UDC: 621.643.2-034:621.791.753
Professional paper

Selection of filler materials for submerged arc welding of steel pipes

Rrahim Maksuti[1], Hysni Osmani[2], Hamit Mehmeti[1], Asan Idrizi[1], Mursel Rama[3]

[1*] *Department of Mechatronics, Faculty of Applied Sciences, University of Tetova, MK*
[2] *Department of Manufacturing and Automation, Faculty of Mechanical Engineering, University of Prishtina "HASAN PRISHTINA" KS*
[3] *Department of Metallurgy and Materials, Faculty of Geosciences, University of Mitrovica "ISA BOLETINI" KS*
[*] *Corresponding Author: e-mail: rrahim.maksutis@unite.edu.mk*

Abstract

During submerged arc welding (SAW), filler materials (wire and flux) play a leading role on the weld joint quality. Nowadays, the variety available filler materials which are available in welding technology, does not make it easy to select them, but on the contrary makes it very difficult. The wide range of wire and flux combination in the steel pipe industry can make selecting the best weld joint quality, although often it is not a simple issue since there are several factors to be considered. When the selection is performed correctly, welded joint mechanical and technological properties are at least equal to that of base metal, higher to that of base metal or in worse case, lower to that of base metal. Among the mechanical properties of the welded joint, tensile strength (R_m) of the welded joint is the most important feature that helps in the selection of the filler materials (wire and flux) for submerged arc welding (SAW) of steel pipes, while in the framework of technological properties, plasticity of the welded joint is the most important feature that helps in the selection of the filler materials (wire and flux).This paper presents the selection of filler materials (wire and flux) for submerged arc welding (SAW) of welded steel pipes from the aspect of the tensile strength (R_m) and plasticity.

Keywords: Filler materials, steel pipes, weld joint, tensile strength.

Introduction

Submerged arc welding (SAW) is an arc-welding process that uses a continuous consumable, wire electrode, and a cover of granular flux [1, 2] provides arc shielding. Submerged arc welding (SAW) is a process that melts and joins base metal (BM) by heating with the arc between a consumable welding wire (WW) being shielded by a molten slag and granular welding flux (WF), as shown in Figure 1 [3, 4, 5]. Submerged arc welding (SAW) is one of the most extensively used process for production of double sided spiral welded steel pipes, Figure 2.

