THE WEIGHT IS OVER

The Positive Use of Aluminum in the Oilfield

(Part 2 of 4)

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In part 1 we discussed the reticence of the energy extraction industry to accept advanced technologies even as the effort to streamline operations and reduce lifting costs continues apace. Part 2 will deal with a few specific issues related to the work completed to validate the use of drill pipe in the oilfield. Aluminum per se does not represent a technological advance but the correct use of this alloy brings many advantages hitherto not exploited. In part 1, we mentioned the adverse effects of heavy traffic on local infrastructures, mainly road damage. The Texas Department of Transportation, in response to this, plans to convert many roads back to gravel and reduce speed limits to 30 mph. (The San Antonio Express-News, 30th July 2013). Is this really the answer and is this the best we can do? Also, an additional $1 billion will be appropriated to deal with the need to restore rural roads.

It is now generally accepted that giant offshore platforms may be as much as 3 times as heavy as needed, resulting in huge capital cost increases and additional maintenance over time. Even the old soldier, the wire rope, is being replaced by lighter and stronger and longer lasting polymer materials. So the time is right to highlight the benefits of today’s advanced high strength, low weight and corrosion resistant Aluminum alloys.

Deepwater wells of extraordinary depth are being discussed. These wells will most likely require a redefining of the materials used and one focus will undoubtedly be on final weight.

ALUMINUM DRILL PIPE

Aluminum pipe is manufactured in an extrusion process and can be produced with varying wall thickness along a seamless tube
pipe body. This tapering allows for increased thickness and greater strength around the tool-joint interface and, in addition, an upset wear band can be integrally extruded in the center of the pipe body. Both of these features play a role in increasing the pipe’s resistance to bending fatigue and to a certain extent help to reduce the tendency of the pipe to become helically buckled. The tapering and the center wear band also play beneficial roles in reducing pipe body wear and mitigating the fatigue risk due to bending stress.

Given the tapered geometry and lower material hardness of the aluminum pipe profile some relatively minor handling modifications should be made relative to normal rig operations. The first, and most critical, is to provide for tapered and non-marking slip dies. The tapered and non-marking dies will allow for a larger and more consistent area of contact between the pipe body and the dies, reducing stress concentrations and the potential for impartation of stress concentrating deformations in the aluminum pipe body. The second key consideration is for a slight relief of the elevator bushings to accommodate the larger outside diameter of the tapered aluminum pipe profile near the tool joint shoulder. Finally, consideration should be made to minimize, to the extent practical, aggressive contact between steel surfaces and the softer aluminum pipe body. This can easily be accomplished through the use of soft spacers, soft slings, modified lifting elevators or lifting caps.

Aluminum pipe is manufactured in standard nominal sizes from 4” to 5⅞”, but typically has a greater wall thickness than equivalent steel pipe. The pipe is generally ±40% lighter than equivalent sized steel pipe.
The most common alloy used in the manufacture of aluminum drill pipe is in the Aluminum Association 2xxx series (Copper-Silicon-Manganese) and has maximum yield strength of 58,000 psi. This is considerably lower than common steel pipe grades, such as S-135. However, due to its lighter material density and greater buoyancy effect, the strength-to-weight ratio of aluminum pipe is equivalent to or better than steel pipe.

Aluminum drill pipe is fitted with standard steel tool joints through a thermal shrink fit process and resulting interference fit between the steel tool joints and aluminum alloy pipe body. The connection is typically hydrostatically tested and rated pressure tight up to 5,000 psi. The pipe body is machined with threads on either end and tool-joints are back threaded with a “service connection” and then thermally fitted to the pipe. Essentially any type of API or premium tool joint can be fitted to the pipe, allowing for a wide range of operating conditions.

The critical buckling limit of aluminum pipe is approximately 60% that of steel, meaning
aluminum pipe has the potential to become helically buckled in situations where a full string of steel pipe would not. However, due to its lighter weight per foot, the compressive loads on aluminum pipe are generally lower than with steel while tripping in or while slide drilling. In rotary drilling mode, drill pipe is most likely to buckle when it is placed in the horizontal section of a wellbore where weight on bit induces compressive loads on the pipe. While slide drilling, drill pipe is most likely to buckle when it is placed above the kick-off point or in the upper portion of the lateral (near the end of the build section).

For the trial described in this case study, only rotary drilling was used.

Aluminum pipe also has lower resistance to bending fatigue than steel, and therefore there is a greater risk of pipe failure if the aluminum pipe is placed in the string and operated in a portion of the wellbore with high dogleg severity, or if it is rotated while helically buckled. While the fatigue endurance of aluminum is lower than steel, this attribute is somewhat offset by aluminum’s lower modulus of elasticity, which results in lower bending stress when compared to steel, assuming other parameters are identical (such as dogleg severity and tube dimensions).

