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THE INFLUENCE OF COMPOSITION HIGH-CARBON DEPOSITED METAL ON STRUCTURE AND LAMELLAR TEARING

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The work is deals with research composition of high carbon deposited metal on formation microstructures in the partially melted zone and initiation of cracks, lamellar tearing, as one of the most dangerous defects that occurs hard-facing layers. Experiments carried out for the series of compositions chromium-manganese high-carbon depositions with varying carbon content. Additionally, the influence of boron and titanium concentrations on the formation of such defects was research. Observed negative promotion increasing concentration of carbon for deposited metal and it is due to increasing volume effect of transformation of austenite to martensite. Latter initiate normal and shear stresses increasing in “light lamellar zone” of partially melted zone. Additionally alloying the deposited metal with titanium prevents cracking in the partially melted zone.

Keywords: cold cracks; lamellar tearing; deposited metal; hard-facing; alloying; boron; titanium.

Петренко А.М. «Вплив складу високовуглецевого боротитанового наплавленого металу на структуру і розвиток тріщин-відшаровувань»

Робота присвячена дослідженню зв'язку складу високовуглецевого наплавленого металу з утворенням мікроструктур в зоні сплавлення і розвитком тріщин-відшаровувань. Проведено експериментальні дослідження для серії складів високовуглецевого хромомарганцевого наплавленого металу з різним вмістом вуглецю. Додатково з'ясовували вплив різних концентрацій бору і титану на утворення таких дефектів. Відзначено негативну дію підвищення концентрації вуглецю на стійкість хромистого наплавленого металу до відшаровування і воно пояснюється збільшенням ефекту об'ємного перетворення аустеніту в мартенсит. Останнє призводить до збільшення нормальних і сколюючих напружень у «світлій смузі» зони сплавлення. Введення в хромистий наплавлений метал титану запобігає появі білої смуги і розвитку тріщин в зоні сплавлення.

Ключові слова: холодні тріщини; відшаровування; наплавлений метал; зносостійкість; легування; бор; титан.

Петренко А. М. «Влияние состава высокоуглеродистого боротитанового наплавленного металла на структуру и развитие трещин-отслаиваний».

Работа посвящена исследованию связи состава высокоуглеродистого наплавленного металла с образованием микроструктур в зоне сплавления и развитием трещин-отслаиваний. Проведены экспериментальные исследования для серии составов высокоуглеродистого хромомарганцевого наплавленного металла с различным содержанием углерода. Дополнительно выясняли влияние различных концентраций бора и титана на образование таких дефектов. Отмечено отрицательное действие повышения концентрации углерода на стойкость хромистого наплавленного металла к

отслаиванию и оно объясняется увеличением эффекта объемного превращения аустенита в мартенсит. Последнее приводит к увеличению нормальных и скалывающих напряжений в «светлой полосе» зоны сплавления. Введение в хромистый наплавленный металл титана предотвращает появление белой полосы и развитие трещин в зоне сплавления.

Ключевые слова: холодные трещины; отслаивания; наплавленный металл; износостойкость; легирование; бор; титан.

1. Introduction the problem

In a weldments both the fusion zone and the heat affected zone can be formed so-called “cold” cracks. Named so because of occurrence at relatively moderate temperatures (considerably lower than the melting temperature or hot treatment) or room and low temperatures. The most typical type of “cold” cracks in weldments are transverse cracks close to the fusion boundaries in the heat affected zone (a), transverse cracks in the fusion zone (b) and cracks parallel to the fusion boundary, the so-called lamellar tearing. Universally accepted theory describing the nature of cold cracks, especially strain-age embitterment (which occur in days, weeks or months after welding) until now does not exist.

2. Survey of prior research

Quite a lot of experimental data and analytical information relating weldments of carbon and high-alloyed austenitic steels, nickel and titanium alloys are represented. For example, in [1-3] carried out a fundamental analysis of the issue of initiation cold cracking in weldments of martensitic and ferritic steels, and lamellar tearing in the heat affected zone (partially melted zone) parallel to the fusion boundary. At the same time, much less studied are issues associated with the cracking and tearing of high-carbon, high-alloy steels and cast irons as deposited metal. These cases often are more complicated and represented data from different authors [4-9] deals with especial cases, and represents data of experimental nature.

