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Thème

Influence of the rheological parameters of drilling fluid at the drilling performance study of the well RECSWS EXT#1, 26" section at (Hassi Berkine East field)

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Résumé

En raison de l'importance des fluides de forage et le rôle essentiel au cours du processus de forage et dans le but de nettoyer le puits de roches brisées par le outil de forage, et pour cela, nous avons un suivi régulier de certaines des propriétés physiques du fluide de forage, et en particulier la viscosité, afin d'assurer un bon nettoyage du puits.

C'est pourquoi nous avons considéré que cette étude expérimentale pour améliorer les caractéristiques de viscosité du fluide de forage après avoir constaté qu'il ne suffisait pas de nettoyer le puits, c'est après la coincement de garniture de forage dans le puits
RECSWS EXT 1 du champ HASSI BERKINE Est.

Enfin, ont montré les résultats obtenus un bon nettoyage du puits.

Les mots-clés: Fluides de forage, viscosité, nettoyage de puits.

Abstract

Due to the importance of the drilling fluids and their basic role during the drilling process which is the clean of the well from the rocks cut by the bit of the drilling, therefore we have periodic monitoring the viscosity of liquid to have a good cleaning of the well.

This is why we considered this experimental study to be in improving the viscosity characteristics of the drilling fluid after we found that it is not sufficient to clean the well. This is after the stuck pipe in the well RECSWS EXT 1 field of the east of HASSI BERKINE.

Finally, the results obtained showed good cleaning of the well.

Key words: Drilling fluids, viscosity, hole cleaning.

الملخص

نظرا الى اهمية سوائل الحفر و دورها الاساسي اثناء عملية الحفر و المتمثل في تنظيف البئر من الصخور المقطوعة من طرف راس الحفر ،ولهذا يتوجب علينا المراقبة الدورية لبعض الخصائص الفيزيائية لسائل الحفر و بالاخص اللزوجة لنتحصل على تنظيف جيد للبئر.

ولهذا ارتئينا الى هذه الدراسة التجريبية و المتمثلة في تحسين خصائص لزوجة سائل الحفر بعدما تبين لنا انها غير كافية لتنظيف البئر وهذا بعد حدوث التصاق لمصورة الحفر بجدار البئر في حقل بركين شرق للبئر RECSWS EXT-1

وفي الأخير ،أظهرت النتائج المتحصل عليها تنظيف جيد للبئر.

الكلمات المفتاحية: سوائل الحفر ،اللزوجة ،تنظيف البئر.

Summary

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Chapter III

Nomenclature

Va	Annular velocity in (ft/min).
μ_e	Fluid viscosity.
CCI	Cleaning index.
Re	Reynolds number.
d	Mud weight in (ppg).
k	Power Law Constant.
n	The flow behavior index.
Q	Flow rate (gallon per minute).
Dh	Hole diameter(inch).
Dop	Outside diameter of drill pipe (inch)
Pc	Loss circulation in annular (kpa)
L	Length of interval (m)
Yp	Yield Point (lbs/100 sqft)
Pv	Plastic viscosity (cp)
K	Coefficient of pipe friction.
δ	Coefficient of friction.
θ600	600 Dial reading.
θ300	300 Dial reading.
θ3	3 Dial reading.
BHA	Bottom Hole Assembly.
DST	Drilling Stem Test.
LWD	Logging While Drilling.
MD	Measured Depth.
MWD	Measurement While Drilling.
ROP	Rate of penetration (ft/hr).
RPM	Rotation Per (Minute).
TVD	Total Vertical Depth en (ft).
WOB	Weight on bit (lbf).
WBM	Water base mud.
OBM	Oil Base Mud.
FT	formation testing.

General introduction

A – Problematic

The first oil wells, called "wildcats," drilled to rather shallow depths of approximately 304 meter, hole depth was limited because of primitive drilling equipment and the limited technology, the first types of rigs called "cable tool rigs" gave way to the rotary rigs in the 1900's which immediately improved drilling techniques and permitted greater depths, the use of drilling fluids were discovered by a drilling accident, when the advantages of drilling fluids were recognized they became an essential part of the planned drilling program.
At first the mud was used primarily to clean, cool and lubricate the bit as it drilled through formations the fluid also removed the formation cuttings from the hole by circulating the mud using surface pumps in those early years (early 1900s) well analysis consisted primarily of examining the mud and returns for visible signs of oil and by using the sense of smell to detect the odor of hydrocarbons, around 1930 it was realized that mud and cuttings could be correlated to well depth and analyzed to supply more specific data about the formation.
The hole cleaning it is big problem in drilling it cause a several problem that have negative effect in the performance of drilling, so to get a good cleaning we should control the rheological parameters of the mud, the major problem of bad cleaning it result from the viscosity of the mud when we have low viscosity we have a bad cleaning.

B – Objective of this work

The hole cleaning it is big problem in drilling it cause a several problem that have negative effect in the performance of drilling, so to get a good cleaning we should control the rheological parameters of the mud, the major problem of bad cleaning it result from the viscosity of the mud when we have low viscosity we have a bad cleaning so we trying to solve this problem by tow experimental hydraulic analyses in the same well (RECSWS EXT 1) by changing in the hydraulic and the rheological parameters and we finished by Technical and economic s study in chapter III.
While drilling 26" hole section and at 286m torque indicator indicate increase in torque after that we have a no rotation and no movement but we have circulation (stuck pipe), due of the bad hole cleaning, we start jarring the drilling BHA after six hours we get free pipe so it is the time to start mud treatment to solve this problem by increasing in mud viscosity [16].

C – Work organization

This work was organized in three chapter, it distributed like a:
We start by a general introduction of drilling and the drilling fluids then we continue with:

- The first chapter, generality of drilling parameters and the main role of drilling fluid, classification, definition of all fluid parameters and his methods of measurement.
- The second chapter, definition of rheology and the type of fluids rheology, concepts on flow regimes.
- The third chapter, Problematic, different problems caused by bad cleaning of the wells an experimental analyses of the well RECSWS EXT-1, using ANSYS application.

Then we finished with general conclusion and same recommendation to be used in the future for anther wells in this field to avoid these problems.

Chapter I:

Generality of drilling parameters and the main role of drilling fluid

Abstract:

The objective of this chapter is the comprehension of drilling parameters and drilling fluids classification, definition of all fluids parameters and his methods of measurement.

I.1 Introduction

The term drilling indicates the whole complex of operations necessary to construct wells of circular section applying excavation techniques, to drill a well it is necessary to carry out simultaneously the following actions (drilling process):

- to overcome the resistance of the rock, crushing it into small particles measuring just a few mm;
- to remove the rock particles, while still acting on fresh material;
- to maintain the stability of the walls of the hole;
- to prevent the fluids contained in the drilled formations from entering the well.

This can be achieved by using rotary drilling rigs which are the ones operating today in the field of hydrocarbons exploration and production, the drilling rigs are complexes of mobile equipment which can be moved (onshore and offshore) from one drill site to another, drilling a series of wells, in rotary drilling the rock is bored using a cutting tool called the bit, which is rotated and simultaneously forced against the rock at the bottom of the hole by a drill string consisting of hollow steel pipes of circular section screwed together, the cuttings produced by the bit are transported up to the surface by a drilling fluid, usually a liquid (mud or water), or else a gas or foam, circulated in the pipes down to the bit and thence to the surface, the rotation is transmitted to the bit from the surface by a device called the rotary table or, in the modern rigs, by a top drive motor with the rotary table as backup additional rotation can be added by down hole motors located directly above the bit, after having drilled a certain length of hole, in order to guarantee its stability it has to be cased with steel pipes, called casings, joined together by threaded sleeves, the space between the casing and the hole is then filled with cement slurry to ensure a hydraulic and mechanical seal, the final depth of the well is accomplished by drilling holes of decreasing diameter, successively protected by casings, likewise of decreasing diameter, producing a structure made up of concentric tubular elements

I.2 Drilling parameters

We call drilling parameters the various factors that condition the speed progress of a drilling bit, they can be classified in two categories.

I.2.1 Mechanical parameters

Lands crossed during the drilling operation have a wide variety of hardness the speed of advancement may vary depending on the nature of training it is obvious that for to drill rocks of different hardness we use very specific tools depending on the nature geological.

I.2.1.1 Weight on the bit

Weight on bit (WOB) is the amount of downward force exerted by a drill bit during drilling operations. Weight on bit is generally measured in thousands of pounds and is provided by the thick-walled drilled collars, a significant amount of weight on the drill bit is crucial to allow the drill bit to effectively cut or break through hard material, such as rock (Figure I-01), [01].

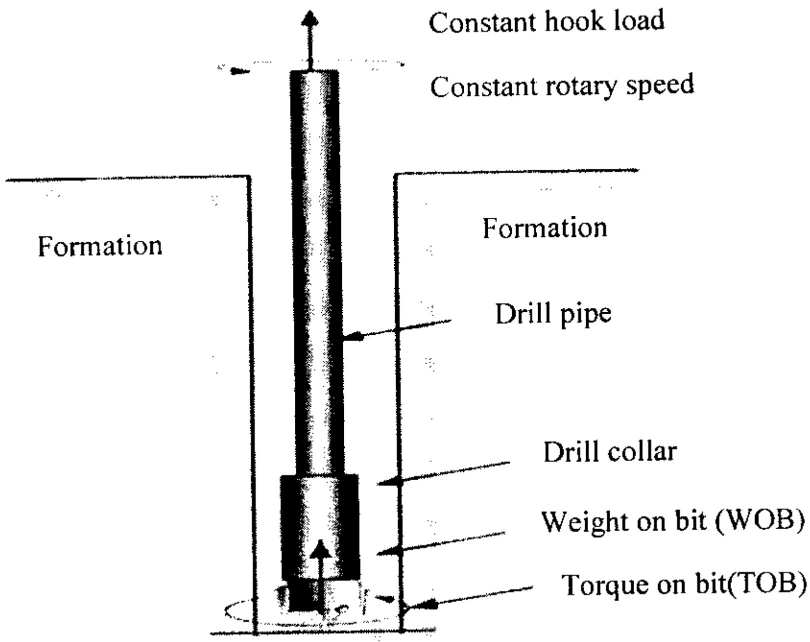

Figure I-01: Diagram represents weight on bit [01].

I.2.1.2 Rotation speed

The rotational speed (RPM) is a physical parameter that indicates the number of turn the table in the rig-floor per minute, identified by a sensor, the speed of rotation increases depending on the hardness of the formation and the parameter torque and can be limited also by the vibration that affects the drill string (phenomenon resonance that can be the cause of fatigue and disruption).

I.2.1.3 Torque concept

It is a physical parameter recorded during drilling, torque is defined as the turning force that is applied to a shaft or other rotary mechanism to cause it to rotate or tend to do so, and it is measured in units of length and force it is units depend on the unit system used, in metric system it has a unit of newton per meter (N.m) and in imperial system, it has a unit of pound force per foot (lbf.ft)

In drilling, torque is the force or moment used to rotate the drill string, and therefore the bit, around it is axis, the torque is generated by the top drive and is used to overcome the frictional forces opposing rotation of the drill string and bit [02].

I.2.2 Hydraulic parameters

I.2.2.1 Flow rate

It is the volume, masse or weight of fluid passing through any conductor, such as pipe or tubing, per unit of time [03].

Drilling pumps are characterized by:

- The number of pistons (02 duplex, 03 triplex).
- The diameter of the liner (piston).
- The length of pistons (10 " or 12").
- The unit rate and its efficiency.

I.2.2.2 Well bottom pressure

Since the bottom pressure is the differential between the hydrostatic pressure of the drilling fluid and the sum of the weight of the overlying sediments exerted at a depth and the pore pressure, the greater this difference is the greater the effort to overcome is important and if the difference decreases the speed of advance will be high because it plays the phenomenon of Archimedes push on the pad.

I.2.2.3 Type of drilling fluids

The choice of the type of mud to use and of these characteristics, plays a very important role, because the choice depends on the formation crossed, the pressure and also the problems could be met later and the duration of drilling and therefore the price, if we choose a mud that is not suitable for the drilled layer, we will be exposed to enormous problems that result either from its composition (contamination) or its characteristics (losses, kicks).

I.3 Drilling fluids

A drilling fluid is any fluid which is circulated through a well in order to remove cuttings from a wellbore, this section will discuss fluids which have water or oil as their continuous phase air, mist and foam, which can be used as drilling fluids.

A drilling fluid must fulfill many functions in order for a well to be drilled successfully, safely, and economically, the most important functions.

I.3.1 The functions of the mud

Drilling fluid functions describe tasks which the drilling fluid is capable of performing, although some may not be essential on every well removing cuttings from the well and controlling formation pressures are of primary importance on every well though the order of importance is determined by well conditions and current operations, the most common drilling fluid functions are [4]:

1 Remove cuttings from the well.
2 Control formation pressures and maintain wellbore stability.
3 Suspend and release cuttings.
4 Seal permeable formations.
5 Minimize reservoir damage.
6 Cool, lubricate, and support the bit and drilling assembly.
7 Transmit hydraulic energy to tools and bit.
8 Ensure adequate formation evaluation.
9 Control corrosion.
10 Facilitate cementing and completion.
11 Minimize impact on the environment.

I.3.1.1 Remove cuttings from the well

Fluid flowing from the bit nozzles exerts a jetting action to clear cuttings from the bottom of the hole and the bit, and carries these cuttings to the surface. Several factors influence cuttings transport if the cuttings generated at the bit face are not immediately removed and started toward the surface, they will be ground very fine, stick to the bit and in general retard effective penetration into uncut rock.

Velocity - Increasing annular velocity generally improves cuttings transport variables include pump output, borehole size and drill string size.

Density - Increasing mud density increases the carrying capacity through the buoyant effect on cuttings.

Viscosity - Increasing viscosity often improves cuttings removal.

Pipe Rotation - Rotation tends to throw cuttings into areas of high fluid velocity from low velocity areas next to the borehole wall and drill string.

Hole Angle - Increasing hole angle generally makes cuttings transport more difficult.

Drilling fluids must have the capacity to suspend weight materials and drilled solids during connections, bit trips, and logging runs, or they will settle to the low side or bottom of the

hole, failure to suspend weight materials can result in a reduction in the drilling fluid density, which in turn can lead to kicks and a potential blowout [04].
The drilling fluid must also be capable to transporting cuttings out of the hole at a reasonable velocity that minimizes their disintegration and incorporation as drilled solids into the drilling fluid system at the surface, the drilling fluid must release the cuttings for efficient removal failure to adequately clean the hole or suspend drilled solids are contributing factors in such hole problems as fill on bottom after a trip, hole pack-off, lost returns, differentially stuck pipe, and inability to reach bottom with logging tools

I.3.1.2 Controlling formation pressures and maintain wellbore stability

Fluid hydrostatic pressure acts as a confining force on the wellbore this confining force acting across a filter cake will assist in physically stabilizing a formation.
Borehole stability is also maintained or enhanced by controlling the loss of filtrate to permeable formations and by careful control of the chemical composition of the drilling fluid.
Most permeable formations have pore space openings too small to allow the passage of whole mud into the formation however, filtrate from the drilling fluid can enter the pore spaces the rate at which the filtrate enters the formation is dependent on the pressure differential between the formation and the column of drilling fluid, and the quality of the filter cake deposited on the formation face. fluids, may destabilize the formation through hydration of shale and/or chemical interactions between components of the drilling fluid and the wellbore.
Drilling fluids which produce low quality or thick filter cakes may also cause tight hole conditions including stuck pipe, difficulty in running casing and poor cement jobs [04].
Filter Cake: A layer of concentrated solids from the drilling mud which forms on the walls of the borehole opposite permeable formations.
Filtrate :The liquid portion of the mud which passes through the filter cake into the formation.

I.3.1.3 Suspend and release cuttings

Drilling muds must suspend drill cuttings, weight materials and additives under a wide range of conditions, yet allow the cuttings to be removed by the solids-control equipment drill cuttings that settle during static conditions can cause bridges and fill, which in turn can cause stuck pipe or lost circulation, weight material which settles is referred to as sag and causes a wide variation in the density of the well fluid sag occurs most often under dynamic conditions in high-angle wells, where the fluid is being circulated at low annular velocities high concentrations of drill solids are detrimental to almost every aspect of the drilling operation, primarily drilling efficiency and ROP they increase the mud weight and viscosity, which in turn increases maintenance costs and the need for dilution they also increase the horsepower required to circulate, the thickness of the filter cake, the torque and drag, and the likelihood of differential sticking drilling fluid properties that suspend cuttings must be balanced with those properties that aid in cuttings removal by solids-control equipment cuttings suspension requires high-viscosity, shear thinning thixotropic properties, while solids-removal equipment usually works more efficiently with fluids of lower viscosity solids-control equipment is not as effective on non-shear-thinning drilling fluids, which have high solids content and a high plastic viscosity for effective solids control, drill solids must be removed from the drilling fluid on the first circulation from the well if cuttings are re-circulated, they break down into smaller particles that are more difficult to remove one easy way to determine whether drill solids are being removed is to compare the sand content of the mud at the flow line and at the suction pit [04].

I.3.1.4 Seal permeable formations

Permeability refers to the ability of fluids to flow through porous formations; formations must be permeable for hydrocarbons to be produced when the mud column pressure is greater than formation pressure, mud filtrate will invade the formation, and a filter cake of mud solids will be deposited on the wall of the wellbore drilling fluid systems should be designed to deposit a thin, low-permeability filter cake on the formation to limit the invasion of mud filtrate this improves wellbore stability and prevents a number of drilling and production problems potential problems related to thick filter cake and excessive filtration include "tight" hole conditions, poor log quality, increased torque and drag, stuck pipe, lost circulation, and formation damage in highly permeable formations with large pore throats, whole mud may invade the formation, depending on the size of the mud solids for such situations, bridging agents must be used to block the large openings so the mud solids can form a seal to be effective, bridging agents must be about one-half the size of the largest opening bridging agents include calcium carbonate, ground cellulose and a wide variety of seepage-loss or other fine lost-circulation materials depending on the drilling fluid system in use, a number of additives can be applied to improve the filter cake, thus limiting filtration these include bentonite, natural and synthetic polymers, asphalt and organic deflocculating additives (Figure I-02),[04].

