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Hardbanding and Its Role in Directional/Horizontal 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 been 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 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 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 or the drill string, but only one or two of them can sufficiently protect both 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 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 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 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 causing some sort of wear, either tool joint wear, casing wear, 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 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 wear. Casing failures caused by drill string have practically been eliminated when using the proper wear resistant alloy hardbanding with the appropriate application.

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. This hardbanding consisted of a mild steel matrix with crushed sintered tungsten carbide particles dropped into the molten weld puddle. 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 very successful 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 developed pelletized tungsten carbide particles. Being round in shape, compared to the sharp, angular shape of the crushed sintered particles, was an improvement, but the operators were still experiencing casing failures. It was finally determined that the raised application of the hardbanding was acceptable for tool joint protection, but extremely detrimental to the casing wall. 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 ever before. Again, the tungsten carbide hardbanding was blamed for these failures. It was then that 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 a layer of tungsten carbide hardbanding, and finally, 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 body diameter 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 drill pipe that had no hardbanding on the tool joints. It was then that the problems seemed to be compounded. Now, to go along with casing wear, operators were required to repair or replace the drilling contractor'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 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 know at the time was that the milder tool joint steel caused almost as much casing wear as did 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 casing, contact each other and create friction. It was not until the industry began searching for some real answers to their continuing problems that they realized that unhardbanded tool joints caused more wear than tungsten carbide hardbanded tool joints **(Ref. 1)**.

In 1989/1990, Amorphous Technologies, Inc. developed a chromium hardbanding, *ArmacorM™*, that, when run inside the casing, would substantially reduce casing wear. This was an amorphous (i.e. work hardened) type material that had a low co-efficient of friction, therefore created very little casing wear. This hardbanding was developed primarily to protect the casing from wear caused by the rotation and tripping of the drill string in and through the casing. Because of the high priority on casing protection, the composition of this hardbanding had a very low resistance to the high stress abrasion experienced during drilling in the open hole. Consequently, it offerred poor tool joint wear protection. This was disturbing to the drilling contractors and they were very reluctant to apply it to their drill strings, but, due to the insistence of the operators, this hardbanding gained a relative amount of popularity in a very short time. Casing wear rates dropped drastically, but the tool joint wear rates were almost as high as ever.

When the directional and horizontal drilling activity escalated in the mid-1990's and 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 alloy hardbanding, *Arnco 200XT™*, that protected both the casing and the drill pipe tool joint at the same time. This was a crystalline, rather than an amorphous, hardbanding and, because of its composition, the matrix of the *Arnco 200XT™* hardbanding had a consistent through-wall hardness between 52 - 60HRc as well as a low co-efficient of friction. 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 joints from rapid abrasive wear experienced in the open hole.

Tests performed by Maurer Engineering on behalf of Arnco Technology showed that *Arnco 200XT™* hardbanding had an open hole wear life only slightly less than tungsten carbide hardbanding (Ref. 1, **Table 2**). Some field tests results showed that this hardbanding actually wore 29% longer than the tungsten carbide previously used under the same open hole conditions. The casing wear reduction gained by the use of the *Arnco 200XT™* hardbanding allowed Arco Alaska to change their casing program from 9-5/8", 47 ppf, to 9- 5/8", 40 ppf, resulting in a substantial cost savings on their casing purchases. In addition to this, the use of this hardbanding accomplished several other things. Most importantly, it eliminated the 10% casing failure rate caused by previously used tungsten carbide hardbanding on the drill string. It also eliminated the environmental problems associated with casing failures **(Ref. 2)**.

Because of its high resistance to open hole abrasion, it is recommended that this hardbanding be applied in a raised application, 3/32" above the tool joint O.D. **(Ref. 3)**. By using it in this condition, the tool joint does not contact the casing or open hole wall on a continuous basis, therefore, the casing wear and tool joint wear are reduced. Also, the downhole drag and torque is substantially lowered, thereby reducing rig fuel consumption **(Ref. 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.

Most all the other derivatives of the original hardbanding have fallen short of their objective; to protect the casing at the same time as it protects the tool joint from abrasive wear. To date, one type of hardbanding, *Arnco 200XT™*, has successfully achieved the total objective. Because of its extremely low co-efficient of friction and its excellent resistance to the high stress abrasion experienced in open hole drilling, it protects both the casing and drill pipe tool joints from abrasive wear at the same time. Other wear resistant alloy hardbandings do work somewhat, but not to the same extent as *Arnco 200XT™*.

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 help to 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 are no environmental problems
- When the tool joint body does not contact the casing or open hole wall, it does not experience abrasive wear
- 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
3	Tungsten Carbide	0.072	15

* 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	0.014	Low Torque
2	Smooth Steel	0.043	High Torque
3	Tungsten Carbide	0.010	High Torque

* Amount of torque experienced during lab testing