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THE INFLUENCE OF FILLER MATERIAL ON MICROSTRUCTURE OF HIGH-CARBON STEEL SURFACE WELDED LAYER

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ABSTRACT
Surface welding is the dominant maintenance way to prolong exploitation life of damaged parts. Also, by properly choice of welding technology, it is possible to get improved structure, with dominant properties comparing to the original part. In that way, new layer becomes area of future crack initiation, that in turn will delay its initiation and provide secure and reliable exploatation. In this paper, high-carbon steel, which is used for rail production, is surfaced by semi-automatic arc welding process, using self-shielded and flux-cored wires, with different alloying concepts. Microstructures of surface welded layers show that obtained layers are more similar to the new rail steel generation-bainitic steel, than original pearlitic base metal, in both cases. In this paper is also shown that multi-pass surface welding does not produce classic heat affected zone, i.e. its structure is improved and it is not a critical place in weldment.
Keywords: high-carbon steel, suface welding, bainitic microstructure

1. INTRODUCTION
High-carbon steels are in use for many applications, mostly due to their high hardness. For some applications, such as for rails, these steels pearlitic microstructure are replacing by new generation of bainitic steel, with variable success and higher price. During exploatation, occurs processes such as wear and rolling contact fatigue and results are damaged parts [1,2]. Damaged parts produced from high-carbon steel can be surface welded, in spite of their poor weldability, and by properly choice of welding technology, it is possible to get improved structure with dominant properties comparing to the original part. To achieve that, it is necessary that obtained morphology coresponds to the new steel generation, i.e. bainitic microstructure.

2. TYPES OF FILLER MATERIAL
For surface welding are mostly in use semi-automatic arc welding processes, with flux-cored and self-shielded wires. Basic difference between them is that first one requires an external shielding gas, and second does not. In both cases, core material acts as a deoxidizer, helping to purify the weld metal, generate slag formers and by adding alloying elements to the core, it is possible to increase strength and provide other desirable weld metal properties [3,4]. These processes have replaced slowly MMA process and they almost ideal for outdoors in heavy winds. The result of flux-cored wire application is higher quality welds, faster welding and maximizing a certain area of welding performance. Most frequently, surface welding is performing in three layers, sometimes with buffer layer. It is necessary to obtain structural compatibility with base metal, good properties of HAZ, and by properly chemical composition of filler material it is possible to get desirable microstructure of final surface layer.
The final surface layer microstructure is the result of complex influence of many factors: type of filler material, heat input, mixture degree with previous layer and post heat treatment with next layer, because each subsequent pass alters the structure in regions of the previous pass that are heated.

Having on mind interactions of all mentioned parameters, it doesn′t surprise insufficient literature data about obtained results, i.e. microstructures.

3. EXPERIMENT AND DISCUSSION

Base metal used in this work is high-carbon steel, pearlitic microstructure. Chemical composition is given in Table 1. The steel is surface welded by semi-automatic process, with self-shielded wire (sample 1) and flux-cored wire (sample 2). Chemical composition of filler material is given in Table 2. Surface welding is carried out in three layers. Sample 1 is surfaced with one type of filler material (self-shielded wire), while for surfacing of sample 2 were used 2 types of wires, but both flux-cored: one for buffer layer and the second one for last two layers. Heat input during welding was about 10 kJ/cm and preheating temperature was 250^0C.

Table 1. Chemical composition and mechanical properties of base metal

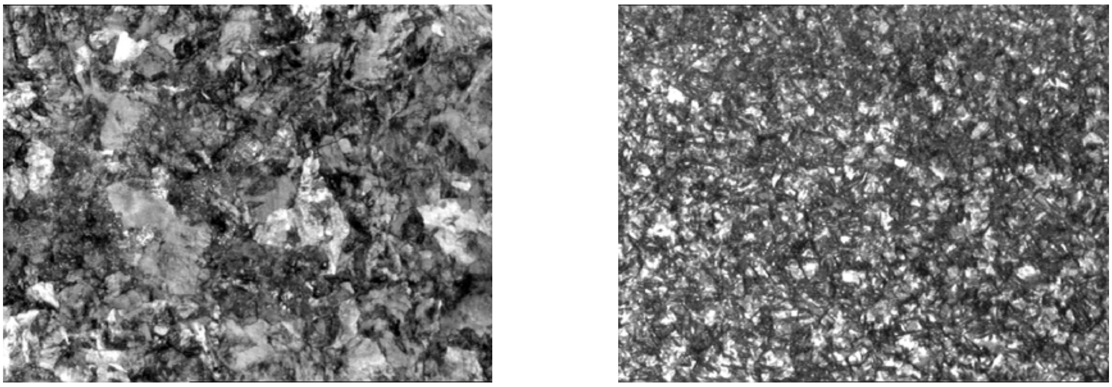
Chemical composition, %							Tensile strength R_m (N/mm^2)	Elongation A_c (%)
C	Si	Mn	P	S	Cu	Al		
0.52	0.39	1.06	0.042	0.038	0.011	0.006	680-830	≥14

