Drill String Fatigue in Short Radius Horizontal Applications

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Abstract

Damaged pipe, especially in horizontal applications, is costly. The large number of planned horizontal drilling projects coupled with the expense of pipe replacement and fishing operations made it imperative that Mobil E&P gain a better understanding of drillpipe life. Previous internal studies of failure flurries have shown that excessive doglegs, high H_2S environments, and improper specifications or makeup on tubing connections can accelerate fatigue leading to failure. The effect of high bending stresses on drill pipe connections is also a concern. Inspections, typically used to determine pipe condition, prove only obvious defects and not fatigue. The goal is to evaluate DPLIFE2's ability to predict failures by comparing the program result with actual failures. Another objective is to evaluate the overall consumed life of the tubing and determine a "best practice" for replacing pipe before failures occur.

Introduction

When drilling horizontal wells with hole sizes of 4 3/4", premium connection tubing has been used in the curve and lateral since drill pipe tool joints leave little room for fishing. Along with this, there is a concern of the effects of high bending stresses on drill pipe connections. The tubing used is P110 grade with connections of both Hydril PH-6 and Grant Prideco STP (PH-6 interchangeable). Whether rented or purchased, damaged pipe is costly.

From previous studies of failure flurries, excessive doglegs are conditions under which more failures occur. Improper specs on tubing connections or improper makeup can also accelerate fatigue leading to failure. It is also a known that high H_2S environments will fatigue pipe faster specially pipe as hard as P110 grade. Therefore, it would be helpful to look at as many of these factors as possible as they interact together. Mobil E&P US has a greater stake in understanding the life of tubing used in horizontal drilling. The number of future horizontal projects and the high costs for replacing rental pipe and for fishing operations make it imperative to understand the life of tubing.

Drill Pipe Life software (DPLIFE2) developed by Maurer Engineering has been used as a post analysis tool in an attempt to arrive at a greater understanding of the consumed life of the premium connection when used in a horizontal well. This program evaluates the survey data, the RPM, the ROP, the WOB, and the corrosivity of the drilling fluid and how it changes the S-N curve for the pipe. For each grade of pipe there is an S-N curve in the program that is altered depending on the corrosive environment in which the pipe is run. This curve is a relationship of the number of turns with the strength of the tubing.

Project Goal

Successive runs were made of this program for each lateral the tubing went through for each well it was used on. The consumed life history of the pipe can be captured and used as a previous history for each successive case. This enables the cumulative condition of the pipe to be seen over the course of the wells the tubing is used on.

The goal is to compare the results with the actual failures that occurred to evaluate the program's ability to predict failures. Another goal is to evaluate the overall consumed life of the tubing and determine a "best practice" for replacing pipe before failures begin to increase the well cost through fishing operations and unnecessary standby time for drilling operations.

Input Assumptions

The input data for this program can be time intensive. Along with survey information and tubing and BHA lengths that are known, some other general assumptions were made:

1) All tubing run in the hole on one well is moved to the next well and run in the same order.
2) New pipe that is picked up for added length was added to the top joint with a 0% previous life.
3) Tubing from the East Mallet that was sent to Ratherford was run above the bit. When new joints were added for length, this tubing was added to the top of the East Mallet section of tubing carrying its previous history.
4) Failed joints were removed from the string and all pipe shifted and new joints added accordingly.
5) The S-N curve used was for S135 modified to a Yield of 110,000 lbs for the entire string although part of it is 2 7/8" Grade X AOH.
6) The corrosivity of the environment was entered as a 0.85 (1 is the worst) and the friction factor for the open hole used was 0.3.

Program runs were made for four strings of pipe. One string drilled five laterals, starting at Salt Creek and finishing at East Mallet Unit. The second string was tubing used at Ratherford Unit. The third was a combination of pipe that had been in continual use at Ratherford (second string) and the string from East Mallet (first string). The fourth is a new string (a second string) currently in use at Ratherford.

Review of Results

Salt Creek/East Mallet

This tubing had a consumed life at the end of five runs of 73%. There was a failure during the fourth lateral. That joint had a consumed life of 64%. (Figure 1.)

