

Weld Distortions with Different Shaped Heat Sources – A Numerical Study

Arunjith A.R.¹, Jose M.J.²

P.G. Student, Department of Mechanical Engineering, Govt. College of Engineering Kannur, Kerala, India¹

Assistant Professor, Department of Mechanical Engineering, Govt. College of Engineering Kannur, Kerala, India²

ABSTRACT: Welding heat causes distortion in welded structures and a quality weld necessitates its distortions restricted within specified tolerances. The extent of distortions depends on both the amount of heat input and the type of clamping conditions of work piece. Elastic strain due to thermal expansion is a measure of deflection due to welding. Present work is a numerical study of the effect of different shaped surface heat sources such as triangular and circular on distortions in welded structures. Sequentially coupled thermo-mechanical model was developed in ANSYS Workbench 15.0 for this study and the circular heat source was concluded as the better choice because of less weld distortion.

KEYWORDS: ANSYS Workbench 15.0, Welding distortion, Circular heat source, Triangular heat source.

I. INTRODUCTION

Maintaining the dimensional accuracy within specified limits in arc welding has always been a challenge for welding engineers. The tremendous rate of heat input from the welding arc causes distortions in the work pieces even if they are tightly clamped. The clamping positions and methods have substantial effect on the welding distortions. Also, the quantity of heat load influences the distortions. The relationship between physical situations, such as the type of clamps used and the amount of heat input, and distortions resulted due to welding can be effectively studied using computational methods. So far as the welding heat source is concerned, simply specifying the quantity of heat input will not give the true idea regarding the actual presence of heat source. The size and shape of heat source is as important as the amount of heat load.

There were several efforts from the part of researchers to design the shape and size of the heat source using Finite Element (FE) methods [1, 2] so as to better represent the real heat source in arc welding. Several types of heat sources such as point heat source, line heat source, circular heat source, elliptical heat source and double-elliptical heat source have been discussed in literature. Apart from the above mentioned surface heat sources, volumetric heat source models like ellipsoidal and double ellipsoidal were also developed and they were found better in establishing a match between the experimental and computational results. The better performance of volumetric heat source models were with those welding processes where the depth of penetration was comparatively more like laser welding [3, 4]. For the shallow-penetration type welding processes like Metal Inert Gas (MIG) welding and Tungsten Inert Gas (TIG) welding, the surface heat source models can be used without much difference from the nature of true heat source. For the point and line heat sources, there are much less scope for designing the shape and size, but the planar models like circular and elliptical may be explored further for better size or shape. In case of a static welding heat source, circular shape may be the best appropriation, but when it starts moving, the circle seems to be stretched. Since a welding heat source is well represented by the weld pool, the shape and size of weld pool should be there in the mind of the researcher while modelling its equivalent heat source.

Normal elastic strains due to thermal loading may be used as a measure of the deformations after welding. The type and quantity of heat source affects the strain largely and hence it can act as a representative of weld distortions.

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Present work consists of modelling of two differently shaped moving heat sources such as circular and triangular and estimating the better one among them in terms of less normal elastic strain. Each model was simulated with three different amount of heat input and its effect on strain was also studied. A transient thermal model for moving heat source was made and the resulting temperature field was fed to a static structural model to get sequentially coupled thermo-mechanical model. The deformations at specified points were measured for each models and it was concluded that the circular heat source was causing less welding distortions.

