Analysis of the Impact of Drill String Rotation on the Casing Wear in Directional Wells Using Drill Scan Software.

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Abstract: Casing maintains the structural integrity of the wellbore it is the barrier between collapsing forces and the hydrocarbon's production pathway. Structural damage, wear and defects in its reliability cannot be tolerated. Due to the increasing demand of hydrocarbon production, exploiting unconventional reservoirs and targeting multiple reservoirs from single platform more and more tortuous, deviated and high dog leg severity wells are being drilled these days. In drilling such complex trajectories the problem of severe casing wear is encountered, which sometimes leads to minor technical problems like leakages, inability to hold operational pressures and in other cases it may invite a catastrophic event like blow-out. In this research the impact of the rotation speed of the drill string on the wear groove depth and the integrity of the casing is analyzed using the casing wear module of the DRILLSCAN software. The rotation of the drill string is increased from 60 RPM to 120 RPM with the gradual increment of 20 RPMs. The results show that the wear of the casing increases linearly with increasing drill string rotation and the internal yield strength decreases with increasing the rotation of the drill string.

Keywords: *Casing Wear; Dog leg severity; casing integrity; Drill string rotation; Contact force*

1. Introduction

Casing wear is one of the ongoing problems faced by the oil industry [l]. The challenge of casing wear is becoming more alarming as the demand of drilling more tortuous well paths is increasing. Mostly the wells drilled today are directional, Multilateral, or horizontal. In such kind of deviated trajectories the contact of drill string with the inner wall of the casing is high in terms of severity and frequency. These contacting surfaces, in the sliding and rolling mode depict a typical tribological system which not only offers the friction but is also followed by the wear or damage of the surfaces [2-3].

Once the casing, which serves as a primary safety barrier, is worn and scratched it cannot be considered of possessing the initial designed strength properties [4]. The now reduced burst strength and collapse resistance may offer the variety of technical problems and safety hazards which may include casing leakages, inabilities to hold high pressures, and in worst cases a catastrophic event like blow-out [3]. Friction, drag and Wear and are the outcome of a tribological process which is happening between the drill string and inner wall of the casing with drilling fluid as an intermediate fluid between them. Drag due to drill string movement is determined by the friction between drill string and casing and the friction between drill string and the open hole. In directional wells the wear rate of casing is higher, because well paths are not smooth and trajectories are complex, subsequently the contact of the drill string with the inner wall of the casing is lengthier and more forceful [5]. For the development of unconventional reservoirs, relief wells, side tracking, multiple wells from single platform, a large number of directional wells are being drilled with complex trajectories, highly tortuous paths and increased dog leg severities [6]. Casing wear problem is alarming in drilling such kind of wells. A good understanding of the wear mechanism, its underlying causes, and its relation with the prominent contributing parameters is the need of the hour. Although the casing wear problem cannot be avoided altogether, yet if the concept of casing wear is grasped well, it can be approached differently and controlled to the minimum possible level.

1.1 Impact of Drill String movement

The vital cause of the casing wear is the rotation of the drill string [7]. The impact of drill string rotation on the casing wear can be quantified by measuring the contact force that rotating tool joint is applying on the inner wall of the casing, the total time tool joint is in contact with casing and the type of wear mechanism that is causing the wear. In general Range 3 Drill pipes which are approximately 43 ft long have advantage over Range 2 Drill pipes with approximate 30ft length. The reason is that the drill string composed of range 3 drill pipes will be having lower total weight due less number of tool joints to total length of drill string however localized wear due to range 3 drill pipe can be more than the range 2 drill pipes because of the likelihood of pipe body touching the casing wall [8]. The relationship between the drill pipe rotation and casing wear rates has been experimentally observed. In one experiment, using pin-on-disc machine, N-80 Carbon disc steel and G-105 steel grade pin were used to see the effects of changing rotary speed of the pin on the wear rate of the disc. It was observed that that wear rate does increase with the increase of rotating speed; however, it does not change so linearly. the wear rate first decreases when the rotating speed is increase from 60 RPM to 80 RPM. The reason for this is the presence of Cl- in the mud system, it is suggested that the presence of Cl- in the drilling fluid can enhance the properties of protective film or layer of the mud between

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the pin and disc. However when the rotating speed increases from 80 RPM to 100 RPM and then 120 RPM it can be seen that wear rate increases linearly with the increasing speed [6].

