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MECHANICAL PROPERTIES OF WELDED PIPES PRODUCED BY HIGH FREQUENCY WELDING OF THE STEEL API J55

Srđan Bulatović[1], Živče Šarkoćević[2], Mladen Mladenović[3]

Summary: *Selection of steel, dimensions and methods of production of welded pipes is a segment of the design process, because it is closely related to the function of a piping as a structural whole under predetermined conditions and for a precisely anticipated service life. The quality of welded pipes during the production process is defined by characteristics that they must possess in order to meet certain requirements, which is being achieved by choosing appropriate procedures and welding parameters, execution of control process for all technological operations during the production, as well as by carrying out mechanical and technological tests regarding the strength and straining of base material and welded joints. This paper presents the results of tests carried out in order to determine mechanical properties of longitudinally welded pipes made by high-frequency contact welding of steel API J55.*
Key words: longitudinal welded pipes, high frequency welding, mechanical properties

1. INTRODUCTION

High strength steel API J55, which is being used for the production of welded pipes, is covered by API 5CT standard [1]. Chemical composition and tensile properties are given in tables 1 and 2.

Table 1. *Chemical composition of API J55, according to API 5CT [1], mass. %*

Steel	C		Mn		Mo		Cr		Ni	Cu	P	S	Si
	min	max	min	max	min	max	min	max	max	max	max	max	max
API J55	-	-	-	-	-	-	-	-	-	-	0,03	0,03	-

Table 2. *Tensile properties of API J55, according to API 5CT [1]*

Steel	R_e [MPa]		R_m [MPa]	A [%]
	min	max	min	min
API J55	379	552	517	24

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High-frequency contact welding parameters are important for the quality management during the automatic production of seam pipes, since their variation considerably alters the quality of welded pipes. Basic parameters of HF welding are current intensity, voltage and welding speed. The quality of welded pipes during the production process is defined by characteristics that they must possess in order to meet certain requirements, which is being achieved by choosing appropriate procedures and welding parameters, execution of control process for all technological operations during the production, as well as by carrying out mechanical and technological tests regarding the strength and straining of base material and welded joints.

2. EXPERIMENTAL PROCEDURE

In order to determine the quality of base metal (BM), heat-affected zone (HAZ) and weld metal (WM) of API J55 steel pipe, welded by HF welding, analysis of chemical composition of base metal and mechanical properties of base metal and welded joint were performed through the use of samples taken from the pipes with diameter of 139.7 mm and nominal wall thickness of 6.98 mm that belonged to the same batch. Welding parameters: electric current 23 A, voltage 12,5 KV and welding speed 12 m/min.

Sampling performed in order to determine mechanical properties of welded pipes

Locations of samples of material from which the specimens should be extracted in order to perform the testing and determine the mechanical properties of base material, heat affected zone and weld metal are defined in standard API 5CT, Fig. 1. Overview of tests executed during these researches is given in Table 3.

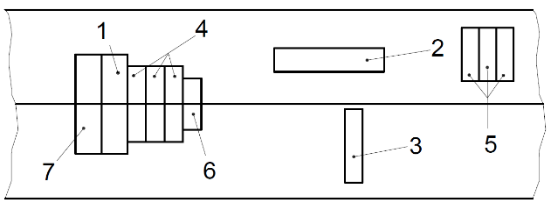

Figure 1. *Locations from which the samples for the production of specimens were taken*

Table 3. *Overview of the performed tests*

Position	Test	Specimen position
1.	Tensile	Perpendicular to welded joint
2.	Tensile	Parallel to the direction of rolling
3.	Tensile	Perpendicular to the direction of rolling
4.	Impact	Perpendicular to welded joint
5.	Impact	Perpendicular to the direction of rolling
6.	Hardness	Perpendicular to welded joint
7.	Bend	Perpendicular to welded joint

3. TEST RESULTS

Analysis of the chemical composition of the base material

Analysis results regarding the chemical composition of API J55 steel, of which seam welded pipes are made, are given in Table 4. Analysis of the chemical composition was carried out in the Laboratory of Zastava Automobiles, Kragujevac. Values of calculated carbon equivalent show that this steel is prone to cold cracking.

