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Numerical Analysis on the effect of welding parameters in TIG welding for INCONEL 625 alloy

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Abstract:

At present scenario, INCONEL alloy 625 becomes widely used material in aero industry due to its High tensile, creep, and rupture strength, outstanding fatigue and thermal-fatigue strength, oxidation resistance, and excellent weld ability properties. In present work, the plates of 50mm×50mm×3mm are modelled and assembled for v-butt joint using solid works. This model is imported in the FEA software (ANSYS) to carry out the transient thermal analysis. The analysis is carried out with different combinations of welding parameters such as voltage, current, velocity, speed and melting efficiency. From the analysis result, the temperature distribution at various locations around the weld bead is evaluated. From structural analysis result, the distortion of work piece due to the thermal effect is analysed.

Keywords- **Transient thermal analysis, Voltage, Current, Steady state thermal analysis.**

I. INTRODUCTION

There are number of welding methods available for welding materials such as shielded metal arc welding, Gas metal arc welding, Flux cored arc welding, submerged arc welding, electro slag welding, electron beam welding, and Gas Tungsten arc welding methods. The choice of the welding depends on several factors; primarily among them are the compositional range of the material to be welded, the thickness of the base materials and type of current. Tungsten inert gas (TIG) welding is the most popular gas shielding arc welding process used in many industrial fields. Other arc welding processes have limited quality when they are compared to TIG welding processes. However, TIG welding also needs improvements regarding spatter reduction and weld quality of the bead. Shielding gas in TIG welding is desirable for protection of atmospheric contamination. TIG welding process has the possibility of becoming a new welding process giving high quality and provides relatively pollution free.

TIG welding was developed during 1940.TIG's development came about to help in the welding of difficult types of material, example aluminum and magnesium. The use of TIG steels.

Arc welding is a technique to melt and join different materials that is widely used in the industry. The gas tungsten arc welding (GTAW) process is sometimes referred to as TIG, or heliarc. The term TIG is short for tungsten inert gas welding. Under the correct welding conditions, the tungsten electrode does not melt and is considered to be non consumable. To make a weld, either the edges of the metal must melt and flow together by themselves or filler metal must be added directly into the molten pool. Filler metal is added by dipping the end of a filler rod into the leading edge of the molten weld pool. Most metals oxidize rapidly in their molten state.

To prevent oxidation from occurring, an inert gas flows out of the welding torch, surrounding the hot tungsten and molten weld metal shielding it from atmospheric oxygen. GTA welding is efficient for welding metals ranging from sheet metal up to 1/4 in.

MATERIAL USED FOR PRESENT WORK

At present scenario, INCONEL alloy 625 becomes widely used material in aero industry due to its High tensile, creep, and rupture strength, outstanding fatigue and thermal-fatigue strength, oxidation resistance, and excellent weldability properties. Service temperatures range from cryogenic to 1800alloy 625 is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus precipitation hardening treatments are not required.

Table 1: Material Properties used for Analysis

Temperature (K)	Thermal conductivity (W/mK)	Density (kg/m3)	Specific heat (J/kgK)
273	9.64	8446	405.5
293	9.8991	8440	410.36
323	10.292	8430.7	417.65
373	10.958	8414.6	429.8
423	11.637	8398.3	441.95
473	12.33	8381.8	454.1
523	13.038	8365.3	466.25
573	13.758	8348.7	478.4
623	14.498	8331.9	490.55
673	15.242	8314.6	502.7
723	16.004	8296.9	514.85
773	16.78	8278.6	527
823	17.57	8259.9	539.15
873	18.374	8211.3	551.3
923	19.191	8162.7	563.45
973	20.022	8111.9	575.6
1023	20.868	8083.8	587.75
1073	21.726		599.9
1123	22.599		612.05
1173	23.486		624.2
1223	24.386		636.35
1273	25.3		648.5
1323	26.228		660.65
1373	27.17		672.8
1423	28.125		684.95
1473	29.095		697.1
1523	30.078		709.25

This combination of elements also is responsible for superior resistance to a wide range of corrosive environments of unusual severity as well as to high-temperature effects such as oxidation and carburization.

II. LITURATURE

Paulo roberto de freitas teixeira et al [1], presented he welding process as an thermal-mechanical-metallurgical coupled issue. In this study, the accuracy of the Gaussian heat source model is investigated in bead-on-plate welding by the TIG process. Analyses are performed by the ANSYS software, considering the convection and the radiation phenomena. Several cases with different parameters of heat distribution, heat input and plate thickness have had their weld pool geometries analysed and compared with those obtained experimentally. Analyses of the influence of the radial distance from the centre of the Gaussian heat source and the thickness of the plate on the bead width and the penetrated depth of the fusion zone boundary are presented. Results have shown the adequacy and the limitations of the Gaussian heat source model in the welding simulation.