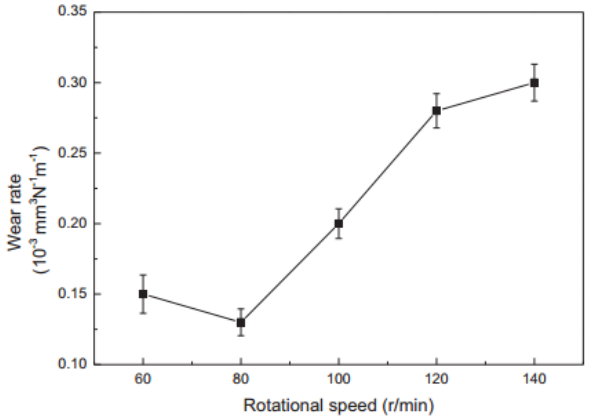

Figure 1 Pin on disc experiment results [6]

1.2 Contact Force

Contact force is the most important parameter in understanding the wear of the casing [9]. Casing wear, occurring at the interface of tool joint and inner wall of the casing can be correlated to the Contact force. Magnitude of the contact force is directly linked to the wear rate of the casing. Contact force or side force is the forced applied by drill pipe body or tool joint on the inner wall of the casing [8]. In the directional wells the drill pipe tends to lie on low side of the well and depending on the compression on the drill pipes they may acquire helical or sinusoidal shapes [10, 7]. When both the Drill pipe body and tool joint are wearing the casing, it will be known as dual or alternate wear, which is more harsh form of the wear and can cause 150% more wear as compared to single wear process [2].

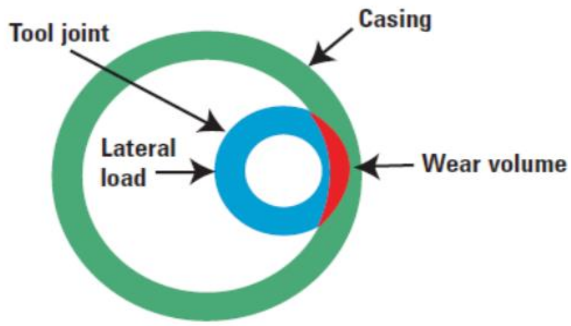

Figure 2 Contact force pushing drill string towards casing [11]

1.2.1 Total sliding distance

The wear track length is the total distance that the two surfaces of drill string and casing slide against one another. Because of the dimensional differences the profile of the tool joint or drill pipe body will not accurately accommodate in the casing profile, rather they will be touch on a single point of contact. The total distance that the body of drill pipe or tool joint will slide against the point of contact with the casing can be calculated from the below equation [12].

$$L_{wtf} = \pi \times d_f \times v_f \times 60 \times \frac{L_{tjf}}{L_s} \times t_f$$

Where,

$L_{wL_{wtf}tf} =$ Wear track length in the field, [ft]

L_{tjf} = Tool joint contact length in the field [in]

L_s = Length of drill pipe [ft]

d_f = Tool joint diameter [in]

v_f = Drill string rev/min while drilling

t_f = number of hours to drill the hole section.

1.3 Wear Processes in casing

The important wear processes which are relevant with the casing tool joint contact scenario are abrasive wear and adhesive wear. The abrasive wear, when the asperities which are the pointed projections of an uneven and rough surface tend to plough into the softer surface of the body in contact. The other important wear type is the adhesive wear where two smooth surfaces or sliding against each other and adhesive forces are high due to high contact loads, here the material from one softer surface is transferred to the harder surface. If the tool joint of the drill pipe are hard banded and surface of the tool joints are rough the abrasive wear is expected on the other hand tool joints with smoother and polished surface will cause the adhesive wear, the severity of adhesive wear will be depending on the contact force being applied [9].

1.4 DLS and Casing Wear

Long horizontal wells for shale development, extended reach wells and multilateral wells, for exploiting unconventional reservoirs and targets are the need of the hour. The problem of casing wear should proactively be addressed in planning the high dog log leg severity wells. The demand for drilling complex wells, extended reach and multi-lateral wells is increasing. These well paths present a high dog leg severity sections which are critical from casing wear point of view [1]. The casing wear is expected more in the intermediate casings as they are the longer casing and mostly passing through highly deviated sections in the extended reach drilling operations. In extended reach drilling operations, the severity of the contact between the rotating tool joint of the drill pipes and the internal wall of the casing may cause a greater damage to the integrity of the casing, resulting in highly expensive remedies. Installation of pipe protectors can minimize the impact of wearing forces in the highly crooked sections of the well [13].

