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Analysis of Welding Joint of 304 Stainless Steel And 1020 Mild Steel

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ABSTRACT- Joining of dissimilar metals has discovered its utilization widely in power age, electronic, atomic reactors, petrochemical and substance ventures mostly to get customized properties in a part and decrease in weight. Anyway productive welding of divergent metals has represented a significant test because of contrast in thermo-mechanical and synthetic properties of the materials to be joined under a typical welding condition. This causes a precarious inclination of the thermo- mechanical properties along the weld. An assortment of issues come up in different welding like breaking, enormous weld leftover anxieties, relocation of particles during welding causing pressure focus on one side of the weld, compressive and tractable warm burdens, stress erosion splitting, and so forth. Weld remaining pressure and warm pressure have been broke down for different metal welding of 304 treated steel to 1020 mellow steel accepting 302 tempered steel as the filler metal. Essentially taking strain created as a record the powerlessness of the welded joint to pressure consumption breaking have been contemplated. It is discovered that when the filler metal is supplanted by Inconel 625 critical improvement is gotten in the welded joint as far as decrease in pressure created and stress consumption breaking. Additionally the issue of carbon movement is wiped out by the utilization of Inconel 625 as a weld filler metal because of the obstruction of nickel-based amalgams to any carbon dissemination through them.

Keywords- dissimilar welding; stress corrosion cracking; thermal stress; residual stress.

1. INTRODUCTION

Welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. The materials to be joined may be similar or dissimilar to each other. The heat required for the fusion of the material may be obtained by burning of gas or by an electric arc. The latter method is more extensively used because of greater welding speed.

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 strategies like Plasma Arc Welding, Laser Beam Welding, Electron Beam Welding, Electro-Magnetic Pulse Welding, Ultrasonic Welding, and so forth are presently being widely utilized in electronic and high exactness mechanical applications.

1.1 Fusion Welding

If there should be an occurrence of combination welding the parts to be joined are held in position while the liquid metal is provided to the joint. The liquid metal may originate from the parts themselves for example parent metal or filler metal which ordinarily has the equivalent or almost comparable arrangement as that of the parent metal. Subsequently, when the liquid metal sets or circuits, the joint is shaped.. The fusion welding, according to the method of heat generated, may be classified as:

1. Thermite Welding
2. Gas Welding
3. Electric Arc Welding

1.2 Forge Welding

In forge welding, the parts to be joined are first heated to a proper temperature in a furnace and then hammered. Electric Resistance Welding is an example of forge welding. The principle of applying heat and pressure, either sequentially or simultaneously is widely used in the processes known as Spot, Seam, Projection, Upset and Flash Welding.

1.3 Metallurgy of a Welded Joint

Metal is warmed over the scope of temperature up to combination and followed by cooling encompassing temperature. Because of differential warming, the material away from the weld dot will be hot however as the weld globule is moved toward logically higher temperatures are gotten, bringing about a complex smaller scale structure. The ensuing warming and cooling brings about setting up inward burdens and plastic strain in the weld. Contingent on the incline of temperature angle following unmistakable zones as appeared in 1.welded joint 2.Base metal 3.Heat Affected Zone (HAZ) 4.Weld metalA joint created without a filler metal is called autogenous and its weld zone is made out of re-hardened base metal. A joint made with a filler metal is called weld metal. Since focal segment of the weld globule will be cooled gradually, long columnar grains will created and in the out ward bearing grains will get better and better with separation.So the pliability and strength diminishes away from the weld dab. Anyway quality increases with the good ways from the weld globule. The first structure in prepares comprising of ferrite and pearlite is changed to alpha iron.

1.4 Residual Stress

Lingering pressure is a pressure or pressure that exists in a material with no outer burden being applied, and the leftover worries in a segment or structure are brought about by inconsistent inner perpetual strains. Welding, which is one of the hugest reason for lingering pressure, ordinarily creates huge malleable anxieties, the greatest estimation of which is around equivalent to the yield quality of materials that are joined by lower compressive remaining worries in a part. The lingering worry of welding can altogether disable the presentation and dependability of welded structures. Two of the serious issues of any welding procedure are remaining pressure and contortion. Lingering pressure is essentially brought about by the compressive yielding that happens around the liquid zone as the material warms and extends during welding. At the point when the weld metal cools it contracts which causes a malleable leftover pressure, especially in the longitudinal course. Subsequent to welding a leftover elastic pressure stays over the weld centerline and causes an adjusting compressive pressure further from the weld zone. The elastic remaining weight on the weld line lessens the weakness quality and the durability, especially when joined with any indents or deformities related with the weld dot. To alleviate a portion of the lingering stresses brought about by the welding procedure, the structure misshapes, causing mutilation. There are a few methods of bending, however the one that is generally normal, especially in slim welded structures is clasping contortion, which is brought about by the compressive worry in the parent material.