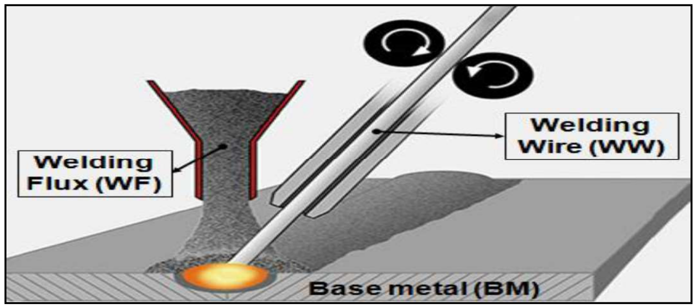


Figure 1. Schematic illustration of SAW

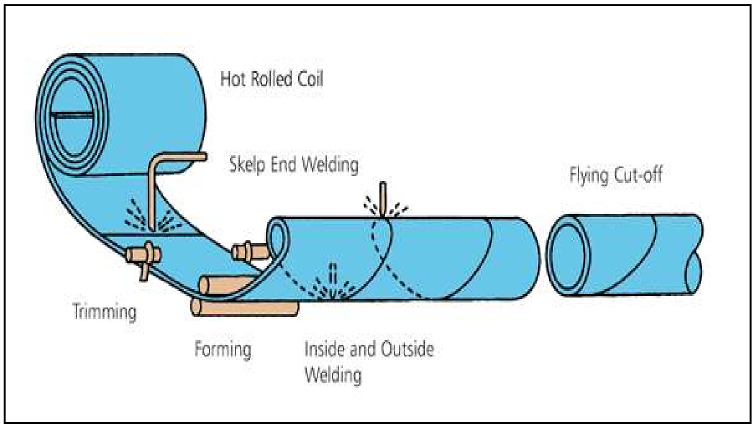


Figure 2. Production of spiral welded steel pipes by SAW

Apart from base metal (BM), two main materials are generally used as filler materials for submerged arc welding (SAW): welding wire (WW) and granular welding flux (WF), and together with welding parameters: current welding (I), current voltage (U) and welding speed (v), determine the quality of welded joint of steel pipes. During submerged arc welding (SAW) of steel pipes, the prime concern is to select a filler material, which produces a weld metal (WM) of the same properties and microstructures as the base metal (BM), and it is worth noting that this is a very important activity. Selection a filler material that provides the equivalent properties between weld metal (WM) and base metal (BM) is extremely delicate issues and almost impossible in this conglomerate of three different materials.
The most important consideration in selecting the right filler materials for SAW is matching the filler materials as closely as possible to the base metal.
Selecting the right tensile strength is an almost as important as matching filler and base metal type, coming in a close second among key considerations in your filler metal selection process. Basically, the tensile strength welding wire (RmWW) must be equal or exceed the tensile strength of base metal (RmBM). In selecting welding wire (WW) for submerged arc welding (SAW), the most important considerations are manganese (Mn) and silicon (Si) contents, while in the welded flux (WF), the recovery of manganese (Mn) and silicon (Si) in the weld metal (WM) must be considered [6].
The weld metal strength (RmWM) and ductility are at least equal to that of base metal (matching criteria), higher to that of base metal (overmatching criteria) or in worse case, lower to that of base metal (under matching criteria), depending on the combination of filler materials (WW & WF) selection with base metals (BM) [7]. The most important consideration in selecting the right

filler materials (WW & WF) is matching the weld metal strength and plasticity as closely as possible to the base metal.
Correct selection of filler materials for welding, apart from influence on mechanical and technological properties of welded joint, influences also to the costs of welded steel pipes [8].

Experimental Procedure

Spiral line pipes Ø813x12mm were fabricated using high strength steel coils X65 according to API [9] (American Petroleum Institute) standard, which chemical composition and mechanical properties are given in Table 1 [10], according to the Certificate of Quality.
Spiral line pipes Ø813x12 mm were fabricated in two-stage process according to the BLOHM+VOSS, with welding wire (WW) and welding flux (WF) according to the Table 2 and 3.

Table 1. Base material for welded pipes

Base Metal (BM)	Chemical analysis -wt						Mechanical Properties		
	C	Mn	Si	P	S	V	Re	Rm	A
	[%]						[MPa]		[%]
API Grade X65	0.09	1.31	0.43	0.020	0.005	0.048	549	649	23.6

Table 2. Welding wire

Welding Wire (WW)	Chemical analysis -wt				Mechanical Properties		
	C	Mn	Si	Mo	Re	Rm	A
	[%]				[MPa]		[%]
S_2Mo	0.11	1.36	0.37	0.50	499	608	26.8

Table 3. Welding flux

Welding Flux (WF)	Chemical analysis -wt							
	SiO_2	MnO	CaO	MgO	Al_2O_3	TiO_2	CaF_2	Other
	[%]							
API Grade X65	18.0	14.0	2.0	5.0	41.0	9.0	4.0	7.0

For the purpose of fulfilling the objective of the paper, adequate samples were taken from the spiral welded pipes Ø 813x12mm, for tensile testing, and bend testing, Figure 2, in the universal machine: MOHR-FEDERHAFF-LOSENHAUSEN, Figure 4.

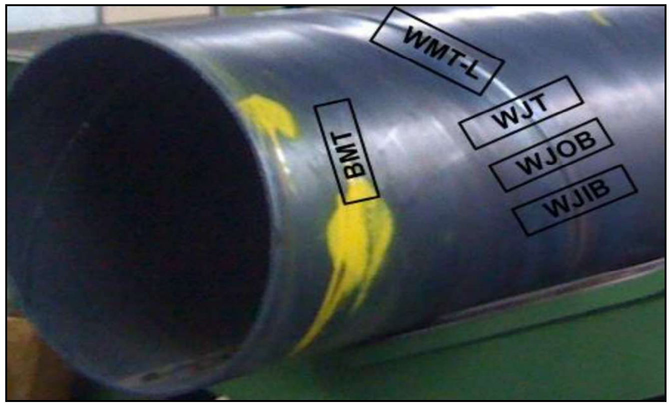
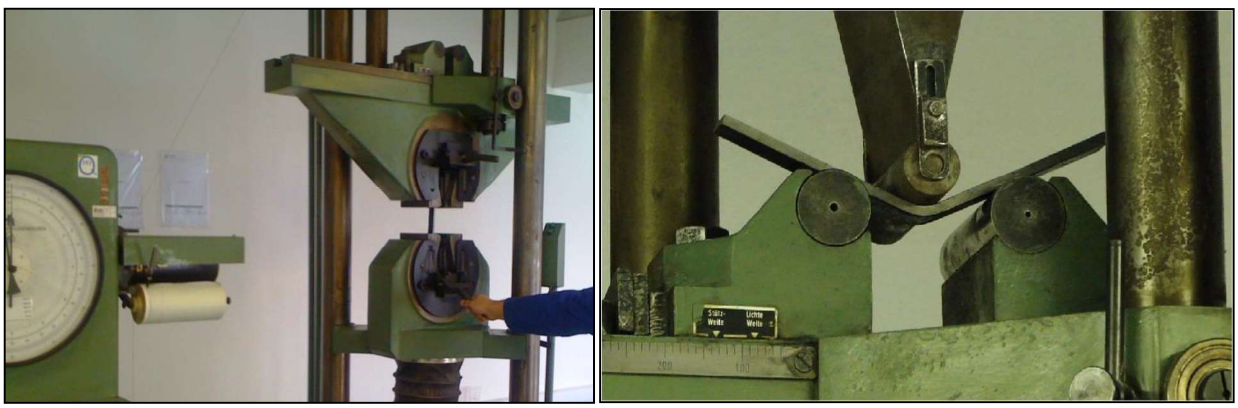


