An Investigation of Stuck Pipe Occurrences in Iran

Abbas Roohi[1], Gerhard Thonhauser[1], Mehran Makvandi[2], Khalil Shahbazi[3], Rahman Ashena[1], Abbas Zamani[1],Asad Elmgerbi[1]

1- Montanuniversität Leoben (MUL)
2- National Iranian Drilling Company (NIDC)
3- Petroleum University of Technology (PUT)

Abstract— One of the major sources of lost times in Iranian oil fields is stuck pipe which may occur due to differential sticking forces, inadequate hole cleaning and the consequent formation of cuttings beds in high angle wells, chemically active formations and inadequate mud weight leading to wellbore instability, fractured/faulted formations, and over-pressured formations. There are various methods of dealing with stuck pipe to prevent or alleviate it.

Therefore; in this paper, the data corresponding to more than 1000 stuck pipe occurrences and cases have been gathered in several fields and formations in Iran. Using statistical modeling and categorization, the stuck pipe occurrences have been attributed to the related drilling data including drilling mud properties, wellbore geometry, stuck pipe depth, description of stuck freeing operations and associated time. Thus, the effect of different parameters on stuck pipe have been analyzed statistically with the objective of presenting effective ways of mitigation or prevention or at least alleviation of stuck pipe occurrences in oil and gas drilling in Iran.

Index Terms— Stuck Pipe, Hole Size, Mud Wieght, Hole Deviation

1 INTRODUCTION

FOr many years, several problems related to oil and gas industry are identified and various solutions associated with them have been proposed. Drilling operations have been one of the most troublesome parts of oil and gas industry. During drilling a well, various problems such as wellbore instability, lost circulation, kicks and blowouts and stuck pipe may be encountered [1]. Stuck pipe has been well recognized as the drilling industry began [2]. This problem may occur at any stage of drilling. Stuck pipe is classified into two categories; differential pressure pipe sticking and mechanical pipe sticking. Various operational procedures are applied to make them free. These procedures include raising and lowering the drill string, attempting to rotate the string and pumping mud or lubricator through the drill bit to make the pipe release [3]. It should be noticed that these procedures are time-consuming and costly. For each type of pipe sticking, there are signs by which it is identified. For instance, differential sticking is accompanied by possible ability to rotate and circulate while with mechanical sticking only circulation is possible [2].

In Iran, a large number of pipe sticking has occurred in different fields and formations annually. Each of them has their own difficulties to free and their specific time to work on which imparts a huge financial burden. In this study, drilling data and reports of about thousand stuck cases have been gathered and categorized after some introductory material regarding the mechanisms of stuck pipe. These data correspond to pipe sticking scenariosin different fields in Iran for three years from early 2004 to 2006. The second step was dedicated to investigation of the number of stuck pipe in each formation and field and the time elapsed to make them free. The effects of different parameters (inclination angle, hole wellbore size, wellbore depth, and distance to the last casing shoe) on the number of stuck pipe occurred were investigated statistically. Finally, taking into account the investigation carried out, the probability of facing stuck pipe in different fields and formations can be induced and the importance of studying the effect of various parameters on stuck pipe occurrence is investigated.

STUCK PIPE MECHANISM

Often during drilling operations, the drill string becomes stuck. Sticking can occur while drilling, making a connection, logging, testing, or during any kind of operation which may involve leaving the equipment in the hole [4]. Generally, stuck pipe problems are divided into two categories: mechanical sticking and differential sticking. Mechanical sticking usually occurs when the drill string is moving and is caused by a physical obstruction or restriction [6]. Mechanical sticking can be classified into two major subgroups: a) Hole pack-off and bridges; stuck pipes which are related to wellbore instability or settled cuttings and b) Wellbore geometry interferences which refers to stuck pipes and are related to the condition of wellbore geometry such as key seats or an under-gage hole.

Major causes of mechanical stuck pipe are wellbore instability and improper hole cleaning. Most wellbore instability problems are related to shale layers due to swelling and hole enlargements resulting from compressive failure owing to excessively low wellbore pressure [7]. Adequate hole cleaning, on the other hand, is an essential part of the drilling operation. If the cuttings are not removed from the well properly, they settle around the drill string causing the drill collars to become stuck. This problem is encountered often in over gauged sections where annular velocities are low. Also, risk of hole cleaning increases in directional wells. The directional well having an inclination angle between 30-60° is the worst condition for

hole cleaning [5].

