

Experimental Study and Modeling of Yield Power-Law Fluid Flow in Pipes and Annuli (Effects of Pipe Rotation and Temperature)

INVESTIGATOR: Ramadan Ahmed, Senior Research Associate

INTRODUCTION: This report presents experimental studies conducted on the effect of inner pipe rotation on the annular pressure loss. Experiments were conducted at different rotational speeds and flow rates under laminar and turbulent flow conditions. Previous reports presented at the TUDRP Advisory Board Meeting covered the effects of inner pipe rotation and temperature on the annular friction pressure loss predominately under laminar flow conditions. This report summarizes literature review and theoretical studies conducted on the flow of non-Newtonian fluids in concentric annuli.

OBJECTIVES: The overall aim of this study is to develop reliable hydraulic models that accurately predict the frictional pressure losses in pipes and annuli under laminar, transitional and turbulent flow conditions. The research involves both mathematical modeling and experimental investigations. The effects of fluid properties, eccentricity, and pipe rotation on the relationship between frictional pressure losses and flow rate have been studied experimentally and theoretically.

APPROACH: For this reporting period, the emphasis is given to investigate the combined effect of pipe rotation on annular friction pressure loss under laminar and turbulent flow conditions. Flow experiments with polymer-based fluids were carried out using the Dynamic Testing Facility. Two pipe and one concentric annular test sections were considered for this investigation. Experimental results suggest that inner pipe rotation can strongly affect the annular pressure loss under laminar flow conditions.

DELIVERABLES:

- Experimental database for flow of YPL fluids (synthetic/polymeric);
- Mathematical models that can predict frictional pressure losses of YPL fluids in pipes and annuli under different flow conditions (flow regimes, temperatures, pressures, eccentricities, pipe rotations and wall roughnesses);
- Computer codes to predict frictional pressure losses in boreholes;
- Recommendations and guidelines in the use of YPL (synthetic/polymeric) fluids for ECD management and hydraulics optimization.

Cuttings Transport with Foam at Simulated Downhole Conditions – The Effect of Hole Inclination Angle

INVESTIGATOR: Yuan Ma

Executive Summary

The use of foams as drilling fluid is increasing because foams have properties that are desirable in many drilling operations. The advantages of foam drilling over conventional mud drilling have long been recognized and include stable flow regime with no slug, increasing penetration rates, longer bit life, prevention of lost circulation and elimination of formation damage to the producing reservoir.

In this proposal, a review of literatures was carried out to generalize and classify the results and conclusions from previous studies, and to summarize the achievements acquired. Then a preliminary theoretical investigation was conducted to understand the mathematical and mechanical explanation of the process of cuttings transport with foams and rheology of foams.

In the literature review, investigation of cuttings transport with foams and foams rheology was carried out. The results and conclusions obtained from the studies were categorized and compared with each other. There are many papers and reports on the cuttings transport with foams under low pressure and ambient temperature (LPAT) conditions; however, only **TWO** studies on cuttings transport with foam at elevated pressure and elevated temperature (EPET) conditions were recently finished. Moreover, neither of them took hole inclination angle into consideration.

Further investigation on rheology of foams will be conducted on both Foam Generator/Viscometer (FGV) and Advanced Cuttings Transport Facility (ACTF). Cuttings transport tests will be carried out on Advanced Cuttings Transport Facility (ACTF) under simulated downhole conditions to investigate the effect of the hole inclination angle. Meanwhile, modification of Duan's computer simulator will be conducted by taking effect of hole inclination angle into consideration. Finally, the deliverables are an experimental database, more comprehensive computer simulator, and semi-annual Advisory Board Meeting (ABM) reports and the final report.

The Effect of Depth of Cuts and RPM on Mechanical Specific Energy

By: Sandeep Tammineni

Executive Summary

The Drilling industry faces problems with varied Rates of penetration (ROP). There are various factors that affect the rate of penetration. As we don't have a clear understanding of these factors they need to be studied and understood better.

In this proposal, a review of literatures was carried out to generalize and classify the results and conclusions from previous studies, and to summarize the achievements acquired. Then a preliminary theoretical investigation was conducted to understand the other factors that attribute to lower rates of penetration. The main factors that will be detailed in the research will be Bit balling and the effect of depth of cut and RPM on Mechanical specific energy (MSE)

There are various tests that will be performed which will give the calculation of the forces required to calculate MSE. These tests will be done under various depths of cut and RPMs. They will then be used to determine their effect on MSE. The temperature at the cutter rock interaction will be recorded by installation of the infrared temperature measurement device which will be used to calculate the amount of energy dissipated due to friction.

