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Experimental Investigation on Transverse Shrinkage Stress and Distortion of Extra Narrow and Conventional Gap Dissimilar Butt Joint of Austenitic Stainless Steel to Low Alloy Steel

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Abstract- Nowadays, joining dissimilar metal often becomes indispensable in manufacturing and constructing advanced equipments and machineries. Dissimilar metal welds between austenitic stainless steel and low-alloy steel are widely used in high-temperature applications. In present investigation welding of dissimilar austenitic stainless steel and low alloy steel plate has been carried out using pulse current gas metal arc welding (PGMAW) and SMAW process for joining the narrow and conventional gap butt joint of thick section(25mm). The experimental techniques of studying the shrinkage stresses, microstructures of different regions as well as mechanical properties of weld joints prepared at different welding parameters as a function of mean current I_m, heat input (_) for PGMAW and SMAW process, have been estimated and procedures have also been described. In 25mm thick plates observed that pulsed current GMAW is advantageous than SMAW process because pulsed current GMAW produces relatively lower heat build up in weld pool. It is also observed that a narrow groove design in 25mm thick plate is beneficial due to the comparatively lower amount of weld metal deposition in narrow groove than the amount of weld metal deposition in conventional groove.

Keywords**:** Dissimilar weld joint, Pulsed current GMAW, Narrow groove, Transverse shrinkage stress.

1. Introduction

Dissimilar metal welding (DMW) of thick wall austenitic stainless steel (γ-SS) and low-alloy steel plates are used in the power generation, chemical, petrochemical, and nuclear industries where, the temperature exceeds upto 400°C. The dissimilar metal welding (DMW) of thick section γ-SS and low alloy steel is critical. The difficulties include the problems largely associated with difference in coefficient of thermal expansion (CTE) and thermal conductivity respectively affecting the undesirable development and distribution of residual stresses, development of undesirable weld chemistry due to dilution, metallurgical incompatibility primarily with respect to the formation of undesirable phases in the weld and HAZ and the segregation of high and low melting phases due to chemical mismatch.

The present work is being carried out by experimental methods to evaluate transverse shrinkage stresses and distortion generated in the dissimilar welded structure as well as mechanical and metallurgical properties of dissimilar weld joint of austenitic stainless steel (γ-SS) and low-alloy steel plates have been studied. The weld area has been varied by varying different groove design like narrow groove (13.6mm) and conventional groove(28mm). For 25mm thick dissimilar plates SMAW and pulsed current GMAW processes were used to make the weld joints.

2. Experimental Procedure

2.1 Base Material

Commercially available Austenitic stainless steel and Low alloy steel of 25mm plate thicknesses were used as a base material. The chemical composition of the plates is shown in Table2.1.

Table 2.1 Chemical compositions of Low alloy steel base metal.

Materials	Chemical composition (Wt. %)						
	C	Si	Mn	Cu	Al	P	S
Low alloy steel Plate (450 HI)	0.19	0.33	1.48	0.07	0.02	0.026	0.012

Table 2.2 Chemical compositions of austenitic stainless steel base metal and filler metal.

Material	Chemical composition (wt %)								
	C	Cr	Ni	Mn	Mo	Si	Cu	S	P
SS plate (304L)	0.087	21.1	7.5	1.42	0.35	0.54	0.20	0.015	0.012
GMAW SS filler wire(ER308L)	0.022	19.65	9.55	1.25	0.10	0.39	0.08	0.007	0.016
SMAW SS filler wire(ER308L-15)	0.046	18.7	11.9	1.8	0.1	0.22	0.12	0.006	0.016

2.2 Welding Process and Procedure

In this experiment to join Y-SS and HSLA steel, SMAW and P-GMAW process are used to join conventional and narrow gap weld joint. Narrow gap weld joint significantly improve the quality of weld as compared to conventional gap weld joint because narrow gap reduces the number of passes to fill the gap, which reduces amount of weld deposit as well as thermal severity of weld joint and its directly affect the mechanical and metallurgical property as well as significantly reduces the undesirable development and distribution of residual stresses. However narrow gap welding requires a appropriate selection of welding parameters and suitable procedure.

