Study of Stick-slip torsional vibration in Drilling Operation

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Michael Arob Deng Chol

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Mechanical Engineering Programme

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ABSTRACT

The purpose of this work is to analyze drill string torsional vibrations modes, and to advise on whether it is best to minimize, if not entirely eliminate these vibration or if they can be utilize to the benefit of the drilling performances. The work consists of two generic parts. One addressing resonance vibrations when employing roller cone bits, the other dealing with torsional vibrations when drilling using PDC bits. Furthermore , to equip the engineer with the knowledge to visualize and understand the shocks suffered by downhole tools, their distinction and causes to allows them to CORRECTLY interpret the shock data in Real Time, and subsequently take intelligent decisions to mitigate those vibrations and shocks.

The methodology implemented in this project involved Simulating Drillstring and find out natural frequency behavior of vibration and the friction force side effect. The results would be interpreted in term of external force frequency and the force frequency of the system which resulted always into resonance, this resonance affect the drillstring by either ‘Twist off, or Washout’ Phenomena. Simulating would entirely be conducted in Matlab software, Drillstring Dynamic Calculator would have been far better to run the simulation.

Amodel describing the torsional behaviour of generic oil drillstring has been presented. This model is acombination of some previous model proposed in the literature. The problem of modeling is divided into two different problems, first, the problem of modeling of torsional behaviours of the drillstring. Second, the problem of modeling the rock bit interaction originating stick –slip self excited oscillations. This behavior are describes by the drilling parameters behaviour in the simulation. The result obtained shows that the most important of this modelingis to show that inserting RPM of more than 45m/h would endanger the drilling operation special when it hard formation as showing the drillstring disturbances.

ACKNOWLEDGEMENTS

Thank almighty God the who gave the author this opportunity to express his grateful honour to those people that had been contributed to completion of his Final Year Project (FYP) entitle study of torsional vibration in Drilling Performances.

First and foremost the author would like to express his heart felt appreciated to FYP supervisors, Dr. Sonny Irawan and external examiners for their guidance and advice through the two semester of the project. The author thanks also gose to external examiner Mr. Rahmat Iskandar for his support, understanding and encouragement that are greatly treasured.

The gratitude also goes to the author University Technology PETRONAS Research Center and Drilling Engineer in Schlumberger Sudan to continue support in the project fundamental in configuring the vibrations mechanism and the common failure interpretation of the shock which resulted normally from vibration Phenomena. Further more, the author gratitude goes to technicians of Mechanical Engineering department, especially to Mr. Bob for their support and guidance in handling the equipment of Drilling Simulator as well as explaining how the MATLAB would participart in running the simulation.

Again, to all the people mentioned above, thank you so much for your kindness that lead to successful completion of the author Final Year Project. It is an honour for the author to know people like you.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Despite continue efforts to controls vibrational modes particular torsional vibration experienced by on – shore drilling – assemblies a comprehensive understanding of their genesis and their interaction remains an important challenge for the field engineers and mathematician. Although numerous control strategies have been advised to mitigate unwanted vibrations practical implementation often rely on anecdotal evidence and the experiences generations of drilling engineers.The dynamic of long slender rotating drill- string under compressive load of several hundred of KN linking source of surface torque to heavy drill bit that cuts into rocks, ejecting fluids “mud “ at high pressure is inherently unstable under lateral, axial and torsional perturbation. Effective stable drilling over a range of configuration can only be achieved by feedback control drive – torque and active monitoring of dynamic environment of drill –string and the bit. The present of frictional torque depend non – linearly on the angular speed of drill bit and its reaction force to rock – surface (“Weight on bit”) is responsible excitation of torsional relaxation oscillation in turn can excite axial flexural modes that result in phenomena of “bit bounce” and drill – string collision with well of bore hole cavity the existence these dangerous dynamical states is responsible of much of continuing effort in identify the concrete solution to the drill string system.

Recently, attention has been paid to improving drilling efficiency by imposing dynamic loading at the bit – rock interface.To date, this has been applied only in the restrictive circumstances of shallow, hard rock drilling where air –based drilling is possible. This project deals specifically with two separate concepts that take advantage of the vibrations of the drill string to enhance the perfmance of the bit in the formations characterized by low penetration rates. The various modes of vibrations of the drill strings (axial, torsional, and bending which in their most severe forms lead respectively to bit bouncing ,stick–slip oscillations,and bit whirling) are

generally regarded as detrimental. However, it appears possible to control some of these vibrations modes in such away as to enhance drilling performance.
The first technique to be investigated deals with resonance drilling which is applicable to " hard" rock drilling using rock bits (roller – cone bit). The key concept of this first step is to either avoid resonance behavior by regulating the operational parameters, in particular rpm, and weight – on – bit (roller – cone bits). The key concept of this first step is to either avoid resonance behavior by regulating the operation parameters, in particular rpm, and weight– on –bit (WOB), or by adjusting the resonance frequency of the drill string through mechanical filters in the bottom hole assembly (BHA) so as to match the loading excitation at the drill bit . Examples of performance improvements would be include the results and discussion part at the end of this thesis.

The second research area explores the benefits of acoupled axial/torsional vibration system, which is aimed at improving drilling rates of PDC bits in "soft" impermeable rocks. The concept of this second project is to minimize energy dissipation due to friction losses at the wear flats, or chamfers. The generation of parametric maps will help to demonstrate the effect of influence and eventually should help PDC manufactures optimize bit design, and perfect bit selection. Two different concepts for hard and soft rocks are needed because of the very different rock destruction mechanisms behind the low penetration rates observed in these formation, as discussed below.

The means with which this research would be done is through Simulation in the Matlab. The expect outcome of this research is the prediction of the drilling parameters plus the appropriate adjustable controlling of the drilling. Hence the author is expected to interpret the findings based on the field data which had experiences failure of drillstring. These data are compare with one which didn't experience any failure. other considerations made are the type of formation encountered during drilling operations.

1.2 Background of the Study

Vibration and the shock are well known for their severe damage that they both cause to drill string and the bottom hole assembly (BHA). In the drill string, drill pipe are run in such way that they give compression force meanwhile drill collars act in tension however the act of vibration and shock had been the only means which enhances cyclic stress. This cyclic stress fatigue usually results into tensile failure (twisted off). Shock can be experiences by drill string and the BHA due the condition of wellbore and the techniques the driller perform the drilling procedure, e.g. applying weight on bit, increasing RPM, the adjustment of rotary table.

The placement of the wellhead has direct effect with TOP drive or Kelly system during drilling. Another major obstacle is the inclination of the well bore, if the inclination of the wellbore stays uncontrolled the drill string and BHA would be inclined too at certain angle this enhances the shock effect to strengthen its control over the drill string and BHA. To further simplify shock and vibration damage that they both cause to components in drill string and BHA is by highlighting what contributes to rough drilling.

Mentioning rough drilling implies the following scenarios: Formation effect which is represented in term of 1) Coefficient of friction, 2) Coefficient of restitution. Hole gauge/shape - planning done gauge hole .on other hand well path has important such high side loads increase friction, but that never the less seemed the only obstacle, there is also hole cleaning problem. The experimental study of shock and vibration would involved the Simulation of the the drill string and BHA in the wellbore and the precise recommendation to future extension of the research o the shock and vibration. The study is partial fulfillment of the requirement for Bachelor of Engineering (Hons), Mechanical Engineering.

1.3 Problem Statement

The initiation of shock and vibration depend on the wellbore condition and the way the drilling performances are contacted by the driller. There are three broad categories of shocks – (1) Lateral (when the BHA/Tool is flexing and hitting the sides of the borehole); (2) Axial (such as in bit bounce); and (3) Torsional (such as in stick slip when the rotation of the drill-string is inconsistent and non-uniform). It could also make a BHA in a whirl, where the motion is eccentriced.

Axial vibration results in the BHA moving up and down. They result from movement of the bit and are most common in vertical hole with tri-cone bits in hard formation or formations containing boulders and large pebbles. Most often a soft formation bit in hard rock. This type of vibration will break the bit and downhole tools and result in slow ROP.

It can be cured by pulling of bottom and changing the RPM and weight on bit. If they are consistent then a shock sub should be run which will absorb the axial movement and result in changing the resonant frequency of the BHA. A PDC could also be considered instead of a tri-cone bit.

The experiment in this research would involve the use of ANSYS software in order to simulate how the shock could be minimized by predicting out the flow characteristic, and the effect of weight put on bit and RPM applied.For that, reason author would collect the necessary tools which would be involved and run the simulation during Seven weeks of semester break. And see if there is enough time to go for prototype.

1.4 Problem Identification

The problem identification can be represented in the following points based on the research overage.

- The BHA stuck vibration and shock effect either in form of Twist off, or Washout phenomena.
- Incorrect positioning of stabilizer in BHA
- In appropriate mud (drilling fluid) selection
- Pumps malfunction, incorrect liner, unstable pump output
- Application of unsuitable revolution per minute(RPM) and weight on bit(WOB)

The mentioned above problems are seriously against the safety of BHA in horizontal wells, because once the stuck occurs it is hard to fish the tools back, such as radioactive tool which are entirely dangerous if they are left buried underground due to their reactive.

radioactive source. Each and every one of these problems brings into drilling operation undesirable down time for the client (operating company) which usually resulted into lost in term of cost and time.

a) Significants of the Project

- Propose a solution that would minimize the shock and vibration in drilling Operation.
- Run experiments to investigate the vibration and shock which commonly damages electronic apart in the tools within BHA.
- The thesis would hopefully be distribute to company men and drilling superintended in the rig side to be as short guideline in monitoring the phenomena which disturbs the drilling Propose how to control the pump out stability .

