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Impact of Groove Area on Longitudinal Shrinkage in CO_2 Arc Welding Process

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Abstract: Stress in the welded joints is due to the longitudinal shrinkages and transverse shrinkages. This is annoying as it lower the strength of the welded structure. The issues of distortion in welded joints are of key concern in the shipbuilding industry, structures, etc. The degree of shrinkages prediction in ship panels as a result of welding are of huge significance especially from the dimensional control perspective and thus it is very crucial to resolve longitudinal shrinkages and transverse shrinkages. In this regard, the present work estimates the longitudinal shrinkages in single v - groove, double v - groove and bevel - groove areas in butt welded joints in CO_2 Arc Welding practice preserving constant process parameters. It was observed that the longitudinal shrinkage increases through the expansion in the groove area.
Keywords: Longitudinal shrinkage; CO2 Arc Welding; Bevel groove; V-groove; double V-groove; Distortion.

I. INTRODUCTION

Carbon dioxide arc welding is the prominent and versatile means of fabrication available to industry. Welding in general is widely used in the fabrication of numerous structures, including pressure vessels, airplanes, buildings, ships, etc, [1]. The weld joint design is performed for an assembly that will carry out its expected work required for safety and reliability, accomplished of fabricated with respect to distortion [2]. The research has been done on the significance of groove angle in V - Groove butt joints and throat thickness on longitudinal shrinkages and transverse shrinkages with constant heat input using co_2 arc welding with reference [3, 4, 17]. But no research has been carried out on the influence of bevel groove, double V - groove and single V - groove in co_2 arc welding method.

In the past, efforts have been made by many researchers on welding deformation and have advised many techniques to approximate these shrinkages. Gupta [5], presented an analytical model to envisage the transverse shrinkage. The cause of the mechanical and physical properties of metals on distortion has been addressed [6]. The work in [7], studied on the cause of welding procedures, the assembly parameters and welding parameters on longitudinal and transverse shrinkages. The theoretical analysis of transverse shrinkage in a welded butt joint was studied in Mandal et al. [8].

The residual shrinkage considering a temperature - dependent coefficient of thermal expansion [9] has been calculated by partitioning the in close proximity to field into finite strips [10]. A variety of experiential relations have been offered for approximating diverse varieties of distortions in welding [11, 12]. Apart from these empirical means, various other techniques depending largely on the finite element technique have been adopted by researchers to calculate distortions in welding [13, 14]. In this work to estimate transverse shrinkage of welded steel panels, a technique based on a logical sequence of thermally induced distortions is suggested. By inferring near and far field zones, a mathematical model for predicting transverse shrinkage due to welding has been established [15].

The near field has been speculated to expand from the weld line to a distance where the peak temperature attained, and the other plate is considered to comprise the far field. The far field acts elastically all over the cooling and heating cycles, whereas the plastic deformations are predictable to arise only in the near field.

By using a temperature - dependent specific heat and the thermal conductivity and also assuming a quasi-stationary state [16], the temperature field correlated with the moving welding arc can be solved. In this context, in the present work, attempts have been made to study the consequence of bevel, V - groove and double V - groove angle butt joints on longitudinal shrinkages and analyzing these shrinkages. In this investigation, experiments were conducted on different specimens by varying single v-groove, bevel v-groove and double v-groove angle for different root openings and different diameter of electrode wire in a groove butt welded joints with other process specifications constant. The deviation of longitudinal shrinkage through V, double V and bevel groove areas of butt welded joints for different root opening have been studied.

II. EXPERIMENTAL PROCEDURE

The specimens were prepared by welding using CO_2 arc welding process and the specimens were measured for longitudinal shrinkage to study the cause of grooves and edge preparations such different butt joints keeping process parameters constant. The experiments were conducted at Mechanical Engineering department of University Visvesvaraya College of Engineering (UVCE), Bengaluru.

A. Base Material and Welding Consumables

The mild steel material has been used for the base plate for the preparation of welded plates. The size of the specimen used for the experimental work was 250x125x8 in mm. The electrode wire selected for welding mild steel as per AWS A5.18-79 standards. The electrode wires of diameter 0.8 mm and 1.2 mm have been used in the investigation for plate thickness of 8 mm. The carbon dioxide was used as the shielding gas.