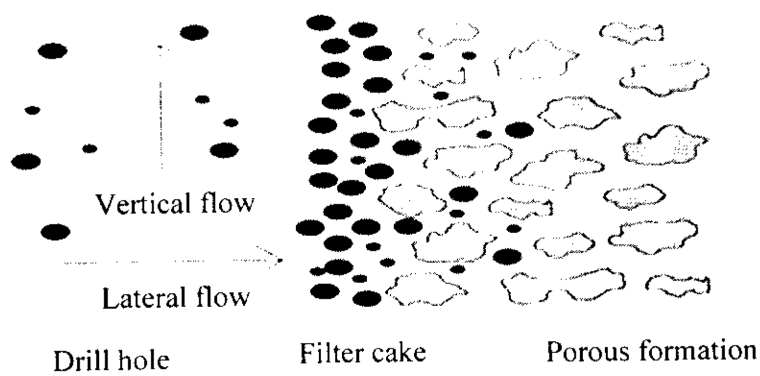

Figure I-02: formation of filter cake in a porous formation [05].

I.3.1.5 Minimize formation damage

A producing formation can be damaged by a poor drilling fluid damage mechanisms include formation fines migration, solids invasion, and wettability alterations, identification of potential damage mechanisms and careful selection of a drilling fluid can minimize damage [04].

I.3.1.6 Cool, lubricate and support the bit and drilling assembly

Considerable heat and friction is generated at the bit and between the drill string and wellbore during drilling operations contact between the drill string and wellbore can also create considerable torque during rotation, and drag during trips circulating drilling fluid transports heat away from these frictional sites, reducing the chance of pre-mature bit failure and pipe damage. The drilling fluid also lubricates the bit tooth penetration through the bottom hole debris into the rock and serves as a lubricant between the wellbore and drill string thus reducing torque and drag [04].

I.3.1.7 Transmit hydraulic energy to tools and bit

Hydraulic energy can be used to maximize (ROP) by improving cuttings removal at the bit it also provides power for mud motors to rotate the bit and for measurement while drilling (MWD) and logging while drilling (LWD) tools, hydraulics programs are based on sizing the bit nozzles properly to use available mud pump horsepower (pressure or energy) to generate a maximized pressure drop at the bit or to optimize jet impact force on the bottom of the well hydraulics programs are limited by the available pump horsepower, pressure losses inside the drill string, maximum allowable surface pressure and optimum flow rate nozzle sizes are selected to use the available pressure at the bit to maximize the effect of mud impacting the bottom of the hole this helps remove cuttings from beneath the bit and keep the cutting structure clean drill string pressure losses are higher in fluids with higher densities, plastic viscosities and solids the use of small (ID) drill pipe or tool joints, mud motors and (MWD/LWD) tools all reduce the amount of pressure available for us eat the bit low-solids, shear-thinning drilling fluids or those that have drag reducing characteristics, such as polymer fluids, are more efficient at transmitting hydraulic energy to drilling tools and the bit in shallow wells, sufficient hydraulic horse power usually is available to clean the bit efficiently because drill string pressure losses increase with well depth, a depth will be reached where there is insufficient pressure for optimum bit cleaning this depth can be extended by carefully controlling the mud properties [04].

I.3.1.8 Ensure adequate formation evaluation

The gathering and interpretation of surface geological data from drilled cuttings, cores and electrical logs is used to determine the commercial value of the zones penetrated. Invasion of these zones by the fluid or its filtrate, be it oil or water, may mask or interfere with the interpretation of the data retrieved and/or prevent full commercial recovery of hydrocarbon.
Since the objective in drilling is to make and keep a borehole which can be evaluated for the presence of commercially-producible fluids, functions four and five should be given priority in designing a drilling fluid and controlling its properties the conditions imposed by these functions will determine the type of drilling fluid system to be used in each hole section and the products needed to maintain it after the drilling fluid has been selected, the properties required to accomplish the first three functions can then be estimated by hydraulic optimization procedures.
While drilling, a considerable amount of heat is generated at the bit and along the drill string due to friction an additional source of heat is derived from the increasing thermal energy stored in formations with depth the circulating fluid not only serves as a lubricant helping to reduce the friction between the drilling components in contact with the formation, but also helps conduct heat away from the friction points and formation [04].

I.3.1.9 Control corrosion

Corrosion control can reduce drill string failure through removal or neutralization of contaminating substances specific corrosion control products may be added to a drilling fluid; or the drilling fluid itself may be selected on the basis of its inherent corrosion protection [04].

I.3.1.10 Facilitate cementing and completion

The drilling fluid must produce a well bore into which casing can be run and cemented effectively and which does not impede completion operations cementing is critical to effective zone isolation and successful well completion during casing runs, the mud must remain fluid and minimize pressure surges so that fracture-induced lost circulation does not occur running casing is much easier in a smooth, in gauge wellbore with no cuttings, caving's or bridges the mud should have a thin, slick filter cake to cement casing properly, the mud must be completely displaced by the spacers, flushes and cement effective mud displacement requires that the hole should be near gauge and the mud must have low viscosity and low, non-progressive gel strengths completion operations such as perforating and gravel packing also require a near-gauge wellbore and maybe affected by mud characteristics (Figure I-03).

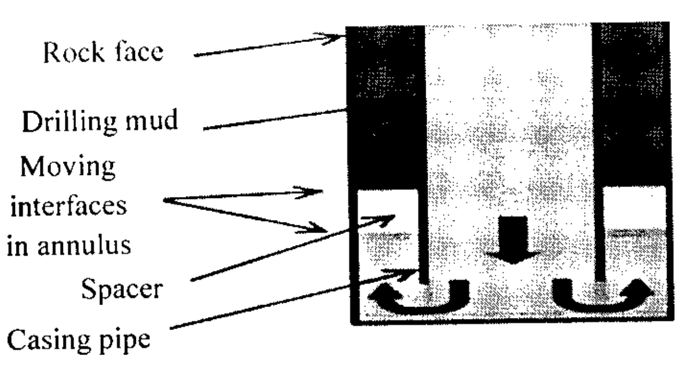

Figure I-03: Cement & mud placement in the well [06].

I.3.1.11 Minimize impact on the environment

Fluid selection and engineering can reduce the potential environmental impact of a drilling fluid in the event of a spill, reclamation and disposal costs, as well as pollution associated problems are greatly reduced by proper fluid selection and control (Figure I-04), [04].

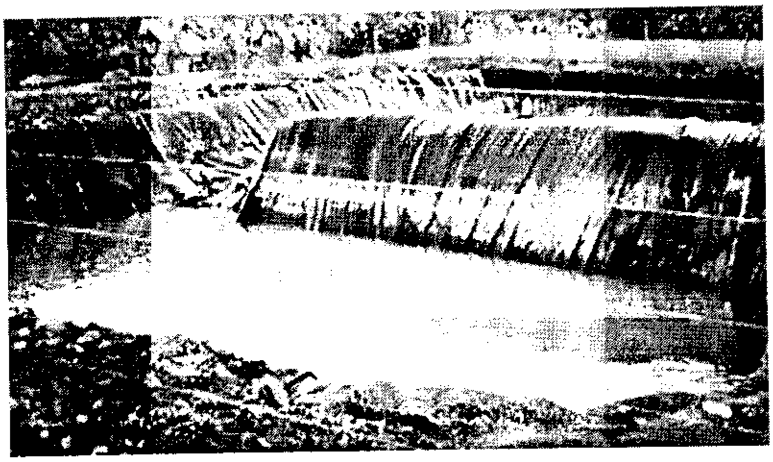

Figure I-04: waste pits [08].

I.3.2 Mud circuit.

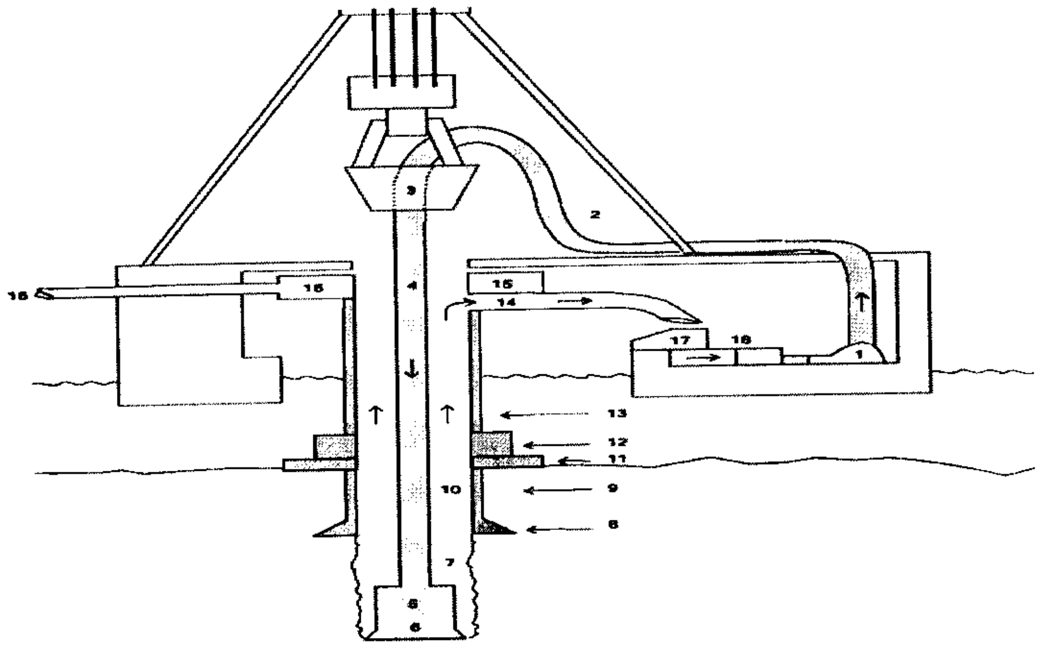

Figure I-05: Circulating System cross section [21].

1 Pump
2 Shock Hose / Stand pipe
3 Swivels / Top Drive
4 Kelly / Drill pipe
5 Bottom Whole Assembly
6 Bit
7 Open whole annulus
8 Casing Shoe
9 Casing
10 Cased Annulus
11 Guide Base
12 Blow Out Prevention Stack
13 Riser
14 Flow line
15 Diverter
16 Diverter Line
17 Shakers
18 Mud Pits

When drilling is in progress (Figure I-05), the components of the hoisting system, mud pumps and prime movers are used to circulate drilling fluid from the mud pits through the drill string and out the bit cuttings are flushed from the bottom of the borehole up to the surface, thus cleaning the bottom of the hole and providing the logging geologist with samples at the surface.

I.3.3 Make-up of a drilling fluids

In its most basic form a drilling fluid is composed of a liquid (either water or oil) and some sort of viscosity agent if nothing else is added, whenever the hydrostatic pressure is greater than the formation pore pressure (and the formation is porous and permeable) a portion of the fluid will be flushed into the formation since excessive filtrate can cause borehole problems, some sort of filtration control additive is generally added in order to provide enough hydrostatic pressure to balance abnormal pore pressures, the density of the drilling fluid is increased by adding a weight material (generally barite).

In summary, a drilling fluid consists of:

The Base Liquid

- Water - fresh or saline.
- Oil - diesel or crude.
- Mineral Oil or other synthetic fluids dispersed solids.
- Colloidal particles, which are suspended particles of various sizes dissolved Solids.
- Usually salts, and their effects on colloids most is important.

All drilling fluids have essentially the same properties; only the magnitude varies these properties include density, viscosity, gel strength, filter cake, water loss, and electrical resistance [07].

I.3.4 The types of drilling fluids

I.3.4.1 Normal drilling fluids

Though this type of drilling fluid is easy to describe, it is hard to define and even more difficult to find in the field, a normal fluid generally means there is little effort expended to control the range of properties as such, it is simple to make and control general rules include:

1.It is used where no unexpected conditions occur.

2.The mud will stabilize, so its properties are in the range required to control hole conditions.

3.The chief problem is viscosity control.

Formations usually drilled with this type of mud are shale's and sands since viscosity is the major problem, the amount and condition of the colloidal clay is important to do this, two general types of treatment are used:

1.Water soluble polyphosphates.

- They reduce viscosity.
- Can be used alone or with tannins.
- If filter cake and filtration control is required- add colloidal clay to system.

2.Caustic soda and tannins.

- They also reduce viscosity.
- Used under more severe conditions than phosphate treatment.

The upper portions of most wells can use "normal" muds

1.Care must be taken not to add chemicals which may hinder the making of special muds.

2. Native clays used to make the mud are usually adequate [07].

I.3.4.2 Special drilling fluids

These drilling fluids are made to combat particular abnormal hole conditions or to accomplish specific objectives [07].

These are:

1.Special Objectives.

- Faster penetration rates.
- Greater protection to producing zones.

2.Abnormal whole conditions.

- Long salt sections.
- High formation pressures.

I.3.5 Drilling fluid classification systems

Drilling fluids are separated into three major classifications:

- Pneumatic
- Oil-Based
- Water-Based

I.3.5.1 Pneumatic fluids

Pneumatic (air/gas based) fluids are used for drilling depleted zones or areas where abnormally low formation pressures may be encountered an advantage of pneumatic fluids over liquid mud systems can be seen in increased penetration rates cuttings are literally blown off the cutting surface ahead of the bit as a result of the considerable pressure differential the high pressure differential also allows formation fluids from permeable zones to flow into the wellbore air/gas based fluids are ineffective in areas where large volumes of formation fluids are encountered a large influx of formation fluids requires converting the pneumatic fluid to a liquid-based system as a result, the chances of losing circulation or damaging a productive zone are greatly increased. Another consideration when selecting pneumatic fluids is well depth they are not recommended for wells below about 3048 m because the volume of air required to lift cuttings from the bottom of the hole can become greater than the surface equipment can deliver [04].

I.3.5.2 Oil-Based Fluids

A primary use of oil-based fluids is to drill troublesome shale's and to improve hole stability they are also applicable in drilling highly deviated holes because of their high degree of lubricity and ability to prevent hydration of clays they may also be selected for special applications such as high temperature/high pressure wells, minimizing formation damage, and native-state coring. Another reason for choosing oil-based fluids is that they are resistant to contaminants such as anhydrite, salt, and CO_2 and H_2S acid gases.

Cost is a major concern when selecting oil-based muds. Initially, the cost per barrel of an oil-based mud is very high compared to a conventional water-based mud system however, because oil muds can be reconditioned and reused, the costs on a multi-well program may be comparable to using water-based fluids also, buy-back policies for used oil-based muds can make them an attractive alternative in situations where the use of water-based muds prohibit the successful drilling and/or completion of a well.

Today, with increasing environmental concerns, the use of oil-based muds is either prohibited or severely restricted in many areas. In some areas, drilling with oil-based fluids requires mud and cuttings to be contained and hauled to an approved disposal site the costs of containment, hauling, and disposal can greatly increase the cost of using oil-based fluids [04].

I.3.5.3 Water-Based Fluids

Water based fluids are the most extensively used drilling fluids they are generally easy to build, inexpensive to maintain, and can be formulated to overcome most drilling problems in order to better understand the broad spectrum of water-based fluids, they are divided into three major sub classifications:

- Non-inhibitive
- Inhibitive
- Polymer

- **Non-Inhibitive Fluids**

Those which do not significantly suppress clay swelling, are generally comprised of native clays or commercial bentonites with some caustic soda or lime they may also contain deflocculants and/or dispersants such as: lignites, lignosulfonates, or phosphates. Non-inhibitive fluids are generally used [04].

as spud muds, native solids are allowed to disperse into the system until rheological properties can no longer be controlled by water dilution [04].

- **Inhibitive Fluids**

Those which appreciably retard clay swelling and, achieve inhibition through the presence of cations; typically, Sodium (Na+), Calcium (Ca++) and Potassium (K+). Generally, K+ or Ca++, or a combination of the two, provide the greatest inhibition to clay dispersion these systems are generally used for drilling hydratable clays and sands containing hydratable clays because the source of the cation is generally a salt, disposal can become a major portion of the cost of using an inhibitive fluid [04].

- **Polymer Fluids**

Those which rely on macromolecules, either with or without clay interactions to provide mud properties, and are very diversified in their application these fluids can be inhibitive or non-inhibitive depending upon whether an inhibitive cation is used polymers can be used to viscosify fluids, control filtration properties, deflocculates solids, or encapsulate solids the thermal stability of polymer systems can range upwards to 400°F in spite of their diversity, polymer fluids have limitations solids are a major threat to successfully running a cost-effective polymer mud system [04].

I.3.6 Physical characteristics of mud.

I.3.6.1 Density pounds/gallon (lb/gal)

The density of the drilling fluid is important to maintaining well control as mentioned earlier, fresh water has a density of 8.34 lb/gal, with a corresponding gradient of 0.433 psi/ft as long as the formations have the same gradient, fresh water will "balance" the formation pressures since this is generally not the case, some weight material must be added to the fluid, the most common being barite and hematite, the drilling fluids density is measured using a "mud balance" this balance contains a mud cup on one end of a beam with a fixed counterweight on the other end of the beam the beam is inscribed with a graduated scale, contains a level bubble and a movable rider when the cup is filled with fresh water, steel shot is added to the counterweight container until the beam is level, with the rider pointing at the 8.34 scribe line. During well site operations, the mud's density is checked by filling the cup with drilling fluid and moving the rider until the level bubble indicates the beam is balanced the density is then read using the position of the rider (Figure I-06), [07].

Figure I-06: Densymètre [08].

I.3.6.2 Plastic viscosity centipoise (cps)

The plastic viscosity (PV) is calculated by measuring the shear rate and stress of the fluid these values are derived by using a Fan viscometer, which is a rotating-sleeve viscometer, and may be a simple hand operated two speed model or a more complex variable speed electric model the two speed model operates at 300 and 600 rpm, the Fan viscometer consists of an outer rotating sleeve and an inner bob when the outer sleeve is rotated at a known speed, torque is transmitted through the mud to the bob the bob is connected to a spring and dial, where the torque is measured, the shear rate is the rotational speed of the sleeve and the shear stress is the stress (torque) applied to the bob, measured as deflection units on the instrument dial, these measurement values are not true units and need to be converted, shear rate is the rate of change as the fluid layers move past one another per unit distance, and is measured in reciprocal seconds (i.e. (ft/sec)/ft) and is usually written as seconds-1 to convert the dial reading to shear stress, the dial reading is multiplied by 1.067 to give a reading in lb/100ft2.