Ratherford Unit

This analysis was of the first seven laterals before being used in combination with the tubing from East Mallet. At the end of seven runs the tubing had a consumed life above or at 200% in some sections. There were two failures, one in the first run and one in the second. The consumed life of these joints was 95% and 81%, respectively. (Figure 2)

Combined Use at Ratherford Unit

There were two failures, each during the drilling of the same lateral. These occurred during the twelfth run. The consumed life of these joints was 73.78% and 51.56%, respectively. During the fourteenth run, all of the tubing that had been used in the curve was laid down and sent for inspection along with all other tubing which had been used. Then brand new tubing was picked up to drill the lateral section to finish. This tubing was used to drill fourteen laterals, 21,351 feet, at a cost of $3.41/ft. (Figure 3)

2nd New String at Ratherford Unit

Thus far the analysis includes the first seven runs for this tubing. This includes one medium radius lateral that was 3500 ft horizontal displacement. It can be seen in the attached graphs that the lower build rate curves drastically improve the percentage of tubing life spent. Although there were no failures, approximately 15 jts have been set aside mostly due to connection damage during make-up. (Figure 4)

After seven runs, the highest consumption of tubing life is approximately 6.5%.

Summary of All Tubing Strings Used at Ratherford Unit

String Number	# of Laterals Drilled	Footage Drilled	$/ft
1	**14**	21351	**3.41**
2	**19**	37960	**1.90**
3	**38**	74634	**1.34**
4	**36**	67753	**1.45**

Inspection

It is typical to rely upon an inspection in determining the condition of pipe of interest. However, an inspection will not prove fatigue but only obvious defects. Due to repetitive cracked connections, the pipe from the combined string was sent to Midland to be inspected (inspection attached). Of 60 joints that were sent in, 59 joints were white band and one was red band. Two pin-ends were damaged and one box was damaged. Twenty-one joints were rejected because they were crooked. These were straightened. The comments were that the "pipe appears to have been in a high corrosive environment with H_2S infestation that could cause stress cracking." The pin ends were looked at by a manufacturing rep, a local machine shop owner (that does re-cutting work), and the engineer. The pin-ends looked in good working condition with only a few threads with minor flaws.

This tubing was sent back to Utah where 16 jts were used at the top of the second string of new pipe for drilling two 4000 foot laterals. The remainder was sent to the completion well service unit and will be used for completion work.

Conclusions

From the above results, it is concluded that pipe which has consumed over 60% of its usable life expectancy is more likely to be a potential source for failure. It is not clear why so much of the tubing with over 100% of its consumed life did not result in failure. That is a point that needs clarification with Mauer Engineering. It may be the conservative nature of the program or it may be the fact that the S-N curve choice was S135 modified to with 110,000 lb. Yield (to accommodate P110). Where consumed life is low and failures occur it is most likely attributable to improper make-up.

As for the number of runs tubing can make before needing to be replaced, it is highly dependent on dogleg severity of the laterals that are drilled and corrosive environment. When drilling laterals with doglegs greater than 60 deg/100, the tubing may reach its usefulness by the seventh or eighth run. When drilling laterals with build rates between 18 and 55 deg/100, the tubing life may be extended for fifteen or more. Corrosive environments may decrease the number of runs before cracking becomes a problem or potential fishing job.

The practical application of DPLIFE2 is in the pre-planning phase to optimize both the directional plan and tubing fatigue. It can assist in post analysis to estimate the point at which a purchased string of tubing should be replaced. It can also assist in simulating conditions that may have added to multiple failures.

Tubing inspections should not be relied upon alone when determining the condition of tubulars that have been used in horizontal drilling.

This monitoring of tubing life consumption continued through mid-July 1997 using a copy of the software on lend from Mauer Engineering, Inc.

Appreciation

This paper and the sharing of the results would not have been possible without the support and encouragement of Mobil E&P U.S. in Midland, especially Drilling Superintendent Mike Kimbro. Special thanks also to Mauer Engineering Inc. for making the software and technical support available. Final thanks go to the drilling supervisors that spent time and effort to assist in implementing these findings.

