurement under one condition. However the effective viscosity can be determined from following simple formula.

$$\mu = p(t-25) \dots \dots \dots (2.1)$$

Other flow cones: The term marsh cone is also used concrete and oil industries.

European standard EN445 and American slandered C939 for measuring flow properties of cement grout mixers specify a funnel similar to the Marsh cone . Some manufactures supply devices which they call Marsh cones, with removable tubes with size ranges from 5-15 mm.

These can be used for quality control by selecting a tube which gives convenient time, say 30-60 seconds

Chapter 3:

Methodology

Chapter 3

Methodology

The purpose of these experiments was to measure the rheological properties of drilling mud . The experimental work for this project was divided into 3 parts. The first part focused on the readings from lab which include Mud balance ,Marsh funnel and viscometer readings. And second part focused on mathematical model,a certain way to calculate the rheological properties by Marsh funnle and used many equation to do that. All mud samples were prepared (Gul mud and Silicate polymer), by the addition of additive and thorough mixing using a variable speed mixer. at the last part a software program was designed (Visual Basic) to calculate all these properties in a simple manner.

3.1. Lab Experimental

Two types of drilling fluid were prepared in the lab, depending on the proposal For STAROIL OPERATING CO. Ltd by adding certain amounts of additives (Table 3.1) to control the properties of the fluids.

Many of the fluids used in these experiments must be mixed before testing. The used fluids are water- based fluids (Gel mud, Kcl silicate). Before adding any solid particles and polymer to the water-based fluids used here, For all tests, the fluid was at room temperature (30 °C), the density was measured using a density balance, and the Rheological properties measured using 6-Speed Rotational Viscometer and marsh funnel.

Readings were taken using mud balance from different well prepared densities. Then time and volume were taken from Marsh Funnel. Finally calculated accurately from Viscometer.

Table 3.1: Material used in Laboratory experiments (M-I Drilling Fluids UK Ltd, Pocrá Quay, Footdee,)

Name	Temperature (°C)	Specific Gravity (S.G)	pH-value	Application
Bentonite	20	3 - 2.6	9 – 10	Viscosifier
Barite	20	2 - 4.25	7-9.5	Weighting agent

Caustic soda	25	2.13	14	pH modifier
Soda Ash	20	2.53	11.6	pH modifier
KCL	20	1.94-1.95	7	Laboratory chemical
PAC-LV	25	1.5 - 1.6	5.5 - 8.5	Fluid loss control
Flowzan	20	1.5	7	Viscosifier

3.2 Equipment and Devices:

3.2.1 Mud Balance:

A mud balance, also known as a mud scale is a device used to measure the density (weight) of drilling fluid, cement or any type of liquid or slurry.

It consists of a graduated beam with a bubble level and a weight slider along its length and a cup with a lid on one end. The cup is used to hold a fixed amount of fluid so it can be weighed. A slider-weight can be moved along the beam, and a bubble indicates when the beam is level. Density is read at the point where the slider-weight sits on the beam at level.

Calibration is done using a liquid of known density (often water) by adjusting the counter weight. Typical balances are not pressurized, but a pressurized mud balance operates in the same manner.

Reason for use the mud balance is there is no reliable visual method of determining the density of drilling mud; the mud balance is the most reliable and simple way of making the determination.



Figure 3.1: Mud Balance

3.2.2 Marsh Funnel:

The Marsh funnel is a simple device for measuring viscosity by observing the time it takes a known volume of liquid to flow from a cone through a short tube. It is standardized for use by mud engineers to check the quality of drilling mud.

The Marsh Funnel Viscometer is a rugged, easy to operate instrument that is used for making rapid, on the spot measurements of drilling mud viscosity. Marsh Funnel readings are only general measurements, but the frequent reporting of the Marsh Funnel Viscosity will alert the mud engineer to sudden changes in the mud viscosity that could require corrective action. The Marsh Funnel Viscosity is the ratio of the speed of the mud as it passes through the outlet tube (the Shear Rate) to the amount of force—the weight of the mud itself, which is causing the mud to flow (the Shear Stress). Marsh Funnel Viscosity is reported as the number of seconds required for one quart of mud to flow out of a full Marsh Funnel. Shipping wt. 5 lbs (2kg)

In use, the funnel is held vertically with the end of the tube closed by a finger. The liquid to be measured is poured through the mesh to remove any particles which might block the tube. When the fluid level reaches the mesh, the amount inside is equal to the rated volume. To take the measurement, the finger is released as a stop clock is started, and the liquid is allowed to run into a measuring container. The time in seconds is recorded as a measure of the viscosity.



Figure 3.2: Marsh Funnel

3.2.3 Six -speed rotational viscometer:

Six -speed rotational viscometer is API designed and manufactured in accordance with specifications. The instrument can measure a variety of rheological parameters, draw flow curves plotted according to multi-point measurement values, determine the liquid in the flow process flow pattern, chose appropriate formula, test non-Newtonian fluid precisely. At the same time can be test cut force, static shear force, flow index, consistency coefficient of determination and so on technical parameter. It is suitable for test and analyzes rheological parameters drilling site. It is easy to operate and precisely. Meet the needs of the safe and quick scientific drilling.

It can measure all kinds of technological parameter, and issue liquid behavior in the course of flow according to curve, which make more precise measure for Non–Newtonian fluid. It is used in research and analysis of drilling parameter, and at the same time, it has characteristics of convenient operation and precise test.



Figure 3.3: The MKW-RV 6 Speed Rotational Viscometer

3.3 Mathematical Model:

Model assumption:

Following assumptions are made to develop Marsh Funnel consistency plot:

- i. Flow through Marsh Funnel cross section is quasi-stationary, since the volume of viscous liquid in the funnel changes slowly with time particularly at the end of experiment(Balhoff et al., 2011).
- ii. Though the downward velocity through the funnel depends on radius and vertical height, it is assumed that the flow through the funnel is fully developed without exit effect at the outlet tube i.e.,

velocity distribution is unaffected by the change in length and diameter of funnel. This assumption is almost true where the change in funnel diameter with height is very less.

iii. Marsh Funnel wall shear rate is the measure of speed of the sample fluid as it passes through the funnel outlet tube.

iv. The fluid is time-independent, i.e. $\gamma = f(\tau)$ only.

v. Flow through the funnel is laminar and isothermal.

vi. Density of flowing fluid is constant, i.e., flow is incompressible.

vii. There is no slip at the wall and fluid behaves as a continuum since the funnel diameter is comparatively larger than the molecular mean free path of the fluid.

viii. There is no existence of elongation flow since drilling fluids are purely viscous.

Marsh Funnel wall shear stress is obtained by balancing the Forces in conical and cylindrical section of the funnel separately. Balancing the net hydrostatic downward force and upward wall shear force across the conical section of the funnel can write the following equation:

$$\pi R_w^2 \Delta P_{cone} = \pi R_L L \tau_w \quad (3.1)$$

Substituting, $L = (Z / \cos \alpha)$ and $R_w(Z) = R_L + (R_o - R_L)(Z/Z_1)$ in the above equation, the following relation for pressure drop is obtained for conical section of the funnel can write the following equation:

$$\Delta P_{cone} = \frac{\tau_w Z}{\cos \alpha \{R_L + (R_o - R_L)(Z/Z_1)\}} \quad (3.2)$$

Similarly, pressure drop across the cylindrical section of the funnel can be written by the following equation:

$$\Delta P_{cy} = \frac{2 \tau_w Z_2}{R_L} \quad (3.3)$$

Therefore, total pressure drop across the funnel is written in the following form

$$\Delta P = \Delta P_{cone} + \Delta P_{cy} = \frac{\tau_w Z}{\cos \alpha \{R_L + (R_o - R_L)(Z/Z_1)\}} + \frac{2 \tau_w Z_2}{R_L} \quad (3.4)$$

Substituting, ΔP in terms of liquid level in the Marsh Funnel, one may obtain the wall shear rate by the following equation:

$$\tau_w = \frac{\rho g(Z+Z_2)}{(Z/(\cos \alpha \{R_L + (R_0 - R_L)(Z/Z_1)\})) + (2Z_2/R_L)} \quad (3.5)$$

In Eq. (3.5), remaining liquid height in conical section of the funnel (i.e. Z) is calculated from discharge volume (V) and funnel geometry which is given by

$$Z = \sqrt[3]{\frac{V_0 - V - \pi R_L^2 Z_2}{(\pi/3)(R_0/Z_1)^2}} \quad (3.6)$$

Where $V_0 = 1500 \text{ cm}^3$

Marsh Funnel wall shear rate is a measure of speed at which Sample fluid passes through the funnel outlet. Therefore, wall shear rate is written in the following form based on funnel outlet sectional area. To estimate Marsh Funnel wall shear rate let the linear velocity of flowing fluid at the funnel outlet at distance R from the center by v_z and volumetric flow rate through fluid thickness dR is given by the following equation i.e.,

$$Q = 2\pi \int_0^{R_L} R v_z dR \quad (3.7)$$

Though v_z is a function of R and Z, it is assumed that for a given circular cross section of the funnel, v_z depends only on R. Applying no slip condition at the wall and integrate Eq.(3.7) by parts ,following equation result, i.e.,

$$Q = -\pi \int_0^{R_L} R^2 dv_z \quad (3.8)$$

Above equation may be written in terms of velocity gradient i.e.,

$$Q = -\pi \int_0^{\tau_w} R^2 \frac{dv_z}{dR} dR \quad (3.9)$$

Using Eq. (3.1), the radial shear stress variation in the cylindrical section of funnel is written as

$$d\tau = \frac{\tau_w}{R_L} dR \quad (3.10)$$

Now, substituting Eq.(3.9)into Eq. (3.8), following equation is written for Q i.e.

$$Q = -\pi \int_0^{\tau_w} R^2 \dot{\gamma} \frac{R_L}{\tau_w} d\tau \quad (3.11)$$

Where shear rate= $\dot{\gamma} = \frac{dv_z}{dR}$

Substituting $\tau = (\tau_w/R_L)R$ into Eq. (3.11) and rearranging, following equation is obtained:

$$\frac{Q\tau_w^3}{\pi R_L^3} = -\int_0^{\tau_w} \dot{\gamma} \tau^2 d\tau \quad (3.12)$$

Now, differentiating both sides with respect to τ_w using the Liebnitz rule for differentiation of a definite integral, one may obtain

$$-\dot{\gamma}_w \tau_w^2 = \frac{1}{\pi R_L^3} \left(\tau_w^3 \frac{dQ}{d\tau_w} + 3\tau_w^3 Q \right) \quad (3.13)$$

Rearranging Eq. (3.13), one may obtain the following equation:

$$\dot{\gamma}_w = \frac{3}{4} - \left(\frac{4Q}{\pi R_L^3} \right) + \frac{\tau_w}{4} \frac{d(4Q/\pi R_L^3)}{d\tau_w} \quad (3.14)$$

Above equation is written in the following convenient form:

$$-\dot{\gamma}_w = \frac{3}{4} \left(\frac{4Q}{\pi R_L^3} \right) + \frac{1}{4} \frac{4Q}{\pi R_L^3} \frac{d \log(4Q/\pi R_L^3)}{d \log \tau_w} \quad (3.15)$$

Now substituting $\frac{d \log(4Q/\pi R_L^3)}{d \log \tau_w} = 1/\dot{\gamma}$ in Eq. (3.16), one may obtain the following equation in the convenient form:

$$-\dot{\gamma}_w = \frac{3n+1}{4\dot{\gamma}} + \frac{4Q}{\pi R_L^3} \quad (3.16)$$

Eq. (3.16) is the desired expression for the estimation of wall shear rate through Marsh Funnel for known volumetric flow rate through nozzle.