B. Edge Preparations

Edge preparations were selected for single V - groove, bevel - groove and double V - groove butt joints. The different electrode diameters and edge preparations such as groove angle and root opening for different electrode diameters were used on these butt joints. The edge preparations were carried out on the plates for preparing welded specimens.

C. Butt Joints Used

The three butt joints were used in the experiments with single V - groove, bevel - groove and double V - groove butt joints. The geometry of Single V - groove butt joint, bevel - groove butt joint and double V - groove butt joint are shown in the Figure 1. The edge preparations selected for these butt joints were included angle and root opening, and the process parameter like electrode diameter.

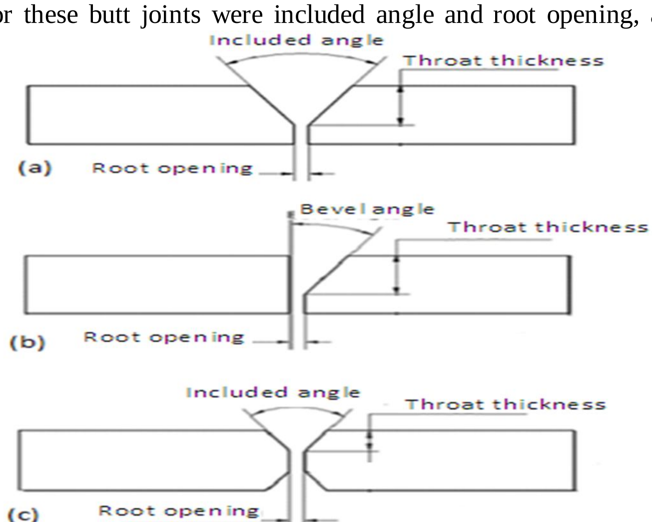

Figure 1. Geometry of Single (a) V-Groove, (b) Bevel-Groove and (c) Double V-Groove butt joints

D. Parameters Selected

The three parameters include groove angle, root opening and electrode diameter were selected in this investigation for the experimentation in single V - groove, bevel - groove and double V - groove butt joints.

E. CO_2 Arc Welding Machine

The CO_2 Arc Welding apparatus has been used in the welding of specimens. The specimens were fabricated using CO_2 arc welding process by considering different parameters on edge preparations and different electrode wire diameter with the following setup. The CO_2 Arc Welding equipment has been used in the welding of specimens. ADORE, Advani-Oerlikon (India) limited make, Semi-Automatic CO_2 Arc Welding Machine was used for preparing specimen samples. The CO_2 Arc Welding Machine with carbon dioxide shielding gas cylinder is shown in the Figure 2. The electrode was made positive for all the weld samples. The voltage can be adjusted to suitable values by means of rotary knob mounted on the front panel of the machine. The feeding of the wire into the arc is automatically controlled. The CO_2 arc welding machine is not equipped with controls to regulate the welding current, but the required welding current automatically comes into existence for the given wire feed rate, electrode diameter and electrode extension.

Figure 2. CO_2 Arc Welding Machine

F. Welding of Plates.

The base plates were cleaned to take away dirt, rust, scales before welding with the help of emery sheets and files. The base plate was made negative and the electrode was made positive in the CO_2 arc welding process for welding plates. For each weld plates, the process variables were preset, the tack welded base plates were welded in single pass by means of CO_2 Arc Welding procedure by proper welding parameters and welding parameters for butt welded joints used were Voltage = 22 Volts, Current = 100 Amps, Electrode diameters of 0.8 mm and 1.2 mm, Wire feed rate is 6 m/min and Electrode extension is 6 mm. The specimen length of 250 mm was welded in particular time and recorded. The welding speed and heat input are almost constant with little variation for all the specimens. In welding double side the same heat input is used for welding both sides and double the heat input. The surface of the weld bead is free from blow holes and porosity. The Welded plate after welding operation is shown in the Figure 3. The specimens were measured for distortion after welding. The heat input was calculated using an equation (voltage*current)/ (welding speed*60).

