International Symposium of Research Students on Materials Science and Engineering
December 20-22, 2004, Chennai, India
Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras

EXPERIMENTAL INVESTIGATION ON THE TRANSVERSE SHRINKAGE STRESS AND DISTORTION GENERATED IN BUTT WELDED JOINTS

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ABSTRACT

Experimentally the shrinkage stress and distortion developed during welding of mild steel plates has been studied. The magnitude of transverse shrinkage stress and distortion generated during welding under the unrestrained welding of butt joints is the main objective of the study. Effect of variation of weld areas has been studied. The weld areas varied by using different plate thicknesses such as 10mm, 12mm and 25mm. For 10mm and 12mm thick plates, single V-groove designs are used as joint designs for welding of these plates. Effect of variation of weld areas on the stresses developed has been studied under different welding processes such as continuous current GMAW and pulsed current GMAW. In case of 25mm thick plate two groove designs have been used namely, conventional V- groove (included angle 60-70°) design and narrow groove (13mm groove width) design Effect of variation of weld areas on the stresses developed has been studied by SMAW process. In 10mm and 12mm thick plates observed that pulsed current GMAW is advantageous than conventional GMAW 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: Conventional GMAW, Pulsed current GMAW, Narrow groove, Cumulative Deflection and Transverse shrinkage stress.

1. INTRODUCTION

Welding is a reliable and efficient joining process in which the coalescence of metals is achieved by fusion. Localized heating during welding, followed by rapid cooling, can generate shrinkage stresses in the weld and in the base metal. Shrinkage stress produces both tensile and compressive residual stress in different zones of the welded structure. Formation of residual stress may result in initiation of fatigue cracks, stress corrosion cracking, or other types of fracture. Therefore, to understand the magnitude of shrinkage stress and distortion generated during welding is important.

The present work is being carried out by experimental methods to evaluate the magnitude of the residual stresses developed in the weldment. In this method transverse shrinkage stresses and distortion generated in the welded structure have been calculated. An attempt has been made to evaluate the residual stress magnitude in case of unrestrained welding of butt joint. The weld area has been varied by varying different plate thicknesses such as 10mm, 12mm and 25mm. Single V groove design is adopted for 10mm and 12 mm thick plates. For 10mm and 12mm thick plates continuous current GMAW and pulsed current GMAW processes were used to make the weld joints. In case of 25mm thick plates two groove designs have been used namely, conventional V- groove design and narrow groove (13mm groove width) design. SMAW process was used to make the weld joints and to study the effect of groove on stress development during multi-pass welding of 25mm thick plates.

2. EXPERIMENTAL PROCEDURE

2.1 Base Material

Commercially available mild steel of different plate thicknesses (10, 12 and 25mm) were used as a base material. The chemical composition of the mild steel plates is shown in Table2.1.

2.2 Electrode/ Filler wire

Continuous current GMA welding and pulsed current GMA welding process commercially available mild steel filler wire of 1.2mm diameter was used. AWS specification is AWS/SFA 5.18ER-70S-6. Commercial available Argon (99.97%) used as a shielding gas. The gas flow rate is 16-18l/min; distance between nozzle to work piece distance is 15- 16 mm was maintained. For SMA welding process basic coated electrodes of 3.15 and 4 mm diameter were used. AWS specification is AWS/SFA 5.1E 7018-1. To remove moisture from the electrodes, they were baked in an electric oven to maintain at 100-200°C for one hour. Chemical compositions of electrode and filler wire are shown in Table2.2.

2.3 Joint Details

Single V- Groove butt joint (included angle is 60° and without root gap) configuration has been chosen for 10mm and 12mm thick plates. In case of 25mm thick plates conventional V-groove (C.G) and narrow groove (N.G) (13mm groove width) configuration was used. The schematic line diagrams of the joint design for different plate thicknesses are shown in Fig2.1.

2.4 Welding Equipments

GMA welding of mild steel plates was done on a semi-automatic welding machine (ESAB-ARISTO-2000) with direct current reverse polarity (DCRP). For SMA welding of mild steel plates was done on a dc generator with direct current reverse polarity (DCRP).

2.5 Welding Fixture

One side of the plates was tightly clamped and other side of plates is without clamp. The schematic line diagram and weld setup photos of the welding fixture are shown in Fig. 2.2.

