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RISER PROTECTION

Hardbanding halts deepwater wear

Rupture of deepwater drilling risers could be devastating. Fortunately, proper modeling and hardbanding can prevent it.

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Figure 1. Riser materials wear up to five times faster than casing materials with comparable physical properties.

Major oil companies, independents and drilling contractors operating in ultradeep waters are encountering a new set of potentially catastrophic operational parameters. Since 40 of the 77 deepwater drilling rigs around the world are equipped to operate in waters deeper than 6,000ft (1,829m), identifying and preventing the causes and effects of riser wear has become a pivotal issue.

While riser failure can be economically devastating, the safety hazards and potential loss of life, combined with environmental discharge and endangerment, require a certain amount of industry collaboration. If the industry does not police itself, the US Minerals Management Service is sure to do so – albeit at a much stiffer price.

A collective industry effort to anticipate riser wear problems already has been initiated in the North Sea region by the Atlantic Margin Joint Industry Group. A consortium of major oil and drilling companies is establishing new standards for inspection and wear criteria in the form of an integrity guideline because existing guidelines do not address ultradeepwater operating conditions.

Recent public forums in the US market, combined with consultations with Maurer Engineering, have enabled us to compile extensive information on riser wear analysis. We also have been researching this problem for the past 9 months and sharing our engineering findings with an international drilling contractor for more than 4 months. Consequently, we believe we have identified one of the critical components that can be controlled in the reduction of riser wear. Below we describe a tool joint hardbanding success that allowed an operator to complete a well without further mishap after a riser failure had occurred.

Causes of riser wear

The precise relationship between several critical variables must be considered to prevent riser wear effectively while drilling in ultradeep waters. The deeper the water, the greater the potential for catastrophic occurrences resulting from wear caused by high drillstring tension pulling the rotating tool joints against the curved sections of the riser. Furthermore, tests on casing and risers have demonstrated riser materials wear up to five times faster than casing materials with comparable physical properties (Figure 1).

According to Maurer Engineering's studies, wear is greatest at the highest curvature points in the riser (particularly at the flex joint), as the normal forces pushing the drillstring into the riser wall are greatest at these points. In fact, wear usually occurs within 50ft (15m) of the flex joint and can continue through the flex joint into the blowout preventer (BOP), reducing wall thickness so much that the BOP will burst (Figure 2). In addition, the heavier the mud, the sooner the riser is likely to fail, as the weighting materials act as grit between the drill string and the riser, wearing it away.

An important symptom of riser wear is keyseating, whereby the tool joint wears a groove in the riser, ultimately causing the riser to burst and release drilling mud onto the ocean floor. If enough drilling fluid is lost through the worn riser, the hydrostatic pressure at the bottom of the well will be reduced, setting the stage for a catastrophic blowout. Keyseating has been observed in more than one riser failure in the Gulf of Mexico (Figure 3).

The variables most likely to influence riser wear include:

- curvature (or dogleg severity) of the riser as it enters the flex joint, which is increasingly difficult to control in deeper waters;
- riser material and positioning (angle between the riser and flex joint);
- type of hardbanding material applied to the tool joint;
- rotating hours;
- riser tension;
- quantity of abrasive materials contained in the mud; and
- rate of penetration.

A sensitive balance

Drilling vessel stationkeeping is certainly one contributing factor in riser positioning. The accuracy of traditional anchoring systems must be compared to the effectiveness of dynamic positioning systems, which are being increasingly used. Probably the most important factors in preventing riser wear are the exact location and finite tolerances of rig positioning over the well, along with the undisturbed maintenance of this position.

High-tension loads occurring in deepwater operations further complicate the positioning balance. The essential variables that need to be evaluated in making these delicate calculations accurately are the 2 million to 3 million lb of tension experienced in ultradeep water, combined with the concurrent need for drillstrings to accommodate significant load increases. Allowances for unpredictable subsea currents and vector forces also must be included in these considerations.

Companies have begun to rely on globally positioned satellites, land stations and acoustic sensors on the subsea BOP pod to ensure an accurate position over the well when drillships are used. The input from each source is combined by sensors that detect the direction and force of wind and water (waves and current), which then are relayed electronically to the vessel's propellers, rudder and thrusters to maintain position within a watch circle having a standard radius deviation of about 15ft (5m).

In true deep water, the effects of gravity (mud weight and distributed riser load), combined with an unknown and probably multidirectional side loading from currents, add to the difficulty of minimizing the flex joint angle. Furthermore, the current loading can change in a short period of time. In such cases, adjustments to the flex joint angle depend upon evaluating the vessel offset and top riser tension. In ultradeep water, guideline offset angles of 0.5° to 1.0° are being used because larger offset angles cause excessive wear in risers, flex joints and BOPs.

Tool joint surface heat

Another new and serious problem that has surfaced in ultradeepwater drilling involves the heat checking of tool joints. It is believed the outer surface of the tool joint must reach 1,400°F (759°C) for heat checking to occur.

At this extreme temperature, the matrix composite of carbide hardbanding (the metal around the carbide deposits) softens, allowing it to be worn away easily. Consequently, the carbide particles, with no material left to anchor them in place, disperse and fall off. However, amorphous metals exhibit excellent hardness resistance and will remain stable up to 1,700°F (926°C).