Table 2. Chemical composition of filler material

Sample No.	Wire designation		Wire diam. mm	Chemical composition							Hardness, HRC
				C	Si	Mn	Cr	Mo	Ni	Al	
1	OK Tubrodur 15.43 (self-shielded wire)		1.6	0.15	<0.5	1.1	1.0	0.5	2.3	1.6	30-40
2	1. layer	Filtub 12B (flux-cored wire)	1.2	0.05	0.35	1.4	-	-	-	-	-
	2. and 3. layer	Filtub dur 12 (flux-cored wire)	1.6	0.12	0.6	1.5	5.5	1.0	-	-	37-42

For further investigation, microstructural analisys of all characteristical zones of welded layer has been done. Heat affected zone (HAZ) also has pearlitic microstructure, but with finer grain, than base metal (Figure 1), so its structure is improved and it is not a critical place in weldment. That is result of thermomechanical treatment of HAZ which is re-heated three times. Structural compatibility between deposite metal and base metal was achieved and martensitic layer wasn't formated.

The greatest differences appear in first layer microstructure. First layer microstructure of sample 1 consists of ferrite, pearlite and bainite, what is result of mixing of low-alloyed filler material with high-carbon base metal. For first layer deposition of sample 2 is used low-carbon wire alloyed with Mn, as a function of buffer layer, so characteristical structure consist of great fraction of ferrite with relatively large primary grains. Beside proeutectoid ferrite, microstructure contains Widmanstatten and acicular ferrite.