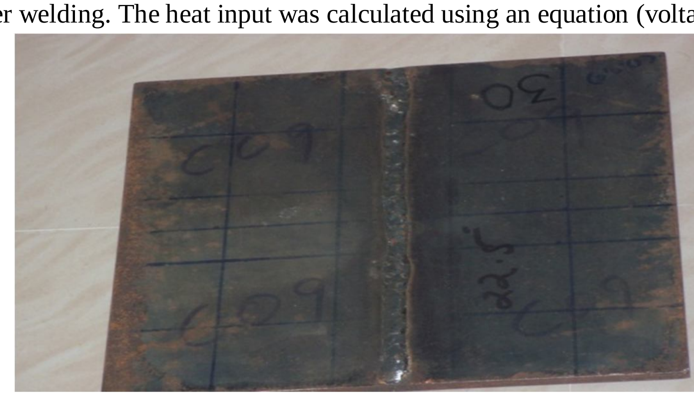

Figure3. Weld plate after welding by CO_2 arc welding process

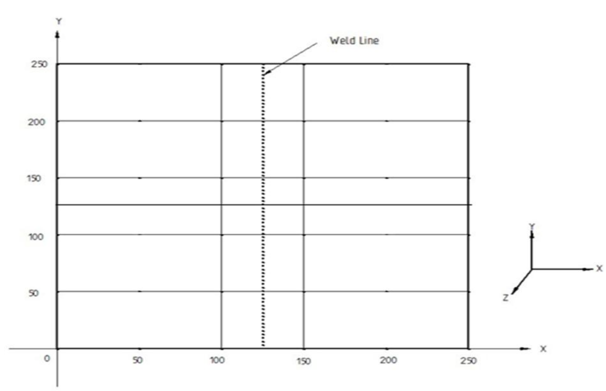

Figure4. Layout on the specimen for distortion measurement

G. Longitudinal Shrinkage

The Longitudinal shrinkages were measured on both surface of the weld line. The difference of the values recorded after and before welding will be the longitudinal shrinkages. The maximum values of longitudinal shrinkages for single V - groove, bevel - groove and double V - groove butt welded joints for different electrode diameters and edge preparations are tabulated as given in Tables 1, 2 and 3 respectively.

Table: 1. Values of Longitudinal shrinkage for distant electrode diameters and edge preparations in single V - groove butt welded joints.

Sl. No.	Parameters for single V - groove butt welded joints			Groove Area, mm^2	Maximum values of Longitudinal shrinkage, mm
	D, mm	R, mm	A, deg.		
1	0.8	0	0	0.0000	0.08
2	0.8	0	30	4.2890	0.08
3	0.8	0	45	6.6304	0.11
4	0.8	0	60	9.2421	0.16
5	0.8	1	0	8.0000	0.19
6	0.8	1	30	12.2890	0.20
7	0.8	1	45	14.6304	0.23
8	0.8	1	60	17.2421	0.25
9	0.8	2	0	16.0000	0.30
10	0.8	2	30	20.2890	0.32
11	0.8	2	45	22.6304	0.33
12	0.8	2	60	25.2421	0.37
13	1.2	0	0	0.0000	0.06
14	1.2	0	30	4.2890	0.06
15	1.2	0	45	6.6304	0.10
16	1.2	0	60	9.2421	0.15
17	1.2	1	0	8.0000	0.19
18	1.2	1	30	12.2890	0.18
19	1.2	1	45	14.6304	0.20
20	1.2	1	60	17.2421	0.22
21	1.2	2	0	16.0000	0.28
22	1.2	2	30	20.2890	0.32
23	1.2	2	45	22.6304	0.32
24	1.2	2	60	25.2421	0.35

Table: 2. Values of Longitudinal shrinkage for distant electrode diameters and edge preparations in bevel - groove butt welded joints

Sl. No.	Parameters for bevel - groove butt welded joints			Groove Area, mm^2	Maximum values of Longitudinal shrinkage, mm
	D, mm	R, mm	A, deg.		
1	0.8	0	0	0.0000	0.08
2	0.8	0	15	2.1445	0.08
3	0.8	0	22.5	3.3152	0.08
4	0.8	0	30	4.6211	0.10
5	0.8	1	0	8.0000	0.19
6	0.8	1	15	10.1445	0.20
7	0.8	1	22.5	11.3152	0.22
8	0.8	1	30	12.6211	0.24
9	0.8	2	0	16.0000	0.30
10	0.8	2	15	18.1445	0.32
11	0.8	2	22.5	19.3152	0.35
12	0.8	2	30	20.6211	0.36
13	1.2	0	0	0.0000	0.06
14	1.2	0	15	2.1445	0.06
15	1.2	0	22.5	3.3152	0.07
16	1.2	0	30	4.6211	0.11
17	1.2	1	0	8.0000	0.19
18	1.2	1	15	10.1445	0.19
19	1.2	1	22.5	11.3152	0.21
20	1.2	1	30	12.6211	0.22
21	1.2	2	0	16.0000	0.28
22	1.2	2	15	18.1445	0.32
23	1.2	2	22.5	19.3152	0.33
24	1.2	2	30	20.6211	0.35

