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ORIGINAL ARTICLE

FREEING STUCK PIPE PROBABILITY AND ESTIMATION OF FISHING SUCCESS IN IRANIAN SOUTHWESTERN FIELDS

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ABSTRACT: Fish and fishing are main causes of drilling NPT. Finding an optimum time for fishing or to quit the operation is extremely difficult since fishing is not an exact science. From all the cases considered as fish in the borehole, stuck pipe is statistically speaking the most severe case. It means that dealing with sticking scenarios is more difficult operationally and much more time consuming compared with the other types of fishes. In this paper it was attempted to introduce a function which has the ability to present a chance of releasing stuck pipes for Iranian southwestern fields. Validation of this model is examined by several case studies; therefore a combined theoretical-experimental approach is used in this research. Also a solution is offered to determine success rate of fishing operations. This information helps the decision makers to figure out when to quit fishing and start sidetracking. Importance of the research is in reducing drilling NPT and undesired costs.

KEYWORDS: Fishing, NPT, Pipe sticking, Formation structure, fishing time, Side tracking.

INTRODUCTION

Inefficient time in drilling consists of two main parts: invisible lost time and non productive time (NPT). Invisible lost time is defined as the time consumed for making up/breaking out connections and the other related operations which is highly dependent on crew efficiency. Non productive time is defined as time which drilling is ceased or penetration rate is very low (Moazzeni *et al.,* 2010). NPT caused by preventable tool and equipment failures in offshore drilling and completion operations typically accounts for 5% of well delivery time, but can reach as high as 30% (Reid *et al.,* 2006). This equates to millions of dollars per year that could have been spent on other well delivery opportunities (Hubbard *et al.,* 2010). Severe and complete loss circulation, stuck pipe, dealing with kicks, wellbore instability issues, formation breakdown, slow ROP in hard formations, fishing operation and remedial cementing are some examples of NPT. NPT can result in loss of and damage to equipments, financial loss and HSE issues, among these mentioned consequences financial issue is the most important case in drilling industry aspect. Dodson in 2004 found that about 40% of non-productive drilling time was caused by both wellbore instability and pore pressure (e.g. kick, gas flow, shallow water flow, lost circulation, wellbore instability, sloughing and stuck pipe) (Vilatoro *et al.,* 2009). Hence by reducing NPT, a considerable decrease in costs can be achieved. Stuck pipe is considered as one the worst NPT cases, although sometimes pipe is easily released with routine procedures, but this is not always the case. Many researchers have investigated different aspects of pipe sticking, from definition of sticking mechanisms and offering suitable responses to introducing success chance of releasing stuck pipes.

In 1983 love introduced the stickiness factor as a new approach of looking at stuck pipe. The stickiness factor is an empirically derived number strongly related to the chances of freeing stuck pipe in a well. Since stuck pipe costs are largely dependent on the ability to free stuck pipe and avoid sidetracking wells, it follows that reducing stickiness factors should result in reduced stuck pipe costs. The stickiness factor is commonly lowered by reducing the API-fluid loss of the mud, reducing the bottom-hole-assembly length, or setting casing. The stickiness factor is based on a study of Gulf of Mexico wells drilled by Exxon Company, USA. Therefore it will not necessarily apply well in the other areas. The factor does not predict when pipe will stick but simply predicts the chance of freeing pipe that has already been stuck. A reduced stickiness factor should reduce the chances of sticking pipe. The stickiness factor will also help evaluate various spotting fluids and fishing techniques since it indicates the relative difficulty (chance of success) of a soaking or fishing job (Love, 1983). Howard and Glover, (1994) introduced another model to show probability of pipe sticking and also chance of freeing pipe. Much like love, Howard also used a statistical approach based

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on a data of the drilled wells in Gulf of Mexico and North Sea. Risk analysis approaches are other kinds of researches which are trying to estimate optimum fishing times to be spent in case of stuck pipe incidents. For instance in one of these risk economical studies in gulf of Mexico authors claim that in case of facing stuck pipes, after 4 days, attempts should be ceased if in process or never be started at all (Shivers and Damangue, 1993). In this paper a study on the drilled wells in Iranian southwestern fields was done. Inability of other mentioned models to present an accurate stuck pipe freeing chance for sticking cases in Iran means different factors affecting the chance of freeing pipes must be taken into account. By doing this and calibration of the results with the cases at hand, a function is defined to tell chances of releasing stuck pipes. Statistical approach used in this study with certain data classifications clarify the effective parameters which play a great role in freeing stuck pipes in Iranian oilfields. This study will be useful in decreasing NPT and followed costs.