2.6 Calculation Procedure

All the calculations relating to the experiment have been presented in Table2.4 to 2.7

3. RESULTS AND DISCUSSIONS

3.1 Effect of plate thickness on cumulative deflection per Weld passes

Fig. 3.1 shows the variation in cumulative deflection with weld pass number of different thicknesses of 10mm and 12mm plates. The plates were welded by Conventional GMAW and Pulsed current GMAW processes. This is observed that GMAW process; at a given sequence of weld pass the thick plate's shows comparatively lower cumulative deflection than the thinner one because relatively uniform heating for thick plates for the same energy input per unit length and thick plate have more rigidity.

3.2 Effect of plate thickness on transverse shrinkage per weld passes

For different thickness of 10mm and 12mm plates, welded by SMAW, Conventional GMAW and Pulsed current GMAW process. The variation in transverse shrinkage with weld pass number is shown in Fig. 3.2.

3.3 Effect of plate thickness on transverse shrinkage stress per weld passes

For different thickness of 10mm and 12mm plates, welded by SMAW, Conventional GMAW and Pulsed current GMAW process. The variation in transverse shrinkage stress with weld pass number is shown in Fig. 3.3.

3.4 Effect of welding processes on cumulative deflection per weld passes

Fig. 3.4 shows the effect of Continuous Current GMAW Process and Pulsed Current GMAW on Cumulative Deflection per weld pass in 10mm thick mild steel plate and 12mm 10mm thick mild steel plate. For 10mm mild steel plate the per weld pass heat input in Continuous Current GMAW process is 9.40 ± 0.06 kJ/cm and in Pulsed Current GMAW process is 9.18 ± 0.14 kJ/cm. For 12mm mild steel plate the average heat input per weld pass in Continuous current GMAW process is 11.58 ± 1.70 kJ/cm and in Pulsed Current GMAW process is 11.00 ± 1.57 kJ/cm.

3.5 Effect of welding process on transverse shrinkage per weld passes

For different thickness of 10mm and 12mm plates, welded by Conventional GMAW and Pulsed current GMAW process. The variation in transverse shrinkage with weld pass number is as shown in Fig. 3.5.

3.6 Effect of welding process on transverse shrinkage stress per weld passes

For different thickness of 10mm and 12mm plates, welded by Conventional GMAW and Pulsed current GMAW process. The variation in transverse shrinkage stress with weld pass number is as shown in Fig. 3.6.

The Fig.3.4, 3.5 and 3.6 shows that the pulsed current GMAW results comparatively lower cumulative deflection, transverse shrinkage and transverse shrinkage stress of per weld passes than the Conventional GMAW. This may have primarily happened because of the pulsed current GMAW process produces relatively lower heat build up in weld pool than the conventional GMAW process due to interruption in weld metal deposition by pulsed current.

3.7 Effect of variation of groove design on cumulative deflection per weld passes for Conventional V-Groove and Narrow Groove weld joints.

The effect of variation of groove design on cumulative deflection per weld pass number for Conventional V-Groove (C.G) and Narrow Groove (N.G) is shown in Fig. 3.7.

During multi-pass welding of 25mm thick 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 cumulative 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.

4. CONCLUSIONS

1. It is concluded that at a given sequence of weld pass the thick plate's shows comparatively lower deflection than the thinner ones.
2. It is concluded that pulsed current GMAW results in lower cumulative deflection of weld pass than that observed in case of the continuous current GMAW.
3. It is concluded transverse shrinkage and transverse shrinkage stress reduces significantly with the use of Pulsed current GMAW with respect to that observed in case of welding with Conventional current GMAW.
4. In multi-pass welding of 25mm thick plate at a given narrow range of heat input per weld pass, the cumulative deflection of the plate enhances significantly with the increase of filling passes. Cumulative deflection is more in case of Conventional groove as compare to narrow groove at a given filling pass.

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TABLES

Table 2.1: Chemical composition of base material

%C	%Mn	%P	%S	%Si	%Ni	%Cr	%Fe
0.18	0.95	0.009	0.0021	0.26	0.0073	0.04	Bal

Table 2.2: Chemical composition of SMAW electrode and GMAW filler wire

Welding processes	%C	%Mn	%P	%S	%Si	%Cu	%Fe
SMAW	0.06	1.02	-	-	0.44	-	-
GMAW	0.08	1.32	0.10	0.002	0.28	0.2	Bal