II. MODELLING & SIMULATION

The modelling and subsequent simulation of moving heat source models was performed using the commercial finite element software package ANSYS Workbench 15.0. Sequential coupling between thermal and structural models was achieved through establishing connection between ‘transient thermal’ module and ‘static structural’ module on ‘Project Schematic’ window of the software. The material selected for the TIG Welding process was structural steel with a density of 7850 kg/m³. Size of the rectangular workpiece was of 300 x 75 x 10 mm and the heat source was assumed to be moving horizontally along the Weld Centre Line (WCL) which was the geometrical centre line of work piece with a length of 300 mm. Leaving 10 mm on either end, welding started at x=10 mm and ended at x=290 mm without using any filler material. Welding torch remained vertical and the heat flux fell on the selected area normally. Two models were made, one with circular heat source and the other with triangular heat source. The radius of welding arc for circular heat source was fixed as 5 mm and a circular area of diameter 10 mm was drawn on work piece. An equilateral triangle with the same area as that of the circular surface was drawn for the triangular model with its flat side facing the direction of moving heat source. Both the circular and triangular areas were created through the extrusion with ‘Imprint faces’. A ‘Static structural’ module was dragged and dropped on the ‘Project Schematic’ window of ANSYS Workbench 15.0 and the default engineering data for structural steel was assigned for the material. The geometrical part of the modelling work was done using the ‘Geometry’ cell of the ‘Static Structural’ module. The geometrical model was fed to a ‘Transient thermal’ module where the necessary heat source parameters were defined. The quantity of heat load was determined using the formula,

$$Q = \eta \times V \times I \text{ (W)} \quad (1)$$

Where Q = Arc power, V=Welding voltage (V), I=Welding current (A), η =Arc efficiency (%).

The selected values for voltage and current were given in the Table 1. Assuming the arc efficiency as 80%, the heat load was calculated as 1920 W, 2880 W and 3840 W for both the circular and triangular heat sources.

Table 1: Welding process parameters

No.	Voltage (V)	Current (I)	Heat Input, (Q) (W)
1	24	100	1920
2	24	150	2880
3	24	200	3840

The resulting temperature distribution from the ‘transient thermal’ model was inserted to another ‘Static structural’ module on the ‘Project Schematic’ window as the sequential coupling between thermal and structural models. The two 75 mm sides and two 300 mm sides were given a boundary condition of ‘fixed support’ and the work piece was allowed to expand laterally during welding. The welding speed was kept constant at 20 mm/s. Simulation of the second ‘static structural’ model gave the elastic strains at specified paths within the model.

III. RESULTS & DISCUSSIONS

Uniformly distributed circular moving heat source and uniformly distributed triangular moving heat source were made and they were simulated with three different amount of heat loads such as 1920 W, 2880 W and 3840 W. The surface areas on which these heat flows were distributed were equal. Fig. 1 shows the three views of the moving heat source, one being at the beginning; one being at the middle and the third one being at the end. Each simulation was for

a welding speed of 20 mm/s. Boundary conditions were applied such that all the four lateral sides were given ‘fixed supports’ and the work piece was free to expand under thermal loading along the direction normal to the flat surface.