3. Exploration objective: are research relations of the composition of high-carbon deposited metal with the formation of microstructures in the fusion zone and the susceptibility of cracking and lamellar tearing.

4. Results of the research

The most potential material with high ability at a contact dynamic loading or abrasive wear [8, 9] are austenitic and martensitic-austenitic steel Fe-Mn-based, Fe-C-Mn and Fe-C-Cr-Mn, capable to intense hardening while loading due to the formation of “deformation martensite transformation”. That alloying system adopted as the basis for our research. In addition, taking into consideration the prospects of increasing wear resistance of deposited metal, alloying with titanium (1...3 %) and boron (0,1...0,5 %) are fulfilled. The chemical composition of the weld deposits in table 1.

Microhardness of austenite welds increases with increasing carbon concentration (№1,2,3, table 2). A comparison of deposited metal composition 1 and 4, 5 shows that the alloying Fe-C-Cr-Mn deposited metal 0,11 %...0,25 boron also causes to a substantial increasing austenite hardness.

Partially melted zone (PMZ) has the “light lamellar zone” close to fusion boundary. It is quite clearly divided into two sections (figure 1):

- Bright structureless zone, located mainly in its upper part,
- Needle structure zone adjacent to the base metal.

Table 1 – Deposited metal chemical compositions

№ prototype	Elements concentration, %					
	C	Mn	Si	Cr	B	Ti
1	2,0	2,20	0,46	8,7	-	-
2	2,38	3,0	0,48	9,0	-	-
3	2,66	2,70	0,43	8,8	-	-
4	1,86	2,90	0,57	7,0	0,11	-
5	1,80	2,57	0,54	6,8	0,25	-
6	1,67	1,21	0,44	-	0,23	1,52
7	1,80	1,23	0,47	-	0,3	1,52
8	2,08	1,32	0,76	-	0,68	2,80
9	1,77	1,40	0,76	-	1,10	3,00
10	1,86	1,38	0,90	-	0,35	2,89
11	1,64	1,41	0,88	-	0,45	3,02

a b c

Figure 1 – Microstructure Fe-C-Cr-Mn weld metal B and Ti alloyed and fusion zone (compositions No. 6, 8 and 4)

In heat affected zone, close to the fusion boundary metal has a compacted structure with a hardness of 330...430 kg/mm^2. The concentration of chromium at the "light lamellar zone" according to the local spectral analysis is 2...4 %. The carbon content was calculated for the distance of 0.03 mm from the fusion boundary is shown in table 3.

The microhardness of structureless part of "light lamellar zone" approximately equal to the hardness of austenite deposition. Hardness of needle-like structure is characteristic to bainite or bainite-martensite structure. Assuming, this case the initiation of cracking or lamellar tearing is the shear stresses occurring in the light lamellar zone.

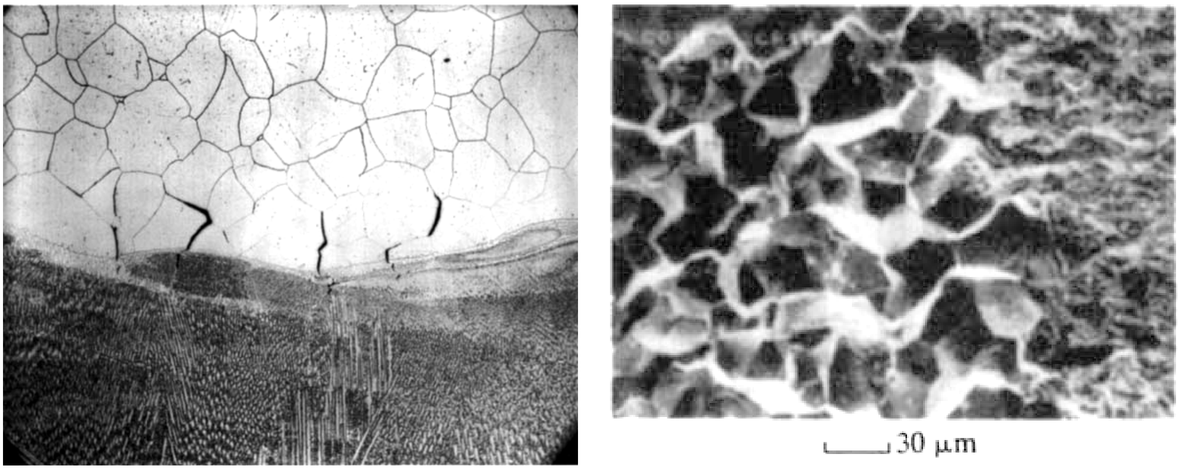
Table 2 – Microhardness different zones of deposited metal

