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CONSIDERATIONS REGARDING THE SCC TESTING OF OLT45.3K STEEL WELDS

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ABSTRACT

Stress corrosion cracking (SCC) is specific for active elements from the thermo-energetic industry that work at high temperature and pressure.

Welds made out of OLT45.3K steel were mount within a brittleness detector, on a thermal circuit.

The paper presents the obtained results following from the verification of the SCC specimen tested on specific circuits by visual examination, free bending testing, metallographic examination and hardness testing.

These results indicate that the stress corrosion cracking resistance for the weld made out of OLT45.3K steel is assured.

KEY WORDS:
OLT45.3K steel, SCC testing, corrosion spot, weld

1. Introduction

The stress corrosion cracking phenomenon (SCC) is specific to active elements in energetics, elements, which run under high pressure and temperature conditions. The OLT45.3K steel is non-alloyed heat resistant steel used in the fabrication of tubular parts of the energetic boilers.

The capacity of the boiler water to produce steel brittleness can be evaluated by an experimental method, which uses a brittleness detector mounted on the boiler element in the interested area.

The testing device (brittleness detector) is so conceived that it simultaneously and continuously reunites three brittle factors: fluid flows, the chemical composition of the water and the thermo-mechanical stress of the steels and welded joints. The quality indexes of the water in the boiler circuit and technological pipelines are added. The proposed testing method for experimentation has an accelerated character as compared with the actual brittleness process in installations by the fact that the most favourable conditions are created to produce cracks in the controlled area of the specimen, easy to be examined and of restrained area.

The method has a prospective character and is applied on specimens

made out of steels and welded joints in the boiler construction. The method consists in exposing in the corrosive environment a pre-tensioned by bending specimen having the radius on the tensile fibre four times its thickness at 15 degree angle.

The fluid has to be focused on an intensely tensioned metallic surface of at least 1000 times.

2. SCC testing on the OLT45.3K welded joints

Specimens are sampled from OLT45.3K+OLT45.3K similar welded joints made out of ϕ168 x 8 mm pipes completed by the customer on the basis of welding specifications applied on execution and mounting. The temperature regime of these joints is maximum 500°C. The verification of the welded joints was performed on the basis of conditions regarding the homologation of welding procedures (PT ISCIR CR7-96). The longitudinal axes of circumferential welds are placed at 57 mm against the threaded end of the specimen. The tensile part of the specimen with pre-strained weld contains the characteristic areas and corresponds to the internal walls of the pipes to the welds roots, respectively.

The SCC specimens subjected to the specific working regime of the steam circuit "continuous purging" on the isometric heat circuit have been verified by:

- visual examination of characteristic areas;
- determination of the residual strain state;
- free bending testing;
- metallographical examinations and hardness testing in the cross section.

2.1. Visual examination of characteristic areas

The state and aspect of examined specimens performed the respecting of the specific conditions imposed by the testing procedures of similar welded joints and of the surveillance instructions. So, specimens have no solid substance depositions coming from the corrosive steam. The fluid acted on the tensile surface continuously by the initial and on going correct adjustment. The aspect of the specimens is presented in figure 1 and the details of the tested surfaces are presented in figure 2.

Figure 1. Specimen 6

Figure 2. Detail specimen 6

The aspect of the specimens (pre-tensioned before testing) subjected

to SCC testing is represented in figure 3.

Figure 3. Specimen 6

All the examined surfaces presented no corrosion cracks on the areas subjected to testing. The predominant color of the tested specimens is grey to black and characterizes the effect of the solid substance in the corrosive fluid.

2.2. Free bending testing

The residual strains obtained by bending in the device are about 8%, corresponding to the 18° angle (figure 3).

To identify the eventually microcracks, the pre-strained specimens have been subjected to the free bending with a 30 mm diameter mandrel, representing a value of four times of the specimen thickness.

The final bending angles, the recorded forces and the corresponding movements of the mandrel are presented in table 1. No SCC brittle cracks were found in the free strain process on the mandrel. This result confirms that the working environment does not produce the brittleness of the base metal and of the welded joint, after a 30 days cycle.

Table 1.