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b) Objectives and Scope of Study

- To confirm generic mathematical equation of drillstring can predict failure
- To model drill string system using generic mathematical equation
- To analyze torsional vibration mode in drillstring.
- Reduce the effective forces in drill string by considering, RPM, WOB

c) The relevancy of the Project

This project is relevant to the controlling of drilling all types of well in less economical way. The approach of the project is to protect both the new advance technologies tools using in Logging While Drilling (LWD) and Measuring While Drilling (MWD) and protecting environment. This helps both investors and operating companies to grantee long term contracts.

d) Feasibility of the Project within the Scope and Time

The feasibility is achievable because, this project is not covering multi – scope research on all vibrations types ,but it focus only the torsional and axial vibration, and avoidance of the Drill string fatigue while drilling multi targets in horizontal, as well as throwing a look at the pumps output stableness. The project could be concluding within two semesters or less as long as the experiments are carried out to give the proposed evidence. The expected results of modeling drill sting by investigating the resonance level due to coincidence of force vibration across the bit and the natural vibration of the drill string.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

[1] [20],There have been so much efforts or attempts by oil and gas industry to a ddresse effects of torsional vibration in drilling operation particularly the damage caused by stick-slip to Downhole tools and reduction.

Torsional resonance in drilling part investigates a technique to improve penetration rates when drilling avery low permeability rocks using drag (PDC) bits. Torsional vibration often manifests itself as a stick/slip action of the bottomhole assembly (BHA). Indicators of these downhole.

[2][11,]Downhole tools, such as those in Bottom Hole Assembly (BHA) 100, are subjected to high shock and extreme vibration intrinsic to the drilling process. These high shock and vibration loads can significantly reduce the efficiency, accuracy and reliability of the tools. Shock and vibration may be of particular concern when the tools carry delicate and sensitive electronics equipment, such as the measuring and communications assemblies described above. MWD tools and their associated sensors may, for example, especially susceptible to damage and inaccurate performance in high shock and vibration environments.

[3] [8],The deep hard rock drilling environment induces severe vibrations into drillingstring, which can cause reduced rates of penetration (ROP) and premature failure of the equipment. The only means of controlling vibrations under varying condition is to change either rotary speed or weight- on –bit (WOB).These changes reduces drilling efficiency.

[4] [9],Drilling string develops vibration when run at critical rotary speeds, and these vibrations are difficult to control due to the string long length and large mass. Operating at acritcal speed imports severe shock and vibration damage to the drilling string, fatigue drill collars and rotary connections. Vibrations also cause the drilling string to lift off bottom, reducing ROP. The effect of axial, lateral and torsional (Stick – slip or bit whirl) vibration upon drilling string have been documented in both the laboratory and the field.

The first well in a small drilling programme in Eastern Europe was spud and drilled without considering drill stem vibration. During the drilling of this first well, 6 drill stem failures (2 washouts and 4 twist-offs) occurred while drilling through a deep section of conglomerates. Recovering from each of these failures typically took between 1 to 2 days and 2 to 5 days for the washouts and twist-offs respectively. After the 6th failure there was an investigation into the cause of the problems and vibration was identified as the primary failure mechanism resulting in fatigue.

(Schlumberger, Drilling & Measurements)

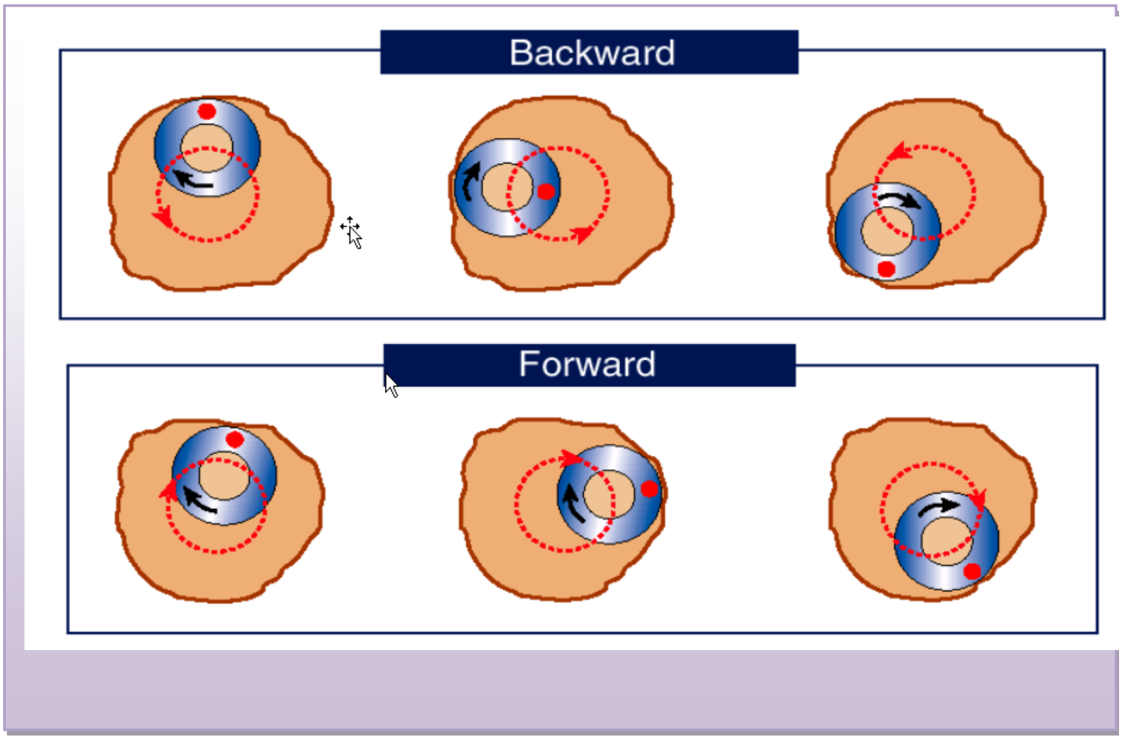


Figure1.1 Whirl interpretation mechanism which resulted as effect of torsional vibration.

[5] [13], This shows the movement of BHA in forward and backward whirl – this can lead to strong torsional, lateral and axial shocks. Note the point of contact (red dot) will progress in forward whirl, but not backward whirl. This can give distinctive wear patterns on the BHA allowing the type of wear to be established after pulling out.

At present, there are no systems that provide real – time monitoring of downhole vibrations etc. That can operate at 175C. Neither is there an active shock attenuation system to reduce the deleterious effect of drill vibration. The combination of these two features will represent a unique advance in the technology of drilling. These benefits will be particularly evident in deep gas drilling.

This project is not covering the modeling frequency which causes the resonances, due to the time frame limit which is confined to the entire project. However, the Modeling of torsional vibration and some analytical program to analyze drillingstring axial vibration. This analytical would includes, the fluids damper, and portion of drilling string above the damper and portion below damper to the bit, all these can be model out in software such as MATLAB .

The scope of this modeling would be only to reduce vibration and shock both above and below the damper. The program enhance accomplishing smoothing out the discontinuities encountered by the bit drills head, the model program has capability to simulate the drilling environment by looking at the depth of the cut along the discontinuities.

CHAPTER 3

THEORY

3.1 Drillsrting Accessories

Bottom Hole Assembly (BHA) configuration is defined as a process of selecting a drilling tools, which are involved in the drilling operation. Bottom Hole Assembly (BHA) is usually agreed upon by company man (client representative) and directional driller from the contractor side. BHA is commonly an obstacle if it is not wisely selected why? Because, there are so many factors and parameters involved when the drilling commences. If it is selected in a such way that it dose not meet the operating Conditions of the drilling process, then the operation will last longer and a lot of money as well as time would be waste by the client.

a) Normally BHA consist of the Following Drilling Tools Parts

- Bit with specific size of that particular hole section
- Drilling motor (PowerDrive or PowerPak, Autotrack
- Measurements drilling tool (Resistivity Electrical Logging tools
- Drill Collars
- Heavy weight drill pipe
- Hydraulic jar
- Drill pipe supply 10% wear

The above mentioned tools such as drill collars, Heavy weight drill pipe are commonly not used as single so as to provide the required task during drilling operations. Normally stabilized BHA can be designed to build, hold and drop inclination.

b) Critical Elements

- Stabilizer gauge
- Stabilizer position
- Drill collar OD/weight/moment of inertia
- Hole inclination, WOB, RPM, flow rates, Hole gauge, Bit type

c) The Purpose of the BHA

The BHA is the part of the drill string below the drill pipe. It is made of the bit, mud motors (or PowerDrive), stabilizers, drill collars, heavyweight drill pipes, jarring devices, crossovers for the threads, MWD, LWD tools, which provide the information needed in real time to steer the well (also provided recorded mode data). When MWD tool is used, it is necessary to add NMDC above and below it, in order to reduce the magnetic interference from other components in the BHA. The BHA must provide enough force for the bit to penetrate the rock (WOB), survive a tough mechanical environment.