The unit of viscosity is poise or centipoise (1/100 poise) and is derived as follows:

Viscosity (poise) = (F/A) / (V/H)

Where:

F = Force (dynes)

A = Area (cm2)

V = Velocity (cm/cc)

H = Distance (cm)

This produces viscosity as Dynes (sec/cm2) or poise, the Fan viscometer reading is therefore multiplied by 1.067 to obtain shear stress in lb/100ft2; or multiplied by 478.8, and divided by the shear rate in second-1 to get Dynes/cm2.

Viscosity then becomes:

511 x dial reading / shear rate (sec-1)

Since 511 sec-1 = 300 rpm

Or (300 x dial reading) / Fan shear rpm

The viscometer is designed to give the viscosity of a Newtonian fluid when used at 300 rpm for Non-Newtonian fluids, the ratio of shear-stress to shear-rate is not constant and varies for each shear rate with a Bingham plastic fluid, a finite force is required to initiate a constant rate of increase of shear-stress with shear-rate to obtain a value for this constant rate of increase, readings are taken with a viscometer at 511 sec-1 and 1022 sec-1 (300 and600 rpm), the 600 dial reading minus the 300 dial reading gives the slope of the shear-stress/shear-rate curve this is the Plastic Viscosity, the "apparent viscosity" is given by the 600 reading divided by 2 this is a measure of that part of resistance to flow caused by mechanical friction between solids in the mud, solids and liquids and the shearing layers of the mud itself we can see that control of the solids will give us control over our PV! This leads to "Why are we controlling the solids?" Since the viscosity of the mud is one of the principal factors contributing to the carrying capacity of the mud, the suspension of weighting materials, and pressure surges applied to the formation through frictional pressures in the annulus, it is obvious that increased solids will increase these annular pressures (and may increase the mud density), so a balance must be found in which the correct mud density and carrying capacity are maintained without exerting unnecessary pressures on the annulus in the mud system, we have solids that are an integral part of the mud (bentonite, starch, CMC, etc.) and solids that are undesirable (sand, limestone, dolomite, etc.), as the mud density is increased, by the addition of barite or hematite (more solids), the PV will automatically increase the PV is also a function of the viscosity of the fluid phase of the mud (as temperature rises, the viscosity of water decreases, and the PV will decrease) [07].

I.3.6.3 Yield point lb/100 sqft

This parameter is also obtained from the viscometer the yield point (YP), as mentioned earlier, is a measure of the electro-chemical attractive forces within the mud under flowing conditions. These forces are the result of positive and negative charges located near or on the particle's surfaces with this in mind, the yield point is then a function of the surface properties of the mud solids, the volume concentration of the solids, and the concentration and type of ions within the fluid phase, the yield point is the shear stress at zero shear rate, and is measured in the field by either;

YP = 300 rpm reading – PV or YP = (2 x 300 rpm reading) - 600 rpm reading this gives a Bingham yield point, which is generally higher than the actual or true yield as stated earlier, at low shear rates, the Bingham model does not give particularly good readings [07].

I.3.6.4 Gel Strength lb/100 ft2 (10 sec/10min)

This is a measurement that denotes the thixotropic properties of the mud and is a measurement of the attractive forces of the mud while at rest or under static conditions as this and yield point are both measures of flocculation, they will tend to increase and decrease together, however allow yield point does not necessarily mean 0/0 gels! Gel strength is measured with the viscometer by stirring the mud at high speeds for about 15 seconds and then turning the viscometer off or putting it into neutral (low gear if it's a lab model) and waiting the desired period, (i.e., 10 seconds or 10 minutes), if the viscometer is a simple field model, the "gel strength" knob is turned counter clockwise slowly and steadily the maximum dial deflection before the gel breaks is then recorded in lb/100 ft2, with a lab model, the procedure is the same except a low speed issued after a wait, the second gel can be taken in a similar manner gels are described as progressive/strong or fragile/weak. For a drilling fluid, the fragile gel is more desirable in this case, the gel is initially quite high but builds up with time only slightly this type of gel is usually easily broken and would require a lower pump pressure to break circulation (Figure I-07), [07].

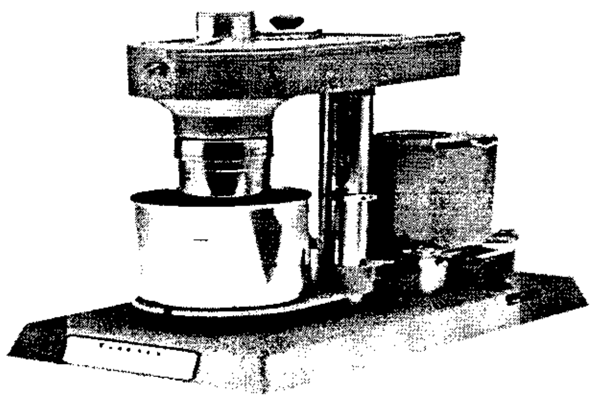

Figure I-07: Viscometer **Fann** [08].

I.3.6.5 Filtrate/water loss ml/30 min, filter cake thickness 1/32 inch

These two properties shall be dealt with together, as it is the filtration of mud that causes the buildup of filter cake loss of fluid (usually water and soluble chemicals) from the mud to the formation occurs when the permeability is such that it allows fluid to pass through the pore spaces as fluid is lost, a buildup of mud solids occurs on the face of the wellbore this is the filter cake two types of filtration occur: dynamic, while circulating and static, while the mud is at rest dynamic filtration reaches a constant rate when the rate of erosion of the filter cake due to circulating matches the rate of deposition of the filter cake. Static filtration will cause the cake to grow thicker with time, which results in a decrease in loss of fluids with time mud measurements are confined to the static filtration, filtration characteristics of a mud are determined by means of a filter press the test consists of monitoring the rate at which fluid is forced from a filter press under specific conditions of time, temperature and pressure, then measuring the thickness of the residue deposited upon the filter paper excessive filtration and thick filter cake build up are likely to cause the following problems:

- Tight hole, causing excessive drag.
- Increased pressure surges, due to reduced whole diameter.
- Differential sticking, due to an increased pipe contact in filter cake.
- Excessive formation damage and evaluation problems with wire line logs.

Most of these problems are caused by the filter cake and not the amount of filtration because the aim is to deposit a thin, impermeable filter cake allow water loss may not do this, as the cake is also dependent upon solids size and distribution.

The standard fluid loss test is conducted over 30 minutes the amount of filtrate increases with direct proportion to the square root of the time this can be expressed by the following;

Q2 = (Q1 x T2)/T1, where Q2 is the unknown filtrate volume at time T2 and Q1 is the known filtrate volume at time T1, pressure also affects filtration by compressing the filter cake, reducing its permeability and therefore reducing the filtrate small plate-like particles act as the best filter cake builders and bentonitements these requirements increased temperature has the effect of reducing the viscosity of the liquid phase and hence increasing filtration with all other factors being constant, the amount of filtrate will vary with the square root of time proper dispersion of the colloidal clays in the mud gives a good overlap of particles, thus giving good filtration control a flocculated mud, which has aggregates of particles, allows fluid to pass through easily the addition of chemicals to act as dispersants will increase the efficiency of the filter cake the standard test is conducted at surface temperature at 100 psi and is recorded as the number of ml's of fluid lost in 30 minutes an API high-pressure/high temperature (HPHT) test is conducted at 300° F and 500 psi the tests may be conducted using a portable filter press that uses CO2 cartridges or using a compressed air supply the high pressure and high temperature test is conducted to simulate down hole conditions, since the degree of filtration may vary, depending upon the compressibility of the filter cake a mud sample may be tested at standard temperatures and pressures, increased temperature and 100 psi, or at high temperatures and pressures, increased pressure will indicate if the filter cake is compressible the primary fluid loss agent in most water based muds are the clays these solids should have a size variation with a large percentage being under 1micron this will produce a filter cake with low porosity and permeability (Figure I-08), [07].

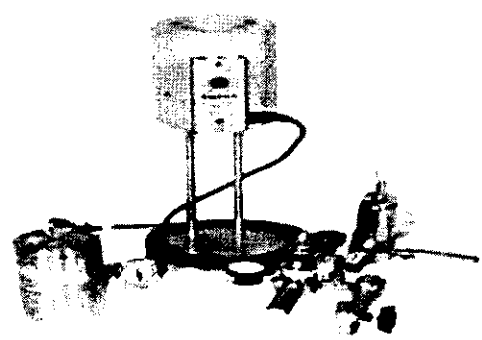

Figure I-08: formation of filter cake in a porous formation [08].

I.3.6.6 Solids content % vol, water content % vol, oil content % vol

A retort is used to determine the quantity of liquids and solids in a drilling fluid a measured sample of fluid is heated until the liquid portion is vaporized the vapors are passed through a condenser and measured as a percentage by volume the solids are then calculated by subtracting the total from 100 (Figure I-09), [07].

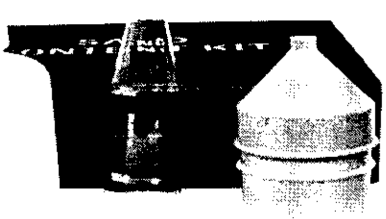

Figure I-09: Solids Content kit [08].

I.3.6.7 Funnel viscosity sec/qt

The Marsh Funnel is the field instrument used to measure viscosity it is graduated so that one quart (946 cc) of water will flow through the funnel in 26 seconds to run a test, the bottom orifice is covered and drilling fluid is poured over a screen until the funnel is full when the bottom is uncovered, the time required to fill one quart is recorded (in seconds) along with the temperature funnel viscosity is a rapid, simple test, but because it is a one point measurement it does not provide information as to why the viscosity has changed, only that it has changed,(Figure I-10), [07].

Figure I-10: Funnel Viscosity kit [08].

Chapter II:

Rheological characteristics of drilling fluid

Abstract:

The objective of this chapter is the comprehension of rheology his different parameters and the effect of this parameters in the determination of flow regimes.

II.1 Introduction.

The word rheology comes from the GREEK word "RHEOS," translated to English as "STREAM," and it might remind some of the Spanish word "RIO" this is important to understand the origin of the word because rheology is the study of the flow (like a stream or a river), rheology is the scientific study of the deformation and flow characteristics of matter. In respect to drilling fluids rheology deals with the relationships and analysis of [20].

- Fluid flow rates and flow pressure.
- Combined influence on the flow characteristics of the fluid.
- Viscosities and hole cleaning capabilities.
- Pressure loss, pressure management and in particular equivalent circulating densities (ECD).

Understanding all of these traits is fundamental for working with liquids at any level of production the machinery that is used to disperse and mix liquid materials is related directly to the kind of material and its rheological properties, how to measure rheological properties?

II.2 Velocity profile

Figure II -01 depicts a fluid flowing up an annulus a force exists in the fluid which resists fluid flow this force, shear stress, is analogous to the friction arising when one fluid layer moves past another the fluid velocity increases progressively away from zero at the walls to a maximum near the center of the annulus this occurs because it is easier for each fluid layer to move past another fluid layer than to move past the walls the rate at which a fluid layer moves past another is called "shear rate"[04].

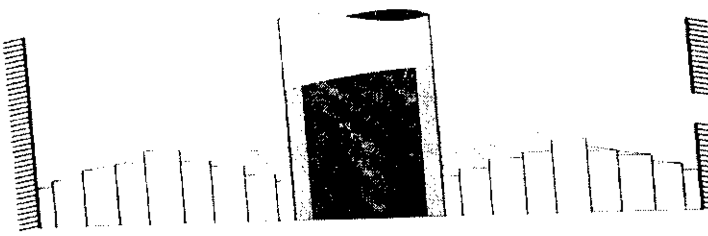

Figure II-01: Flow in an Annulus - Illustrated as Laminar (04).

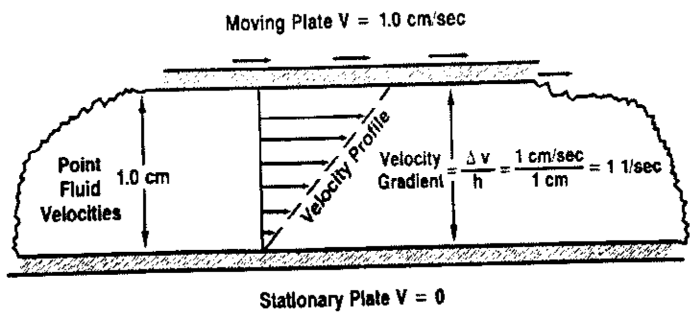

Figure II-02: Concept of Velocity Gradient Shear Rate and Shear Stress [04].

A formula for the annular velocity in an oilfield unit is shown below [09]:

$$Va = \frac{24{,}51.Q}{Dh^2 - Dop^2} \qquad (1)$$

Where
Va Annular velocity, ft/min
Q Flow rate, gallon per minute
Dh Hole diameter, inch
Dop Outside diameter of drill pipe, inch

II.3 Rheology's of newtonian or non-newtonian fluids

Drilling fluids are designed to have several functions during circulation, such as cooling, lubrication and transport of cuttings drilling fluids can be a complex mix of different components in order to obtain the desired properties and qualities needed for a specific operation, the behavior of fluids during flow can be described by different flow models such as Newtonian, Bingham Plastic, Power Law and Herschel-Bulkley (Typical drilling fluid) (Figure II-03).

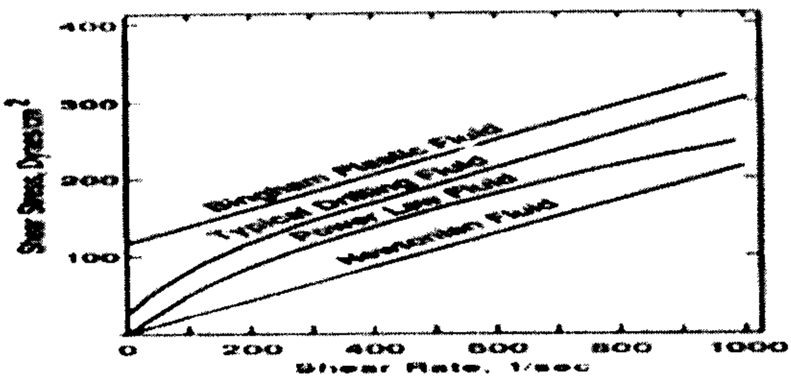

Figure II-03: Rheogram Showing Newtonian & Non Newtonian Fluid Behavior [04].

Drilling fluids are usually non-Newtonian fluids with shear-thinning properties this causes the viscosity of the drilling fluid to decrease as the shear forces acting on the fluid are increasing, Herschel-Bulkley is usually chosen as the most applicable model to most drilling fluid, since it is based on both Power Law and Bingham Plastic, fluid pressure drop from friction when a fluid flows through a pipe or annulus depends on the flow regime, in a laminar flow regime, the friction loss is caused by shear forces between the fluid and pipe wall at a specific velocity, the flow regime turns transient, which means that both shear forces and kinematic forces in the fluid system contributes to the friction pressure loss at even higher flow velocities, the flow regime becomes turbulent, meaning that most of the friction loss is due to kinematic forces in the fluid, as the complex flow pattern in this regime causes the fluid to change direction constantly during flow, whether the flow regime is laminar, transitional or turbulent is defined by the general Reynolds number, given in equation (2).
Since the different rheology models describe fluid behavior differently, the limits between the flow regimes will also different between the models.
The flow regime during drilling is difficult to determine, as parameters, such as string rotation, pipe vibration, pipe eccentricity, tool joints come into play traditionally, laminar flow is defined as a flow with Reynolds number below 2100, and turbulent flow above 2100.
However, turbulence may occur at lower Reynolds numbers, due to the complexity of the flow during drilling.
A formula for the Reynolds number in an oilfield unit is shown below [09]:

$$Re = \frac{D.Va.d}{\mu e} \qquad (2)$$

Where,
D Dimension of flow channel
Va Average velocity in flow channel
d Fluid density, lb/gal
μ_e Fluid viscosity

II.3.1 Newtonian fluids

Newtonian fluids are those in which the viscosity remains constant for all shear rates providing temperature and pressure conditions remain constant, examples of Newtonian fluids are water, light oil, in these fluids, the shear stress is directly proportional to the shear rate, as shown in (Figure II -03).

The rheogram curve of a Newtonian fluid is a straight line passing through the origin, the origin is the starting point on the graph of both the vertical and horizontal axes the slope of the curve defines viscosity where g is the shear rate and t is the shear stress because m (viscosity) does not change with rate of shear it is the only parameter needed to characterize the flow properties of a Newtonian fluid most drilling fluids are not this simple [04].

II.3.2 Non-Newtonian fluids

Most liquids are non-Newtonian fluids, meaning they do not have a constant ratio between their shear rate and shear stress these fluids can be unpredictable in how their shear stress changes according to the shear rate:

As the shear rate increases, the shear stress can either increase or decrease, depending on the fluid's own characteristics as a result, the viscosity of the material is highly variable, Non-Newtonian fluids will have apparent viscosities that depend entirely on the specific experimental conditions, and when working with these materials, it is important to be completely clear as to what these parameters are Non-Newtonian fluids are further classified into three groups, Power law fluids, Herschel-Bulkley fluids and Bingham Plastic Fluids (Figure II-04), [04].

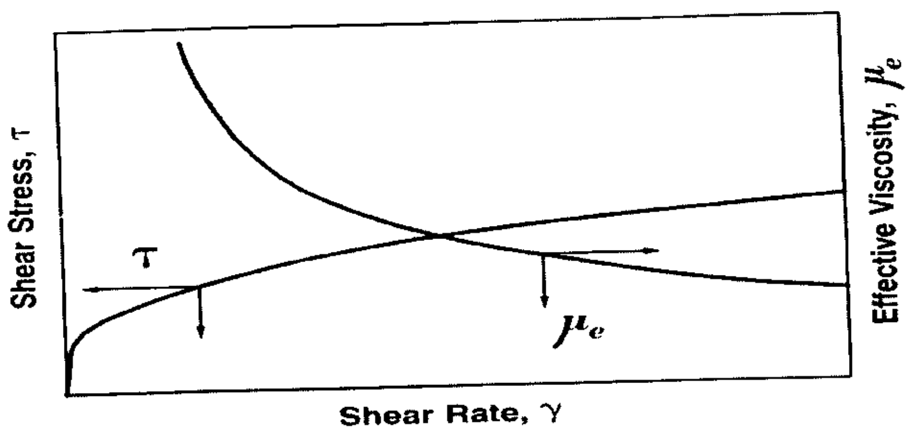

Figure II-04: Rheogram Showing Effective Viscosity of a Non-Newtonian Fluid [04].

