14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

TENSILE PROPERTIES OF FERRITE-AUSTENITIC WELDED JOINT

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ABSTRACT
Very often, in order to optimized welded constructions, some of their parts are made of heterogeneous steels. For example, microalloyed steels are in use for cars chassis making and high alloyed steels for different constructions making. From that reason, it's not rare to find welded joints between ferrite microalloyed and austenitic highalloyed steels. As a rule, these joints are welded by using highalloyed filler material. In that way, obtained welded joint is made of five different materials (two base metals, weld metal and two different heat affected zones).
In the paper, tensile properties of ferrite-austenite welded joints on a storage tank for liquid carbon dioxygen are analysed. Using the results of the research, the appearance of some cracks on the welded joints at the connection part of the tank are explained.
Keywords: ferrite-austenite welded joint, crack, tensile properties

1. INTRODUCTION

After many years observation of tanks for liquid carbon dioxygen storage during explotation, in a certain number of connection welded joints, the cracks are seen. These joints, in the connection part of the tank, are between highalloyed steel pipe and microalloyed steel tank envelope (or bottom). The length of those cracks goes from a few millimeters /1/ to many tens of millimeters /2/. Some of the cracks start from the merging line (between weld metal and microalloyed steel), and the others appear even on the 30 millimeters distance from merging line in microalloyed steel base metal.
Figure 1. shows crack detected in the heat affected zone connection part of the tank for storage of liquid carbon dioxygen [1]. Tank is vertical, cylindrical, capacity 25 m^3. An envelope of the tank (or bottom) is made from steel P 460 NL1 thickness 12 mm, and connection part of the tank is made from highalloyed austenite steel X7CrNiNb18.10. The lowest work temperature of tank is -55 ^{0}C and maximum work pressure is 25 bar. For welding the tank connection for envelope of tank is used cover wire electrode tip INOX 29/9. The crack is detected by method of replica. In Figure 1. could be seen two cracks which are conected. The end of crack is on the fusion line of weld metal and microalloyed steel. The light surface on the Figure 1 is non-etched austenite filler metal. The actual length is 1,8 mm.

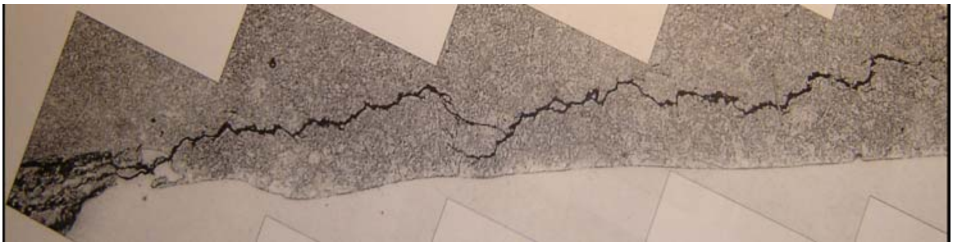

Figure 1. The cracks in the heat affected zone welded join the tank connection

2. MATERIALS AND WELDING PROCEDURE

To estimate the safety of preliminary described joint with cracks in tank exploitation, experimental research is carried out. The specimens are made from same base metals and welded by same welding technology as the tank connection. [1]. The plates are made of microalloyed steel P460NL1 (standard EN 10028 – 3) (designated as M), thickness 14 mm and from highalloyed steel X6CrNiMoTi 17 12 2 (standard EN 10088) (designated as V), thickness 12 mm. In the Table 1. and 2. are shown chemical composition and mechanical properties of these steels. The microstructure of base metals show that microalloyed steel has homogeneous fine grained ferrite-perlite structure and highalloyed steel has austenite microstructure.

