Role Of NDT In Controlling The Failure of Drill String

By Dr. Santosh Gupte – ICO Asiapacific Group- Singapore
E-mail: santosh@icoasiapac.com

Affiliation of Author:
ASNT Level III in RT, UT, MT, PT & VT (C.No. 86050)
Member of ASME, ASQ, ASNT, IIW, etc. Reviewing & Contributing Member of TH Hill-USA for DS1 Standards.

ABSTRACT

The upstream industry of Oil & Gas is very much gets affected by Drill String failure while drilling the wellbore.

There are basically five modes of failure of which Inspection plays a major role.

The role of NDT is the most important attribute in Inspection, to have the reliable Drill String right from the component manufacturing till its in-service inspection.

This paper shall provide the sufficient information on selecting the inspection methods and the role of NDT to provide the reliable Drill String for Upstream Industry.

Key Words: Drill String, Drill String Failure, BHA, Drill String Component Inspection
**Introduction:**

**General:**

Oil Well drilling is performed with the rotary method, using many components in string of tubular assemblies with many high tech specialty tools. These components are joined to each other by the thread connections called as Rotary Shouldered Connection (RSC).

In this situation all the components of the string (Drill String) are subject to variable stresses depending on the position occupied in the string. The main stress on the string is due to its own weight (Tensile) and also compressive during drilling. Bending stresses are present due to crooked holes. Torsional Stresses acts due to the kind of make up of RSC and the sour environment adds the stresses due to heavy attacks of corrosion. This complex phenomenon gives a very high challenge for the manufacturer of components of drill string as well as to keep all components in the condition of fit for purpose.

Out of all these above stated stresses, 90% of the probability of Drill String failure is by the stresses due to it’s weight, bending and make up torques for RSC. The failure can lead, in the presence of defects, to failure of a component from fatigue in a matter of hours.

Fatigue failure of Drill String occupies 17% of the NPT of Rig in the World, as per the information provided by Drilling Association.

The paper aims for preventing fatigue failure during service and it also touches the required care to be taken during manufacturing of some of the Drill String Components.

**Drill Stem / Drill Sting:**

The **Drill Stem** is defined by the American Petroleum Institute (API) and International Association of Drilling Contractors (IADC) as all members in the assembly used for the drilling by the rotary method, from Swivel to bit, including the Kelly, drill pipe with tool joints, drill collars and various auxiliary equipment. The drill pipe section includes conventional drill pipe and heavy weight drill pipe. The Bottom Hole Assembly (BHA) may contain drill collars, stabilizers, jars, reamers, shock sub, bit sub etc. **Drill String** is defined as the drill pipe, with attached tool joints, that is used to transmit the fluid and rotational power from Kelly to the drill collars and bit.
Drill String is 80% part for Drill Stem. And BHA is approx 20% portion of Drill String. Drill Pipes constitutes rest of the Drill String.

RSC concept brought to O&G by API in 1910s... the technology evolved and now Numbered Connection (NC) System is been used all over the world.

Drill Pipes / BHA:

It will be in everyone's interest to understand terminology used in OCTG / Drill String. The drillstring provides a passageway for drilling fluids to be circulated around the well. It also transmits rotation to the bit by either applying rotational torque at the surface, allowing a passageway for fluid to be transmitted to a downhole motor to turn the bit or a combination of both.
The BHA can comprise of many different components like jars, stabilizers, mud motors and logging while drilling tools (MWD & LWD). The predominant components of the BHA are the drill collars. Proper design of components and selection of material, of the BHA can prevent many drilling problems.
Manufacturing Process of Drill Pipe in nutshell: As per API Specification 5DP.

Drill Pipe Manufacturing Sequence: Stage ONE

<table>
<thead>
<tr>
<th>Pipe Body</th>
<th>Tool Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Making</td>
<td>Forged Material – Round Bar</td>
</tr>
<tr>
<td>Pipe Hot Rolling</td>
<td>Turning &amp; Boring</td>
</tr>
<tr>
<td># Inspection</td>
<td>Heat Treatment</td>
</tr>
<tr>
<td>Upsetting</td>
<td>Hardness &amp; Mechanical Rest (DT)</td>
</tr>
<tr>
<td># Inspection</td>
<td>Threading – # Thread Inspection</td>
</tr>
<tr>
<td>Heat Treatment</td>
<td>Cold Working of threads</td>
</tr>
<tr>
<td># Inspection</td>
<td>Die Stamping</td>
</tr>
<tr>
<td>Upset End Machining</td>
<td>Had Facing &amp; Break In (Optional)</td>
</tr>
</tbody>
</table>

Stage TWO

<table>
<thead>
<tr>
<th>Friction Welding</th>
<th>Remove Bead and Burr on ID Boring &amp; OD Turning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Treatment (PWHT)</td>
</tr>
<tr>
<td># Inspection</td>
<td></td>
</tr>
</tbody>
</table>

Stage THREE

<table>
<thead>
<tr>
<th>Measuring of Length and Weight (Talley) &amp; Its marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rack Packing and Shipping</td>
</tr>
</tbody>
</table>

API 5DP covers the following grades of drill pipes:

1. Grade E Drill Pipes
2. High Strength Grade of drill pipes, grades X, G, & S.

NDT Methods for Drill Strings during manufacturing to control failures:

1. **Personnel qualification shall be as per:** ISO 11484 or ASNTTC 1A.
2. **Ultrasonic Testing** of Weld Zone, as per the procedure described in 5DP, shear wave testing directing the beam from tube side, to weld on circumference covering 100% weld. The probe shall be of 2.25MHz and 45 Deg angle.
3. **Wet Fluorescent Magnetic Particle Testing** of Weld Zone, as per ISO 13665 or ASTM E709.
4. **Visual Inspection** of Tube & Forged item individually, and after welding as well as after PWHT. 100% coverage.
5. **After PWHT, UT** as per ISO 9303 (Longitudinal) or ASTM E213 & ISO 9305 or ASTM E213 (transverse).
6. **Electromagnet (Flux leakage)** as per ISO 9402 (longitudinal) and ISO 9598 (transverse) or ASTM E570.
7. **Electromagnet (Eddy Current)** as per ISO 9304 (longitudinal) or ASTM E309
8. **MPI** as per ISO 13665 or ASTM E709.