METHODOLOGY

2.1. Overview

Based on the data acquired, several parameters were found to be of great importance which impact final result of fishing operation. Data classification and analysis was done separately for each factor. Table 1 contains resulting values for these parameters.

Table 1- calculated values for effective parameters on chance of freeing stuck pipes

Stuck pipe mechanism	Threat level (TL)	Formation	Success rate (SR)	Crew performance	Value (CE)
Normal sticking	1	Surface-near surface (up to 1000 meters)	1	-well trained -high experience	1
Twist off / more complicated sticking	0.8	Aghagari	0.8	-well trained -moderate experience	0.8
Stuck pipe/Twist off+ Loss circulation	0.6	Mishan	1	-Well trained -Lesser experience	0.6
		Gachsaran mid-section	0.8		
		Gachsaran upper and lower section / Asmari	0.7		

Finally a formula was extracted from related information. Formula 1 shows the correlation between these factors and chance of freeing stuck pipe.

$$FSN = (CE)\ (TL)\ (SR) \qquad (1)$$

Where,
FSN: Freeing stuck pipe number
CE: Crew efficiency number
TL: Threat level related to sticking mechanism
SR: Fishing success rate in a certain depth

Multiplying the result by 100 gives it in percentage. Therefore FSN is a number, function of parameters such as crew efficiency, formation effect and sticking mechanism of stuck pipes, which is able to predict chance of freeing stuck pipes in wellbores located in Iranian southwestern fields.

In order to achieve the research's goal to formulate chance of freeing stuck pipes, a series of data has been collected, investigated and categorized based on certain purposes; therefore a statistical approach is used in this paper.

The fish is classified into two main parts: stuck pipe and miscellaneous (bit cones, tools, junk, debris and etc.). For each case required data was analyzed, these parameters are:

Fishing time, depth, fishing success/failure, formations and their characteristics, crew response and performance, side tracking information (in case of failed fishing) and pipe sticking mechanism.

Extracting information from data parameters as mentioned resulted in finding a formula which gives a number that represents chance of freeing stuck pipe in vertical wells located in Iranian southwestern fields. This number is considered to be a function of crew efficiency, formation which the sticking occurs and the mechanism of sticking.

2.2. Parameters affecting FSN

2.2.1. Crew efficiency

More experience and proficiency of the rig personnel could largely reduce invisible lost time. On the other hand NPT issue is a more complex matter which needs more than crew experience to be dealt with. Of course, human error has always been a considerable factor resulting in drilling "trouble times". Nowadays, there are service companies available with professional and experienced crew engaged in solving fish problems in boreholes. For instance Medco E&P Indonesia contacted Weatherford Heavy Duty Wireline Fishing Services (HDWF) to provide a solution for one of their wells located in South Sumatra. Two months after the initial event including one month of unsuccessful fishing attempts Medco were facing the prospect of a well workover to recover from the situation.

At last a complete recovery of all fish in 7 days was performed, saving the client a well workover. Knowledge and experience are invaluable in HDW fishing (Vincent *et al.*, 2011). To face cases of stuck pipes proper training is very important. For instance BP exploration is holding courses focused on stuck pipe problems. Fishing is more an art than an exact science (Kemp, 1986) and the fisher man with more gray hair is always preferred. Based on these facts in this paper two factors of training and experience are considered to describe the condition of crew efficiency. Of course, quantification of such parameter is very difficult but having the cases of crew responses against stuck pipe and calibration of the formula with the real stuck pipe examples in Iran, this task was done. Table 1 represents the values of each efficiency state where the well trained, well experienced crew has the maximum number of 1. Figure 1 properly indicates industry understands the importance of crew experience.