Given the properties of aluminum drill pipe, the proper placement of aluminum in a combined (steel + aluminum) string is essential to realize the maximum performance benefits while minimizing risks. Determining the optimum placement requires thorough torque and drag modeling of the planned operation.

Some final considerations that must be taken with 2XXX series aluminum alloy drill pipe are its temperature and corrosion operating limits. 2xxx series aluminum alloys develop
their high strength from thermal heat treating and aging processes that occur in the 240-300F range. As a result, 2XXX alloy pipe should not be used in well environments in which the aluminum alloy pipe body will reach temperatures at or above 240F for extended periods of time, unless a down grading for strength reduction is considered. Well established aging curves are available for 2XXX alloys that will allow for appropriate temperate related strength down grades.

With respect to corrosion, 2XXX alloys are very stable in pH ranges of 3 to 10. Outside the acceptable pH range, pitting can occur that will reduce wall thickness and may require a down grading of the pipe. 2XXX alloy pipe has also shown good resistance to H2S exposure in water based drilling mud with concentrations of H2S up to 10% psia. More data is needed on 2XXX alloy performance in H2S and several studies are now in process.

**TORQUE AND DRAG BENEFITS OF LIGHTWEIGHT DRILL PIPE**

Although the industry has made significant progress in understanding torque, drag and buckling in extended reach wells, there are still many misconceptions in the field. Torque and drag, although generally lumped together, are not directly related to one another, and factors that increase or decrease one does not directly lead to an increase in the other. Lower inclination wells do not necessarily have lower torque or lower drag. “Low dog-leg severity” does not directly result in lower torque and drag. In addition, the occurrence of helical buckling while drilling is often underestimated and frequently not identified when it does occur. Torque and drag monitoring can be a critical tool for monitoring hole conditions while
drilling, but only if the physics of what is occurring down hole is properly understood and accounted for.

The weight of the drill pipe does directly impact torque and drag loads, but pipe weight is not the only factor. The ultimate length of aluminum pipe that can be operated safely is limited either by tensile loads, torsional loads, or bending fatigue. A very significant reduction in torque and drag loads can be achieved through the use of a string containing both steel and aluminum components. Torque and drag are caused by side-forces - normal forces which occur whenever there is contact between the pipe and the wellbore (Johancsik et al, 1983).

There are four distinct categories of these normal forces:

- **Low-side forces** - Occur from the weight of the pipe laying on the low side of the hole in an inclined well,

- **Brake drum forces** - Also known as the capstan effect, this force occurs as the pipe is pulled to the side of the hole by the tension or compression in the string in curved portions of the well.

- **Stiffness forces** - Occurs due to the pipe’s resistance to bending, forcing it towards the sides of the hole through a tortuous well path and,

- **Buckling forces** - Occurs when a pipe becomes helically buckled and the coil pushes laterally into the side of the hole (Wu et al, 1993).

The combination of these four categories of forces creates a complex situation where the loads measured at surface are often not the worst case loads that drill string components experience, and surface measurements do not directly reflect the actual loads imposed.
on any particular component of the string. Over the course of an operation, the relative magnitudes of these torque and drag forces will change.

Aluminum pipe has a lower Young’s Modulus than steel (10,600,000 psi vs. 30,000,000 psi for steel). This serves to decrease the force required to initiate helical buckling and at the same time increases the additional side-forces created when a given compressive load is applied to the pipe. The moment of inertia, and radial clearance, can be increased by manipulating the dimensions of aluminum drill pipe, this helps to reduce the buckling tendency of aluminum pipe but can only go so far without greatly increasing the OD or decreasing the ID of the pipe which would create hydraulics issues making the resulting pipe a poor selection.

**COMBINED EFFECTS OF ALUMINUM PIPE ON TORQUE AND DRAG LOADS**

While aluminum does directly reduce the portion of torque and drag loads created by “low-side” forces, its influence on both “brake-drum” forces and buckling induced side-forces vary depending on the well path, the length of aluminum pipe and its position in the string.

In a low angle well-path, aluminum pipe would reduce torque and drag loads primarily by reducing “brake-drum” side forces through any build section in the well.
path. In a horizontal well path, brake-drum effects are generally less than the “low-side” forces. Use of aluminum pipe would reduce the low-side forces but this may not necessarily translate to reduced torque and drag loads as the risk of buckling would be increased with aluminum pipe in the horizontal. Successfully managing this scenario would require reducing the weight on bit to keep compressive loads on the aluminum pipe below the helical buckling limit. If you made it this far, thank you for your attention. Part Three will follow in 2014.
Offshore Modular CT Spread in Aluminum

Courtesy of CT Logics
Aluminum Construction: Coiled Tubing Trailer, Coiled Tubing Injector, Coiled Tubing Workreel and other Components. Total weight close to half that of steel construction.