The microstructure and properties of the 7CrMoVTiB10-10 steel welded joint

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7CrMoVTiB10-10 is modern steel used to build boilers across Europe. Welding is very important operation during the process of building boilers. Microstructure and properties in the heat affected zone are changed by welding process. Consequently the properties of the whole welded element are different. The aim of this paper is to show microstructure and selected mechanical properties of welded 7CrMoVTiB10-10.
Keywords: steel, microstructure, welding, 7CrMoVTiB10-10, welded joint

Introduction

7CrMoVTiB10-10 is one of the most high tech kinds of steel used for building the energetic devices. This steel was developed due to demand of energetic sector for materials working under supercritical conditions. These requirements effect from steady progress in energetic sector, leaded by necessity of improving the efficiency of power plants and reduction of the emission of the pollutions which is forced by the UE directive. This improvement is realized by enlarging of the base parameters under which boilers work - temperature and pressure. Figure 1 shows the hypothetical thickness of the pipeline wall, which would work under pressure of 19,1 MPa and in temperature of 545˚C.

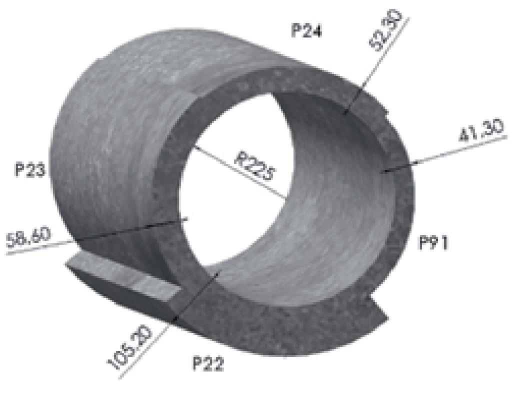

Figure 1. The hypothetic thickness of the pipeline wall from different steels, which would work under pressure of 19,1 MPa and in temperature of 545˚C

The TIG method (141) is used for welding pipes from 7CrMoVTiB10-10 steel during the process of building the energetic boilers in power plants. The microstructural changes are related with the process of welding. It is very important aspect because the mechanical properties of material change together with the microstructural changes.

The topic of 7CrMoVTiB10-10 steel is very popular in recent years. Many scientific papers concerning this topic was published.

The aim of this paper is to show the differences in microstructure and properties between welded joint and the base material in case of the 7CrMoVTiB10-10 steel.

Material

The base material was the 7CrMoVTiB10-10 steel. The chemical composition of 7CrMoVTiB10-10 is shown in Table 1.

Methodology

Welding

Prepared ends of pipes are shown in Figure 2.

The base material was heated to temperature 150 – 200˚C before welding.

Table 1. The chemical composition of the 7CrMoVTiB10-10 steel

Steel	Chemical composition [%]							
	C	Mn	Si	Cr	Mo	V	Ti	B
7CrMoVTiB10-10	0.05	0.3 – 0.7	0.15 – 0.45	2.2 – 2.6	0.9 – 1.1	0.2 – 0.3	0.06 – 0.1	0.0015 – 0.007

Table 2. The chemical composition of filler material

Rod	Chemical composition [%]						
	C	Mn	Si	Cr	Mo	V	Ti/Nb
WZ CrMo2Vti/Nb	0.05	0.5	0.3	2.2	1.0	0.22	0.04