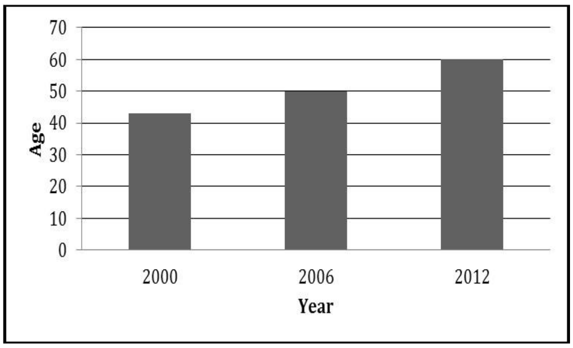

Figure 1: peak age of petroleum engineers (*Pete Stark, VP of industry relations for IHS)*

The crew efficiency values in table 1 are determined by analysis of crew response and act, their experience and performance facing stuck pipe incidents in Iran.

2.2.2. Formation effect

One of the parameters recorded and analyzed was the depth of fish in the borehole. Each depth interval introduces a certain formation. In fact formations are known to be effective in chance of freeing stuck pipes. Hence data classification regarding to depth and formation was performed to give the results related to fish retrieval. Actually this part is a priori knowledge study. Ratio of successful fishing jobs to total fishing operations in each formation presents a number related to chance of freeing stuck pipe in formations.

In table 1, SR is fishing success rate which is ratio of successful fishing jobs to total attempts. This number indicates difficulty of freeing stuck pipe in each formation. A cursory look at these numbers shows that in certain formations especially Asmari, Gachsaran and Aghagari, rate of fishing failure is higher and this is due to characteristics of these layers. Gachsaran formation is known as the cap rock of Asmari reservoir layer. Having plasticity and instability characteristics and being located between more stable Asmari beneath, Aghagari and Mishan formations above, in addition to existence of under pressure brine and low scale folding in this layer, lead marn and salt materials to a less pressured zone (wellbore), resulting in a more chance of sticking and a harder fishing operation.

In lower section of Asmari formation near Pabdeh upper section shale exists in a large scale. Low ROP and water base mud can lead to swelling and sticking of the pipe. This is a very difficult case of fish to deal with.

In Aghagari formation, lack of concentration on pressure drop issue led to pipe twist off in most cases, and latter in this paper it will be discussed that pipe twist off is a level harder than conventional sticking for fish retrieval operation.

2.2.3. Threat level

Stuck pipe consists of various mechanisms including differential and mechanical modes. In this paper twist off is also considered as another scenario of stuck pipes, where pipe is cut in a certain depth. This could be a result of manufacturing mistake, inaccurate design or human error of rig personnel while making up connections.

Like previous sections, data was categorized again, in regarding to mechanism of sticking this time. A ratio of fishing success to total attempts in a certain sticking mechanism was calculated and a set of values was found for different cases.

According to table 1, three total mechanisms were introduced. Normal mode is a sort of sticking which there are no complications such as swelling and key seats which can be routinely dealt with by working with the pipes, jarring, using pipe lax and spotting fluid. Threat level of this scenario is 1, showing that fishing operations in such cases are often successful and easy.

Twist of on the other hand is much more complicated, which needs special fishing tools such as overshoots to remove the failed fish from the borehole. Top of the fish, if misplaced, makes the fishing operation even more difficult and also in need of other tools such as knuckle joints.

Last mechanism is the most severe case. Where stuck pipe or twist off is accompanied with a complete loss of circulation. Fishing job in this situation has a high failure rate.

CASE STUDIES

In this section several examples are made based on real cases to show performance of FSN model properly. In order to use the model, it is essential to know the formation which sticking occurs, diagnose the sticking mechanism and have basic information of crew experience and training.