(Schlumberger Drilling &Measurements)

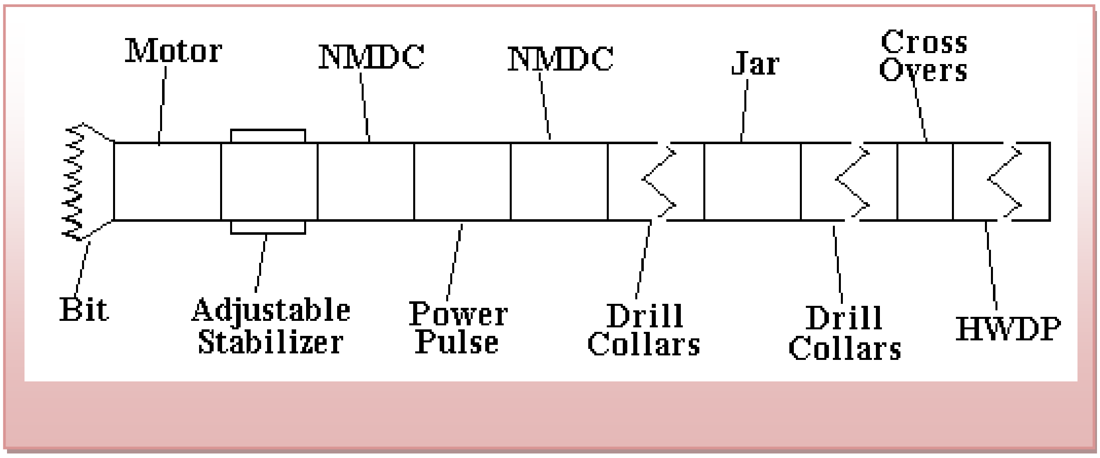


Figure 1.2 Basic components that make up the BHA and drill string, including

d) Transverse vibration - BHA whirl

- Large, frequent shocks
- BHA hits borehole and is flung across by rotation of pipe
- Anti-clockwise progression of whirl (note rotary is clockwise).
- Energy imparted dependant on friction of borehole wall

(Schlumberger, Drilling & Measurements)

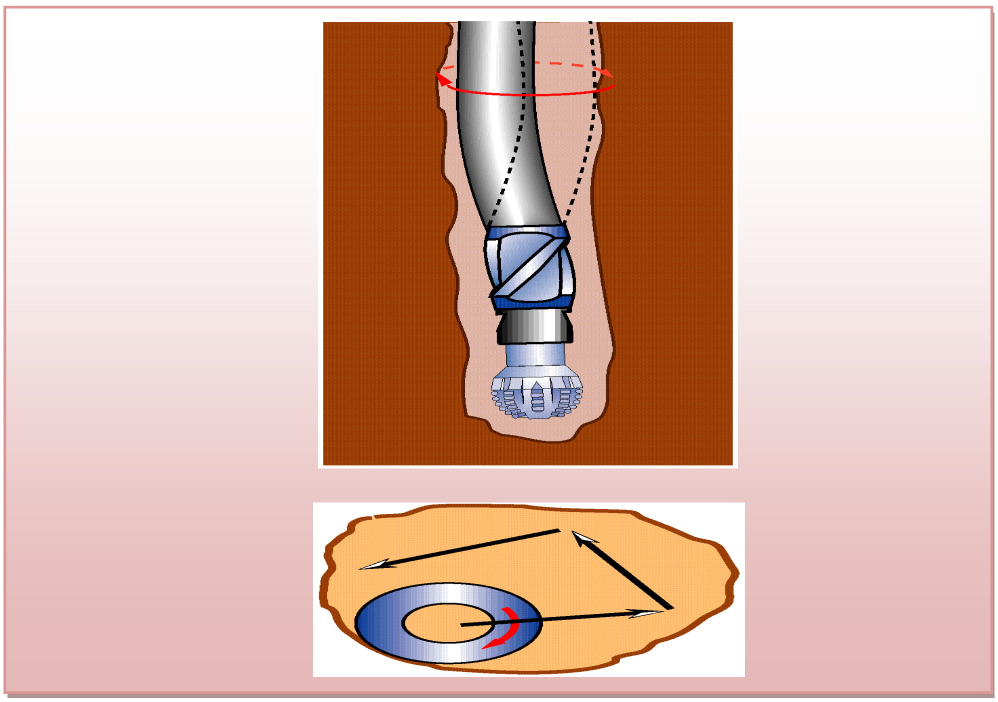


Figure1.3 showing the action of Transverse Vibration - BHA WhirlLarge and frequent vibration is a result of BHA whirl. They occur most frequently but are not limited to near.

3.2 How Resonance affect Drilling performance

The proposition is to make vibrations work towards rock destruction as opposed to BHA destruction. This project is addresses and solves two issues, one related to hard rock drilling and the other related to the mitigation of vibrations within the BHA that enhances the life of the MWD and LWD tools. Dynamic and static axial bit loads that occur while drilling affect rock breakdown at the bottom hole. Rock destruction studies analyzing roller cone bits indicated that dynamic force play amajor role in this process, where as static loads provide continuous contact between the bit and the bottom hole .Dynamic forces result from interaction between the drillstring and bottom hole through adrill bit that is, simultaneously, a rock destruction mechanism and also, a source of dynamic forces.

Adrillstring is, essentially, a physical system with distributed mechanical parameter: mass, rigidity, and damping. Such system feature frequency –dependent dynamic parameters, i.e resonance and anti – resonance. When the bit excitation frequency corresponds with the resonance frequency of the drillstring, the bit is easily displaced. In this case, a small applied force is capable of generating intense oscillation in the drillstring. However, when displacement with anti-resonance excites the drillstring, a significant force must be applied to displace the bit. It is possible to choose a rotational speed to obtain additional dynamic force at the bottom hole.

Vertical wells. They occur when there is enough lateral movement in the BHA (probably rotating at or close to resonance) for it to contact the wellbore. As the the collars hit the wall the rotation of the string causes the BHA to be flung across the wellbore on to the opposite side; where again the rotation flings the BHA across the wellbore. This continues, gaining lateral energy from the rotation, making the BHA whirl in an anti-clockwise manner.

Since extra energy is now in the lateral motion simply reducing the RPM will not reduce the vibration as there is enough energy to perpetuate the lateral borehole contact below the RPM they were initiated. The RPM must be reduced significantly before this type of vibration will die out, however the RPM can then be increased to just below that of the previous onset of vibration. The other very effective method of vibration reduction is to limit the BHA's ability to move from side to side in the borehole. This can be achieved by increasing weight on bit thus "clamping" the BHA to the bore hole wall. However this method may not be possible if the formation is very soft or there is a danger of building angle as the weight is increased.

Clearly the best strategy is to avoid the borehole contact in the first place by placement of a stabilizer above and below the down hole equipment. Avoid running downhole tools as part of the pendulum in a pendulum assembly in near vertical wells. The use of downhole motors will also aid in the reduction of vibration by allowing a reduction of string RPM without reducing bit RPM, and also decouple the string from torsional and axial vibration from the bit which may induce the onset of transverse motion. The mud type can also have a significant effect as a reduction of friction due to lubricity will reduce the energy that the lateral motion receives from the rotation of the BHA. Also, the formation type will effect the damping the lateral movement receives when it impacts the borehole wall and hence the overall transverse vibration level.

a) Determining Shock types / causes

- Identify that shocks are occurring
  - Surface data measuring datas uses control datas
  - MWD data, sensors datas using mud pulses
  - Bit grading usually manually performed

b) Other causes of downhole Vibration

- Reaming - sudden changes in acceleration
- Drilling inside casing
- Under gauge bit
- Straight blade stabilizers

(Schlumberger, Drilling & Measurements)

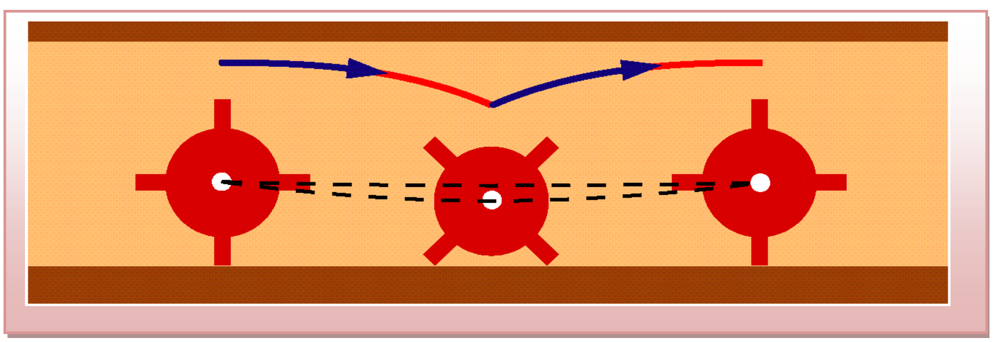


Figure 1.4   Under gauge stabilizers

When reaming the bit or stabilizers may suddenly bite into tight hole which can rapidly decelerate the string causing axial and torsional vibrations. Casing is very hard and provides no damping for transverse vibrations and the assembly will be always under gauged. Consequently great care should be taken when drilling out the shoe track and the vibration measurement should be monitored closely. As the bit becomes undergauge the stabilizers will bite into the borehole wall causing the same effects as reaming.