Figure 3. Sampling for welded joint testing: BMT-Base Metal Tensile Testing, WJT-Weld Joint Tensile testing, WMT-L-Weld Metal Tensile Testing-Longitudinally to Weld Axis, WJOB-Weld Joint Outside Bending, WJIB-Weld Joint Inside Bending



(a) (b)

Figure 4. Universal testing machine: a-tensile testing, b-bend testing

Results and Discussion

Results from the tensile testing in order to determine yield stress of base metal (ReBMT), tensile strength of base metal (RmBMT) and elongation of base metal (ABMT), all in transversal direction to the pipe axis, yield stress of weld metal (ReWMT-L), tensile strength of weld metal (RmWMT-L) and elongation of weld metal (AWMT-L), longitudinally to the weld metal axis, such as tensile strength of weld joint (RmWJT) in transversal direction, were presented in the Figure 5.

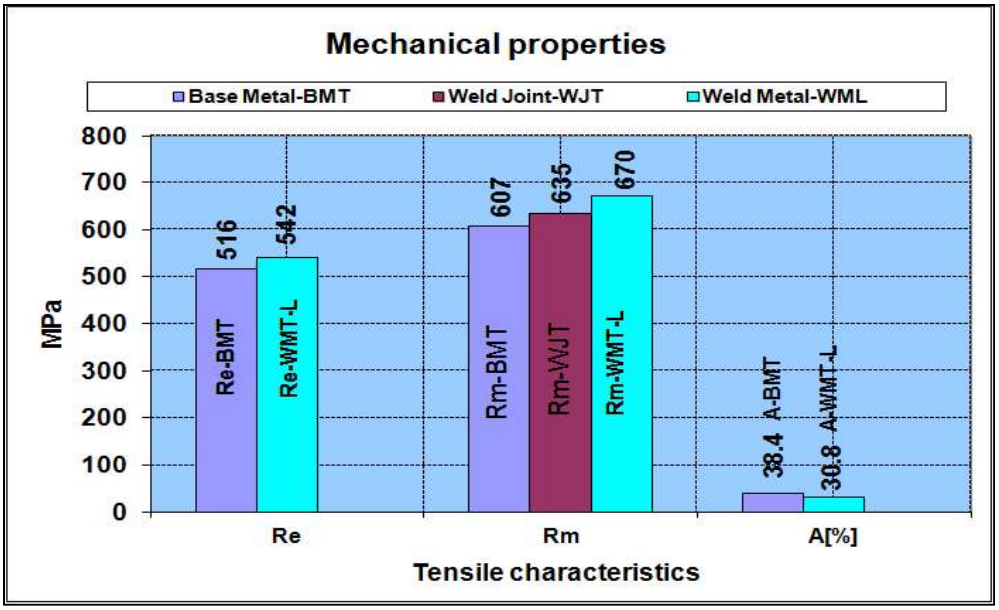


Figure 5. Tensile testing results

All tested specimens were fractured in the base metal (BM), far from the welded joint (WJ), Figure 6.