Finally the deliverables would be as follows:

- Mathematical model to predict the MSE by taking into account the various depths of cuts and RPM.
- A video of cutter rock interaction.
- Temperature measurements at the cutter surface during the cutting process.

Modeling of Yield-Power-Law Type of Drilling Fluid Losses In Naturally Fractured Reservoirs

INVESTIGATOR: Reza Majidi

SPONSOR: TUDRP

OBJECTIVE:

- To develop a model for losses of Yield-Power-Law fluids in fractures and validate the proposed model by field data.
- Quantitative analysis of drilling fluid losses in order to characterize the fracture.

PAST WORK:

- Literature review on modeling of drilling mud losses into natural fractures.
- Development of mathematical modeling of fluid loss for Yield Power Law fluids.
- Include the effect of formation fluid in the model for YPL fluid.
- Field data analysis of the two loss events.
- Provide experimental setup in order to experimental study of YPL fluids between parallel plates.

FUTURE WORK:

- Including fluid leak off through fracture walls
- Conducting more experiment for different fluids and operational conditions.

DELIVERABLES

- Generalized Model for flow of Yield Power Law fluids in fractures.
- Model for ballooning process (deformable fractures)
- Experimental results
- Semi-annual Advisory Board Meeting (ABM) reports and the Final Report.

PROJECT STATUSE:

Literature Review		90 %
Mathematical Modeling	YPL drilling fluid in a deformable fracture	75 %
Experimental study	Radial flow of YPL fluid between parallel plates	60%
Field Data Analysis	Not available-Some data borrowed from literature	70 %
final report		00 %

Study of Modeling Transient Borehole Failure Using Discrete Element Method

INVESTIGATOR: Yongfeng Kang

OBJECTIVES:

- To develop an understanding of transient borehole failure;
- To predict transient borehole failure by modeling rock behavior at the grain level using discrete element concept;
- To develop a computer program to simulate the transient borehole failure at simulated conditions;
- To verify the model with field data or published data.

STATUS OF PROJECT:

Task	Description	Percentage completed
Literature review	Traditional models	90%
	DEM	65%
Mathematical modeling of DEM	For 2D case	85%
	For 3D case	--%
Computer Simulator Development	For 2D case	85%
	for 3D case	--%
Final report		--%

RECENT PROGRESS:

- Literature review has been partly completed.
- Neighbors searching and contact detecting algorithm have been designed and implemented.
- The DEM 2D system is developed, but needs more output function.
- Case study for anisotropic compression is conducted and the result is good agreement with field observations.

FUTURE WORK:

1. Complete the mathematical model of DEM;
2. Add more functions in system of DEM in the 2D case, and add more output;
3. More case studies in under the 2D condition for simulated wellbore conditions;
4. DEM for 3D case

PREDICTING DYNAMIC BARITE SAG IN OIL BASED DRILLING FLUID

INVESTIGATOR: Tan Nguyen

OBJECTIVE

- Study the effects of oil based drilling fluids rheology on static and dynamic barite sag by using the rotational viscometers;
- Experimentally investigate the combined effects of oil base drilling fluids rheology, annular velocity, drill-pipe rotation, eccentricity, and inclination angle on dynamic barite sag;
- Develop mathematical models for predicting dynamic barite sag in yield power law fluid (YPL) in an inclined annulus.

ABSTRACT

This report presents the combined effects of eccentricity and pipe rotation on dynamic barite sag. The Small Scale Flow Loop (SSFL) was used to perform tests with pipe rotation. The results show that eccentricity tends to increase sag. In addition, pipe rotation helps to reduce sag. However, pipe rotation in eccentric case helps to prevent sag better than in concentric case.

Using mass conservation and momentum conservation for solid and liquid phase, a set of four coupled equations to analyze solid-liquid flowing in shear flow are obtained. They are highly non-linear partial differential equations, so a numerical solution with 6 boundary conditions was chosen to solve these equations. The results indicate that liquid velocity is always higher than solid velocity. On the other hand, there is an existence of slip velocity between solid and liquid phase. The solid concentration at the bottom of the pipe increases with time. Solid velocity in lateral direction at the bottom of the pipe decreases with time because of the increase in solid concentration.