Straight blade stabilizers will act like riding a bicycle with square wheels and therefore cause vibration.An undergauge stabilizer will allow for lateral movement of the BHA thus allowing the possibility of BHA whirling and therefore transverse vibration.

Shock risk interpretation in MWD tools

Table 1.1

Shock risk	Severity	Frequency of shock > 50g
0	No risk	cps<= 1
1	Low risk	1<cps<5
2	Medium risk	5<cps< 10
3	High risk	Cps > 10

Shocks measured. It uses the following table (which is programmed in the tool software) to convert shock cps to risk. This risk can be transmitted in real time by the tool and is different for each tool type (MWD / ARC etc).

- Shocks measured by sensors within MWD / LWD tool

- Damage to down hole tools failure
- Damage concentrated on shoulder of bit and the teeth
- BHA pulled because unable to achieve directional goals

Figure 1.5 Shock effect on the bit after it had been pulled out of hole

c) Frequency Effect Level

The natural frequencies of the drilling string often fall in the range excited by typical drilling speeds, between 0.5HZ and 10 HZ depending on the BHA and length of the drillstring.There are many sources that excite drill string vibration, including bits, motors, stabilizers and drill string imbalance. For example, a tricone bits imparts an excitation frequency of three times the rotary speed. If rotary between 120 and 180H RPM, the excitation frequency is 6 -9HZ mud motors are also significant sources of excitation on the drill string.The rotor of the mud motor moves in configuration of the motor, excitation occurs between 1 and 30HZ. The best situation for a drillstring is to operate below its critical speed. By staying below this first critical speed, the drill string is not excited by drilling frequencies and bit maintains contact with cutting with cutting surface of the borehole

d) Drag Forces encountered while drilling

During a normal drilling operation, rotary torque gradually increases with depth due to the effect of wall contact of the drill string on the well bore.increase formation pressure causes larger amounts of shale cuttings to enter the wellbore and the bit teeth will take larger bits into formation. This increased amount of shale tends to impede bit rotation or pile up around the collars.An increase in the torque over several hundred feet is agood indicator of pressure increase. When drilling in a near – balanced situation, an increase in drag occurs while making a connection in an

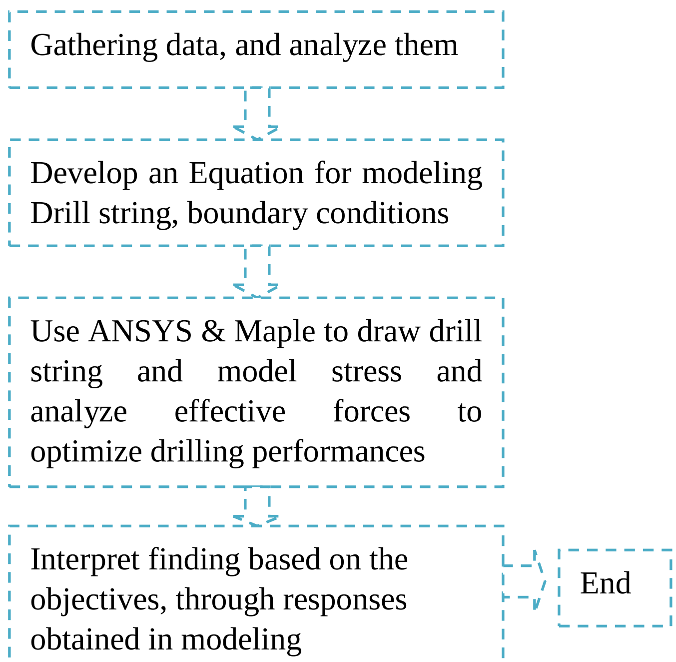
Abnormally pressured zone. The extra shale cuttings that enter the wellbore and pile up around or above the collars cause this increase. Drag may also be increased because the formation is soft, which could cause the hole to close around the drill collar and bit. When monitoring torque and drag, normally a driller is looking for the change or increase in the amount of torque and drag that is being experienced. It is normal when rotary amperage changes from 100 to 400 amps in just matter of minutes.

CHAPTER 4

METHODOLOGY

3.1 Methodology details

The methodology in this project is intend to enable modeling of drill string so as to investigate how torsional effect in drill string system. The step taken within the methodology is as follows:



a) Gathering data and analyze them

The modeling of drill string is difficult to achieve its dynamic motion but with help of maple software, Friction induced Bit Torque could be analyze, that friction vs RPM when certain WOB is applied. Friction induced Torsional Relaxation Oscillation would also be discuses upon obtaining the modeling results. The interpretation would involve comparison of the continuous non – linear friction profile with the piecewise linear one.

3.2 Model Procedures

The motion of drill string can be describe in terms of the motion in space of the line of centroids of its cross –sections and the elastic deformation about the line. Since it is difficult to achieve dynamic motion. Medium as described above can be use to model mathematically by elastic space – curves with structure. This structure defines the relative orientation of neighboring cross – section along the drill string. This project is entirely focus on two problems. First, the problem of modeling the drillstring behaviors considering the effect of friction appeared between the drill string components and between the drill string and the formation.

Second, the problem of reducing Stick – Slip conditions by means of alignment of different drilling parameters, such as rotary speed, drilling torque, weight-on-bit (WOB), the approach follow will be centralized type and will capture qualitatively the driller's expertise. The model use here in this project will be based on differential Equation, the number of degree of freedom in this modeling is consider to be two which has better compatibility in linear controller. On the other hand it would support the mechanical part as well as rotary table and electrical motor system. Thus, manipulating drilling parameter such as weight-on-bit, RPM there can be other possible considerations such:

a) Things to be consider in modeling

- Drill – string dynamics
- Boundary conditions
- The static hanging configuration of drill string
- Torsional behavior of drill string
- Data from the field

b) Boundary Conditions

Assume that the drill – string is connected to rigid bodies with effective masses Mtop and Mbit and rotary inertia tensors $\mathbf{J}_{\mathbf{top}}$ and $\mathbf{J}_{\mathbf{bit}}$ modeling the top drive and bit/BHA respectively. The top – drive connection to the drill string is located at s = 0 and drillbit is located at $s = L_o$. At these points forces $\mathbf{F}_{\mathbf{top}}$ and $\mathbf{F}_{\mathbf{top}}$ and the torques $\mathbf{L}_{top}(t)$ and $\mathbf{L}_{bit}(t)$ act.

