Chandra et al., J Material Sci Eng 2016, 5:4
DOI: 10.4172/2169-0022.1000260

Journal of Material Science & Engineering

Research Article

Open Access

Improvement in Tensile Strength and Microstructural Properties of SAW Welded Low Alloy Steels by Addition of Titanium and Manganese in Agglomerated Flux

Chandra RK*, Majid M, Arya HK and Sonkar A

Department of Mechanical Engineering, SLIET, India

Abstract

The present work is an effort to study the effect of titanium and manganese powder addition in agglomerated flux, on the mechanical properties, of MS 1025 steel welds made by submerged arc welding. The effect of titanium and manganese powder addition on the agglomerated fluxes by varying the welding parameters like welding voltage and welding speed has been evaluated. Taguchi technique has been used for the design of experiments. The effects of flux, voltage and travel speed have been evaluated on the tensile strength and on the microstructure refining. The effect of all the input parameters on the output responses have been analyzed using the analysis of variance (ANOVA).

Keywords: SAW; Tensile strength; Micro structure and various properties using Taguchi technique

Introduction

Submerged arc welding is an arc welding process that uses an arc between a bare metal electrodes and the weld pool. The arc is maintained in a cavity of molten flux or slag which refines the weld metal and also protects it from atmospheric contamination [1-3]. Flux is the main ingredient on which the stability of the arc depends. The Unused flux can be extracted from left behind the welding head and subsequently recycled. The filler material is an uncoated, continuous wire electrode, applied to the joint together with a flow of granular flux, which is supplied from a flux hopper through a tube. The electrical resistance of the electrode should be as low as possible to facilitate welding at a high current, and so the welding current is supplied to the electrode through contacts very close to the arc and immediately above it. The current can be direct current with electrode positive (reverse polarity), with negative (straight polarity), or alternating current. The arc burns in a cavity which, apart from the arc itself, is filled with gas and metal vapors [4-6]. The size of the cavity in front of the arc is delineated by the scrap basic material and behind it by the molten weld.

Welding of 1.25Cr-0.5Mo steel with SiO_2 and TiO_2 based flux increases the heat input, lowers the yield strength and decreases the % elongation [7]. Manganese fluxes give lower residuals of sulphurwhere as calcium silicate fluxes were responsible for removal of phosphorus [4]. Because of small grain size and high angle grain boundaries acicular ferrite is desired microstructure in weld for high impact strength and ductility [8-10]. Low level of oxygen is desired in the weld metal for good impact strength [11]. The effect of wire/flux combination on chemical composition, tensile strength and impact strength of weld metal were investigated and interpreted in terms of element transfer between the slag and weld metal [12-14]. Chemical composition of some flux were studied for microstructure and tensile strength in submerged arc welded metal and compared with those off commercial available flux [9]. Non active flux enhance the formation of pearlite and ferrite in weld having the highest toughness and ductility where as active flux with Cr and Mo promoted the formation of acicular ferrite and fine carbide in the weld showing higher tensile strength and hardness [12]. After literature study we find that very few efforts have been made to understand mechanical properties using Taguchi Technique and Very little work is made to improve the weld joint strength in single pass [15-17]. In this experiment we added titanium and manganese metal powder in 9%, 14% and 18% concentration of titanium and 1.4%, 1.7% and 2% manganese in AUTOMELT B31 flux and investigate its effect on the mechanical properties. The optimization of result has been done by using Taguchi's Philosophy [18,19].

Methodology

Material selection

1025 mild steel is selected over other materials because of its distinct properties, cheaper cost and its Availability in the market.1025 plain carbon steel is used in the manufacturing of ships hulls Table 1.

Flux preparation

The agglomerated flux is prepared by the addition of the TiO_2 and MnO_2 powder in auto melt B- 31. Both the ingredients and Auto melt B-31 were crushed and wet mix in sodium silicate to form chemical bonding. Mixture is then passed through a 10 mesh screen to form small pallets (up to 2 mm diameter). The pellets of the flux were dried in air for 24 hours and then baked in the muffle furnace between 750°C (Figure 1 and Table 2).

Taguchi method analysis

In Taguchi method first optimal parameters were determined by using L9 orthogonal array. L9 means that it will investigate for 3 levels and 3 factors on qualitative index for each factor. Table 3 gives the levels and factors which are employed for welding the samples. Table 4 gives the experimental data that is taken for analysis [20].