As the next category of stuck pipe, differential sticking is due to differential pressure forces from an overbalanced mud column acting on the drill string against a filter cake deposited on a permeable formation. The area of the pipe that is embedded into the mud-cake has a pressure equal to the formation pressure acting on it, while the pressure which acts on the other section of pipe is hydrostatic pressure in the drilling mud. When the hydrostatic pressure (Ph) in the wellbore is higher than the formation pressure (Pf), there will be a net force pushing the collar towards the borehole wall. The resultant force of the overbalance acting on an area of drill string is the force that sticks the string. This type of sticking does not occur in shales and other very low permeability formations where the mud filter cake normally does not form. Commonly, differential sticking occurs when the drill string or tool is stationary (or sometimes when it is moving very slowly) [7]. If the pipe becomes stuck, every effort should be made to free it quickly. The probability of freeing stuck pipe successfully diminishes rapidly with time. Early identification of the most likely cause of a sticking problem is crucial, since each cause must be remedied with different measures. An improper reaction to a sticking problem could easily make it worse. An evaluation of the events leading up to the stuck pipe occurrence frequently indicates the most probable cause and can lead to the proper corrective measures [5].

2 MATERIALS

2.1 Data assembly and quality control

The data used for this study were collected and classified from about thousand stuck pipe events occurred in various fields and formations in Iran from early 2004 to the end of 2006. A summary list of these data is showed in Table 2-1. All drilling data on the number of wells in each field and the time consumed to drill each of them were gathered and classified as well. After correcting and controlling the quality of collected data, 61 mentioned formations on Daily Drilling Reports (DDR) were reduced to 20 formations on the basis of lithology and pressure to have a better analysis.

Table 2-1 Drilling Data

Rig name	*Field name*
Date	*Well Name*
Rotary system (Kelly or top drive)	*Casing size & setting depth*
Time consuming to work on stuck pipe	*Stuck position (Hole size, Depth)*
Survey data	*Formation specification*
Consequence of stuck pipe	*Drill string situation before stuck pipe*
Drilling fluid properties (density, viscosity, PV, YP, Initial and secondary gel	*Drilling operation since 3 stages before stuck*

2.2 Investigation of the number of stuck pipe events in various formations

Each formation has its individual properties and may affect the drilling operation in a different way from other formations.

Figure 1 indicates the number of stuck pipes occurred in different formations from 2004 to 2006. The majority of stuck pipe happened in GS1-6, Asmari, and Bangestan formations respectively. GS1-6 formation presents a rising trend in the studied time interval which might be due to increasing the number of directional wells drilled in this formation at this period of time.

2.3 Investigation of the number of stuck pipes occurred in different fields

Fields with different geological and geographical specifications require various drilling scenarios to be applied. Hence, stuck pipe depending on the field might need a specific way of freeing.

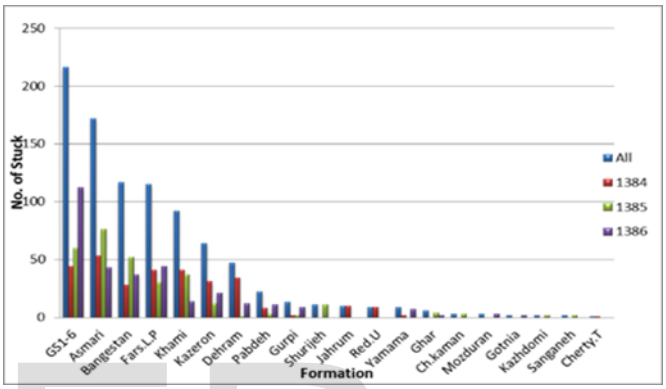

Figure 1 Number of stuck pipe events in various formations

Figure 2 presents the number of pipe sticking in different fields from 2004 to 2006. This figure shows that Marun, GS, and Ahwaz fields have the highest number of stuck pipes respectively.