Where Q is the volumetric flow rate through Marsh Funnel outlet, and $\dot{\gamma}$ is the flow behavior index which is related by the following equation:

$$\frac{1}{\dot{\gamma}} = \frac{d \log(4Q/\pi R_L^3)}{d \log \tau_w} \quad (3.15)$$

calculate apparent viscosity and plastic viscosity by equations :

$$\mu_a = \tau_{1020} \quad (3.16)$$

$$\mu_p = 2(\tau_{1020} - \tau_{510}) \quad (3.17)$$

3.4 Software (MF system):

Had been selected Visual basic to calculate all above equation by simple way and (Figure 3.4) show the main window of the program:

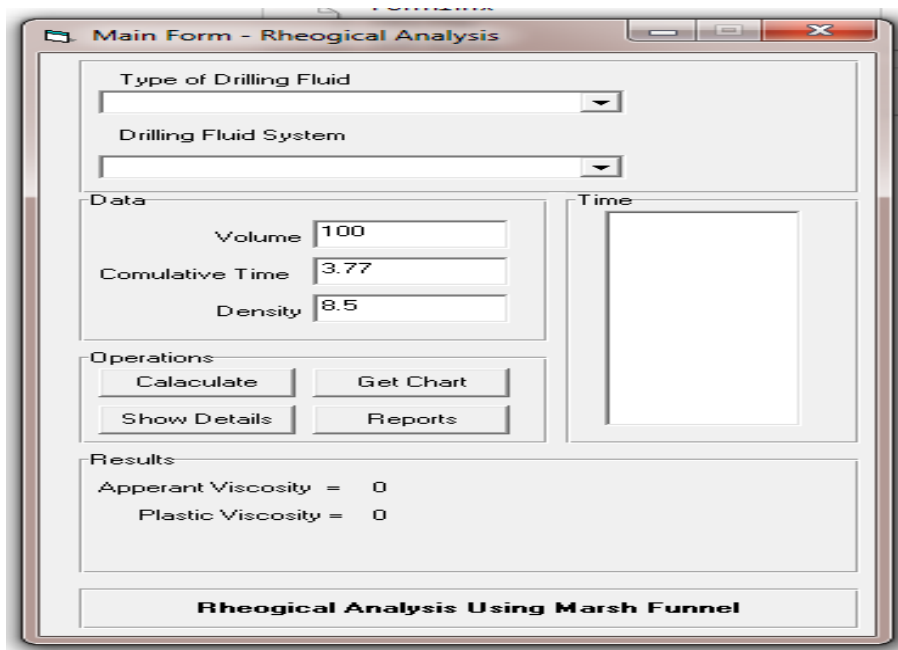


Figure 3.4: Main form of MF system

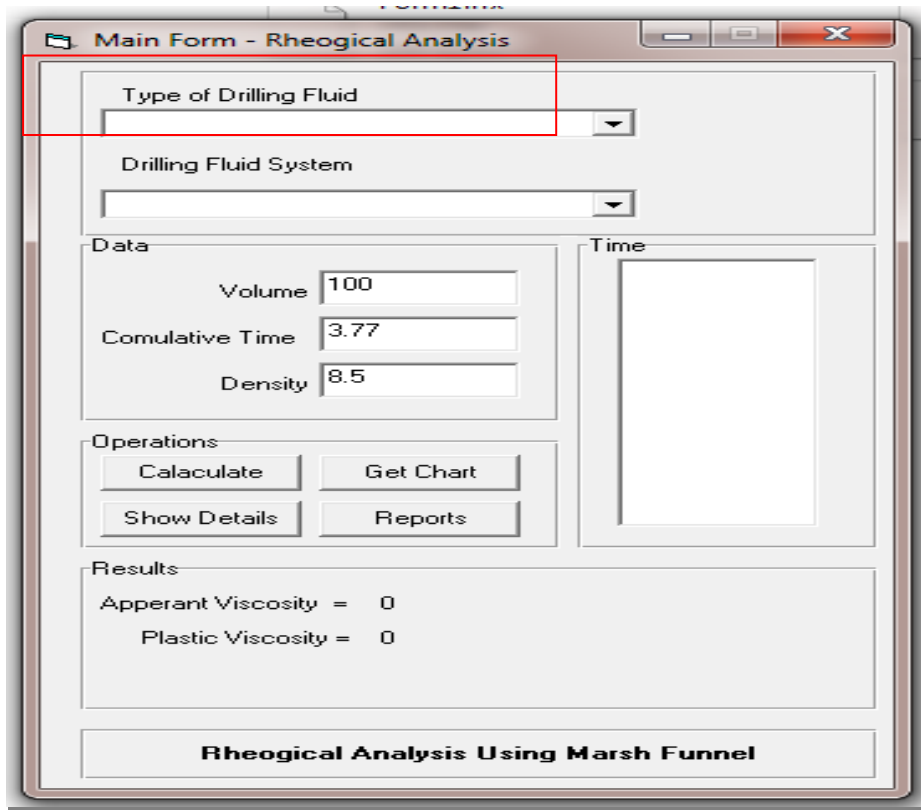


Figure 3.5: To selected type of Drilling Fluid

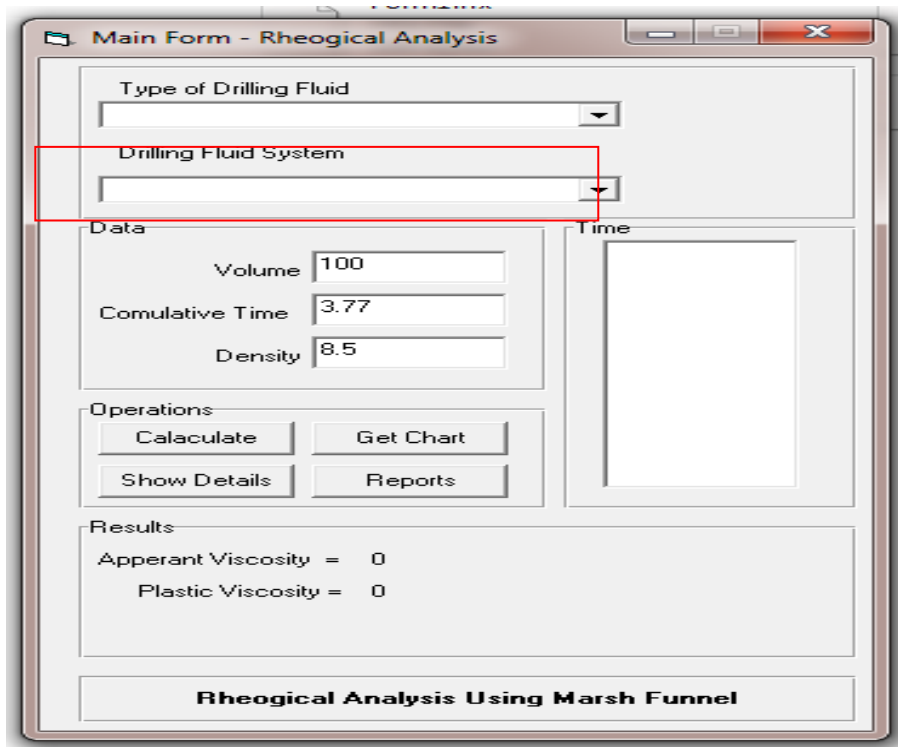


Figure 3.6: To selected Drilling fluid system depend of section.