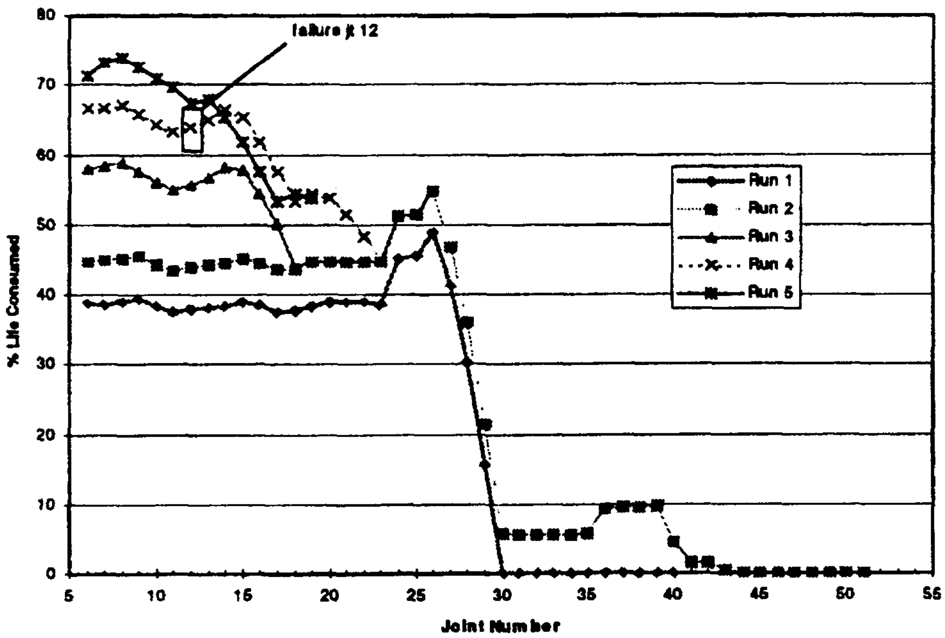

Figure 1 - East Mallet Drill String
% Current Life Consumed for Tubing

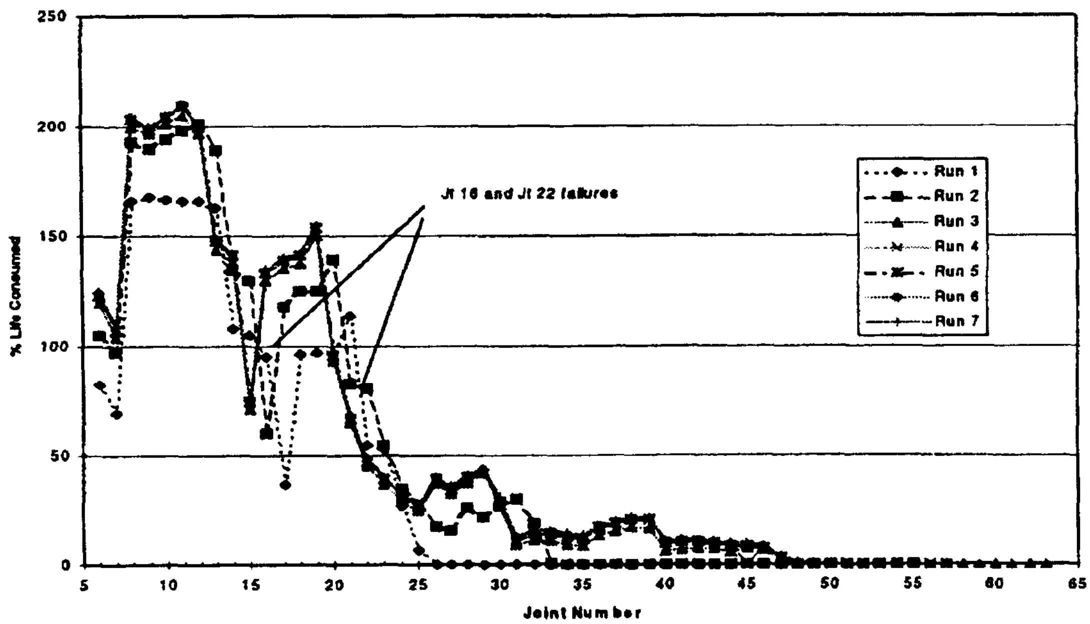

Figure 2 - String #1 at Ratherford
% Current Life Consumed for Tubing

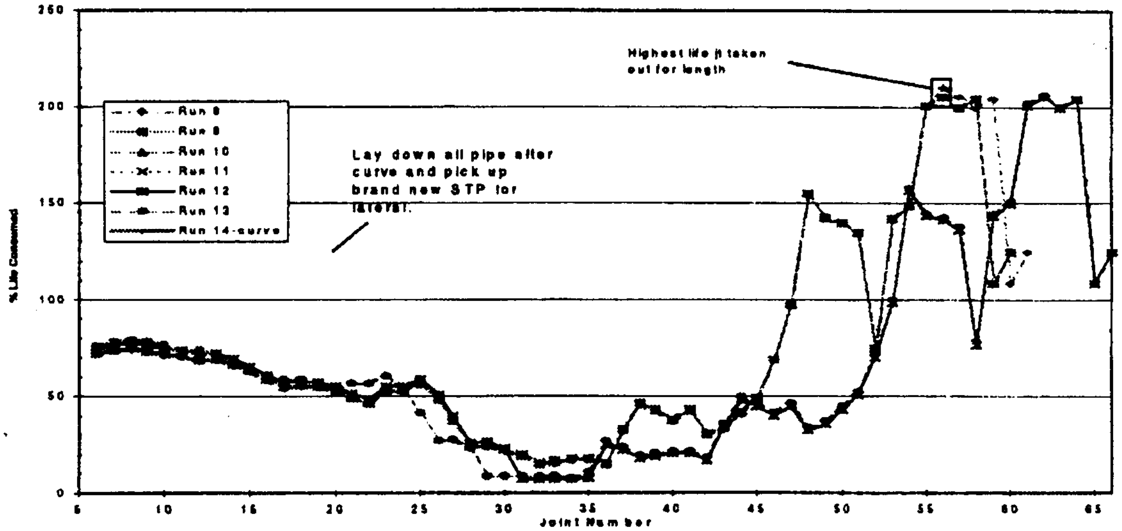