FUTURE WORK

- Continue modification of the Large Indoor Flow Loop
- Characterize the barite bed
- Conduct tests on the LIFL to compare results with the results from SSFL
- Conduct tests on the LIFL to validate results of the modeling part
- The settling of barite particles in shear flow in yield power law fluid flowing in pipe will be explored

PROJECT STATUS

Tasks	Percentage Accomplished
Literature review	90%
Rheology tests	70%
Dynamic tests without pipe rotation with the SSFL	90%
Dynamic tests with pipe rotation with the SSFL	90%
Modifying the LIFL	50%
Dynamic tests with LIFL	0%
Model development	30%
Final report	0%

EXPECTED COMPLETION DATE

Summer, 2009

Effect of Pore Pressure on Single Cutter Forces

INVESTIGATOR: Navid Rafatian

ABSTRACT:

A theoretical and experimental investigation of the effect of pressure on Mechanical Specific Energy and Cutting Efficiency was performed. The bottomhole expansion theory of Warren and Smith was verified and it was shown through finite element analysis that permeability of the formation restricts the use of this theory in many cases. Single cutter experimentations under pressure showed that the pressure environment has significant effects on both impermeable and permeable rocks. A hypothesis was produced to explain for the reduced efficiencies observed in the experiments.

PROJECT STATUS:

Task	Completion
Literature review	100%
Theoretical study	100%
Test facility preparation	100%
Single cutter tests	100%
Test data analysis	100%
Final report	100%

RECENT PROGRESS:

- Permeability effects were introduced into the bottomhole expansions theory and finite element analysis of its effect were done.
- Numerous tests were performed with the single cutter facility under various pressure conditions.
- A hypothesis was produced to explain the behavior of the single cutter under pressure as observed in the experiments.

TRANSIENT CUTTING TRANSPORT (BED EROSION) IN HORIZONTAL WELLS

Investigator: M.Usman Khan

Abstract:

The past attempts to develop practical design models for efficient cuttings transport may be divided into two groups: mechanistic models and empirical models. The studies carried out for transient bed erosion is mostly limited to empirical models only having very limited range of application. Therefore, a rigorous theoretical analysis of “transient cuttings bed erosion” needs to be performed. A combination of mathematical modeling, experimental investigation and utilization of existing transient data from previous research projects is employed to achieve the above objective. This report presents the literature review being carried out, experimental results of cuttings transport on a Low pressure ambient temperature loop, work on transient cuttings transport mathematical model using conservation of mass and momentum, the computer code to predict bed height and pressure drop using two layer method. The Low Pressure Ambient Temperature (LPAT) was used to perform cuttings transport experiments using water and PAC-R with and without drill pipe rotation.

Project Status:

Tasks	Percentage Accomplished
Literature review	95%
Experiments	100%
Model development	45%
Analysis Of Results	25%
Final report	10%

Recent Progress:

- Most of the literature review has been completed.
- Working on mechanistic model, using conservation of mass and momentum.
- Working on the transient cutting transport computer code.
- Wave front propagation concept is replaced by simple conservation principle.

Future Work:

- Complete mechanistic model to predict the bed height for horizontal wells.
- Compare the mathematical model results with that of experimental one.
- Complete the computer code that implements the mathematical model.
- Semi-annual Advisory Board Meetings Progress Reports and Final Report.

EXECUTIVE SUMMARY

Experimental Study and Modeling of Transient Drilling Fluid Gelation

Investigator: Heitor Lima, Petrobras

Introduction

The aim of this study is to develop a model that can predict the pressure required for restarting flow of a transient gel after the fluid has been at rest. The effects of flow rate, temperature, aging time, and pipe rotation on gel strength building and breakdown will be studied experimentally.

The problem is particularly important in deepwater and ultra deepwater drilling operations due to the low temperature the drilling fluid can reach inside the marine riser, causing its viscosity and gel strength undergo a high increase. Depending on the time the drilling fluid is left at rest during drilling operations (such as trips or casing runs), the energy required to break down the fluid solid-like microstructure when resuming circulation can be high enough to fracture the weakest formation in open hole and induce severe lost circulation problems.

