

# Experimental Researches to Establish the Optimum Hardbanding Technology and Materials of the Heavy Weight Drill Pipe

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**Abstract.** The heavy weight drill pipe, one of the most expensive components of the drill string, is exposed, beside fatigue and corrosion, to an intensive wear process as a result of the friction with the inner wall of the casing or the borehole wall, that lead to a drastically decrease of its durability. In order to improve the durability, the worldwide specialists apply the hardbanding technology to increase the heavy weight drill pipe wear resistance. The major problem raised by the hardbanding process is the selection of the most suitable wear resistant alloy and the optimum hardbanding technology. The present research work investigate the possibility of hardbanding the heavy weight drill pipes by using the gas metal arc welding process, taking into considerations three different wear resistant materials with the trade name ARNCO 100XT, ARNCO 300XT and FLUXOFIL M58.

## 1 Introduction

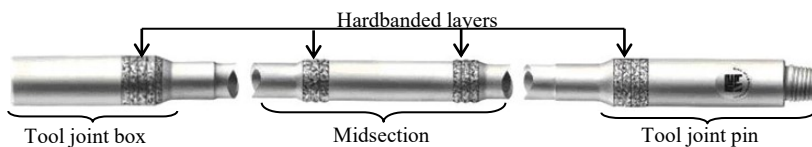
In the petroleum industry, the drill string is the drilling assembly that is used to rotate the bit, to conduct the drilling fluid to the bit, to realize the weight on bit and control the drill bit, [1]. Wear, corrosion and fatigue are recognized as a major cause of drill string failures. In practice, the oil industry attempts to guard against the likelihood of these costly failures by improving the surface characteristics of the drill string components, by using different technologies, [1, 2].

The heavy weight drill pipes, the most expensive elements of the drill string, are inserted between the drill collars and drill pipes in order to ensure that the drill pipe string is kept in tension and realize a flexible transition between the stiffer drill collars and limber drill pipe, [1]. The heavy weight drill pipe has the same outside diameter as standard drill pipe but a much reduced internal diameter, has an extralong tool joint (pin/box) and an integral centre wear pad (midsection/centre upset) which acts as a stabilizer, increasing the overall stiffness of the drill string (fig.1), [1, 2]. Due to friction with the inner surface of the casing (that prevent the borehole from caving in and to support the weak or fractured formations) or the open hole wall, the durability of the heavy weight drill pipes decreased,

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and to improve it, the worldwide specialists apply hardbanded wear resistant materials onto the surface subjected to wear, respectively onto the tool joint pin/box of the heavy weight drill pipe and onto the central zone of the pipe (fig. 1), [1, 2].



**Fig.1.** The hardbanding areas of the heavy weight drill pipe.

The deposit hardness is very important in the drilling process because a value higher than 57-62 HRC will cause an excessive wear of the casing, [3, 4, 5]. The present paper bring forward the results obtained in the case of three different wear resistant wires, FLUXOFIL M58, ARNCO 100XT and ARNCO 300XT, used for heavy weighty drill pipes' hardbanding.

## 2 Experimental procedures

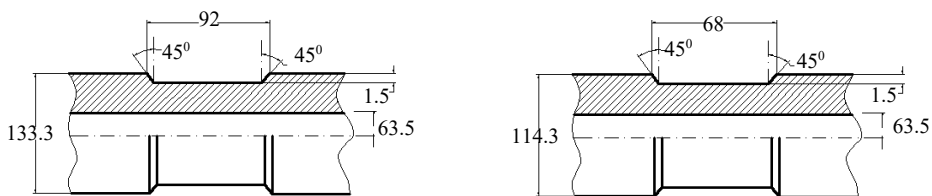
### 2.1 Materials

The experimentally researches were performed on specimens manufactured by steel AISI 4145H (46MoMnCr10), the reference material utilized in heavy weight drill pipes construction. The chemical composition and the mechanical characteristics of the AISI 4145H steel, according to the manufacturer, are presented in table 1, [3].