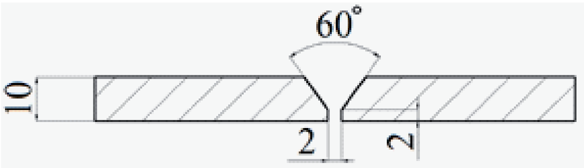

Figure 2. Ends of base material prepared to welding

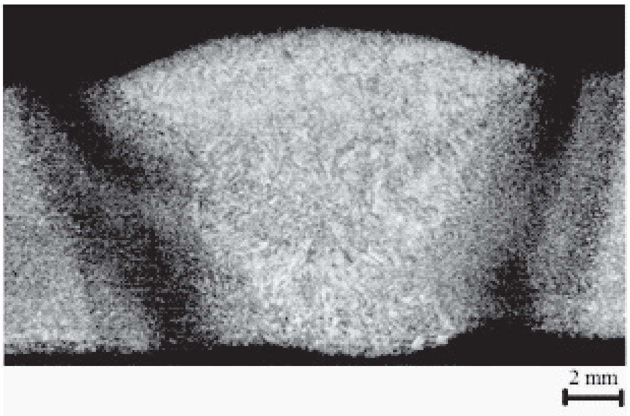

Figure 3. The macrostructure of the welded connection

Table 3. The selected parameters of welding

Weld layer	Welding method	Filler diameter [mm]	Amperage [A]	Voltage [V]	Type/Polarity of current	Estimated welding velocity [mm/s]
1-2	141	2	90-100	20	= (-)	0.5
3-6	141	2.4	100-110	20	= (-)	0.5
7-9	141	2.4	100-110	20	= (-)	0.5

The selected parameters of welding for the 7CrMoVTiB10-10 steel are given in Table 3.

Microstructure examination

The ingredients of an etching reagent used for revealing the microstructure of the welded joint of 7CrMoVTiB10-10 were: 97 cm^3 of ethyl alcohol and 3 cm^3 of nitric acid. The microstructure was observed using an MA-200 microscope.

Hardness examination

The aim of the hardness examination is to determination the width of the heat affected zone. The microstructure in the base material changed by the influence of the heat cycle (heat affected zone) has another hardness than the rest of the base material.

Hardness was measured in the base material, the heat affected zone and in the joint in the root of weld, its center and its face. The measurements was carried out in Vickers scale (HV10). Hardness tester NEXUS 4000 produced by INNOVATEST was used to hardness examination.

Results

The macrostructure of the welded connection is shown in Figure 3.**nection**

The clear look of heat affected zone, sequence of passes and the differences in microstructure of the base material, the heat affected zone and the joint was observed due to macrostructure examination.

The microstructure of the base material is shown in Figure 4.