Mark	Angle	Force (N)	Movement (mm)
6	65^0	6700	5
		8150	10
		9900	15

2.3. Metallographical examination

The macroscopic examination of the SCC specimens longitudinally sampled at the "6" sample subjected to the corrosive action of the overheated steam (figures 4 ... 7) evinced no corrosion cracks.

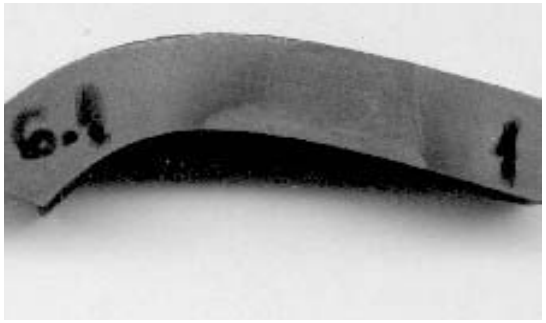

Figure 4. Sample 6.1-1 [Nital etched 10%]

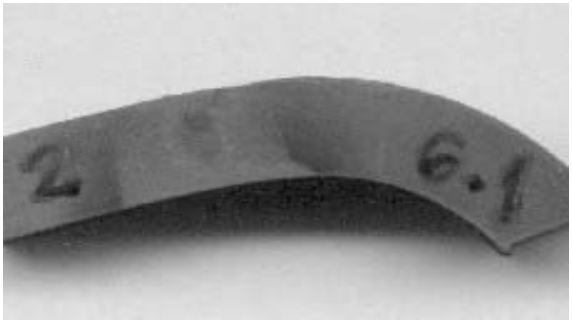

Figure 5. Sample 6.1-2 [Nital etched 10%]

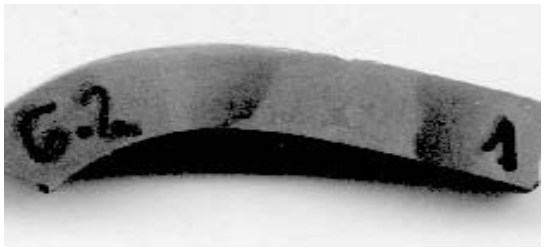

Figure 6. Sample 6.2-1 [Nital etched 10%]

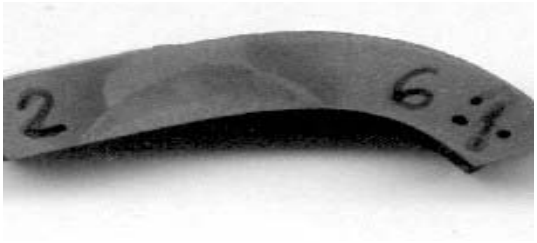

Figure 7. Sample 6. 2-2 [Nital etched 10%]

The microscopic examinations according to EN 1321 and SR ISO 643 were performed in the characteristic areas of the welded joints subjected to the corrosive action of the steam in the heat circuits.

The area subjected to the corrosive action was sectioned longitudinally by "the corrosion spot" obtaining two samples 6.1 and 6.2. Each sample present two faces "1" and "2".

- In the base metal (BM), the structures are ferrito-pearlitic granular, granulation of 8-9 points, according to SR ISO 643 (figures 8...11).

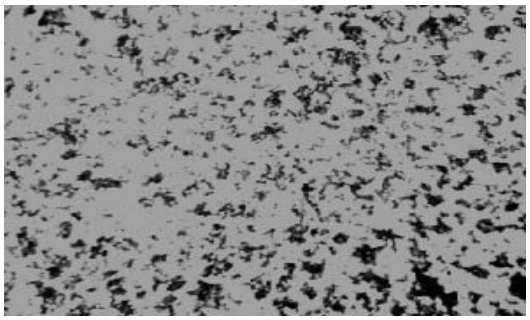

Figure 8. Sample 6.1-1 BM
[Nital etched 3%, x100]

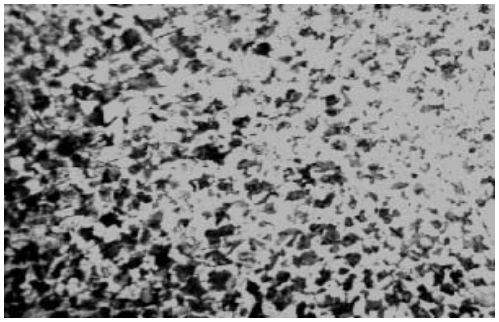

Figure 9. Sample 6.1-2 BM
[Nital etched 3%, x100]