Heat Input	**Transverse Shrinkage**	**Transverse Shrinkage stress**
$q_w = \eta_m VI/S$ Where η_m=Process efficiency, $\eta_m = p\,\eta_t \eta_h$, $p<1.0$; η_t=0.368 η_h =Heat efficiency For SMAW, η_h =65-75% For GMAW, η_h =75-85% V=Welding voltage in volts, I=Welding current in ampere S=Travel speed in cm/min	$\Delta_{tr} = (\mu_t\, 2\alpha\, q_w)/C_\rho h$ Where, Δ_{tr} = Transverse shrinkage (mm) μ_t = Transverse stiffness factor = 0.5 α = Thermal conductivity (K^{-1}) = 12 x 10^{-6} C_ρ = Material specific volume density (J/mm^3K) = 4.9 x 10^{-3} h = Plate thickness (mm)	$\sigma_{tr} = \Delta_{tr}\, E/l$ Where σ_{tr} = transverse shrinkage stress E = Young's modulus of material = 210 x 10^9 N/m^2 l = straining length (mm) = 144mm

Table 2.4 Experimental calculations for 10mm thick plate welded by GMAW processes

Welding Process	Weld Pass No	Wire feed rate (m / min)	Welding current (A)	Welding Voltage (V)	Travel speed (Cm / min)	Heat Input (kJ / cm)	Transverse shrinkage (mm)	Transverse Shrinkage stress (MPa)	Cumulative Deflection (mm)
CGMAW	1	8.5	234	25	25	9.52	0.231	336.43	9.95
	2	8.5	231	26	25	9.51	0.233	339.64	16.51
PGMAW	1	8.5	227	25	25	9.00	0.220	321.43	8.2
	2	8.5	228	26	25	9.39	0.230	335.36	13.22

Table 2.5 Experimental calculations for 12mm thick plate welded by GMAW processes

Welding Process	Weld Pass No	Wire feed rate (m/min)	Welding current (A)	Welding Voltage (V)	Travel speed (Cm/min)	Heat Input (kJ/cm)	Transverse shrinkage (mm)	Transverse Shrinkage stress (MPa)	Cumulative Deflection (mm)
CGMAW	1	8.5	233	25	25	9.23	0.188	274.70	4.63
	2	8.5	230	27	20	12.29	0.251	365.77	7.90
	3	8.5	230	29	20	13.21	0.269	393.15	13.04
PGMAW	1	8.5	219	25	25	8.67	0.177	258.04	4.29
	2	8.5	220	26	20	11.33	0.231	337.20	8.12
	3	8.5	226	28	20	12.53	0.256	372.92	12.52

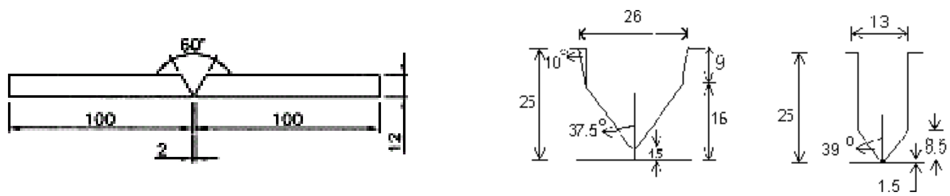
Table 2.6 Experimental calculations for 25mm thick conventional V -groove joint welded by SMAW process

Welding Process.	Weld pass No.	Welding current (A)	Welding Voltage (V)	Travel speed (cm/min)	Heat input (kJ/cm)	Transverse shrinkage (mm)	Transverse Shrinkage stress (MPa)	Cumulative deflection (mm)
SMAW	1	120	30	7.40	6.42	0.062	90.42	6.93
	2	120	30	7.31	6.50	0.064	93.33	7.83
	3	120	30	7.60	6.25	0.059	86.04	11.53
	4	120	30	7.70	6.17	0.058	84.58	15.99
	5	120	30	7.50	6.34	0.058	84.58	20.09
	6	120	30	7.40	6.42	0.058	84.58	24.24
	7	120	30	7.40	6.42	0.057	83.13	28.10
	8	120	30	7.60	6.25	0.058	84.58	30.76
	9	120	30	7.70	6.17	0.058	84.58	33.22
	10	120	30	7.92	6.00	0.058	84.58	35.40
	11	120	30	7.60	6.25	0.058	84.58	37.20
	12	120	30	7.70	6.17	0.055	80.21	38.12

Table 2.7 Experimental calculations for 25mm thick narrow groove joint welded by SMAW process

Welding Process.	Weld pass No.	Welding current (A)	Welding Voltage (V)	Travel speed (cm/min)	Heat input (kJ/cm)	Transverse shrinkage (mm)	Transverse Shrinkage stress (MPa)	Cumulative deflection (mm)
SMAW	1	120	30	7.60	6.25	0.061	89.32	6.14
	2	120	30	7.70	6.17	0.060	88.13	6.62
	3	120	30	7.50	6.34	0.062	90.51	9.03
	4	120	30	7.40	6.42	0.063	91.70	13.56
	5	120	30	7.40	6.42	0.063	91.70	18.96
	6	120	30	7.60	6.25	0.061	89.32	22.89
	7	120	30	7.70	6.17	0.060	88.13	26.46
	8	120	30	7.92	6.00	0.059	85.75	28.73
	9	120	30	7.60	6.25	0.061	89.32	30.38
	10	120	30	8.26	5.75	0.056	82.18	31.43

