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X-Ray Radiography of Micro-alloyed Steel Joined by Submerged Arc Welding

Mustafa Türkmen[1]

Abstract

In this study, micro-alloyed steels were welded by using submerged arc welding method. Different welding current values in experimental studies were carried out according to Table 3. After welding process, the radiographic tests were examined by using X-Ray. The experimental results indicated that microalloyed steel could be joined by using the submerged arc welding technique with sufficient strength. The results of the radiographic tests indicated that with increasing welding current, the amount of deep penetration increased in all samples.

Keywords: Micro-alloyed Steel, Submerged Arc Welding, Radiographic Test.

1. INTRODUCTION

Welding technology is used commonly in many areas. Non-destructive testing methods are important for quality control strategies related to the wear since it is aimed to provide high and constant quality in manufacturing sector and in products,. Accordingly, the non-destructive testing of welded joints has become a part of total quality system [1-2].

Being one of the most important parts of quality control, non-destructive material testing method is the complementary part of the manufacturing. Non-destructive method is the common name of testing methods which ensures to obtain the static and dynamic information of the materials by testing them without giving any damage. By means of the non-destructive testing method, the defects such as cracks occurring during manufacturing or after used for a while, space in internal structure, edge reduction etc. are detected [Table 1].

The methods applied in non-destructive testing are visual testing, liquid-penetrant testing, eddy current testing, magnetic particle inspection, ultrasonic inspection, and radiographic inspection respectively [3-6]. Radiography method is applied to ferromagnetic metals, non-ferromagnetic metals, and other all materials. Because X-ray provides the opportunity to analyse the microstructure of the materials without giving any damage, it is widely used in non-destructive testing. Thickness changes, structural changes, inner defects, and installation details can be determined through X-ray or gamma ray [7-11]. The inspection requires method of the radiographic images to be first-rate and consequently controlled by standard. However; being carried out subjectively by inspectors the radiographic inspection requires great experience and there are interpretation errors due to non-detection of defects [6-12-14].

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Table 1. Non-destructive testing experiments in industry application areas [3].

Practice Area	Function	Application Examples
Research and Development	Structural evaluation of materials, Comparison of production and assembly methods and evaluation findings.	Examination of fatigue and microstructure of metals and the detection of cracks in the welding seam.
Production Control Method	Determination of the variable production method and to control.	Radiographic and ultrasonic thickness measuring method and determination of the manufacturing parameters.
Quality Control	Defective parts and the detection of abnormalities, Manufacturing assembly defects, place and method of evaluation.	Poor adhesion, cracking in welding, metal in the non-uniform pores and the determination of material defects.
During the service evaluation	Wear and use during the early identification of abnormalities.	Corrosion in pipes and location of warehouses and detection, Variety of early warning systems in vehicles.

The advantages of radiography method may be listed as follows; the result is shown with an image, permanent records seen outside of the test area can be obtained, the sensitivity is shown on every film, and the method may be applied to any kind of material. As for its disadvantages, they may be mentioned as follows; it is not suitable for thick pieces, it may be harmful to health, direct calorie is needed for two-dimensional faults, it is not suitable for automation, and surface defects, and it does not give information about the depth of the defect under the surface. The equipment used is rather expensive compared to other methods and mostly needs careful work concerning the radiation safety [15].

In this study, X-Ray radiographic test of micro-alloyed steel joined by using Submerged Arc Welding (SAW) was investigated.

2. EXPERIMENTAL PART

Microalloy steel having 400x200x6 mm dimensions was used to join the samples which Table 2 shows the chemical compositions in this study.

The welding process was performed as two passes by using Oerlikon Magmaweld brand ZD5-1000 B model saw machine. S690QL steels were applied to pre-annealing at 100 oC before the welding. Temperature of pre-annealing was determined by being controlled with heat chalk. Three different welded joints specified in Table 3 were performed by using test materials at 300 A, 350 A and 450 A welding current. Oerlikon-S2 submerged arc welding wire, whose chemical composition is shown in Table 2, and SF-104 submerged arc welding powder, proper to this wire, were used in the welding process. Table 3 illustrates welding parameters used in the experimental studies. Table 4 illustrates physical properties of microalloyed steel.

Tablo 2. Compositions of test materials

Materials	C	Si	Mn	Cr	Ni	Mo	V	Ti
Micro-alloyed Steel	0,13	0,8	1,0	1,5	1,1	0,3	0,1	0,05
Oerlikon S2 (SAW wire)	0,08	0,6	1,3	-	-	-	-	-

Tablo 3. The welding parameters

Sample Number	Current (A)	Voltage (V)	Welding Speed (cm/min)	İnput Heat (kj/mm)
S1	300	30-32	46	1,34
S2	350	30-32	46	1,53
S3	450	30-32	46	1,73

Table 4. Physical properties microalloyed steel.