Main Form - Rheological Analysis

Type of Drilling Fluid

Drilling Fluid System

Data

Volume 100

Cumulative Time 3.77

Density 8.5

Operations

Calaculate Get Chart

Show Details Reports

Results

Apperant Viscosity = 0

Plastic Viscosity = 0

Time

Rheogical Analysis Using Marsh Funnel

Figure 3.7: The Marsh Funnel readings

Main Form - Rheological Analysis

Type of Drilling Fluid

Drilling Fluid System

Data

Volume 100

Cumulative Time 3.77

Density 8.5

Operations

Calaculate Get Chart

Show Details Reports

Results

Apperant Viscosity = 0

Plastic Viscosity = 0

Time

Rheogical Analysis Using Marsh Funnel

Figure 3.8: Cumulative Time

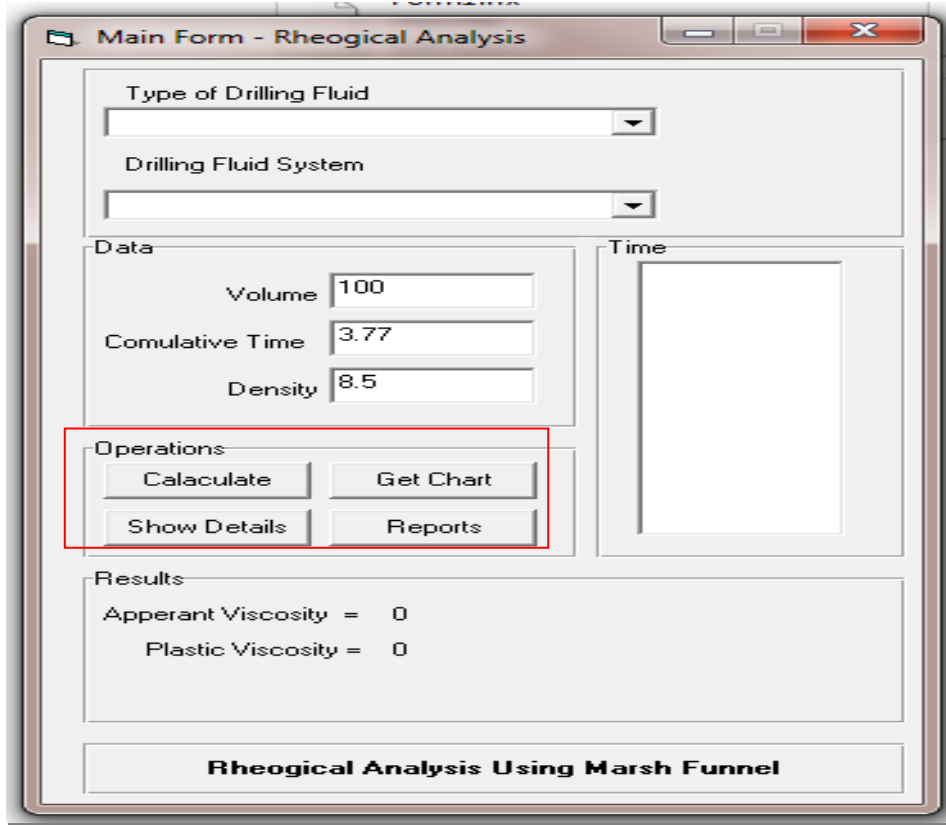


Figure 3.9: Operation options to start MF system

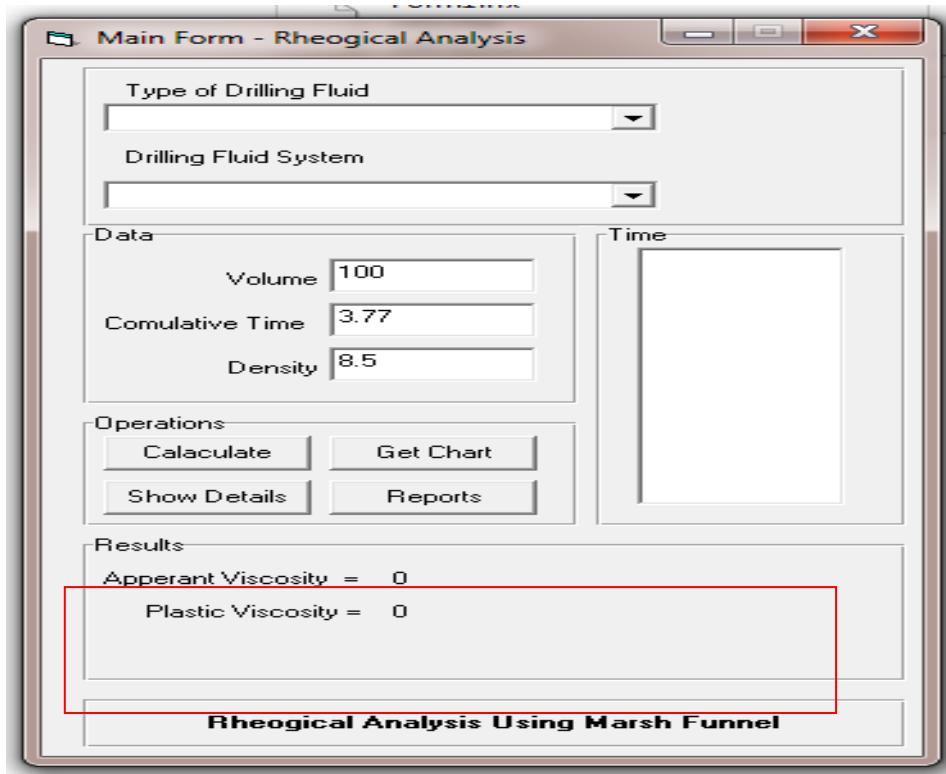


Figure 3.10: Final results from MF system

Main Form - Rheological Analysis

Type of Drilling Fluid

Drilling Fluid System

Data

Volume

Comulative Time

Density

Time

Operations

Results

Apperant Viscosity = 0


Plastic Viscosity = 0

Rheological Analysis Using Marsh Funnel

Figure 3.11: Title of MF system

MF Report

Zoom



MF Report

12:49:59 AM Sunday, November 01, 2015

Type of Drilling Fluid

Drilling Fluid System

Barite
 Costic soda
 Silicate
 KCL
 Dolvis

Density

Apperant Viscosity

Plastic Viscosity

Pages:

Figure 3.12: Example for Report

Chapter 4:

Result & Discussion

Chapter 4

4.1 Results :

Rheology experiments for water base mud were carried out using Marsh Funnel and 6 Speed Rotational Viscometer. Marsh Funnel readings (i.e., funnel drainage volume and corresponding drainage time) for several suspensions were noted and the details of funnel readings are shown in (Table 4.1) for all the suspensions.

Table 4.1 :Marsh Funnel readings from lab

Volume	Time							
	1 $\rho = 8.72$ <i>lb / gal</i>	2 $\rho = 8.90$ <i>lb / gal</i>	3 $\rho = 8.85$ <i>lb / gal</i>	4 $\rho = 8.77$ <i>lb / gal</i>	5 $\rho = 8.82$ <i>lb / gal</i>	6 $\rho = 9.03$ <i>lb / gal</i>	7 $\rho = 8.79$ <i>lb / gal</i>	8 $\rho = 8.90$ <i>lb / gal</i>
100	3.77	3.25	2.1	2.9	2.32	2.6	2.52	3.33
200	7.64	5.1	5.44	5.7	5.27	5.1	5.76	5.43
300	11.29	7.22	8.83	9	8.35	8.1	7.91	7.57
400	14.63	10.03	11.91	12.2	11.08	11	9.1	10.49
500	18.59	12.82	14.54	15.3	14.24	13.7	13.23	13.19
600	22.6	14.33	17.85	19	17.02	16.4	16.37	15.99
700	26.51	18.92	21.12	22.1	19.71	19.1	18.92	19.22
800	30.48	23	24.13	25.8	22.81	22.9	22.07	22.54
900	35.04	26.02	27.88	29.6	26.16	25.9	25.65	25.68
1000	38.96	29.66	31.38	32.6	29.29	29.35	29.2	29.51
1100	43.81	31.51	34.78	36.6	31.39	32.4	31.92	33.07
1200	48.59	40.43	38.43	40.1	35.53	35.7	35.3	38.41
1300	54.01	42.6	42.53	44.3	39.53	39.5	38.73	43.12
1400	59.59	48.78	46.22	49.2	43.29	43	42.63	49.62
1500	67.69	52.26	49.5	54	47.94	52.31	51.81	53.71

For known suspension densities, funnel wall shear stresses are calculated using equation (4) with varying drainage volumes. As Marsh Funnel geometry is fixed, maximum and minimum shear stresses depend only on the suspension density. It is also noted that complete drainage is observed for all the suspensions. Yield point is zero for complete drainage of the suspension. Funnel wall shear rate is estimated from equation (6). Now, flow behavior index (n') values are calculated from equation (5) and are obtained from $\log(4Q/\pi R_f^3)$ vs. $\log \tau_w$ plots (Figures 4.1) to (Figures 4.8).

