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A study of microstructure and tensile property with casting S45C welding

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Abstract. For energy saving and longer life time of a large casting iron may use of weld repairs or make up to more save manufacture time and energy than re-casting. Such as breakage, crack and wear in large casting iron castings used weld to repair casting for eco-energy.
The purpose of this study is to investigate the dissimilar joint property of S45C carbon steel with the multi-layer method and the multi-pass welding method. Four weld rods, experimentally examined the influence on microstructures, which were marked as A, B, C and D, respectively. The microstructures of joint bead were observed by the optical microscope. The specimens of tensile test were made according to ASTM E8M. The experimental results were shown as following:
1. The pearlite structures and the bainite structures were formed in welded zone by the weld rod of middle carbon steels. The yield strength and ultimate strength of the specimens were 360MPa and 460MPa.
2. The feature of welded specimen was close to stainless steel due to the stainless steel rod included some Cr and Ni. In addition, a ferritic-austenitic two-phase stainless steel was observed in optical microscope.

1 Introduction

Generally, the big constructional machines are used to manufacturing by foundry (as Fig.1). In solidification, shrinkage accompany with many defects in working. Those defects like crack, wear or shrinkage are often fixed by welding and therefore weld traces are found in such machine as engines or cases. The joint consequence not only related to the skill but also need to take care the mechanical properties. Thus, it must base on material science knowledge to prevent the damages, not experience or favor.

Fig.1. Example of constructional S45C steel.

The weld mechanical property concerns the microstructures and the composition. To investigate the joint property, the method of multi-layer and multi-pass welding[1-4] is one way often used. Multiple complicated phase transformation happens under heat treatment[5,6]. Because of the different cool rate and dissimilar materials, the weld bead involves several particular microstructures that affect mechanical property[7-10]. In addition, the joint property affected a lot by the rod composition[11-13] and the microstructure analysis plays important role in understanding of joint strength. Therefore, the present research aimed at the microstructure analysis of casting S45C welding and the tensile property.

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2 Experiments

The base metals (BM) in the present study are S45C carbon steel. Its dimension is length 100mm x width 50mm x thickness 16mm, respectively. In order to avoid temperature affect in deformation, keeping cool with water is necessary. Every metal bulk has 30 degree in bevel angle[14], 2 mm in depth and 2 mm in space. Prior to experiment, a backing strip is weld spotted at the bottom which is a carbon steel plate and whose volume is 100×25×6mm, as shown in Fig.2.

The acetone is utilized cleaning particles on the weld zone. Experimental process shows in Fig.3. Experiment equipments include: Olympus BX51 used for OM microstructure, SMAC ARC-300 used for flat-weld, AG-10TE used for tensile test, JEOL-JSM 6360 used for SEM picture and OXFORD INCA Energy 300 used for EDS analysis.

Fig. 2. V-butt of S45C base metal.

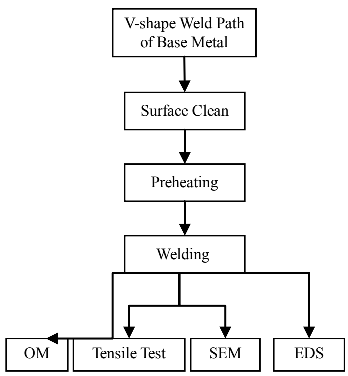


Fig. 3. Experimental flow chart.

There are four kinds of rods those are popular in industry. Every one of them is from separate company and specification is for CNS E4303 carbon steel rod, marked as A, B, C and D, respectively. Their individual parameters show in Table 1 below. Before welding, residual steam must be removed carefully as following：

1. These rods keep dry in 300℃ to 500℃ for 60 minutes until welding. When weld beginning, rods keep in a dry container between 100℃ to 150℃, whose quantities is going to be used out in half day.
2. To avoid porosity formed, the arc must be moved back and forth.
3. A uniform weave beading, not over three times the electrode diameter, will aid greatly in preventing undercut in butt welds.
4. Based on different thickness, the metals preheated in 80℃ for a period of time.
5. Corners held with fixtures in order to avoid distortion.

