

# UPSTREAM TECHNOLOGY

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## CFat Computes Pipe Stress Before, During, After Drilling

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It's a tough life, being a drill pipe. You're pushed up against hard rock and turned to the right at high RPMs. You're under a lot of tension because hundreds of your heavy brothers keep pulling you down, and you're bent this way and that due to dog-legs in the well. No wonder you're experiencing a lot of fatigue – it's enough to make you crack!

Wouldn't it be great if somebody could truly understand how much you've been through lately, and maybe give you a break by locating you in a part of the drillstring where you could take it easy for a while? A little vacation, as it were, before you're put out to pasture? Because if this keeps up, you're surely going to go to pieces, and that won't be a pretty sight!

Enter CFat<sup>SM</sup>, a proprietary software application and service designed by T H Hill Associates Inc. to calculate relative drillstring fatigue for each section of drill pipe. CFat, which stands for corrosion fatigue, evolved from Curvature Index (CI) technology first introduced to the industry in Standard DS-1<sup>®</sup> 3<sup>rd</sup> Edition where:

$$CI = 5 \times 10^8 / \text{number of cycles to failure}$$

The lower the CI value, the better the drillstring integrity.

### Cumulative and Irreversible

"Fatigue due to tension and bending is both cumulative and irreversible," said DeWayne Everage, VP Engineering, T H Hill. "Traditional pipe inspection methods are based on hours drilled and/or footage drilled, neither of which indicate the proportion of damage to the pipe," he told *Upstream Technology*.

Using the Curvature Index, on the other hand, engineers can determine for a given wellpath which drillstring configuration is better from a fatigue standpoint, all things being equal. Alternatively, engineers can compare one wellpath to another for the same drillstring.

"For about 80% to 90% of a drillstring component's usable life, no crack exists. Once a crack forms, failure is accelerated, slowed principally by the material's inherent fracture toughness. The time span from brand new to failure could be hours or it could be years, depending on conditions," Everage explained. "But stress-induced fatigue cracks can exist in a component long before they can be detected by non-destructive testing. If one

crack is missed during inspection, it could cost millions of dollars in non-productive drilling time. However, using fracture mechanics and advanced crack growth models, we can estimate the fatigue performance of the drillstring. Tracking the 'status' of each joint of drill pipe as a result of the forces imposed during operations allows us to assess the relative damage along the drillstring."

The method assumes there is a crack in every pipe joint just small enough to be missed by most commercial inspections, then calculates the Curvature Index. If Drillstring #1 has a CI value that is four times greater than Drillstring #2, then it will fail four times faster, all other things being equal.

"It's all relative, not absolute," Everage said. "Absolute is impractical at plus or minus 1,000% error."

The Damage Point (DP), which is the basis of the CFat service, is proportional to:

$$\text{RPM} \times \text{Curvature Index} \times \text{footage} / \text{ROP}$$

CFat is a service that takes the relative fatigue damage concept and incorporates it into a proprietary software application that is used to estimate the condition for each joint of drill pipe in the drillstring. The software uses real-time data to draw a digital picture as a function of time, calculating the amount of imposed

cumulative damage. Stands of drill pipe that experience far more damage than the others can be taken out of service, or given a "vacation" in another "less dam-

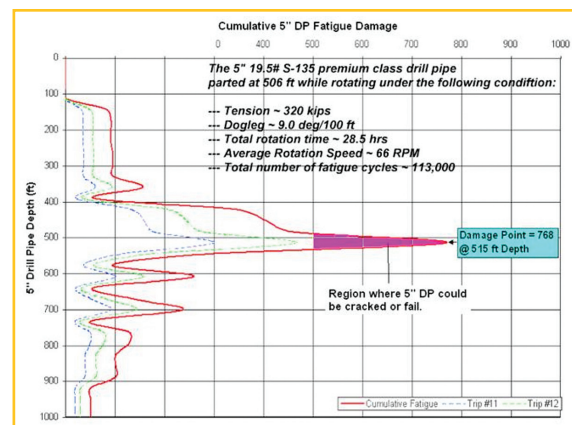


Figure 1. Pre-drill fatigue analysis of 5-in. drill pipe without rotation after drilling the 8.5-in. hole (blue) and with pipe rotation when the drillstring was pulled to change bits.

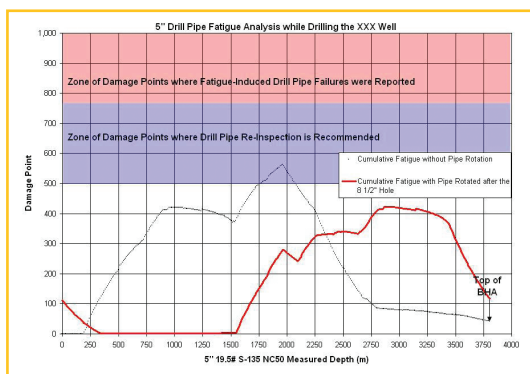


Figure 2. After sidetracking, the pipe joints in the red area would have had a high risk of fatigue failure, so these were removed from the drillstring and laid down. Drilling continued successfully.

pre-drill planning using a mixed-history drillstring; real-time monitoring and updating the well plan; and hindsight analysis or “forensics” after drillstring failures.