a) 200x b) 200x

Figure 1. Microstructure of a) base metal and b) HAZ of both samples

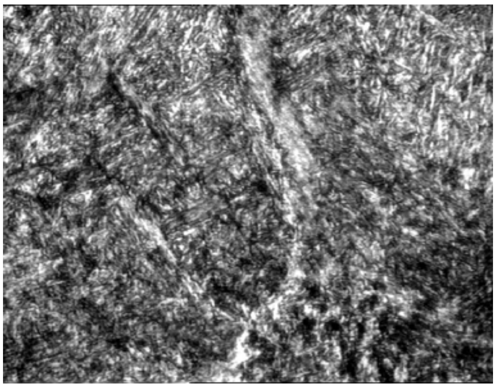
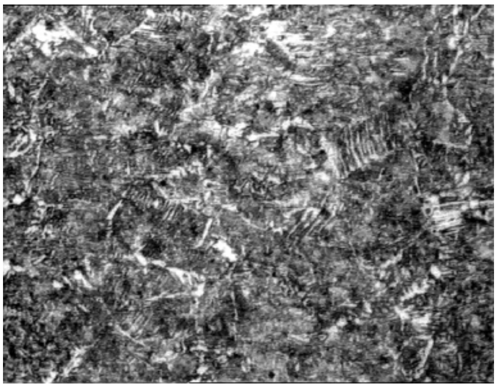
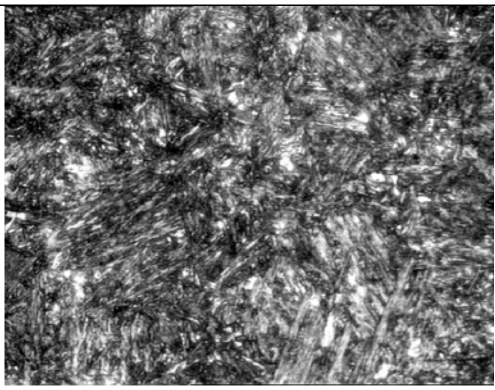
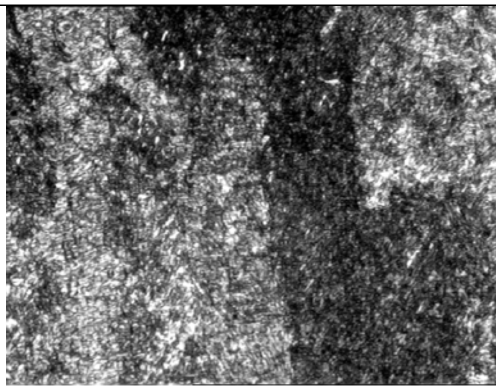
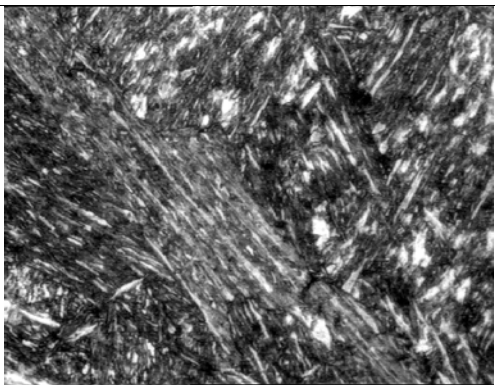
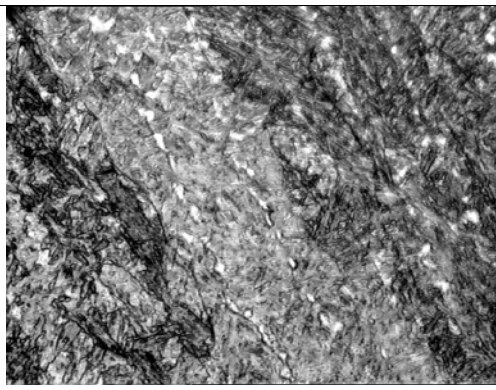
	Sample 1	Sample 2
1. layer	 *500 x*	 *500 x*
2. layer	 *500 x*	 *500 x*
3. layer	 *500 x*	 *500 x*

Figure 2. Microstructure of all surface welded layers

The second layer microstructure is the most important in surface welded joint, because it has the greatest influence on mechanical and technological properties and exploatation behavior of repaired parts. For this structure is characteristic larger fraction of bainite, consequence to the less mixing with base metal. In second layer of sample 2 occurs fine grain ferritic structure with low content of bainite. This structure has finer grain compare to first layer, what is result of heat treatment and chemical composition (presence of Mo in filler material).
The third layer of sample 1 has some coarser grain structure, with higher content of bainite, compare to previous layer, what is consequence of re-heating absence. For third layer of sample 2 is characteristical bainitic microstructure with small amount of martensite and locally zones of proeutectoid ferrite.
Though used filler materials are different type, alloying concepts, sort of protection, buffer layer, as final result is obtained desirable bainitic microstructure superior properties compare to base metal. Except metallography examination, this is confirmed by other detail tests [5]. It has been showned that, thanks to appropriate choice of filler material and welding technology, surface welding of damaged parts is not only a way of reparation, but and a way of improvement of starting properties.

4. CONCLUSIONS

Considering performed examinations the following is concluded:

1. It has been shown that, in spite of high-carbon steels poor weldability, i.e. susceptibility to welding defects, due to its high carbon equivalent(CE=0.64), they can be successfully surface welded. Structural compatibility between deposite metal and base metal was achieved and martensitic layer wasn't formated. Obtained HAZ has better structure compare to base metal.
2. Filler material is relevant parameter which affects on deposite layer quality. Work with self-shielded wires is more simple, specially for outdoor applications. Both used wires are on high technological level and can be recomended for reparation of high-carbon steel damaged parts.
3. Final microstructure is the result of different influences: type of filler material, heat input, degree of mixture with previous layer and post heat treatment with subsequent surface layer. It is necessary to know all these factors and also to know the way of affect. Though applied wires are with different alloying concepts, result in both cases is that initial pearlitic moprhology is replaced by final desirable bainitic microstructure. It was shown that, by selecting corresponding parameters, it is possible to obtain the morphology for the best properties.

5. REFERENCES

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