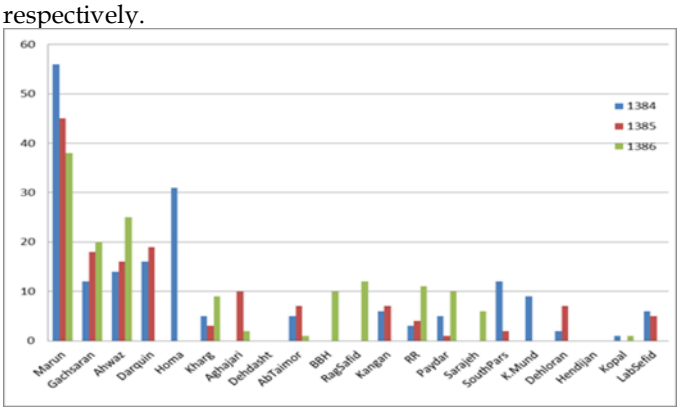

Figure 2 Number of stuck pipe events in different fields

The number of stuck pipe events have falling trend in Marun field in the studied time interval while GS and Ahwaz fields have rising trends at the same time interval. This contrast is highly due to the number of wells drilled every year. Hence, the number of stuck pipes in each year was divided by the number of wells drilled every year. Figure 3 exhibits the average number of pipe sticking occurred in each well. It is concluded from Figure 3 that the average number of stuck pipe occurred in Marun oil field for each well was reduced to

3.3, 2.6, and 2 respectively. But, GS oil field showed between 2 to 3 pipes sticking for each well without having a falling or rising trend. Ahwaz oil field presents rising trend of 1 to 1.4.

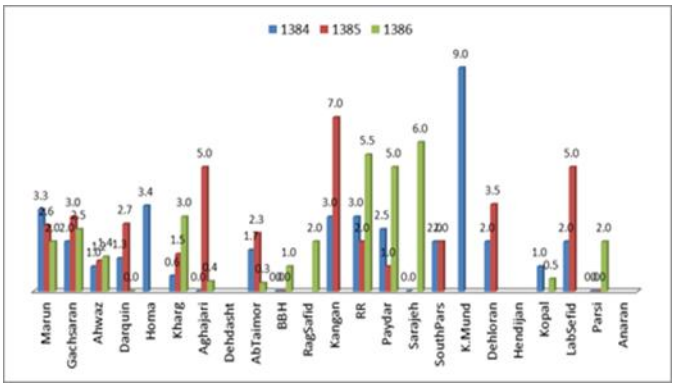

Figure 3 Normalize number of stuck per well

Khark oil field shows a rising trend, and it was 3 stucks per well in 2006. The average number of stucks in Ramshir field is high in the mentioned time interval.

In other fields, due to drilling only for a short period of time and having small number of wells, it does not follow a specific trend.

Since Marun oil field had the majority of stuck pipe cases during the cited time period, number of stuck occurrences in different formations of this field were taken into consideration (Figure 4). GS1-6 formations show the highest number of stucks. It shows a significant increase in 2006. Asmari formation exhibits a falling trend in the studied time interval.

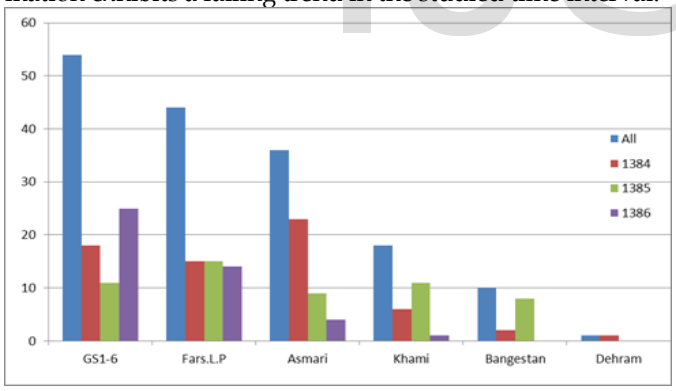

Figure 4 Number of stuck in Marun oil field

2.4 Investigation of elapsed time to free stuck pipe

Right and immediate decisions are highly important once drill string gets stuck. In the following, this issue will be demonstrated using the prepared data base. The time elapsed to work on the pipe sticking are investigated for various time intervals. Making a comparison between the number of stuck and the time elapsed to get rid of them showed that the effort to free the stuck in the first 30 minutes after pipe sticking is as valuable and crucial as the effort applied in the next 2.5 hours and also as valuable as the efforts in the next 100 hours to free the stuck (Figure 5). The same results were obtained after dividing them by the number of wells drilled every year.