1.5 Carbon Migration

Carbon relocation over the weld interface is viewed as a noteworthy factor in the "life" of a progress joint, since time subordinate property changes happen in the districts where carbon development occurs. The carbon movement causes loss of solidarity in the ferrite material contiguous the weld interface and an expansion in hardness (and presumably additionally in quality with an adjustment in the modulus of flexibility conceivable) in the filler metal (carbon-advanced zone). These zones are promptly nearby each other and give a huge change in properties over a tight district. Be that as it may, a few speculations can be expressed concerning carbon movement in a welded joint: Carbon relocation is legitimately subject to time, temperature and carbon substance of the base metals. Carbon diffuses five to multiple times quicker in ferrite than in austenite at a similar temperature. Warm anxieties following up on the weld interface upgrade carbon dispersion, in this manner the metals having bigger co- effective of warm extension like tempered steel willencounter progressively fast development of the carbon drained zone. The carbon drained zone displays low pliable and creep quality and decreased recrystallization temperature. In any case, the properties are not explicitly defined. The carbon-drained delicate zone is controlled by the harder and more grounded carbon-enhanced zone quickly neighboring during warm cycling. The advancement of an intricate pressure state including shear along the interface, in this way restraining uniform strain and will in general make misshapenness in the delicate zone.

1.6 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.

1.7 Composition

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

1. 304 Stainless Steel-The composition of 304 stainless steel is shown in table 1.

Table 1: *Composition of 304 Stainless Steel*

Fe	C	Si	Mn	S	P	Cr	Ni
71.433	0.058	0.35	1.32	0.007	0.032	18.52	8.28

2. 1020 Mild Steel-In plain carbon steel, carbon is the principle alloying element. Composition of 1020 mild steel is shown in table 2.

Table 2: *Composition of 1020 Mild Steel*

Fe	C	Mn	P	S
99.31	0.2	0.4	0.04	0.05

3. 302 Stainless Steel-The composition of 302 stainless steel is almost similar to that of 304 stainless steel and the composition has been taken same for the purpose of analysis. 302 stainless steel has been used as the weld metal in the first analysis and subsequently replaced by Inconel 625 in the second analysis.

4. Inconel 625-Inconel 625 is a non-magnetic, corrosion and oxidation resistant, nickel-based alloy. This alloy has high fatigue strength, exhibits excellent resistance to stress corrosion cracking. Nickel and Chromium provide stabilizing effect from oxidizing environments. The nickel based alloys like Inconel also resist problems caused due to carbon migration. Pitting and crevice corrosion are prevented by Molybdenum stabilizes the alloy against sensitization during welding. Due to these properties, Inconel is widely used in dissimilar welding. The composition of Income 625 which has been used in this analysis has been shown in Table 3.

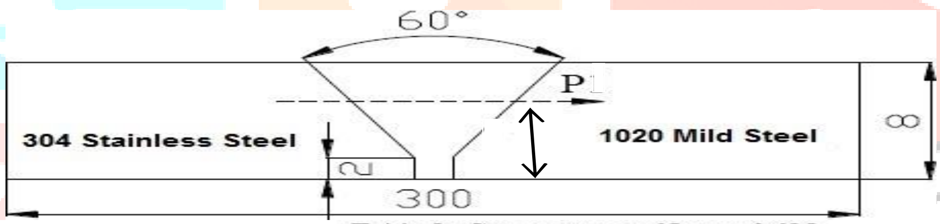

Table 3: *Composition of Inconel 625*

Ni	Cr	Mo	Fe	Mn	C	Cu	Si
61.5	23.0	8.0	6.5	0.25	0.08	0.2	0.25

1.8 Mechanical Properties

The mechanical properties that have been chosen for the purpose of analysis are density, Poisson's ratio, modulus of elasticity and yield strength. The mechanical and thermal properties of the materials used in this analysis have been extrapolated from the graph published by Jiang and Guan [2] in their study on residual stress in a welded joint.1.304 Stainless Steel-The mechanical properties of 304 stainless steel that have been used in this analysis have been given in below table.