Experimentation

In this study L 9 was chosen as the preferred array, 18 plates were cut to size of dimension 150 × 120 × 14 mm for experiment because four

***Corresponding author:** Chandra RK, Department of Mechanical Engineering, SLIET, India, Tel: 01672280072; E-mail: Rinku007chandra@gmail.com

Received May 17, 2016; **Accepted** May 31, 2016; **Published** June 10, 2016

Citation: Chandra RK, Majid M, Arya HK, Sonkar A (2016) Improvement in Tensile Strength and Microstructural Properties of SAW Welded Low Alloy Steels by Addition of Titanium and Manganese in Agglomerated Flux. J Material Sci Eng 5: 260. doi:10.4172/2169-0022.1000260

Citation: Chandra RK, Majid M, Arya HK, Sonkar A (2016) Improvement in Tensile Strength and Microstructural Properties of SAW Welded Low Alloy Steels by Addition of Titanium and Manganese in Agglomerated Flux. J Material Sci Eng 5: 260. doi:10.4172/2169-0022.1000260

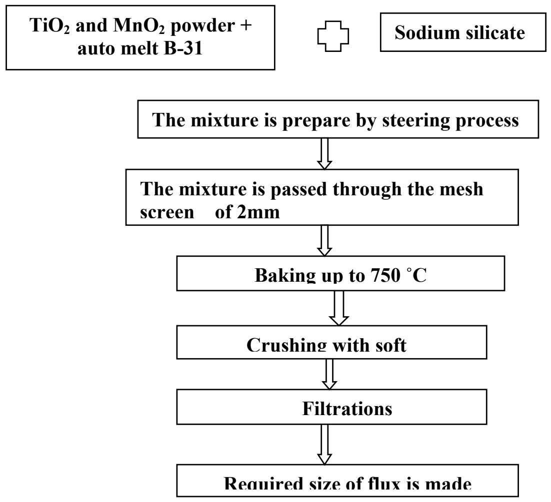

Figure 1: Methodology for preparation of flux.

Elements	C	Si	Mn	Ti	S	Fe
Base plate	0.250	0.1728	0.5050	0.0022	0.0426	Rest
Electrode	0.068	0.17	0.4	-	-	Rest

Table 1: Chemical composition of base plate.

SiO_2+ TiO_2	Al_2O_3+MnO	CaO + MgO	CaF_2
15%	30%	20%	35%

Table 2: Chemical composition of auto melt B31.

Parameter	% age composition of TiO_2	% age composition of MnO_2
Level 1	9	1.4
Level 2	13.5	1.8
Level 3	18	2.0

Table 3: Levels and factors used in design.

Sample no.	% age composition of TiO_2	% age composition of MnO_2
1	9	1.4
2	9	1.7
3	9	2.0
4	13.5	1.4
5	13.5	1.7
6	13.5	2.0
7	18	1.4
8	18	1.7
9	18	2.0

Table 4: Design of taguchi orthogonal array.

plates were required for welding in each trial. Edge preparation was completed on each of the 18 plates as per the requirement of 9 trial condition given by Taguchi orthogonal array. The edge preparation of 45 degree was made on 120 mm side Edge preparation was done on shaper. Groove between two plates. After edge preparation, the plates were tacked through manual arc welding to avoid misalignment. Following tests are carried out in the present study to study mechanical properties.

a) Tensile strength test

b) Micro structural study

c) Spectroscopy

Results and Discussion

Table 5 shows percentage composition of TiO_2 and MnO_2.

Analysis of tensile strength

Tensile strength analysis done here is dependable variable on two factors:

1. Percentage composition of TiO_2
2. Percentage composition of MnO_2

Analysis of variance for S/N ratios for tensile strength calculated from software is given in Table 6. Since the p -value in the Table 6 is less than 0.05; there is a statistically significant relationship between the variables at the 95.0% confidence level. From the Table 6 it can be easily figure out that percentage composition of MnO_2 are most significant.

The main effect of MnO_2 is to increase ductility of the weld metal and slight loss in the tensile strength which is overcome by TiO_2 so nominal is better option is selected from Taguchi design and accordingly response for signal to noise ratio is generated. It was found that level-3 of Percentage composition of TiO_2 and level-3 of e composition of MnO_2 gives the optimum values [21].

