EFFECTS OF WELDING PASSES ON PROPERTIES OF FERRITIC STAINLESS STEEL

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Abstract: This paper describes the effect welding passes on material properties of Ferritic Stainless Steel (FSS). FSS contains the lowest chromium content of all stainless steels and is also the least expensive, currently produced by Steel Authority of India Limited (SAIL). SAIL uses FSS in building up of railway wagons, which were earlier built with Low carbon Steel. FSS has high strength-to-weight ratio which makes wagons lighter by yet, keeps them strong to take more payload. The objective of this work is to compare the experimentally obtained weld bead results for Shielded metal arc welding (SMAW) welding.

Keywords: FSS, HAZ, SMAW, Welding pass, Steel.

Introduction: Welding is a precise, dependable, economical method of joining materials. Most widely used by manufacturers to join metals and alloys efficiently and to add value to their products. Unfortunately the welding process induces also few problems that need to be more accurately identified and after that minimized as much as possible. Among the welding typical problems and most important are the residual stress/strain and the induced distortions in structures. In the process of welding, heat flows into the materials being joined and sometimes may cause serious metallurgical changes in the welded structure, which may lead to the early failure of the component. Study of thermal cycles will be the basis for many other analysis like prediction of distortion and residual stresses, metallurgical analyses, surface discoloration studies, and so forth. Hence, the study of heat flow temperature distribution in the parts being welded becomes necessary. In welding, the application of a heat source is called energy input. It is defined as the quantity of energy introduced per unit length of weld from a traveling heat source. The energy input (heat input) is expressed in joules per meter. Heat input per mm length of weld 'Q' was calculated using welding variables.

$Q = (\eta\ V\ I\ /v)$

Where, "V" is arc voltage in volts (V),
"I" is welding current in amperes (A),
"v" is speed of welding in (mm/sec),
"η" is the heat transfer efficiency (0.75)

Shielded metal arc welding (SMAW) and tungsten inert gas welding (TIG) are the most commonly used welding process for Steels as they are easily available. SMAW uses a consumable electrode coated in flux to place a weld. An AC/DC electric current is used to form an electric arc between the electrode and the metals to be joined. As the weld is placed, the flux coating of the electrode break down, giving off vapors that help in forming a shielding gas which protect the weld area from atmospheric adulteration as shown in Fig. 1. Because of the flexibility of the SMAW it dominates other welding processes. A bead weld is the result of a welding pass that deposits filler material.

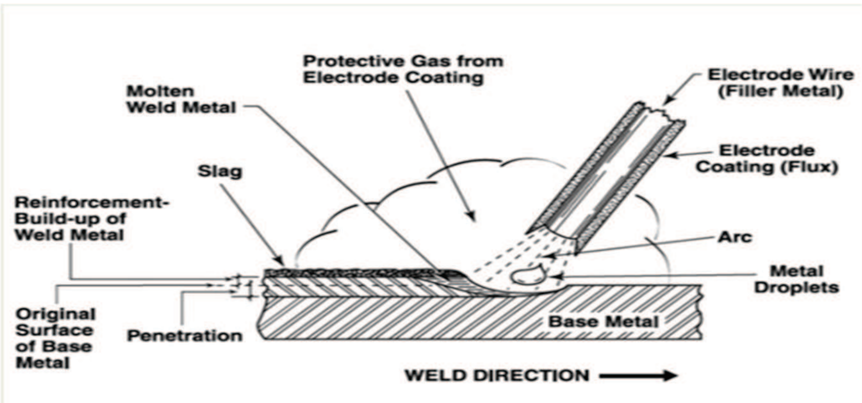
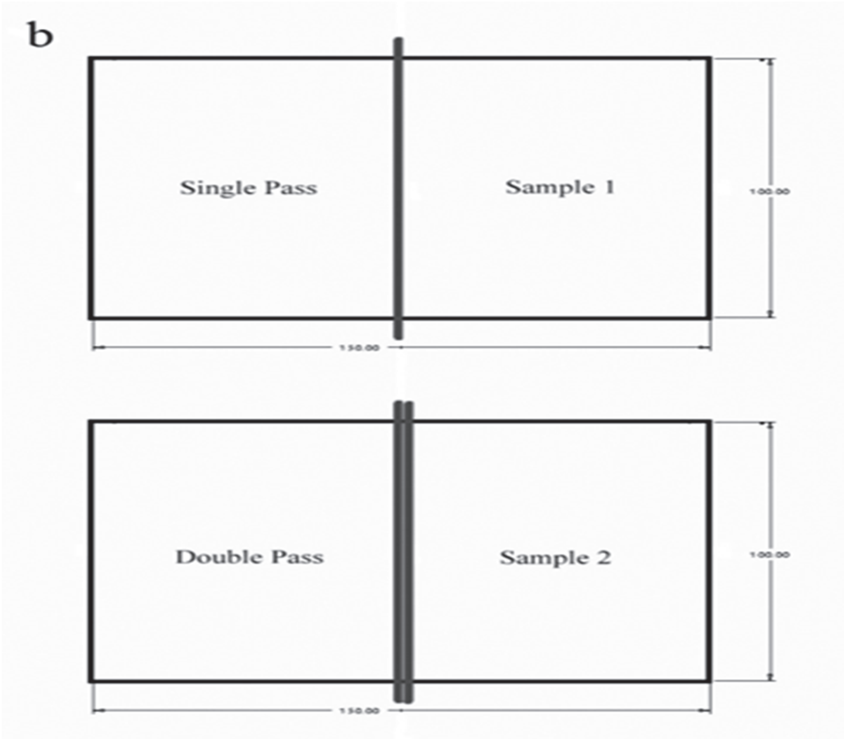