3.2 Model describing drillstring torsional behavior

Source: Schlumberger, Drilling & Measurement

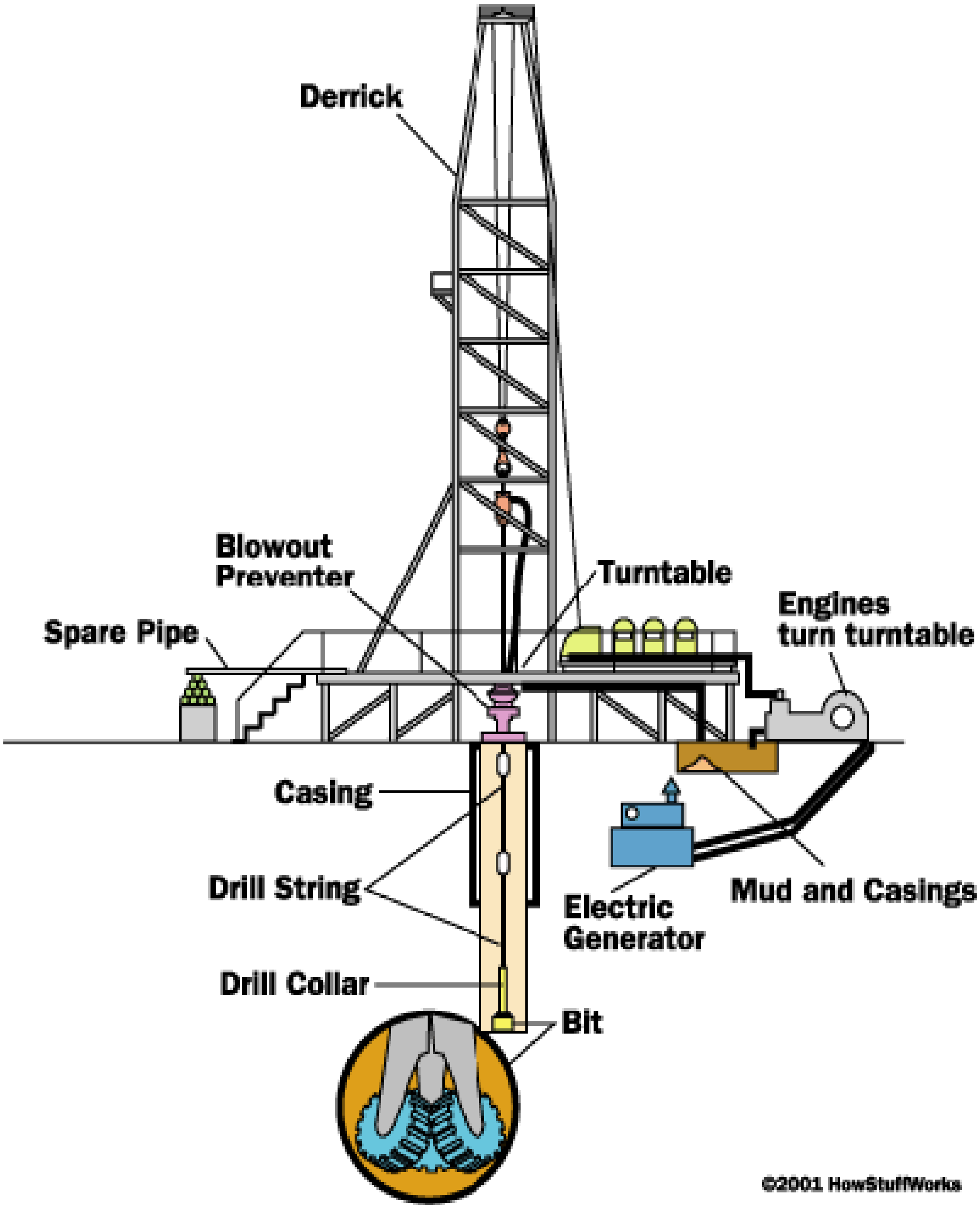


Fig 1.6 Rig system showing position of Drillstring

The drillstring torsional behavior is described by asimple torsional pendulum driven by an electrical motor.The drill pipes are represented as linear spring of torsional stiffness k and torsional damping c which are connected to J_r and $J_{b,}$ crresponding to the inertia of the rotary table or top drive and to the inertia of the pipeline of the whole drillstring plus the inertia of the downhole end, respectively. J_b is usually considered as the sum of the BHA inertia plus one third of the drill pipes inertia. Dry friction torque plus a viscous damping torque are also considered at the rotary table.

Some assumptions are made, such as: (i) the borehole and the drillstring are both vertical and straight, (ii) no lateral bit motion is present, (iii) the rotary top system is supposed to have an angular velocity different from zero (iv) the friction in the pipe connections and between the pipes and the borehole are neglected, (v) the drilling mud is simplified by a viscous – type friction element at the bit, (vi) the drilling mud fluids orbital motion is considered to be laminar, i.e without turbulences. Then, the equations of the motion of the drillstring are as follows:

$J_r\text{Ö}_r + C\,(\text{Ó}_{r\,–}\,\text{Ó}_b) + K\,(\text{Ó}_{r\,–}\,\text{Ó}_b) = T_m - T_r\,(\text{Ó}_r)$ ………………….3a

$J_b\text{Ö}_{b\,-}\,C\,(\text{Ó}_{r\,–}\,\text{Ó}_b) - K\,(\text{Ó}_{r\,–}\,\text{Ó}_b) = -T_b\,(\text{Ó}_b)$ ………………………3b

With Ó_r the angular displacement of the roatry top system, Ó_b the angular displacement of the BHA, T_m the drive torque coming from the electrical motor at the surface. $T_{r,}$ T_b represetns the dry friction torque plus the viscous damping torque associated with J_r and J_b respectively. In the fig1.6 it is clear that Drillstring system is mainly composition of Drillpipes, Drillcollars and BHA components

3.3 Consideration of top velocity

The top driving motor dynamics is not considered. Starting point is assuming that arbitrary torques Tm can be applied without taking into consideration the actuators dynamic generating this toque. In order to satisfy one of the most important driller's goals, can be proposed in such a way that the top rotary velocity is constant.

By considering Tm = u with u as control input which would help to balance up the rotation in the top part of the drillstring to the bit rotation part

This can be estimate from the field data of torsional behavior in the field as shown below in the graph.

Table 1.2 RPM vs. Friction force values

RPM	Friction force
20	7
40	7
60	7
80	8
100	7
120	7

Data from the field showing the response when RPM varies

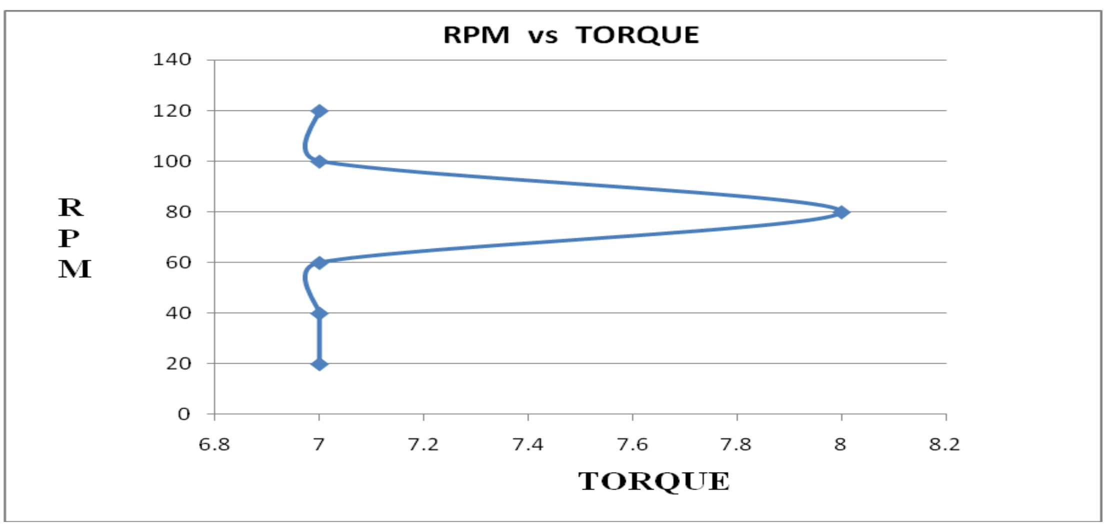


Figure 1.7 RPM vs Torque

Table 1.3 WOB vs. Friction force values

WOB	Friction force
4.6	7
5.5	7
7.8	7
8.5	8
9	7
10.4	7

Data from the field showing the response when WOB varies

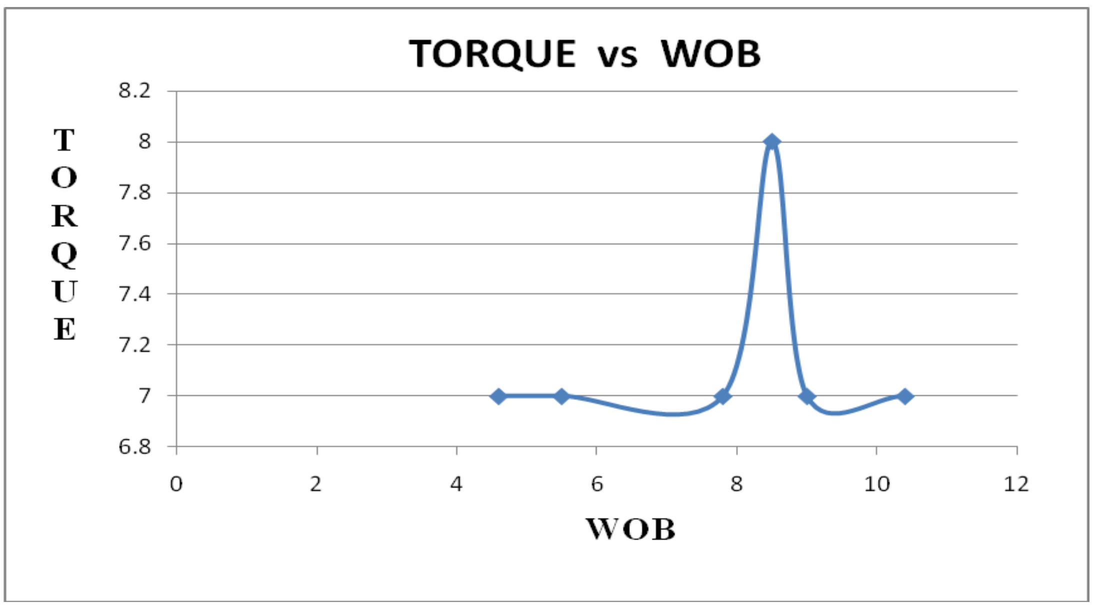


Figure1.8 showing Torque vs WOB

The above results are the estimation of how much the increase in RPM and WOB would create destructive friction force or torque while drilling vertical well using the PDC bit. PDC is fixed head type of bit which induces avery high level of torque when drilling sandstone formation. In order to achieve the objectives of this project the drillstring is modeled by using the generic drillstring mathematical equation. After verifying that the generic equation of the drillstring can predict the failure, then the values of the RPM, WOB and Rate of penetration from the field data which had experiences the failure of the drillstring would be model in the same generic equation so as to predict the failure of the drillstring at certain given values.

The difficulties however, are available in modeling drillstring, especially the modeling procedure in Matlab, the differential equation of generic equation given above are currently under modeling.

CHAPTER 4

DISCUSSION AND RESULTS

4.1 DISCUSSION

From the generic equation of the drillstring, in order to obtain the response using the input of the field data in the equation.