Figure 3 - String #1 at Ratherford
% Current Life Consumed for Tubing (reversed string order)

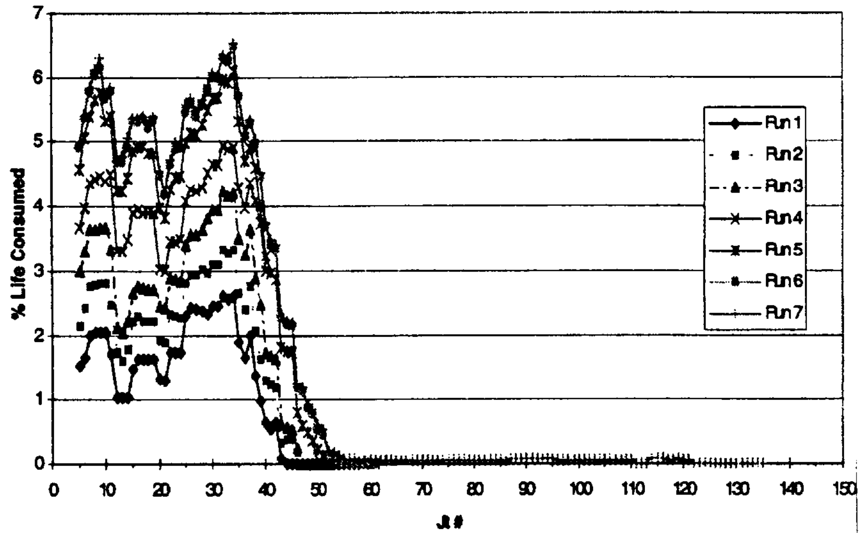

Figure 4 - String #2 at Ratherford
% Consumed Life of Tubing

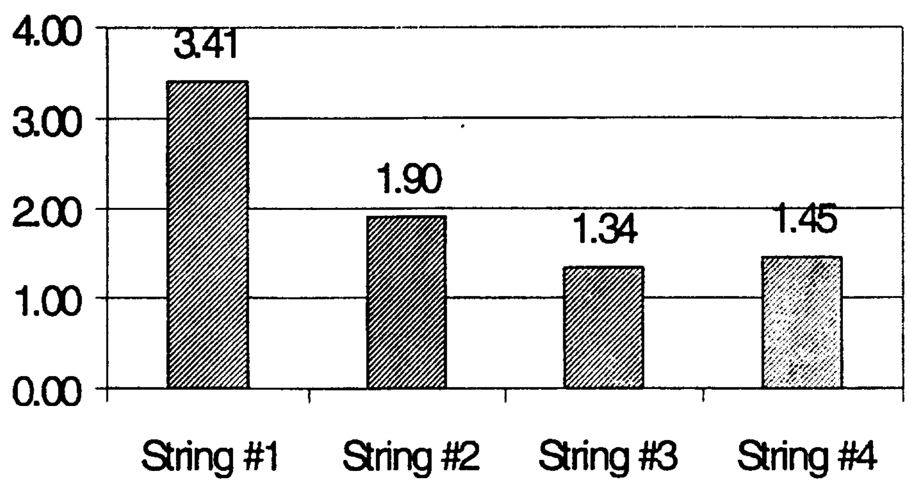

Figure 5 - Ratherford Unit Workstring Costs