Analysis of Dissimilar Metal Welding of 1020 Mild Steel and 304 Stainless Steel

Prasath. P [1], R.Prabu [2]
[1]M.E Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Mahendra Engineering College, Namakkal, India

Abstract— Joining of dissimilar metals has found its use extensively in power generation, electronic, nuclear reactors, petrochemical and chemical industries mainly to get tailor-made properties in a component and reduction in weight. However efficient welding of dissimilar metals has posed a major challenge due to difference in thermo- mechanical and chemical properties of the materials to be joined under a common welding condition. This causes a steep gradient of the thermo-mechanical properties along the weld. A variety of problems come up in dissimilar welding like cracking, large weld residual stresses, migration of atoms during welding causing stress concentration on one side of the weld, compressive and tensile thermal stresses, stress corrosion cracking, etc. Weld residual stress and thermal stress have been analysed for dissimilar metal welding of 304 stainless steel to 1020 mild steel taking 302 stainless steel as the filler metal. Similarly taking strain developed as an index the susceptibility of the welded joint to stress corrosion cracking have been studied. It is found that when the filler metal is replaced by Inconel 625 significant improvement is obtained in the welded joint in terms of reduction in stress developed and stress corrosion cracking. Also the problem of carbon migration is eliminated by the use of Inconel 625 as a weld filler metal due to the resistance of nickel-based alloys to any carbon diffusion through them.

Keywords: Dissimilar welding; Stress corrosion cracking; Thermal stress; Residual stress

I. INTRODUCTION

Joining of dissimilar metals has found its use extensively in power generation, electronic, nuclear reactors, petrochemical and chemical industries mainly to get tailor-made properties in a component and reduction in weight. However efficient welding of dissimilar metals has posed a major challenge due to difference in thermo- mechanical and chemical properties of the materials to be joined under a common welding condition. This causes a steep gradient of the thermo-mechanical properties along the weld.

A. Objectives of the Work

The aim of the present work is to simulate a welding joint between 304 stainless steel and 1020 mild steel using 302 stainless steel as the weld metal and analyse the joint for thermal and residual stresses developed in them. Then the weld joint is to be analysed for residual stresses superimposed on thermal stresses.

After the results are obtained the aim is to suggest improvement in the joint by minimizing the stresses and reducing chances of stress corrosion cracking by a change in the weld metal.

II. PROBLEM FORMULATION

The aim of this research project has been to study dissimilar metal joint using a filler metal. Dissimilar welding is used to fabricate the pressure vessels and piping in power plant but failures occur frequently due to:

- Thermal Stress which is generated due to difference in co-efficient of thermal expansion.
- Difference mechanical properties, the local heating and subsequent cooling results in large residual stress.

This thermal stress superimposed on weld residual stress and operating tensile stress promotes brittle fracture, increase susceptibility to fatigue and stress corrosion cracking during its service life. The domain of this research covers cause, effect and elimination of problems caused due to stresses, carbon migration and stress corrosion cracking.

The metals to be welded are 304 stainless steel and 1020 plain carbon steel and the filler metal used is 302 Stainless steel whose properties has been taken similar to 304 stainless steel for the purpose of analysis.

The welding process has been simulated using finite element analysis. The software used for this analysis is ANSYS 13.0 using its Workbench module. It is because Workbench is a very powerful tool to simulate a welding joint and infer the results. Also it has a reputation of coming up with results very close to the practical values. The input parameters are easily fed and boundary conditions, simulation programmers and geometrical modelling is very convenient due to its user-friendly graphic interface.

III. METHODOLOGY

The results that are obtained after the weld simulation can be taken considering two cases. In the first case 302 stainless steel has been taken as the weld filler metal whose properties are taken the same as 304 stainless steel which is one of the parent metals. So the results inferred from all the three models viz. A, B and C which will be taken one by one.

IV. RESULTS AND DISCUSSION

Models	Nature of Stress	Case I: 302 Stainless Steel	Case II: Inconel 625
A	Tensile	118 MPa	71 MPa
	Compressive	112 MPa	101 MPa
B	Tensile	92 MPa	63 MPa
	Compressive	107 MPa	91 MPa
C	Tensile	127 MPa	82 MPa
	Compressive	140 MPa	112 MPa

Table 1: From the above table some of the results that can be inferred are mentioned

- The maximum value of superimposed stress i.e. Model C is greater than the maximum values of both the thermal stress and weld residual stress in all thecases.
- This explains the reason why it is necessary to consider the weld residual stresswhileexposingaweldedparttocyclicthermalstresses. Itwillbean
- Underestimation of the maximum working stress and result finally into an unsafe joint.
- The values of stress both either of compressive or of tensile nature arefound to be reduced significantly when the weld metal is changed from 302 stainless steel to Inconel625.

From Fig. The strain developed in the weld metal and the HAZ of parent metals is found to have a maximum value of 0.0335 m/m in the weld metal zone. After Inconel 625 is used as the weld metal, the highest value of strain is reduced to 0.0276 m/m as shown in Fig.