Table 1. Welding parameters of every weld.

Filler	A	B	C	D
Diameter (mm)	3.2	3.2	3.2	3.2
AC (A)	100~140	100~130	80~110	80~120
Actual AC (A)	130	130	110	120
Method	Flat weld	Flat weld	Flat weld	Flat weld

The method of multi-layer and multi-pass welding is according to the functional conditions of SMWA rectifier. Temperature keeps in interpass-temperature while welding and weld slag and oxide impurity are removed with brush. The aim at this study is to analyze the microstructure and mechanical property of joint in between base metal and rod.

Selected microstructure zones of weld were observed by optical microscope and which is showed in Fig.4：Base Metal(BM)、Hot Affect Zone (HAZ)、Fusion Line、Cover Pass、Filler Pass and Root Pass. In addition, according to ASTM E8M, all welded bead are deformed into tensile specimens and which are show in Fig.5 and Table 2. After tensile fracture, different cross section features from base metal are observed by JEOL-JSM 6360 Scanning Electronic Microscope. Then, OXFORD-INCA Energy 300 is used for qualitative analysis.

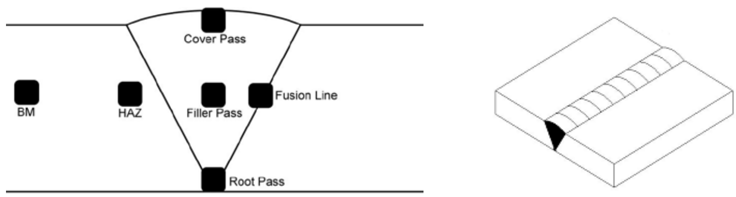


Fig. 4. Selected weld position for microstructure.

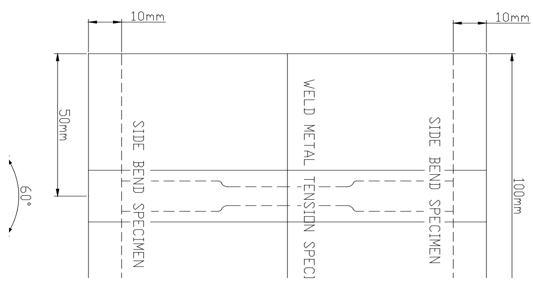
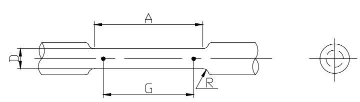


Fig.5. Sample position of tensile specimen.

Table 2. ASTM E8M Rule for tensile test.

	Standard Specimen				
	mm	mm	mm	mm	mm
G	62.5±0.1	45.0±0.1	30.0±0.1	20.0±0.1	12.5±0.1
D	12.5±0.2	9.0±0.1	6.0±0.1	4.0±0.1	2.5±0.1
R	10	8	6	4	2
A	75	54	36	24	20

G---Length D---radius R---minimum radius
A---the scale of reduction of the minimum length



3 Experimental results

3.1 Microstructure observation

Fusion Zone is divided into three parts to discuss, which are cover pass, filler pass and root pass. Rod contents of those, marked as A, B and C, have few impurities as Si, Mn, P and S. All of their compositions and microstructures are similar. Pearlite exit in filler pass and root pass. Because root pass reaches low temperature faster than that filler pass, so that pearlite in root is fine. The Bainite microstructure, which the upper Bainite appeared more than the lower Bainite, was observed at the cover pass. The weld microstructures showed in Fig.6 to Fig.8.

As shown in Fig. 9, Dendritic ferrite in filler pass and dual phase in cover pass were found obviously. Owing to the rod D comprised Cr and Ni, so that Austenitic-Ferritic Stainless Steel (a mixture of austenite and ferrite) formed during heat treatment.