To join narrow gap weld joint two procedures are used i.e.

a) multi pass multi-seam per layer deposition(MPMSPL)
b) multi pass single seam per layer deposition (MPSSPL)

In this experiment to join dissimilar Y-SS to HSLA by SMAW and P-GMAW process one conventional weld groove(CG-28) and one narrow weld groove(NG-13.6) design are used. Multi pass single seam per layer deposition(MPSSPL) is the advanced procedure to join the thick wall(25mm) plates. To produce the sound weld by using this procedure is strongly depend upon the selection of welding parameter.

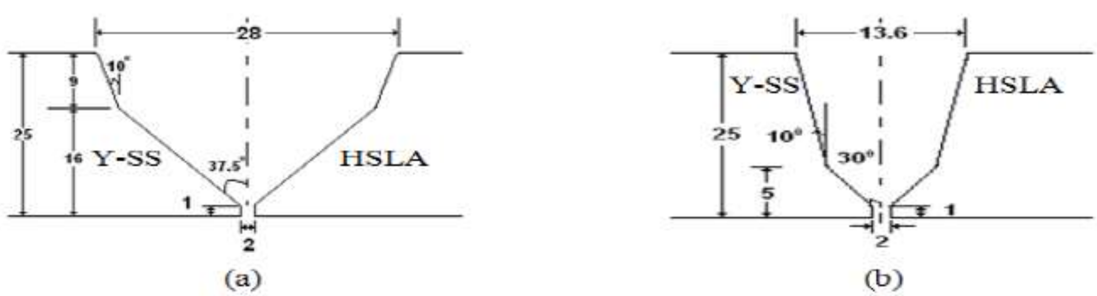

Fig. 2.1 Schematic diagram of (a) conventional V-groove (CG) and (b) Extra narrow groove (NG)

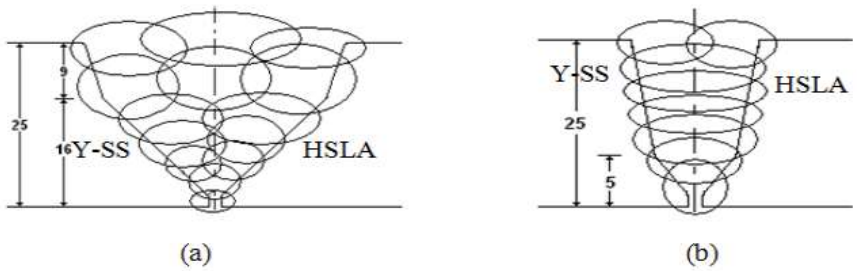

Fig.2.2 Schematic diagram of (a) multi pass multi seam per layer deposition and (b) multipass single seam per layer deposition technique.