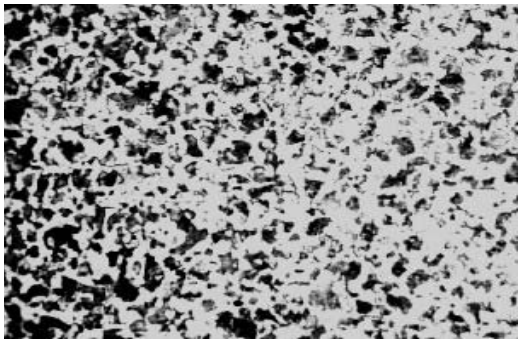

Figure 10. Sample 6.2-1 BM
[Nital etched 3%, x100]

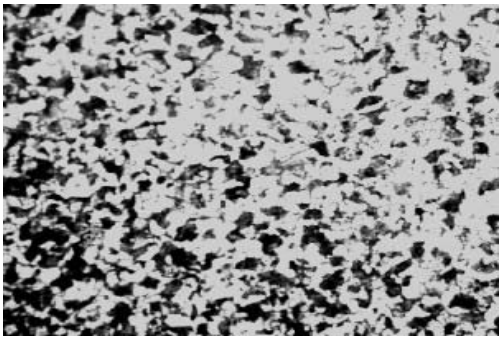

Figure 11. Sample 6. 2-2 BM
[Nital etched 3%, x100]

No fabrication defects and corrosion cracks have been found in the examined areas of the base metal, the corrosion depth does not exceed the value of 0.09 mm.

- In the weld (WELD), the structures are dendritic pearlitic ferritic with elongated dendrites on the thermal flux direction and on the restrained areas acicular ferrite structures were developed, which do not exceed 2 points (W2), according to STAS 7626 (figures 12 ... 19)

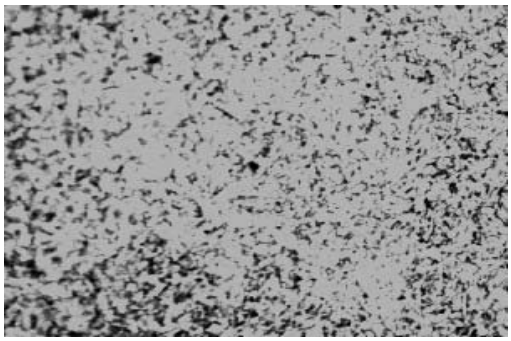

Figure 12. Sample 6.1-1 WELD
[Nital etched 3%, x100]

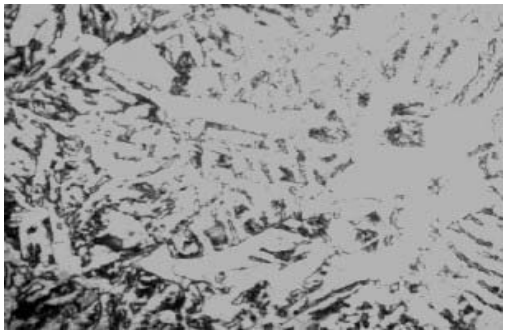

Figure 13. Sample 6.1-1 WELD
[Nital etched 3%, x500]

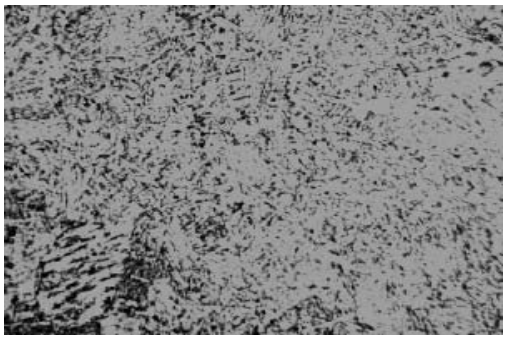

Figure 14. Sample 6.1-2 WELD
[Nital etched 3%, x100]