II.3.2.1 Power law fluids

Power law fluids are categorized based on how the viscosity is affected by the shear if the viscosity increases as the shear increases, this is a dilatant fluid examples of dilatant fluids include candies, sand/water mixtures, and clay slurries on the other hand, if the viscosity decreases as the shear increases, this is a pseudo plastic, pseudo plastics are the most common type of non-Newtonian fluids, and they include inks, mayonnaise, paints, emulsions, and dispersions.

II.3.2.2 Thixotropic fluids (Herschel-Bulkley)

The viscosity of time-dependent fluids will change over time if the viscosity increases as time increases, these fluids exhibit time-dependent behavior they develop gel structure when at rest or when decreasing the applied shear rate this gel structure may be manifested as a "true yield stress" or a gel strength or both true yield stress is the residual stress on the fluid after reducing the shear rate to zero true yield stress is not measured in the field but can be approximated by extrapolating low shear rate data to zero a fluid may be described by one of constant shear rate models, Bingham Plastic or Pseudo plastic, and at the same time be thixotropic the strength of the gel structure depends on time the structure begins to break down as shear is initiated and ultimately breaks with higher, prolonged shear.

(Figure II-05) is an example of a graph of a thixotropic fluid behavior if the shear rate on a fluid is increased from point D it will follow the curve DEA, after reaching A, the shear rate is gradually reduced, the shear stress will follow curve AFD the area within loop DEAFD is an indication of the degree of thixotropic if the shear rate is held constant after point A is reached, the shear stress will decrease to its lowest point C beyond C there is no further structural breakdown for that constant shear rate if the shear rate is reduced, the curve CHD is obtained [04].

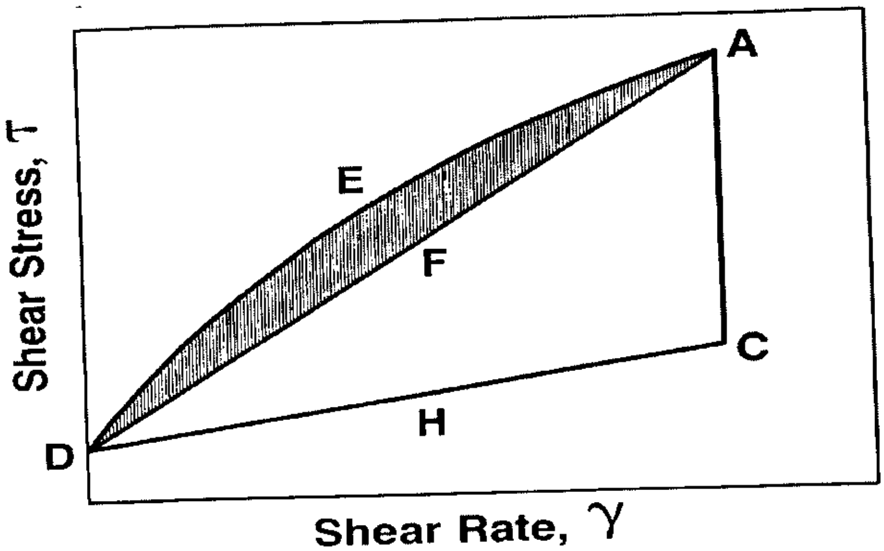

Figure II-05: Rheogram Showing thixotropic fluid behavior [04].

II.3.2.3 Bingham plastic fluids

These fluids yield a straight-line relationship between shear stress and shear rate that does not pass through the origin a finite shear stress is required to initiate flow the value of this shear stress is called the "Yield Point" (Figure II -06),
The Bingham Plastic Model is the most widely used mathematical rheological model in the oil field all data are generated from the 600 and 300 readings on a VG Meter the model assumes that the fluid evaluated acts in a linear manner on the shear rate - shear stress curve, but has a positive yield stress (Figure II-07,08).
The equation for the Bingham Plastic model [04] is:

$$\tau = PV.\left(\frac{\gamma}{300}\right) + YP \qquad (3)$$

Where:
Plastic Viscosity (PV) = Q600 - Q300
Yield Point (YP) = Q300 – PV

Common terms associated with the Bingham plastic model are:
Plastic Viscosity (PV), Apparent Viscosity (ma), Yield Point (YP) and gel strengths most drilling fluids, as seen in (Figure II-07), do not conform exactly to the Bingham plastic model or to any universal model, but drilling fluid behavior can usually be approximated with acceptable accuracy the Bingham Plastic model assumes that the curve (Figure II-09) is

approximated by a straight line this is seldom true for drilling fluids, especially at low shear rates found in the annulus [04].

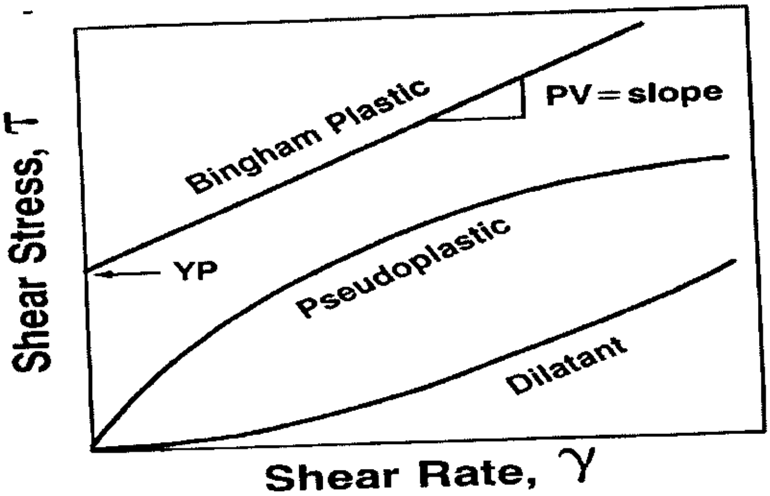

Figure II-06: Rheogram Showing Bingham Plastic, Pseudo plastic and Dilatant Fluids Behavior [04].

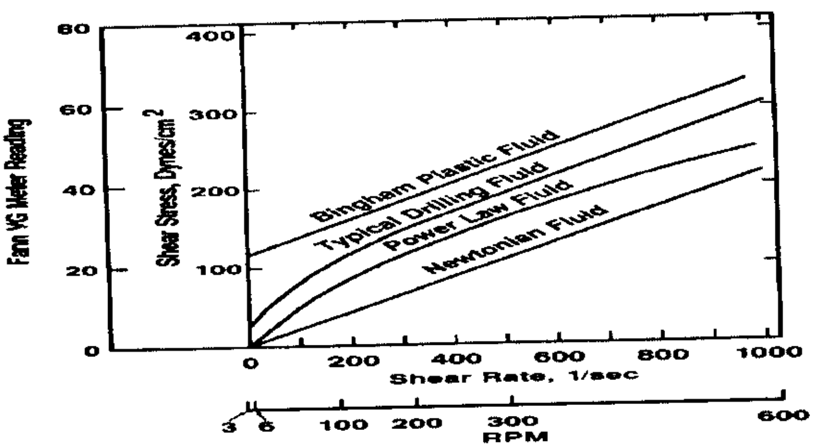

Figure II-07: Rheogram Showing Shear Stress - Shear Rate Curves Behavior [04].

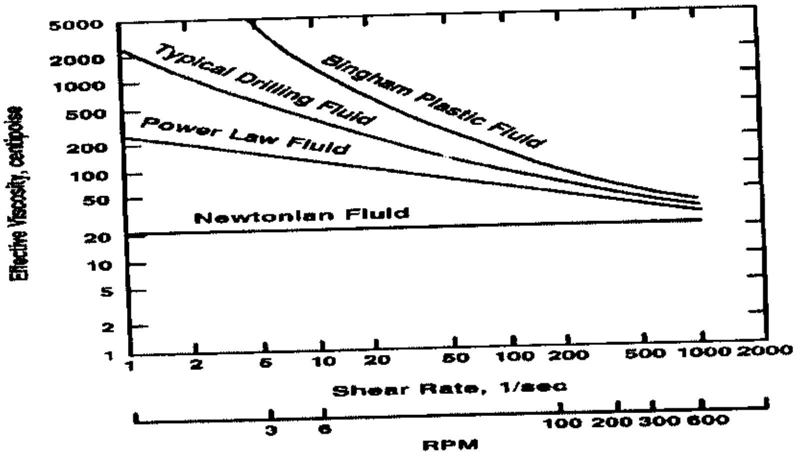

Figure II-08: Rheogram Showing Effective viscosity - Shear Rate Curves [04].

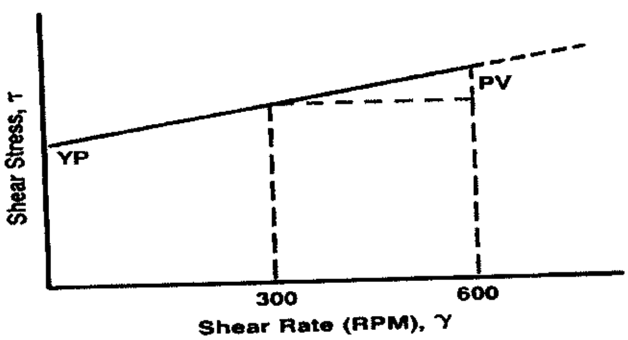

Figure II-09: Rheogram Showing Bingham Plastic Model Parameters [04].

- **Plastic viscosity (PV)**

Drilling muds are usually composed of a continuous fluid phase in which solids are dispersed plastic viscosity is that part of the resistance to flow caused by mechanical friction the friction is caused by:

- Solids concentration.
- Size and shape of solids.
- Viscosity of the fluid phase.

For practical field applications, plastic viscosity is regarded as a guide to solids control plastic viscosity increases if the volume percent of solids increases, or if the volume percent remains constant, and the size of the particle decreases decreasing particle size increases surface area, which increases frictional drag. Plastic viscosity can be decreased by decreasing solids concentration or by decreasing surface area plastic viscosity is decreased by reducing the solids concentration by dilution or by mechanical separation as the viscosity of water decreases with temperature, the plastic viscosity decreases proportionally therefore, controlling PV of a mud in practical terms involves controlling size, concentration and shape of the solids and minimizing the viscosity of the liquid phase such as avoiding viscosifying polymers and salts unless absolutely needed.
The value of plastic viscosity is obtained by subtracting the 300 RPM reading from the 600 rpm reading (Figure II -09), PV = Q600 – Q300.

PV of a mud is the theoretical minimum viscosity a mud can have because it is the effective viscosity as shear rate approaches infinity the highest shear rate occurs as the mud passes through the bit nozzles; therefore, PV will approximate the mud's viscosity at the nozzles, this is illustrated in (Figure II-10), where the effective viscosity of the mud approaches the value of plastic viscosity at high shear rates [04].

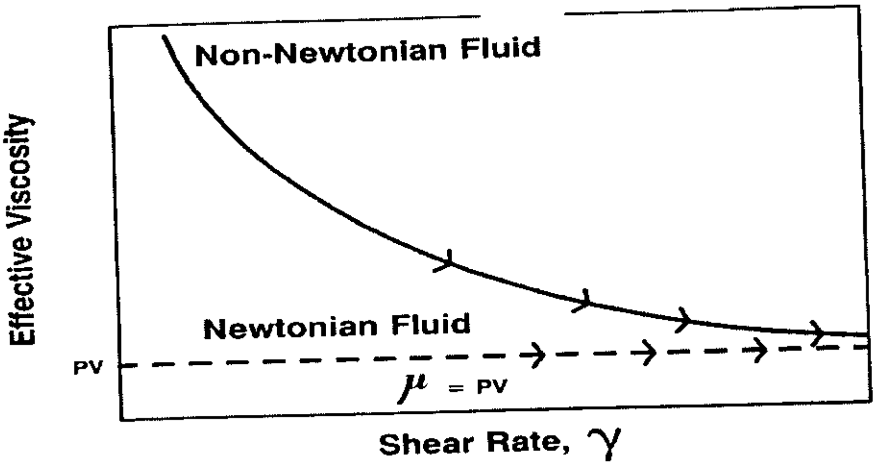

Figure II-10: Rheogram Showing Comparison of Effective Viscosity Newtonian vs Non-Newtonian [04].

- **Yield point (YP)**

The yield point is the initial resistance to flow caused by electrochemical forces between the particles this electrochemical force is due to charges on the surface of the particles dispersed. In the fluid phase Yield point is a measure of these forces under flow conditions and is dependent upon:

- The surface properties of the mud solids.
- The volume concentration of the solids.

Ionic environment of the liquid surrounding the solids high viscosity resulting from high yield point is caused by:

- Introduction of soluble contaminant (ions) such as salt, cement, anhydrite or gypsum, which interact with the negative charges on the clay particles.
- Breaking of the clay particles through mechanical grinding action creating new surface area of the particles these new charged surfaces (positive and negative) pull particles together as a flocks.
- Introduction of inert solids (barite) into the system, increasing the yield point this is the result of the particles being forced closer together because the distance between the particles is now decreased, the attraction between particles is greatly increased.
- Drilling hydra table shale's or clays which introduces new, active solids into the system, increasing attractive forces by bringing the particles closer together and by increasing the total number of charges, and
- Insufficient deflocculant treatment Yield point can be controlled by proper chemical treatment as the attractive forces are reduced by chemical treatment, the yield point will decrease the yield point can be lowered by the following methods:
- Charges on the positive edges of particles can be neutralized by adsorption of large negative ions on the edge of the clay particles these residual charges are satisfied by chemicals such as: tannins, lignins, complex phosphates, lingo sulfonates, ..etc.

The attractive forces that previously existed are satisfied by the chemicals, and the negative charge of the clay particles predominates, so that the solids now repel each other.

- In the case of contamination from calcium or magnesium, the ions causing the attractive force are removed as insoluble precipitants, thus decreasing the attractive forces and YP of the mud.
- Water dilution can lower the yield point, but unless the solids concentration is very high, it is relatively ineffective.

Yield point (YP) is calculated from VG measurements as follows:

or

YP = Q300 – (Q600 – Q300)

YP = Q300 – PV

The limitation of the Bingham plastic model is that most drilling fluids, being pseudo plastic, exhibit an actual yield stress which is considerably less than calculated Bingham yield point this error exists because the Bingham plastic parameters are calculated using a VG meter at 600 RPM (1022 sec-1) and 300 RPM (511 sec-1); whereas, typical annular shear rates are much less (04).

- **Gel strength**

Gel strengths, 10-second and 10-minute, measured on the VG meter, indicate strength of attractive forces (gelation) in a drilling fluid under static conditions excessive gelation is caused by high solids concentration leading to flocculation signs of rheological trouble in a mud system often are reflected by a mud's gel strength development with time when there is a wide range between the initial and 10-minute gel readings they are called "progressive gels" this is not a desirable situation if initial and 10-minute gels are both high, with no appreciable difference in the two, these are "high-flat gels", also undesirable the magnitude of gelation with time is a key factor in the performance of the drilling fluid gelation should not be allowed to become much higher than is necessary to perform the function of suspension of cuttings and weight material for suspension "low-flat gels" are desired - as indicated in (Figure II-11), excessive gel strengths can cause:

- Swabbing, when pipe is pulled out of the hole.
- Surging, when pipe is run in hole.
- Difficulty in getting logging tools to bottom.
- Retaining of entrapped air or gas in the mud.
- Retaining of sand and cuttings while drilling.

Gel strengths and yield point are both a measure of the attractive forces in a mud system a decrease in one usually results a decrease in the other; therefore, similar chemical treatments are used to modify them both the 10-second gel reading more closely approximates the true yield stress in most drilling fluid systems water dilution can be effective in lowering gel strengths, especially when solids are high in the mud [04].

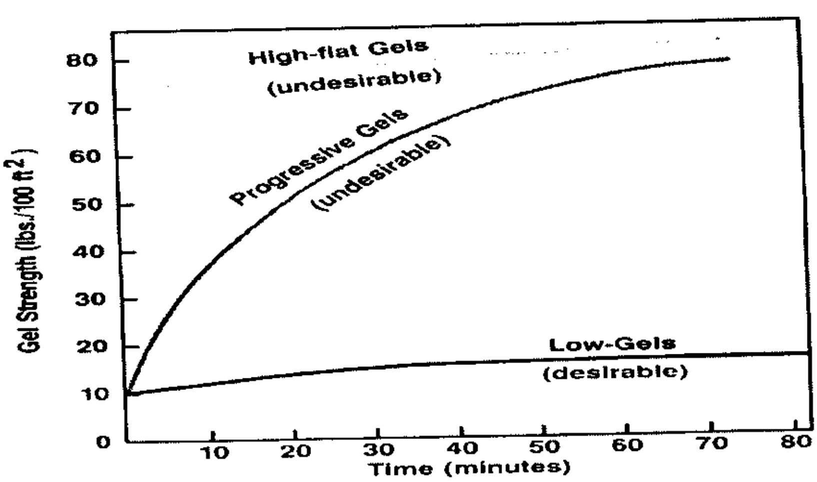

Figure II-11: Rheogram Showing Types of Gels [04].

- **Apparent viscosity (μa)**

Apparent viscosity, measured by the VG meter, is the viscosity that a drilling fluid has at 600 RPM (1022 sec-1) it is a reflection of the plastic viscosity and yield point combined an increase in either or both will cause a rise in apparent viscosity (and probably in funnel viscosity) this is sometimes called single point viscosi.y the equation for apparent viscosity is μa=Q600/2, [04].