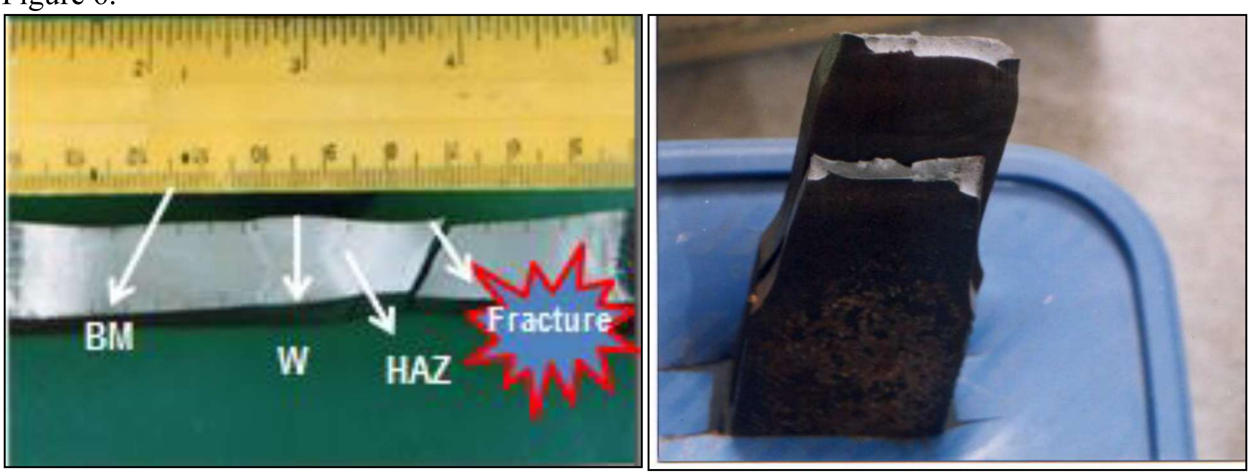


Figure 6. Fracture of the welded joint (WJ)

Results from the technological testing, respectively results of bend angle (α°) of weld joint were presented in figure 7.

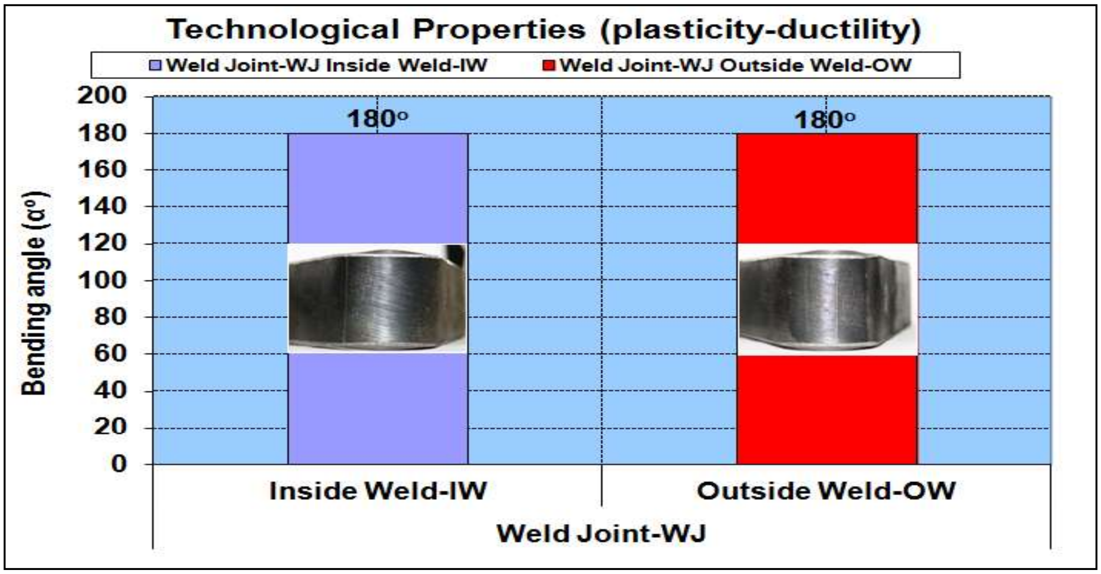


Figure 7. Plasticity (ductility) of the welded joint

Conclusions

Based on the results obtained in this paper it is concluded:
The filler materials selected for submerged arc welding (SAW) of steel pipes is correct and suitable because in this case is achieved high quality and high mechanical and technological properties of the welded joint (WJ) and the welded metal (WM) in the as-welded condition.
Ultimate tensile strength of the welded joint (WJ) and the welded metal (WM) in the as-welded condition as the factor of integrity of the welded joint (WJ) and the welded metal (WM) is higher than the ultimate strength of base metal (BM), so that is fulfilled the overmatching concept.
Ductility of the welded joint (WJ) and welded metal (WM) in the as welded-condition as the ability of plastic deformation, during inside and outside static bending, meet the requirements of the API standard, because all specimens were bended up to 180 degrees, without any cracks or other visible discontinuities in the entire welded joint area.

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