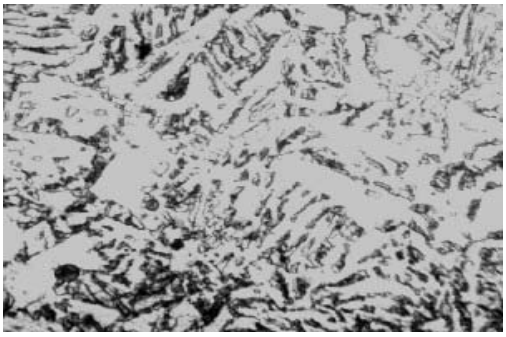

Figure 15. Sample 6.1-2 WELD
[Nital etched 3%, x500]

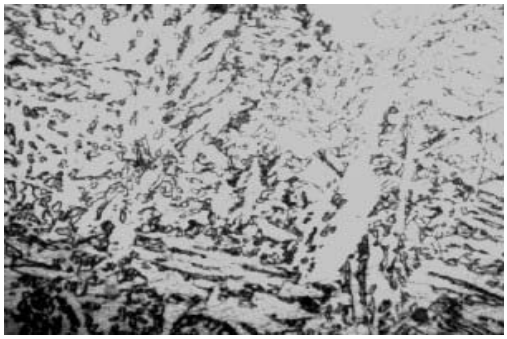

Figure 16. Sample 6.2-1 WELD
[Nital etched 3%, x 100]

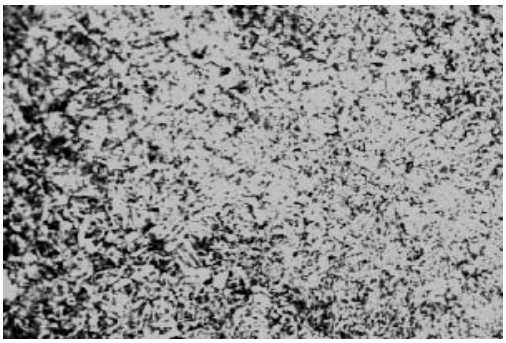

Figure 17. Sample 6.2-1 WELD
[Nital etched 3%, x 500]

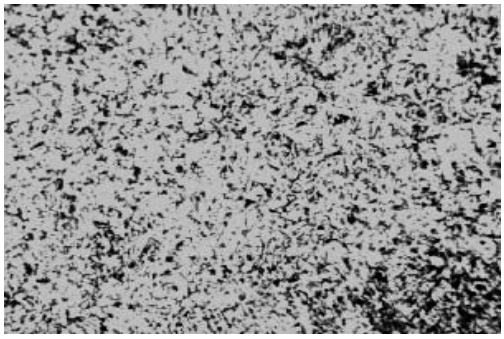

Figure 18. Sample 6.2-2 WELD
[Nital etched 3%, x 100]

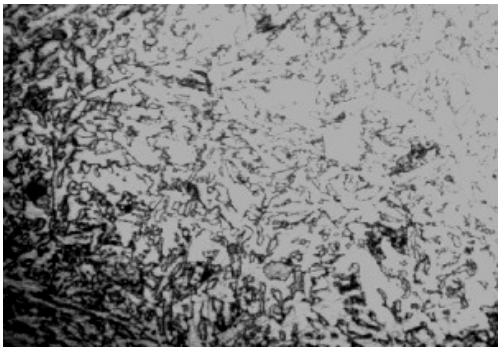

Figure 19. Sample 6.2-2 WELD
[Nital etched 3%, x 500]

The depth of "the corrosion spot" in the weld has minimum values of 0.40 mm for the 6.2-1 sample (figure 20) and of 0.38 mm for the 6.1-1 sample (figure 21).

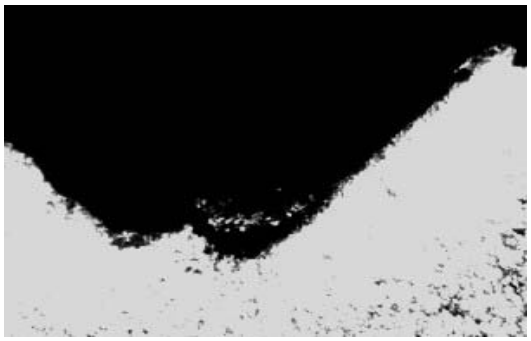

Figure 20. Sample 6.2-1 WELD
[Nital etched 3%, x 100]