Materials	α 10^{-6}	λ W/m ^{o}C	Ω nΩm	E kN/mm^2
Microalloyed Steel	11.5	44	140	226

During controlling of the weld seam, radiographic testing among the non-destructive methods was chosen and X-ray tube was chosen as the radiation source since the thickness was 6 mm. Figure 1 shows the principle [16-17]. TS 5127 and EN 1435 Testing standards were applied. According to these standards, the investigated area covers the weld and heat-affected zone (Figure 2).

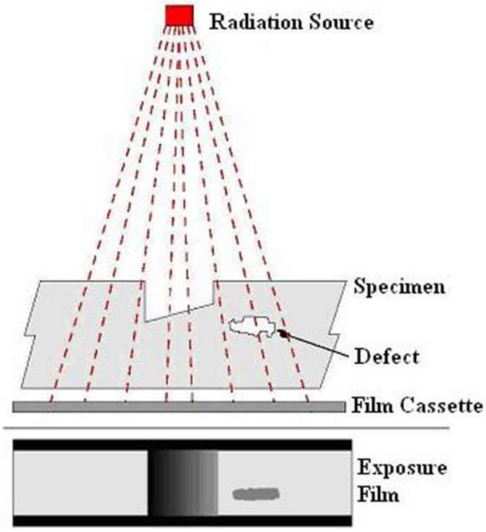


Figure 1. Principle of radiographic test

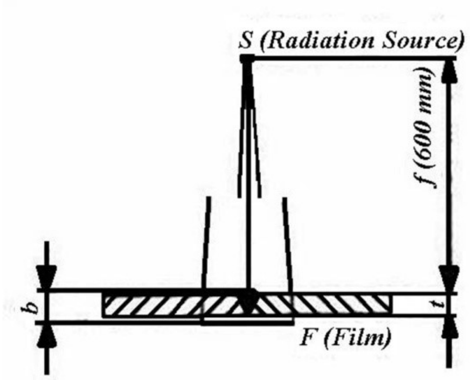


Figure 2. Test preparation for plane wall and one wall.

The X-ray tension chosen according to the thickness of the material was 130 kV (Figure 3) [18-20]. The X-ray device, Rigaku Radioflex–300EGS3 type, having the capacity of 300KV was used (Figure 4a-b). C4 type 100x240 mm Kodak film as well as front and back lead screens with the thickness of 0.125 mm were used. The weld seam applied to the 6-thick material was filmed by sending beam to pose diagram for 48 seconds. The distance between the X-ray device and film was 600 mm. Figure 5 shows placement of the film.

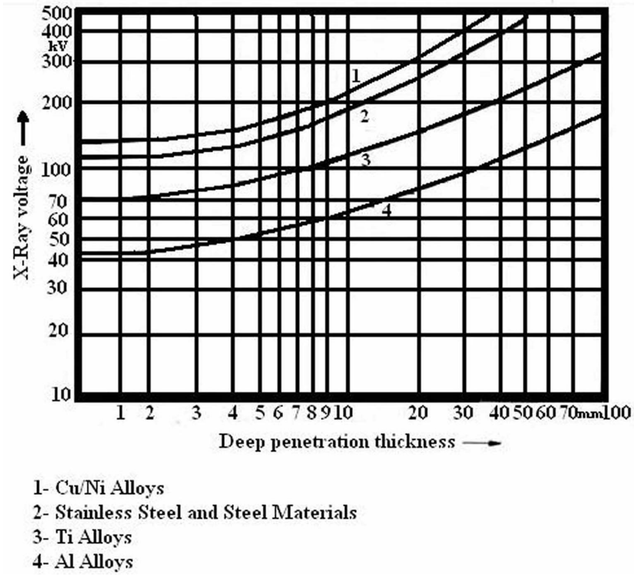


Figure 3. The deep penetration thickness and material as a function 500 kV up to radiography

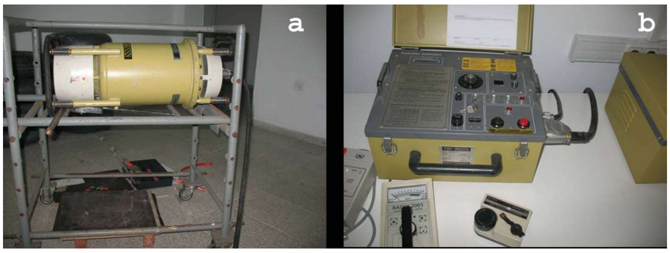
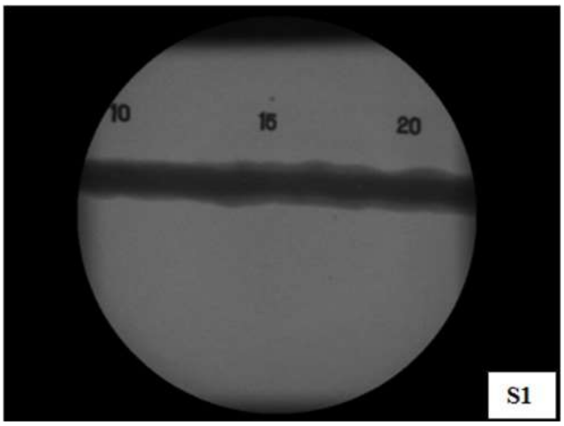