FIGURES

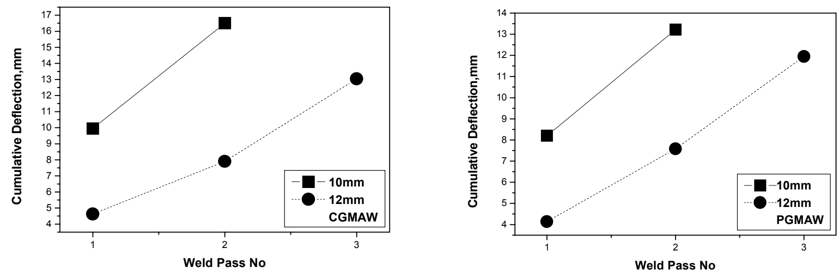


(a) (b) (c)

Fig2.1. a) Single V groove design for 10mm and 12mm thick mild steel plate's
b) Conventional V-groove design for 25mm thick mild steel plate and
c) Narrow grove design for 25mm thick mild steel plate.

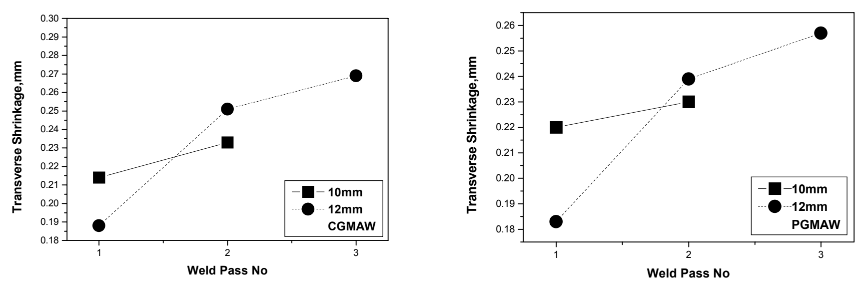
(a) (b) (c)

Fig2.2 a) The schematic diagram of welding fixture, b) Weld setup photos of SMAW and c) Weld setup photo of GMAW



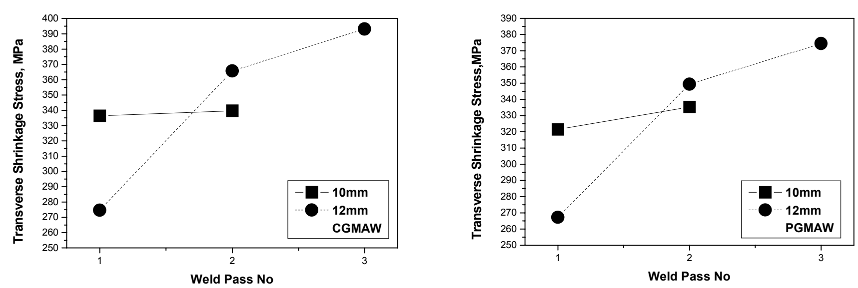
(a) (b)

Fig. 3.1 Variation of Cumulative Deflection with consequent Weld passes of different plate thicknesses. (a) Conventional GMAW and (b) Pulsed current GMAW



(a) (b)

Fig. 3.2 Variation of Transverse shrinkage with consequent Weld passes of different plate thicknesses. (a) Conventional GMAW and (b) Pulsed current GMAW



(a) (b)

Fig. 3.3 Variation of Transverse shrinkage stress with consequent Weld passes of different plate thicknesses (a) Conventional GMAW