Table: 3. Longitudinal shrinkage values for different electrode diameters and edge preparations in double V-groove butt welded joints

Sl. No.	Parameters for double V - groove butt welded joints			Groove Area, mm^2	Maximum values of Longitudinal shrinkage, mm
	D, mm	R, mm	A, deg.		
1	0.8	0	0	0.0000	0.08
2	0.8	0	30	4.8251	0.12
3	0.8	0	45	7.4592	0.14
4	0.8	0	60	10.3974	0.16
5	0.8	1	0	8.0000	0.23
6	0.8	1	30	12.8251	0.23
7	0.8	1	45	15.4592	0.26
8	0.8	1	60	18.3974	0.29
9	0.8	2	0	16.0000	0.33
10	0.8	2	30	20.8251	0.38
11	0.8	2	45	23.4592	0.40
12	0.8	2	60	26.3974	0.42
13	1.2	0	0	0.0000	0.10
14	1.2	0	30	4.8251	0.10
15	1.2	0	45	7.4592	0.13
16	1.2	0	60	10.3974	0.15
17	1.2	1	0	8.0000	0.20
18	1.2	1	30	12.8251	0.18
19	1.2	1	45	15.4592	0.21
20	1.2	1	60	18.3974	0.28
21	1.2	2	0	16.0000	0.30
22	1.2	2	30	20.8251	0.37
23	1.2	2	45	23.4592	0.39
24	1.2	2	60	26.3974	0.41

III. RESULTS AND DISCUSSIONS

The results of the research work carried out in the area of distortion of welded joints in CO_2 arc welding method for edge preparations of 8 mm plate thickness electrode and distant diameter are presented in this work. The research for analyzing the distortion in the welded plates by the use of CO_2 arc welding has been carried out on sixty six specimens in controlled environmental conditions in single V - groove, bevel - groove and double V - groove butt joints for different electrode diameters and edge preparations. The various edge preparations such as groove angle and root opening were varied for 0.8 mm and 1.2 mm electrode diameters for 8 mm plate thickness of size 250 mm x250 mm. Longitudinal shrinkage was measured on welded specimens.

The investigation has been carried out to study the effect of groove area on longitudinal shrinkage for different electrode diameters in single V - groove, bevel - groove and double V - groove butt welded joints. Further, the influence of edge preparations on longitudinal shrinkage is discussed under the following subheadings.

A. Cause of Groove Area on Longitudinal Shrinkage

The efforts were made to study the significance of groove area on longitudinal shrinkage in single V - groove, bevel - groove and double V - groove butt welded joints on longitudinal shrinkage for 0.8 mm and 1.2 mm electrode diameters. The consequence of groove area on longitudinal shrinkage for different butt joints and electrode diameters are presented

B. Cause of Groove Area on Longitudinal Shrinkage in single V-groove Butt Joints

The longitudinal shrinkage with groove area for single V-groove butt welded joints for 0.8 mm and 1.2 mm electrode diameters is shown in Figure 5. It can be observed from the figure that, longitudinal shrinkage increases with the expansion in the groove area. When the groove area is increased from 0 to 25.24 mm^2, the longitudinal shrinkage for 0.8 mm electrode diameter increased from 0.08 mm to 0.37 mm. For 1.2 mm electrode diameter, the longitudinal shrinkage increased from 0.06 mm to 0.35 mm. The longitudinal shrinkage reduced in welded joints of 1.2 mm electrode diameter when compared to the welded joints of 0.8 mm electrode diameter. The filler metal deposited would be deeper and wider due to increase in groove area. Because of raise in the groove area, the area of weld metal exposed to the surrounding reduces. The cooling rate decreases with decrease in the exposed weld metal area. Therefore the longitudinal shrinkage increases with the expansion in the groove area. This may be due to the rate of cooling of weld metal. The longitudinal shrinkage increases as expansion in the groove area in single V-groove butt welded joints. The heat produced in welded joints of 0.8 mm electrode diameter is more than welded joints of 1.2 mm electrode diameter. Hence there is a reduction of longitudinal shrinkage in the welded joints of 1.2 mm electrode diameter.