In response Table 7 Delta value indicates the variability of factors. Table 7 shows that percentage composition of MnO_2 has highest variability. Also rank of parameters in response Table 7 indicates the order at which the parameters influence the quality characteristics. So MnO_2 has greatest influence on the Tensile strength of the weld.

Mathematical model

Tensile strength = 20 + 3.63 % composition of TiO_2 + 197.8% composition of MnO_2. Table 8 shows the model summary.

Main effects for S/N ratios

Figure 2 shows main effect plots for S/N ratio of tensile strength.

Percentage composition of TiO_2	Percentage Composition of MnO_2	Tensile Strength(MPa)	S /N ratio of tensile strength
9	1.4	320	49.6575
9	1.7	445	52.9672
9	2.0	465	52.1919
13.5	1.4	359	51.1019
13.5	1.7	490	50.9061
13.5	2.0	529	54.4691
18	1.4	330	51.7990
18	1.7	393	51.8879
18	2.0	472	53.4788

Table 5: Shows percentage composition of TiO_2 and MnO_2.

Parameter	Degree of freedom(DF)	Sum of square(SS)	Mean square(MS)	F– value	P –value
Percentage composition of TiO_2	2	6291	3145.4	7.37	0.046
% age composition of MnO_2	2	36692	18314	42.91	0.002
Residual error	4	1707	426.8		
Total	8	44626			

Table 6: Analysis of variance for S/N ratios for tensile strength.

Citation: Chandra RK, Majid M, Arya HK, Sonkar A (2016) Improvement in Tensile Strength and Microstructural Properties of SAW Welded Low Alloy Steels by Addition of Titanium and Manganese in Agglomerated Flux. J Material Sci Eng 5: 260. doi:10.4172/2169-0022.1000260

Interaction effect for tensile strength

Microstructures analysis of various specimens was done with an optical microscope of magnification up to 100 X to compare microstructure of the welded samples. Images were taken that are shown in Figure 4-7. All the welded samples show a microstructure composed of acicular ferrite. It is conforming that Ti containing white inclusions in the sub arc weld metals plays a very important role The term interaction expressed by inserting "x" mark between the two interacting factors is used to explain a condition in which the influence of one factor upon the result, is dependent on the condition of the other [22-24]. The two factors A & B are said to interact written as (A×B) when the effects of changes in the levels of A, determines the influence of B and vice versa. If there is absolutely no interaction, these lines would be parallel. Figure 3 shows the interaction plots for S/N ratio. The interaction plot for the tensile strength shows that the tensile strength is improved at the less amount of percentage of TiO_2 and then it becomes reduced due to the quasi cleavage fracture occurring in the microstructure to overcome this issue we add the manganese in the weld metal to improve the tensile strength it becomes highest at the moderate value of manganese [25].

Level	Percentage composition of TiO_2	Percentage composition of MnO_2
1	51.61	50.85
2	52.16	51.92
3	52.39	53.38
Delta	0.78	2.53
Rank	2	1

Table 7: Response for signal to noise ratios: nominal is better.

S	R-sq	R-sq(adj)	R-sq(predicted)
20.6586	96.17%	92.35%	80.63%

Table 8: Model summary.

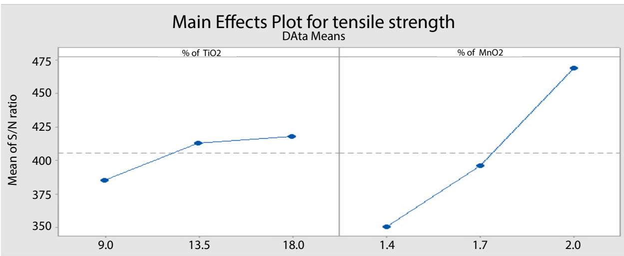

Figure 2: Main effect plots for S/N ratio of tensile strength.

