ISSN 2395-1621

Residual Stress Analysis & Optimization

#1R. R. Prabhu, #2V. R. Deulgaonkar

#1G. S. Moze College of Engineering, Pune, India
#2Mitramandal College of Engineering, Pune, India

ABSTRACT

The study of Residual stress analysis in Aluminium alloy plate T-joint welding and optimization of welding parameters to improve the weld life of the joint.Residual stresses and distortions on fillet welded joints are numerically evaluated by means of finite element method. The FE analysis allows highlighting and evaluating the stress field and its gradient around the fusion zone of welded joints, higher than any other located in the surrounding area. The practical validation of residual stress measurement through X-ray diffraction techniques (XRD) is to optimizing the welding parameter for controlling the residual stress.The main conclusion is the significant effect of varying the value of the conductivity on residual stresses.Several experimental destructive and non-destructive techniques for directly measuring residual stress have been developed. However, the application of these methods in practice is usually limited by either cost or accuracy. Numerical simulation based on finite element techniques, therefore, offers a comprehensive solution for the prediction of residual stress and strain as well as welding distortion in welded structures.Neglect of residual stresses created during welding processes can lead to stress corrosion cracking, distortion, fatigue cracking, premature failures in components, and instances of over design. This paper illustrates the importance of residual stress characterization in Aluminium alloy plate welding.

Keywords: Numerical techniques; Residual stresses; Welding; XRD; Thermo-mechanical analysis

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Aluminum alloy T-welded structure is increasinglyused in automotive, petroleum storage, railway vehicles, bridges and other fields. Thus, it is of great significance to achieve the high quality and high efficiency welding of aluminum alloy T-joint. However, compared to the simple joint, the welding defects are generated easily in the T-joint welding ofaluminum alloy due to the complexity of its physical process. Welding induced residual stress and distortion can greatly affect the final welding quality and service behavior of the welded structure. Therefore, it has important theoretical and practical value to study the welding residual stress analysis and deformation for deep understanding of welding process of complex joint.

In this study, a thermo-mechanical finite element model is developed to predict the temperature field and thermally induced residual stress and distortionin laser fillet welding of aluminum alloy T- joint and the characteristics of residual stress distribution and deformation are numerical analyzed, which will lay a foundation for process optimization of laser filler welding of aluminium alloy T-joint.

TABLE I. CHEMICAL COMPOSITIONS (WT. %) OF 6061-T6 ALUMINUM ALLOY AND ER5356 FILLER MATERIAL

material	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	oth
6061-T6	0.4-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.1
ER5356	0.25	0.4	0.1	0.13	4.9	0.065	0.1	0.11	0.1