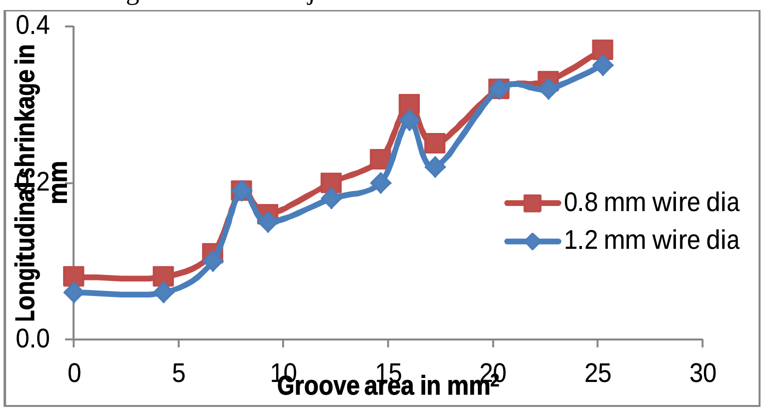

Figure 5. Diversity of longitudinal shrinkage with groove area for single V-groove butt joints.

C. Cause of Groove Area on Longitudinal Shrinkage in bevel-groove Butt Joints

The longitudinal shrinkage with groove area for bevel - groove butt welded joints for 0.8mm and 1.2 mm electrode diameters is shown in Figure 6. It can be observed from the figure that, the longitudinal shrinkage increases with the expansion in the groove area. When the groove area is increased from 0 to 25.24 mm^2, the longitudinal shrinkage for 0.8 mm electrode diameter increased from 0.08 mm to 0.36 mm. For 1.2 mm electrode diameter, the longitudinal shrinkage increased from 0.06 mm to 0.35 mm. The longitudinal shrinkage reduced in welded joints of 1.2 mm electrode diameter when compared to the welded joints of 0.8 mm electrode diameter. The filler metal deposited would be deeper and wider due to increase in the groove area. The part of weld metal bared to the surrounding diminishes with the groove area enhancement.

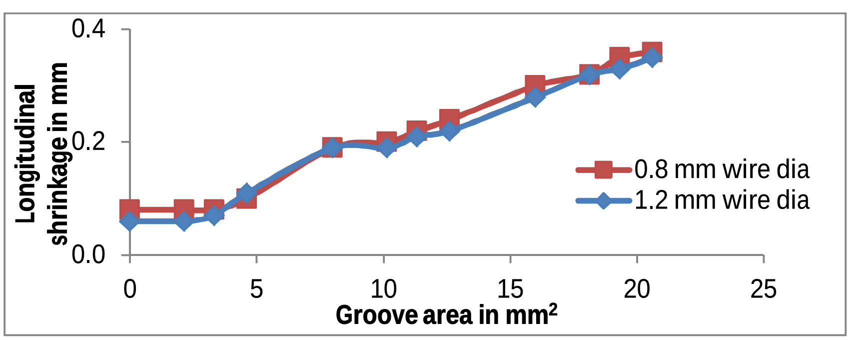

Figure 6. Diversity of longitudinal shrinkage with groove area for bevel - groove butt joints.

The rate of cooling diminishes with decrease in the exposed weld metal area. Therefore the longitudinal shrinkage increases with enhance in groove area. This may be due to the rate of cooling of weld metal. The longitudinal shrinkage increases as rise in the groove area in bevel - groove butt welded joints. The heat produced in welded joints of 0.8 mm electrode diameter is more than welded joints of 1.2 mm electrode diameter. Hence there is reduction of longitudinal shrinkage in the welded joints of 1.2 mm electrode diameter.

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D. Effect of Groove area on Longitudinal Shrinkage in double V - groove Butt Joints

The longitudinal shrinkage with groove area for double V - groove butt welded joints for 0.8 mm and 1.2 mm electrode diameters is shown in Figure 7. It can be observed from the figure that, the longitudinal shrinkage increases with enhance in the groove area. When the groove area is increased from 0 to 25.24 mm^2, the longitudinal shrinkage for 0.8 mm electrode diameter increased from 0.12 mm to 0.42 mm. For 1.2 mm electrode diameter, the longitudinal shrinkage increased from 0.1 mm to 0.41 mm. The longitudinal shrinkage reduced in welded joints of 1.2 mm electrode diameter when compared to the welded joints of 0.8 mm electrode diameter. The filler metal deposited would be deeper and wider due to increase in groove area. Because of raise in the groove area, the area of weld metal exposed to the surrounding reduces. The cooling rate decreases with decrease in the exposed weld metal area.