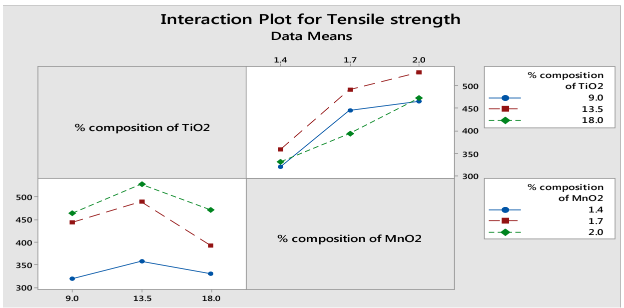

Figure 3: Interaction plot for tensile strength.

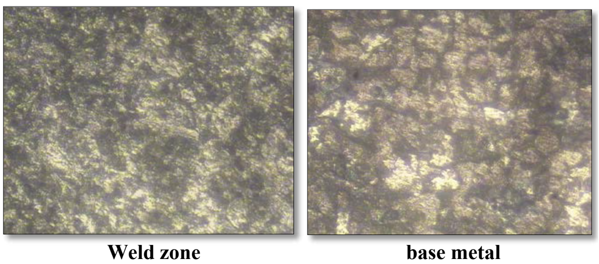

Figure 4: Microstructure of flux 1 at 100X magnification.

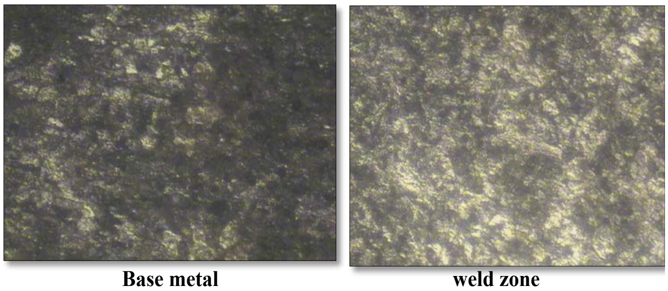

Figure 5: Microstructure of flux 2 at 100X magnification.

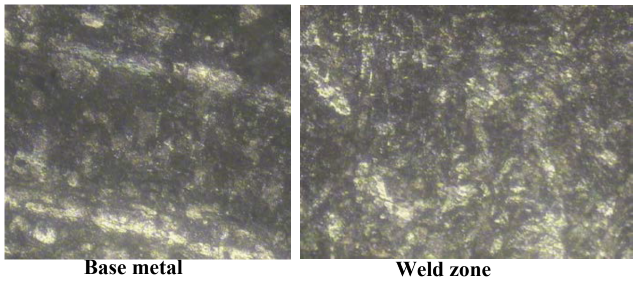

Figure 6: Microstructure of flux 5 at 100X magnification.

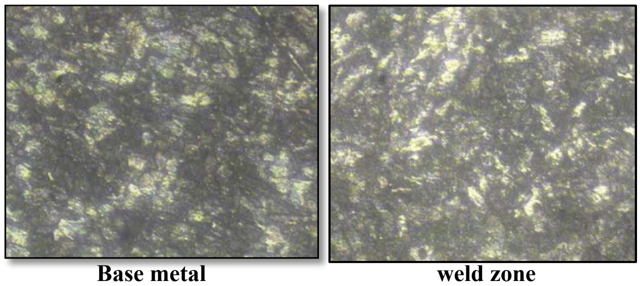

Figure 7: Microstructure of flux 9 at 100X magnification.

Micro-structural analyses

Micro-structural analyses for heterogeneous nucleation of acicular ferrite. Figure 7 shows the microscopic magnification graphs of the welded steels corresponding to the fluxes with different percentage composition of TiO_2. The microstructure of the weld metal for each flux consisted mainly of equaxed ferrite and acicular ferrite. Some small pearlite colonies were also observed in the welds. The micro constituent's volume percentage, as well as mean radius of equiaxial ferrite and mean length of acicular determined by means of quantitative metallographic. The lowest and highest volume percentages of acicular ferrite corresponded to the weld with 9% and 18 % of TiO_2 fluxes respectively.

Chemical composition analysis of welds

The chemical composition of the weld metal is obtained from the spectroscopy of the weld joints and the specimen of the spectroscopy (Figure 8 and Table 9).

