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

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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.

Keywords : Dissimilar Welding, Stress Corrosion Cracking, Thermal Stress, Residual Stress.

I. INTRODUCTION

Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement for bolted and riveted joints. It is also used as a repair medium e.g. to reunite a metal at a crack or to build up a small part that has broken off such as a gear tooth or to repair a worn surface such as a bearing surface.

Advance welding techniques like Plasma Arc Welding, Laser Beam Welding, Electron Beam Welding, Electro-Magnetic Pulse Welding, Ultrasonic Welding, etc. are now being extensively used in electronic and high precision industrial applications.

Metallurgy of a Welded Joint

Metal is heated over the range of temperature up to fusion and followed by cooling ambient temperature. Due to differential heating, the material away from the weld bead will be hot but as the weld bead is approached progressively higher temperatures are obtained, resulting in a complex micro structure. The subsequent heating and cooling results in setting up internal stresses and plastic strain in the weld.

Depending upon the slope of temperature gradient three distinct zones as shown in Fig. 2 can be identified in welded joint which are:

1. Base metal
2. Heat Affected Zone (HAZ)
3. Weld metal

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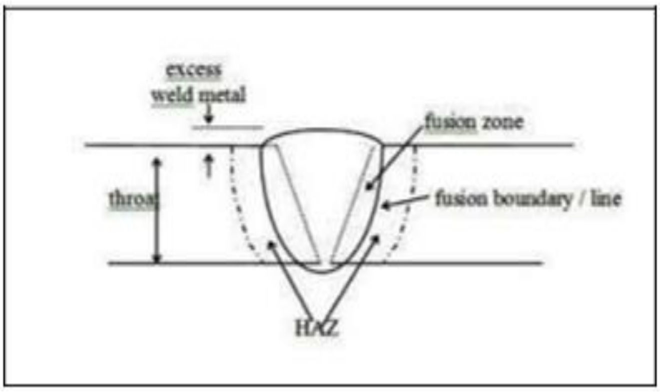

Fig .1 Zones in a welding joint

A joint produced without a filler metal is called autogenous and its weld zone is composed of re-solidified base metal. A joint made with a filler metal is called weld metal. Since central portion of the weld bead will be cooled slowly, long columnar grains will developed and in the out ward direction grains will become finer and finer with distance.

So the ductility and toughness decreases away from the weld bead. However strength increases with the distance from the weld bead. The original structure in steels consisting of ferrite and pearlite is changed to alpha iron. The weld metal in the molten state has a good tendency to dissolve gases which come into contact with it like oxygen, nitrogen and hydrogen.

So during solidification, a portion of these gases get trapped into the bead called porosity. Porosity is responsible for decrease in the strength of the weld joint. Cooling rates can be controlled by preheating of the base metal welding interface before welding.

II. METHODS AND MATERIAL

2.1 Input parameters

The input parameters in this analysis are the thermo-mechanical properties of the materials getting into the welding joint. All the properties used in this analysis are temperature dependent.

Composition

The composition of the metals used in this simulation of welding joint is given below:

304 Stainless Steel

The composition of 304 stainless steel is shown in table 1. Chromium along with nickel is the principal alloying elements. The mechanical properties of 304 stainless steel that have been used in this analysis have been given in table 1.

Table 1. Mechanical Properties of 304 Stainless Steel

Variation of properties with temperature	Density (kg/m3) * 103	Poisson's Ratio	Modulus of Elasticity (Pa) * 1011	Yield Strength (Pa) * 108
0 °C	7.9	0.295	2	2.7
200 °C	7.78	0.3	1.9	1.9
400 °C	7.67	0.31	1.8	1.6
600 °C	7.55	0.315	1.7	1.2
800 °C	7.43	0.32	1.5	0.8
1000 °C	7.32	0.327	1	0.6
1200 °C	7.2	0.335	0.h4	0.55
1400 °C	7.12	0.341	0.5	0.5
1600 °C	7.04	0.346	0.5	0.5

III. RESULTS AND DISCUSSION

1.1. Analysis of 302 Stainless steel

ANALYSIS- 302 Stainless Steel as Weld Filler Metal

Thermal stress has developed inside the welded part as both of its ends across the weld have been fixed against any kind of motion by setting up in nodal displacement in all directions as zero. This is the boundary conditions used in model A

Considering Model A, where only the part has been subjected to thermal stresses the results are explained in the figures below. The figures below show the stress contour near the weld metal and the graphs which are path results along the line of length 30 mm at the centre of the filler metal and at a distance of 5 mm from the weld root. The line is called line P in the subsequent paragraphs.

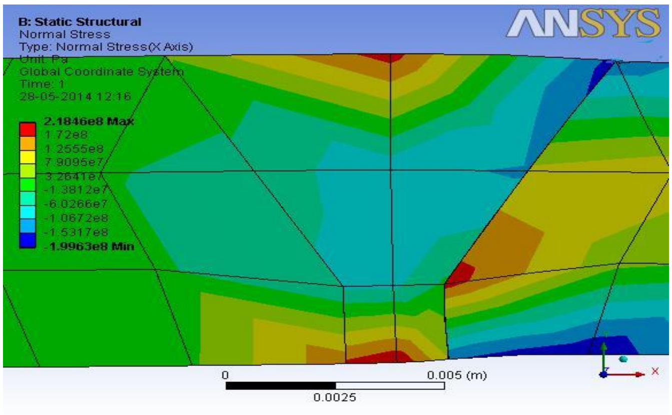

Fig .2 Normal stress contour of Model A

The normal stress varies from 218 MPa tensile to 199 MPa compressive. The peak of the tensile lies along the centreline of the weld metal. However peak of the compressive stress lies in the weld interface of weld filler metal and 1020 mild steel.

This is due to larger coefficient of thermal expansion of 304 stainless steel. The stress gradient in the filler metal is very steep due to rapid change in the direction of stresses.

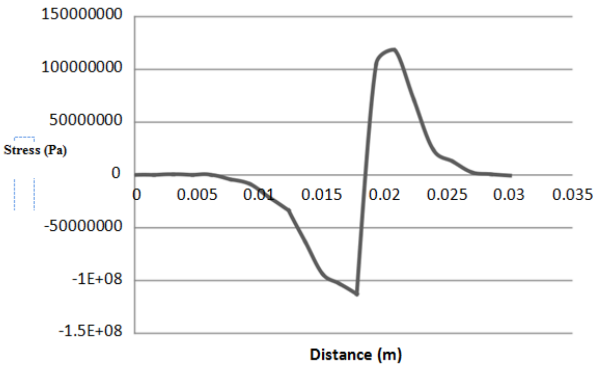

Fig .3*Normal stress distribution along line P*

Table 1 *Comparison of normal stress values in the two cases of welding*

Models	Nature of Stress	Case I: 302 Stainless Steel
A	Tensile	118 Mpa
	Compressive	112 Mpa
B	Tensile	92 Mpa
	Compressive	107 Mpa
C	Tensile	127 Mpa
	Compressive	140 Mpa

IV.CONCLUSION

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

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.

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.

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