**Table 1.** Chemical characteristics of AISI 4145H alloy steel.

C, %	Mn, %	Si, %	P, %	S, %	Cr, %	Mo, %	Al, %	Ni, %	Cu, %	Hardness, HB	Tensile strength, R <sub>m</sub> , N/mm <sup>2</sup>	Elongation, A, %	Striction, Z, %
0.43	0.97	0.31	0.022	0.012	0.99	0.21	0.028	0.11	0.14	336	1124.7	14.75	51.0

The specimens used had 1500 mm length, considered to be sufficient to reproduce the heating and cooling conditions of the hardbanded area under real conditions, with different outer diameters, that corresponds to the surfaces subjected to hardbanding, respectively  $\phi$  133.3 mm (corresponding to the outer diameter of the tool joint pin/box) and  $\phi$  114.3 mm (corresponding to the midsection), with an inner diameter of  $\phi$  63.5 mm. A recess groove was machined onto the specimens (fig. 2) to be filled flush with hardbanding material in order to avoid the wear of casing inner diameter, [3]



**Fig.2.** Recess groove of the specimens.

In the experimental works were used tree different wear resistant flux core tubular wires of 1.6 mm diameter, named FLUXOFIL M58, ARNCO 100XT and ARNCO 300XT, having the characteristics, according to manufacturer, presented in table 2, [3]

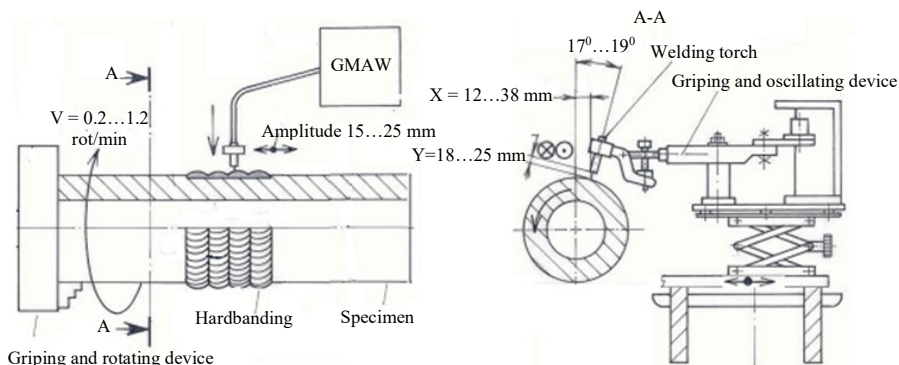
**Table 2.** The deposit characteristics.

Type of wire	Chemical composition of the deposit											Hardness
	C, %	Mn, %	Si, %	P, %	S, %	Cr, %	Mo, %	Nb, %	Ni, %	B, %	Fe, %	HRC
ARNCO 100XT	0.7-0.75	1 max	0.5-0.7 max	0.030 max	0.030 max	7.0-8.0	0.15-0.20	-	-	-	rest	48-52
ARNCO 300XT	0.75-0.80	0.90-1.2	0.55-0.75	0.030 max	0.030 max	-	-	5.3-5.7	2.0-2.5	3.8-4.2	rest	min 60
FLUXOFIL M58	0.45-0.85	1.5-2.1	0.50-0.85	0.020	0.020	5.0-7.0	0.35-0.85	-	-	-	rest	57-62

The metal active gas welding process (GMAW) was used for hardbanding.

### 2.2 Hardbanding equipment

The hardbanding equipment, used, allowed, from the cinematic point of view, the following movements: continuous rotation of the specimen, axial feed of the welding torch and oscillate the welding torch (fig. 3), [3, 4].



**Fig. 3.** The hardbanding equipment scheme.

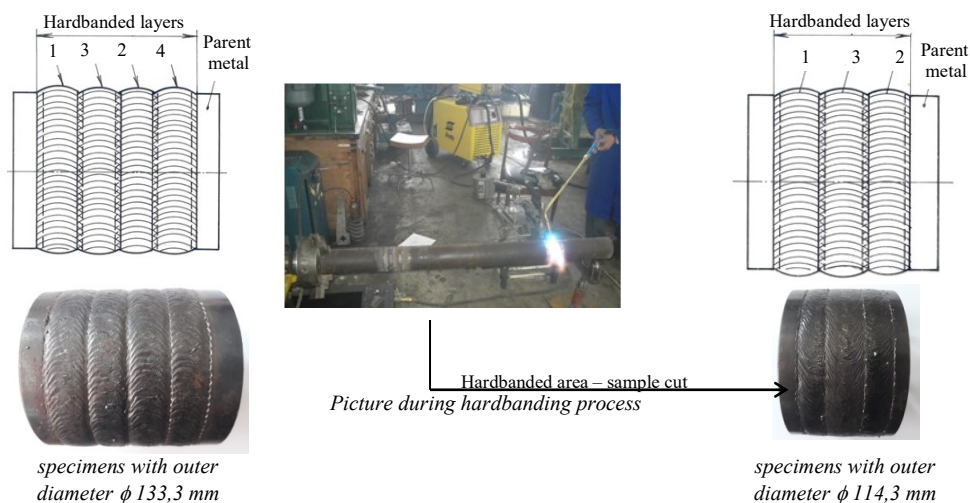
### 2.3 Hardbanding research methodology

In order to establish the optimum hardbanding technology, based on the own experience, on the wear resistant wires manufacturers’ recommendations and on the technical information presented in the specialized literature by the specialists, the methodology presented below has been applied, [3].