Vishnu V.S et al [2], developed a 3D thermo-mechanical simulation model to predict distribution of temperature and residual stresses during Tungsten Inert Gas (TIG) double-side arc welding (DSAW) process on a low carbon steel plate. An uncoupled thermal–mechanical finite element analysis is performed using ANSYS. In this study the effects of welding process parameters (welding speed and welding current) in the symmetrical and asymmetrical double-side TIG welding process were investigated. The simulated results show that the residual stresses are tensile at the weld pool region and as the distance from the weld line increase it tends to compressive. Also found that welding process parameters in welded structures are the most influential parameter for the occurrence and control of residual stresses.

Vijay Gohel et al [3], presented the variation of temperature in TIG welded SS 304 plate of 3 mm work piece thickness. In this work, thermal analysis with the help of ANSYS workbench carried out for butt joint stainless steel base metal (SS 304) using Gas tungsten arc welding (GTAW) process. Thermo - Mechanical simulation is developed. Comparison with the temperature measured by the thermocouples records shows that the results from the present simulation have good agreement with the test data.

N.Jeya prakash et al [4], presented the influence of the power source, type of current, gas flow rate, electrodes, filer wire, TIG Machines settings, and shielding gases which are most important in determine arc stability, arc penetration and defect free welds. To do this a thorough literature survey is carried out on various aspects of the proposed topic, in various peer-reviewed journals, patents, books and other research resources. This work have identified the suitable range of current, the thickness of the base metal, the diameter of electrode, the composition of electrode and filler wire, the gas flow rate required for high quality TIG welding process.

Paulo J.Modnesi et al [5], explicated the Gas tungsten arc welding is fundamental in those applications where it is important to control the bead shape and the metallurgical characteristics. This process is however of low productivity particularly in the welding of larger components. The present work evaluates the use of TIG welding for austenitic stainless steels with fluxes of only one major component. The changes in weld geometry were compared to variations in the electrical signals from the arc and the arc shape. The effect of the flux on the weld microstructure was also studied.

PROCESS PARAMETERS OF TIG WELDING

The parameters that affect the quality and outcome of the TIG welding process are given below.

Welding current

Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials.

Welding voltage

Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance. Too high voltage, can lead to large variable in welding quality.

Welding velocity (or) speed

Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed or travel speed is primarily control the bead size and penetration of weld.

Shielding gases

The choice of shielding gas is depends on the working metals and effects on the welding cost, weld temperature, arc stability, weld speed, splatter, electrode life etc. it also affects the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness and brittleness of the weld material .

Melting efficiency

Melting efficiency is one of the more important measurable parameters in TIG welding when assessing the performance of a process. It is well known that a relatively small portion of the net energy is actually used for melting. The ratio of energy used for melting to that which is delivered to the substrate defines the melting efficiency.

III. FINITE ELEMENT ANALYSIS

A 3D CAD model of butt welded plate is developed in solid works and it is saved in IGES format and imported to the ANSYS software as shown in Figure. The element type in thermal analysis is PLANE 55. The boundary conditions are the constraints applied to the workpiece and the values of various process parameters of the welding are given to the pre-processor as an input. The geometrical details of the workpiece are also has to be detailed in the pre-processor. The element is applicable for three dimensional, steady-state or transient thermal analysis. In this analysis, element PLANE 55 is replaced with by a three-dimensional (3-D) structural element. The complete work in ANSYS is carried out on workbench.

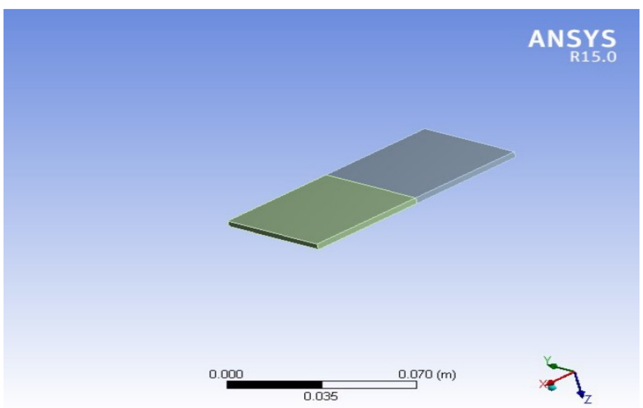

Fig.1 Modelling of component

Boundary Conditions

Heat Input= $\frac{V\,I}{U}$

Actual Heat Input=ŋ $\frac{V\,I}{U}$

Where, V=Voltage (Volts)
I=Current (Amperes)
U=Weld speed (mm/sec)
ŋ=Melting efficiency

