AN INVESTIGATION INTO DISTORTION IN WELDED TEE JOINTS

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Abstract : *Though fusion welding is the most versatile process of joining of materials, it is fraught with change in shape and configuration of the fabricated structures due to distortion. There are some common guidelines to combat distortion of weldments. Considerable amount of literature is available on controlling distortions of butt joints but the same on T-joints is rather meager. In the present investigation, single fillet T-joints were made of mild steel plates using manual metal-arc welding process. A number of parameters including state of the base plate (such as, pre-welding stress relieving, preheating), size of flux-coated electrodes, size of the fillet weld, etc. were considered. Factorial design of experimental technique was adopted to optimize the number of experiments performed. Useful conclusions of practical significance have been drawn.*

Introduction

Manual metal-arc welding (MMAW) is the most widely practiced welding process to join materials. It uses a flux-shielded electrode and hence is also known as shielded metal-arc welding (SMAW) process. The electrodes are available in different sizes or gauge numbers and the welding current used is in the range of 25 to 35 ampere per unit diameter (measured in mm) of the medium carbon steel electrode. Being a fusion welding process, the heat input during welding affects the base material both physically and metallurgically. Physical effects are in terms of distortion and residual stresses and metallurgical effects include microstructural changes.

During fusion welding a weldment is heated locally by the welding heat source. The temperature distribution in the weldment is not uniform causing complex strains. As a result, residual stresses remain after the welding is completed, and shrinkage and distortions are produced. Due to distortion the base metal component (plate) is pulled out of its original alignment.

There are three main types of distortions: (i) When the contraction occurs along the length of the weld, it causes longitudinal contraction or distortion. It is the highest along the weld and decreases at points away from the line of the weld. (ii) Transverse distortion or shrinkage is perpendicular to the weld and it may lead to development of high residual stress and also may cause cracking in case of highly restrained joints. (iii) There may be bending transverse to the weld due to non-uniform heating and cooling along the thickness of each of the two parts being welded causing angular distortion. It is

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the main source of mismatch. Figure 1 shows the distortion in a double fillet T-joint.

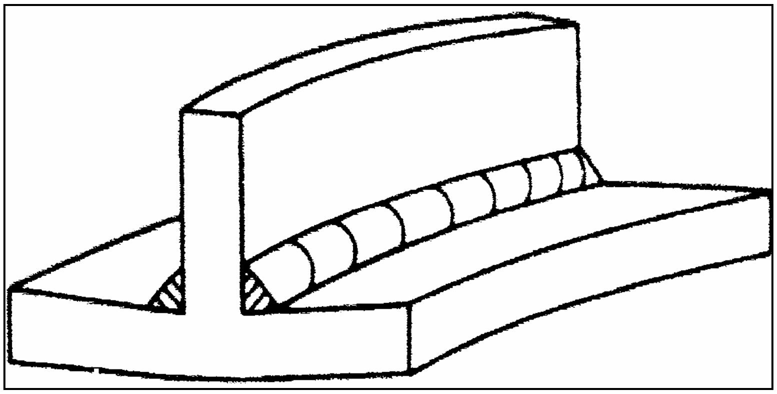

Fig. 1: Distortion in a double fillet T-joint

Since distortion is caused by the effects of differential heating and cooling between any two points from the centerline of the weld, it involves stiffness and metal yielding. Thus the mechanical and physical properties of the metal as well as the type of joint would affect the degree of distortion. In general, it can be said that there is more chance of distortion, if the metal has

(i) Higher coefficient of thermal expansion,
(ii) Higher yield strength,
(iii) Lower thermal conductivity and
(iv) Lower modulus of elasticity (stiffness).

Among the welding parameters, which are likely to affect the distortion are:

(i) Type of joint and edge preparation,
(ii) Welding sequence,
(iii) Steps in progression of welding,
(iv) Continuous or intermittent weld,
(v) Number of passes or runs,
(vi) Nature of stress existing in tne individual members prior to making the welded structure,
(vii) Pre- and post-weld heating,
(viii) Current, welding speed and arc length.

There are some common guidelines to combat distortion (such as, welding from both the sides, back step welding, minimum amount of weld metal deposition, and so on). Considerable amount of literature is available on butt joints [1-2] but the same on fillet welded T-joints are rather meager. Fillet weld is used to connect sheet to sheet or cross section-to-cross section. Fillet welding has been a subject of considerable interest in many industries like ship building. Distortion is a serious problem during fabrication. In the present investigation, studies were made on angular distortion occurring in single fillet T-joints.