- **Effective viscosity (me)**

The effective viscosity from a VG meter is the viscosity of the drilling fluid at that particular RPM it is calculated by the equation below [04].

$$\mu e = \frac{300.\theta\ for\ any\ RPM}{RPM} \tag{4}$$

A formula for the effective viscosity in an oilfield unit is shown below [09]:

$$\mu e = 100.K.\left[\frac{144.Va}{Dh - Dop}\right]^{n-1} \tag{5}$$

Where:
Va Means flow velocity in m/s
Dh Hole diameter, inch
Dop outside diameter of drill pipe, inch
n The flow behavior index
K The Power Law constant

- **Funnel viscosity**

The funnel viscosity is measured with the Marsh funnel and is a timed rate of flow in seconds per quart it is basically a quick reference check that is made routinely on a mud system; however, there is no shear rate/shear stress relationship in the funnel viscosity test thus it cannot be related to any other viscosity nor can it give a clue as to why the viscosity may be high or low [04].

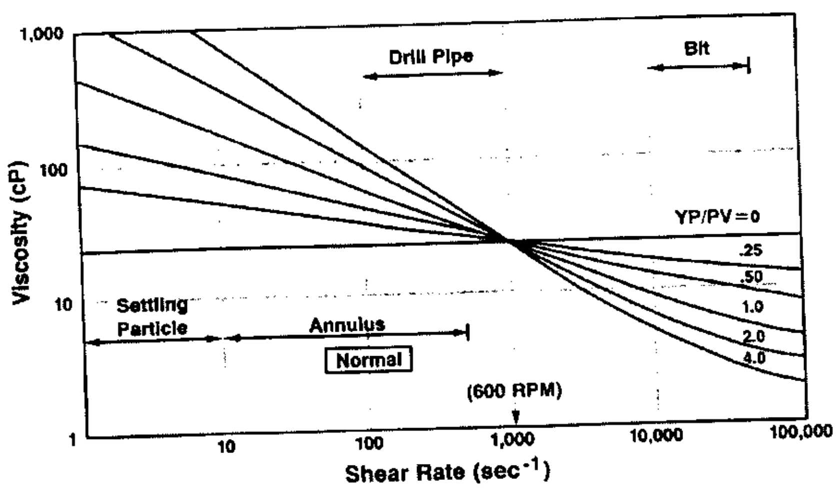

Figure II-12: Rheogram Showing Viscosity vs Shear Rate for Various YP/PV Ratios [04].

II.4 Concepts on flow regimes

The mud flow in various parts of the circulating system will be either laminar, transition, or turbulent, depending on the magnitude of the Reynolds number, Reynolds number is a dimensionless number which indicates the type of fluid flow [04].

II.4.1 Laminar flow

Laminar flow occurs when the individual flow layers (laminar) slide past each other with a minimum of mixing (Figure II-12) demonstrates laminar flow in an annulus generally, laminar flow is the preferred annulus flow profile because it results in less pressure loss and reduces hole erosion to achieve efficient cuttings transport in laminar flow, the fluid rheology should be tailored to give a flat velocity profile, with a small "n" value for power-law fluid this avoids excessive cuttings slip near the borehole wall and drill pipe [04].

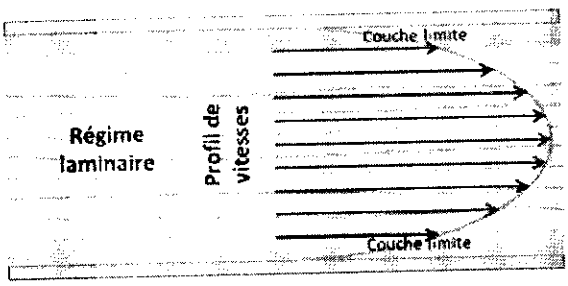

Figure II -13:Régime & vitesses profil for laminaire flow [10].

II.4.2 Turbulent flow

Turbulent flow occurs when the fluid is constantly swirling and eddying as it moves through the flow channel pressure losses within a circulating system increase as the degree of turbulence increases additionally, in turbulence, the viscous properties of a mud no longer have an effect on cuttings removal efficiency, only the momentum forces of a mud weight and predominantly velocity, affect hole cleaning in turbulent flow, the fluid velocity at the walls is zero however, the velocity profile within the stream is essentially flat this flat profile improves hole cleaning characteristics but, at the expense of increased pressure losses through fluid turbulence, a highly turbulent flow may also erode a soft formation (washout) which can reduce cuttings removal efficiency, increase cementing volumes, prevent zonal isolation, and affect wire line log quality generally, turbulent flow should be avoided if possible [04].

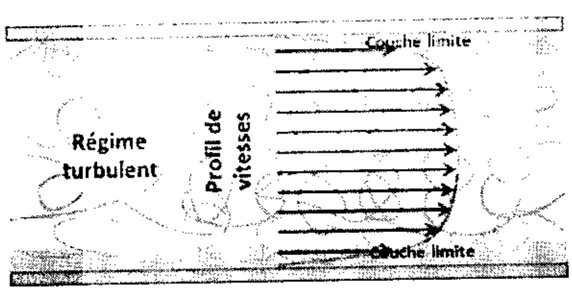

Figure II -14:Régime & vitesses profil for turbulent flow [10].

II.4.3 Determination of the flow regime

We compare the calculated Reynolds number with the critical Reynolds number to know the flow regime for Bingham fluids the critical Reynolds number equals Rec = 2100 so,
If Re <2100 laminar flow regime
If Re >2100 turbulent flow regime
And we have two equations to calculate Reynolds number [09]:
In annular,

$$Re = \frac{928.(Dh - Dot).Va.d}{\mu_e.(\frac{2n+1}{3n})^n} \quad (6)$$

In side drill string,

$$Re = \frac{928.Dint\ t.Vt.d}{\mu_e.(\frac{2n+1}{3n})^n} \quad (7)$$

II.5 Concept on pressure losses

Each fluid, flowing in a pipe, undergoes a loss of its energy this loss is due to two types of friction forces namely:

- Friction due to fluid viscosity.
- Friction caused by the roughness of the walls of the pipe.

This loss is called loss of charge and is expressed by the pressure difference between two points of the fluid.
The equation for pressure drops in pipes with flows with the prerequisite of a constant density is:

$$\Delta p = \frac{d.Va^2}{2}.\left(k.\frac{L}{D} + \sum \delta\, i\right) \quad (8)$$

This is the Bernoulli's energy equation, whereby the term of the static height is not taken into account because it does not represent a pressure drop [11].

Where:
d density in kg/m3
Va means flow velocity in m/s
K Coefficient of pipe friction
L Length of the pipe in m
D Diameter of the pipe in m
δ Coefficient of friction

If we take the example of the drilling mud, there is a total pressure drop between the pumps and the mud tanks the fluid is at atmospheric pressure.
These pressure drops occur:

- In surface circuit.
- Inside the drill pipe and drill collars.
- Through the bit.
- In the annular hole-drill whole space.

Chapter III:

Problematic, different problems caused by bad cleaning of the wells.

Abstract:

The objective of this chapter is the experimental study of or problematic of stake pipe in the well RECSWS EXT-1, using an hydraulic analyses and ANSYS Simulation.

III.1 Introduction

The hole cleaning it is big problem in drilling it cause a several problem that have negative effect in the performance of drilling, so to get a good cleaning we should control the rheological parameters of the mud, the major problem of bad cleaning it result from the viscosity of the mud when we have low viscosity we have a bad cleaning so we trying to solve this problem by tow experimental hydraulic analyses in the same well (RECSWS EXT 1) by changing in the hydraulic and the rheological parameters and we finished by Technical and economic s study in chapter III.

While drilling 26" hole section and at 286m torque indicator indicate increase in torque after that we have a no rotation and no movement but we have circulation (stuck pipe), due of the bad hole cleaning, we start jarring the drilling BHA after six hours we get free pipe so it is the time to start mud treatment to solve this problem by increasing in mud viscosity [16].

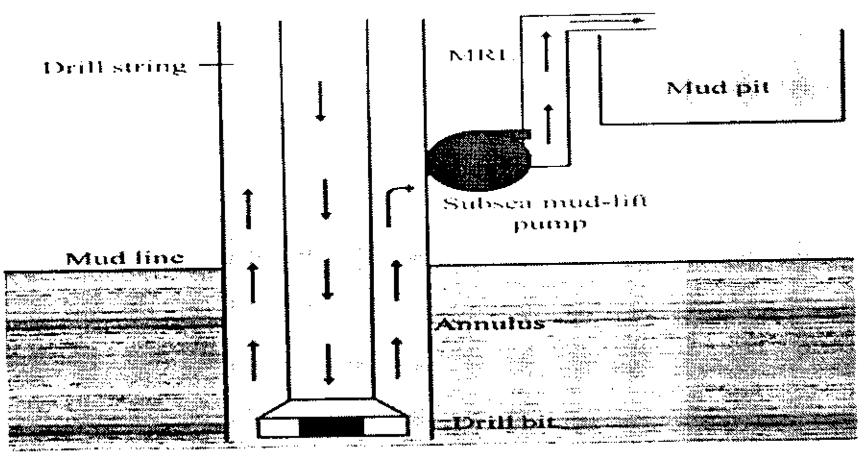

Figure III-01: Mud flow in the annular space [12].

III.2 Different problems caused by bad cleaning of the wells

- Increase in torque, drags and run draw.
- Difficulties of movement of drill string and risk of stuck pipe.
- Well instability and loss circulation.
- Bad cementing.
- Well Control Difficulties.
- Bit balling.

III.2.1 Increase in torque drags and run draw

Drill string drag is the cumulative force required to move the pipe up or down inside the hole, torque is the movement required to rotate the pipe, drag forces usually are paralleled to the string weight measured with the string rotating but not reciprocating measured from the rotating string weight, the pickup drag is usually vaguely greater than the slack-off drag.
The magnitudes of torque and drag are related in any particular well, high drag forces and excessive torque loads usually occur together there are various causes for excessive torque and drag, such as tight whole conditions, key seats, differential sticking, sloughing hole, sliding wellbore friction and cuttings buildup caused by poor hole cleaning [18].
With the exception of sliding friction, these causes are associated with problem conditions in the wellbore contrarily, in wells with great hole conditions, the primary source of torque and drag is sliding friction, torque and drag from any source tend to be more troublesome in extended-reach directional wells in very deep, highly deviated wells, overcoming torque and drag can be vital to the successful well completion the capability to predict frictional loads on drill pipe has two main benefits:

- Deep, highly deviated wells can be planned to minimize torque and drag and ensure successful drilling operations to total depth.
- A more complete knowledge of drill string loading allows use of improved drill string design techniques, having considered the extra forces involved.

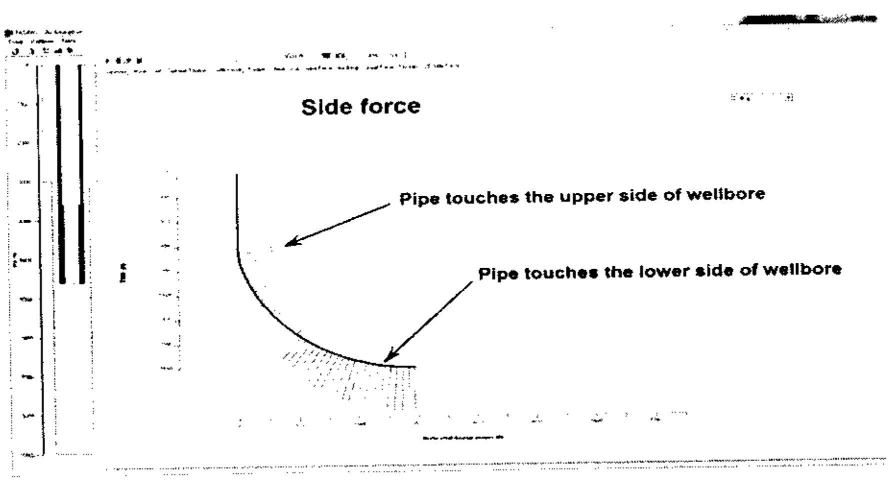

Figure III-02: Side Force along a Drill Pipe [13].

III.2.2 Difficulties of movement of drill string and risk of stuck pipe

The accumulation of cuttings in the hole can increase the rheological parameters and physical drilling mud (viscosity, density, ...), this will result in an increase in frictional forces that can lead to pressure sticking differential this difficulty of moving of drill string will result a very slow rate of maneuvering operations [18].

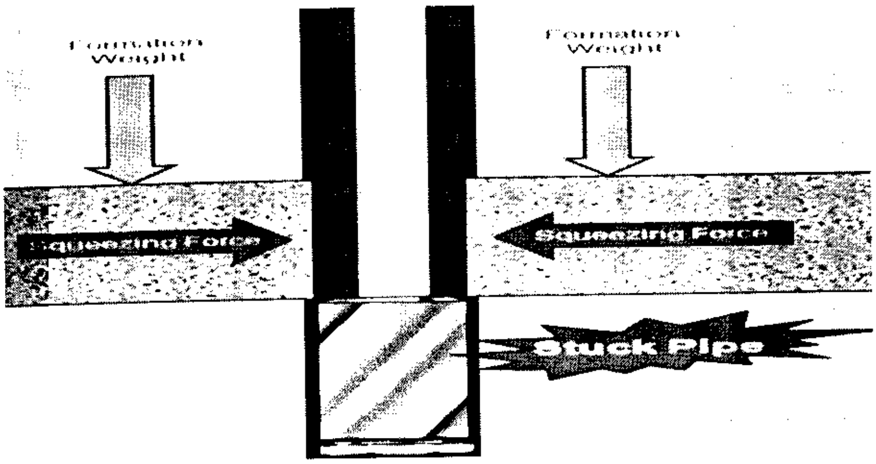

Figure III-03: Stuck pipe [09].

III.2.3 Well instability and loss circulation

Lost circulation is one of the most fundamental problems encountered in drilling it results in costly mud and time involved in rig operations it also requires the use of materials and techniques in order to prevent them and the resultant loss of petroleum reserves.

Lost circulation is a phenomenon in which the drilling fluid flows into one or more geological formations instead of returning back to the annulus as a result of this, the oil industry suffers a loss of over one billion dollars annually in rig time, materials and other financial resources lost circulation normally occurs when the mud flows into the natural fractures and caverns as shown in (Figure III-04), it may also be caused if there is an overbalance of pressure applied on the drilling mud, as a result of which fractures are created inside the formation, allowing mud losses through them [18].

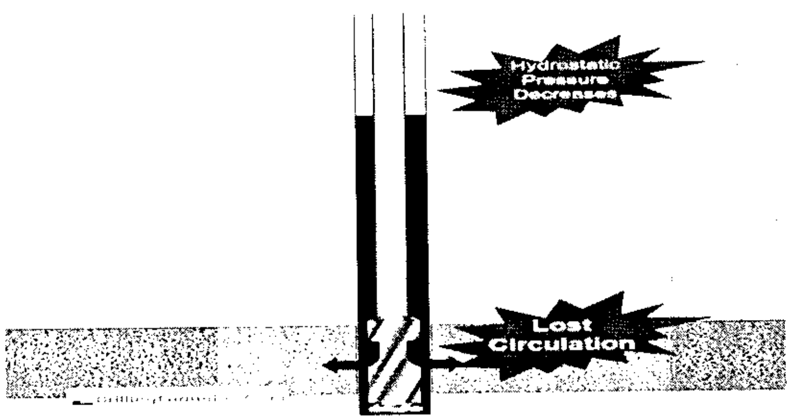

Figure III-04: Loss circulation inside a formation [09].

There are two basic consequences of lost circulation, first if the level of fluid in the well bore is lost due to losing mud inside the formation, lower hydrostatic pressure is created which results in the flow of fluids inside the formation into the well bore this process is commonly called kick, second if the drilling is continued to a point where there is no fluid left inside the well bore, it can result in damage to the well bore, including the destruction of the bit this phenomenon is called dry drilling categories of losses the nature of losses as a result of lost circulation can be categorized in terms of degree and the time needed to control them [18].

The two types of losses are:

- Partial losses, these are losses in the range of 1–3 m^3/h.
- Total losses, there no returned to surface.

After lost circulation takes place, an effort is made to reduce the severity of the loss by increasing the viscosity of the drilling mud by adding certain additives this allows drilling to continue uninterrupted the most commonly used additives are [17]:

- Bentonite is used to increase the viscosity of the drilling mud which slows the flow of fluid in the nearby formations.
- Polymers are used for increasing the viscosity of the drilling mud, but they are more expensive.
- Sawdust, flaked cellophane and ground gypsum are used to physically plug or seal the sources of losses.
- Cheaper options include shredded newspaper and cotton seed hulls, which also act as plugs or seals.

III.2.4 Bad cementing

The success of a well cementing job begins with the quality of wellbore construction achieving a quality wellbore in terms of consistent gauge (diameter of the bore), small scale variations on the surface of the wellbore surface and the stability of the wellbore during the drilling process the careful selection of appropriate drilling fluids for the given wellbore conditions is crucial to achieve good cleaning of the wellbore and minimize wellbore erosion (washouts, chemistry).

The fluid hydraulics is crucial for this purpose, the engineers have control over:

- fluid density
- rheological properties
- frictional pressure losses
- flow rates

The drilling process may cause some damage to the formation, the cement slurry is a very dense fluid and a bad cementing job may cause fractures in the formation, hence the requirement to balance hydrostatic and hydrodynamic pressures [18].

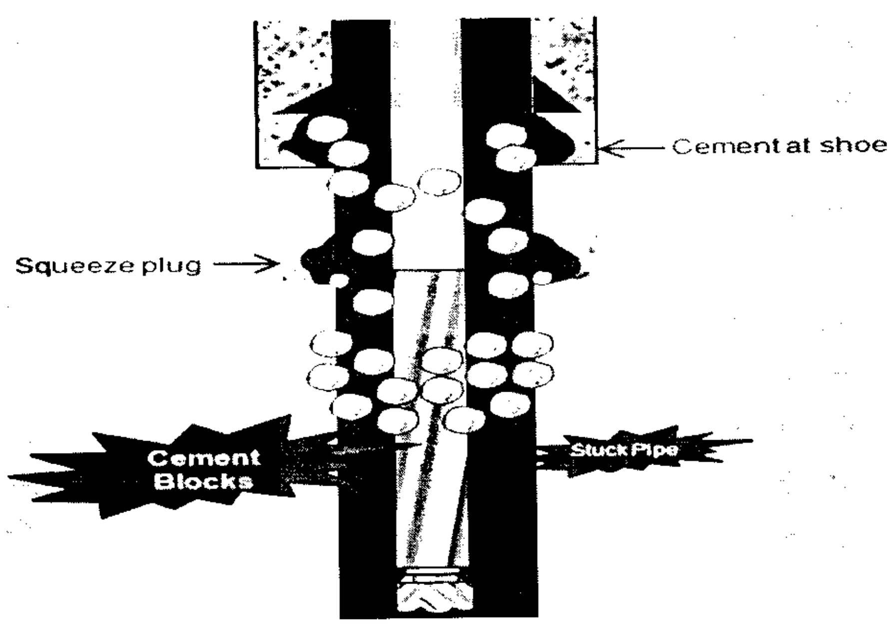

Figure III-05: Bad cementing [14].