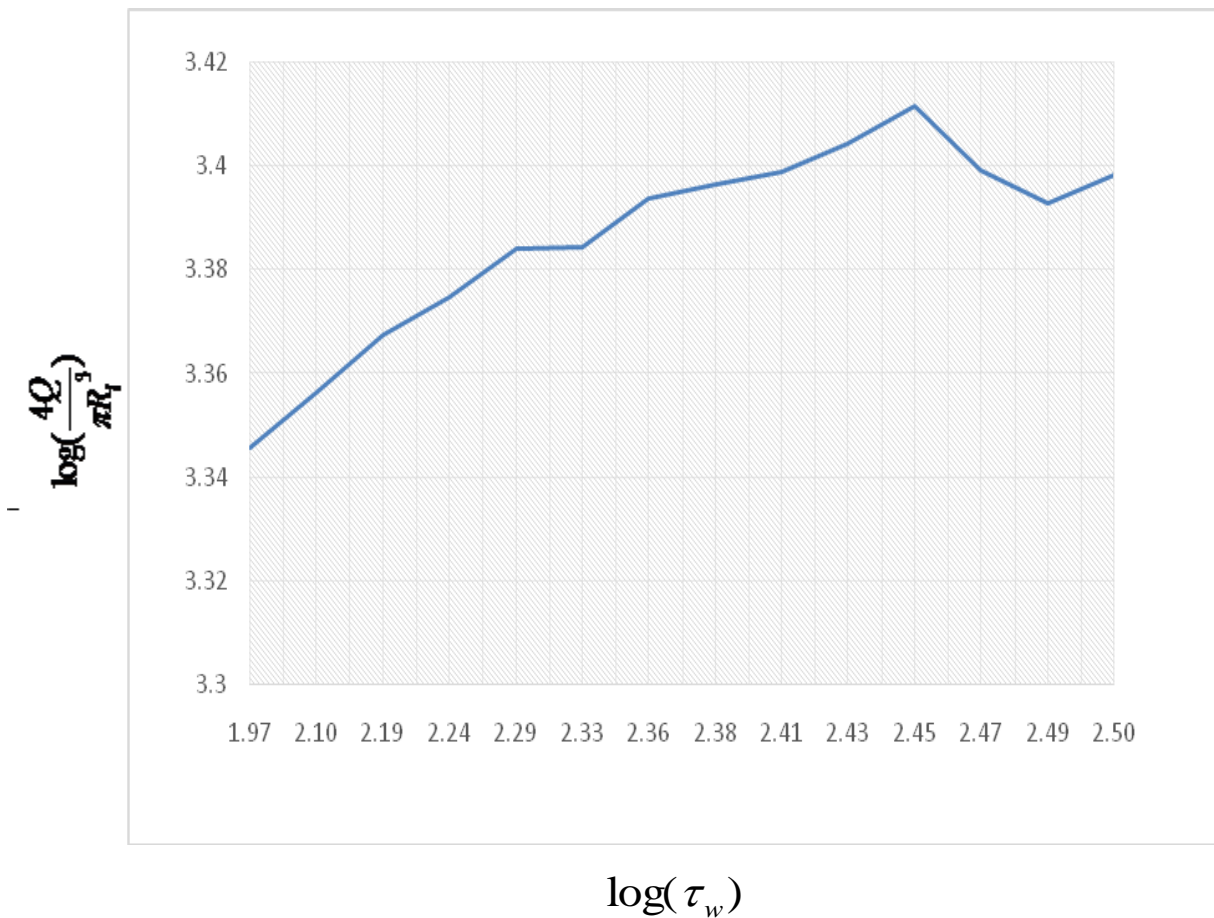


Figure 4.1 : Represent Experiment 1 to Calculate Flow Behavior Index

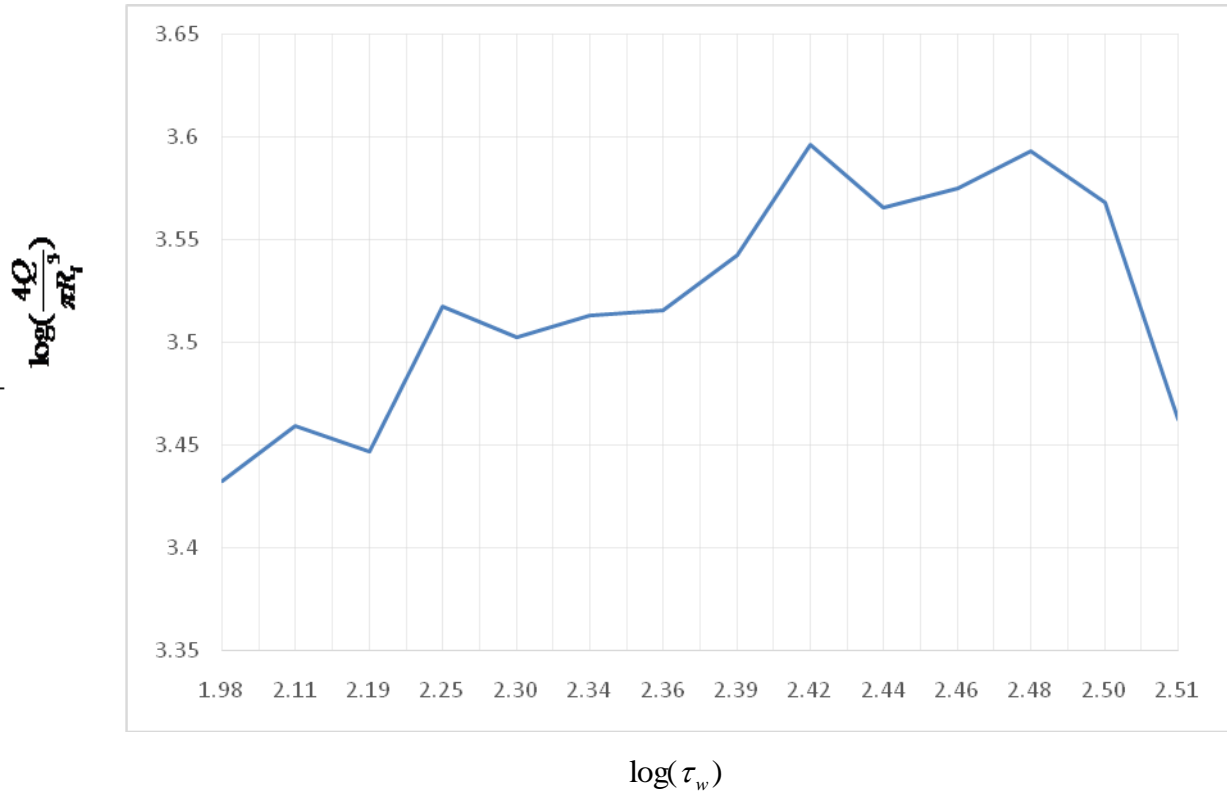


Figure 4.2 : Represent Experiment 2 to Calculate Flow Behavior Index

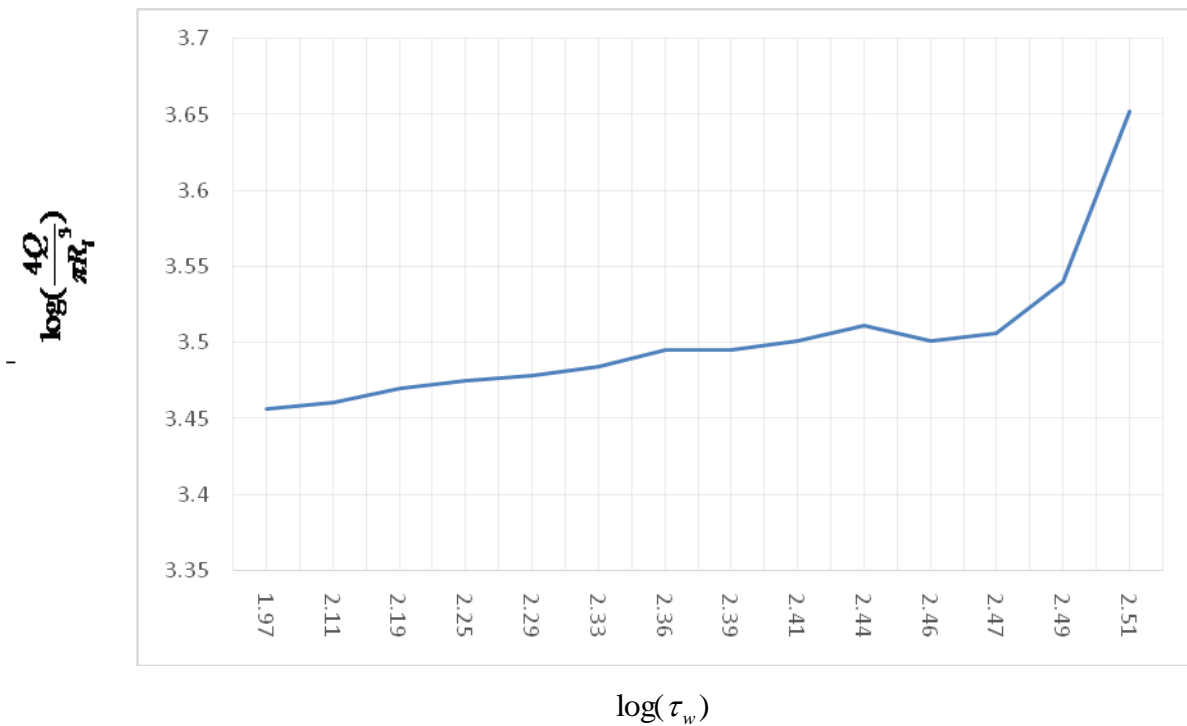


Figure 4.3 : Represent Experiment 3 to Calculate Flow Behavior Index

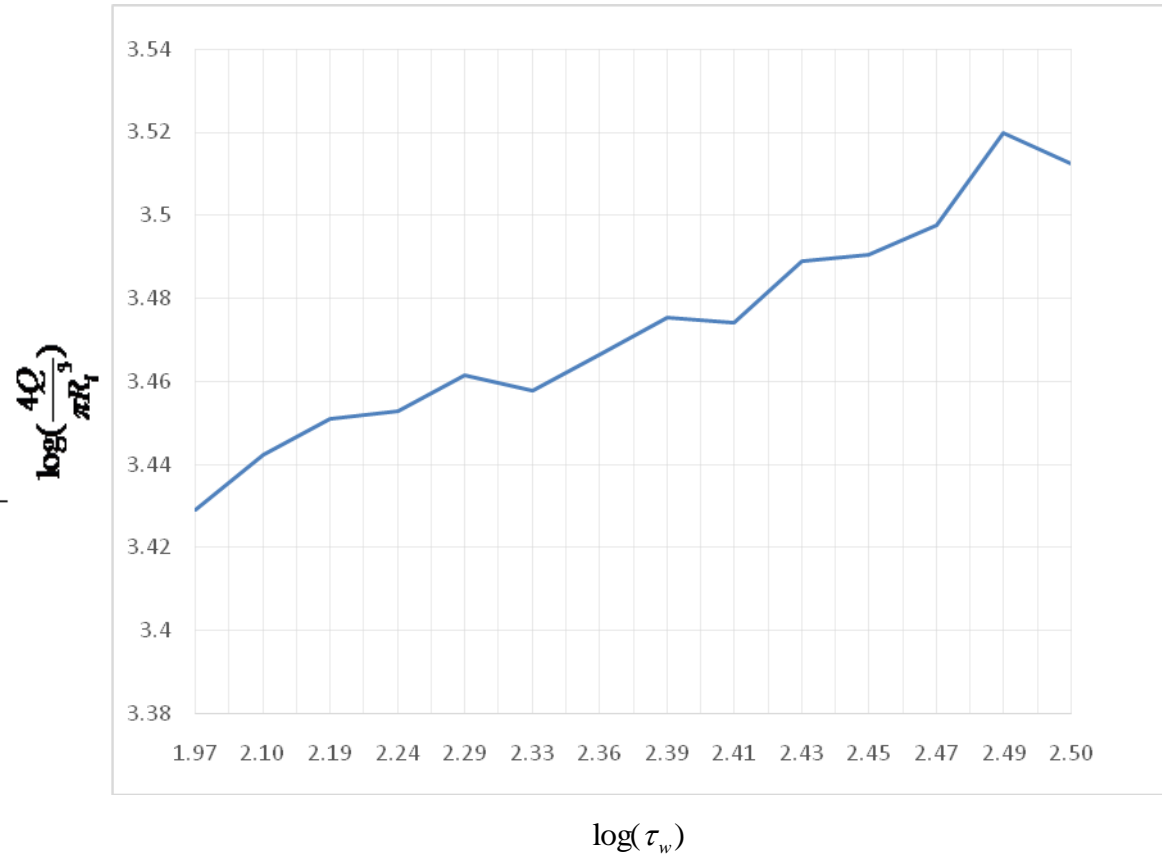


Figure 4.4 : Represent Experiment 4 to Calculate Flow Behavior Index