Experimental Details

Single fillet T-joints were made on medium carbon steel plates (170x110x6.5 mm and 110x100x6.5 mm) using SMAW process. The parameters varied were: (i) electrode size (14, 10 and 8 SWG), (ii) state of stress relieve before welding – normalizing at 620 ^oC or no normalizing, (iii) state of preheating – preheating at 150 ^oC or no preheating, (iv) steps in progression in welding – back step or no back step, and (v) leg lengths of the base (horizontal) and vertical members – 6 mm, 8 mm and 10 mm. The type of power source used was dcsp.

To minimize the number of experiments needed to arrive at any positive conclusion, the principle of fractional factorial design was adopted. Angular distortion was obtained by calculating the angle between the normals at any point on the members prior to and after welding. Drilled grid points were made on the base plates. The x, y and z coordinates of these grid points before and after welding were noted to determine the distortion caused.

Results

Tables 1 to 3 show the angular distortion under various conditions of stress relieving, preheating and steps in progression in welding (‘1’ stands for treatment given and ‘0’ for no treatment).

Table – 1: Angular Distortion

Leg length on base plate = 8 mm, Leg length on vertical plate = 10 mm,
Electrode size = 8 SWG

Sl. No.	Stress relief	Preheating	Back step	Angular distortion (θ_m) in degrees on	
				Base plate	Vertical plate
1	1	1	1	0.25	0.13
2	1	1	0	0.54	0.21
3	0	1	0	0.65	0.27
4	1	0	1	0.70	0.16
5	0	0	1	1.01	0.36
6	1	0	0	1.03	0.44
7	0	0	0	1.08	0.60

The results in all these tables show that stress relief treatment, preheating treatment and back step welding significantly reduce the distortion on both the plates. A plate, which has not undergone the processes of stress relief, preheating and back step welding clearly shows the highest degree of distortion. Individually any one of the treatments can also reduce distortion. However, preheating seems to have the most prominent role amongst these three treatments in reducing distortion.

Table – 2: Angular Distortion

Leg length on base plate = 10 mm, Leg length on vertical plate = 8 mm,
Electrode size = 10 SWG

Sl. No.	Stress relief	Preheating	Back step	Angular distortion (θ_m) in degrees on	
				Base plate	Vertical plate
1	1	1	1	0.25	0.16
2	1	1	0	0.28	0.22
3	0	1	0	0.37	0.31
4	1	0	1	0.43	0.28
5	0	0	1	0.53	0.38
6	1	0	0	0.79	0.44
7	0	0	0	1.29	0.57

Table – 3: Angular Distortion

Leg length on base plate = 6 mm, Leg length on vertical plate = 6 mm,
Electrode size = 14 SWG

Sl. No.	Stress relief	Preheating	Back step	Angular distortion (θ_m) in degrees on	
				Base plate	Vertical plate
1	1	1	1	0.66	0.05
2	1	1	0	0.81	--
3	0	1	0	0.82	0.11
4	1	0	1	0.95	0.15
5	0	0	1	0.97	0.22
6	1	0	0	1.03	0.17
7	0	0	0	1.41	0.85

A plate, which has not undergone the processes of stress relieving, preheating and back step welding clearly shows the highest degree of distortion. The effect of preheating is more pronounced among these three measures.

The plates are rolled products and have some amount of residual stress existing in the body. When such plates are welded, the distortion due to welding gets affected. Preheating is known to be an important measure in reducing cooling rate and equalizing temperature distribution and thus lowering distortion. In the same manner back step welding reduces distortion.

The amount of distortion on the vertical plate is less as compared to that on the base plate. The difference is of the order of 20 to 80% depending on the treatment parameters.

The effects of electrode size and leg lengths are on the expected line. Distortion increases with electrodes of lower diameter, which requires more number of runs to make the same volume of deposition. Similarly, the distortion increases with leg length, though the electrode diameter has a more pronounced effect as compared to that of leg length.

CONCLUSION

The following conclusions can be drawn based on the present experimental investigation conducted on single fillet Tee-joints made on medium carbon steel plates:

(i) Pre-welding stress relieving, preheating and back step welding individually reduce distortion. The effect of preheating is more pronounced.

(ii) The distortion on the vertical plate is much less as compared to that on the base plate.

(iii) The lower the diameter of the electrode for the same amount of weld deposit, higher is the degree of distortion.

(iv) The distortion also increases with the increase in leg length on any member.

References

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