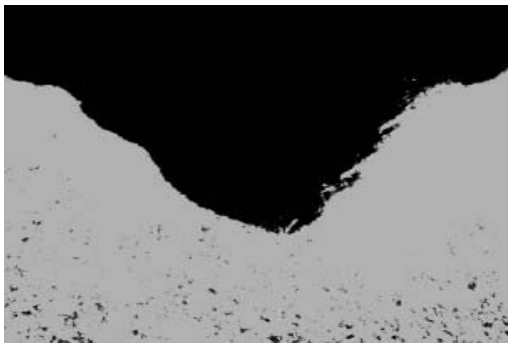

Figure 21. Sample 6.1-1 WELD
[Nital etched 3%, x 100]

In the examined welds were found no welding defects such as microcracks and corrosion microcracks type defects due to the corrosion phenomena of the steam. "The corrosion spot" was formed in the direct contact area steam - specimen where the most corroded areas appear, the other areas present reduced corrosion phenomena, the corrosion depths varies between 0.03 and 0.11 mm.

- In the heat affected zones (HAZ_1, HAZ_2), the structure is pearlite ferritic granular with acicular ferrite and the granulation 4-6 points, according to SR ISO 643 (figure 22 ... 29).

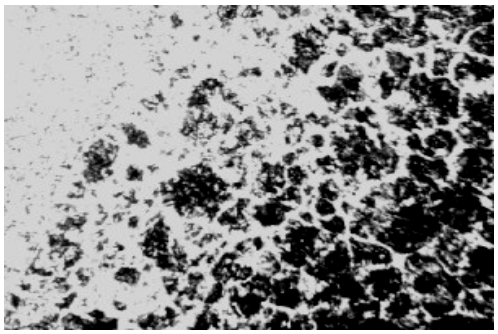

Figure 22. Sample 6.1-1 HAZ
[Nital etched 3%, x 100]

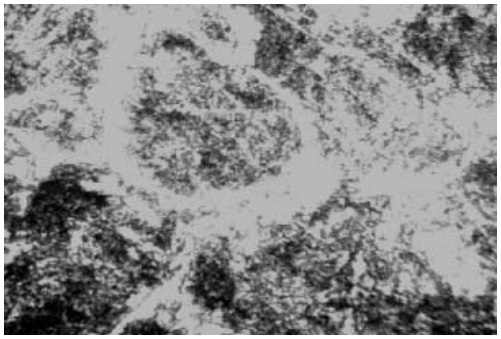

Figure 23. Sample 6.1-1 HAZ
[Nital etched 3%, x 500]

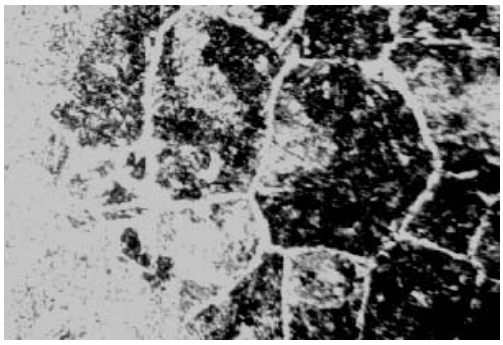

Figure 24. Sample 6.1-2 HAZ
[Nital etched 3%, x 100]

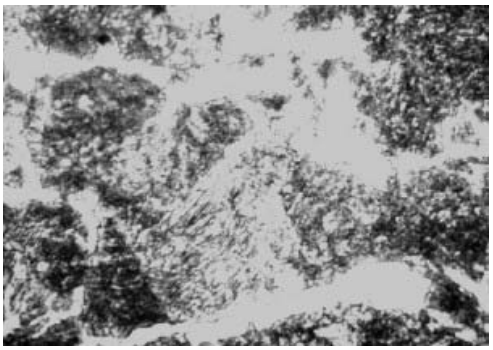

Figure 25. Sample 6.1-2 HAZ
[Nital etched 3%, x 500]