$J_r\ddot{O}_r + c(\acute{O}_r - \acute{O}_b) + k(O_r - O_b) = T_m - T_r(\acute{O}_r)$ 3a

$J_r\ddot{O}_r - c(\acute{O}_r - \acute{O}_b) - k(O_r - O_b) = -T_b(\acute{O}_r)$ 3b

The equation 1a can be further simplified by collecting the like terms together into transfer functions equations.

Thus, the equation becomes

$O_{b(s)} \; / \; O_{r(s)} = Cs + k \,/\, J_r\, s\text{^}2 + (Cs - T_r) + (T_m - k)$ ……. 2

The values estimated in the field for the above constant in the equation are :

Table 1.4: Numerical value of Model Parameter

Parameter	Description	Value	Unit
C	Rotary table damping	25	[Nms / rad]
K	Torsional damping constant	473	[Nms/rad]
T_r	Motor power	0.5	[N]
J_r	BHA+ 1/3drill-string inertia	374	[Kg^2]
T_m	Arbitary torque	1209	[N.m]

4.2 SIMULATION RESULTS

After that the models block diagram is build including the following parts:

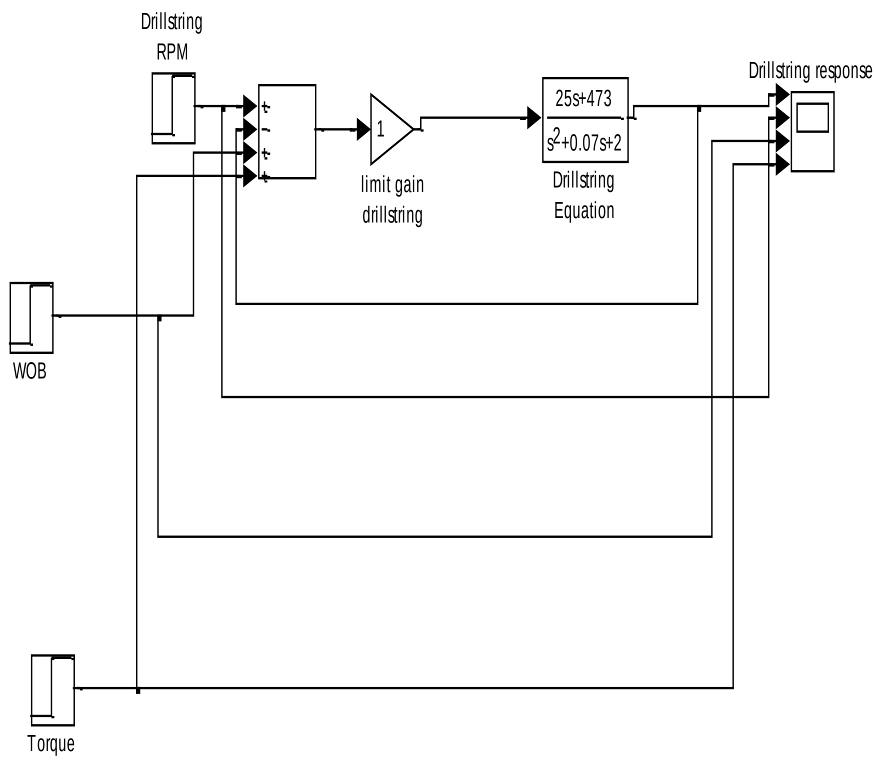


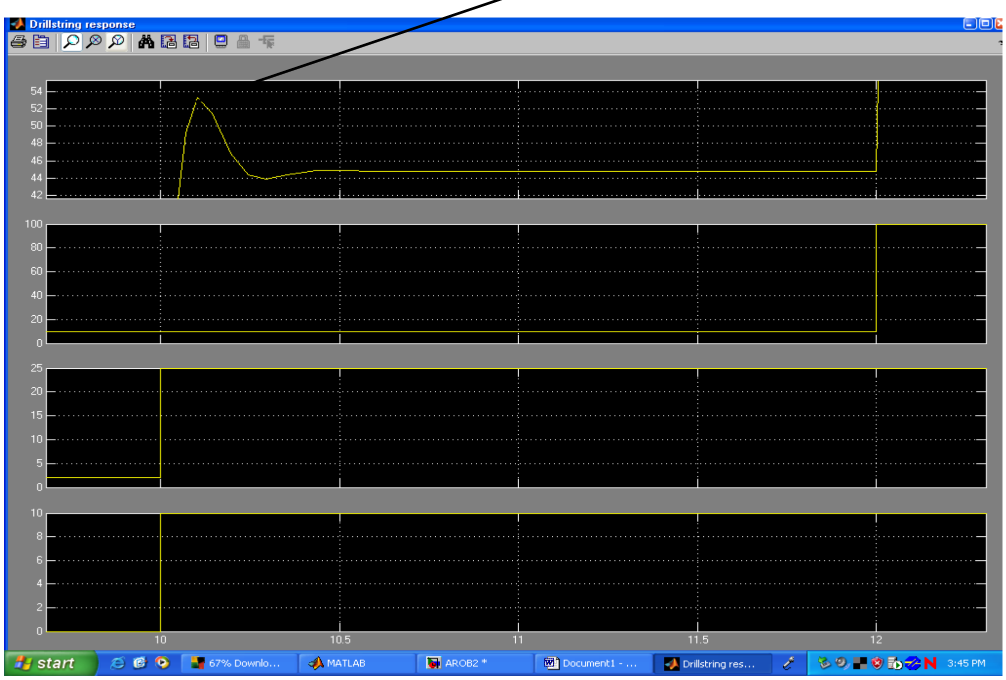
Figure1.9 Drillstring modeling system block diagrams

From figure 1.9 the following parameters are consider

- RPM block diagram unit response
- WOB ,, ,,
- Torque ,, ,,
- When the simulation is RUN, the response can be access in the SCOPE response UNIT block diagram to show the graph response.
- The Gain limit of the drillstrring implies how stable is the drillstring system prior to any RUN or drilling commences, the bigger the gain value is the more unstable the system becomes.
- The Drilling string equation ..2 which is in transfer function form.

From the above response which can be interpret individually and as group response of the drillstring system, thus, it is possible to figure out when the system reaches the peak. When the system attends its peak these parameters response can be interprets to show the stable and unstable zone values of the drilling parameters. Here by inputting the three drilling parameters this response is :

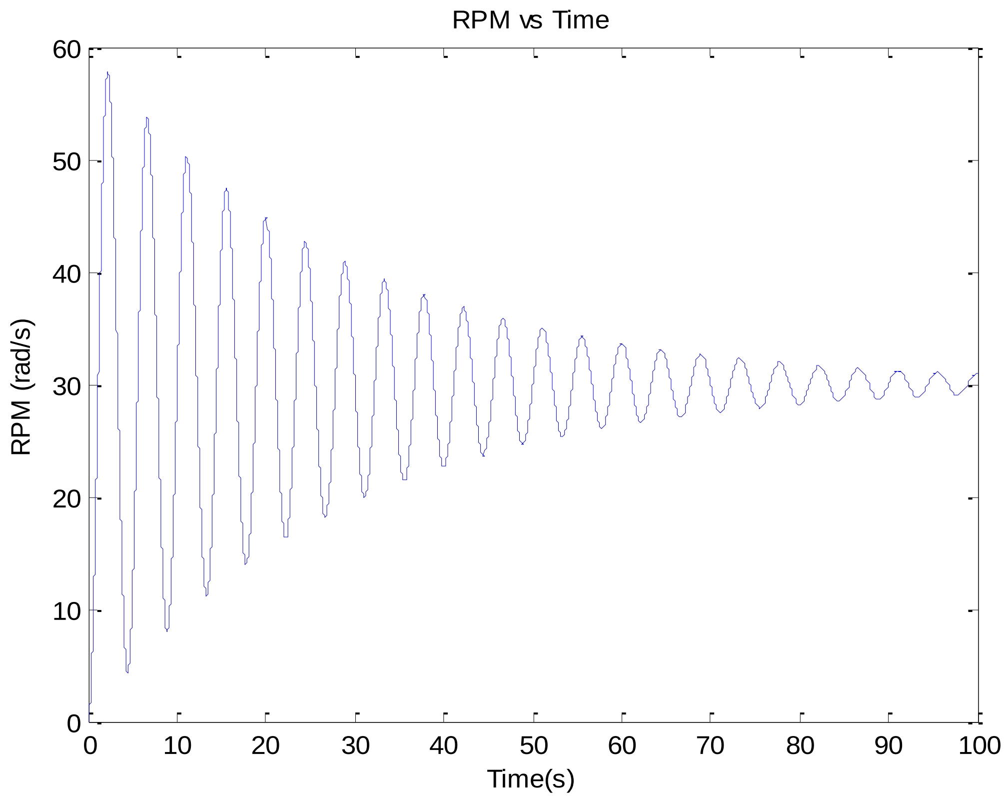
The Peak response of Drillstring system (Twist off level)