Table 4. *Chemical composition of the basic pipe material, [%]*

Steel	[%] mass											
	C	Si	Mn	P	S	Cr	Ni	Mo	V	Cu	Al	Cek
API J55	0,28	0,20	0,99	0,016	0,018	0,09	0,06	0,00	0,00	0,11	0,00	0,47

Tensile properties of base material

Tensile tests on specimens taken from samples of pipes made of steel API J55 and longitudinally welded through the application of HF welding were performed at +20°C. Testing has been performed on the electromechanical testing machine SCHENCK-TREBEL RM 100 in order to determine the elongation. The increment of load application was 5 mm/min. Test procedure is defined by standard ASTM E8-08 [2]. Mean values of test results obtained for specimens taken from samples positioned parallelly and perpendicularly to the direction of rolling are presented in Table 5.

Table 5. *Tensile properties of the base material*

Steel	Specimen position	Re, [MPa]	Rm, [MPa]	A_5, [%]	Z, [%]
API J55	Parallel to the direction of rolling	537	585	27.4	32.5
	Perpendicular to the direction of rolling	552	595	28.3	34.2

Bend testing performed on pipe weld metal

Bend testing was performed in accordance with ASTM 370 standard [3] on specimens taken from samples positioned perpendicularly to the weld axis (3 specimens). All of tested pipes were bent at an angle of 180° without the occurrence of cracks, which points to the fact that satisfiable homogenization of welded joint structure was achieved due to heat treatment of the welded joint by induction annealing.

Tensile testing performed on pipe weld metal

Shapes and dimensions of specimens weld metal are defined by standard ASTM A370 [3]. Mean values of tensile results for the welded joint are shown in Table 6.

Table 6. *Tensile properties of welded joint*

Steel	Specimen position	Re, [MPa]	Rm, [MPa]	A_5, [%]	Z, [%]
API J55	Perpendicular to welded joint	554	580	30.5	35.2

Hardness testing performed on pipe weld metal

Hardness testing was performed on pipe samples (position 6, Fig. 2) in accordance with standard EN ISO 6507-1:2011 [4]. Vickers method was used, while the applied load was HV10. Test was carried out using the hardness tester WOLPERT model V-Testor 2, by creating indentations in the material outside and inside the pipe, at a distance of 2 mm. The magnification at which the size of indentation was determined 200x. Hardness measurement locations are shown in Fig. 2, while measurement results are given in Fig.3

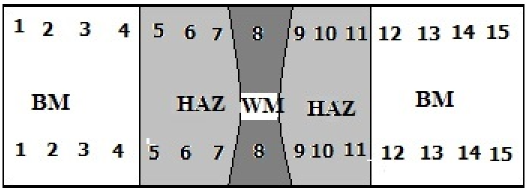

Figure 2. *Hardness measurement locations*

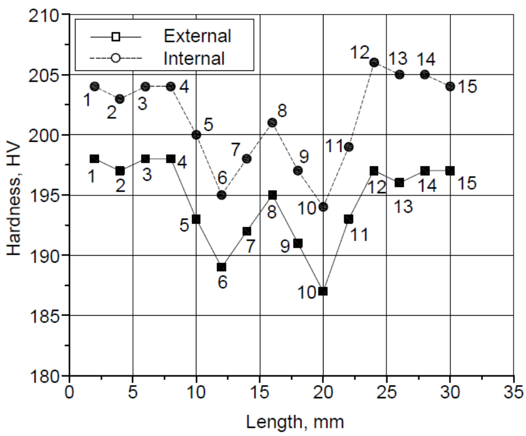

Figure 3. *Diagram of the hardness of the outside and inside of the pipe samples*

Impact tests performed on pipe base material

Impact energy on pipe base material was determined by tests carried out on specimens with V-notch through the use of instrumented Charpy pendulum SCHENCK TREBELL 150/300 J, in accordance with ASTM E23-02 [6] and ASTM E23-07 [6] at +20°C, -20°C and -40°C. Values of tests results are presented in Table 7 and Fig. 4.