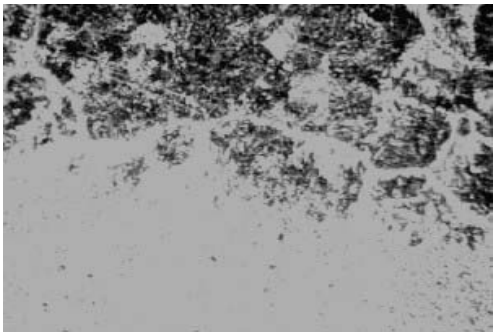

Figure 26. Sample 6.2-1 HAZ
[Nital etched 3%, x 100]

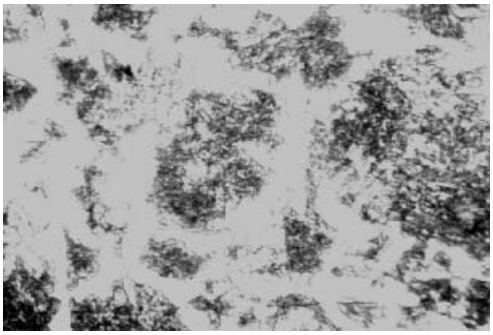

Figure 27. Sample 6.2-1 HAZ
[Nital etched 3%, x 500]

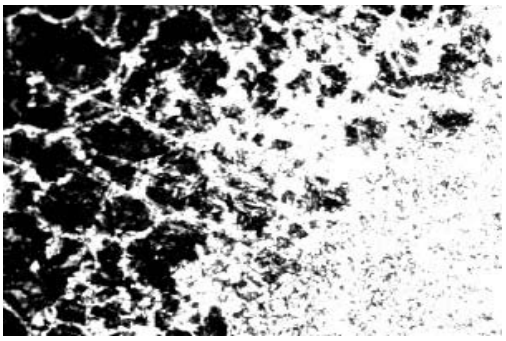

Figure 28. Sample 6.2-2 HAZ
[Nital etched 3%, x 100]

Figure 29. Sample 6.2-2 HAZ
[Nital etched 3%, x 500]

The examined areas had no microcracks, they presented in the contact areas steam - metal different corrosion depths in the range 0.07 and 0.12 mm.

2.4. Hardness testing

The Vickers (HV5) hardness test was performed according to STAS 492/1-85. The distribution scheme of the hardness indentations is according to figure 30, and the results of the tests are included in table 2.

The relative justice error "E" is ± 3%.

The relative fidelity error "E" is ± 4%.

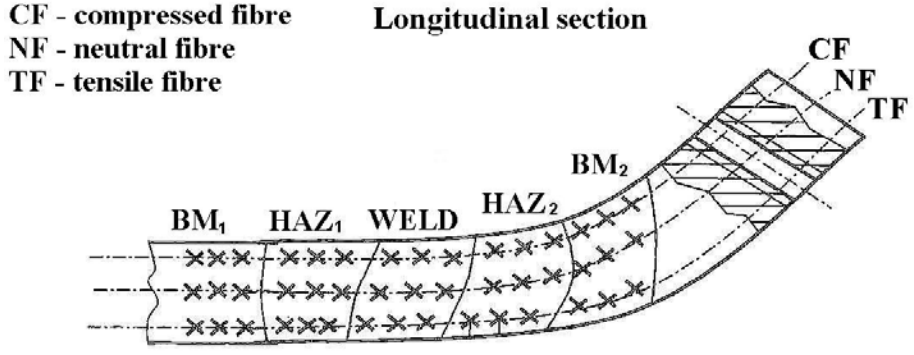

Figure 30. The distribution scheme of the hardness indentations

Table 2.

Sample mark	Investigated zone	Tensile fibre (TF)		Neutral fibre(NF)		Compressed fibre(CF)	
		Hardness					
		HV5	HB	HV5	HB	HV5	HB
6.1-1	BM_1	178	169	165	157	170	161
		175	166	166	158	175	166
		177	168	167	159	178	169
	HAZ_1	241	229	238	226	228	217
		236	224	230	219	240	228
		225	214	232	220	225	214
	WELD	236	224	230	219	219	208
		229	218	220	209	217	206
		221	210	225	214	226	215
	HAZ_2	244	232	235	223	226	215
		242	230	237	225	228	217
		236	224	235	223	224	232
	BM_2	172	163	160	152	172	163
		170	161	162	154	170	161
		176	167	164	156	170	161
6.1-2	BM_1	168	160	166	158	172	163
		168	160	162	154	176	167
		172	163	164	156	177	168
	HAZ_1	247	235	222	211	229	218
		246	234	223	212	239	227
		237	225	231	219	228	217
	WELD	235	223	230	219	232	220
		237	225	229	218	227	216
		230	219	235	223	228	217
	HAZ_2	244	232	231	219	241	229
		248	236	237	225	240	228
		250	238	235	223	244	232
	BM_2	166	158	160	152	160	152
		172	163	150	143	160	152
		165	157	149	142	162	154
6.2-1	BM_1	177	168	160	152	170	161
		171	162	159	151	172	163
		182	173	160	152	177	168
	HAZ_1	250	238	226	215	229	218
		249	237	225	214	221	210
		240	228	220	209	219	208