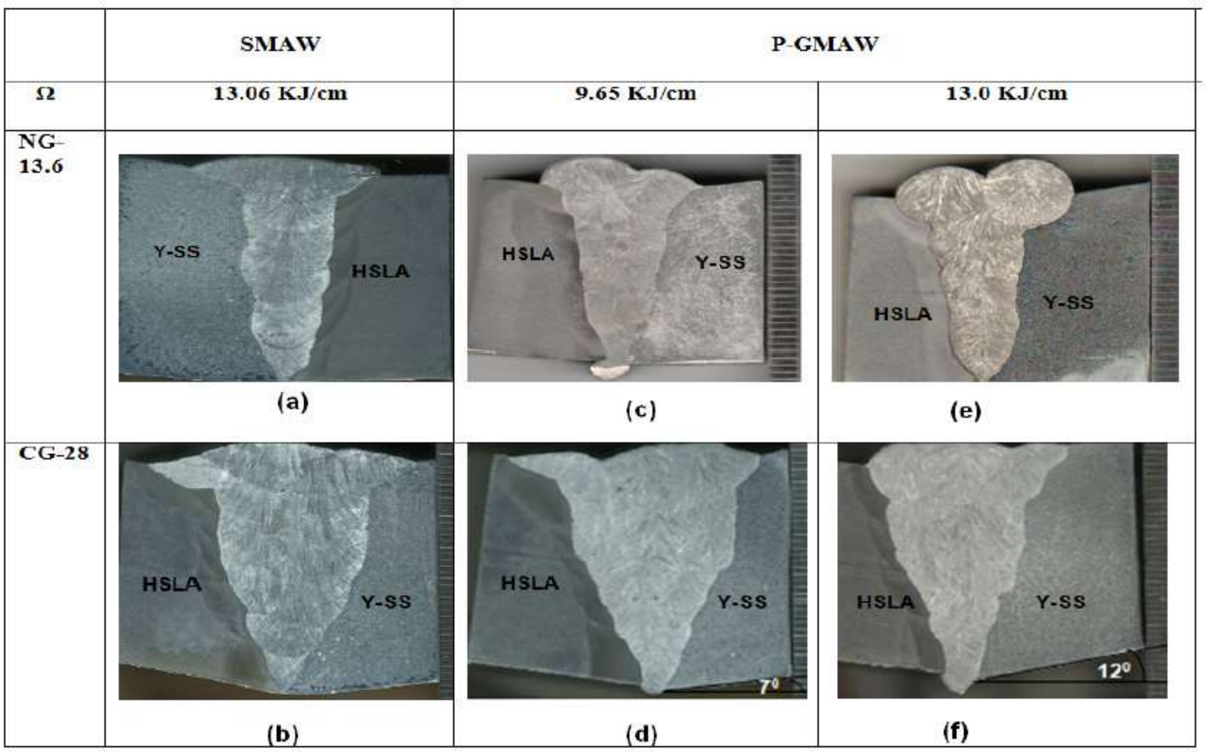

Fig.2.3.Typical macrograph of dissimilar narrow & conventional gap weld joints of HSLA and Y-SS steel (a,b)SMAW at _=13.06kJ/cm, Im=160A & V=28V ,(c,d)P-GMAW at _=9.65kJ/cm, Im=176A & V=26V, (e,f) P-GMAW at _=13.0kJ/cm, Im=220A & V=28V

3. Results and Discussion

3.1 Effect of Welding Processes on Cumulative Deflection Per Weld Passes

Figure 3.1.shows the effect of Pulsed Current GMAW Process and SMAW on Cumulative Deflection per weld pass in 25mm thick dissimilar weld joint of austenitic stainless steel and low alloy steel plate.

For 25mm dissimilar plate per weld pass heat input in Pulsed Current GMAW process is 9.65kJ/cm and 13.0 kJ/cm but in SMAW process is 13.6 kJ/cm.