Fig. 1 SMAW welding

Ferritic grades have been developed to provide a group of stainless steel to resist corrosion and oxidation, while being highly resistant to stress corrosion cracking. These steels are magnetic but cannot be hardened or strengthened by heat treatment. They can be cold worked and softened by annealing.



(b) Schematic view of single and double pass on plate.

As a group, they are more corrosive resistant than the martensitic grades, but generally inferior to the austenitic grades. Like martensitic grades, these are straight chromium steels with no nickel. They are used for decorative trim, sinks, and automotive applications, particularly exhaust systems. FSS Type 409 contains the lowest chromium content of all stainless steels and is also the least expensive. With 12 wt% Cr developed to feel the gap between stainless steels and the rust prone carbon steels has been attracted as low cost utility stainless steels. FSS is majorly used for muffler stock and also used for exterior parts in non-critical corrosive environments. During welding a certain portion of base metal experiences peak temperatures high enough to develop microstructural changes. These microstructural changes have detrimental effects on the mechanical properties of metal i.e. Heat Affected Zones (HAZ) are formed. Welding reduce toughness, ductility, corrosion resistance and life of metal.

Experimental Work: The FSS Type 409 was acquired from market in the form of sheet.

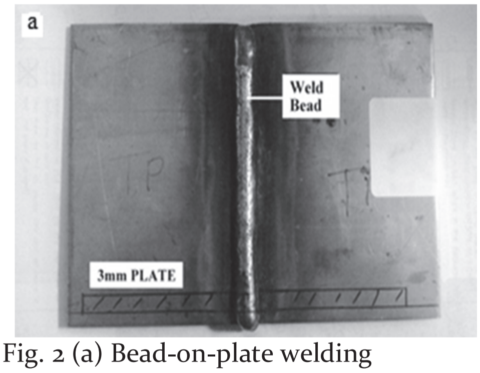


Fig. 2 (a) Bead-on-plate welding

Their typical chemical composition was determined by optical emission spectrometer to check the exact type of material and material properties. The chemical composition of base metal is presented in Table I. Plates of size 150 mm × 100 mm × 3 mm were obtained using wire-cut electrical discharge machine (WEDM). Bead-on-plate SMAW was performed along the centre line of the plates by electrode. Single and double passes were carried out at a uniform speed by an experienced welding operator as explained in Fig.

2(b). The heat input was kept constant for all the passes. The plate after welding is shown in Fig. 2(a).