Table 1. Chemical composition of base metals

Steel	C	Si	Mn	P	S	Cr	Ni	Cu	Al	Mo	Ti	V	Nb
M	0,10	0,49	1,26	0,011	0,014	0,08	0,11	0,21	0,067	0,019	0,002	0,048	0,053
V	0,04	0,35	1,73	0,031	0,004	17,9	11,6	0,18	0,061	2,16	0,38	0,079	0,016

Table 2. The mechanical properties of base metals

Basic metal	Upper yield strength R_{EH}, MPa	Lower yield strength R_{EL}, MPa	Yield strength $R_{p\,0,2}$ MPa	Ultimate tensile strength R_m, MPa	Elongation A %	Contraction Z %
Steel M	453	435	-	565	25	58
Steel V	-	-	324	595	37	53

The plates are welded by manual arc welding process. Filler material used in this work is covered electrode INOX 29/9. The chemical composition and mechanical properties of filler material are given in Table 3. and 4. The electrode has rutile cover and designed for heterogeneous materials welding.

Table 3. The chemical composition of electrode INOX R 29/9

C	Si	Mn	Cr	Ni
0,15	≤ 0,9	0,9	29	9

Table 4. The mechanical properties of electrode INOX R 29/9

Yield strength $R_{p0,2\%}$ MPa	Ultimate tensile strength R_m MPa	Elongation A_5 %	Contraction Z %
553	750	43	41

Plates, dimensions 500 x 200 mm with V groove, are prepared for welding by planing. Four plates welded like four the plates of research. Only microalloyed steel was preheated, as well as it knew weldability of both base metals. The preheating temperature was calculated on the Itto Bessyo's method [3] and it was 200 ^{0}C. The parametres and conditions described in literature [4].

3. RESULTS AND DISCUSSION

The tensile properties of weld metal were determined on specimens (Ø6mm) on the Testing Machine SCHENCK TREBL RM 100. The middle values of three test of specimens are given in Table 5. In

Figure 2.a) is given a diagram of σ - ε obtained by testing specimens from weld metal. The diagram is typical for austenitic steels.

The tensile properties of welded joint are determined by testing of specimens with smooth flat parallel sides. The specimen was tested in the Testing Machine SCHENCK TREBL RM 400. The diagram σ-ε, obtained by tensile testing is shown in Figure 2.b). In the diagram are identified four characteristic points, which are marked the letters A to D. The values of tensile strength are given in Table 5, corresponding to these points, so as the total elongation for each tested specimen.

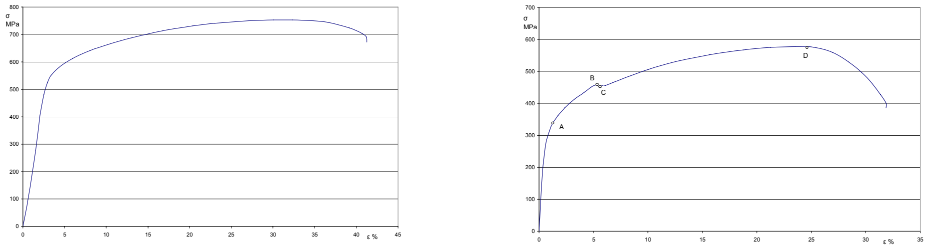

Figure 2. a) Diagram obtained by the tensile testing from weld metal, b) The characteristic points of tensile in the diagram σ - ε, testing the whole joint

In Figure 3 is shown specimen No. 1 after fracture. The specimen is unevenly deformed. In Figure 4 is shown a change of contraction of cross-section of specimen No.1 along part of its measurement. The other specimens have the similar character of diagram, and in all three cases the fracture occurs in base metal of microalloyed steel.

Table 5. The characteristic of tensile points in the diagram σ - ε, testing the whole joint

No. of specimen	Tensile strength in point A (MPa)		Tensile strength in point B (MPa)		Tensile strength in point C (MPa)		Tensile strength in point D (MPa)		Elongation A %	
	Indivi-dualy	middle value	Indivi-dualy	middle value	Indivi-dualy	middle value	Indivi-dualy	middle value	Indivi-dualy	middle value
1.	337	341	458	462	450	450	579	584	*32*	31
2.	337		463		450		579		*31*	
3.	350		465		450		595		*31*	