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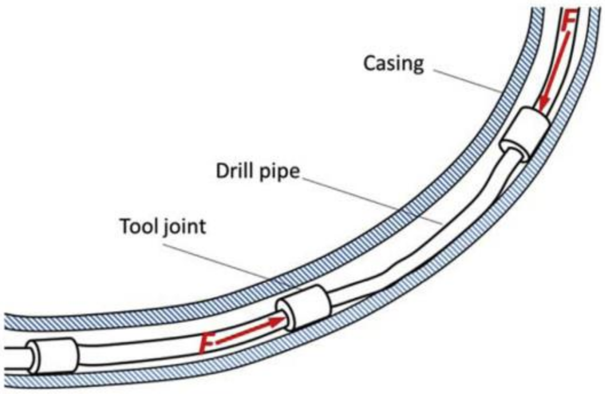

Figure 3 Tool joint and Body contact with casing in deviated section [2]

1.5 Effects of Drilling Mud

Drilling Mud is one of the crucial factors that may affect the casing wear rate positively or negatively. Drilling Mud acts as protective film between the tribological system of drill pipe tool joint and casing wear. The drilling fluid with high content of softer solids and the ability to develop a good protective layer between the sliding surfaces can be expected to lower the wear rates. In addition to these increasing the lubricity of the drilling fluid will reduce the frictional coefficient thereby decreasing the surface damage to the casing and tool joint [5]. Oil based Drilling Mud provide good slippage to the contacting surface, this ability of oil based mud significantly reduces the system friction, as a result the overall wear of the casing and the tool joint may be decreased sufficiently [14,18]. It has been observed that Drilling muds with higher content of weighting additives especially the barite decrease the casing wear sufficiently, because the huge amount of barite provides a protective layer between the drill pipe tool joint and the inner wall of the casing [11].

One the question of the effects of the drilled solids, Contradictory opinions are found in literature. One view suggests that as the particle size of the formation cutting is greater than the size of the weighting agents present in the drilling mud, hence the inclusion of formation particles will hinder the formation of effective protective film between the casing and the drill pipe. On the contrary the other literature proposes that the formation cuttings will decrease the wear rates [7]. However, the addition of salt in drilling fluid can reduce the friction as it helps in forming a good protective layer, the addition of the lubricants to lessen the effects of friction can be considered, however it must be stressed that the effect of the lubricant will largely depend on the surface conditions of the tool join and casing and secondly the type of the solids present in the mud system [5]. As diesel has no any property that may help in forming a protective layer hence it has got no benefits in reducing the friction between tool joint and the casing [11]. The sand content of the drilling mud should be kept to minimum possible limit as the sand has potential to impact the surfaces negatively [7].

2. Problem Statement

Casing wear is a growing concern in the oil industry. As the more and more deviated and deep wells are being drilled the problem of casing wear is becoming intense and hazardous. In addition to the reliability and integrity concern, the safety limits of the well can be compromised when the wear rates are higher than the acceptable limits

3. Methodology

In this research work Casing wear module of DrillScan software is used to analyze the impact of drilling parameters impacting the casing wear. The case study of directional well in the pothwar region is included. Sensitivity analyzes is performed by increasing the rotation speed of the drill string at the high dog leg severity depths where the maximum wear of the casing is expected.

4. Preceding Work

In this research article the authors have proposed a mathematical model to calculate the dual or the alternating wear. They suggested that in case of highly deviated wells not only the tool joint of the drill pipes but also the body of the pipes comes in contact with the inner wall of the casing and causes the casing wear [2].

In this research laboratory experiments were conducted using pin-on-disc machine. G105 grade pin and N80 grade disc of steel was used to see the effects of rotating pin the surface morphology of the disc. It was concluded that the wear rate of increases but not linearly with increasing the rotating speed, the non-linearity was due the effects of additives in the mud system [6].

A model was presented to identify the location and size of the groove made on the casing wall due to the rotation of the drill string. The location and the size of the groove are mathematically linked to the well trajectory, drill string movement and geometry of the tool joint [13].

In this research Range 2 and Range 3 drill pipes impact on casing wear was investigated. It was found that range three pipes cause less wear of casing in vertical wells. However in the tortuous well the casing wear becomes severe due to the use of the range 3 drill pipes [8].

In this research several cases are studied and various well geometries to account for the realistic calculation of the casing wear factor for the accurate modeling of the casing wear process [1].

A typical field case of extremely deep well is presented for analyzing the casing wear. Casing monitoring SOP prepared by the shevron company is overviewed. Additionally, the well control and safety issues are analyzed in the light of the casing wear monitory and mitigating SOPs [12].