1.9 Thermal Properties

The thermal properties of the materials that were necessary for this analysis were melting point, thermal conductivity, specific heat and co-efficient of thermal expansion.

1. 304 Stainless Steel-The thermal properties of 304 stainless steel that have been used in this analysis have been given in table 7. The melting point of 304 stainless steel is taken as 1427ºC.

Table 7: *Thermal Properties of 304 Stainless Steel*

Variation of properties with temperature	Thermal Conductivity (W/m^{0}C)	Specific Heat (J/Kg^{0}C)	Thermal Expansion Coefficient ($^0C^{-1}$) * 10^{-5}
0 ^{0}C	15	501	1.8
200 ^{0}C	18	530	1.9
400 ^{0}C	21	580	2.0
600 ^{0}C	26	620	2.05
800 ^{0}C	34	650	2.1
1000 ^{0}C	36	680	2.15
1200 ^{0}C	36	690	2.2
1400 ^{0}C	36.1	700	2.25
1600 ^{0}C	36.1	705	2.29

2. 1020 Mild Steel: The thermal properties of 1020mild steel that have been used in this analysis have been given in table 8. The melting point of 1020 Mild Steel has been taken as 1515^{O}C.

3. Inconel 625: The thermal properties of Inconel that have been used in this analysis have been given in table 9. The melting point of Inconel 625 is taken as 1404ºC. For cooling of the parts after the welding is over the convective heat transfer co-efficient has been taken as 15 W/m^{2O}C. The ambient air temperature has been taken equal to 27^{O}C.

1.10 Finite Element Analysis

Finite element analysis has been done in the case of this welding to predict stresses, susceptibility to stress corrosion cracking and the location where failure is most likely to occur. Some of the other methods of analysis were not used due to the following given reasons:

1. Accurate measurement of stresses is very difficult using conventional testing techniques.

2. X-ray method can be used for analysis but it is capable of giving only surface stresses.

3. Neutron Diffraction Method can give the through thickness stress but not the stress distribution.

So, this is the reason why finite element analysis has been used because it is capable of predicting highest risk zone and the stress distribution throughout the parent metals, heat affected zone and the weld metal.

2 Problem Statement

The problems which have been analysed in this research are three. First aspect is reduction in stresses developed, second is minimization of carbon migration and the third is decreasing the susceptibility to Stress Corrosion Cracking. Considering the above objectives two metal plates, equal in size with a dimension of 300 x 150 x 8 mm are butt welded with filler between them. The parent metal plates are of304 stainless steel and 1020 mild steel material. The welding arrangement .The welding simulation has been done firstly by studying the welding temperature field followed by incrementally applying the temperature results to simulate the weld. After the welding process is over residual stresses get developed inside the welded parts. This welded part when kept under operating conditions which are taken as high as 600^{O}C, results in development of thermal stresses inside the welded part.

The analysis has been done considering three models. Model A is analysed only for thermal stresses and the results are inferred. Model B is analysed only for residual stresses and the results are inferred. Model C is analysed for thermal stresses superimposed with residual stresses. That means mathematically-Model A + Model B = Model C.And all the results are taken along the line of length 30mm which lies 5mm above the weld root. Now in the second case, the weld metal A302 Stainless Steel is changed to Inconel 625 and then again the thermal, residual and thermal stress superimposed on residual stresses are calculated.

3. Assumptions and Conditions

1. Heat flow inside the welded parts is assumed to be by conduction using the fundamental equation of conduction as given in equation (i);

$$k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+Q_{int}=\rho c\frac{\partial T}{\partial t} \qquad (i)$$

where k is the thermal conductivity, T is the transient temperature field which is a function of time t and Cartesian co-ordinates (x, y, z) with Q as internal heat source rate, ρ as density and c as specific heat capacity.

2. Heat loss from the welded part to the ambient air is assumed to occur by convection following the governing equation of

cooling(ii);

$$= -hA(Ts - Ta) \qquad \text{(ii)}$$

, where Qc is the rate of cooling, h is the convection co- efficient taken here 15 W/m2^{O}C for all the cases, Ts is the surface temperature and Ta is the temperature of ambient air taken 27^{O}C.