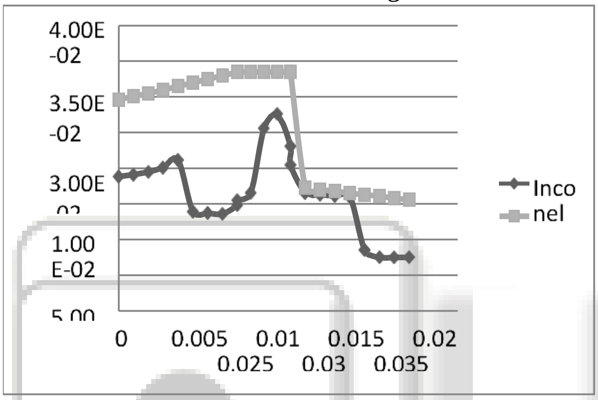

Fig. 1: Comparison of strain values between case I and case II

Fig. shows that the value of strain induced in Inconel weld metal is significantly lower than that induced in 302 stainless steel weld metal throughout the path line P. The reduction in maximum strain is 17%.

The suggested model's trustworthiness was evaluated using Analysis of Variance (ANOVA). The mathematical models establish to be significant with P-values of 0.0372, 0.0180 and 0.0376 for tensile, flexural and compression strength respectively. This shows that the model is significant fit to the experimental value and the lack of fit is not significant. From the variance analysis, R- squared value for tensile, flexural and compression was found out to be 0.8418, 0.8752 and 0.8412 respectively. Results showed that the quadratic models can be used to predict the results with 95% confidence level. The optimum weight percentage values of first five rank of tensile, flexural and Compressive strength.

Number	Groundnut shell powder (wt %)	Roselle powder (wt %)	Pineapple leaf fiber (wt %)	Tensile	Flexural	Compression	Desirability
1	2	2	5	15.71456	9.13861	13.69953	0.606388
2	2	1.31	5	15.42825	9.403322	13.4015	0.605223
3	2	1.34	5	15.61374	9.208936	13.58781	0.603866
4	2	2	4.96	15.6189	9.176595	13.60423	0.601407
5	2	1.35	4.98	15.64973	9.150833	13.62417	0.601029

Table 2: Optimum weight percentage of Pineapple leaf fiber, Roselle powder and Groundnut shell powder.

V. CONCLUSIONS

This research presents a study of thermal stress in a dissimilar welding joint between 1020 mild steel and 304 stainless steel, and the effect of weld residual stress on the thermal stress has been discussed. From the results above we arrive at the following conclusions:

- Welding which is a significant cause of residual stress generates a large amount of residual stress in the weld metal and HAZ of the parent metals, which increases the final thermal stress and should be considered while determining the strength of the joint.
- If the residual stresses are not considered, due to lower co-efficient of thermal expansion, 1020 mild steel develops tensile thermal stress while compressive thermal stress is generated in 304 stainless steel during operating conditions.
- The peak of the stress is reached in the weld interface of 1020 mild steel and weld metal near the mild steel side, which becomes the highest risk zone.
- If A302 steel is replaced by Inconel 625 then the developed peak stress falls by 15-30%, and hence the welded joint becomes safer.
- Inconel 625 is recommended to be used as the weld metal, because it also reduces strain which is an index of stress corrosion cracking as result of which the chances of stress corrosion cracking are reduced by17%.
- Also by introducing a weld metal which is a nickel-based alloy decreases the carbon activity gradient due to its low carbon diffusivity. Thus there is no abrupt change in material composition and hence a steep stress gradient is avoided.
- A future work that can be undertaken from this research can be:
- Superimposing fatigue loads on weld parts.
- Introduction of a new weld metal that can still improve the results Inconel 625 for dissimilar steels.

References

[1] Chengwu Yao, Binshi Xu, Xiancheng Zhang, Jian, Huang, Jun Fu and Yixiong Wu "Interface microstructure and mechanical properties of laser welding copper-steel dissimilar joint" Optics and Lasers in Engineering, Vol. 47, 2009, PP807–814.

[2] Wen-chun Jiang and Xue-wei Guan "A study of the residual stress and deformation in the welding between half-pipe jacket and shell" Materials and Design, Vol. 43, 2013, PP213-219.

[3] Man Gyun Na, Jin Weon Kim and Dong Hyuk Lim "Prediction of Residual Stress for dissimilar metals welding at nuclear plants using Fuzzy Neural NetworkModels"NuclearEngineeringandTechnology, Vol.39, 2007, PP337- 348.

[4] M.M.A. Khan, L. Romoli, M. Fiaschi, G. Dini and F. Sarri "Laser beam welding of dissimilar stainless steels in a fillet joint configuration" Journal of Materials Processing Technology, Vol. 212, 2012, PP856-867.