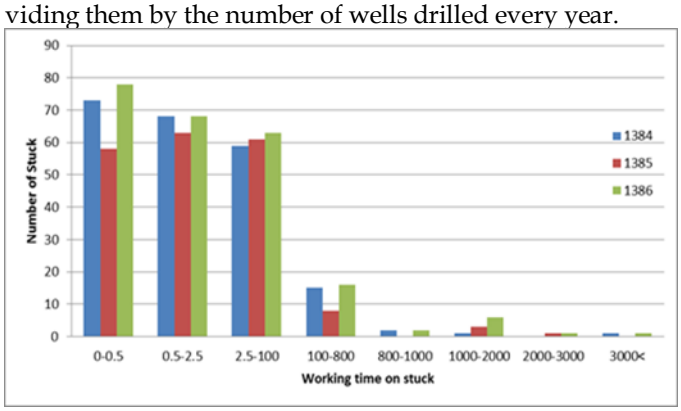

Figure 5 Comparison of the number of stuck with the time elapsed to work on them

The investigation of the number of stuck pipe cases in each well based on the time elapsed to free them is presented in Figure 6. This figure demonstrates the importance of the fast and right decision in the first moments after occurring pipe sticking.

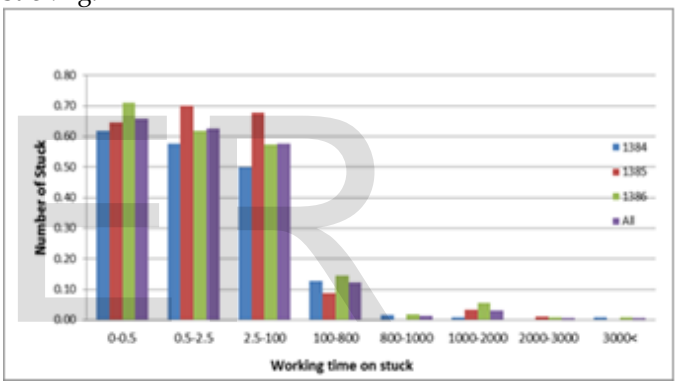

Figure 6 Number of stuck on the basis of elapsed time to free them

The elapsed time of more than 100 hours is often led to unsuccessful stuck pipe freeing attempts and side tracking. Same trend can be included in Marun, GS, and Ahwaz, but in other fields due to a non-continuous drilling operation, a special principle was not observed. Figure 7 shows this scenario in Marun oil field.

2.5 Impact of inclination angle on stuck pipe

High inclination angle does not by itself lead to pipe sticking but applying an inappropriate drilling method may bold the effect of inclination angle on stuck pipe.

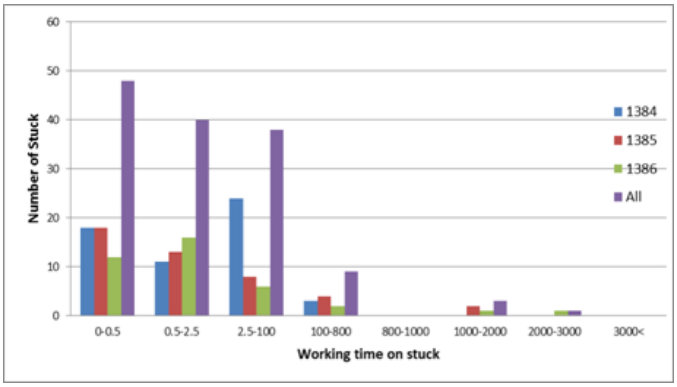

Figure 7 Average number of stuck in each well based on elapsed time to free them in Marun

Figure 8 links the number of stuck pipes with inclination angles. This figure indicates a high number of stuck in vertical wells and inclination angles of 20-40 degrees of directional wells.

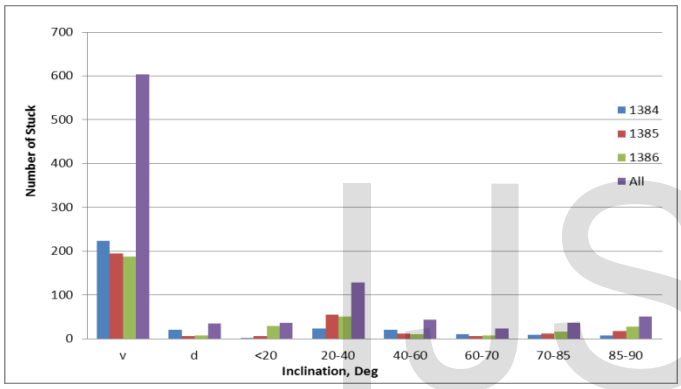

Figure 8 Number of stuck pipe events compared to the inclination angles

In the next step, the wells were classified into exploration, workover, and development wells. Figure 9 shows the number of stuck cases based on inclination angle and type of the well. This figure represents the variations of the number of pipe sticking in development wells with different inclination angles. Since exploration wells are drilled only in vertical, hence in exploration wells, limited data in vertical situation are available. The majority of stuck pipe cases in workover wells happened in vertical sections and at inclination angles in the range of 20 to 40 deg.