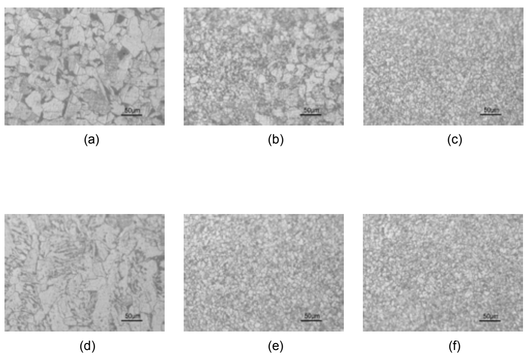


Fig. 6. Microstructure of the weld bead A (a) BM (b) HAZ (c) Fusion Line (d) Cover Pass (e) Filler Pass (f) Root Pass.

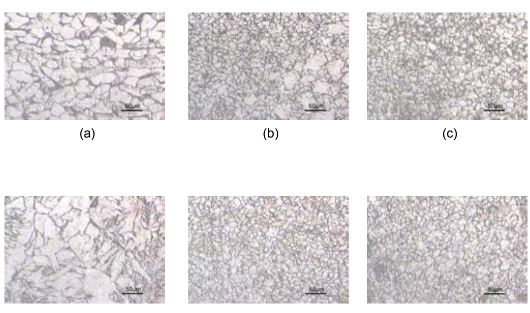


Fig. 7. Microstructure of the weld bead B (a) BM (b) HAZ (c) Fusion Line (d) Cover Pass (e) Filler Pass (f) Root Pass.

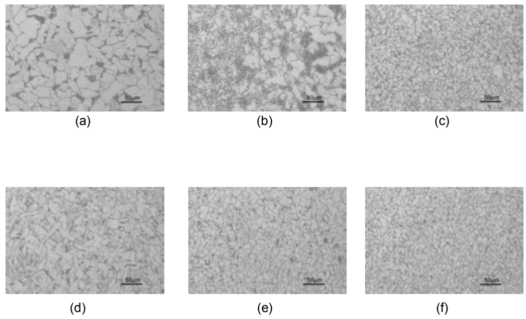


Fig. 8. Microstructure of the weld bead C (a) BM (b) HAZ (c) Fusion Line (d) Cover Pass (e) Filler Pass (f) Root Pass.

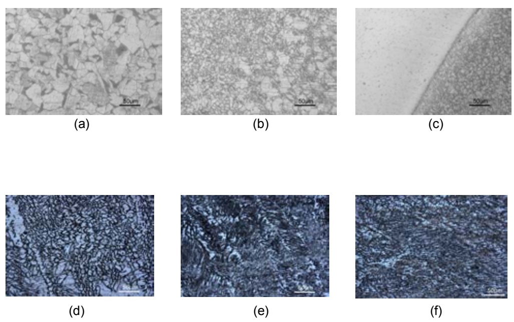


Fig. 9. Microstructure of the weld bead D (a) BM (b) HAZ (c) Fusion Line (d) Cover Pass (e) Filler Pass (f) Root Pass.

3.2 Tensile experiment

Specimens were according to ASTM standard and made of full weld bead. Table 3 showed the ultimate strength, the yield strength, the elongation and the reduction of area (R. A.). The ultimate strength of BM and D are 664 MPa and 702 MPa, respectively. The yield strength of BM and D are 475Mpa and 486MPa.

All of the heat treated specimens, the elongation and the R.A. of BM were worse than others. That indicated the ductile of the welding specimens enhanced by the heat treatment. However, the heat treatment only improved slightly the yield strength and ultimate strength of the rod D, as showed in Fig. 10.

Table 3. Tensile test data.