III.2.5 Well control difficulties

An influx of formation fluids (gas, oil or water) into the hole occurs when the hydrostatic pressure of the column of mud in the hole is less than the formation pressure unable to balance or "stay on top of " the formation pressure, the formation pressure enters the annulus as depicted in the above schematic this situation occurs through the mud weight being too light or when pulling out of the hole too fast (swabbing) gas is the worst influx to have in the hole as it typically continues to rise at quite a fast rate if the well stays shut-in and it's not circulated out of the hole to prevent an influx into the hole from occurring the hydrostatic pressure (determined from the basic formula Hydrostatic Pressure (psi) = Mud Weight (ppg)x True Vertical Depth (feet) x 0.052) must be at least equal to (but preferably greater than) formation pressure also, the hydrostatic pressure should not be momentarily reduced through pulling out of the hole too fast (swabbing) [18].

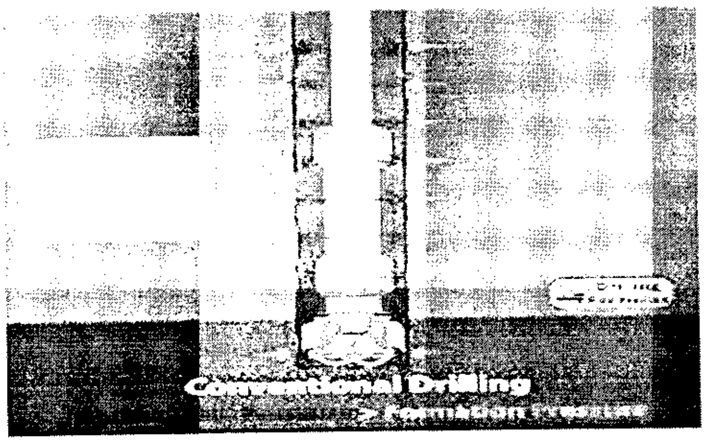

Figure III-06: Well Control [09].

III.2.6 Bit balling

Bit balling is a major problem that occurs during drilling of a formation containing water-sensitive clays, such as shale's the analysis results show that while normal drilling the laminar flow should be made by controlling viscosity and gel strength, while in soft mud stone formation the turbulent flow should be kept by adding much polymer solution [18].

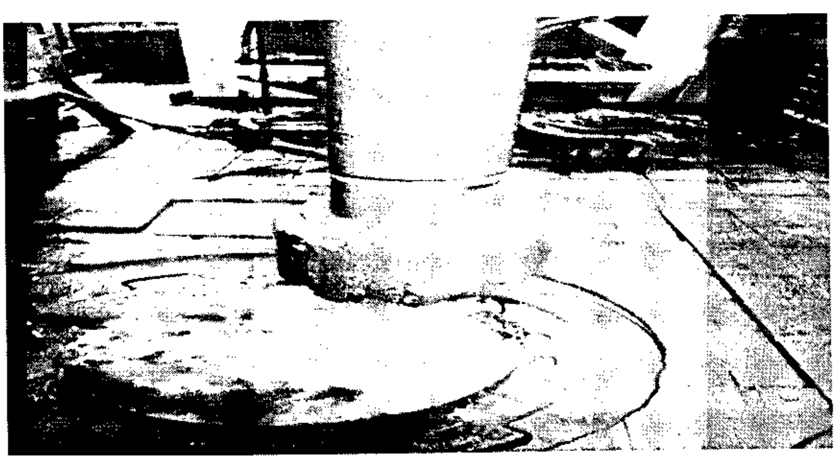

Figure III-07: Bit balling caused by bad cleaning [08].

III.3 Hole Cleaning and preventative action to avoid these problems

Removal of cuttings from the well bore is an essential part of the drilling operation efficient whole cleaning must be maintained in all wells failure to effectively transport the cuttings can result in a number of drilling problems including (Excessive over pull on trips, High rotary torque, Stuck pipe, Whole pack-off, Formation br.aks down, Slow ROP, Lost Circulation…etc.).

The rig team have control over a number of parameters that assist hole cleaning, namely pumping hole cleaning pills, methods used to pull out of the hole, choice of reaming speeds, choice of ROP, flow rate, movement of string while circulating, ..etc., of these the annular flow rate is very important.

Hole cleaning is often more of an issue in a gauge hole than it is in an over gauge hole for example when drilling a 26 inches hole using a spud mud system with frequent dumping and diluting the diameter of the hole can be as much as 30 inches so a 8 inches of cuttings bed exists the BHA will pass this with only minimum extra drag, over pull problems in this hole, all of these are potential problems for near vertical (less than 30 deviation), wells generally hole cleaning rarely presents a problem in near vertical wells the problems listed above are common on highly deviated wells successful hole cleaning relies upon integrating optimum mud properties with best drilling practices when difficulties are encountered it is essential to understand the nature and causes of the problem this allows options to be focused on determining the most appropriate actions, there is a large number of drilling parameters which influence the hole cleaning process the driller has a direct control on some parameters, others are pre-determined by the constraints of the drilling operation [18].

III.3.1 Cuttings transport

In holes inclined at less than 30", the cuttings are effectively suspended by the fluid shear and cuttings beds do not form conventional transport calculations based on vertical slip velocities are applicable to these wells generally for these shallow angled wells, annular velocity requirements are typically 20-30% in excess of vertical wells.

In deviated wells, those above 30, cuttings tend to settle on the low side wall and form cuttings beds cuttings fall to the low side of the hole and are transported along the low side of the hole as cuttings beds these beds often form into dunes if string rotation is not present these cuttings beds can slide back down the well, causing the annulus to pack-off, this is referred to as avalanching cuttings which form on the low side of the hole can either move en-masse as a sliding bed or alternatively may be transported at the cuttings bed / mud interface as ripples or dunes the problem is they can move in either direction even when the pumps are on [20].

III.3.2 Rheology

The effect of mud rheology on whole cleaning depends on the annular flow regime.

- When laminar flow exists, increasing the mud viscosity will improve whole cleaning (This is particularly effective if the low shear, rheology and YP/PV ratio are high).
- When turbulent flow exists, reducing the mud viscosity will help remove cuttings [20].

III.3.3 Yield stress

This is a measure of the low shear properties of the mud, it is determined from the 6 and 3 rpm readings of a conventional Fann viscometer, YS=2x (Fann 6 - Fann 3)], yield stress controls the size of cuttings which can be suspended by the flowing mud (dynamic suspension), the dynamic suspension will be affected by cuttings' size and mud density in practice the optimum level required is best established based on field data and experience [20].

III.3.4 Flow rate

The mud flow rate provides a lifting force on cuttings to carry them out of the well in highly deviated wells, mud flow rate combined with mechanical agitation are the most important factors for whole cleaning for vertical wells the rate of cuttings' removal increases with increasing annular velocity and/or increased rheological properties [20].

III.3.5 Hole geometry

Whole diameter has a very significant effect on annular velocity for example using equation (6), reducing whole diameter from 17½" to 16" will increase annular velocity by 18% [20].

III.3.6 Mud weight

Mud weight influences hole cleaning by affecting the buoyancy of the drilled cuttings as mud weight increases, the cuttings will tend to "float" out of the well making hole cleaning easier in practice the mud weight window will be constrained by drilling factors other than hole cleaning (well bore stability, ECD, differential sticking, etc.) [20].

III.3.7 Cuttings properties

Hole cleaning is dependent upon both cuttings' size and density increasing size and density both tend to increase the cuttings' slip velocity, this makes transport more difficult the effects of higher slip velocity can be combated by an appropriate increase in yield stress and mud gel in extreme circumstances bit selection can be used to generate smaller cuttings and, hence, reduce slip velocity however, if cuttings get ground up into fines they can be hard to remove from a deviated section of well bore [20].

III.3.8 Rate of penetration

An increase in penetration rate results in a higher cuttings' concentration in the annulus this will lead to a higher effective mud density in the annulus and higher circulating pressures, which may in turn limit flow rates [20].

III.3.9 Drill string rotation

In deviated wells high drill pipe rotation speeds provide an effective means of mechanically disturbing cuttings beds and lifting them from the low side into the main mud flow for removal rotary speeds of 150 rpm have been shown experimentally to dramatically increase the removal of cuttings beds drill string rotation has little effect on hole cleaning in near vertical wells in the smaller hole sections of HTHP wells, string rotation can cause an increase in pump pressure ECD [20].

III.4 Experimental study of the well RECSWSEXT-1

III.4.1 Hydraulic calculation and interpretation of the results

III.4.1.1 Hydraulic analysis

The purpose of a hydraulic analysis is to evaluate the effects of drilling mud viscosity on drilling parameters, the viscosity and other rheological parameters of the drilling mud have an effect meaning on the well cleaning, the variation of the cleaning according to the viscosity of the drilling mud, can obtained from the cleaning index formula as follows, [09]:

$$CCI = \frac{K.Va.d}{400,000} \tag{5}$$

Where;

Va is annular velocity in ft/min.

d is mud weight in ppg.

K is a Power Law Constant.

Annular velocity is the speed of fluid moving up the annulus and it must be high enough to transport cuttings generated while drilling from the wellbore however, if the annular velocity is too high, it can create whole wash out and excessive equivalent circulating density when the drilling mud is circulated through a system, the moving speed is lower at location where the cross section area is bigger conversely, when the fluid flows through the small cross section area, the annular velocity at that point is higher the cross section area around drill collar and BHA has the smallest area so the annular velocity is the highest on other hand, the area around drill pipe has the biggest cross sectional area, hence, the speed of fluid around the drill pipe area is smallest the annular velocity around drill pipe must be used to determine if it is good enough for hole cleaning because it is the lowest velocity in the wellbore. If the

annular velocity around the drill pipe is good enough for hole cleaning purpose, it will definitely be sufficient for hole cleaning around drill collars, BHA and tool joints, if you have some formations which can be easily washed out, you need to look at the annular velocity around drill collars, BHA and tool joints the size of drill collars and BHA should be reduced if the flow rate can cause excessive wellbore erosion, to adequately transport the cuttings from the wellbore; the annular velocity is affected by mud properties, rate of penetration, mud types, formation types, whole angle, size of cuttings, etc.
A formula for the annular velocity in an oilfield unit is shown below [09]:

$$Va = \frac{24{,}51.Q}{Dh^2 - Dop^2} \quad (6)$$

Where
Va = annular velocity, ft/min
Q = flow rate, gallon per minute
Dh = hole diameter, inch
Dop = outside diameter of drill pipe, inch

III.4.1.2 Well description of RECSWS EXT-1

RECSWS EXT-1is located in the field BERKINE EST is a vertical well; TD at 4450m in 70 days exploration well, objective order of potential investigation of hydrocarbon reservoirs Unite A1, Unite M2 SILURIEN ARGILO-GRESEUX

III.4.1.3 Drilling program RECSWS EXT-1

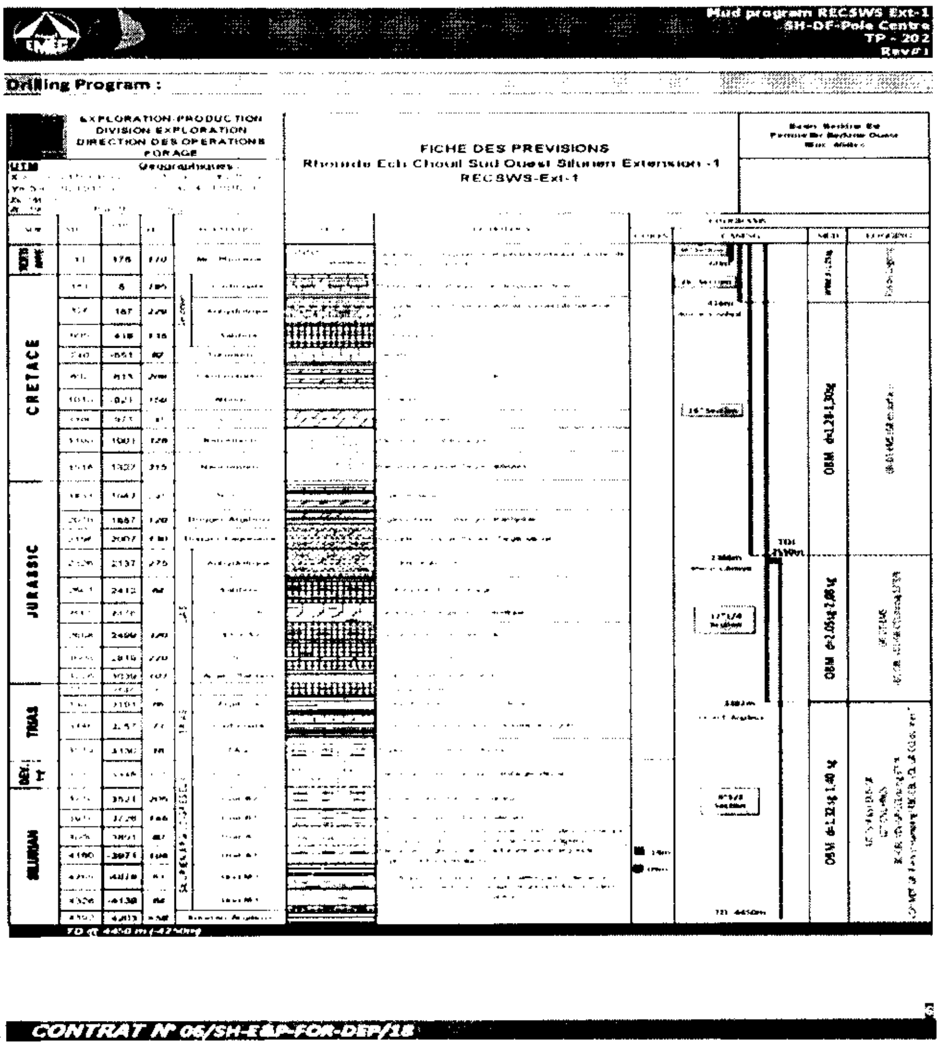

Figure III-08: Drilling program [17].

III.4.1.4 Mud program for the 26" section RECSWS EXT 1

Intervals mud properties:	26" Before treatment	26" after treatment
Interval Depth	60 – 416	60 – 416
Casing Size	18 5/8"	18 5/8"
Mud Type	Spud mud	Spud mud
Mud Weight	1.05	1.05
Yield Point	**50**	**65**
Plastic viscosity	**5**	**5**
Flow rate	831,9	739,7
θ600	60	75
θ300	55	70
θ3	12	18

Figure III-09: Mud program [17].

III.4.1.5 Daily mud report RECSWS EXT 1

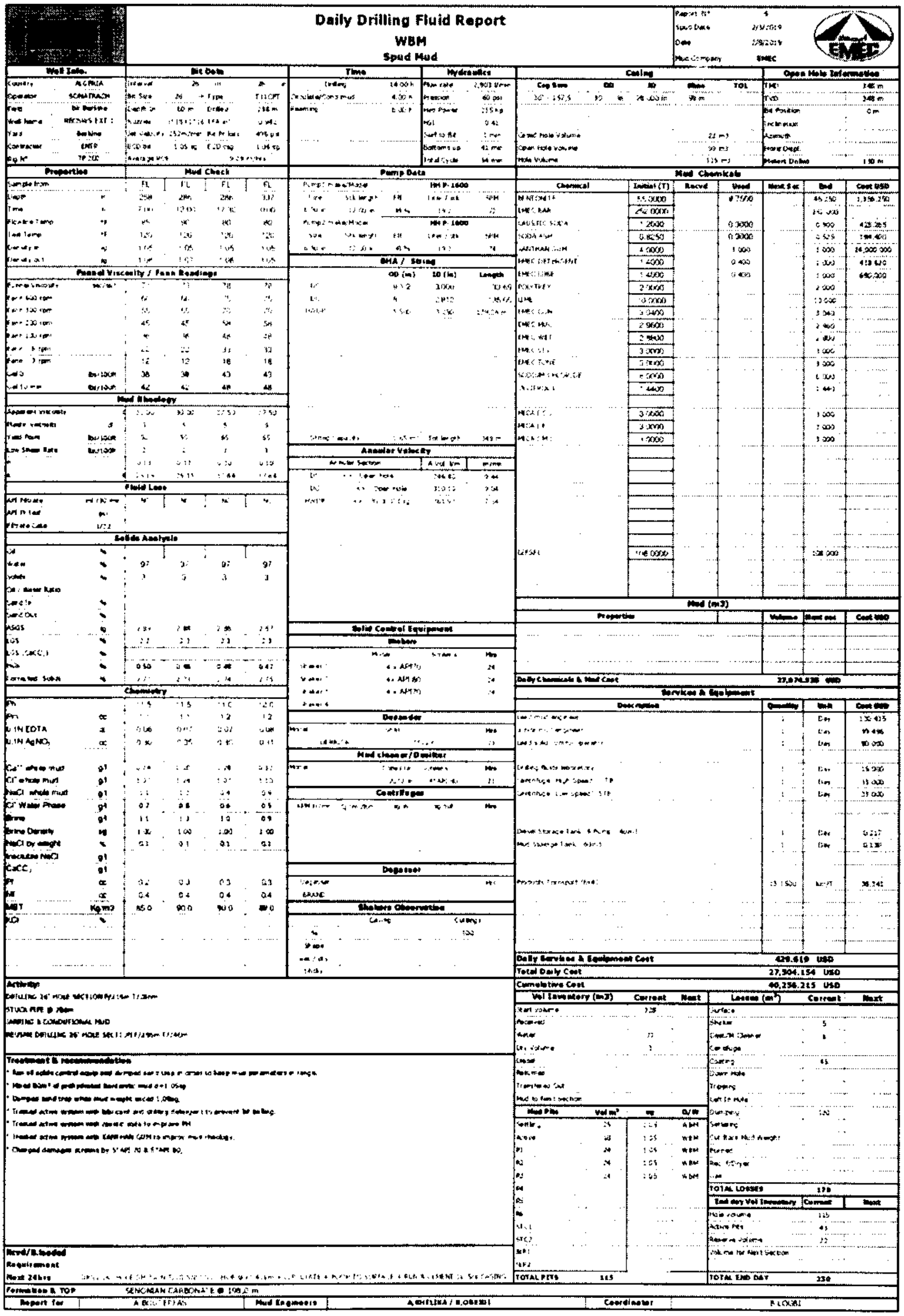

Figure III-10: Daily mud report [16].