To make our investigation more precise, the effect of formation was added to two mentioned parameters. The effect of inclination angle on stuck pipes in GS1-6 formation of development wells is indicated in figure 10. This figure shows a higher number of pipe sticking in inclination angles of 20-40 degrees in GS1-6 formation compared to other inclination angles. In other formations, a specific relationship cannot be extracted.

In the study of the effect of the time elapsed to work on the stuck pipes, unsuccessful freeing operations in this formation in the range of 20-40 degrees of inclination angles are considerable in addition to the mentioned parameters, with respect to the number of directional wells drilled in GS1-6 formation,.

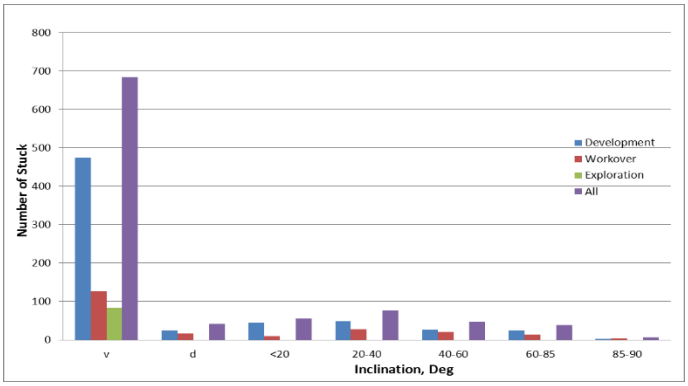

Figure 9 Number of stuck pipe occurrences based upon the inclination angles and the well type

2.6 Impact of hole size on number of stuck pipe

Stuck pipe may happen in wells at various hole sizes with regards to the chosen drilling scenario.

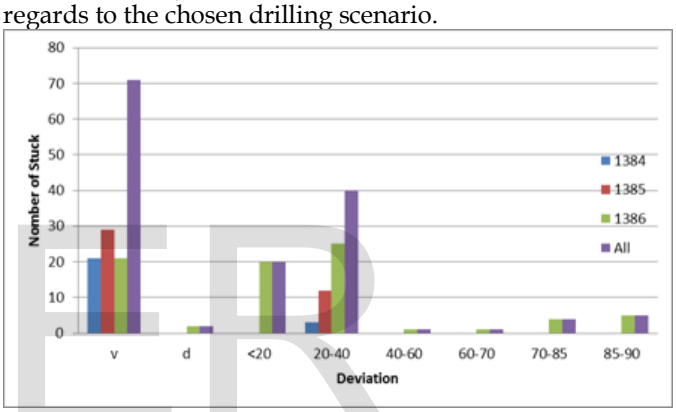

Figure 10 Effect of inclination angle on the time elapsed to work on stuck in development wells of GS1-6 formation

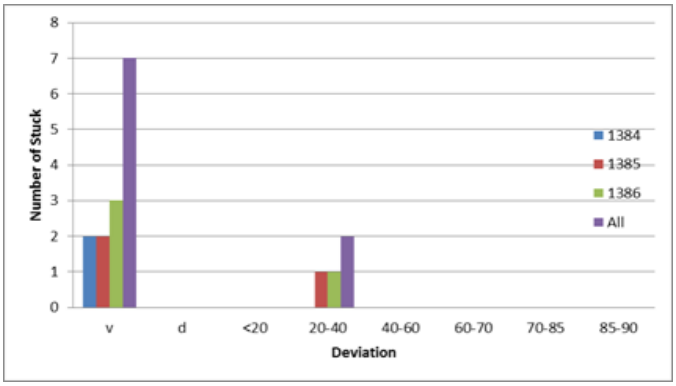

Figure 11 Impact of inclination angle on stuck pipes on development wells of GS1-6 formation

Figure 12 shows that the highest number of pipe stuck cases were happened in the hole sizes in range of 8 3/8 - 8 1/2, 5 7/8 - 6 1/8, 12 1/4, and 17 1/2 inches. Marun field does not follow this order.