Example 1:
Drilling pipes fell into the borehole in Mishan formation while crews were making up connections. A bad top of the fish situation was reported. Drilling team was highly experienced:
FSN = 0.8 or 80 % chance of freeing stuck pipe, a less experienced crew (moderate) could lower the chance down to 64 %. After 154 hours crew successfully pulled out the fish out of the borehole, misplaced top of the fish increased fishing operational time considerably.

Example 2:
A conventional sticking occurred in Aghagari formation. Crew was highly trained and experienced.
FSN = 80 %
In less than 4 hours drilling team successfully freed the pipes. Crew proficiency had a major role in releasing the drilling string with short operational time.

Example 3:
Sticking occurred in Asmari formation. Considerable lost circulation (over 60 barrels) was observed.
Crew efficiency is moderate.
FSN = 33%, even if the crew was highly experienced chance of freeing stuck pipe is below 50%. After 1094 hours crew was unable to free the stuck pipes.

DATA

Data for more than 70 wells, all placed in the southwestern fields of Iran, related to the years 1974 and 1990, was collected and analyzed in this study. About 70% of cases are stuck pipe scenarios. Data was sorted regarding desired parameters such as fish type, fishing hours, depth of fish and sticking mechanism. Raw data included: fishing job description, fishing hours, sidetracking hours, depth of the fish and type of the fish. Figure 2 displays Iranian southwestern fields.

Figure 2: Iranian southwestern fields high scale map.

In Middle East (Iranian oilfields) due to complicated lithology, stressed zone (under Zagros mountain chain), enormous transverse faults and extreme over pressure formations in southwest of Iran (Gachsaran formation), drilling operation suffers from frequent kick, loss and pipe sticking problems. In order to assess the data properly, fish was categorized into two tubular and non tubular modes, and then fishing time versus depth of the fish was plotted for each case, Figures 3 and 4 show these plots for two classes of fish mentioned. In these figures, failed jobs are illustrated by crosses.

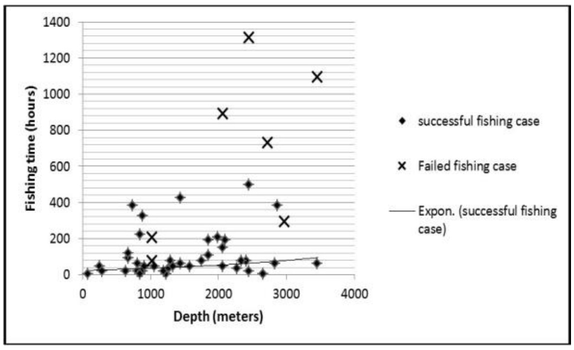

Figure 3: plotting fishing time vs. depth for tubular fish type

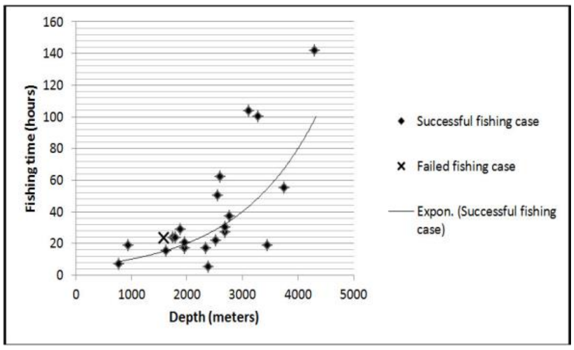

Figure 4: plotting fishing time vs. depth for non-tubular fish type.

RESULTS

5.1. General observations

In the figures 3 and 4, time spent on fishing job is plotted versus depth. The trend line for both tubular and non tubular type of fish proves increase in depth has a correlation with fishing time. This seems to make a sense. As depth increases, operational complications also increase but it doesn't necessarily mean failure rate should also increase. This fact is displayed in table 1 and formation characteristics are the reasons for such behavior. Figure 5 schematically shows fish occurrence regarding to depth for stuck pipes.