% age composition	C%	Si%	Mn%	Cr%	Mo%	Ni%	Cu%	Al%	S%	Ti%
base plate	0.25	0.1728	0.505	0.1406	0.0055	0.0485	0.1232	0.0098	0.0426	0.0022
F1 (9, 1.4%)	0.151	0.2361	1.1115	0.0971	0.0052	0.0416	0.0963	0.0278	0.0217	0.0143
F2 (9, 1.7%)	0.141	0.2441	1.1358	0.0987	0.006	0.039	0.089	0.0333	0.0214	0.0195
F3 (9, 2%)	0.125	0.2048	1.0745	0.0889	0.0034	0.0327	0.0957	0.0121	0.0254	0.0092
F4 (13.5, 1.4%)	0.143	0.1691	0.9941	0.0987	0.0026	0.0279	0.1127	0.0121	0.0281	0.0096
F5 (13.5, 1.7%)	0.125	0.1829	1.0682	0.0923	0.0026	0.0244	0.1109	0.0169	0.0272	0.0132
F6 (13.5, 2%)	0.14	0.1961	1.0312	0.0773	0.0023	0.0247	0.1126	0.0148	0.0277	0.0165
F7 (18, 1.4%)	0.125	0.1611	0.9461	0.088	0.0034	0.0327	0.0957	0.0121	0.0254	0.0092
F8 (18, 1.7%)	0.133	0.1675	1.0074	0.0932	0.0025	0.0215	0.1135	0.0131	0.0327	0.0125
F9 (18, 2%)	0.146	0.2351	1.0754	0.0945	0.005	0.0412	0.0878	0.0199	0.0212	0.0178

Table 9: Chemical composition of the base metal and weld metals.

Figure 8: Weld composition test piece.

Conclusions

The present study was carried out to study the effect of titanium and manganese addition in submerged arc welding flux on the mechanical properties of AISI 1025 welds by keeping all other variables constant like current, speed and arc voltage. The tensile strength value is maximum (529Mpa) at flux composition having titanium 13.5% and 2% manganese at 400 A and 27 V. As a result of increasing the titanium content in the flux, the amount of acicular ferrite was increased in the weld metal. With the further addition of titanium, the microstructure the weld has changed from a mixture of ferrite, grain-boundary ferrite to a mixture of acicular ferrite, bainite and ferrite with M/A micro-constituents. The higher percentage of titanium in weld metal encouraged formation of hard phases in the weld microstructure which increases the micro hardness of the weld. The increase in the titanium content in the fluxes improved the ductility and toughness of the weld due to the formation of white inclusions in the sub-arc weld metal and heterogeneous nucleation of acicular ferrite but tensile strength is slightly loss which was overcome by the addition of the moderate % age of manganese in the flux, it refines the microstructure and micro constituent in the flux. The micro structural refining improved the impact strength properties of the weld but the hardening effect produced by the manganese reduced the toughness which is overcoming by % age composition of titanium improves the toughness of the weld. From the spectroscopy of each weld it is found that the carbon percentage in weld is reduced due to use of low carbon electrode for welding the plates. Also the percentage composition of titanium and manganese is increased in the weld when compared with the base metal of each weld.

From the results it concluded that the titanium addition and manganese addition in the flux helped to refine the micro structure of the weld moreover it improves the mechanical properties like tensile strength which is necessary objective of the research work.

Acknowledgement

I would like to express a deep sense of gratitude and thanks profusely to my esteemed guide Mr. Mohd. Majid, Assistant professor and Mr. H.K. Arya, Assistant Professor Department of Mechanical Engineering, SLIET Longowal, for his exceptional patience , for all kind of help and for being there to encourage me all the times. His enthusiasm and optimism made this experience both rewarding and enjoyable. Thank you for all what you have done for me and for providing me with valuable feedback in my research which made it stronger and more valuable. I humbly express my thanks to Dr. Kulwant Singh (HOD), Department of Mechanical Engineering and Technology, SLIET, for his concern at every step of my project and providing me necessary facilities.