III.4.1.6 Hydraulic analysis of the Binghamian rheological model

- **The calculation steps in the annular**

1st: Describe the geometry of the well

Annular			
Section et element	L (m)	OD(in)	ID(in)
OH 26" & HWDP 5,5"	179,26	26" & 5,5"	26" & 3,25"
OH 26"& DC 8"	135,05	26" & 8"	26"& 2,812"

Figure III-11: well geometry [17].

2nd: Calculate the velocity of the first geometric interval
According to the equation (6):

$$Va = \frac{24{,}51.Q}{Dh^2 - Dop^2}$$

Initial value Va1=33,3 ft/min, Va2=29,61ft/min
Final value Va1=31,57 ft/min, Va2=28,07 ft/min
3rd: Calculate the effective viscosity in the annular
A formula for the effective viscosity in an oilfield unit is shown below, [09]:

$$\mu e = 100.K.[\frac{144.Va}{Dh - Dop}]^{n-1} \quad (7)$$

Where,
The flow behavior index (n) can be determined by the following equation, [09]:

$$n = 0{,}5\log \theta 300 / \theta 3 \quad (8)$$

n1=0,330, n2=0,294

The Power Law constant (K) can be calculated from the equation, [09]:

$$K = (5.11)\, \theta 300/511^n \quad (9)$$

K1=35, 89 poise, K2=57, 23 poise

So,
Initial value μe1=1321, 98 cp, μe2=1494, 83 cp
Final value μe1=2170, 68 cp, μe2=2470, 86 cp
4th: Calculation of the Reynolds number
According to the equations (2):

$$Re = \frac{928.(Dh - Dop).Va.d}{\mu_e.\left(\frac{2n+1}{3n}\right)^n}$$

Initial value Re1=3104, 35 Re2=2964, 26
Final value Re1=1677, 40 Re2=1590, 82

5th: Determine the flow regime
After the first and the second analyses we determined that in the first analyses Re=3104, 35 so it is turbulent flow, but in the second Re=1677, 21 it is a laminar flow.
6th: Calculation of the annulus pressure loss
After determining the flow regime we can calculate the annulus pressure losses from the [09].
Equation for laminar flow regime:

$$Pc = \frac{L.Q.PV}{408,6.(Dh-Dop)^3.(Dh+Dop)} + \frac{YP.L}{13,26.(Dh-Dop)} \quad (10)$$

Equation for turbulent flow regime:

$$Pc = \frac{L.Q^{1,8}.PV^{0,2}.d^{0,8}}{709,96.(Dh-Dop)^3.(D\,h+Dop)^{1,8}} \quad (11)$$

Where,
Pc: Loss circulation in annular (kpa)
L: Length of interval (m)
Q: Flow (l/min)
Dh: diameter of the hole
Dop: outside diameters of drill pipe
D: mud weight (sg)
YP: Yield Point (lbs/100 sqft)
PV: Plastic viscosity (cp)

Initial value Pc1=0, 00166 bar, Pc2=0, 00171 bar
Final value Pc1=0, 3679 bar, Pc2=0,4282 bar
7th: Calculation of the cleaning index
According to the equations (5):

$$CCI = \frac{K.Va.d}{400,000}$$

Initial value CCI 1=2, 61 CCI 2=2, 44
Finial value CCI 1=3,70 CCI 2=3, 50
Where;
How will the CCI tell you about whole cleaning?
If CCI is equal to 0.5 or less, the whole cleaning is poor and the whole problem may be seen.
If CCI is equal to 1.0 or greater, it indicates that the whole cleaning is good.

- **Calculation results by RECSWS EXT-1 well data**

Annular												
ection	Va (ft/min)		μe (cp)		Re		regime		Pc		CCI	
6"& DC 8"	33,30	29,61	1321,98	2170,68	3104,35	1677,21	turbulent	laminar	0,00166	0,3679	2,61	3,70
26"& 5,5"	31,57	28,07	1494,83	2470,86	2964,26	1590,82	turbulent	laminar	0,00171	0,4282	2,44	3,50

Table III -01: Calculation results

III.4.2 Analysis with ANSYS

III.4.2.1 Problem description

The said mud circulate through the annulus with a rate of 0.8319 m^3/min, the diameter of the hole 26", the mud viscosity is 13.2198 kg/m-s, mud density is 1.05 sg.

- **The well geometry**

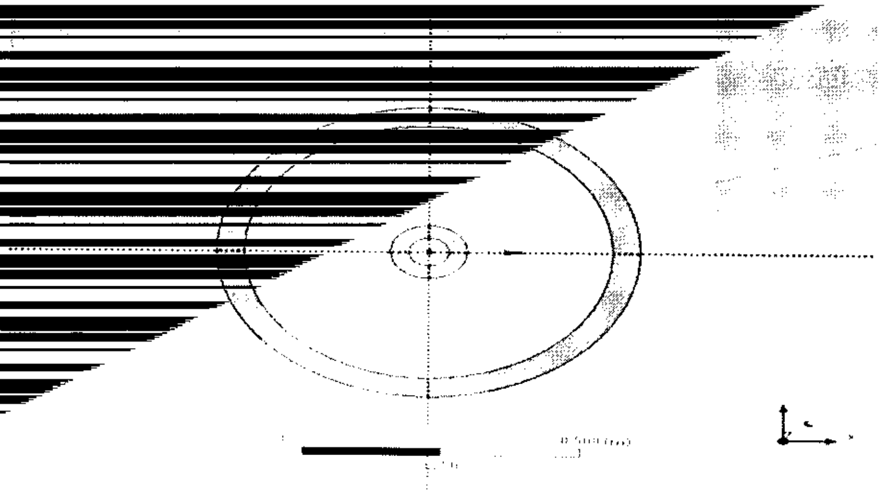

Figure III-12: Ansys well geometry [19].

According to the figure III-12 we conclude that the geometry of our sample are with 26" diameter of the hole and 8" of drill collar.

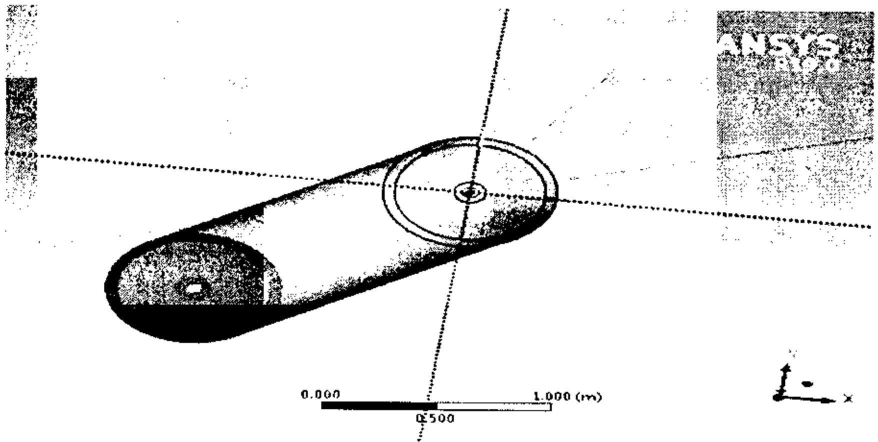

Figure III-13: Ansys extrude of the sample [19].

According to the figure III-13 the extrude of our sample are 20m at the axe Z.

III.4.2 Analysis with ANSYS

III.4.2.1 Problem description

The spud mud circulate through the annulus with a rate of 0,8319 m^3/min, the diameter of the hole 26" the mud viscosity is 13.2198 kg/m-s, mud density is 1.05 sg.

- **The well geometry**

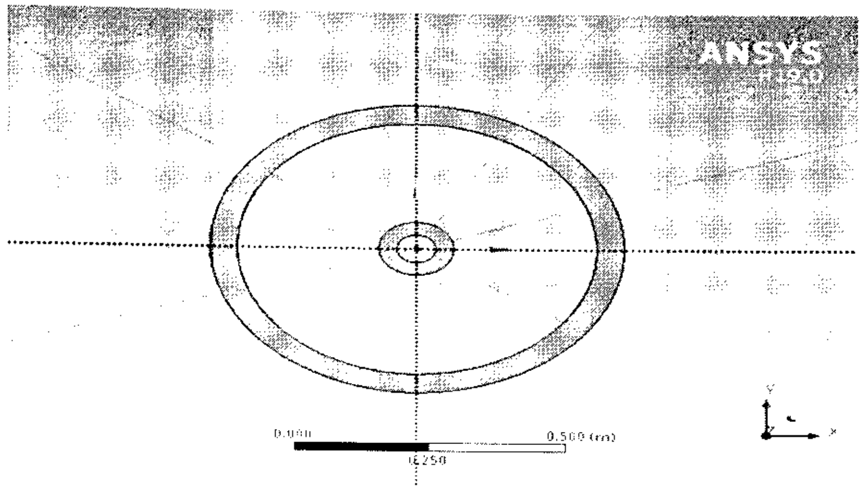

Figure III-12: Ansys well geometry [19].

According to the figure III-12 we conclude that the geometry of our sample are with 26" diameter of the hole and 8" of drill collar.

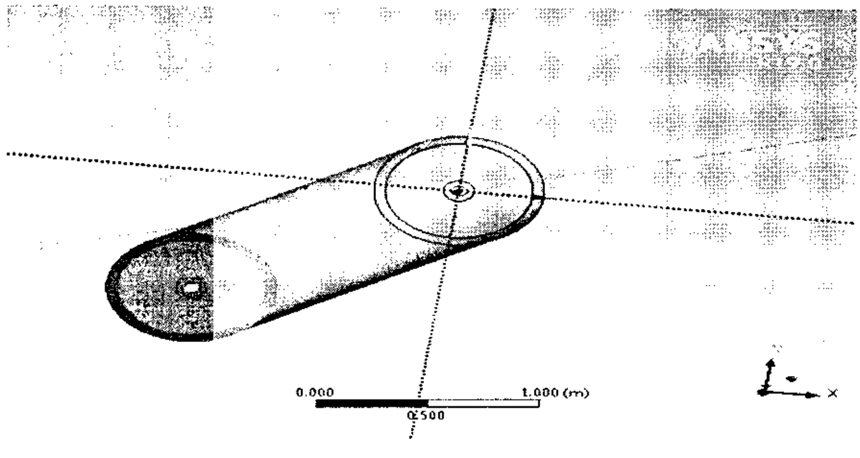

Figure III-13: Ansys extrude of the sample [19].

According to the figure III-13 the extrude of our sample are 20m at the axe Z.

- **Meshing**

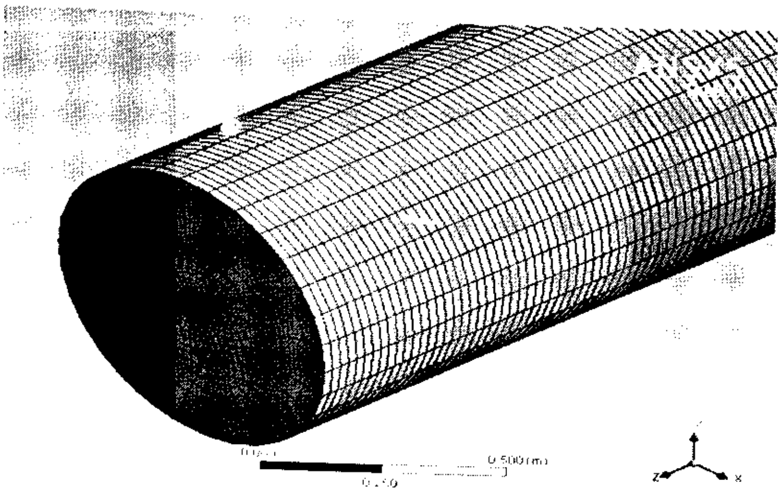

Figure III-14: Ansys mesh of the sample [19].

According to the figure III-14 we conclude that the design of the meshing of our sample using the curvature function and we give all named section in this steps of the setup.

- **Turbulent flow results**

The setup and the calculation of sample using the flowing data (the last 20m of the bottom of the hole, 0.1692 m/s velocity magnitude, flow rate 831.9 l/min, viscosity 13.2198 kg/m-s).

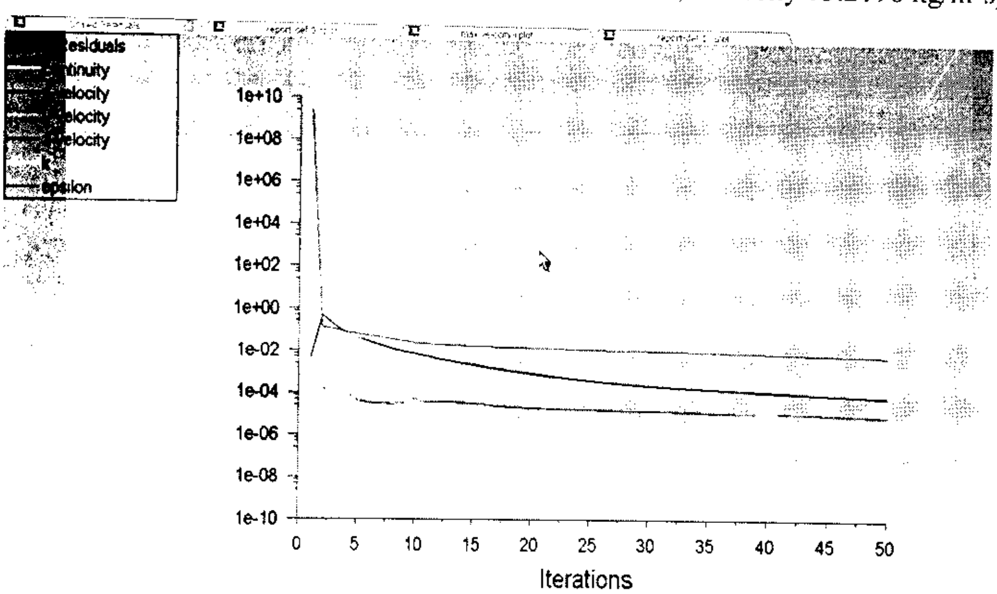

Figure III-15: Ansys Turbulent flow velocity iterations [19].

According to the figure III-15 the progress of iterations from (0) to (50) iteration give as the velocity iteration according to (x, y, z) plan with the pink color and the power low constant with the white color all of them for the turbulent flow.

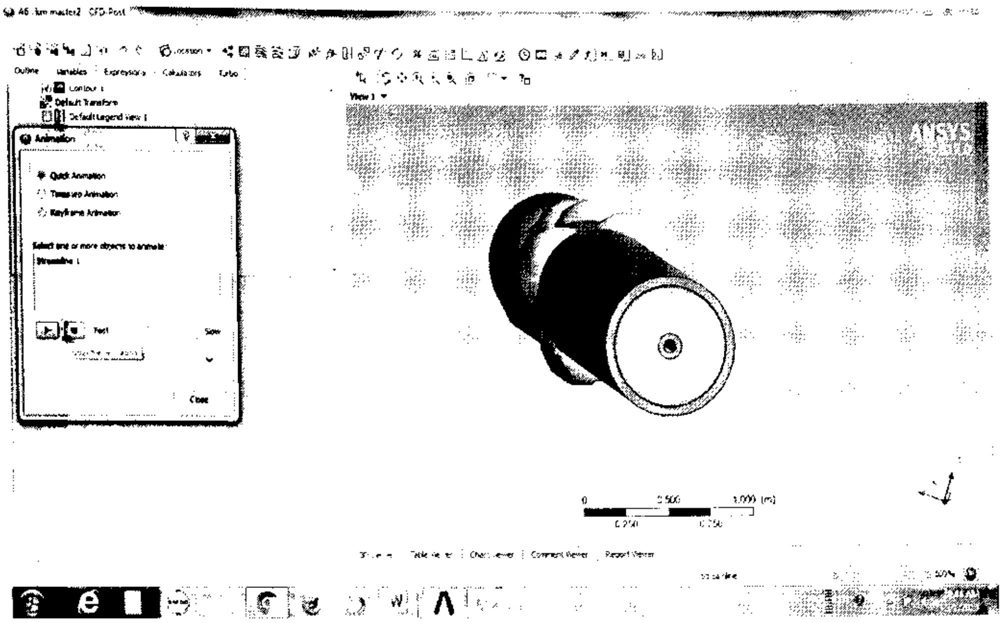

Figure III-16: Ansys Turbulent flow animation [19].

According to the figure III-16 the Streamline show the 3D view of fluid flow through the annular.

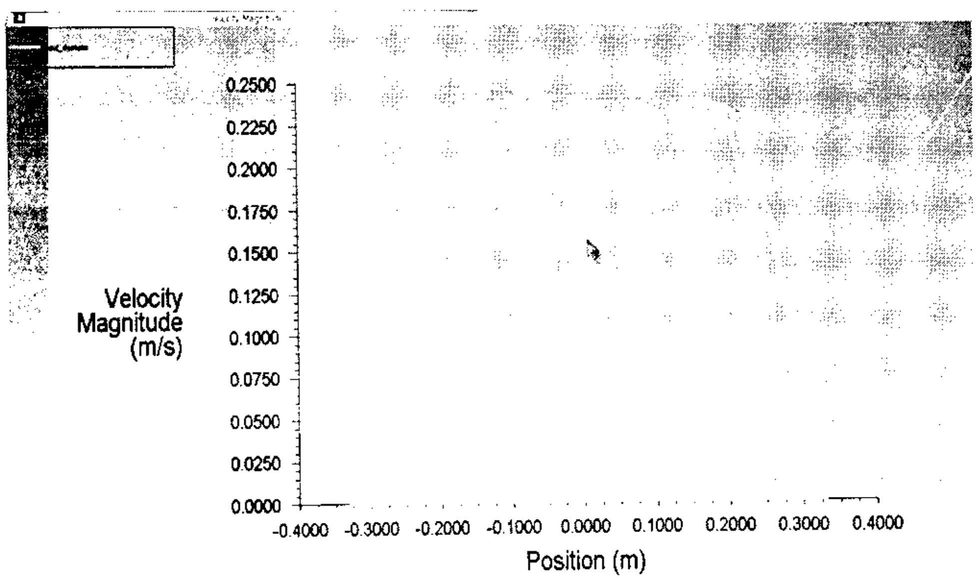

Figure III-17: Ansys Turbulent flow fluid domain velocity magnitude [19].