Table I Chemical composition of base metal							
Sample	C %	Si %	Mg%	P %	S %	Cr %	Ni %
FSS Sample	0.044	0.525	0.323	0.027	0.003	12.040	0.132

Table II Welding conditions and process parameters							
Welding pass	Welding machine	Current. (Ampere)	Voltage (Volts)	Efficiency	Welding speed (mm/sec)	Heat Input. (Joules/mm)	Electrode Diameter (mm)
Single	EWM HIGHTECH Welding	100	24	0.75	3.75	450	3.15
Double							

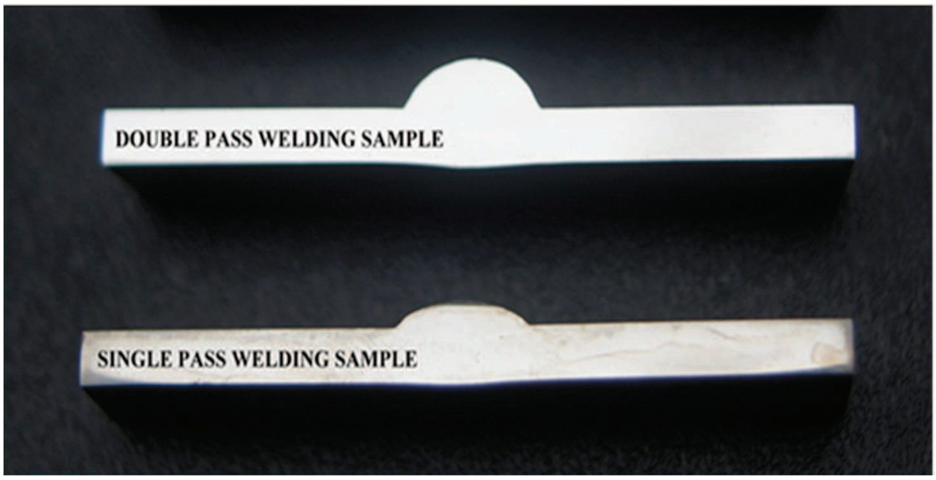
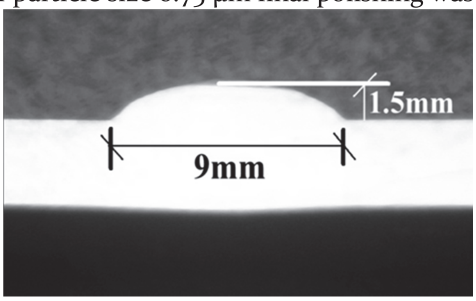


Fig. 3 Samples after Polishing

Microstructural examination was carried out using a light optical microscope with image processing software.The specimens of size 50 mm × 10 mm × 3 mm were sectioned using wire-cut electrical discharge machine (WEDM) to the required size comprising of weld bead metal, heat affected zone (HAZ) and base metal regions. The open surface of sample was polished on emery papers of grade 180, 320, 600, 800 and 1200. Using the diamond compound of particle size 0.75 μm final polishing was done in the disc polishing machine as shown in Fig. 3. The specimens were electro etched using solution of 95 ml hydrochloric acid and 5 ml methanol for 10-15 seconds. The structures then are viewed in computer software. Also the welded plates were sliced using power band-saw and then machined to the required dimensions as per ASTM standard for preparing tensile sample. The tensile specimens had gauge length of 50 mm and they were tested in an INSTRON Series IX testing machine.



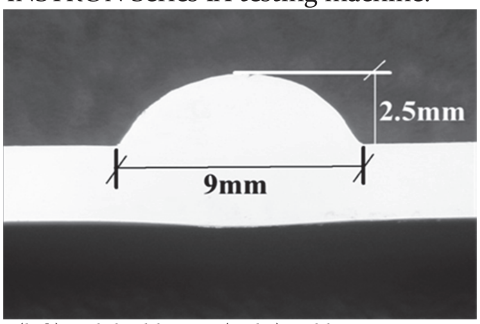


Fig. 4 Weld bead comparison of single pass (left) and double pass (right) welding

Result: Fig. 5 shows the schematic representation of various regions of welded plate. The various zones are explained as follows:

1. Fusion Line – There is a narrow zone consisting of partially melted base material which has not got an opportunity for mixing. This zone separates the HAZ and Filler structure.
2. Casting Structure - The fusion zone exhibits a typical cast structure and can be characterized as a mixture of completely molten base metal and filler metal if consumable electrodes are in use.
3. Base Structure – This zone does not undergo any change in the microstructure as it is not affected by heat generated during welding. Also this zone is surrounded by the HAZ.
4. Heat Affected Zone - HAZ will exhibit a heat-treated structure involving phase transformation, recrystallization and grain growth. The amount of change in microstructure in HAZ depends on the amount of heat input, peak temp reached, time at the elevated temp, and the rate of cooling. Also this zone is the weakest section in a weldment.

The result obtained from the microstructural study is shown in the table III for different passes. As we increase the number of passes the heat input generated gets more and more hence the heat affected zone spreads more.

Table III Data obtained from microstructures of top surface

Steel	Sample	HAZ (mm)
FSS Type 409	Single pass	2
	Double pass	3.5

The effect of welding passes on the tensile properties of FSS was studied by performing tensile tests on the welded samples. The variation in the tensile strength of the steels with number of passes is shown in table. It can be seen that there is a significant reduction in tensile strength with increasing number of passes.

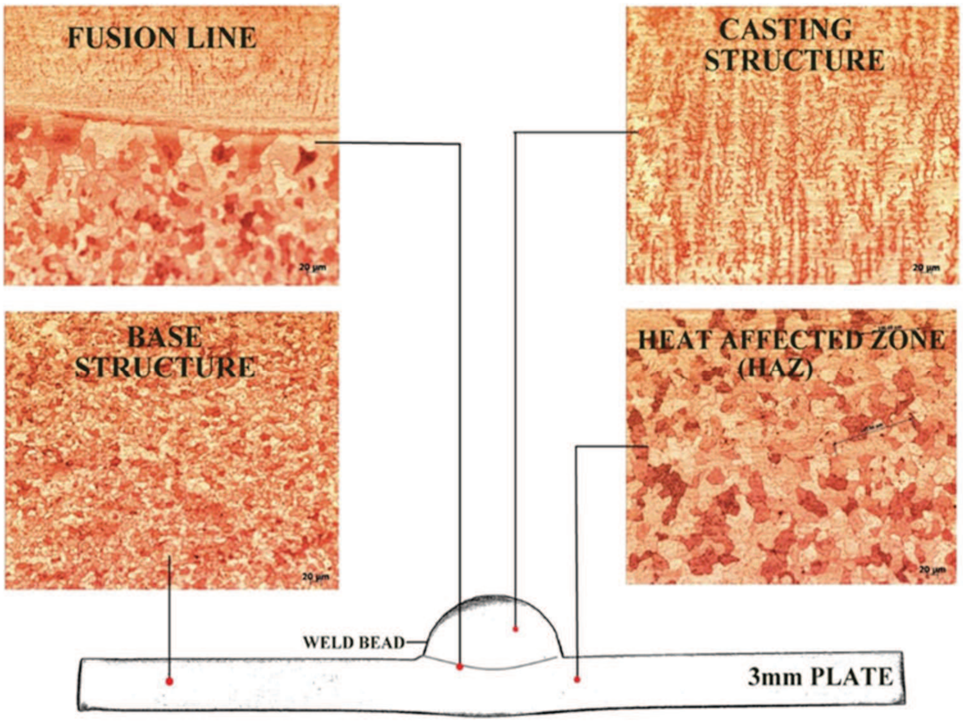


Fig. 5 shows the schematic representation of various regions of welded plate

Table IV Transverse tensile test			
Sample	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)
Parent Metal	465	280	26
Single pass	440	265	20
Double pass	418	241	16

Discussion:

1. It can be seen that there is a significant reduction in tensile strength with increasing number of passes.
2. The microstructure obtained showed that the true HAZ includes the region where microstructures have been altered due to both grain coarsening and carbide precipitation.
3. As we increase the number of passes the heat affected zone increases.
4. The accumulated heat has been distributed between the welding structure and the heat released into the surroundings due to convective heat transfer.
5. As the number of passes increases the height of bead increases.

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