3. Thermal stress is calculated from the start up at 27^{O}C to 600^{O}C. Thermal stress simulated in the welding using its global modelling matrix reduced to give thermal stress at any two nodes is given in equation (iii);

$$\begin{bmatrix} -E\alpha T \\ -E\alpha T \\ 0 \end{bmatrix} = \frac{AE}{L}\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix} \qquad \text{(iii)}$$

, where E is the Young's Modulus of Elasticity, T is the transient temperature field, α is the co-efficient of thermal expansion, A is the cross sectional area, L is the length of the section and (d1, d2, d3) are the nodal displacements caused due to temperature load at any three nodes.

However displacement boundary condition d1=0 is taken to avoid rank deficiency. In this case of modelling the welded part is assumed to be fixed normal to the weld.

4. For residual stress analysis the elements are activated and deactivated by element birth and death technique. This means that after a weld pass is over on an element, after solidification the element gets structurally activated.The material properties are set to zero for the deactivated elements. The welding has been carried out at 1500^{O}C. Therefore, the initial condition for an element after reactivation is its melting point. When an element gets reactivated i.e. born then its mass, element load, etc. are set to their original values.

4. Results and Discussion

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.This examination presents an investigation of warm worry in a unique welding joint between 1020 mellow steel and 304 hardened steel, and the impact of weld lingering weight on the warm pressure has been talked about. From the outcomes above we come to the accompanying end results:

1. Welding which is a critical reason for lingering pressure creates a lot of remaining worry in the weld metal and HAZ of the parent metals, which expands the last warm pressure and ought to be thought of while deciding the quality of the joint.

2. If the leftover anxieties are not thought of, because of lower co-proficient of warm extension, 1020 gentle steel creates ductile warm pressure while compressive warm pressure is produced in 304 treated steel during working conditions.

3. The pinnacle of the pressure is reached in the weld interface of 1020 gentle steel and weld metal close to the mellow steel side, which turns into the most noteworthy hazard zone.

4. If A302 steel is supplanted by Inconel 625 then the created top pressure falls by 15-30%, and consequently the welded joint gets more secure.

5. Inconel 625 is prescribed to be utilized as the weld metal, since it additionally lessens strain which is a list of pressure consumption splitting as aftereffect of which the odds of stress erosion breaking are diminished by 17%.

6. Also by presenting a weld metal which is a nickel-based combination diminishes the carbon action angle because of its low carbon diffusivity. In this way there is no unexpected change in material arrangement and consequently a precarious pressure slope is stayed away from.

Case I 302 Stainless Steel as Weld Filler Metal

The normal stress varies from 218Pa tensile to 199Mpa compressive. The peak of the tensile lies along the centerline of the weld metal, however peak of the compressive stress lies in the weld interface of weld filler metaland 1020 mild steel.

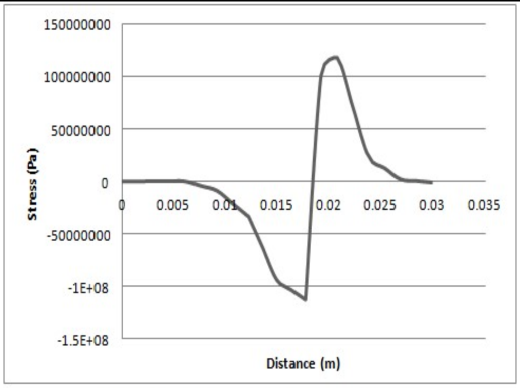

Fig. 7: *Normal stress distribution along line P*

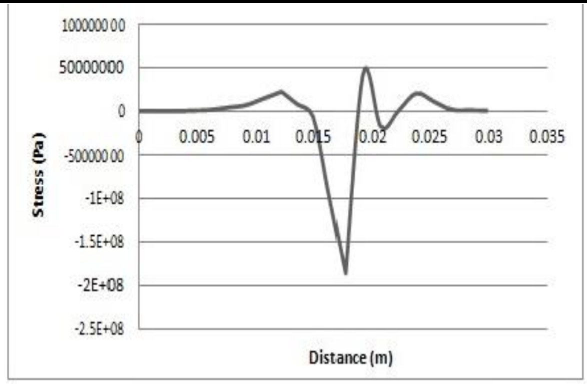

Fig. 9: *Shear stress distribution along line P*

The normal stress along the line P in both directions is found in the weld interface near the 1020 mild steel. The maximum stress is found to be 118 Mpa in the tensile direction.

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