Heat Flux = $\frac{\text{Heat input}}{\text{Area}}$

Area = 50×3mm^2 = 150×10 $^{-6}$ m

Convection co-efficient of heat transfer

Q = h A ΔT

Q/A= Heat flux, W/m^2

h= Convection co-efficient of heat transfer, W/m2K

In present analysis, the convection heat transfer due to ambient air is considered.

h= Convection co-efficient of heat transfer of air = 10 W/m^{2}K

Table 1: Boundary conditions for different cases

Case	Sub case	V (volts)	I (amp)	ŋ	U (mm/min)	Q (W/m^2)
1	**1-1**	10	80	0.8	2	2.13E+06
	1-2	10	90	0.8	2	2.40E+06
	1-3	10	100	0.8	2	2.67E+06
2	**Sub case**	**V (volts)**	**I (amp)**	**ŋ**	**U (mm/min)**	**Q (W/m^2)**
	2-1	5	90	0.8	2	1.20E+06
	2-2	10	90	0.8	2	2.40E+06
	2-3	15	90	0.8	2	3.60E+06
3	**Sub case**	**V (volts)**	**I (amp)**	**ŋ**	**U (mm/min)**	**Q (W/m^2)**
	3-1	10	90	0.8	2	2.40E+06
	3-2	10	90	0.8	4	1.20E+06
	3-3	10	90	0.8	6	8.00E+05
4	**Sub case**	**V (volts)**	**I (amp)**	**ŋ**	**U (mm/min)**	**Q (W/m^2)**
	4-1	10	90	0.6	2	1.80E+06
	4-2	10	90	0.7	2	2.10E+06
	4-3	10	90	0.8	2	2.40E+06

