THE EVOLUTION OF ***<u>HARDBANDING</u>*** ©

Casing "unfriendly" Hardbanding

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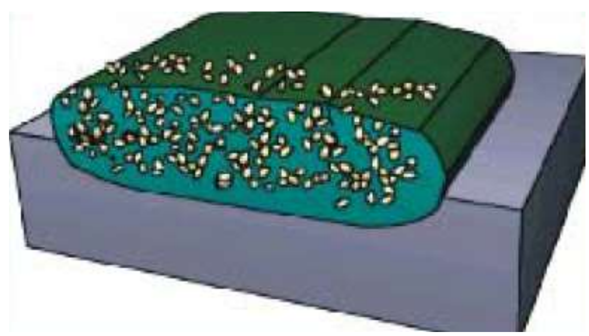
The Evolution of Hardbanding

Tungsten Carbide Hardbanding:

The process of “hardbanding” started almost 60 years ago. “Hardbanding” as it was originally designed, is essentially a welding process where tungsten carbide particles are dropped into a molten weld puddle made from mild steel. As it was originally developed, the process never envisioned the use of “casing friendly” welding wires as we use them today for hardbanding. For the most part, all drilling was open hole or straight and casing wear was rarely a problem. Tungsten Carbide in a mild steel matrix was the standard.

The mild steel welding wire acted as a matrix to hold the tungsten carbide particles. It was an easy choice since it was readily available. The tungsten carbide was used tool bits that were crushed to various sizes. However, as good as tungsten carbide is for abrasion resistance, the weak link is the soft mild steel matrix. As the mild steel matrix wears away during the drilling process, the tungsten carbide granules fall out.



Casing Friendly Hardbanding:

As drilling became more complex in the late 1980's and directional drilling started to become more common, new problems were encountered. The traditional tungsten carbide hardbanding still protected the drill pipe, but as the tungsten carbide particles became exposed they rubbed on the casing much like sandpaper against wood, causing premature wear on the casing. The industry then started looking for "Casing Friendly" hardbanding wires that were less abrasive on the casing but would still protect the drill pipe.

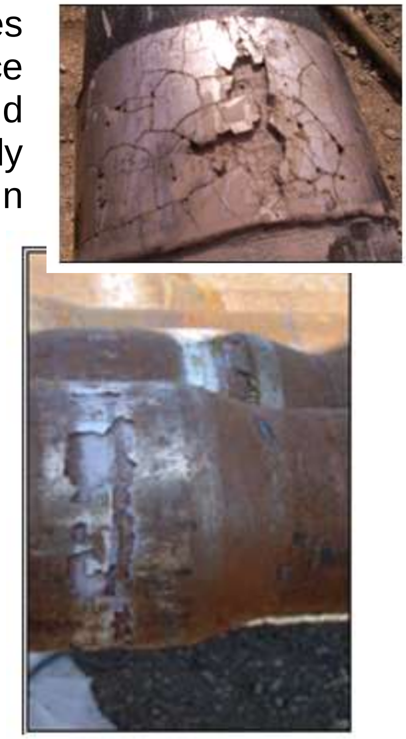
One approach was the development of Spherical Tungsten Carbide Pellets in 1978 which again were dropped into a soft mild steel weld matrix. Another approach was the development of "Casing Friendly" hardbanding wires that did not use tungsten carbide. As the "casing friendly" alloys without tungsten carbide were simpler to use and reduced casing wear substantially, they have become very popular. Tungsten carbide became taboo because of the concern for casing wear and fell out of favor as a hardband where casing wear could be an issue.

There are a number of "casing friendly" hardbanding wires that have been developed since this time that have given various results. Initially it was thought that "the harder the better" was the way to go. It soon became apparent that there were a number of factors that needed to be taken into account to have a good "casing friendly" hardbanding wire. Some of these factors are the "as welded" wires abrasion/wear resistance, the wires Rockwell hardness, as well as the coefficient of friction of the wire against the inside of the casing (ie. non-cracking, lubricity).