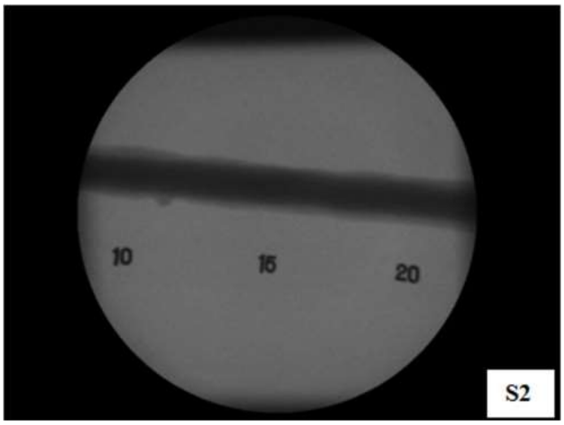
Figure 4. Rigaku mark Radioflex -300EGS3 type device (a) and control panel (b)

Figure 5. Film, penetrometer, stenciling pattern and setting the beam

3. RESULTS AND DISCUSSION

S690QL microalloyed steel was joined by using SAW process at 300, 350, 450 A welding current and 46 cm/min constant welding speeds. According to the International Institute of Welding, welding defects and the explanations of the radiographic images were defined as in Table 5 [18-20]. The image was assessed according to Table 5. It was determined that there was lack of penetration among the most common welding defects shown in Table 5 according to the definitions of welding defects and the radiographic images (D) (Sample No: 1 and 2). No defect was observed in the other sample.





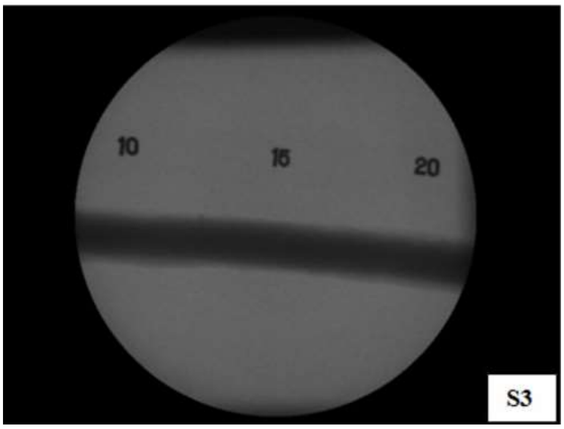


Figure 6. Radiographic-test-images-of-specimens

Figure 6 shows radiographic testing images of all the samples. The experimental results indicated that microalloyed steel could be joined by using the submerged arc welding technique in order to sufficient strength. The radiographic test results demonstrated that as the welding current increased, the amount of deep penetration increased in all samples (Figure 6). The best joining was observed in number S3. The joining decreased in the other samples.

Table 5. Definition of weld defects and radiographic image [18-19].

A: Gas gaps **Aa:** Porosity **Ab:** Gas bubbles	Description	* Because the captured gas bubbles are formed. * Gas channels or long gaps
	Radiographic Image	* Sharp black shadows around the circle. * Sharp black depending on the round or the long shadows
B: Slag **Ba:** Slag **Bb:** Slag errors	Description	* Slag or other foreign materials during the welding. * Captured within gaps slag or foreign matter.
	Radiographic Image	* Dark shadows or random shapes. * Continuous dark lines parallel to the seam edge welding.
C: Insufficient Welding	Description	Welding seam merger due to lack of two-dimensional error.
	Radiographic Image	Sharp-edged thin dark line.
D: Insufficient Deep Penetration	Description	The lack of sewing filled fully with the welding or root.
	Radiographic Image	The middle of the dark seam continuous or discrete line
E: Cracks **Ea:** Vertical Cracks **Eb:** Horizontal Cracks	Description	Local tensile strength of metal exceeded.
	Radiographic Image	Flat thin dark line.
F: Swelter Channel	Description	Welding material on the surface along the seam formed channel or groove.
	Radiographic Image	Welding are spread wide and dark line along the seam.

4. CONCLUSIONS

In this study, X-Ray radiographic test of microalloyed steel joined by using submerged arc welding was investigated. The following results were obtained;

- Submerged arc welding experiments were carried out according to Table 5. This study concluded that microalloyed steel could be joined by using the submerged arc welding technique. The best joining was observed in number S3. The joining decreased in the other samples.
- The microstructural changes took place in HAZs. An increase in the contraction of the samples was observed after increasing the welding current. The width of HAZ was mainly affected by welding current and heat input.
- It was determined that there was lack of penetration among the most common welding defects shown in Table 5 according to the definitions of welding defects and the radiographic images (D) (Samples No: 1 and 2). No defect was observed in the other sample. The radiographic test results showed that as the welding current increased, the amount of deep penetration increased in all samples. The best properties were observed at the samples welded at 450 A welding current and 1.73 kj/mm heat input. (Figure 6-S3).

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