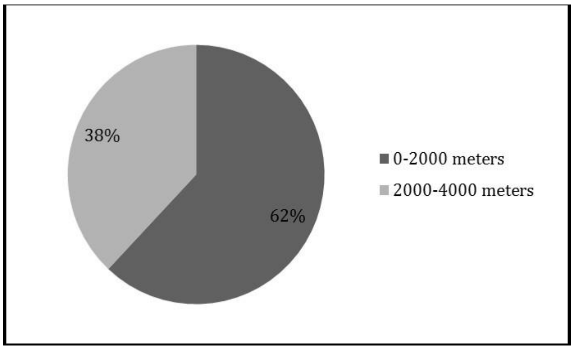

Figure 5: stuck pipe distribution regarding depth.

Fishing time Comparison of tubular and non tubular classes indicates, at least in Iran, stuck pipe is a much more complicated issue to deal with. This is also the case throughout the world. Until 1991, Historically BP's stuck pipe costs have exceeded $30 million per year and various estimates indicate industry stuck pipe costs exceeded $250 million per year (Bradley *et al.*, 1991). Figure 6 displays average fishing hours for tubular and non tubular modes according to the data acquired from Iranian fields.

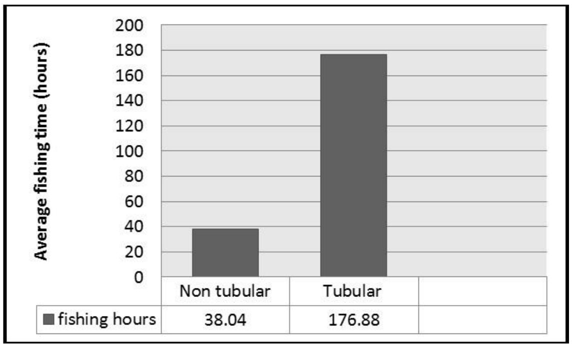

Figure 6: average fishing time for tubular and non-tubular fish types.

5.2. When to quit fishing?

This is a very important question that engineers are trying to find a proper and exact answer for and yet no precise solution has been suggested. For a better understanding of the problem, this question must be divided into two separate questions: 1- should we even start the fishing operation? 2- The operation is in process, when should we end it if not successful?

Two key factors are relevant to this subject: time and cost. With a good prediction of time, expenses can be calculated. Once a fishing operation fails two options are available, sidetracking or well abandonment. In order to save the well, sidetracking will be the only option. A comparison of sidetracking and fishing costs is the most helpful method to answer the questions asked in this section.

Fishing costs include: price of special fishing tools necessary, daily expense of drilling system, fishing operation cost, drilling fluid cost, cost of drilling to assigned target area, costs of services and other costs.

While sidetracking costs include: costs of deviation of the well, cost of drilling to assigned target area.

According to the mentioned expenses all the factors can be easily estimated except fishing operation cost since the time consumed in this operation can't be predicted. If the fishing time is found then costs can be calculated and once the expenses of fishing and sidetracking are known it is easy to choose one best solution. According to figure 3, trend line cannot work as an estimator to predict fishing time because of severe data dispersion.

By calculation of fishing success for different operation times some useful information could be found. Figure 7 displays rate of successful fishing jobs for higher depths regarding operational time.

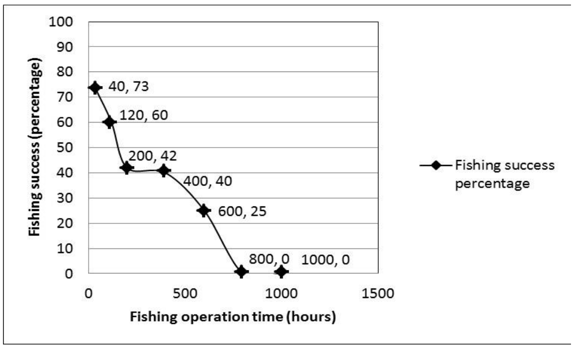

Figure 7: Successful fishing jobs of certain fishing times for depths over 2000 meters.