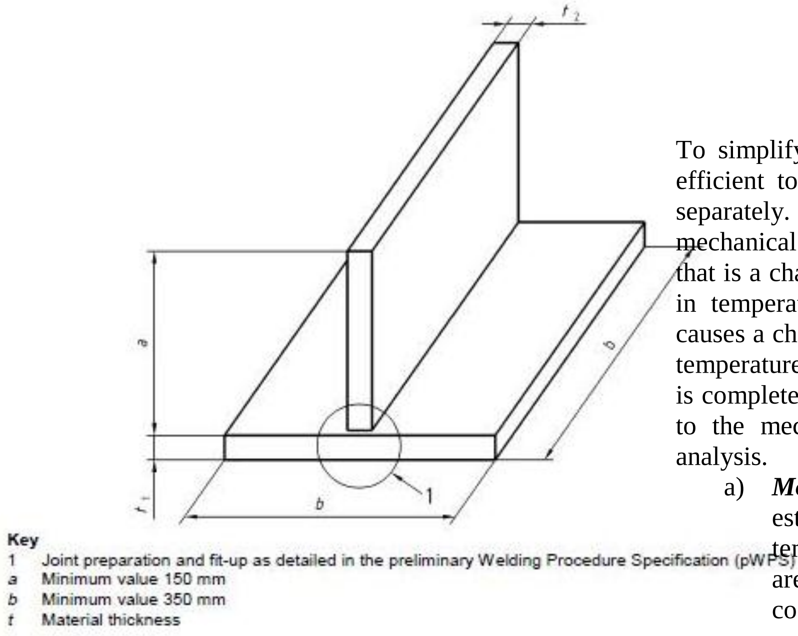


fig.1: Experimental set-up

1. Experimental validation

The base metal and the filler materials usedin the present study are 6061-T6 aluminum alloy and ER5356 aluminum alloy welding wire. The chemical composition shows in above table 1. The fillet welding was conducted on the aluminum alloy T-specimens, as shown in figure. The flange and webhad dimensions of 150 x 100x 2 (mm) and 150x 50x 2 (mm) respectively.In the hybrid welding process,laser was in front of arc and fillet welding torch wastiltled 30° with respect to the flange. Metal dropletwas transferred in short circuiting mode. Two welding passes were carried out separately with opposite welding direction.The initial welding parameters werewavelength 1.06 µm, focus diameter 0.6 mm, focus position 8 mm, laser-arc distance 1 mm, laser-arc angle 25°, wire diameter 1.2 mm, wire extension 12 mm,peak current 142 A, background current 26 A, averagevoltage 15 V and the wire feeding rate 3 m/min. After welding the static load F1N will be applied as shown in below figure 2. The X-Ray diffraction machine will generate the strain values and plot the results. Then we will calculate the Residual Stress values with the help of Strain. This will help to optimize the welding parameter to improve the weld life of the part.

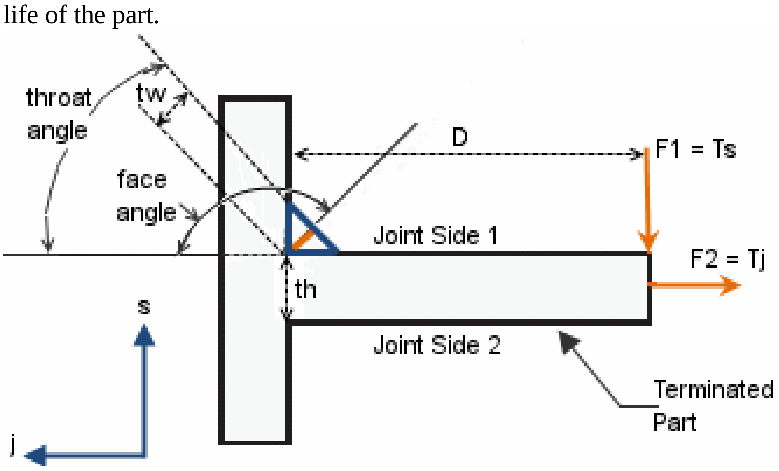
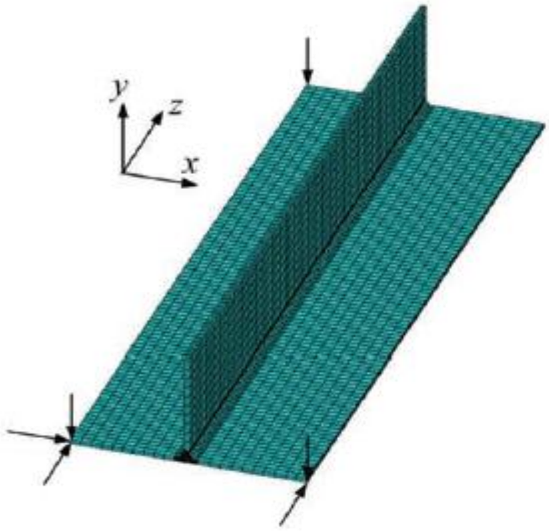


Fig. 2: Load carrying diagram

2. Finite element Approach

To simplify the welding simulation, it is computationally efficient to perform the thermal and mechanical analyses separately. Physically, it is assumed that changes in the mechanical state do no cause a change in the thermal state that is a change in stress and strain does not cause a change in temperature. However, a change in the thermal state causes a change in the mechanical state. Computation of the temperature history during welding and subsequent cooling is completed first, and then this temperature field is applied to the mechanical model to perform the residual stress analysis.

a) ***Model Mesh:***The finite element model was established on a scale of 1:1. Due to a great temperature drop from the weld to its surrounding area, finer grids were used in the former, while coarse grids were adopted in the latter; in other words, the overall performance of the transition is from dense to sparse. This approach of meshing division can not only ensure accuracy of the calculation, but also reduce the computing time. The finite element model geometry is divided into approx.15200 eight-nodehexahedral elements and approx. 18000 nodes.