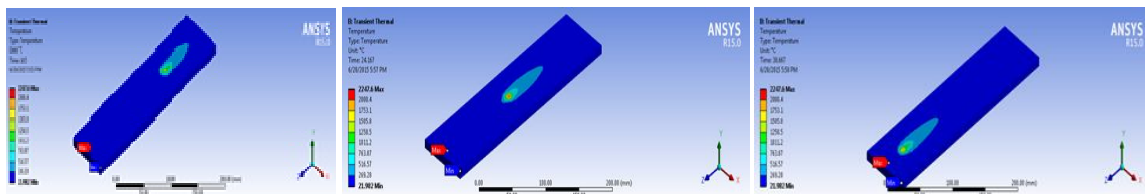


Fig. 1: Uniformly Distributed Circular Moving Heat Source Model

The strain was measured along the pre-defined ‘paths’ in each model. Two ‘paths’ were defined for each model, one along the Weld Centre Line (WCL) and the other across the WCL. The ‘path’ along WCL was of length 150 mm and it started at 50 mm from the beginning edge of work piece and ended at 100 mm ahead of the edge at end. The ‘path’ across the WCL was of length 75 mm and covered the entire width of the work piece. Fig. 2 (a) shows the distributions of strain across WCL in the case of circular heat source model. It is clear that the weld with higher arc power caused more strain. The similar kind of distribution was obtained for triangular heat source also which is shown in Fig. 2 (b) Comparison between these two figures reveals that, for the same amount of arc power, triangular heat source produces higher strains. The difference is apparent and consistent also for the three heat loads. For circular heat sources, the curves are more flat and closer to the shape of circular arcs. But, the strain distributions for triangular heat sources are more like part of an ellipse giving steeper profiles. Apart from steeper, they are more regular also. The reason may be attributed to the difference in their shapes only. The equilateral triangle has one of its flat ends facing the direction of welding. When we overlap the circle over this triangle, the higher frontal area of the later helps to make the weld pool size larger which gives rise to more bead width, it is assumed. The increase in bead width may be behind the more softening of area near to WCL and higher value of elastic strain.

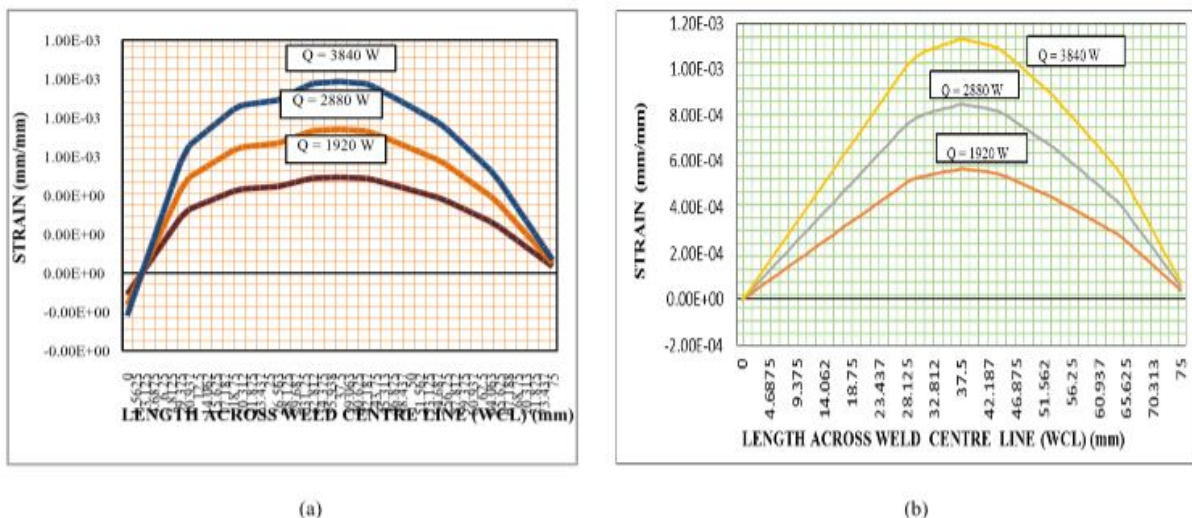


Fig. 2: ‘Strain Vs Length across WCL’ (a) for circular heat source model (b) for triangular heat source model