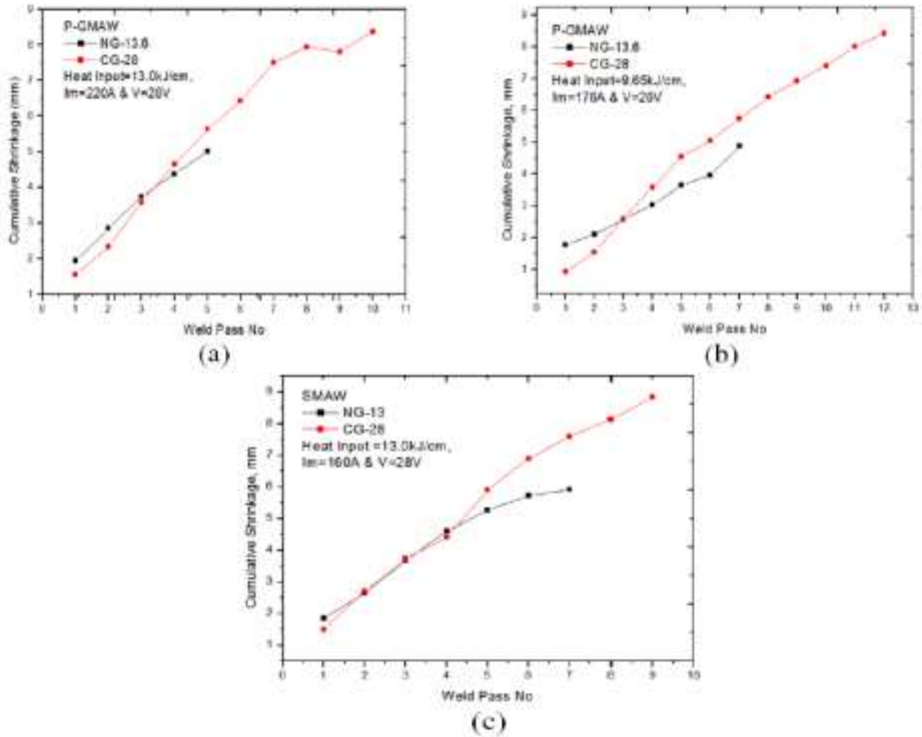

Fig.3.1 Typical cumulative shrinkage of dissimilar narrow & conventional gap weld joints of Y-SS steel and low alloy steel (a) P-GMAW at _=13.0kJ/cm, Im=220A & V=28V (b) P-GMAW at _=9.65kJ/cm, Im=176A & V=26V (c) SMAW at _=13.0kJ/cm, Im=160A & V=28V

3.2 Effect of Welding Process on Transverse Shrinkage Stress With Weld Groove Design

For different welding process, welded by Pulsed current GMAW process and SMAW process variation in transverse shrinkage with weld groove design and heat input is as shown in Figure 3.2

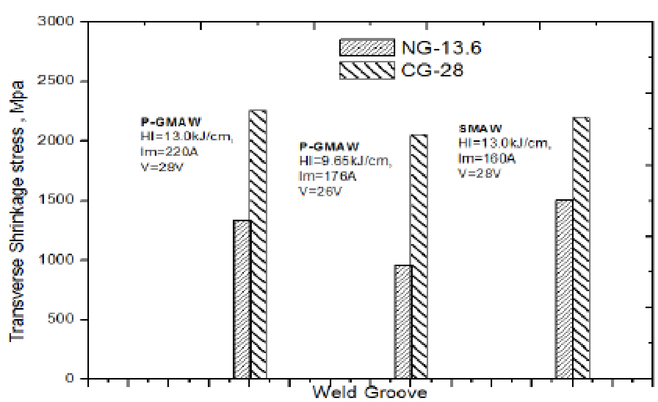

Fig:3.2 Typical transverse shrinkage stress of dissimilar narrow & conventional gap weld joints of Y-SS steel and low alloy steel

The Fig.3.1and 3.2 shows that the pulsed current GMAW results comparatively lower cumulative deflection and transverse shrinkage stress of per weld passes than the SMAW process. This may have primarily happened because of the pulsed current GMAW process produces relatively lower heat build up in weld pool than the SMAW process due to interruption in weld metal deposition by pulsed current.

In multi-pass welding of 25mm thick dissimilar plate at a given narrow range of heat input per weld pass, the cumulative deflection of the plate enhances significantly with the increase of number of filling passes. But it is observed that at a given number of filling pass the deflection of Conventional groove weld is comparatively more then that observed in narrow groove weld. This may have primarily happened due to the comparatively lower amount of metal deposition in narrow groove than the amount of weld deposition in conventional groove.

In Pulsed Current GMAW process heat input significantly enhance the cumulative shrinkage and transverse shrinkage. lower heat input gives lower cumulative deflection and transverse shrinkage stress of per weld passes than higher heat input.

4. Conclusion

1. MPSSPL extra narrow gap P-GMA weld joints significantly reduce the transverse shrinkage by about 35-45% than that of the MPMSPL conventional groove P-GMA weld and SMA welds..
2. The MPSSPL extra narrow gap P-GMAW lowers the deflection of weld joint than that of the conventional groove weld joint as shown in the macrograph.
3. In multi-pass welding of 25mm thick dissimilar plate at a given narrow range of heat input per weld pass, the cumulative deflection of the plate enhances significantly with the increase of number of filling passes.
4. it is observed that at a given number of filling pass the deflection of Conventional groove weld is comparatively more than that observed in narrow groove weld.
5. In Pulsed Current GMAW process heat input significantly inhence the cumulative shrinkage and transverse shrinkage. lower heat input gives lower cumulative deflection and transverse shrinkage stress of per weld passes than higher heat input.

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