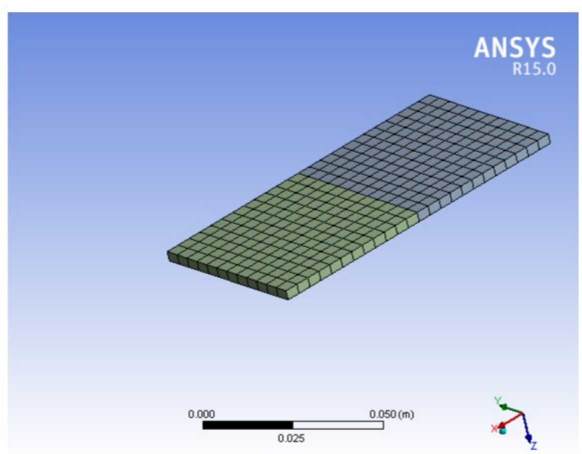

Fig.2 Three dimensional model and its meshed grids

IV. RESULT AND DISCUSSIONS

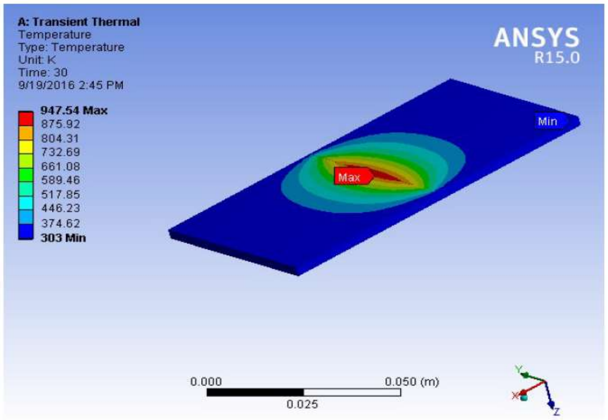

Fig.3 Temperature distribution in case 1-1

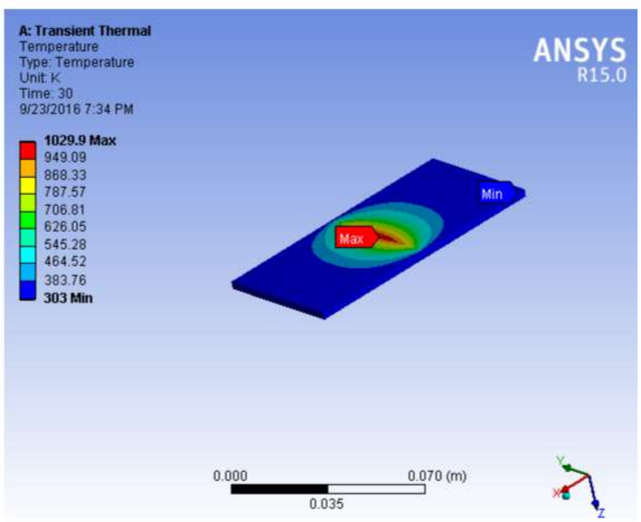

Fig.4 Temperature distribution in case 1-2

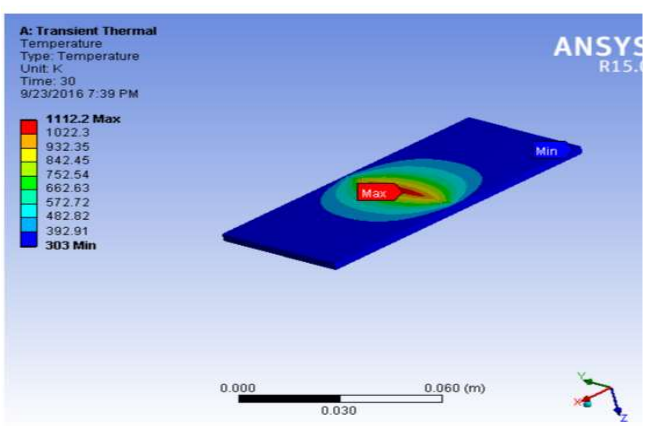

Fig. 5 Temperature distribution in case 1-3

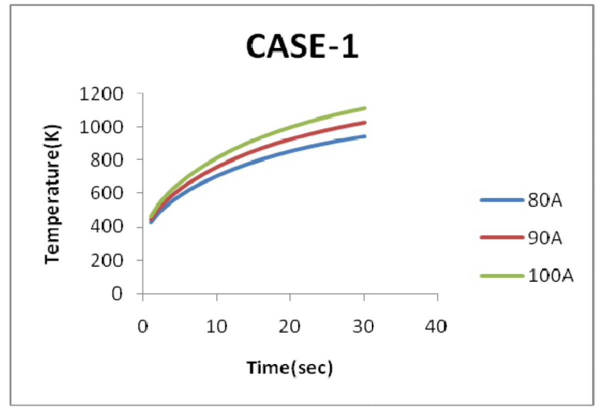

Fig. 6 Temperature vs time for case-1

From the analysis results for the case-1 boundary conditions, it is inferred that the maximum and minimum temperature occurred at 100A and 80A respectively. From this, it is concluded that the welding current is a significant parameter.

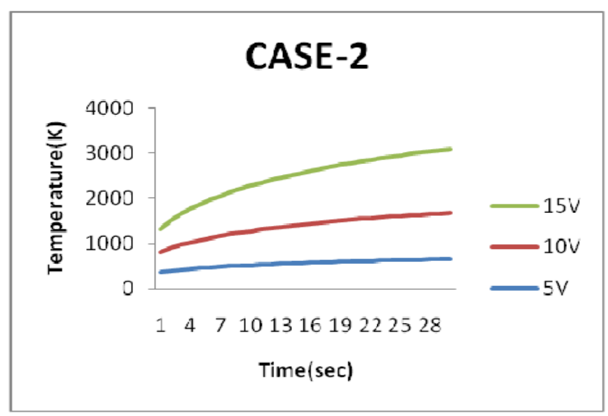

Fig.7 Temperature vs time for case-2

From the fig.7, it is inferred that as the welding voltage increases, the temperature around weld zone is also increased and it is found to be 1395.7K as maximum temperature at 15V.

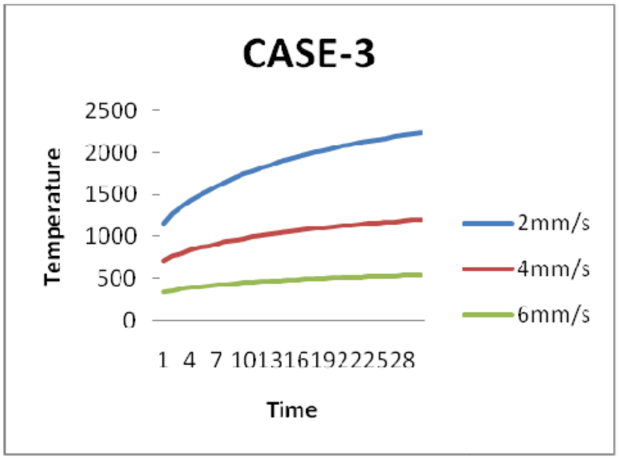

Fig.8 Temperature vs time for case-3

From the fig.8, it is inferred that as the welding velocity increases, the temperature around weld zone decreases and it is found to be 1029.9K as maximum temperature at 2mm/s.