### Pre-Drill Planning

In one major drilling campaign, a prediction of pipe movement was critical to use the rig time effectively while minimizing the risk of drill pipe fatigue failure. The main consideration was when to pick up or lay down certain stands of pipe and how to arrange the drill pipe racking sequence within the capacity of the rig.

In this case, the rig was limited by the availability of drill pipe and the mixed drill pipe conditions. The pipe available included Class 2, premium and new drill pipe. The drill pipe racking sequence and a mid-well drill pipe rotation at the end of the 8.5-in. hole section were suggested based on CFat and pre-drill torque-and-drag modeling. The rig crew planned and implemented the drill pipe movement accordingly, and the well was drilled without any fatigue-related failures (Figure 1).

### Real-Time Fatigue Monitoring

Some of the assumptions made during pre-drill modeling, often based on offset well data, may not reflect the actual drilling parameters experienced while drilling. For example, sometimes the ROP is slower than expected due to downhole vibrations, or in a worst-case scenario, the original well needs to be sidetracked due to other well problems. With the drilling data tracked closely, the cumulative fatigue damage in the drill pipe can be carried over into a new well plan.

In one such case, where a well had to be sidetracked due

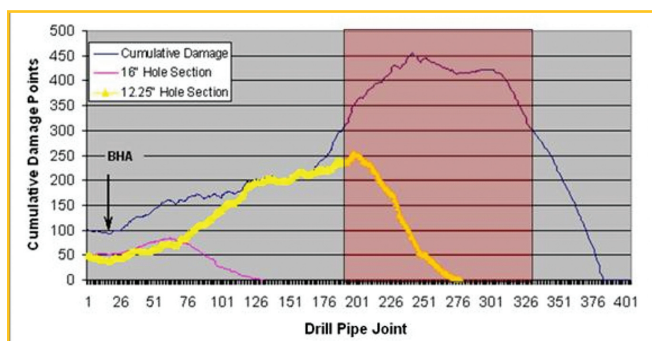


Figure 3. Used in forensics mode, CFat can use actual operations data to determine whether cumulative pipe stress caused a drillstring failure.

aging” location in the drillstring.

To date, T H Hill has performed about 20 different CFat jobs for eight operators. Three different applications of the technology are described below:

to stuck pipe, the pre-drill modeling showed that cumulative pipe fatigue damage at the end of the well would have been below the level where re-inspection or relocation of the pipe would be required, and real-time data tracked the model closely throughout the 12.25-in. section of hole. However, when the drill pipe got stuck in the middle of the 8.5-in. hole section and the well was sidetracked, the pipe had a much higher cumulative fatigue than the pre-drill model had predicted. CFat simulation indicated a high risk of potential drillstring failure for the next section, so T H Hill engineers recommended that a certain section of pipe be laid down, either when pulling the 8.5-in. string or on the way in for the next section of hole. The plan was implemented, and the well was drilled successfully without fatigue failure incidents (Figure 2).

### Failure Forensics

CFat can also be used to investigate the crime scene after fatigue failures. “You’re basically doing forensic analysis with the data,” said Everage.

In one instance, a freshly inspected 5-in., 19.5#, S-135 drillstring was used for a cased-hole fishing/milling job. Total time that this pipe had been rotated before the eventual failure was less than 30 hours, or about 113,000 rotation cycles.

Because of the rapid nature of the failure, poor inspection practices or potential material property deficiencies were initially suspected as the cause. Metallurgical analysis quickly ruled out substandard material.

CFat modeling of the cumulative fatigue in the pipe based on the actual operational parameters unambiguously showed a high level of fatigue damage in a certain section of pipe (Figure 3). The actual failure occurred just seven feet away from the maximum fatigue point predicted by CFat. This “hindcast” failure analysis pinpointed the cause of the failure, which was due to the combined effect of high tension and the 9° dogleg. The results of the analysis strongly suggested that operating conditions, not missed cracks during inspection, had led to the failure.

### Who Keeps Track of the Pipe?

“The contractors who own the pipe want to maximize the drillstring’s use, but it’s the operators who lose big money if there’s a drillstring failure,” Everage said. “The onus is on the operator, but the success of the CFat service is based on keeping accurate track of pipe location.”

T H Hill has stenciled the pipe on the hardness flat of the pin to identify each joint uniquely. Even then, longevity has proven to be an issue. Regardless, the largest hurdle has been the fact that drilling crews are not used to keeping track of the order of individual joints.

“When push comes to shove, it’s amazing how inaccurate most pipe tallies are,” Everage told *Upstream Technology*. For the most effective use of the CFat service, T H Hill recommends having a person on site with the direct responsibility of keeping track of the pipe. This individual does not necessarily have to be a T H Hill employee but, as Everage pointed out, “must be an individual who understands the importance of the process and the value of the results.”

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