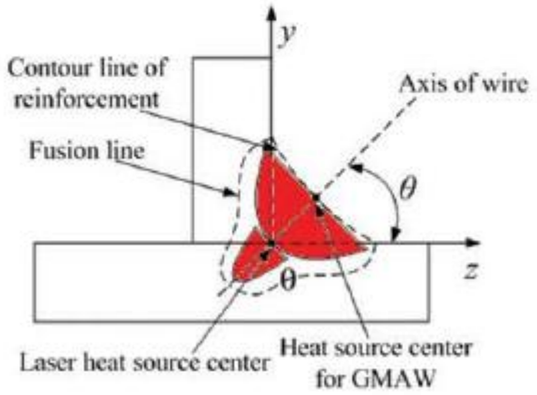


Fig. 3: Mesh model
Fig. 4: heat source model

b) ***Thermal analysis***: The material property parameters include mechanical properties and thermal physical parameters, which are functions of temperature. In the simulation, a piece-wise linearization form of 'temperature-corresponding performance' was established to provide computer program and was assigned to units as material properties in which the yield strength was obtained by high-temperature tensile test. Welding residual stress and deformation are produced due to the heterogeneous temperature field caused by localized heat input in the welding process.The heat conduction equation is as follows:

$$\rho c\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}(k\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(k\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(k\frac{\partial T}{\partial z})+Q$$

Where ρ is density, c is the specific heat capacity, k is the thermal conductivity coefficient, and Q is the heat flux. The FEA validation approach is in progress so the results are still waiting for the research

3. weld optimization with taguchi Approach

In order to find out the optimal combination of welding parameters, the Taguchi method was considered. The focus in the Taguchi method is to reduce the variation of system performance responses caused by uncertainty of crack deformation parameter values. Solutions, which are system designs represented through settings of the control parameters, are sought to minimize response variation in addition to the achievement of performance targets. The Taguchi method is built on the foundation of statistical DOE. In Taguchi's parameter design method, the mean performance and performance variation are evaluated through a product array experimental design constructed by control parameters. In this study, Different parameters like weld dimensions, arc speed, arc angle, voltage, current,welding output etc. were selected as the parameters with four levels. The welding output consisted of laser output and arc output estimated from torch voltage and current.

4. Conclusion

(1) A 3-D finite element model is developed toinvestigate the residual stress and deformation inlaser welding of aluminium alloy T-joint. The heat source model considers the influenceof joint form and welding torch inclination on heat flux distribution, and the calculated weld geometryand sizes agree well with the experimental data.

(2) High tensile residual stress in the welding direction is located in the weld zone and itsvicinity,and its peak value is lower than the yield strength ofbase metal. The corresponding von-Mises equivalentstress has the similar distribution feature with a peakvalue slightly larger than the yield strength of aluminium alloy. Besides, there exists a wider area withhigh residual stress on the wed surface at the pass I side.

(3) Under the welding condition of this study, asmall welding angular distortion emerges near thefront-end of T-specimens, and relatively large onestake place in the middle and rear parts of weldment.With the distance away from the weldment front-end,the transverse shrinkages on both upper and lower surface of the flange firstly increase and then remain basically stable and their difference has the similardistribution.

(4) The developed thermo-mechanical finite element model could be further used to optimize theprocess parameters in laser weldingof T-joint.

5. *References*

1) P. Martinson, S. Daneshpour, M. Koçak, S. Riekehr, P. Staron ; 'Residual stress analysis of laser spot welding of steel sheets'; Materials and Design 30 (2009) 3351–3359
2) Tso-Liang Teng, Peng-Hsiang Chang, Wen-Cheng Tseng, "Effect of welding sequences on residual stresses" Journal of Computers and Structures 81 (2003) 273–286
3) Yusuf Ozcatalbasa,, H. Ibrahim Vural b," Determination of optimum welding sequence and distortion forces in steel lattice beams", Journal of Materials Processing Technology 209 (2009) 599–604
4) Liam Gannon , Yi Liu , Neil Pegg , Malcolm Smith, "Effect of welding sequence on residual stress and distortion in flat-bar stiffened plates", Marine Structures 23 (2010) 385–404
5) Robert Stone, 'Processing Effects on Residual Stress