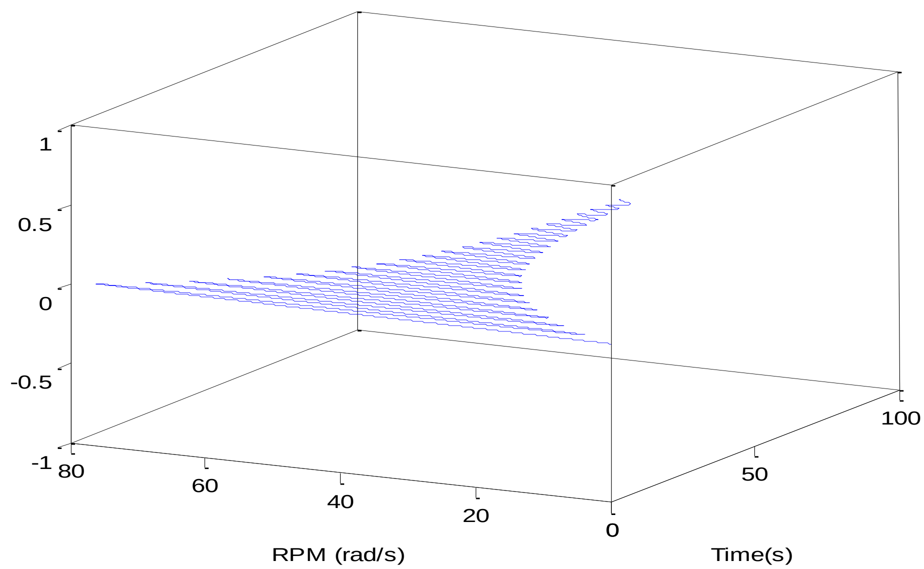
:

Figure 2.0 Responses of four drilling parameters .The same equation can be run directly without building block diagram to obtain the response of each parameter with respect to time.

a)



b) Drillstring system disturbances. 2D view



c)

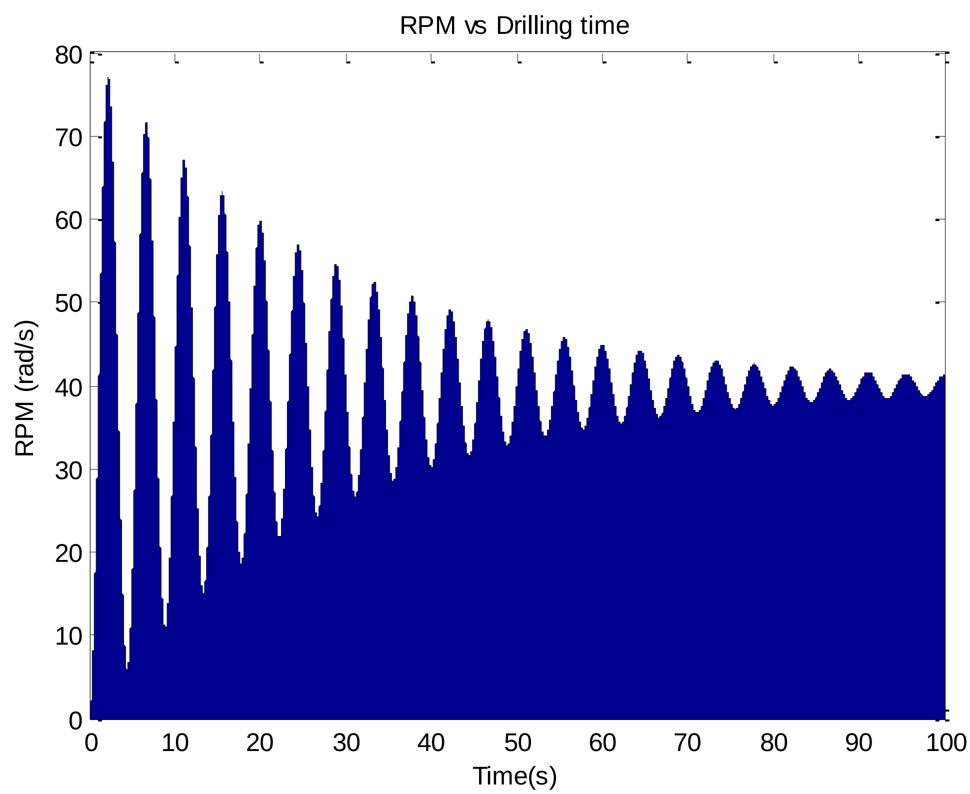


Figure 2.1(a,b,c) Drillstring system disturbances in the area form

Programs: by inserting the following coding the above graph can be obtain

```
>> num=[473];den=[1 0.07 2]; sys=tf(num,den);
>> t=[0:0.005:100];
>> [y,t]=step(sys,t);
>> plot(t,y)
```

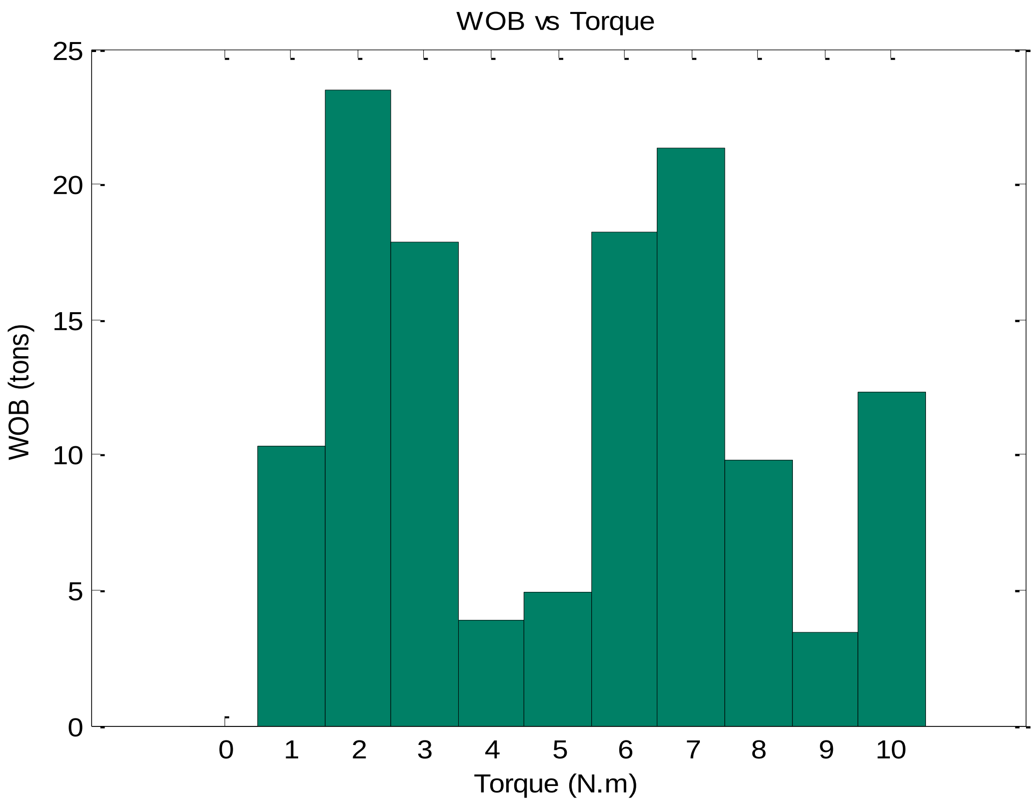


Figure 2.2 Characteristic in soft formation WOB vs Torque

```
>> num=[25];den=[1 0.07 2]; sys=tf(num,den);
>> t=[0:10];
>> [y,t]=step(sys,t);
>> plot(t,y)
```

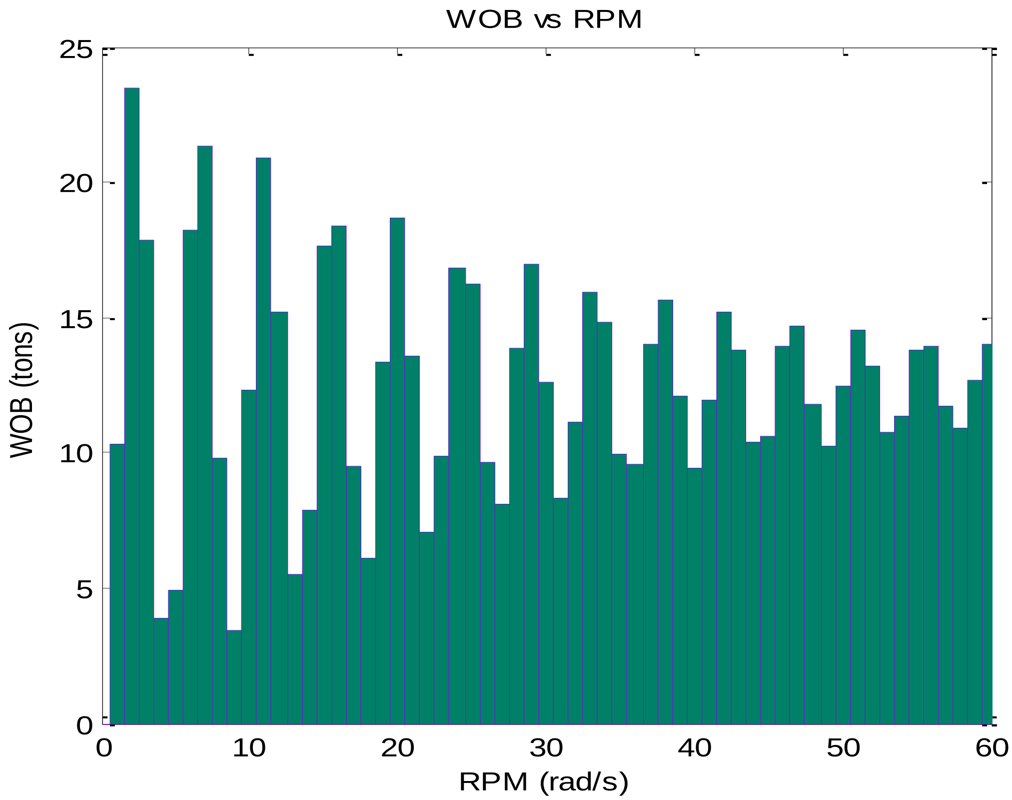


Figure2.3 WOB vs RPM in the soft formation with PDC

Figure2.0 show the entire response of the drilling string system in combination of the four drilling parameters.