Objectives

The specific objectives of this study are: i) to experimentally investigate the thixotropic rheology of YPL (synthetic/polymeric) fluids under different temperatures, shear rates and aging times in order to determine the effects of these parameters on rheological parameters; ii) to compare the experimental data with the predictions of currently existing rheology models for YPL (synthetic/polymeric) fluids; iii) to investigate experimentally the effects of pipe rotation on the breakdown of gelled YPL (synthetic/polymeric) fluids; iv) to develop a new gel-breaking model for YPL (synthetic/polymeric) fluids taking into account temperature, shear rate, aging time and pipe rotation effects; and v) to present recommendations and guidelines for restarting pumps when using YPL (synthetic/polymeric) fluids where drilling conditions demand extra care.

Scope of work

The proposed research is arranged into two phases, with a number of tasks to be accomplished in each phase. Due to time limitations, initially two types of fluids will be tested, a polymeric fluid and a synthetic fluid, at the following conditions: i) Temperature (F): 40, 60 and 80; ii) Shear rate (s⁻¹): 5, 10 e 15 and iii) Aging time (min): 0.5, 1, 2, 4, 8, 16, 32.

Phase I will investigate a polymeric fluid (aqueous Xanthan Gum solution) and consists of a literature review, theoretical studies, rheology characterization using a rotational rheometer (RS 300) and flow experiments in the dynamic test facility (DTF). **Phase II** involves the same tasks performed in Phase I but now applied to a synthetic based drilling fluid to be provided by Petrobras.

Deliverables

A final report comprising the methodology and experimental results of this study.

Modeling of Thermal Effects on Wellbore Stability

INVESTIGATOR: Duc Nguyen

OBJECTIVES:

- Enhance our understanding of the thermal effects on wellbore stability.
- Develop a heat transfer model that takes into account the effect of mechanical friction.
- Create a computer simulator based on the mechanistic model to predict and analyze wellbore stability problems.
- To verify the developed models by means of experimental investigation.

PROJECT STATUS:

Literature review	75 %
Mechanistic model of heat transfer in wellbores	80 %
Mechanistic model with mechanical friction effect	60 %
Wellbore stability model	0 %
Experimental investigation	0 %
Computer simulator	50 %
Final report	0 %

RECENT PROGRESS:

- Analytical model that can generate temperature profiles for drilling fluid in drillpipe and annulus for 3D directional wells.
- Effect of mechanical friction on drilling fluid temperature profile assuming even distribution of heat along the wellbore.

FUTURE WORK:

- Complete the full numerical model and compare with analytical model.
- Investigate the effect of uneven distribution of heat sources.
- Prepare building experimental test section.
- Study existing wellbore stability models with the effect of temperature.

Study of Effect of Drill Pipe Rotation and Downhole Mechanical Cleaning Devices on Cuttings Transport

INVESTIGATOR: Munawar Sagheer

OVERVIEW:

With the increase in horizontal and extended-reach drilling, greater emphasis is being placed on effective removal of drilled cuttings out of the well bore. The problems associated with inadequate hole cleaning such as excessive torque, drag, and mechanical pipe sticking have been recognized by the drilling industry for a long time. Efficient cutting transport is an important issue in drilling highly deviated and horizontal wells.

Several solutions have been suggested in the literature to address the challenging issue of efficient hole cleaning. These include controlling the drilling fluid rheology and hydraulics, introducing a viscous pill while circulating the drilling fluid, appropriate combinations of drill pipe rotation and eccentricity, adjustment of flow rate, etc. Recently, hydro-mechanical hole cleaning devices (MCDs) have been developed to enhance cutting transport efficiency.

These tools are introduced in the drill string with different spacing arrangements. The tools, or subs, have a modified outer periphery (like blades) and are introduced in the drill string while drilling. While rotating the drill pipe, the blades agitate the cuttings bed and help bring the cuttings into suspension. At the same time, the circulation of the drilling fluid allows the suspended cutting particles to be readily carried away, thus leading to better hole cleaning.

RESEARCH OBJECTIVES:

Specific objectives of this research are:

- 1) To investigate experimentally the effect of MCD on cutting transport under various operating conditions;
- 2) To evaluate and compare the performances of MCDs;
- 3) To study transport mechanisms of MCDs under various operating conditions;
- 4) To simulate the performance of MCDs in large boreholes (12 1/4" and 17 1/2" hole sizes) by using reduced scale testing specimens; and
- 5) To present an experimental data base for further technology developments.

PRACTICAL APPLICATION:

- Effective removal of drilled cuttings out of the well bore during horizontal and extended-reach drilling.
- Minimize the problems such as excessive torque, drag, and mechanical pipe sticking due to inadequate hole cleaning.