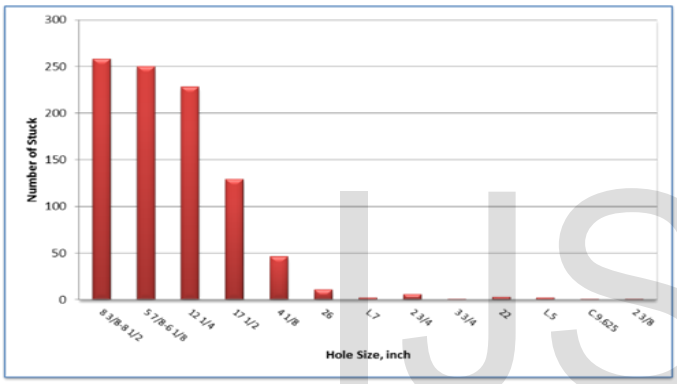

Figure 12 Number of stuck relative to the hole size

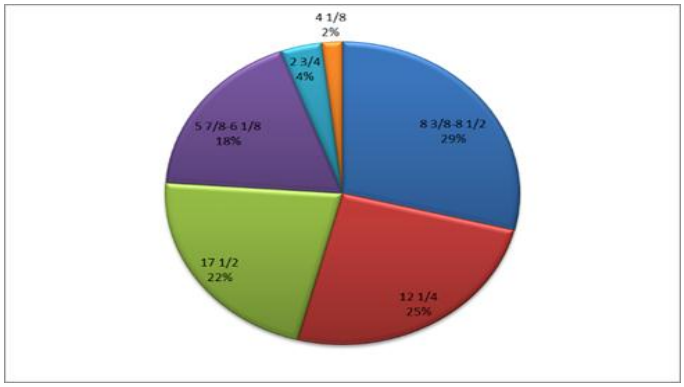

Figure 13 Number of pipe sticking in Marun field relative to the hole size

2.7 Impact of depth on number of stuck pipes

Some parameters should be noted to prevent pipe sticking. Neglecting each of these parameters can conduct to suck pipe incidents at various depths.

Figure 14 shows the number of stuck cases relative to the wellbore depths. As can be seen in figure 14, the higher numbers of stuck cases are in the range of 2500 to 3000 meters. Figure 15 indicates that the development wells of Marun field have the same condition.

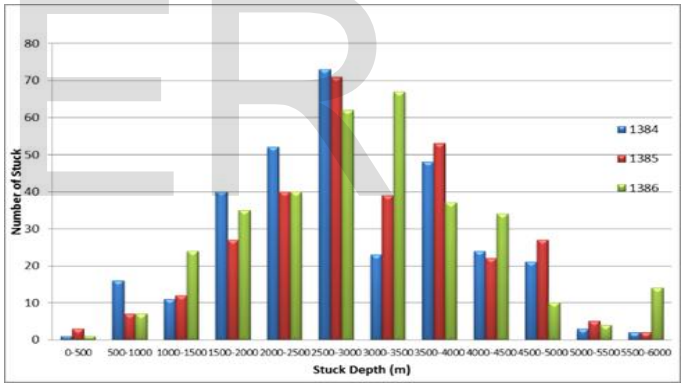

Figure 14 Number of stuck relative to the wellbore depth

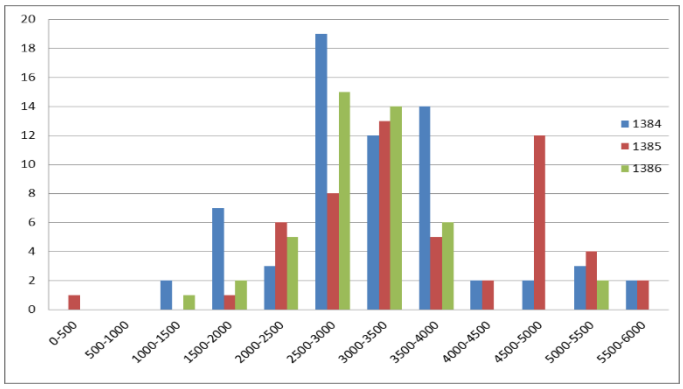

Figure 15 Number of stucks in various depths of Marun field

2.8 Impact of length of open hole on number of stuck pipes

As can be observed in figure 16, the highest number of stuck cases relative to the distance to the last casing, are in the range of 200 to 400 meters. It should be noted that in longer intervals, the number of stuck cases reduces due to having fewer wells.