№	PMZ width, mkm	Microhardness, kg/mm^2		
		Deposited metal (austenite)	Light lamellar zone	
			Structureless zone	Needle structure zone
1	20…30	203…209	251…259	456…492
2	20…40	319…331	441…343	522…547
3	20…50	319…333	319…331	547…603
4	20…30	227…287	268…277	-
5	20…30	297…307	357…396	-

Table 3 – Carbon concentration in light lamellar zone

№	Carbon concentration in the base metal, %	Carbon concentration in the deposited metal, %	Fusion boundary spacing, mm	Calculated carbon concentration, %
1	0,20	2,00	0,03	1,55
2	0,20	2,38	0,03	1,85
3	0,20	2,66	0,03	2,04

This thesis is confirmed by data showing the impact of carbon content in deposited metal on the microhardness of separate sections of the light lamellar zone and the tendency for metal within it to crack. As shown above, with increasing concentration of carbon increases the hardness of austenitic and bainite-martensite parts of the light lamellar zone. Since the cooling conditions in the all experiments remained unchanged, the increasing of hardness of needle zone can be considered due to increased concentration of carbon. The increasing concentration of carbon enforces the volume effect of austenite transformation, which facilitates the occurrence of lamellar tearing [6]. Indeed, if in light lamellar zone of deposited metal No. 1, containing 2.00 % of carbon, cracks is almost absent. While increasing concentration to 2.38 cracks will appear (figure 2).



a b

Figure 2 – Micro-cracks near the fusion boundary (a), surface of lamellar tearing fracture (b)

A further increasing of carbon concentration up to 2.66 % causes cracks at the fusion boundary on the greater part of its length. Cracks occur mainly in the zone of the needle structure, extending sometimes to structureless area and the heat affected zone (figure 1, b). Thus, the negative effect of increasing concentration of carbon on susceptibility of Fe-C-Cr-Mn deposited metal to lamellar tearing is not due to the reduction in the width of the interlayer, but increasing its hardness and volume effect of transformation of austenite to martensite. Which should cause to increasing of normal and shear stresses in “light lamellar zone”. This conclusion is confirmed by the crack initiation in heat affected zone of depositions with lower carbon content. Despite the increasing “light lamellar zone” width from a few microns up to 60 mkm the nature of the development of cracks and lamellar tearing was approximately the same as in the described experiments.

Alloying the deposited metal with boron (No. 4, 5) causes increasing hardness of austenite, as in fusion zone, so in the light lamellar zone. Increased hardness of the base metal close to fusion boundary of 350 kg/mm^2 (No. 3) to 410 kg/mm^2 and 512 kg/mm^2 for the weld metal containing

0,11 % and 0.25 % boron, respectively. Given the similarity of the chemical composition of samples No. 1 and No. 5 increasing the hardness of metal light lamellar zone and the base metal close to the fusion boundary can be explained by the influence of boron, the diffusion coefficient which closely spaced to carbon. So, both of it is able to diffuse sufficiently deep into the base metal from fusion boundary. Alloying with boron depositions with relatively low carbon content (No. 4, No. 5) cause cracks initiation mainly in needle structure zone.

Alloying with titanium [6] eliminates cracks and lamellar tearing when the concentration of boron is up to 0.68 % (No. 6,7,8). However, when the carbon concentration increases to 1,77 %, boron 1,1 % in the weld metal have already appeared a single hair-like cracks. With further increasing of carbon content and boron (No. 10,11) causes occurrence of cracks and tearing.

Summary and conclusions

1. The influence of carbon, boron and titanium on structure and properties of fusion zone high-carbon deposited metal was carried out.

2. Observed negative promotion increasing concentration of carbon for on the resistability of chromium deposited metal to lamellar tearing. Thus, the negative effect of increasing concentration of carbon on susceptibility of Fe-C-Cr-Mn deposited metal to lamellar tearing is not due to the reduction in the width of the interlayer, but increasing its hardness and volume effect of transformation of austenite to martensite.

3. Alloying with titanium eliminates formation of light lamellar zone, cracks and lamellar tearing.

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