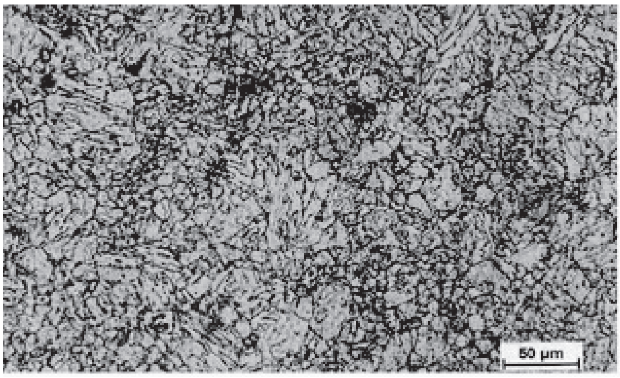

Figure 4. The microstructure of the base material

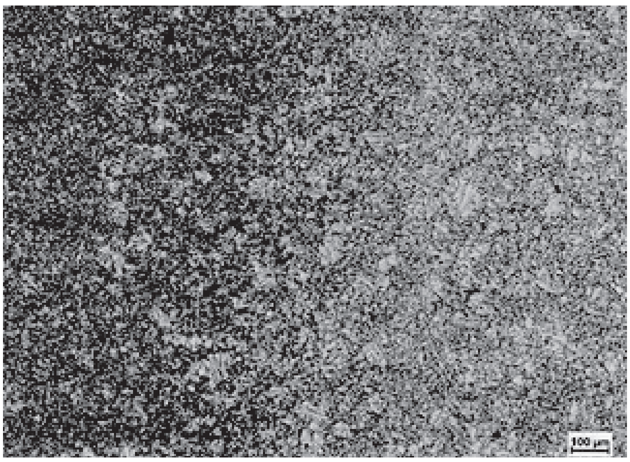

Figure 5. The contrast between the base material and the heat affected zone

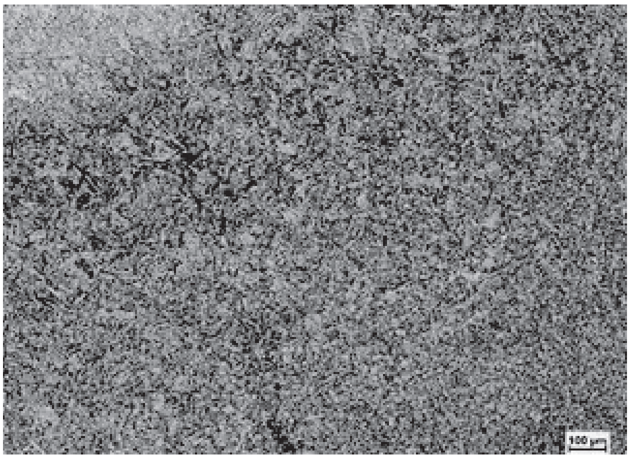

Figure 6. The zone of normalization and growth of grain

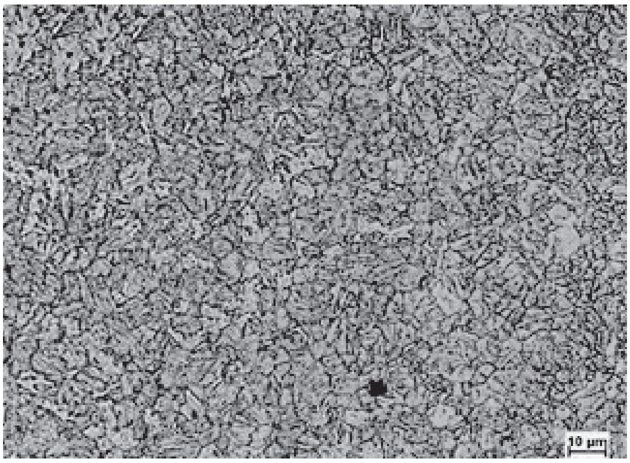

Figure 7. The zone of normalization

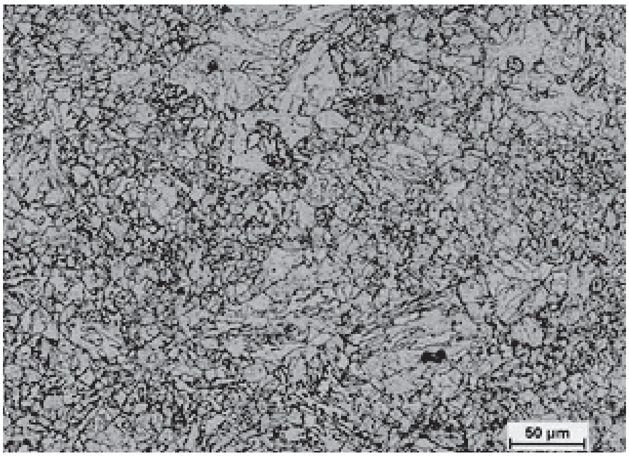

Figure 8. The zone of half normalization

The diversity of morphology of the base material was exposed – the needle-shaped grains and round-shaped grains were observed. The small precipitations of carbonitride phase was also revealed there. The morphology of the base material testify to ferritic-bainitic type of steel.

