"How fast can we rotate this casing?"

A seemingly simple question without a simple answer.

Oil Country Tubular Goods (OCTG) were designed for static load conditions. Even though dynamic loads occur during running associated with lifting, lowering, and stopping, those types of dynamic loads only impart axial load cycles. Rotating casing introduces repeated and persistent dynamic bending loads that cycle casing and connections through alternating tension and compression.

It isn't possible to precisely determine actual combined loads associated with rotating at all points in the casing string. This is due to the number of unknown factors associated with the wellbore geometry and trajectory. Higher rotating speeds amplify impact loads that occur downhole.

Fatigue Life

API material grades for OCTG have a finite fatigue life. The number of stress reversals to failure by fatigue, commonly known as the endurance limit, is indirectly proportional to the applied stress range. Higher stress ranges result in lower number of cycles to failure. This is illustrated by the S-N Curve for Tubulars presented in the attached figure.

Rotating in a "Straight" Hole

Probably the best place to start the discussion is with an understanding of how rotating affects casing. In a perfectly straight hole with a perfectly balanced, free-hanging string (i.e. casing/connection combination), rotating is benign. In this ideal scenario, there would be no bending stresses or vibration. The casing would simply be spinning about its own axis with no additional introduction of bending stresses or stress reversals. An analogy would be like a perfectly balanced automobile wheel or ceiling fan blades. There would be little if any rotationally induced vibration.

However the downhole world is not ideal. Few wellbores are perfectly straight. Few casing strings are balanced. Casing joints are not straight nor are they perfectly round and may even have hooked ends. There may also be wall thickness variations within individual casing joints and among joints of casing. It is rare for top drive equipment that turns the pipe to be perfectly aligned with the wellbore. So, spinning pipe wallows, imparting repeated stress reversals into the casing string. Since the string is not balanced, the casing deflects differentially along its length thus inducing bending stresses which are variable along the string length. Higher rotating speeds impart additional harmonics with greater deflections and correspondingly higher bending stresses.

In Drilling-with-Casing (DwC) operations which are performed primarily in "straight" holes, the amount of off-axis deflection in the casing string is limited by the annular clearance between the casing OD and the wellbore. A corresponding scenario might assume a ±3°/100 ft. bend. On 5 ½" OD, 20.00 ppf, P-110 casing, this equates to a bending stress of ±~3,600 psi or a total stress range due to axial bending of ±~7,200 psi. Admittedly, this does not appear severe as the total stress range consumes only 6.5% of the specified minimum yield strength (SMYS) for P-110 material. This simple example assumes only uniaxial bending and does not include buoyant string weight, differential pressure, or additional applied axial load to assist string advancement. Nor does this account for impact loads such as where the casing interacts with the wellbore wall or when the DwC casing bit encounters hard spots or rocks. Under these conditions rotating at high RPMs ranging from 60 to 100 (and higher) is common and has been successful.

It should be noted that vibration, slip-stick, and impact loads common to these operations have been ignored in this trivial example. These potentially damaging localized and potential high stress inducing loads cannot be accurately quantified without full string instrumentation.

Rotating in a "Deviated" Hole

Rotating in a deviated hole is typically performed to assist string advancement to target in an extended reach horizontal well. In these cases, there are numerous unknowns that render the question, "*How fast can I rotate this string?*" un-answerable with any certainty.

The best place to start is to answer the question about wellbore condition.

- What is the trajectory?
- Are there micro-doglegs?
- What are the actual localized build rates?
- Is there a constant radius of curvature?
- Are there washouts?
- Are there tight spots?
- Are there ledges?
- Are there wellbore irregularities that are larger than the upset between the pipe and coupling ODs?

Any of these conditions, individually or in combination, can result in unexpected excessive bending stress levels that can be detrimental to string performance during rotating operations.

Using 5 1/2" OD, 20.00 ppf, P-110 casing installed in a well with a nominal 10^{o}/100 ft. build section and assuming a uniform radius of curvature, the associated stress range (due to bending only) with a rotating cycle is ~24,000 psi (±~12,000 psi bending stress), or 22% of P-110 SMYS. Obviously, this results in a higher stress range than rotating in a "straight" hole and a correspondingly lower expected fatigue life.

Directional holes never have uniform radii of curvature and wellbores are rarely regular. Let's look at a case in the wellbore where there is a 22^{o}/100 ft. micro dogleg. In this localized area, the stress range more than doubles, increasing to ±~52,800 psi or 48% of SMYS. With an irregular wellbore, where the casing is intimately in contact with the wellbore at a connection, bending stresses increase significantly which further decreases expected fatigue life.

This simplified example does not account for applied axial (tension or compression) loads that may be applied, vibration(s), slip-stick, impact loads, and possible local buckling associated with washouts, differential pressure, and other factors that may induce increased stresses in the casing string.

Conclusion

So, "***How fast can we rotate this casing?***"

Fatigue life is a function of material properties, stress range, and number of stress reversal cycles. API 5CT, API 5L, and mill proprietary casing/coupling materials have a finite fatigue life. Higher stress ranges yield lower fatigue life. So, as a general rule of thumb, casing should never be rotated at higher RPMs than needed for task accomplishment. For the same stress range, casing rotated at 10 RPMs will last 2 times longer (more rotating hours) than casing rotated at 20 RPMs.