*A) Specimen preparation* - After turning the specimen by using a lathe machine, in order to prepare the recess groove, a visual inspection of the specimen’s surface was performed, to ensure it is clean and without rust, dirt, grease, oil etc.

*B) Preheating the specimen* - Before the hardbanding process, the specimen was preheated at 100 degree Celsius, in order to not cause undesirable cracking in the parent metal).

*C) Hardbanding the specimen* - The number of the hardbanded layers and the order of their applications were different, depending on the width of the hardbanded area (fig. 4).



**Fig.4.** Applications of the hardbanded layers.

The recess groove of the specimen was filled flush with hardbanding material by using the technological parameters mentioned in table 3.

**Table 3.** Hardbanding technological parameters.

Technological parameter	Type of wear resistant wire /adopted values		
	FLUXOFIL M58	ARNCO 100XT	ARNCO 300XT
Polarity	reverse	reverse	reverse
Amperage $I_s$ , A	250...270	250...270	250...270
Voltage $U_g$ , V	23...25	23...25	23...25
Shielding gas	80% Ar + 20% CO <sub>2</sub>	100 % CO <sub>2</sub>	100 % CO <sub>2</sub>
Shielding gas flow rate $Q_g$ , l/min	13.5	14	14
Filler metal speed $v_{sm}$ , m/min	4.5	4.5	4.5
Y distance (from figure 3), mm	20	20	20
X distance (from figure 3), mm	20	20	20
Rotating speed of the specimen, rot/min			
- for specimens with $\phi$ 133,3 mm	0.57	0.57	0.57
- for specimens with $\phi$ 114,3 mm	0.66	0.66	0.66
Welding speed $v_s$ , m/h	14.5	14.5	14.5
Oscillating the welding torch:			
- oscillating speed, oscillation/min	60	60	60
- oscillation amplitude, mm	25	25	25
Preheat temperature $T_{pr}$ , °C	100	100	100
Maximum interpass temperature, °C	350	350	350

D) *Controlled cooling of the hardbanded specimen* - After finishing the hardbanding process, the hardbanded specimens were slowly cooled by using a thermal isolated blanket with a thickness of 100 mm, to avoid the cracks in the hardbanded layers.

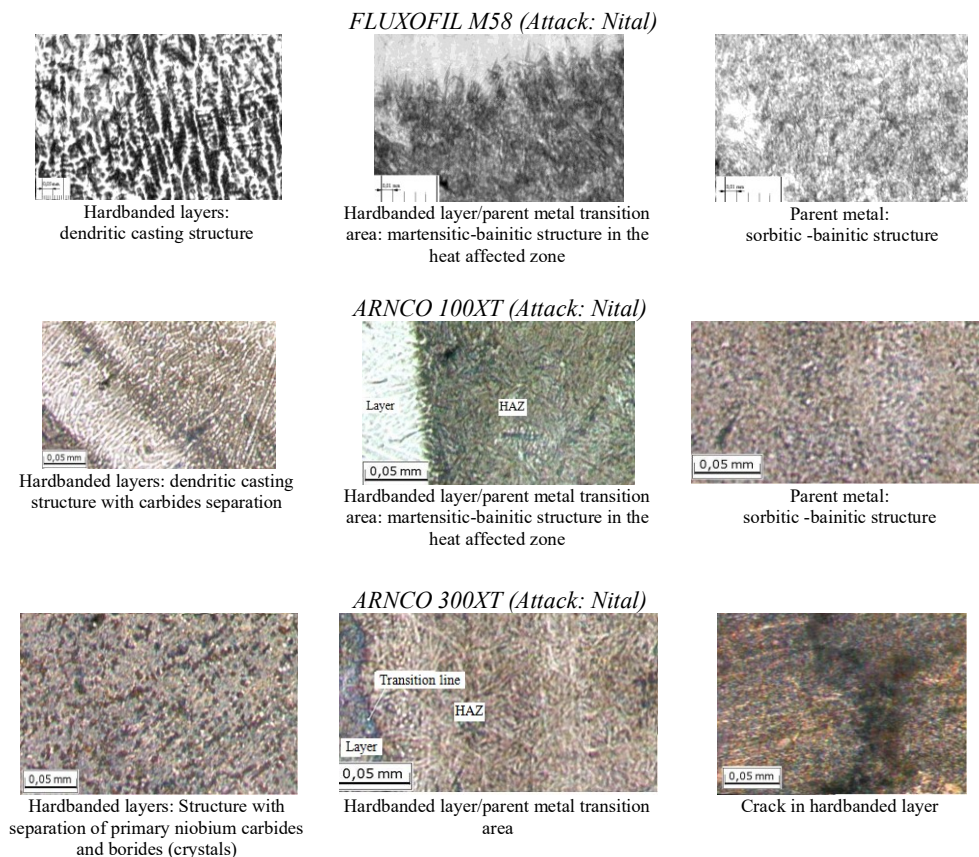
E) *Quality Control* - After cooling of the specimens, the quality of the hardbanded area was verified by: macroscopic analyses, metallographic analyses by optical microscopy, Rockwell hardness and micro hardness measurements.