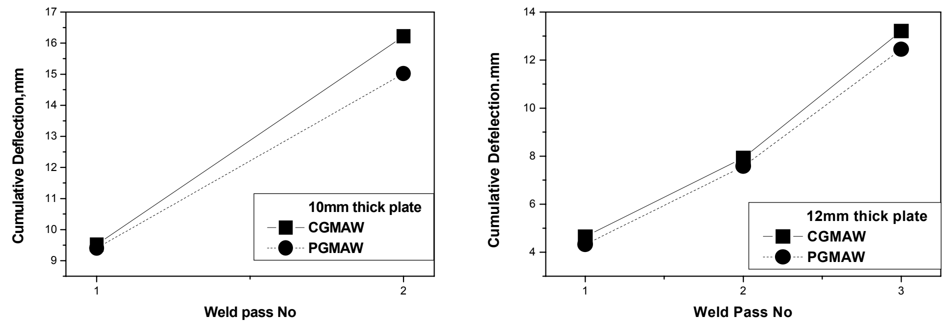


Fig. 3.4 Effect of Welding Process on Cumulative Deflection per weld pass

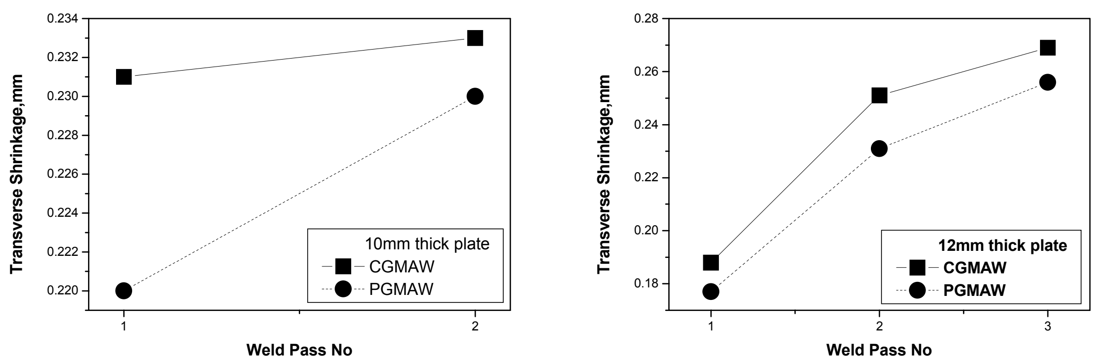


Fig. 3.5 Effect of Welding Process on Transverse shrinkage per weld pass

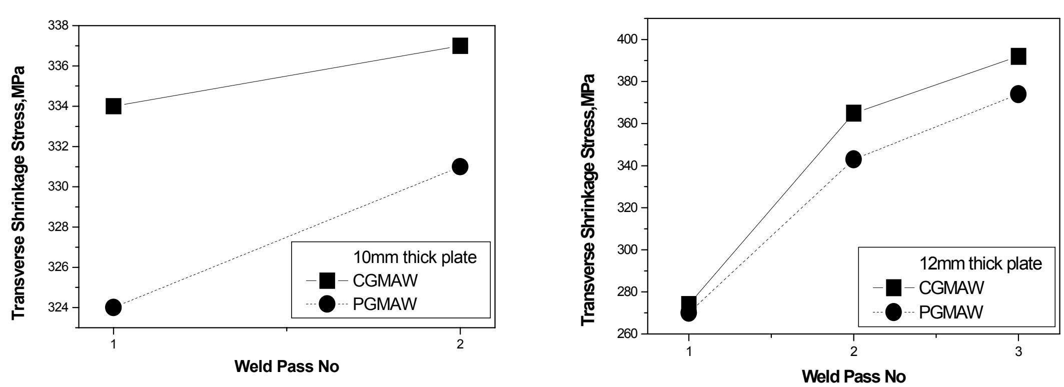


Fig. 3.6 Effect of Welding Process on Transverse shrinkage stress per weld pass

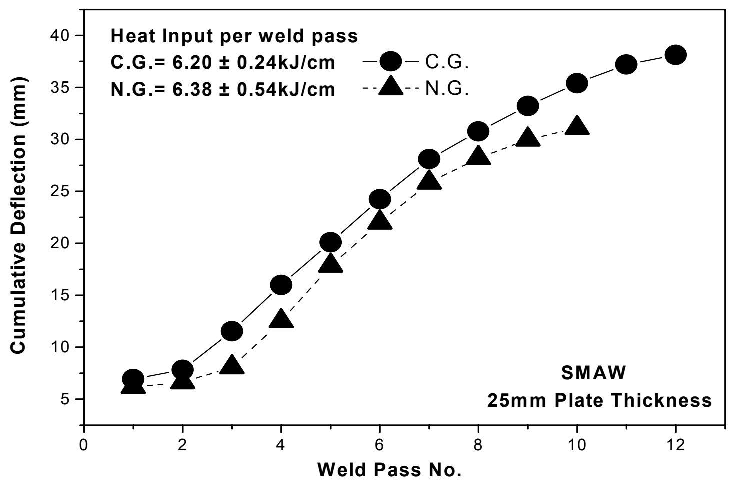


Fig. 3.7 Variation of Cumulative Deflection with weld pass no. for Conventional V-Groove and Narrow Groove.