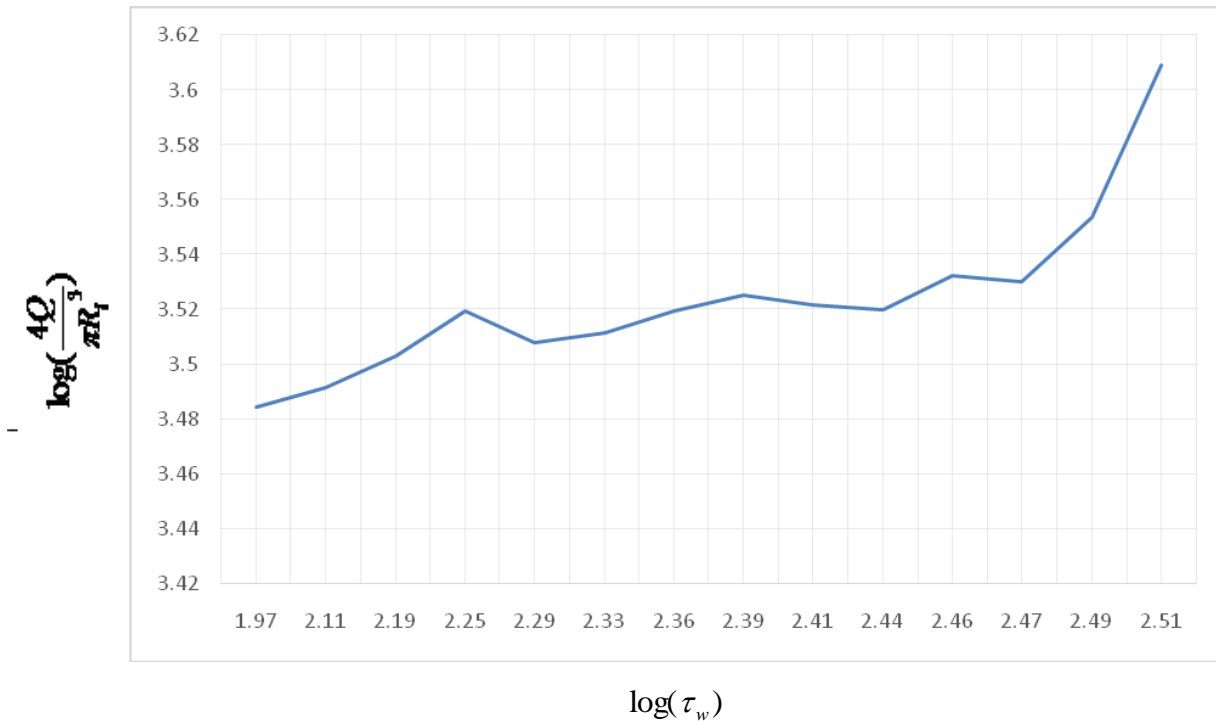


Figure 4.5 : Represent Experiment 5 to Calculate Flow Behavior Index

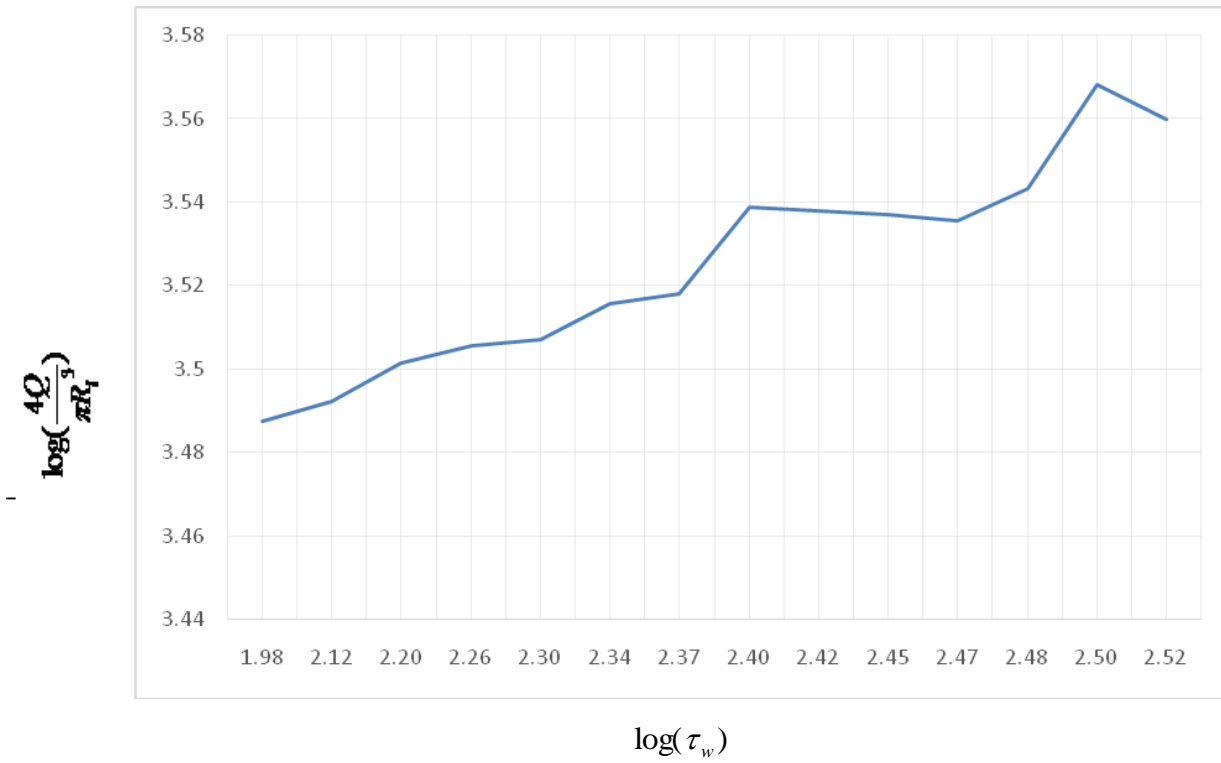


Figure 4.6 : Represent Experiment 6 to Calculate Flow Behavior Index

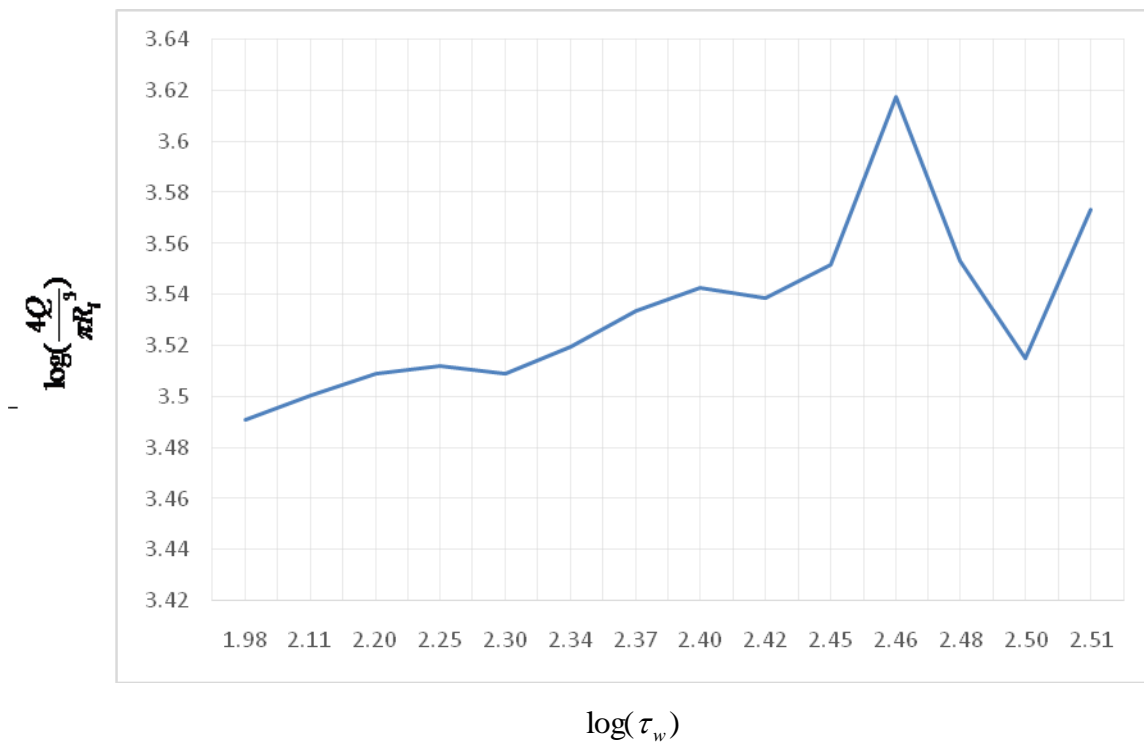


Figure 4.7 : Represent Experiment 7 to Calculate Flow Behavior Index

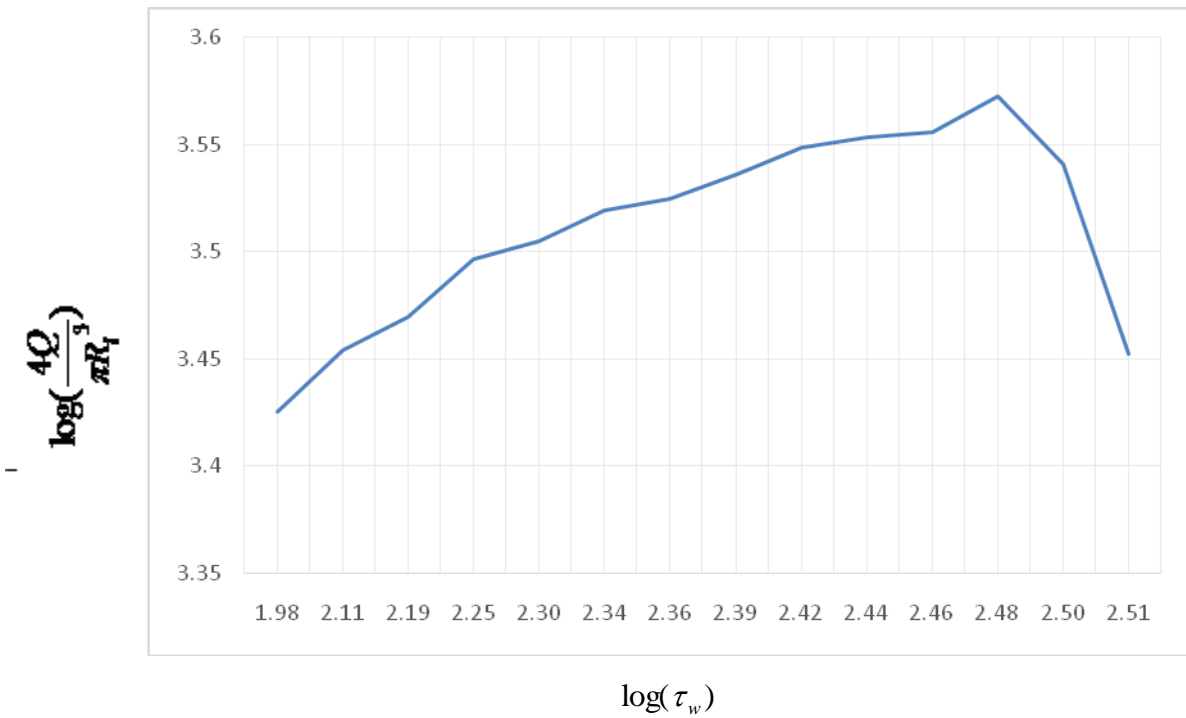
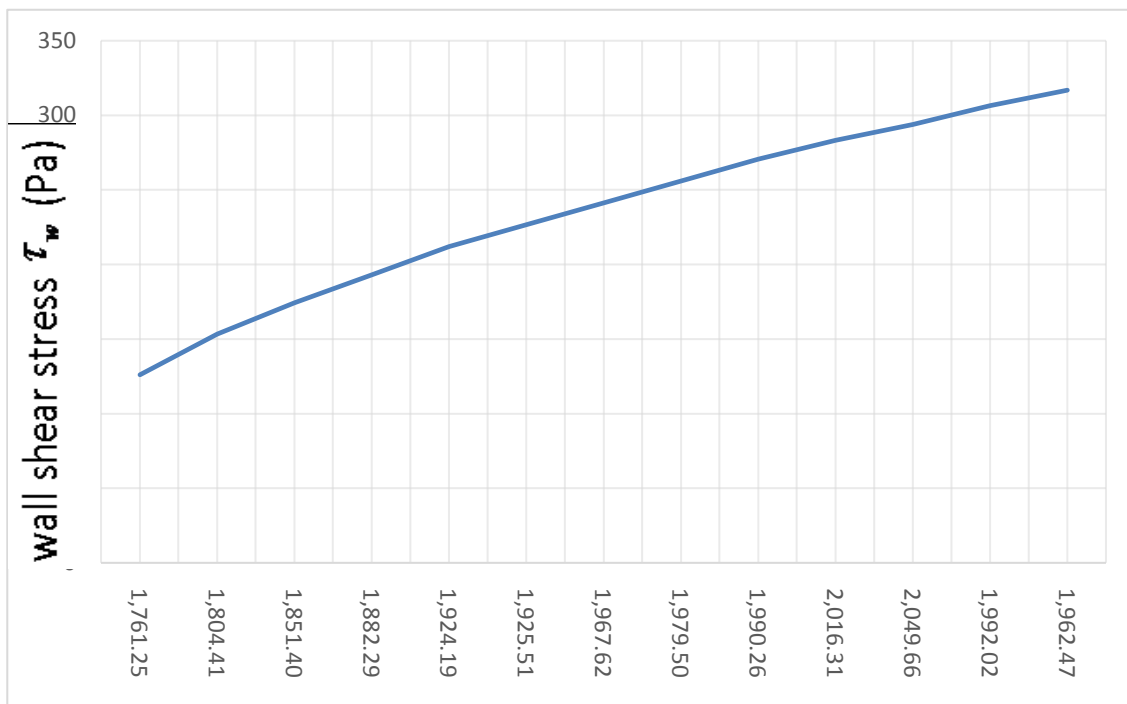