Table 7. *Total impact energy of base material*

Specimen position	Test temperature, [°C]	Mean value, E_{tot} [J]
Perpendicular to the direction of rolling	+ 20	99,0
Perpendicular to the direction of rolling	- 20	52,3
Perpendicular to the direction of rolling	- 40	26,3

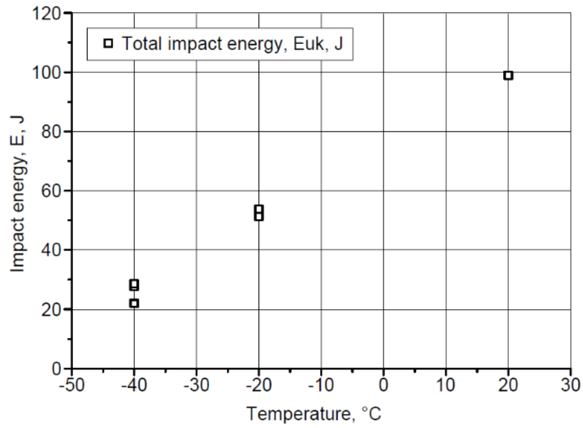

Figure 4. *Mean values of total impact energy of base material*

Impact tests performed on weld metal of the pipe

Specimens extracted from samples taken from weld metal were tested through the use of Charpy pendulum SCHENCK TREBELL 150/300 J at +20 °C, 0 °C, -20 °C and -40 °C. Mean values of results (for 3 spec.) are presented in Table 8 and Fig. 5.

Table 8. *Total impact energy of weld metal*

Specimen position	Test temperature, [°C]	Mean value, E_{tot} [J]
Perpendicular to welded joint	+ 20	72,7
Perpendicular to welded joint	0	69,3
Perpendicular to welded joint	- 20	60,3
Perpendicular to welded joint	- 40	27,3

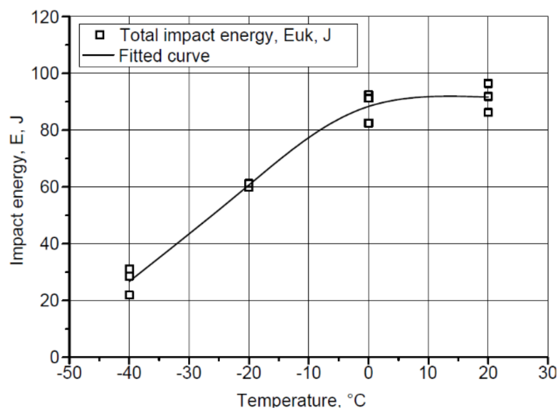

Figure 5. *Mean values of total impact energy of welded metal*

4. CONCLUSION

Analysis results regarding the chemical composition of base material showed that the steel of which longitudinally welded pipes were made had significantly lower impurity content (P and S) than the maximum allowed content defined in API 5CT standard. However, the carbon equivalent value calculated according to MIZ indicates that the steel is prone to the appearance of cold cracks.

Differences between yield strength and tensile strength of basic material in the direction of rolling and perpendicular to the direction of rolling and welded joint of pipe, which are within the 3 % range, are negligible and in accordance with values presented in API 5CT standard. Small difference in values of yield strength and tensile strength of base material in direction perpendicular to the direction of rolling, in direction parallel with the direction of rolling, as well as values of yield strength and tensile strength of weld metal are caused by high compatibility of welding parameters (temperature, voltage, welding speed and achieved pressure of rollers).

Measurement of hardness on the outer and inner surface of the pipe wall showed that base material has the highest, while heat-affected zone has the lowest value of hardness. The highest value of hardness measured at the surface of base material was 206 HV (approximately 18,5 HRC). According to API 5CT, tested pipe batch can be used for operation under the conditions which include the appearance of hydrogen-sulfide (H2S), because the maximum recommended hardness when carbon and low-alloy steels H40 and J55 are applied is 22 HRC. This is valid when the pipes need to fulfill the requirements of NACE standards.

Impact toughness of longitudinally welded pipes made by high-frequency contact welding of API J55 steel at temperatures below 0°C has no effect on their integrity because they are being applied when the operating temperature ranges from 0°C to 80°C.

Acknowledgements

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