Specimen	Average Elongation (%)	Average Yield Strength (MPa)	Average Ultimate Strength (MPa)	Average R.A. (%)
A1				
A2	36	367	456	63
A3				
B1				
B2	30	359	477	68
B3				
C1				
C2	36	358	460	66
C3				
D1				
D2	41	486	702	68
D3				
BM1				
BM2	18	475	664	53
BM3				

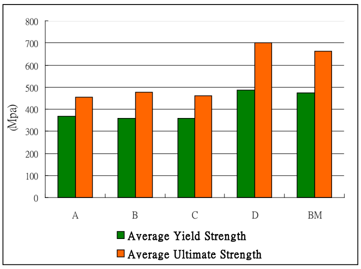


Fig. 10. Bar chart of tensile test.

3.3 SEM and EDS analysis

Different from cleavage of BM, all specimens represent vary ductile fracture about dimple(as Fig.11). Some carbide-like particles are inside the dimple. Either material void caused by particles inside dimple or by interface between particle and matrix. Ductile fracture is importantly based on the volume fraction of carbide, distribution and appearance. While the method of multi-layer and multi-pass welding induced phase transformation, the particles and distribution affected the ductile property in heat treatment.

When tensile test started, initial dimples exited some brittle particles which concentrate many dislocations. Micro-voids happened in the interface between brittle particle and matrix. Dimples were elongated by tensile stress and they laterally connected to each other with internal stress. Finally, micro-cracks formed a lot of dimples on ductile fracture surface.

As shown in Fig.12, specimens of D are with the finest dimple in fracture surfaces. It means that the micro-voids are many and concentrated. Overall, fracture surfaces are totally matched to their mechanical property.

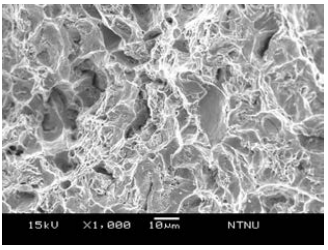


Fig.11. Fracture surface of base metal.

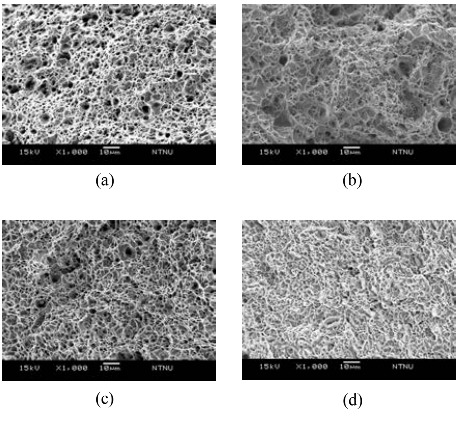


Fig.12. Fracture surface of A, B, C and D weld.

3.4 EDS analysis

The compositions of all specimens are presented in Table 3. On one hand marked as A, B and C, they are close to normal carbon steel. Besides Fe and C, there are some elements Si, Mn, P and S exited. Their compositions are similar, but each weight percent is kind of different. On the other hand, the compositions of D are with 27.3% Cr, 0.66% Co and 9.17% Ni. It is similar to the dual phase stainless steel, whose features are better strength than stainless steel 304 and good resistance to corrosion. The EDS analysis shows in Table 4.

Table 4. EDS Analysis of weld bead.

wt% / specimen	Fe	C	Si	Mn	P	S
A	99.11	0.42	0.08	0.29	0.05	0.05
B	98.63	0.50	0.25	0.53	0.04	0.05
C	98.99	0.55	0.21	0.17	0.03	0.05
D	60.98	0.01	1.39	0.49	27.30	0.66
BM	98.59	0.48	0.30	0.57	0.02	0.04

4 Conclusions

The composition of the rod D is close to stainless steel. It causes austenitic-ferritic stainless steel or dual phase stainless steel in cover pass as shown in Fig. 9. On the other hand, the compositions of the others are close to middle carbon steel so pearlite and bainite exit from root pass to cover pass as shown in Fig.6 to Fig.8.. The yield strength and the ultimate strength of them are smaller than base metal.

Every cross section appears ductile failure. Of all, dimple is finer in specimen D and it connects to better ductile property in mechanical test. In order to application in casting S45C material, the research is a reference for choosing weld rod kind.

Acknowledgments

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