According to the figure III-17 we conclude that the velocity magnitude profile through the annular of fluid domain give the maximum of velocity 0.248 m/s, the axe X (it is the cut of annular through the plan x) and the axe Y (it is the variation of the velocity).

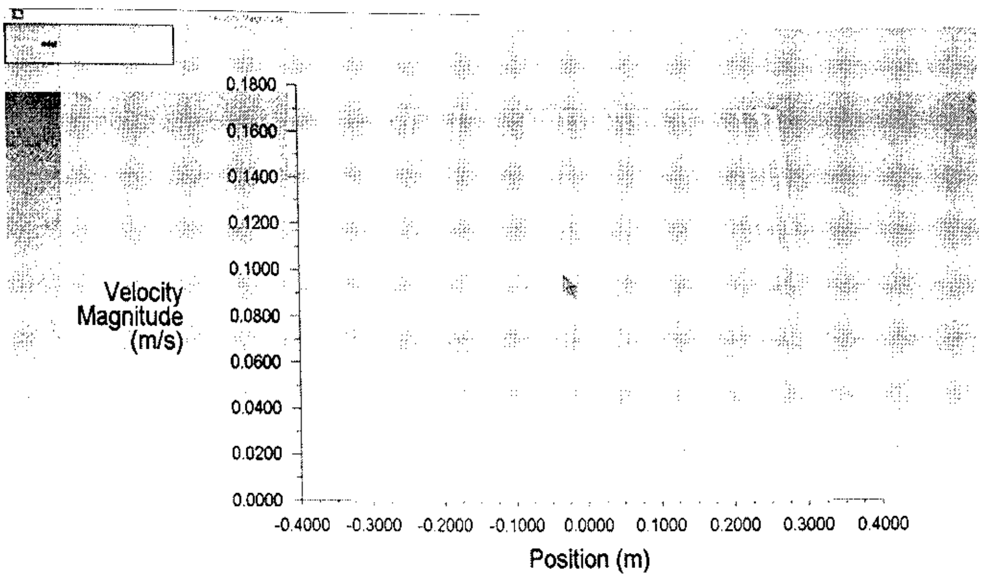

Figure III-18: Ansys Turbulent flow inlet velocity magnitude [19].

According to the figure III-18 the velocity magnitude profile at the inlet are 0.1692 m/s, the axe X (it is the cut of annular through the plan x) and the axe Y (it is the variation of the velocity).

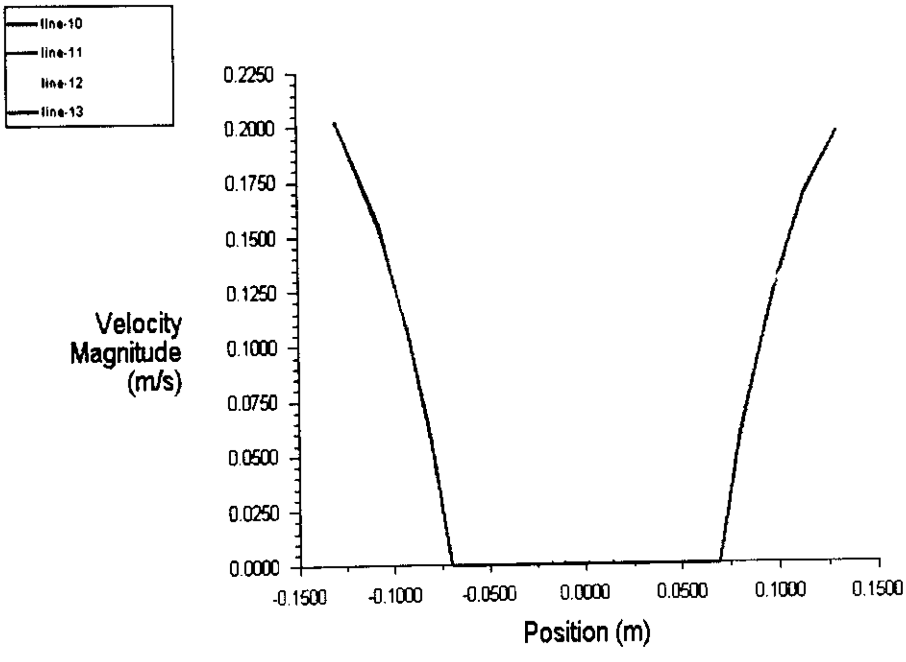

Figure III-19: Ansys Turbulent flow inlet velocity magnitude according to (x) plan [19].

According to the figure III-19 we conclude that the velocity magnitude at the inlet go to the value max- velocity in the inlet 0.205 m/s.

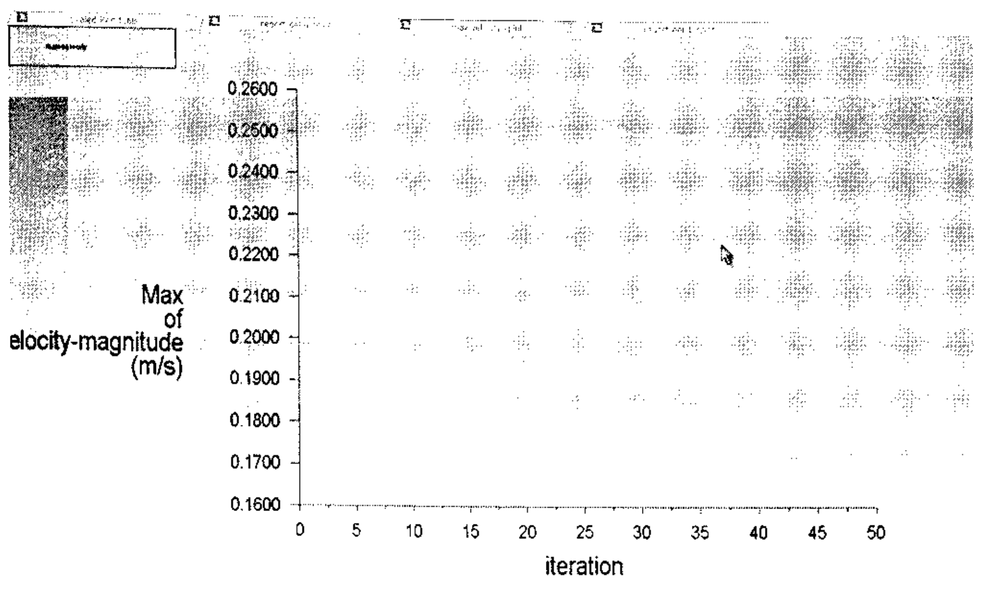

Figure III-20: Ansys Turbulent flow Maximum velocity magnitude [19].

According to the figure III-20 the progress of iterations from (0) to (50) iteration at the axe X and the velocity magnitude at the axe Y, as result the velocity variation from 0.1692 to the max- velocity 0.248 m/s.

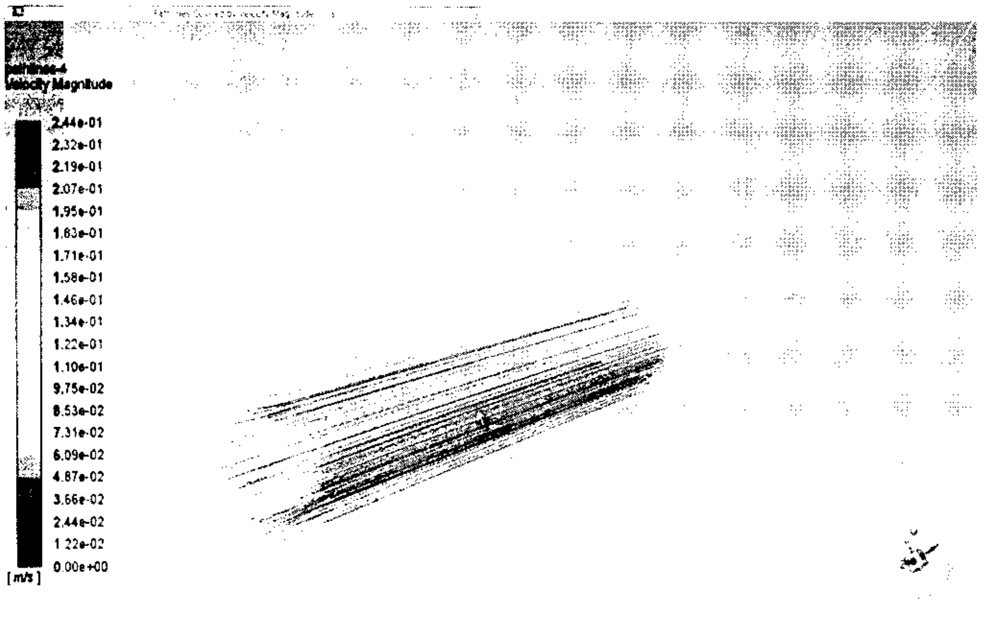

Figure III-21: Ansys Turbulent flow path lines velocity magnitude in the sample [19].

According to the figure III-21 the pathilines show the velocity magnitude distributions on our sample using, for example the red color show the maximum of the velocity and green give minimum of velocity.

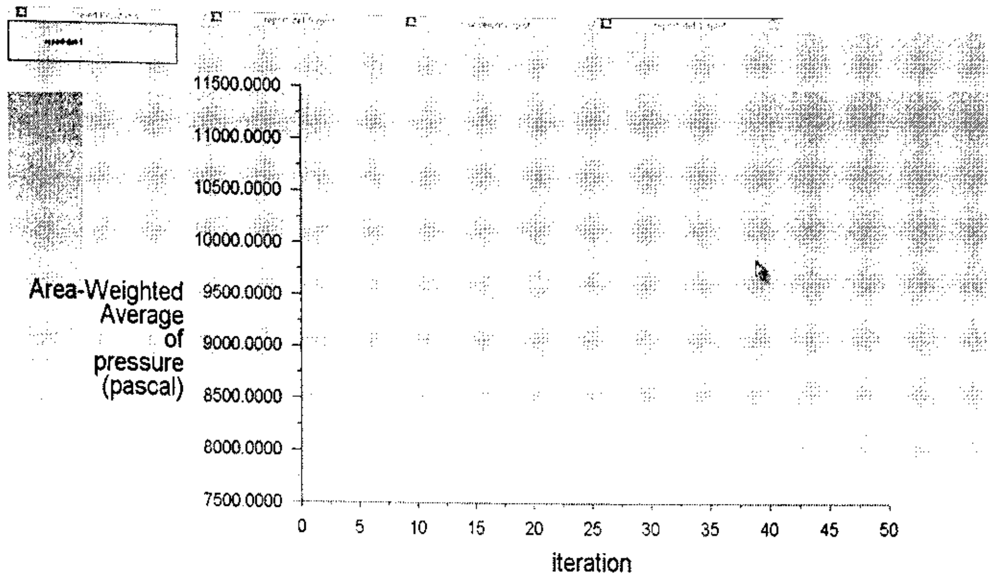

Figure III-22: Ansys Turbulent flow inlet pressure iteration [19].

According to the figure III-22 progress of iterations from (0) to (50) iteration at the axe X and the variation of pressure in the inlet at the axe Y give as the maximum pressure 11250 Pa but after stabilization have the value of 7780.4 Pa.

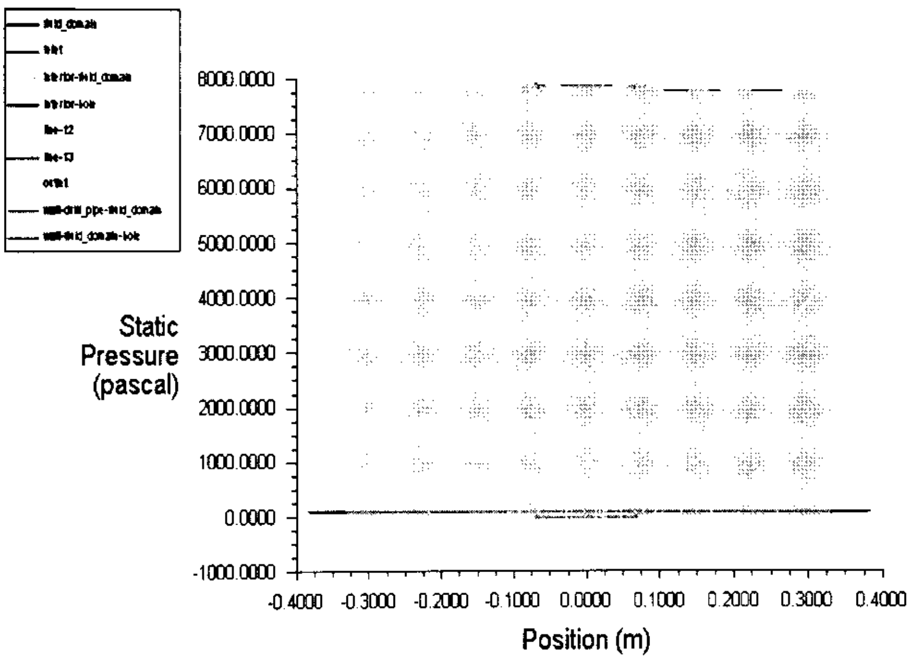

Figure III-23: Ansys Turbulent flow static pressure [19].

According to the figure III-23 we conclude that the pressure distribution on all domain, are at the axe Y and the axe X (it is the cut of annular through the plan x), the static pressure get the value 7780.4 Pa after stabilization.

- **Laminar flow results**

The setup and the calculation of sample using the flowing data (the last 20m of the bottom of the hole, 0.1604 m/s velocity magnitude, flow rate 739.7 l/min, viscosity 21.7068 kg/m-s).

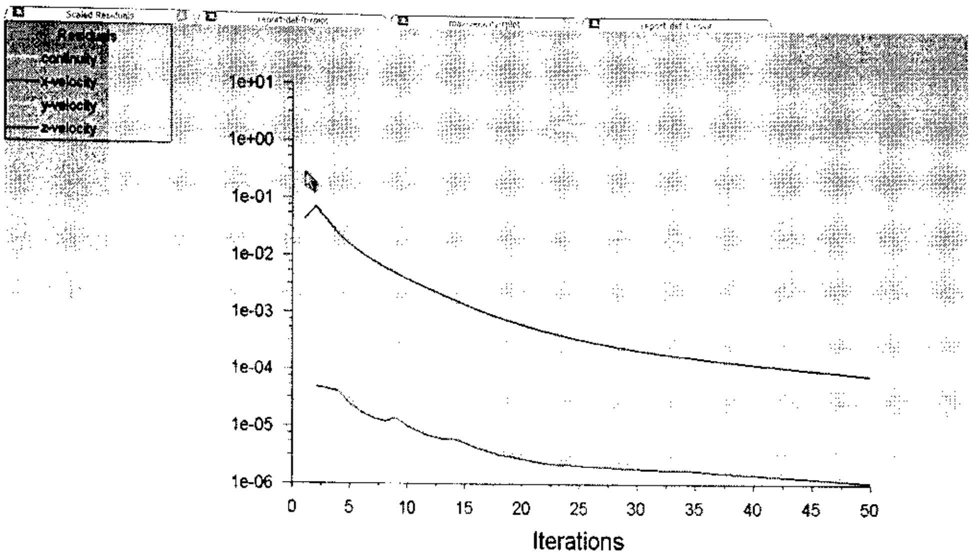

Figure III-24: Ansys Laminar flow iterations [19].

According to the figure III-24 the progress of iterations from (0) to (50) iteration give as the velocity iteration according to (x, y, z) plan with the white color.

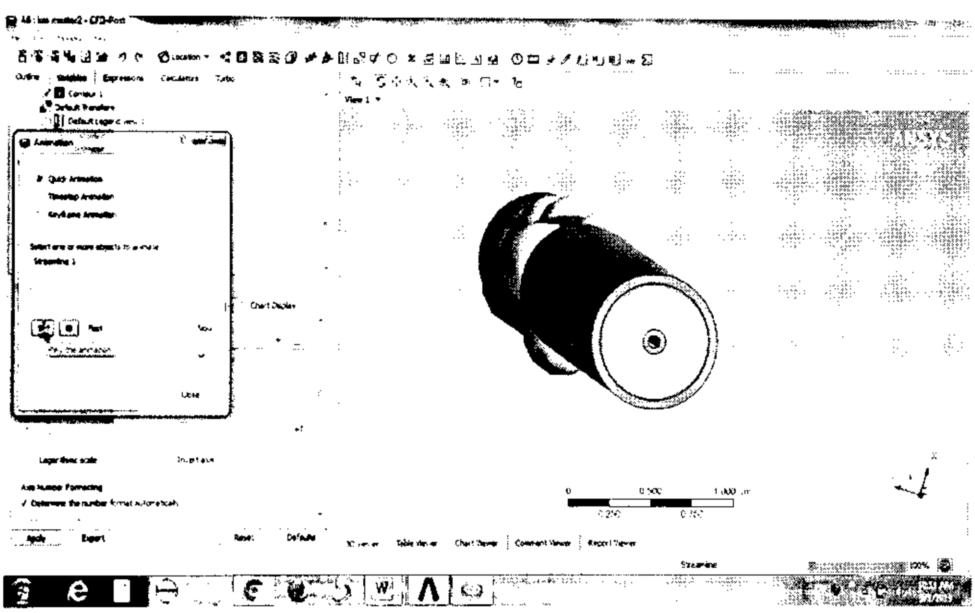

Figure III-25: Ansys Laminar flow animation [19].

According to the figure III-25 the Streamline show the 3D view of fluid flow through the annular.