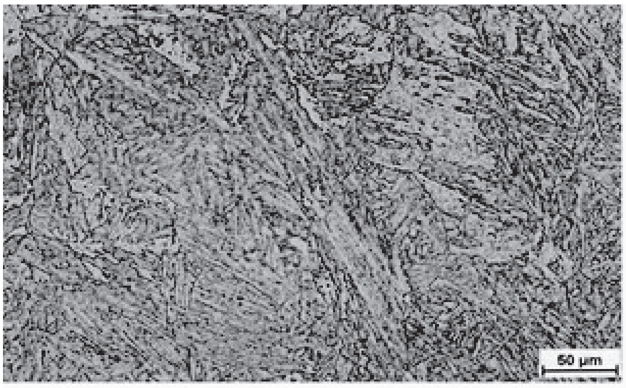

Figure 9. The microstructure of the joint

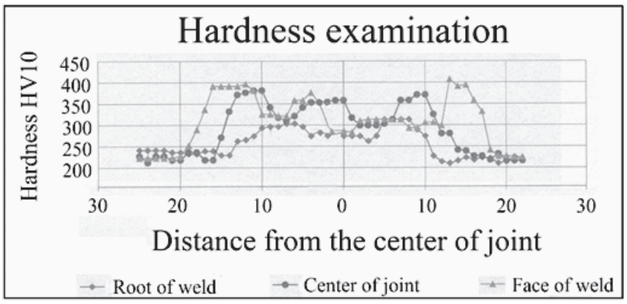

Figure 10. Hardness penetration pattern in the welded joint

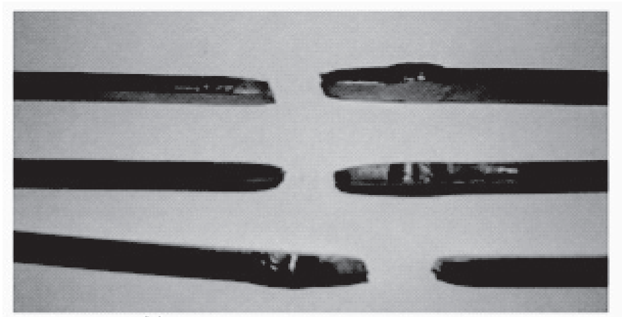

Figure 11. The tensile test specimens after tensile testing

Figures 5 ÷ 8 show the various areas of the heat affected zone.

The heat affected zone next to base material featured the fine granularity.

The coarse and patchy prior austenite grains were observed in area of normalization and growth of grain. The bainite was discovered inside the prior austenite grains. Farther needle-shaped was observed there. It can suggest the presence of martensite.

The fine ferritic-bainitic microstructure was observed in the area of normalization.

The area of half-normalization featured the differentiation of size of grains. The size is in the range 5 – 50 .

The microstructure of the joint is shown in Figure 9.

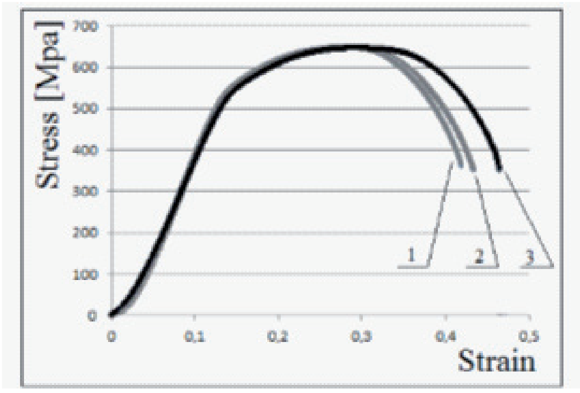

Figure 12. The tensile test diagrams received by tensile testing of welded connection

Table 4: The values of tensile strength for tested specimens

Properties	The number of specimen		
	1	2	3
The value of tensile strength [MPa]	646	652	649

The dendritic structure is characteristic for the joint. The axises of dendrites go towards various directions.

Figure 10 shows the hardness penetration pattern in the welded joint.

The hardness examination (over 350 HV10) confirms the occurrence of a martensite in the microstructure of the heat affected zone.

Figure 11 shows the tensile test specimens after tensile testing.

The tensile test diagrams received by tensile testing of connection are shown in Fig. 12.

The values of tensile strength for tested specimens are shown in Table 4.

Discussion and conclusions

The width of the heat affected zone is about 4-5 mm. It is confirmed by microstructure examination and hardness examination.

The values of tensile strength are satisfactory. Tensile test pieces extracted from welded joints fractured in the base material due to high tensile strength of the welded connection.

The microstructure examination revealed clear changes in the microstructure of welded connection in relation to the microstructure of the base material. The fine grains were observed in the zone of normalization. It is positive phenomenon because of satisfactory mechanical properties.

The high heterogeneity of size of grains in the heat affected zone is unfavourable phenomenon.

The hardness examination shown that the hardness of welded connection was too high – it was much higher than 350 HV in the area of heat affected zone. 350 HV is the limit value of hardness in case of welded joints. This results from the occurrence of a martensite in the heat affected zone, which can be also observed under microscope.

The mixture of bainite and martensite which was observed in the heat affected zone can aids the cracking of welded connection. The formation of that type of microstructure is the reason of occurence stresses in the connection. The lack of heat treatment after welding conduces that.

On the base of the results of research (specifically microstructure examination and hardness examination) it can be stated that the heat treatment directly after welding is necessary in the case of 7CrMoVTiB10-10 steel.

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Paweł Bolanowski obtained his Master of Science degree in Mechanical Engineering from the Kielce University of Technology in 2010. He worked in the following positions: Welding Technologist at CHEMAR Armatura (2010-2012) and Welding Engineer at Energomontaż Południe (contract job in Mannheim – Germany) (2012). He joined the Department of Applied Computer Science and Armament Engineering of Kielce University of Technology as a PhD Student in 2012.

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