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Hardbanding And Its Role in Deepwater Drilling

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Abstract

Hardbanding of drill pipe tool joints and other drilling equipment has been around since the late 1930's. Originally, hardbanding was applied primarily to protect the drill pipe and other tools from premature abrasive wear. Since that time, there have numerous changes in hardbanding and its application, but only within the last few years has new technology been introduced that allows hardbanding to protect the casing, the marine riser and the drill pipe at the same time.

Hardbanding is one of the most simple yet most misunderstood products being used on a drilling rig today. Along with the new technology being utilized to drill the highly deviated wells such as horizontal, ERD, or multi-directional, comes the problem of creating excessive downhole drag and torque. All of this drag and torque creates friction, which, in turn, creates wear on the drill string, the marine riser and the casing. Today, there are several types of wear resistant alloy hardbandings on the market. Most of them are designed to protect either the casing, riser or the drill string, but only one or two of them can sufficiently protect all of them at the same time.

Though the wear resistant alloy hardbanding technology has only been on the market for 6-8 years, it has gained increased popularity over conventional tungsten carbide hardbanding for several reasons. This technical paper will attempt to address these points in order to educate concerned parties as to which hardbanding to use in a particular situation.

The proper hardbanding with the right application can:

- Substantially increase the tool joint wear life
- Greatly reduce casing wear caused by the drill string
- Substantially reduce downhole drag and torque
- Reduce rig fuel consumption
- Allow operators to run lighter weight and grade casing

Introduction

Over the past 60 years hardbanding has been responsible for many casing failures costing operators literally millions of dollars in repairs, sidetracks, even well abandonment. In addition to this, it cost the drilling contractors equally as much in drill string and marine riser repair and/or replacement.

Along with the need to drill more critical wells, such as directional, horizontal, ERD, and deepwater, came the need to develop products that would reduce the amount of wear caused by the drill strings being rotated or tripped inside the casing or riser and in long sections of open hole.

Extensive casing wear studies, such as the Maurer Engineering DEA-42, have taught us the primary causes of casing failure and what products may be used to prevent them. The object that causes the most casing and riser wear is the drill pipe tool joint. Because of the larger diameter of the tool joint, compared to the drill pipe tube, whether in tension or compression, whether it is tripping or rotating, it is constantly in contact with either the open hole or the casing wall. With this in mind, that constant contact is always creating some sort of wear, either tool joint wear, casing or riser wear, or, most common, all of the above.

In 1990, new wear resistant hardbandings began being introduced to the drilling industry. Now, after some eight years of development, these hardbandings have been found to offer a viable solution to the problem of casing and riser wear caused by tool joint contact with the casing or riser wall. Even further developments have resulted in extended tool joint wear life while, at the same time, drastically reducing the casing and riser wear. Casing failures caused by drill string wear have practically been eliminated when using the proper wear resistant alloy hardbanding.

History

When hardbanding was developed in the late 1930's, it was primarily used to protect the drill pipe tool joints from rapid abrasive wear in open hole drilling. This hardbanding consisted of a mild steel matrix with sintered tungsten carbide particles dropped into the molten weld puddle during the hardbanding application process. It was applied in a raised, or proud, condition to prevent the tool joint from contacting the side of the hole, either open or cased. This was a very successful method of protecting the tool joints until the wells became more critical, deeper and more directional in nature. When this happened the industry began experiencing casing failures caused by the raised tungsten carbide hardbanding that was cutting away at the casing wall during drilling and tripping operations. To combat this problem the drill pipe manufacturers tried different shapes of tungsten particles, but to no avail. It was finally determined that no matter what shape the tungsten particles were, as long as it was applied in a raised condition, they would still experience severe casing wear. It was then that Hughes Tool Company developed and introduced *Hughes Smooth X™* hardbanding. This entailed machining a groove into the tool joint body and applying the tungsten carbide hardbanding flush with the tool joint O.D. This seemed to improve the casing wear problem considerably and soon became the industry's standard hardbanding for drill pipe. However, as the wells became even deeper and more directional in nature, the issue of casing failures became even more critical than before. Again, the tungsten carbide hardbanding was blamed for these failures. Hughes Tool Company developed and introduced *Hughes Super Smooth X™* hardbanding. This consisted of machining an even deeper groove into the tool joint body, applying one layer of tungsten carbide hardbanding at the bottom of the groove and then applying a layer of mild steel on top of the tungsten carbide, flush with the tool joint O.D. This, in turn, prevented the tungsten carbide particles from making direct contact with the casing wall. That was, until such time as a large portion of the tool joint O.D. was worn away and the tungsten carbide was finally exposed.

When operators continued to experience casing failures, they decided to discontinue the use of hardbanding altogether and use only drill pipe that no hardbanding on the tool joints. It was then that the problems seem to be compounded. Now, to go along with casing wear, operators were required to repair or replace the drilling contrator's drill string, as it was wearing out at an alarming rate. Up until this time, drill pipe was considered an expendable item. Delivery time for new drill pipe was short and there was a considerable amount of used pipe available at very reasonable prices. Protecting the drill pipe tool joints had been a low priority and much less expensive than casing failures.