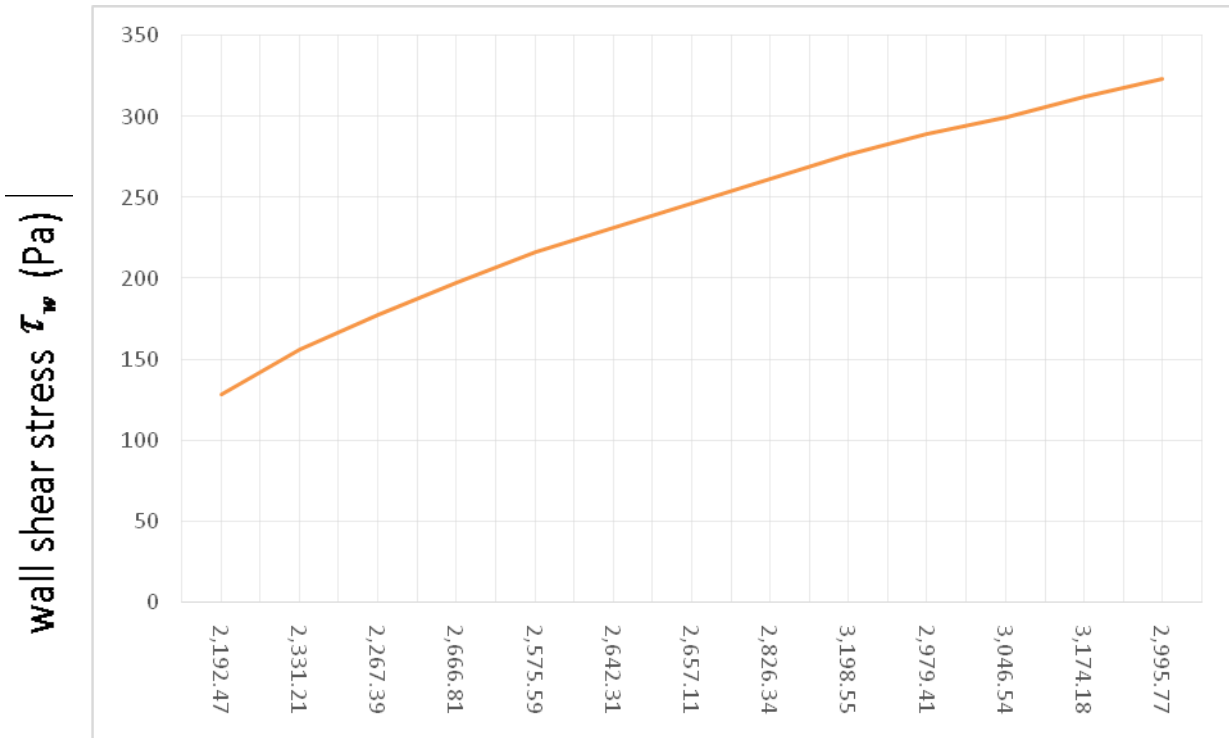
Figure 4.8 : Represent Experiment 8 to Calculate Flow Behavior Index

Figure 4.1 through Figure 4.8 are used to obtain the flow behavior index (n) by plotting $\left(\log \frac{4Q}{\pi R_L^3}\right)$ versus $(\log \tau)$ as shown in equation(3.15) in chapter (3)