From the figure2.1 the graph was taken from the Matlab modeling showing the disturbances of the drillstring system, these disturbances based on the generic drillstring equation model. The prediction from the figure shows that the average RPM of 30 -35 is suitable for the drilling to continue and avoiding any stick – slip phenomenon to occur.Figure2.2 indicates the WOB applied while drilling and the induced torque value which is bound output, the more WOB and the harder the formation, the higher the induced torque value . The grap have also shown which value of WOB is suitable for optimum drilling that would make the drillstring stable.

Figure 2.3 shows how WOB affected the RPM when the PDC bit is use in the hard formation. The higher the value of the applied WOB the less value of RPM would be obtained if the situations continue like that the twist off might occur to the drillstring system as the results of compression and tension forced created by the WOB onto drillstring. The preferable option is when it is hard formation is that less WOB is preferable and high RPM this would Maximize the ROP value

CHAPTER 6

6.1 Conclusion

Amodel describing the torsional behaviour of generic oil drillstring has been presented. This model is acombination of some previous model proposed in the literature. The problem of modeling is divided into two different problems, first, the problem of modeling of torsional behaviours of the drillstring. Second, the problem of modeling the rock bit interaction originating stick –slip self excited oscillations. This behavior are describes by the drilling parameters behaviour in the simulation

6.2 RECOMMENDATION AND FUTURE WORK

Based on the entire research results it possible to say that this work has achieved it its objectives. But further future is needed to be done in order to refine the obtained results.

- Drilling Dynamic simulator should be use, because it provides the drilling oparameters function unlike the matlabe which required transfer function.
- The research should also be extended to include, Axial and Lateral vibration each of these vibration modes incorporated a lot of details pertaining the vibration modes effect on the drillstring.
- Two transfer functions should be develop, one representing WOB and other RPM, because these two drilling parameter as considered as an input for the drillstring system producing certain value of torque depending on the formation type.
- Drilling parameters data should be fetch from the field if necessary for the both drillstring system which has undergone breakdown and the normal operating drillstring system for purpose of simulation comparison results

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Appendice1.1Suggested Milestone for the Second Semester of 2-Semester Final

Bit Record

GREATER NILE P

Well Name	Block	Area
NEEM K-1	4	SOUTH KORDUFAN

Coordinates	Easting 669115.00 m E Northing 1204685.00 m N	Grid Coordinates	

Spud Date (D/M/Y)	Spud Time	Rig Release Date (D/M/Y)	Rig Release Time	
26/04/07	0900 hrs			

Pump# 1 - Make and model	Stroke length (in)	Liner/in	Surface Csg set @	OD & ID (in)
F-1600/TRIPLEX	1.2	6.5	Inte. csg set at	9-5/

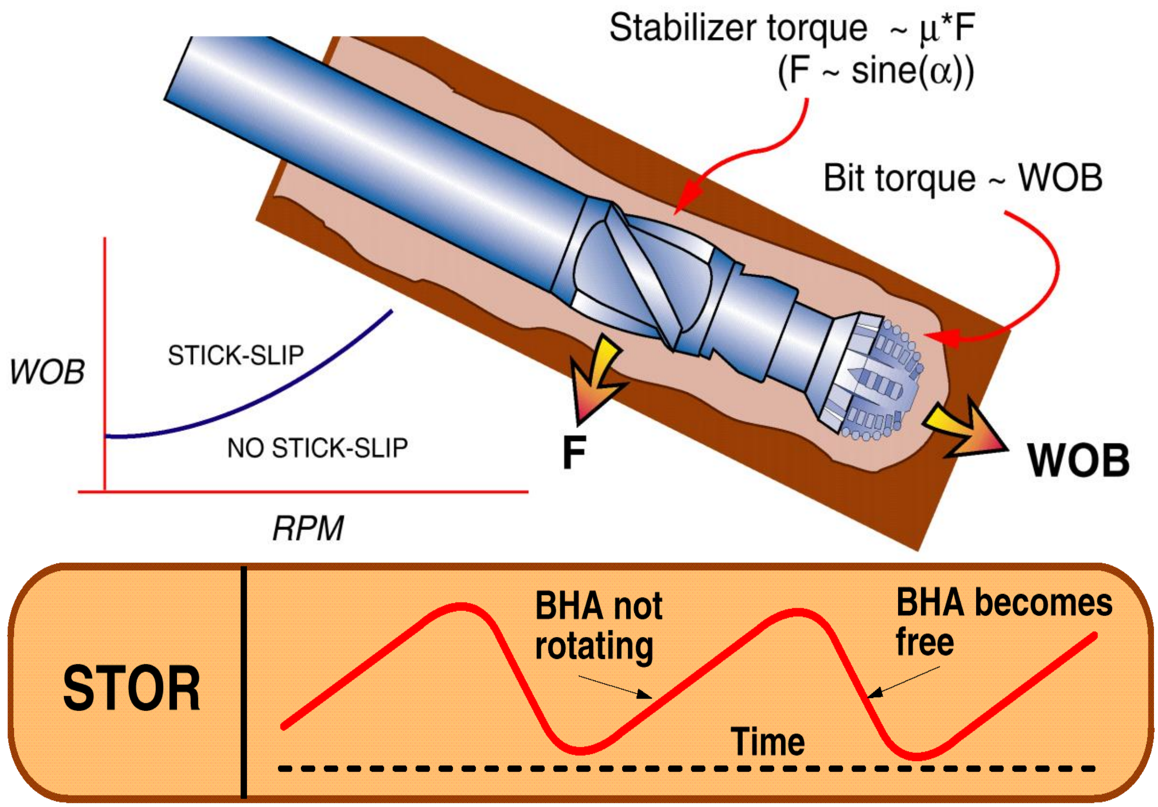
Pump# 2 - Make and model	Stroke length (in)	Liner/mm	Drill Pipe (in)	Weight (
F-1600/TRIPLEX	1.2	6.5	5	19.5

BIT NO	SIZE (mm)	TYPE	Jets (in/32)				SERIAL NUMBER	Depth (m)		METRES DRILLED	HOURS	ACCUM HOURS	ROP (M/HR)	WIEGHT KdaN	RPM
			1	2	3	4		IN	OUT						
RR1	609.6		18	18	16		MS11CKPR	9.00	30	21	2.00	8.00	10.50	2-3	60-80
2	445	XR+VC	3X18,1X14				MY9187	30.0	422	392	54.00	54.00	7.26	2-8	70-110
3	445	XR+C	18	18	18	14	MY 8353	422.0	900	478	60.50	60.50	8.00	2-10	90-115
4	311.15	DSX519S-C4	7 X 13				215432	900	2498	1598	82.7	82.70	19.32	2-10	90-110
5	311.15	GF15 BDVRC	16	16	18	14	MY 6700	2498	2519	21	9.0	9.00	2.33	4-10	90-100

RR1	311.15	DSX519S-C4	7 X13				213443	2519.00	2750	231	45.30	145.30	5.00	4-10	90-100
7	311.15	CH 24 MS	16	16	18		192554	2750.00	2865	115	39.10	39.10	2.97	5-16	90-100
8	216	VTD 616GX	5X12, 1X13				8874 C	2865.00	3194	329	58.20	58.20	5.65	4-9	70-90
9	216	M713BKPX	7X12				SC 2154	3194.00	3500	306	52.70	52.70	5.80	4-9	80-95
RR1	216	M713BKPX	2X13	5X12			SC 2154	3500.0	3593	93	33.80	86.50	2.75	4-9	80-95
11	216	GF15DODPD	2X18, 1X20				MY 5904	3593	3640	47	38.2	38.20	1.23	6-10	70-100
12RR2	216	M713BKPX	2X13	5X12			SC 2154	3640	3678	38	13.9	100.40	2.73	5-8	70-230
13	216	GF20DODPD	1X16	2X18			MY 8658	3678							

Appendic 1.3

Stick slip – torsional vibrations



Common causes of Stick-slip torsional vibration

- Twist off, of drillstring
- BHA stalling
- Repeated cycles
- May be seen on surface.