There is a lot going on when rotating casing. Some, but not necessarily all, factors that may be detrimental to casing/connections during rotating operations are presented in the list below.

- Casing whirl – Excessive vibration that sometimes occurs with rotating casing at high RPMs.
- Wide torque variations or undulations; beware of torque spikes that exceed the yield or maximum operating torque for the casing and connections.
- Impact loads due to slip stick, hard spots, tight hole, and other wellbore anomalies.
- Applying axial loads (tension or compression) while rotating at high torque. Casing strings should not be treated like drill pipe. Combined torsion with axial (tension or compression) loads may cause unexpected casing or connection failure.

The user has superior knowledge about all aspects of the wellbore and well site operations and therefore assumes all risks associated with casing and connection related issues that occur during and after rotating operations. In addition, dynamic operations, such as rotating casing, need to be monitored by qualified and experienced professionals who understand all potential issues and can make informed decisions to reduce the associated potential risks.

2.4.6 S-N curves for tubular joints

S-N curves for tubular joints in air environment and in seawater with cathodic protection are given in Table 2-1, Table 2-2 and Table 2-3.

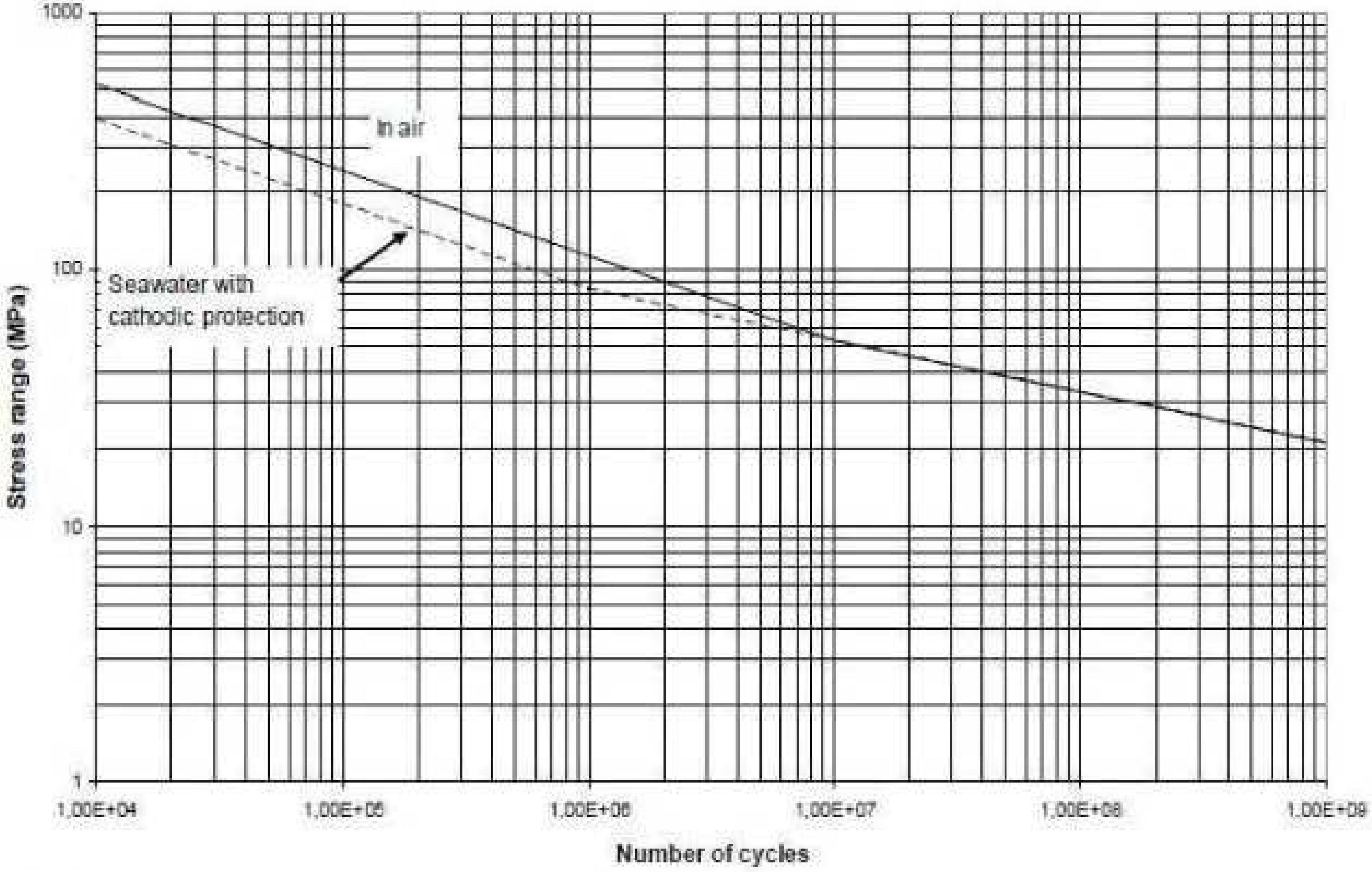

Figure 2-8
S-N curves for tubular joints in air and in seawater with cathodic protection

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Reference: DNV Recommended Practice DNV-RP-C203 Fatigue Design of Offshore Steel Structures, April 2008, Page 15