Test formula was developed to determine if the wire was truly casing friendly. Numbers were affixed to the wear factor, friction factor as well as the % of casing wear. These numbers of one wire were then compared to other wires to determine which wire was "more" casing friendly. (for more information go to Maurer Vs Mohr)

No Cracks Vs Cracks in Casing Friendly Hardbanding:

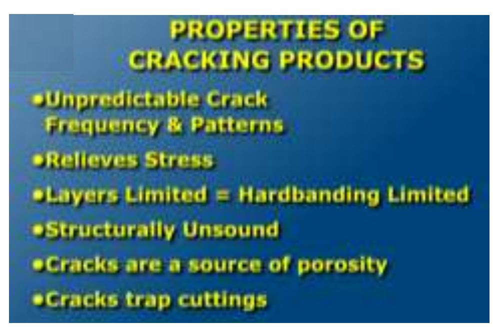
There are more differences than just esthetic appearance between a non-cracking and a cracking casing friendly hardbanding wire. Certain hardbanding wires crack because of the fine carbides that form on grain boundaries during cooling. As stress is generated by the shrinking weld deposit as it cools down, they will crack, or "cross check" to relieve the built up stress. This cracking, although good because it relieves the stress of the welded material, is detrimental as it is structurally unsound and now becomes a potential source of failure. If proper procedures are not followed during the reapplication of the hardbanding wire, the potential of spalling or "chunking" of the hardbanded wire could occur turning the "casing friendly" hardbanding into "casing unfriendly" and also cause problems for the tool joint.



Example of Spalling

For years cracking in the hardband was accepted because there was no other option available. With the advent of "non-cracking" hardbanding wires, the issue of spalling is eliminated along with any inherent problems associated with spalling.

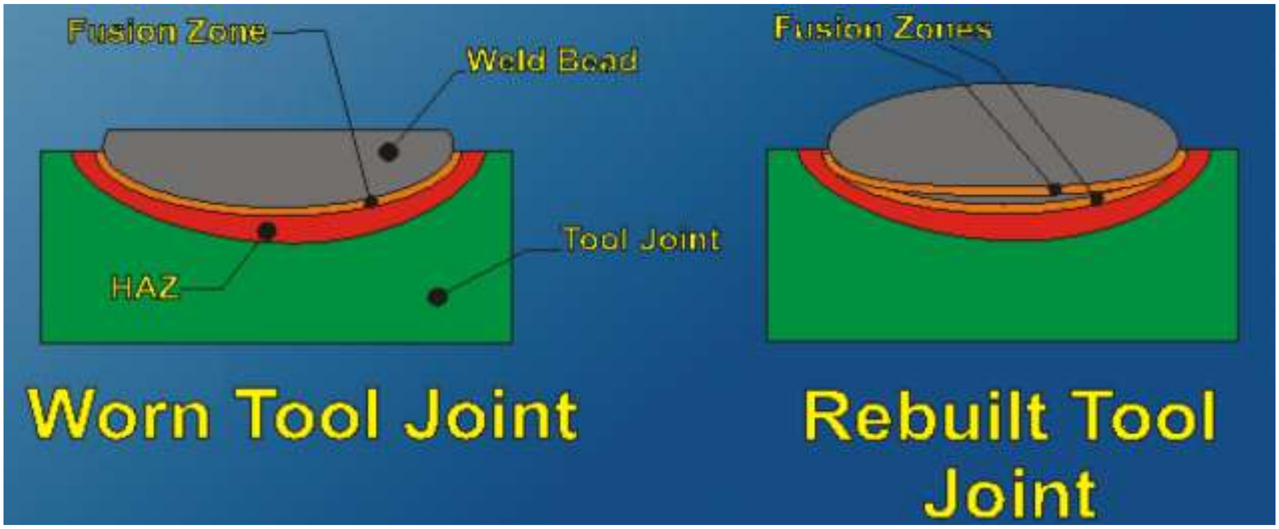
Product that does not crack, normally will rebuild very easy. In addition, as there are no cracks, foreign matter such as drilling fluids, abrasives and H2S cannot become entrapped, making reapplication even easier for the hardbander.



Reapplication of Hardbanding wire:

Once the original hardbanding has worn down enough that it is no longer protecting the tool joint, a new layer will need to be reapplied. The type of hardbanding that was originally laid down will determine what type of reapplication procedure is required.

Cracking Hardbanding wire:
If the original application was a cracking hardbanding, the original hardband will have to be removed to the point that the reapplied hardband will penetrate past the original Heat Affected Zone (HAZ). If the material is not removed to this point, there is an increased risk of spalling or chunking of the hardband material due to the fine carbides that form on grain boundaries. The fact that there would be two fusion zones that have these weakened grain boundaries would create additional stress in the hardbanded wire.



Non cracking Hardbanding wire:
The reapplication of the non cracking hardbanding wire does not have the grain boundary problem, as the carbides do not form on this grain boundary, eliminating the possibility of spalling. Reapplication costs are also reduced because grinding off of the original hardbanding wire is eliminated. All the hardbander needs to do is buff of the previous non cracking hardband and reapply.