Therefore the longitudinal shrinkage increases with rise in the groove area. This may be due to the rate of cooling of weld metal. In double V - groove butt welded joints the longitudinal shrinkage induced during welding on one side and further increases during welding on the other side, this results in the higher longitudinal shrinkage when compared to the single V - groove and bevel - groove butt welded joints. The heat produced in welded joints of 0.8 mm electrode diameter is more than welded joints of 1.2 mm electrode diameter. Hence there is a reduction of longitudinal shrinkage in the welded joints of 1.2 mm electrode diameter.

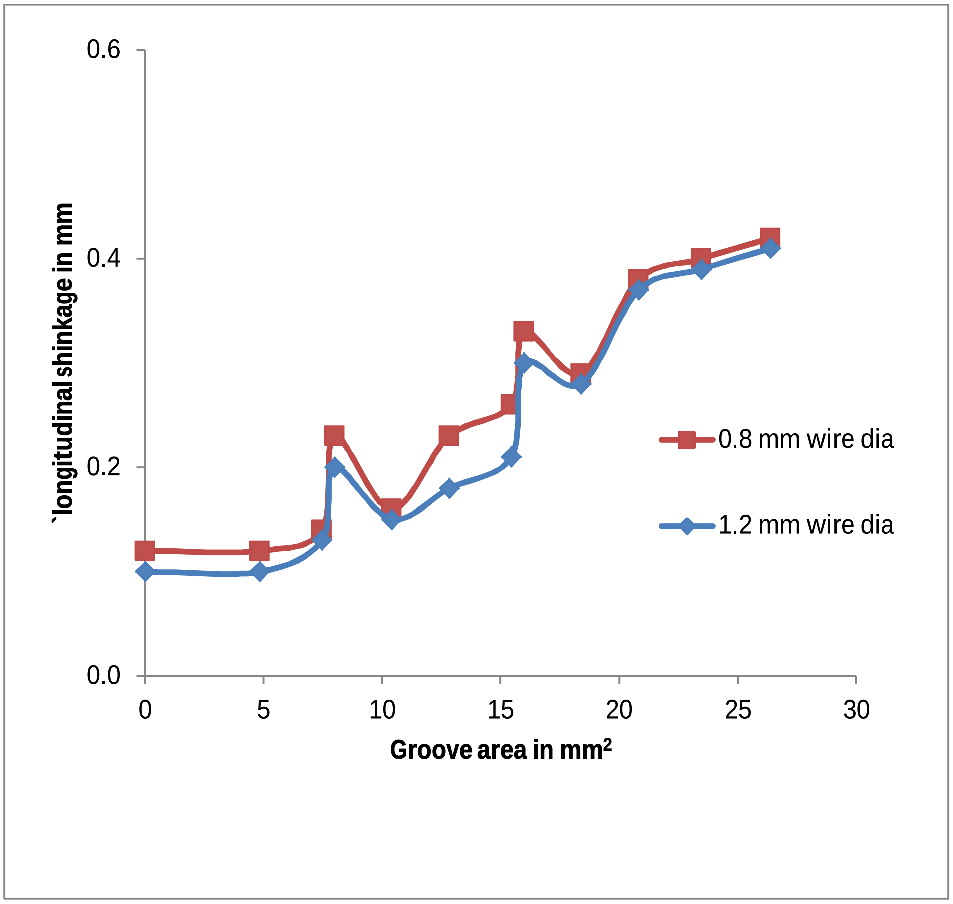

Figure 7. Diversity of longitudinal shrinkage with groove area for double V - groove butt joints.

IV. CONCLUSION

The conclusions of the research work carried out in the present investigation in the area of distortion of welded joints in CO_2 arc welding technique for edge preparations of 8 mm plate thickness and diverse electrode diameter within the scope of this investigation have been presented as follows.

Issues of Groove area on Distortions, the longitudinal shrinkage increases with increase in groove area in single V - groove, bevel - groove and double V - groove butt welded joints because, when there is a increase in the groove area, the filler metal deposited would be deeper and wider. The weld metal area exposed to the surrounding diminishes with enhance in the groove area, therefore decrease in the rate of cooling of weld metal.

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