According to figure 7 it is obvious that in higher depths, all fishing jobs with over 800 hours of operational time failed. With a simple interpolation in almost 164 hours, chance of a successful fishing job descends to 50 percent. By rounding up the operational time, 7 days can be selected as maximum time limit for freeing stuck pipe attempts; longer endeavors have a higher failure chance than success.

DISCUSSION

In the present study data classifications in multiple stages method was used and FSN as a number was used to predict chance of freeing stuck pipe. This number is a function of sticking mechanism, crew efficiency and depth of fish. Other models that were introduced for Gulf of Mexico are unable to predict freeing stuck pipe probability in Iran correctly. Although authors confess this fact, stickiness factor as one of these models is discussed: stickiness factor is considered to be a function of open hole length and maximum inclination, API filtrate volume, BHA length and mud weight. Because this model is based on data acquired from Gulf of Mexico, most of the wells are deviated in offshore drilling; this paper investigates onshore wells of Iranian fields, mostly vertical wellbores. For vertical wellbores from Gulf of Mexico model, it is observed that chance of freeing stuck pipe is considered very high; this is not true for Iranian fields as presented in this paper. Other than hole inclination several other parameters affect sensitivity of models that predict chance of freeing stuck Pipe. For instance usage of latest technologies in fishing jobs has a major role in reduction of Operation time.

Making a decision over choosing sidetracking and fishing operation is another issue that was investigated in this study. Comparing costs of fishing and sidetracking helps the rig crew to choose between sidetracking and fishing options. It is important to notice data dispersions from the trend line in figure 3; it shows persistence of drilling team in resuming fishing operations. Many of these attempts failed and after long hours wasted on fishing operation, NPT increasing severely, crew started working on sidetracking operation. A case study is a good example of making poor decisions facing stuck pipe incidents. In year 1990, mansouri-12 well experienced stuck pipe in Gachsaran formation and a complete loss of circulation, after spending 891 hours for an unsuccessful fishing attempt, it took the team 888 hours to deviate the well for sidetracking. Considering crew efficiency moderate, FSN predicts almost 38% chance for freeing stuck pipe. Even if the crew was a fully experienced and professional team, FSN estimates below 50% chance of freeing stuck pipe for this case. Hence spending so many hours on fishing operation is obviously a great mistake. Financially speaking, sidetracking instead of fishing seems to be a wiser choice in this case. It is essential to know that FSN is achieved using database collected from Iranian wellbores. So its function is limited to a certain region. Values of CE, SR and TL are open to modification with a more extensive database.

CONCLUSIONS

According to the information obtained from the data of wellbores in the Iranian southwestern fields:

1- Generally an increase in fishing time is observed with increasing depth, but it does not mean fishing operation failure rate also increases with depth. Formation characteristics play a great role in final result of the fishing. Aghagari, Asmari and Gachsaran are most troubling formations in stuck pipe scenarios.
2- A comparison of tubular and non tubular fish proves that dealing with stuck pipe cases is much more complicated than non tubular ones. Average fishing time of stuck pipes is almost 4.6 times greater than miscellaneous type.
3- Gulf of Mexico models are unable to predict chance of freeing stuck pipe in Iran correctly, difference in techniques, technologies, hole inclination and many other parameters are the reasons for this fact.
4- FSN model, a number which is a function of crew efficiency, formation characteristics and pipe sticking mechanism is able to predict chance of freeing stuck pipe for wellbores located in Iranian southwestern fields.
5- It is not yet possible to estimate fishing time before starting the job. If this time could be estimated, it would have been easy to calculate the costs of fishing operation, then the sidetracking and fishing costs could be compared with each other and final choice could be made. This results in considerable reduction of drilling NPT. In this paper successful fishing jobs were calculated for different operational times, this is useful to estimate chance of fishing success while operation time reaches a certain amount. It is definitely a guide for decision makers to know when to quit the operation and start sidetracking. Seven days is recommended by the authors as maximum time limit for freeing stuck pipes attempts for wells located in Iranian southwestern fields.
6- FSN is achieved using database collected from Iranian wellbores, so its function is limited to a certain location. Values of CE, SR and TL are open to modification with a more extensive database.

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