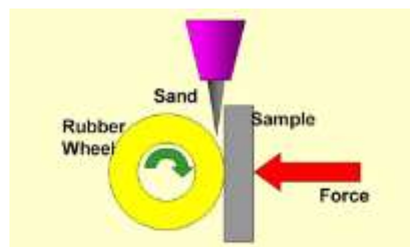
Hardness Vs Wear Resistance:

Although many hardband wires state that they are very hard with a Rockwell of 60Rc+, this does not mean that they will all wear the same or better than other materials of the same hardness.


Hardness Tester

Hardness:
Hardness is a measure of the resistance of a material to indentation. This is determined by use of a machine which presses a steel ball into the material being tested. The result is a number that is expressed by the Rockwell hardness number - the higher the number, the harder the material.

Wear Resistance:
Wear is the erosion of a hardband by being in contact with another media, such as the drilling mud or the casing. If this erosion is left unimpeded, the hardbanded material will wear fairly quickly, depending on the "hardness" of the base material.



ASTM G65 Wear Test

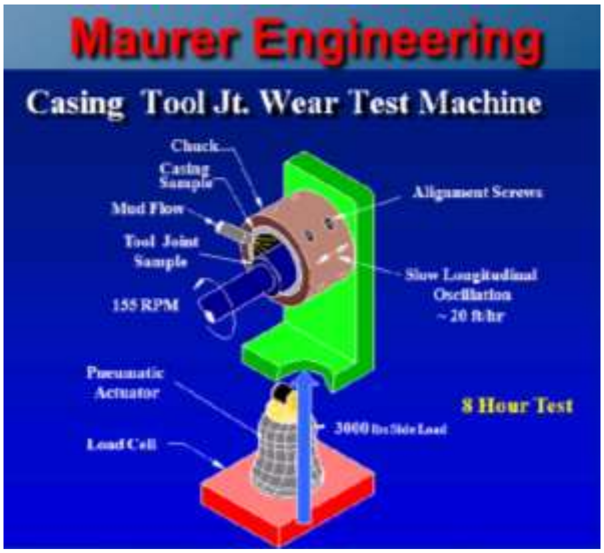
If harder materials, such as carbides, are placed in the way of this erosion, they will impede the wear and the part will last longer. A couple examples of this are as follows:

1- The traditional carbon steel wire with tungsten carbide particles. The wire is much softer (~5 Rc) then the drill pipe (~30 Rc) and would wear out sooner than the drill pipe if applied by itself. With the addition of the tungsten carbide the "wear life" of the hardband greatly exceeds the drill pipe.

2- Both Duraband and Tuffband have a hardness of approximately 60Rc. Duraband has been enhanced with hard round carbide nodules for added wear resistance thus allowing Duraband to outlast Tuffband by over 4- 5 times in wear resistance.

Maurer Vs Mohr ??

The initial testing benchmark was the Maurer Engineering test and all information was compiled by the Drilling Engineering Institute under DEA 42. They attempted to sort the hardbanding wires in the late 1990's, then assigned a "wear factor" of 2.0 for the wire to be considered casing friendly and published the comparative data.



Around 2003 a company called Mohr purchased the testing equipment but encountered problems in recreating the same test results as had previously been achieved by Maurer Engineering. Because of this, Mohr decided to modify the equipment to achieve consistent, repeatable test results. In 2007, Mohr completed its modifications. As test results are not repeatable pre 2007, test data previous to 2007 is considered suspect.

Below are comparative differences from the early Mauer test on an unbanded 4145 tool joint, which was inconsistent in its test results. Compare this to the new Mohr test which is consistent in its test results.

4145 Unbanded Tool Joint

	Maurer	Mohr
Wear Factor	5.5	7.4
Friction Factor	0.20	0.56
% Casing Wear	17.3	25.7

New Benchmark needed:

As it is impossible to repeat the Maurer test results with current Mohr equipment, a new benchmark "wear factor" number needs to be introduced. It is for this reason that the historical wear factor benchmark number of 2.0 is now ineffective as it is not repeatable. Not until all existing hardbanding wires are tested on the new Mohr equipment, can comparative results be determined.

Casing wear tests, as conducted by Mohr Engineering in Houston Texas, have confirmed that Duraband, even though it is highly abrasion resistant, is also very casing friendly.

Fearnley Procter, who administer the NS-1 Certification have also independently evaluated Duraband NC. They have determined that it *"compares favorably for wear in test conditions against other industry hardbanding wire, but appears it to be more casing friendly".*
Also in October of 2009 Duraband became the only active hardbanding wire that is certified to NS-1 for re-application over other hardbanding wires.

Merging the Technology of Tungsten Carbide and Casing Friendly Hardbanding

Duraband and Tuffband are unique for hardbanding. Unlike other wires that stress-crack and are unable to readily accept tungsten carbide particles into their matrix, Duraband and Tuffband are both non-cracking and rebuildable. Being a metal cored wire they also are able to accept tungsten carbide particles directly into the molten puddle, without cracking.