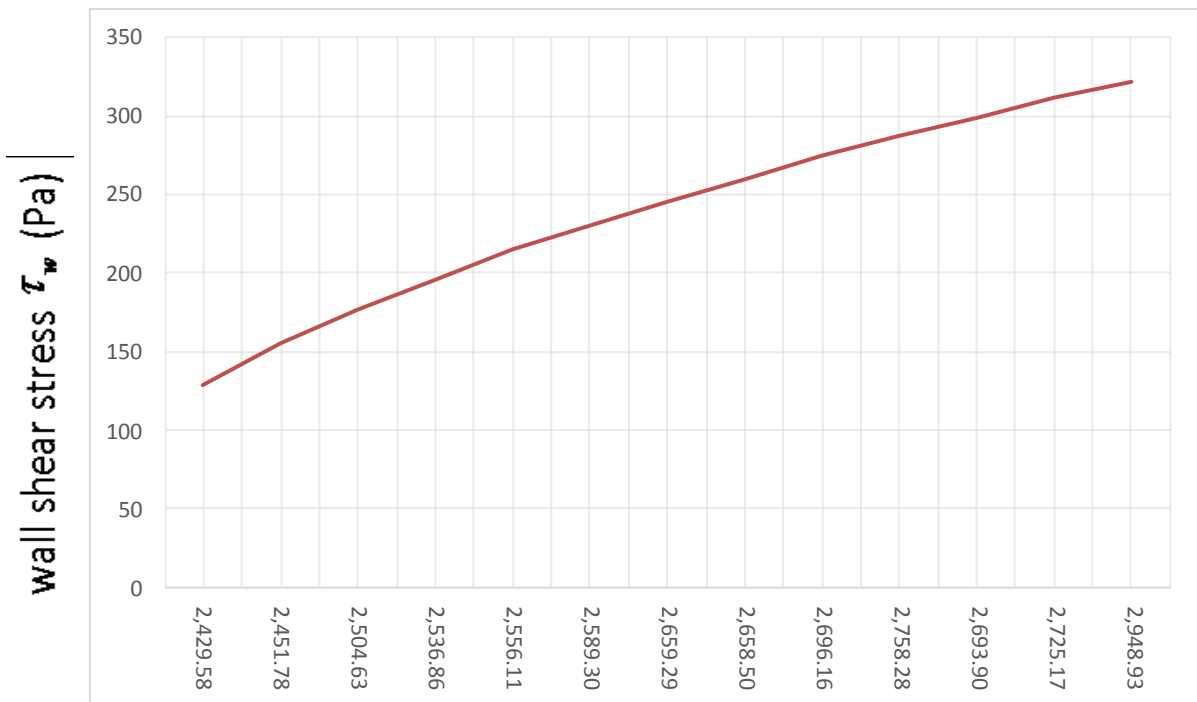
wall shear rate $\gamma_w (s^{-1})$

Figure 4.9: he Relationship between Shear Rate & Shear Stress in experiment 1



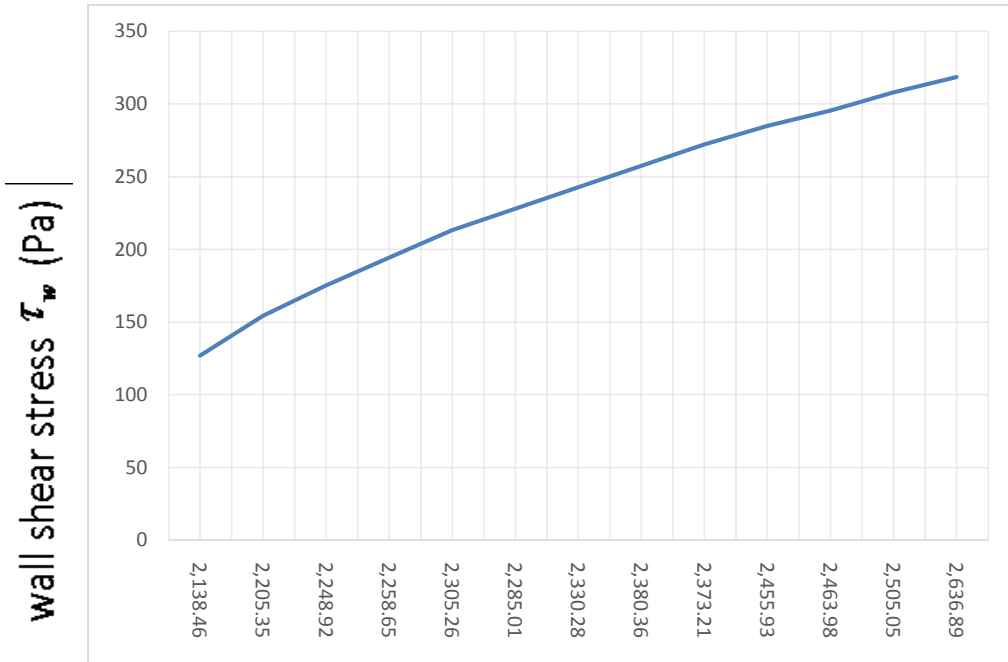
wall shear rate $\gamma_w (s^{-1})$

Figure 4.10: The relationship between shear rate & shear stress in experiment 2



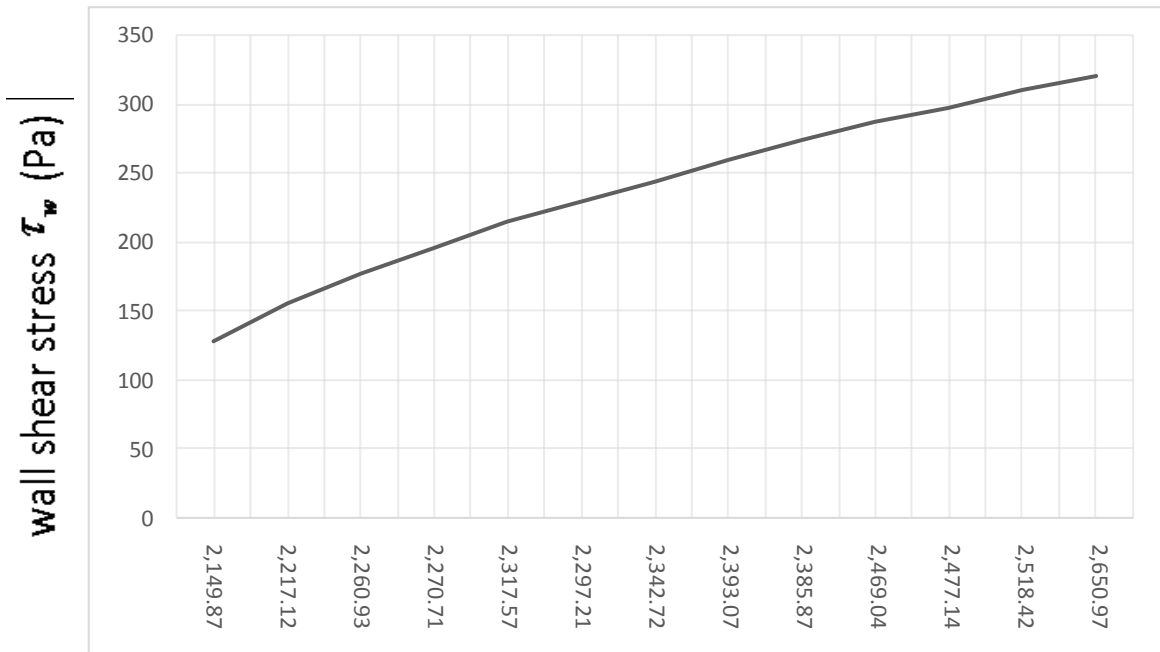
wall shear rate $\gamma_w (s^{-1})$

Figure 4.11: The relationship between shear rate & shear stress in experiment 3



wall shear rate $\gamma_w (s^{-1})$

Figure 4.12: The relationship between shear rate & shear stress in experiment 4



wall shear rate $\gamma_w (s^{-1})$

Figure 4.13: The relationship between shear rate & shear stress in experiment 5

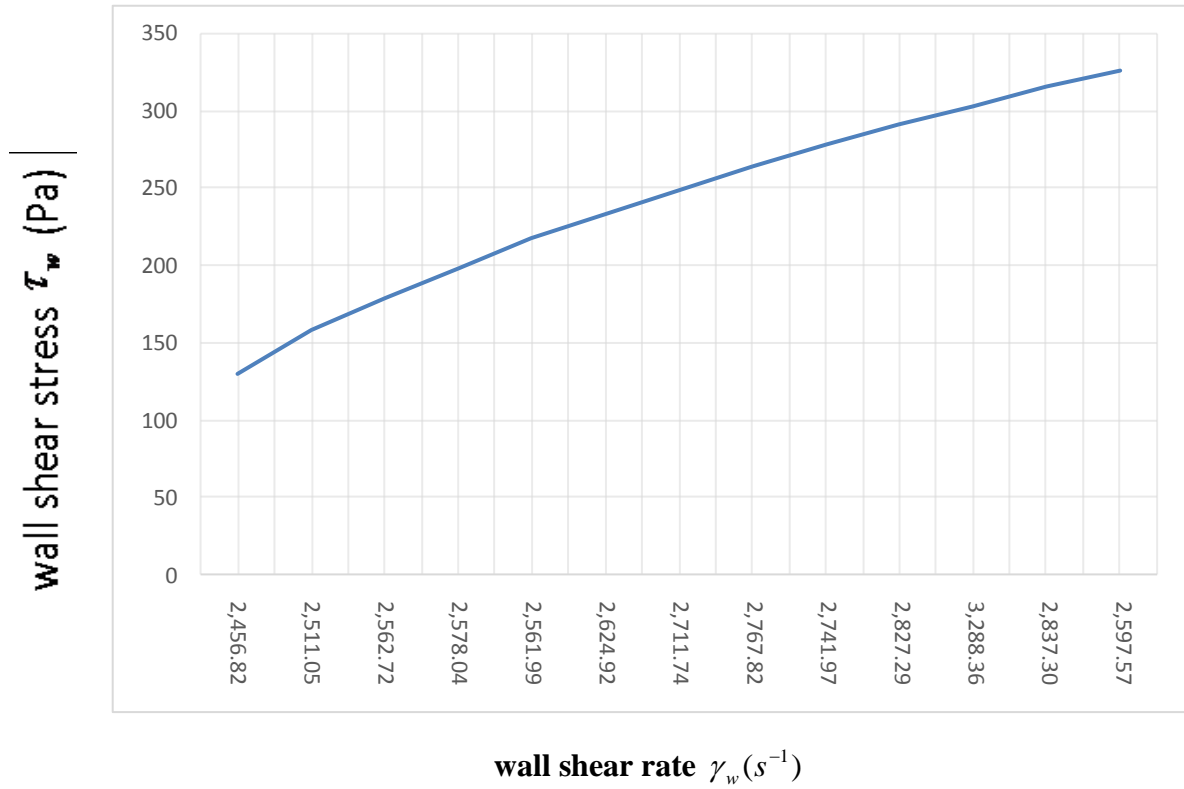
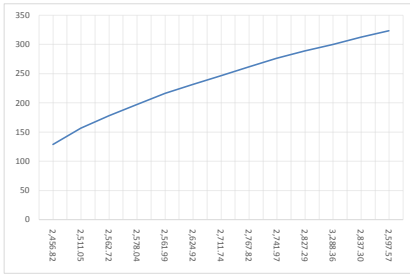


Figure 4.14: The relationship between shear rate & shear stress in experiment 6

wall shear stress τ_w (Pa)



wall shear rate γ_w (s^{-1})

Figure 4.15: The relationship between shear rate & shear stress in experiment

Table 4.2: Final result of Marsh Funnel

Fluid	Experiment	Density $\left(\frac{kg}{m^3}\right)$	PH	μa (cp)	μp (cp)
Bentonite 30gm PAC LV 5gm XC Polymer 5gm	1	1020.41	8	106.65	21.53
Bentonite 60gm PAC LV 2.5gm XC Polymer 2.5gm	2	1042.02	8	100.78	27.4
Bentonite 50gm PAC LV 2.5gm XC Polymer 2.5gm	3	1036.01	8	94.91	25.44
Bentonite 70gm PAC LV 5gm XC Polymer 5gm	4	1026.41	8	86.11	23.48
Bentonite 40gm PAC LV 2gm XC Polymer 1gm	5	1032.41	8	79.26	17.61
Barite 119gm Caustic soda 1.5gm PAC LV 2gm Silicate 20 ml KCl 5gm Dolvis 6 gm	6	1056.42	13	71.43	15.66
Barite 119 gm Caustic soda 1.5gm PAC LV 2gm Silicate 25 ml KCl 7gm Dolvis 6gm	7	1050.42	13	59.69	3.91
Barite 119gm Caustic soda 1.5gm PAC LV 2gm Silicate 30 ml KCl 9gm Dolvis 6gm	8	1042.02	13	56.71	7.83

Table 4.3 : Final result of Viscometer

Fluid	Experiment	Density $\left(\frac{kg}{m^3}\right)$	PH	θ_{300}	θ_{600}	μ_a (cp)	μ_p (cp)
Bentonite 30gm PAC LV 5gm XC Polymer 5gm	1	1020.41	8	20.5	30.8	15.4	10.3
Bentonite 60gm PAC LV 2.5gm XC Polymer 2.5gm	2	1042.02	8	10.2	20.1	10.05	9.9
Bentonite 50gm PAC LV 2.5gm XC Polymer 2.5gm	3	1036.01	8	8.2	15.5	7.75	7.3
Bentonite 70gm PAC LV 5gm XC Polymer 5gm	4	1026.41	8	7	13	6.5	6
Bentonite 40gm PAC LV 2gm XC Polymer 1gm	5	1032.41	8	4.5	8.3	4.15	3.8
Barite 119gm Caustic soda 1.5gm PAC LV 2gm Silicate 20 ml KCl 5gm Dolvis 6 gm	6	1056.42	13	27	36	18	9
Barite 119 gm Caustic soda 1.5gm PAC LV 2gm Silicate 25 ml KCl 7gm Dolvis 6gm Barite 119gm	7	1050.42	13	30	38.5	19.25	8.5
Caustic soda 1.5gm PAC LV 2gm Silicate 30 ml KCl 9gm Dolvis 6gm	8	1042.02	13	25	37	18.5	12

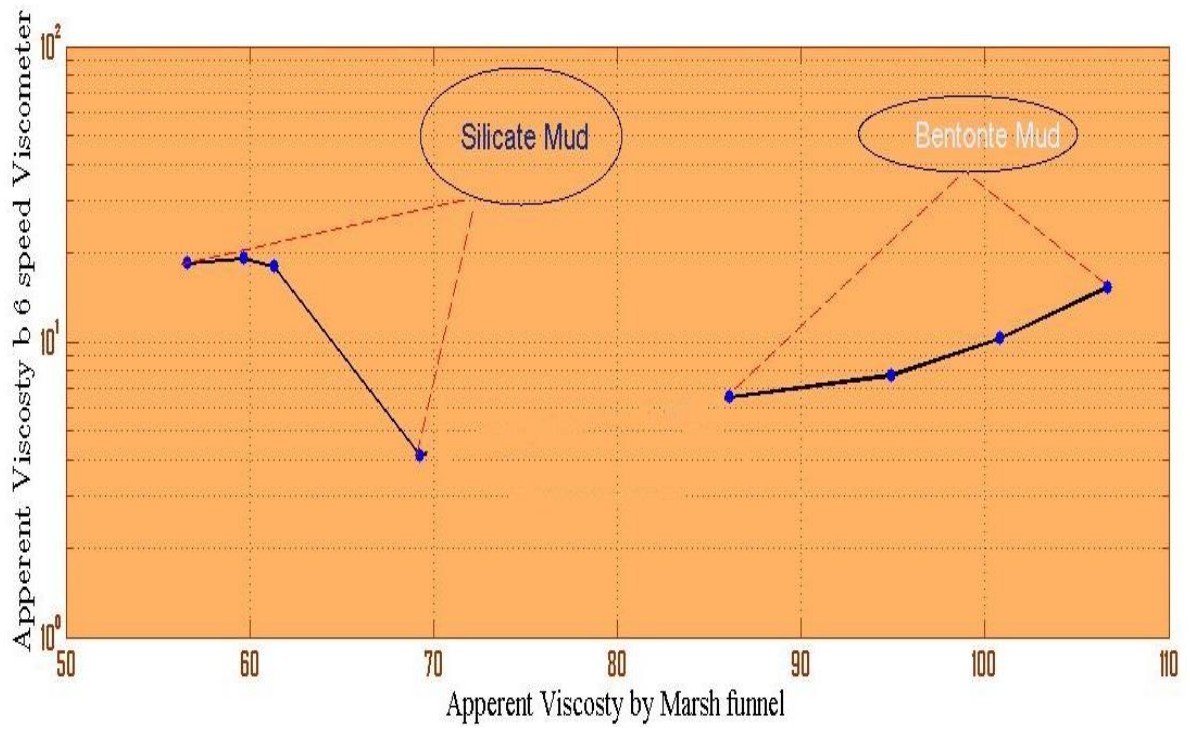


Figure 4.16: relationship between Marsh Funnel and Viscometer in results of Apparent viscosity