It was proposed that by reducing dog leg severity at the shallower depths in the well, minimizing back reaming and using non-rotating protectors on drill string can sufficiently decrease the casing wear [15].

Conducted laboratory experiments to understand the phenomenon of casing wear, they found that adhesive, abrasive and ploughing mechanisms are the main types of wear involved in the casing wear. they also suggested that presence of sand in the mud system also contributes negatively in the casing wear [9].

They performed laboratory experiment to investigate the impacts of drilling fluid properties and composition on the casing wear. Ability of drilling fluid to develop a protective film was found to be important property of drilling fluid that can minimize the casing wear [5].

They pointed out that if the dog leg severity increases than theoretical limit, then the chances of casing wear and equipment failure become maximum [16].

Laboratory experiments were conducted to investigate the casing wear. Different grade casing was subjected to rotating tool joint in a machine with oil based and water-based mud systems. It was observed the casing wear was higher in the oil-based muds and for high grade casings [17].

5. Case Study

A directional well is drilled and cased up to 5000 meter measured depth. The total measured depth of the well is at 5760 meter. The well is cased with 20”, 13 3/8” and 9 5/8” casing. The shoe depth of intermediate (9 5/8”) casing is at the 5000 meters. The remaining well is drilled with 8 ½ “rotary steerable BHA.

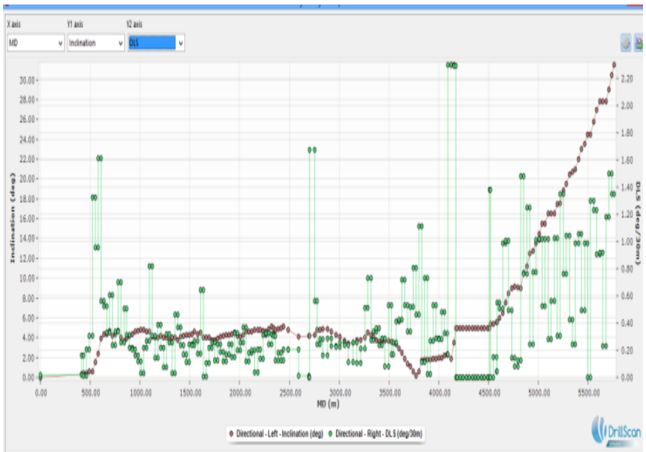

Figure 4 DLS and inclination

Figure 4 shows that the highest DLS is at the measured depth of 4147 meters. The other high DLS depths are 2702 meters and 586 meters. These high DLS depths are critical from casing wear point of view, because maximum contact of the tool joint with the inner wall of the casing is expected at high DLS points. These are the depths where the maximum work and the force of the drill string is expected

6. Results

The results of the casing wear simulation are as under

7.1 Maximum Wear Height

Figure 5 wear height

Figure 5 shows that at the measured depth of 586 meters the wear is 0.3 millimeter, which is the maximum value. Figure 4 shows that the DLS at this depth is 1.61 deg/30 m. Although the values of DLS are higher at the measured depths of 2702 meters and 4147 meters than the values of DLS at 586 meters, yet the high-tension forces due to the weight of drill string are the cause of maximum wear at the measured depth of 586 meters.

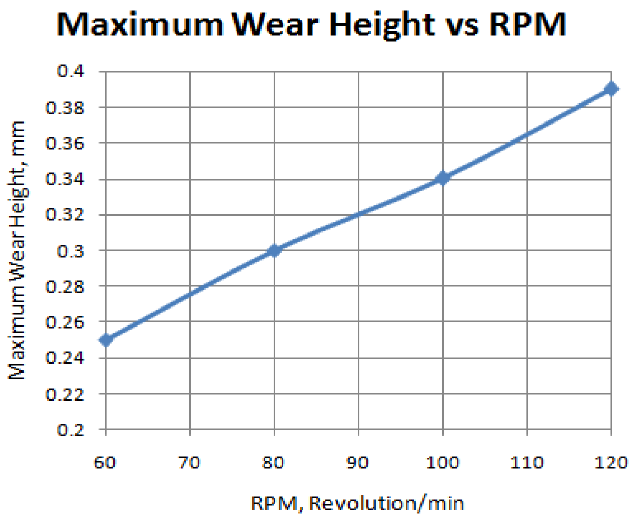

Figure 6 wear height with increasing RPM

At the measured depth of 586 meters the tool joint of the drill pipes is in contact with the inner wall of the casing. As this is the high DLS and shallower depth. The weight of drill string is highest at this depth as compared to other high DLS depths. Due to the combined effects of the drill string weight and well geometry the wear height is maximum at this depth. As the drill string rotation is increased the value of wear height is also increasing. Figure 6 shows that the relationship between casing wear and drill string rotation is linear. Because by increasing the rotary speed of the drill string the total wear track length or the total sliding distance of the surfaces is increased. Hence the total work done on the inner wall of the casing is increased thus the total wear of the casing is increased by increasing the rotary speed.