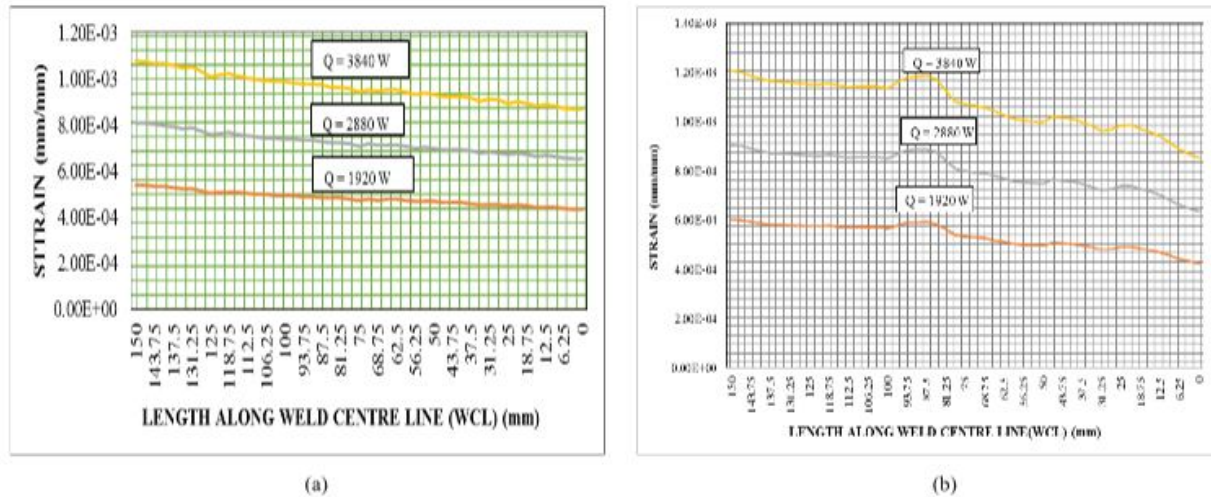


Fig. 3: 'Strain Vs Length along WCL' (a) for circular heat source model (b) for triangular heat source model

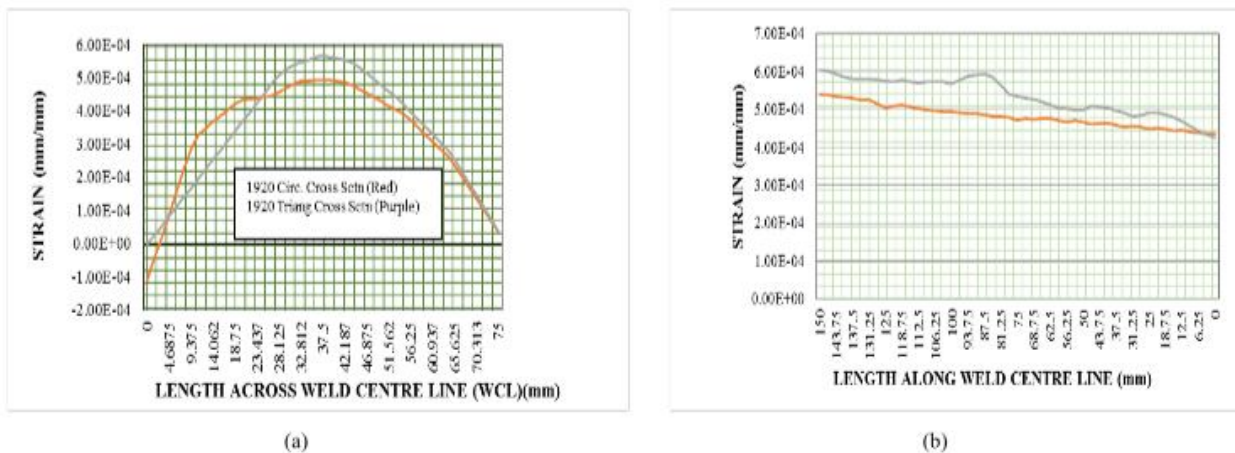


Fig. 7: Comparison of heat source types (a) across WCL (b) along WCL

IV. CONCLUSION

1. Uniformly distributed moving heat source models of circular and triangular shapes were developed and simulated with a welding speed of 20 mm/s. Each type of heat source was studied with three different amounts of heat fluxes. Elastic strain due to thermal loading was more with higher quantity of heat loads keeping other things constant.
2. Strain values for triangular heat sources were higher, more ordered and more symmetrical about the WCL (in the case of 'path' defined across WCL) compared to that of circular ones. The increase in bead width may be the reason for higher value of strains for triangular heat sources.
3. For strain values along the WCL, substantial gap exists between that of circular and triangular heat sources at the 150 mm end. But, the two curves meet at 50 mm end. This may be due to the increased rate of cooling from weld pool for the triangular heat source owing to the higher bead width.

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4. Because of all these findings and observations, it is concluded that the circular heat source is better than triangular one, mainly due to its low values of strain and hence weld distortions.

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