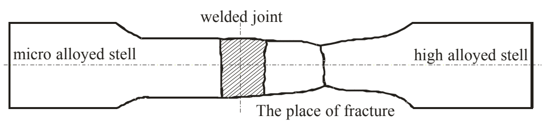

Figure 3. The test of specimen No 1. after fracture

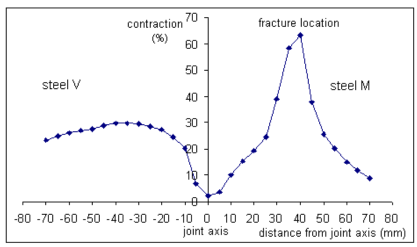

Figure 4. Change the contraction of the cross section along the test of specimen No. 1

Comparing the values from Table 5 with the values of yield strength and tensile strength (tables 2 and 4) and the other hand, having regard to the shape of diagrams σ - ε obtained in the whole joint testing, and by testing of base metal [4] and weld metal, it can be assumed that point A corresponds to the values of yield strength of the highalloyed steel, point B corresponds to the values of the higher yield strength of the microalloyed steel, point C of the microalloyed steel of the lower yield strength of the micro alloyed steel and point D of the micro alloyed steel ultimate tensile strength.

In Table 6 are simultaneously given the strength values of tension corresponding to points A to D and the value of the highalloyed steel yield strength, the value of the microalloyed steels higher and lower yield strength and the value of the microalloyed steel ultimate tensile strength. Comparing these values to their perceived very good agreement (very small deviations in the last columns of Table 6). On this basis, it can be concluded that the point A corresponding the highalloyed steel yield strength, to point B corresponding to the microalloyed steels top yield strength, to point C corresponding to the microalloyed steels lower yield strength and point D corresponding microalloyed steel ultimate tensile strength.

Table 6. Comparison of tensile characteristic points of the diagram σ - ε

Tensile strength in characteristic points		Characteristic tensile strength for base metal		Deviation	Deviation
Mark	The value of middle tensile, tab 2. MPa	Mark/number of table	The value of middle tensile MPa	Δ R MPa	%
R_A	341	$R_{p0,2}$ steel V	324	17	5,2
R_B	462	R_{EH} steel M	453	9	2,0
R_C	450	R_{EL} steel M	435	15	3,4
R_D	584	R_m steel M	565	19	3,4

From Figure 4 can be seen that weld metal has the smallest contraction cross-section, that is minimal deformation (2% in the axis of weld metal) and the fracture occurs in microalloyed steel base metal. On the basis of stated it may be concluded that plastic deformation in the considered, heterogeneous mixture (which consists of five different materials, two different base metals, their heat affected zones and weld metals) takes place by starting in the high alloyed steel base metal (which has the lowest yield strength), then starts in the microalloyed steels base metal (which has a higher yield strength) and finally begins in weld metal (whose yield strength is the highest in the joint). The fracture occurs in the part of specimen with the lowest ultimate tensile strength, and that is microalloyed steel of base metal. The weld metal is a little deformed because the yield strength of weld metal is slightly lower than the ultimate tensile strength of microalloyed steel basic metal (table 2 and 4). Both HAZ must be included in the review. The hardness of both HAZ are close to the hardness of corresponding base metals, and it can be assumed that the yield strength and ultimate tensile strength of the zone close to the yield strength and tensile strength corresponding base metals. Therefore, both HAZ behave similarly to base metals on this joint. The properties of the HAZ can significantly change by selecting different welding parameters, especially in steel M.

4. CONCLUSIONS

1. The high strength of weld metal, (overmatching effect - higher yield strength of weld metal in relation to the base metal) act favorably on the safety of welded joints, so weld metal acts as protection from excessive strain.
2. It was found that the weakest place of microalloyed steel is base metal. It is a cause of cracks in the base metal, near welded joints connection part of the tank for storing liquid carbon dioxide.
3. The security of ferrite austenitic welds (with defects in the weld metal) is not compromised even in the presence of small cracks, not only because of the high plasticity of weld metal and its high resistance to crack growth, but also because of the protective role of overmatching effect (small plastic deformation of weld metal), even at peak loads and fracture of the base metal.

5. REFERENCES

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