7.2 Internal Yield Pressure

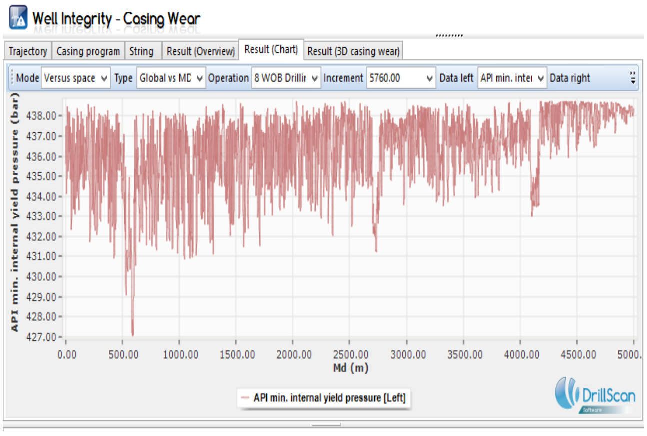

Figure 7 Internal Yield Pressure

The results of Figure 7 are correlating with figure 5. At the measured depth of 586 meter the wear depth is maximum figure 5. Because at this depth the maximum damage to casing has occurred hence the internal yield strength is minimum at this depth figure 7.

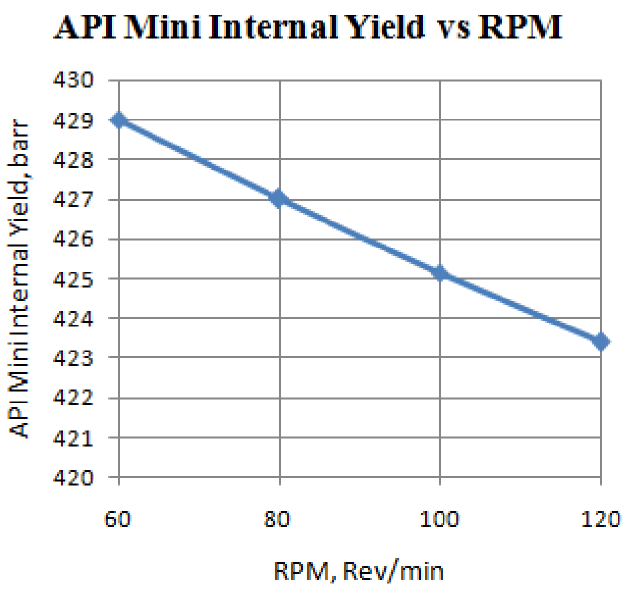

Figure 8 Internal Yield strength at different RPM

Yield strength of casing is decreasing with increasing the rotation speed of the drill string at the measured depth of the 586 meters Figure 8. As the rotation speed of drill string is increasing the work of the drill string is also increasing on the internal wall of the casing, thereby causing maximum wear at this depth and resultantly decreasing the strength of the casing. In this case the measured depth 586 meters is a high dog leg severity point, where the weight of the drill string is higher as compared to other high dog leg severity depths in the well. The increasing speed of drill string will negatively impact the integrity of the casing because the more sliding distance or the wear track length is being covered by the surfaces of the tool joint and the inner wall of the casing.

8. Conclusion

The findings are concluded as follows:

The maximum wear of the casing occurred at the measured depth of 586 meters. At this depth, although the value of DLS is lower as compared to the measured depths of 2702 meters and 4147 meters, yet the higher weight of drill string at the measured depth of 586 meters is causing more damage to the internal wall of the casing. In this case the wear is the function of both DLS and the tension in the drill string. When the rotation speed is increased from 60 RPM to 120 RPM the wear groove depth in the internal wall of the casing is increasing and the internal yield strength of the casing is decreasing. With the increased speed of the drill string the total sliding distance of the tool joint against the casing wall is increased, hence more frictional work is done between the sliding surfaces and resultantly the integrity of the casing is impacted negatively.

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