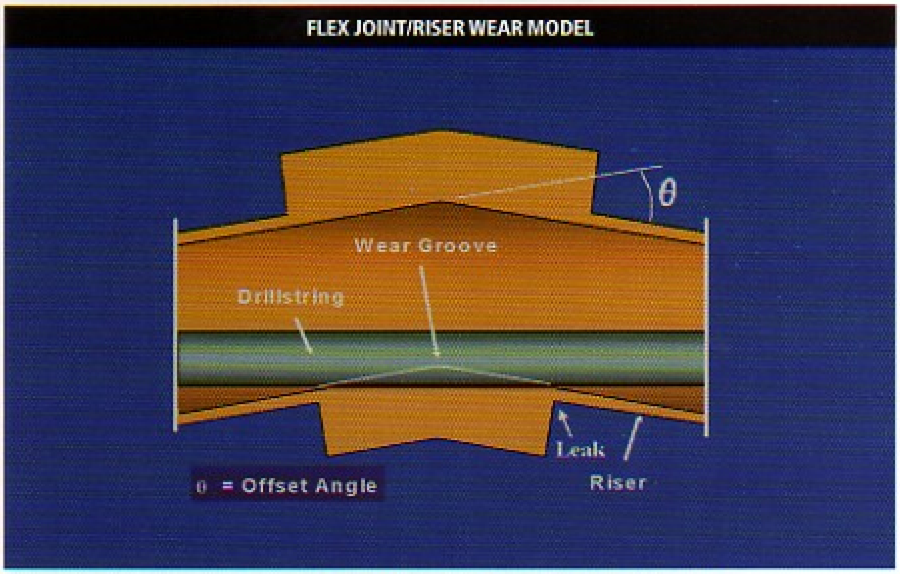
FLEX JOINT/RISER WEAR MODEL

Figure 2. Riser wear usually occurs within 50ft (15m) of the flex joint due to friction.

TABLE 1. ARMACOR MSTAR ALLOYS	
Element	Weight %
Carbon	0.04-0.06
Silicon	0.04-0.06
Chromium	25.5-30.0
Nickel	5.0-7.0
Manganese	1.2-2.4
Boron	3.2-3.7
Iron	remainder

Typical case

Initial riser failure symptoms might first become apparent with the loss of drilling fluid circulation. When pumping material downhole does not revive the circulation, the likelihood of a crack in the riser increases. When this happens, it also is likely that keyseating has been caused by the friction between a tool joint coated with the traditional hardbanding material, such as tungsten carbide or chrome carbide, and the internal diameter of the flex joint. In several cases it has been found that the keyseating wear grooves identically equaled the outside diameter of the tool joint.

Industry consultants believe that in several of these cases, it was primarily the tool joint rotating at a high offset angle that caused the wear resulting in failure. After testing a tool joint from one of these drillstrings using its own N-80 casing samples, Maurer Engineering determined the casing wear factor was 10. According to these consultants, a given wear factor is a "constant of proportionality between wear volume and the frictional work done to produce the wear. The bigger the number, the larger the volume that will be worn away by a given volume of work." It was found that the tool joints in these cases, which were hardbanded with abrasive tungsten carbide, wore the riser samples nine to 14 times faster than standard N-80 casing samples.

The solution

During one particular riser failure, a contractor changed the hardbanding material on its tool joints in an effort to resume drilling and eliminate abrasive materials that might damage the riser again. This action was taken because of the high wear factor of the original tungsten carbide hardbanding. It became clear that chrome carbides and tungsten carbides, when used under severe drilling conditions of metal-to-metal contact, could cause extremely abrasive wear if matrix failure were to occur. The tungsten carbide hardbanding had acted as a grinding machine, wearing through the riser during the keyseating process. The drilling company decided to try a different hardbanding material.

Armacor MStar, which has been used in offshore applications since 1992, already had undergone considerable testing and had performed well in the reduction of casing wear. Consequently, the drilling contractor decided to try Armacor as a hardbanding material to see if it also would reduce riser wear. Armacor has an amorphous surface structure, which possesses a low coefficient of friction and low abrasive potential. Using tool joints hardbanded with Armacor, the well was completed with no further mishaps or drilling disruptions.

New alloys, amorphous structure

Armacor MStar exhibits strong metallurgical properties that are different from the tungsten carbides and chrome carbides traditionally used for hardbanding (Table 1). The random, or amorphous, atomic structure which is inherently present to varying degrees in the material makes Armacor unique. The development of amorphous surface structure during wear is induced by the wear process itself and has been described as a "metamorphic" transformation. It results in a wear surface consisting of a high-strength amorphous matrix containing a dispersion of very


KEYSEATING GROOVE

Figure 3. A cutout of a failed riser reveals a keyseating groove.

refractive boride particles, which are formed during the original deposition of the Armacor and remain embedded in the hard matrix during the wear-induced transformation. The hard boride particles are strongly bonded to the matrix.

Surface transformation occurs upon grinding, which produces an amorphous, nanocrystalline structure at the wear surface. This transformation results in a dramatic increase in surface hardness and a reduced coefficient of friction. The properties attributed to amorphous metals are indigenous to their structure. These metals are comprised of atoms that do not align themselves in any fixed pattern. As there are no patterns or grain boundaries within the metal's structure, there are no weak or inconsistent spots, and the mechanism of deformation is fundamentally different. High hardness, excellent corrosion resistance, good ductility, a lack of spalling, and low friction coefficients characterize the amorphous material.

MStar's amorphous surface is uniquely suited to cased drilling applications, particularly in deeper wells where it may contact the riser wall. In oilfield applications, Armacor strongly recommends that it not be applied over other hardbanding materials whose surface is already cracked or spalling, and whose chemical composition is unknown. ■

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