With flux cored hardbanding wires, the "molten flux" will entrap the tungsten carbide particles as the hardbander is trying to deposit them into the weld. This "molten flux" from the flux cored wire will prevent a majority of the tungsten carbide particles from getting into the weld deposit because of this entrapment, lowering the percentage of the "abrasion resistant" tungsten carbide in the final hardbanded deposit.

Duraband NC wire with Tungsten carbide particles

As it is known that Tungsten carbide has a hardness of over 2200 Vickers (~ 81 Rc), the weak link in its longevity is the traditional matrix of mild steel wire used to hold the tungsten carbide particles. As the mild steel matrix wears away during because of abrasion from the drilling process, the tungsten carbide particles fall out. Mild steel wire has a hardness of only about 170 Hb (~ 10 Rc), very soft in comparison to the tungsten carbide particles.

By using either Duraband or Tuffband that have an undiluted hardness of approximately 60 Rc (over 6 times harder then that of mild steel wire as well as over 12 times the wear resistance), the tungsten carbide particles are held in place longer, providing an extended life expectancy of the hardband, reducing reapplication requirements. In other words, the matrix of Tuffband or Duraband works in conjunction with the tungsten carbide to provide greater wear than the traditional mild steel wire.

Non-Magnetic Hardbanding

As directional drilling became more common through the 1990's and up to current times, new problems were encountered even when using the casing friendly wires. The problem was magnetism! As traditional wires are an iron base, they are magnetic. The magnetism from the wires would affect the downhole measurement tools, especially in measurement while drilling (MWD). In these areas there is need for a nonmagnetic alloy, because magnetic surveying is used to measure the well orientation. At the same time, the material must still have good wear capabilities.

With this in mind, the industry has come up with a few different processes where this can be achieved. Unfortunately, at this time there is no consensus as to which process is the best, as each process has its advantages and disadvantages.

The two most common processes are as follows:

MIG wire non-magnetic hardbanding;
As most hardbanding is done outside of the shop environment, the traditional "on-site" hardbanding companies have adapted their hardbanding equipment to apply non-magnetic alloys with their existing MIG systems. As the only differences are the materials used to do non-magnetic parts, there is relatively little difference from a visual perspective between standard hardbanding and non-magnetic hardbanding. From a materials perspective, rather than using the standard tungsten carbide particles, non-magnetic tungsten carbide particles (NMWc) are used. These NMWc

particles are dropped into a molten puddle of a non-magnetic wire during the welding process, that once solidified encapsulates the NMWc particles and holds them in place. As this is a MIG process, the overall weld produced is a metallurgical "welded" bond.
There are various non-magnetic wires that are used. The most common are 310 stainless steel wire or nickel base wire alloys such as Nickel 625 (ERNiCrMo-3) or Nickel C276 (ERNiCrMo-4). Unfortunately these wires are quite soft with a hardness range of 7-12Rc. There are currently new wires such as the Postle's Ultraband NM, that is a casing friendly non-magnetic wire that has a hardness of ~40Rc.
As this process doesn't require additional equipment, hardbanding companies can provide these services at cost effective prices compared to other alternative processes. The added benefit of being able to do "on-site" hardbanding is also a determining factor.

Plasma Transferred Arc (PTA) non-magnetic hardbanding;
PTA hardbanding is a precise, high energy, inert gas welding process that uses non-magnetic matrix powders of various hardness's to adhere NMWc particles to the part being hardbanded. PTA technology produces a metallurgical "welded" bond. The accuracy in application and parameter control can result in lower dilution levels, compared to the more common MIG wire non-magnetic hardbanding process. The process also results in a narrower heat-affected zone, and a lower dilution rate. It also allows for a variety of combinations of non-magnetic matrix powder to be used. The most common are combinations of nickel base alloys such as Nickel 625 (ERNiCrMo-3) or Nickel C276 (ERNiCrMo-4) by themselves or other similar nickel alloys with boron added to increase hardness.
As traditional PTA hardbanding equipment can only accommodate smaller particles of tungsten carbide, there is a limitation on the overall particle size of the tungsten carbide used in the process. Overall, if applied correctly, PTA is a good alternative to the traditional MIG wire process.
The downfall of PTA hardbanding is that it is substantially higher in cost as compared to the traditional MIG wire non-magnetic hardbanding. It is also not "site" friendly. To date most, if not all, PTA hardbanding is done in house and is not a transportable process to the site.

For further information on magnetic or non-magnetic hardbanding, please feel free to contact Leroy Billesberger at 1-855.WeldCor (935.3267)