What the industry did not realize at the time was that the milder tool joint steel caused almost as much casing wear as the tungsten carbide particles **(Table 1)**. This was due to a galling action that occurs when two relatively soft steels, such as the tool joint and the casing, contact each other and cause friction. It was not until the industry began searching for some definitive answers to their continuing problems that they realized that unhardbanded, plain steel tool joints caused almost as much wear as those hardbanded with tungsten carbide **(Ref 1)**.

In 1989/1990, Amorphous Technologies, Inc. developed a chromium alloy hardbanding, *Armacor M™*, that, when run inside the casing, would substantially reduce casing wear. This was an amorphous (i.e. work hardened) type material that had a very low co-efficient of friction, therefore it created very little casing wear. This hardbanding was developed primarily to protect the casing from wear caused by the drill string rotating in and tripping through the casing. Saving the casing was of utmost importance and the tool joint wear was of little or no priority in the development of this hardbanding. This was great for the operators, but not for the drilling contractors. Casing wear rates dropped drastically, but the tool joint wear rates were almost as high as unhardbanded tool joints.

When the directional and horizontal drilling activity escalated in the mid-1990's, drill pipe became more expensive and delivery times became longer. The drilling contractors began voicing their concern about the added costs involved in maintaining an acceptable string of drill pipe for the operators. They began passing these costs on to the operators and soon there became a need to address the tool joint wear problem associated with drilling these types of wells. Something had to be done to curtail the tool joint wear and rapid destruction of the drill string.

In late 1992, Arnco Technology developed and introduced a new breed of chromium carbide alloy hardbanding, *Arnco 200XT™* . This was a crystalline, rather than amorphous, type hardbanding. Because of its compositioin, the matrix of this hardbanding had a consistent thru-wall hardness between 52 – 60HRc as well as a low co-efficient of friction equal to that of the *Armacor M™*. These two features gave this hardbanding the ability to protect the casing from abrasive wear while, at the same time, protecting the drill pipe tool joint from rapid abrasive wear experienced in the open hole. Because of the excellent open hole abrasion resistance, it was recommended that the *Arnco 200XT™* be applied in a raised condition to take full advantage of the wear resistance.

Laboratory and field test results have shown that there are several advantages to using the chromium based alloy hardbandings (Ref. 1, 2, **Table 2**).

Some of those advantages are:

- 75% - 85% less casing wear than with tungsten carbide hardbanding
- Elimination of casing failures caused by drill string
- Use of lower weight and lower grade casing
- Reduction of downhole drag and torque
- Less likelihood of environmental incidents
- Substantial increase in tool joint life
- Decrease in rig fuel consumption

(Ref. 3, 4)

Summary

The original concept of hardbanding was arguably the most effective method ever devised. The hardbanding was applied in a raised (proud) condition, consequently, the hardbanding accomplished what it intended; protect the tool joint from rapid abrasive wear. The major problem was that, in this raised condition, it caused severe casing wear, therefore resulting in many casing failures. If there was a type of hardbanding that could be utilized in this same raised condition without causing the severe casing wear, then the industry would have solved one of their most pressing problems. Unfortunately, it took many years to solve this problem and several different types and configurations of hardbanding were tried. Because of the unique problem of addressing both casing and tool joint wear with a single hardbanding material, most hardbandings have fallen short of their objective of being able to protect both the casing and the tool joint at the same time.

A continuing search for a more effective hardbanding is in progress through several companies around the world, but it has yet to be developed and proven. Maurer Engineering, through the DEA-42 Casing Wear Study program, is currently testing hardbanding and other products that might achieve the desired goal. Some products have already been introduced and there are still more scheduled to come out in the near future.

Conclusions

To summarize the concept of wear resistant hardbandings, we need only to look at the basic facts:

- Where there is reduced friction there is reduced wear
- Where there is reduced wear there is less chance of casing failure
- Where there is no casing failure there is no environmental problem
- When the tool joint body does not contact the casing or open hole wall, it does not experience excessive drag and torque caused by the drill string
- When there is no excessive drag and torque it requires less rig power, therefore there is less rig fuel consumption
- When there are fewer problems there are less well costs

Nomenclature

ERD	=	Extended Reach Drilling
HRc	=	Hardness Rockwell C
O.D.	=	Outside Diameter
ppf	=	pounds per foot

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TABLE 1 – SUMMARY OF CASING WEAR TESTS

Test No.	Tool Joint	Wear Depth (in.)	% Wear*
1	Arnco 200XT	0.032	7
2	Smooth Steel	0.127	27.0
3	Tungsten Carbide	0.072	15.0

* Percent wear based on nominal casing wall thickness of .472" for 9-5/8", 47ppf, N-80 casing.

TABLE 2 – SUMMARY OF TOOL JOINT WEAR TEST OPEN HOLE SIMULATION

Test No.	Tool Joint	Tool Joint Wear (in.)	Remarks*
1	Arnco 200XT	0.018	Low Torque
2	Smooth Steel	0.043	High Torque
3	Tungsten Carbide	0.010	High Torque

* Amount of torque experienced during lab testing