If the above NDT Methods are applied to segregate components of Drill String having any imperfection and apply the correct acceptance criteria, as mentioned in respective product specification such as API Spec 7-1 or 5DP, the probability of developing fatigue cracks will be minimized.

**Bottom Hole Assembly (BHA):**

These constitute the drill stem members at the lower-most position just above the drilling bit. Typically and traditionally they constitute the following: Bit Substitute (BIT SUB); Stabilizer; Reamers & hole-openers;
Failure of Drill String:

The most common places where fatigue failures normally occur in the drill string are:

1. In the body of the drillpipe tube and usually located in an area where slip damage, mashes or dents have occurred also near internal upsets where there are changes in pipe wall thickness.
   * Tool joints are generally stronger than the drill pipe body.
2. In the BHA Components, the weakest portion is connection. The failure occurs in the connection and usually near the last engaged thread root.
   * Connections are generally weaker than the Drill Collar body.
3. The welded portion of any component of Drill String is the portion of weak zone and probability of failure is high if the weld is with some defect. Please refer the figure below.

Needless to say, that these are the areas, which are by default, has highest probability of failure under stresses, if these areas are inspected with highest care and most reliable way, the integrity of components can be established. And capacity to withstand the load and any fatigue crack or the components with Hughes probability of developing it, can be segregated and the probable failure of Drill String can be prevented.
If any section of the drill string has bends or is buckled while rotating then cyclic stresses will occur in that section. The rotation causes the metal in the bent section to go through continuous compressive and tensile loads. Damage accumulates at stress concentration points on the pipe or drill collar and eventually a fatigue crack forms. The crack will continue to get bigger with each revolution and unless it is located by inspection then a failure will happen.

Slip cuts can account for a large percentage of drillpipe tube washouts. Sharp notches or abrupt section changes will focus and accelerate fatigue attack. Studies have shown that fatigue cracks are more than twice as likely on SLIP CUT box ends than on pin ends and will almost certainly originate at the base of the slip cut. UT & MT is required to be planned to establish the integrity of components.

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Control of failure by applying NDT for Used Components of Drill String:

The used Drill String components are subjected at very complex stress conditions as mentioned above. Due to such complex phenomenon, used components inspected by using NDT methods, specifically written for used components, as per the Standards such as TH Hill’s DS1 or FP’s NS2 or API RP 7G-2.

DS1 Vol 3 has established 6 Categories of wells, and corresponding Drill String Components and Vol 4 is for Specialty Tools.

The crack will continue to get bigger with each revolution and unless it is located by inspection then a failure will happen. Fatigue generally starts from Inner or outer Surface of the Drill String Component, that’s the reason MT or PT plays a vital role. Please refer DS1 Vol 3 and Vol 4.

Fatigue cannot be stopped it is a continuous and cumulative process that begins as soon as the pipe goes into service.

Drill collars & other BHA components, usually fail in the connection area because the body of a drill collar is thicker and stronger than the connection.

In standard type connections, when a connection is made up there are some threads on the pin and box that have no contact with each other, these un-engaged threads are stress concentration areas and are prone to fatigue.

To relieve these connection stresses manufacturers will remove the un-engaged threads with stress relieve grooves and bore back boxes. These stress relief features also make the connection more limber.

Another method used in the manufacturing process is to cold roll the thread roots. This cold rolling lowers the rate of connection fatigue by pre-loading the thread root with compressive stress.
At all these steps, NDT plays important role to find out the fatigue cracks and other imperfections, which may produce the fatigue cracks during drilling operation in down hole. Fatigue cracks propagates from surface imperfections, and through applying NDT, it is 99% certain to locate the weakest area or point at which, due to stresses, fatigue may accumulate to form the crack.

The major NDE methods used as per DS1 / NS2 are:
3. EMI for Drill Pipes and Drill Collars.
4. UT for various tools.
6. ACFM for RSCs

DS1 Vol 3 has categorized the acceptance requirements of all above NDE methods based on the well depth and varies from Category 1 to 5 and Heavy Duty Landing String (HDLS).

By establishing the optimum NDT program on the basis of categories as stated in DS1, the probability of detections of fatigue cracks increases and ultimately the failure is controlled.

“If there is no imperfection on surface; there will not be any failure of component.”
The above statement is very much true in ideal condition, but there are no ideal conditions, in life. However, by applying correct NDT program, we can minimize the Fatigue Cracks and ultimately control the Failure of Drill String. The Role to control the failure of Drill String is very vital.

**Conclusion:**
1. Proper designing and selection of material can control Failure of Drill String,
2. Second most important aspect to control the drill string failure is to apply the NDT programs as per the standards / specifications mentioned in this article for new and used components.

**References:**
- DS1 Standard Edition 4 Vol 3 & 4,
- NS2 Standard,
- API RP 7G-2
- API Specification,
- API Specification 7-1 & 5DP