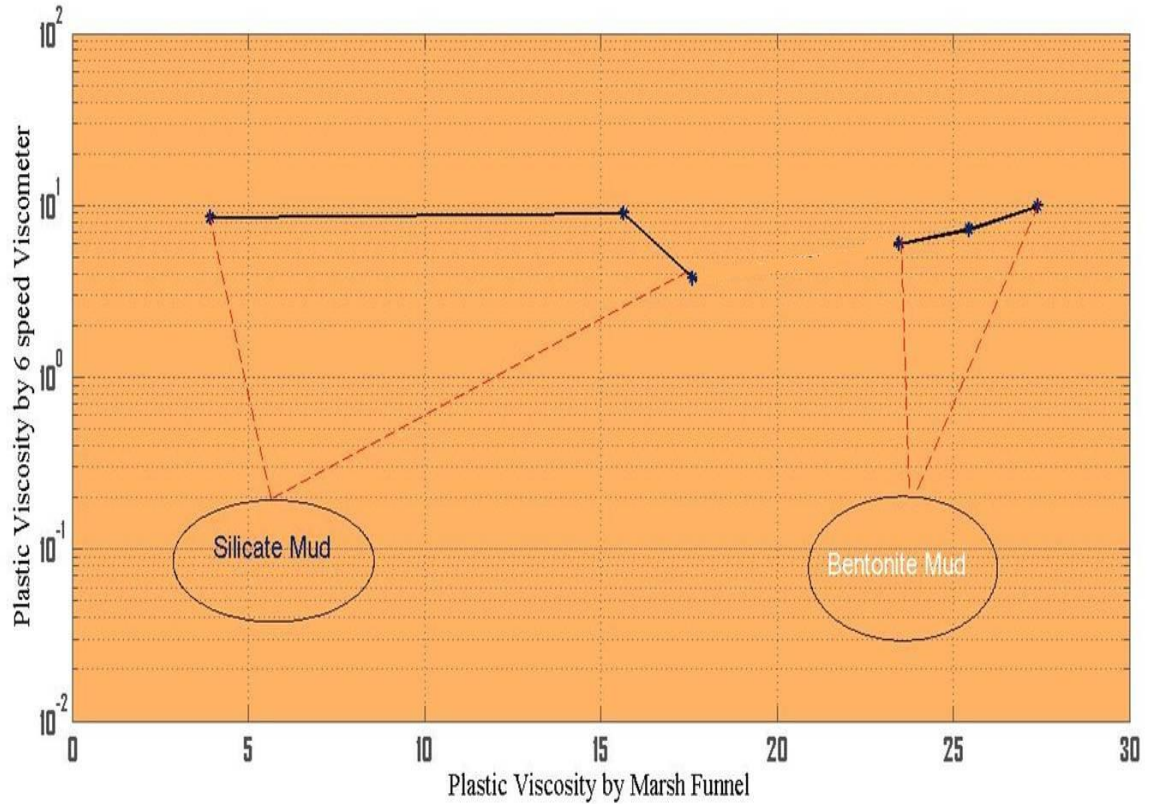


Figure 4.17: relationship between Marsh Funnel and Viscometer in results of Plastic viscosity

4.2 Discussion:

Rheological results obtained from Marsh Funnel readings are compared with 6 Speed Rotational Viscometer readings, the marsh funnel readings were higher than 6 Speed Rotational Viscometer's. and this comparison was obtained from semi log plots shown in the figure (4.16) and figure (4.17) by Matlab.

Chapter 5:

Conclusion & Recommendations

Chapter 5

5.1 Conclusion:

We present a methodology to construct the consistency plot from Marsh Funnel readings for several Newtonian fluids:

1- Marsh Funnel wall shear stress is obtained from drainage volume of the suspension. 2-A rheological model independent shear rate equation is presented and is obtained from volumetric flow rate of the discharged suspension and wall shear stress.

3- apparent viscosity and plastic viscosity are obtained from consistency plot knowing wall shear stresses at 510 s^{-1} and 1020 s^{-1} shear rates.

4- Water base mud and several drilling fluid additives with practical interest have been considered for rheological analysis. Apparent viscosity and plastic viscosity for all these suspensions have been measured from the Marsh Funnel readings.

5-These results are also compared with the rheological properties obtained from 6 Speed Rotational Viscometer. Comparable rheological results are obtained for water base mud from Marsh Funnel whereas relatively higher apparent and plastic viscosities are obtained for other suspensions.

5.2 Recommendations:

From the outcomes of this research, the recommendation can be:

1-Choosing the optimum solution to obtain the apparent viscosity and plastic viscosity from marsh funnel readings for water base mud by using a simple program named MF system.

2-The comparison can easily be shown in the figures from Matlab.

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Appendix A : Visual basic cods was used in design MF system:

Public R0, Z1, Z2, RL, G As Double

Public V, V0, CC As Integer

Public PI As Double

Dim T As Double

Dim SLOP

Dim RW

Dim MA

Dim MP

Dim coss

Private Sub Combo1_Click()

Combo2.Clear

If Combo1.Text = "Water Base Mud" Then

Combo2.AddItem "Gel Mud"

Combo2.AddItem "KCL Polymer"

Combo2.AddItem "Silicate Polymer"

Else

Combo2.AddItem "No"

End If

End Sub

Private Sub Command1_Click()

Dim Q As Double

Dim Z, Y

Dim TW As Double

Dim A, B

Dim AA

PI = 3.14159265

R0 = 6.985

RL = 0.2375

Z1 = 27.94

Z2 = 5.08

V0 = 1500

CC = 33

G = 9.81

coss = 0.8386

V = V + 100

```

If Text1.Text = "" Or Text2.Text = "" Or Text3.Text = "" Then
MsgBox "Please Enter All Values", vbCritical, "System"
Exit Sub
End If

```

```

If Val(Text1.Text) <= 0 Or Val(Text2.Text) <= 0 Or Val(Text3.Text) <= 0 Then
MsgBox "Values Must Be More Than Zero ", vbCritical, "System"
Exit Sub
End If

```

```

Text1.Text = V
List1.AddItem V
List2.AddItem Text2.Text
'===== 1 =====
Q = Val(Text1.Text) / Val(Text2.Text)
Q = Round(Q, 2)
List3.AddItem Q
'===== 2 =====
Z = (V0 - Val(Text1.Text)) - (PI * (RL) ^ 2 * Z2)
Y = (PI / 3) * ((R0 / Z1) ^ 2)
Z = (Z / Y) ^ (1 / 3)
Z = Round(Z, 2)
List4.AddItem Z
'===== 3 =====
'TW = (Val(Text3.Text) * G) * (Z + Z2)
'A = (Cos(CC)) * (RL + (R0 - RL) * (Z / Z1)) + ((2 * Z2) / RL)
'A = Z / A
'TW = TW / A

TW = (Val(Text3.Text) * G) * (Z + Z2)
A = Z / (coss * ((RL + (R0 - RL) * (Z / Z1))))
A = A + ((2 * Z2) / RL)
TW = TW / A
TW = Round(TW, 2)
List5.AddItem TW

'===== 4 =====
AA = Log((4 * Q) / (PI * ((RL) ^ 3))) / Log(10)
AA = Round(AA, 3)
List6.AddItem AA
'===== 5 =====
B = Log(TW) / Log(10)
B = Round(B, 3)

```

List7.AddItem B

'===== 6 =====

```
T = Val(Text2.Text)
If V = 1400 Then
Call Command2_Click
Exit Sub
Else
Call timecalc
End If
End Sub
```

```
Private Sub Command2_Click()
Dim xx As Integer
```

'===== 6 =====

```
SLOP = (Val(List6.List(14)) - Val(List6.List(0))) / (Val(List7.List(14)) - Val(List7.List(0)))
SLOP = 1 / SLOP
MsgBox "SLOP= " & SLOP
```

'===== 7 =====

```
For xx = 0 To 13
RW = (((3 * SLOP) + 1) / (4 * SLOP)) * ((4 * Val(List3.List(xx))) / (PI * (RL) ^ 3))
RW = Round(RW, 2)
List8.AddItem RW
Next
```

'===== 7 =====

```
MA = Val(List5.List(8))
MA = Round(MA, 2)
Label9.Caption = MA
```

'===== 9 =====

```
MP = 2 * (Val(List5.List(8)) - (Val(List5.List(0))))
MP = Round(MP, 2)
Label7.Caption = MP
```

End Sub

```
Private Sub Command3_Click()
If V <> 1400 Then
MsgBox "Please Complete The calculations ", vbInformation, "System"
Exit Sub
```

```

Else
Form2.Show 1
End If

End Sub

Private Sub Command4_Click()
If Command4.Caption = "Show Details" Then
Form1.Width = 15360

Command4.Caption = "Hide Details"
Else
Form1.Width = 5370
Command4.Caption = "Show Details"

End If

End Sub

Private Sub Form_Load()
V = 0
End Sub

Function timecalc()
On Error Resume Next
Dim TN, tt

tt = InputBox("Enter Time")
If tt <= 0 Then
MsgBox "Values Must Be More Than Zero ", vbCritical, "System"
Call timecalc
Exit Function
End If

If tt = "" Then
MsgBox "Please Enter Values", vbCritical, "System"
Call timecalc
Exit Function
End If

TN = T + tt
Text2.Text = TN

```

Call Command1_Click

End Function

Private Sub Form_Load()

On Error Resume Next

Chart1.RowCount = 2

Chart1.ColumnCount = 2

Chart1.ChartData = (Form1.List7.ItemData(xx) & "," & Form1.List6.ItemData(xx))

End Sub