3 Conclusion

Primary evaluation and fast and right identification of stuck pipe cases play an important rule to prevent further problems. This leads to mitigated cost. The first 30 minutes after the stuck occurrence is considered as the golden time to make a fast and right decision to free the pipe. The value of the efforts to free stuck pipe in this time period is equal to the attempts applied to free the pipe in the next 2.5 hours or 100 hours. In addition, the right decision at the right time, along with following the instructions, significantly reduces the cost of freeing the stuck and as a consequence, mitigates the overall cost of drilling.

This study showed that the number of stuck cases happened in vertical wells is more than stuck pipes occurred in directional wells. However, it does not mean that vertical wells are more troublesome, but it is only due to drilling a higher number of vertical wells compared to the directional.

In inclination angles between 20 to 40 degrees, the highest number of stuck cases is observable in directional wells.

Choosing and following a wrong way of drilling can make the drilling strategy including the hole size to be troublesome to lead to pipe sticking.

Marun field has a special condition among other fields in terms of stuck occurrences. In hole sizes of 5 7/8 – 6 1/8 inches, fewer stuck problems can be seen compared to other hole sizes.

The number of stuck has a direct relationship with increasing depth. Nevertheless, the number of stuck cases in the depths more than 2500-3000 meters is low. This isonly due to drilling fewer wells drilled in those depths.

4 Acknowledgment

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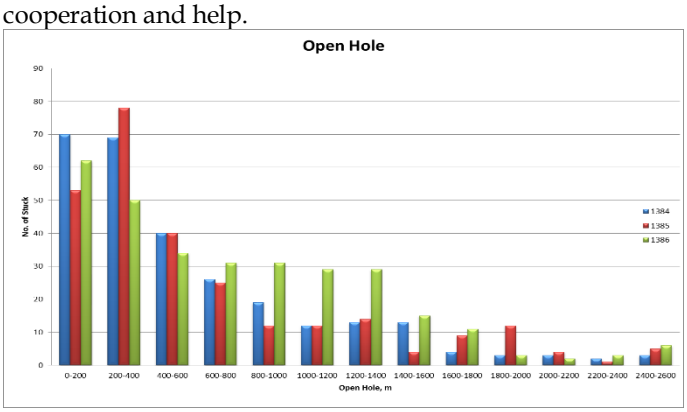

Figure 16 Number of stuck compare to the distance to the last casing

5 References

[1] Meschi, M.R., Shahbazi, K., Pordel Shahri, M., "A New Criteriato Predict Stuck Occurence", SPE 128376, SPE North Africa Conference and Exhibition, Cairo, Egypt, 14-17 Feb, 2010.

[2] Al-Dossary, A., "New Offshore Sidetrack Practices Reduced Significntly Stuck Pipes in KSA", SPE 16461, SPE IPTC, Beijing, China, 26-28 March, 2013.

[3] Aadnoy, B.S., Larsen, K., Berg, P.C., "Analysis of Stuck Pipe in Deviated Boreholes", Journal of Petroleum Science and Engineering 37 (2003) 195– 212.

[4] Bradley, W.B., Jarman, D., Plott, R.S., Wood, R.D., Schofield, T.R., Auflick, R.A., and Cocking, D., "Task force approach to reducing stuck pipe costs". Paper SPE 21999, SPE/IADC Drilling Conference, Amsterdam, Netherlands, 11-14 March (1991).

[5] Drilling Fluid Engineering Manual, MI L.L.C., Page: 15.1-15.10. March (1998).

[6] Reid, P.I., Meeten, G.H., Way, P.W., Clark, P., Chambers, B.D., Gilmour, A., and Sanders, M.W., "Differential-sticking mechanisms and a simple wellsite test for monitoring and optimizing drilling mud properties", Journal of SPE Drilling & Completion, Volume 15, Number 2, pp. 97-104 (June 2000).

[7] Zhang, J. "The impact of shale properties on wellbore stability", Dissertation, the University of Texas at Austin, (August 2005).