References

1. Pandey ND, Bharti A (1994) Effect of submerged arc welding parameters and fluxes on element transfer behavior and weld-metal chemistry. Journal of Materials Processing Technology 40: 195-211.
2. Dallas CB (1995) Studied the effect of flux composition on microstructure and toughness of HSLA weldment by submerged arc welding. Journal of Materials Processing Technology 62: 875-878.
3. Tuseka J (2003) Studied the multiple-wire submerged-arc welding and cladding with metal-powder addition. Journal of Materials Processing Technology 35: 135-141.
4. Singh K, Pandey S, Arul MR (2005) Effect of recycled slag on bead geometry in submerged arc welding. Proceedings of International Conference on Mechanical Engineering in Knowledge Age.
5. Mercado A, Lopez-Hirata VM, Saucedo Munoz ML (2005) Influence of the chemical composition of flux on the microstructure and tensile properties of submerged-arc welds. Journal of Materials Processing Technology 169: 346-351.
6. Kanjilal P, Pal TK, Majumdar SK (2005) Combined effect of flux and welding parameters on chemical composition and mechanial properties of submerged arc weld metal. Journal of Materials Processing Technology 171: 223-231.
7. Prasad K, Dwivedi DK (2006) Some investigations on microstructure and mechanical properties of submerged arc welded HSLA steel joints. Journal of Advanced Manufacturing Technology 36: 475-483.
8. Bhole SD, Nemade JB, Collins L, Liu C (2006) Effect of nickel and molybdenum additions on weld metal toughness in submerged arc welded HSLA line-pipe steel. Journal of Materials Processing Technology 173: 92-100.
9. Shao- Huo S (2006) Studied the effects of submerged arc welding flux components on softening temperature. Transactions of the Faraday Society 134: 22-78.
10. Marcado AM, Lopez VM, Dorantes-Rosales HJ, Valdez ED (2008) Effect of titanium containing fluxes on the mechanical properties and micro structures in submerged arc weld steels. Materials Characterization 60: 36-39.
11. Bang K, Park C, Jung H, Lee J (2009) Effects of flux composition on the element transfer and mechanical properties of weld metal in submerged arc welding. Metals and Materials International 15: 471-477.
12. Beidokhti (2009) The effect of titanium addition on the SAW weld metal microstructure of API 5L-X70 pipeline steel. Journal of Materials Processing Technology 33: 450-459.
13. Mohan N, Khamba JS (2009) Microstructure/Mechanical property relationships of submerged arc welds in HSLA 80 steel. Proceedings of world congress on Engineering, London, UK.
14. Datta S, Bandyopadhyay A, Pal PK (2009) Application of Taguchi philosophy for parametric optimization of bead geometry and HAZ width in submerged arc welding using a mixture of fresh flux and fused flux. Int J Adv Manufacturing Technology 36: 689-698.

15. Kumar V, Mohan N, Khamba JS (2009) Development of cost effective agglomerated fluxes from waste flux dust for submerged arc welding. Preceding the World Congress of Engineering.

16. Aghakhani M, Ghaderi MR, Karami A, Derakhshan AA (2013) Combined effects of TiO_2nano particles and input welding parameters on the weld bead penetration in submerged arc welding process using fuzzy logic. The International Journal of Advanced Manufacturing Technology 70: 63-72.

17. Kumar A, Bhardwaj D (2014) Enrichment of flux by nickel to improve impact strength in submerged arc welding and its effect on the bead height and bead width. International Journal for Research Publication & Seminar 5: 1-6

18. Zhanga T, Li Z, Kou S, Jing H, Li G, et al. (2015) Effect of inclusions on the microstructure and toughness of the deposited metals of self-shielded flux cored wires. Materials Science and Engineering: A 628: 332-339.

19. Ward RG (1962) An introduction to the physical chemistry of iron and steel making. Publisher English Book Society, London.

20. Tarlinsku (1980) The effect of viscosity of slag on the welding and technological properties of electrodes. Svar Proiz 9: 21-22.

21. Tandon S, Kanshal GC, Gupta SR (1988) Effect of flux characteristics on HAZ during submerged Arc welding. Proceedings of the International Conference on Welding Technology.

22. Schwemmer DD, Olson DL, Williamson DL (1979) Relationship of weld penetration to welding fluxes. Welding Journal 58: 153s-160s.

23. Potapov, Lazerev BI (1981) The metallurgical properties of silicon fluxes containing halides salts and alkaline metal oxides. Automatic Welding 6: 38-40.

24. Patchett BM (1974) Some influences of slag composition on heat transfer and arc stability. Welding Journal 53: 203s-210s.

25. Liu S, Olson DL (1986) The role of inclusions in controlling HSLA steel weld microstructures. Weld J Suppl Res 65: 139s-141s.