## 2.4 Experimental results and discussion

The *macroscopic analyses* consisted in investigation by naked eye of the hardbanded layers had indicated that the profiles of the hardbanded layers are flat (deviation from this kind of

profile can cause premature wear of the casing, when the profile is convex, or premature wear of the heavy weight drill pipe, when the profile is concave, [4]). The surface of the hardbanded layers with ARNCO 100XT and FLUXOFIL M58 doesn't contain visible cracks, but in the case of ARNCO 300 XT the cracks were observed. The adhesion between the substrate (parent metal) and the hardbanded layers, also between two adjacent layers is good (without any discontinuities or voids).

The *metallographic analyses by optical microscopy* were performed on metallographic samples cut from the transition zone parent metal-hardbanded layer, also from the overlap zone between two adjacent hardbanded layers. In figure 5 are presented the metallographic structures obtained for the hardbanding. The analysis shows a good adhesion between the hardbanding and the parent metal, and without any cracks for layers hardbanded with ARNCO 100XT and FLUXOFIL M58. In the case of layers hardbanded with ARNCO 300XT, the high percent of niobium leads to the separation of primary niobium carbide, and the high percent of boron leads to the separation of borides, and the separation of these chemical compounds (crystals of carbides and borides) places this material in the field of cast irons. The transition area from the hardbanded layer to the parent metal is more obvious, in this case, which also explain the appearance of cracks (fig. 5).



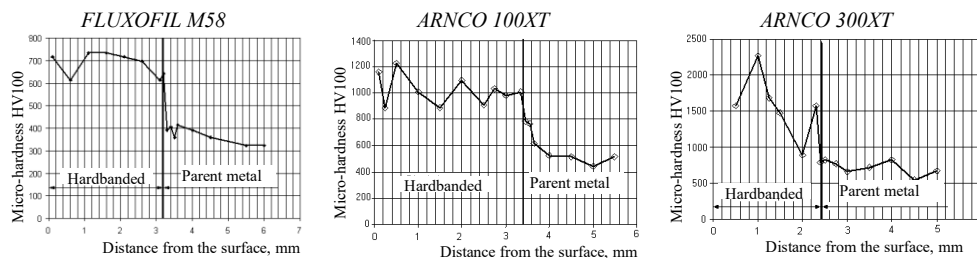
**Fig. 5.** Metallographic structures for the hardbanding.

The *Rockwell hardness* measurements were performed on metallographic samples, and the average values of HRC hardness are presented in table 4.

**Table 4.** Rockwell hardness measurements.

Type of wire	Rockwell hardness, [HRC]		
	Hardbanded layer	Heat affected zone	Parent metal
<i>FLUXOFIL M58</i>	55	50	36
<i>ARNCO 100XT</i>	58	52	36
<i>ARNCO 300XT</i>	62	55	37

The *micro-hardness measurements* were performed on metallographic samples with a load of 100 g. The measurements performed shown high values of hardness in the hardbanded layers and a maintaining initial hardness in the parent metal (fig. 6).



**Fig.6.** Micro-hardness of the hardbanding.

### 3 Conclusions

The hardbanding equipment and the hardbanding technology developed in the frame of this research work allow to perform, in good conditions, the hardbanding with wear resistant alloys of the heavy weight drill pipes, by using the gas metal arc welding - GMAW process. The comparative researches performed with three different wear resistant materials, have shown that ARNCO 100XT wire, successfully used worldwide for hardbanding of the tool joints and the drill collars, can be replaced with the FLUXOFIL M58 wire, available in our country, allowing the delivery of heavy weigh drill pipes hardbanded, competitive worldwide from the point of view of the quality of the hardbanded layers and, at the same time, at a lower price. The experimental results obtained do not recommend the wire ARNCO 300XT to be use for hardbanding of the heavy weigh drill pipes because the hardbanded layers cracks.

### References

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