Sample mark	Investigated zone	Tensile fibre (TF)		Neutral fibre (NF)		Compressed fibre (CF)	
		Hardness					
		HV5	HB	HV5	HB	HV5	HB
6.2-1	WELD	238	226	220	209	229	218
		241	229	225	214	240	228
		240	228	223	209	242	230
	ZIT_2	241	229	219	208	237	225
		244	232	226	215	242	230
		239	227	235	223	240	228
	MB_2	170	161	156	148	166	158
		168	160	150	143	169	161
		168	160	162	154	170	162
6.2-2	MB_1	175	166	160	152	171	162
		178	169	162	154	170	161
		171	162	166	158	177	168
	ZIT_1	237	225	230	219	230	219
		242	230	220	209	232	220
		240	228	225	214	235	223
	SUD	240	228	229	218	245	233
		235	223	232	220	240	228
		232	220	239	227	242	230
	ZIT_2	242	230	230	219	246	234
		240	228	232	220	249	237
		246	234	230	219	231	219
	MB_2	180	171	166	158	169	161
		175	166	171	162	170	162
		171	162	159	151	170	162

The ΔHB estimator represents the local structural hardening of an area reported to another area, the hardening of the (TF) tensile and (CF) compressed area reported to the neutral area (NF). This estimator can be calculated by the relation:

$$\Delta HB = \frac{HB_{max(TF,CF)} - HB_{min(NF)}}{HB_{min(NF)}} \cdot 100 \quad [\%] \qquad (1)$$

When $\Delta HB > 0$ there appears a local structural hardening, and when $\Delta HB < 0$ there appears a local structural softening.

Table 3 gives the ΔHB values calculated by relation (1).

Table 3.

Sample mark	Evaluated zone	ΔHB estimator [%]	
		Tensile fibre (TF)	Compressed fibre (CF)
6.1-1	MB_1	7,80	7,64
	ZIT_1	4,56	4,10
	SUD	4,67	**1,40**
	ZIT_2	4,03	4,03
	MB_2	9,86	5,84
6.1-2	MB_1	5,84	8,44
	ZIT_1	11,37	7,58
	SUD	2,29	1,41
	ZIT_2	8,67	5,93
	MB_2	**14,78**	8,45
6.2-1	MB_1	**14,56**	11,25
	ZIT_1	13,87	**4,30**
	SUD	9,56	10,66
	ZIT_2	11,53	10,57
	MB_2	12,58	13,28
6.2-2	MB_1	11,18	10,52
	ZIT_1	10,04	6,69
	SUD	4,58	6,88
	ZIT_2	6,84	8,21
	MB_2	13,24	7,28

On the basis of the determined ΔHB estimator the following can be concluded:

- for welded samples 6.1-1 and 6.1-2 there appear local structural hardening on TF and CF between 1.40% for the 6.1-1 (WELD) sample and 14.78% for the 6.1-2 (BM_2) sample;
- for the welded samples 6.2-1 and 6.2-2 there appear, local structural hardening on TF and CF fibres, where the minimum value of the estimator is 4.3% for the 6.2-1 sample (HAZ_1) and the maximum one is 14.56% for the 6.2-1 sample (BM_1).

3. Conclusions

3.1. The OLT45.3K +OLT45.3K similar welded joint inestigated by the SCC testing has assured the stress corrosion cracking resistance on the live steam circuits.

3.2. In this way, it is confirmed that the steam produced in installations and which contains nitrides and other solid substances has no brittle effects in welded areas on the heat circuits of the installations under mechanical and thermal tension.

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