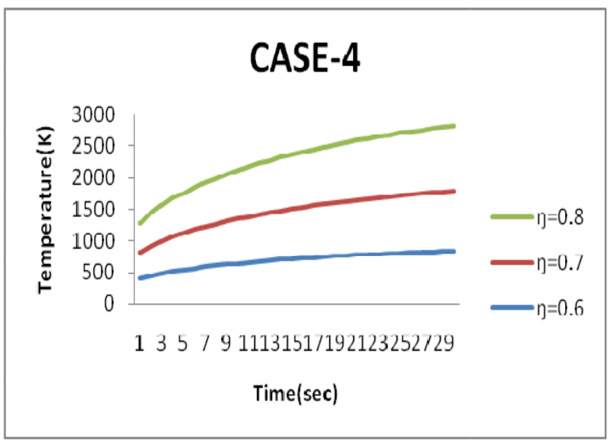

Fig.9 Temperature vs time for case-4

From the fig.9, it is inferred that as the welding voltage increases, the temperature around weld zone is also increased and it is found to be 1029.9K as maximum temperature at η=0.8.

Heat Affected Zone

The heat affected zone is the area of base metal, which is not melted but its microstructure and properties are altered by welding operations. In the present work the heat affected zone is found to be up to 5mm distance from the centre of the weld bead. The measured temperatures in heat affected zone from the ANSYS for case 1 are shown in fig.10.

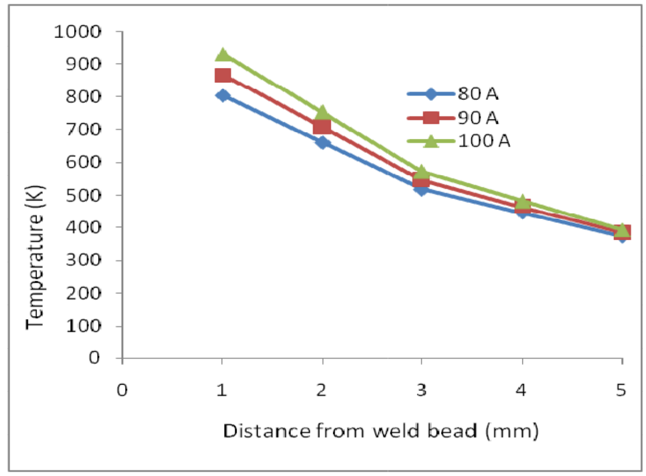

Fig.10 Temperature distribution in HAZ for case 1

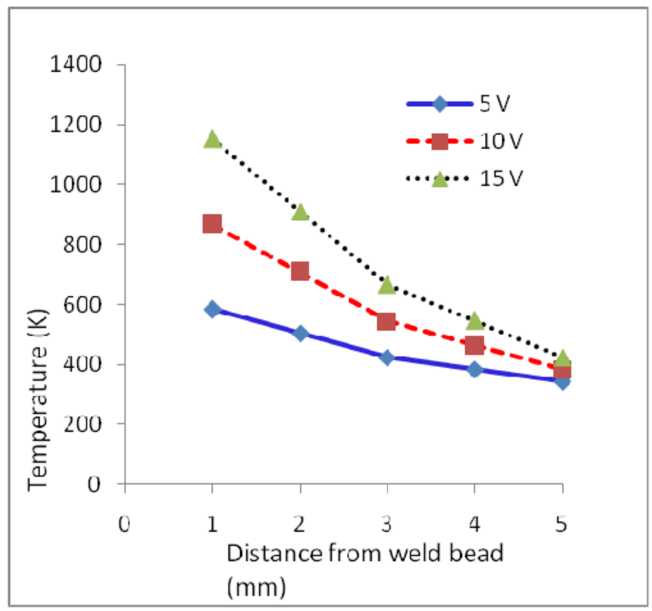

Fig.11 Temperature distribution in HAZ for case 2

V.CONCLUSION

At present research, the effect of welding parameters such as welding current, welding voltage, welding speed, and melting efficiency on TIG welding are analysed by using finite element analysis in ANSYS work bench software and the temperature distributions at various locations from the centre of the weld zone are analysed. The length of heat affected zone for variations of different welding parameters is evaluated.

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