Finite Element Simulation of Residual stresses in TIG welded butt joint

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Abstract:- Welding is the most vital manufacturing process in the mechanical industries like in automobile, nuclear power plant, aerospace, oil and natural gas industries. Defects in the welding process is the most ignorable thing like distortion in the welding joints due to which alignment gets changed and the material has o be repaired or replaced with the correct one. Residual stresses in the welded joint is the most dangerous in the welding manufacturing process which can make the human being life's in danger if the product fails while in process. So welding simulation is the best tool by which these can be ignored without the experimental work.

Introduction

Most of the developing nations are still lagging behind in advancement of machineries. On the other hand, developed countries are implemented new technology in terms of Automation. Automation provides accuracy, quality as well as requires less time and man power. In manual TIG welding process the rate of doing the welding is very less as compared to automated, the accuracy and quality of welding gets adversely affected. But we are talking about mechanism; the motion is smooth while welding[1]. In Auto TIG the data is being entered through the input parameters. The data entered in HMI goes to PLC, PLC execute process and start iterating. Initially the inert flows for some time interval to prevent the impurities. After that Tungsten develop an arc which gets stabilize after some interval. In this way the Auto TIG cycle is executed [2].

Residual Stress

The area surrounding the welding faces heat around its boundaries continuously so there will be irregularities in the weldment. The welding place adjacent to the heating zone affected by the temperature and space above of that is unaffected. The temperature variation is due to the heat movement from the weld pool towards the outer boundaries of the welding part [3].

Now variation in temperature causes rapid cooling of one place as compared to the other unaffected place so that it causes residual stress. Residual stress imparts into the body due to the variation in temperature at each part of that. It can be minimized by controlling the temperature around it [4]. Residual stresses arise due to different regions of the welding part from the main source [5]. Solidification of different regions causes residual stress in the part which can be minimized by controlling the heat flux and temperature. Temperature is also function of current and voltage[6].

Tungsten Inert gas (TIG) Welding process

Tungsten arc welding is highly used welding process which diversified in his own way of carrying out many operations. It can be used to weld strong and high strength materials. It is carried out by using Tungsten as an electrode/ Filler wire. It can be reached till temperature that is far away from other welding processes. It is having lots of applications in automobile sector too.

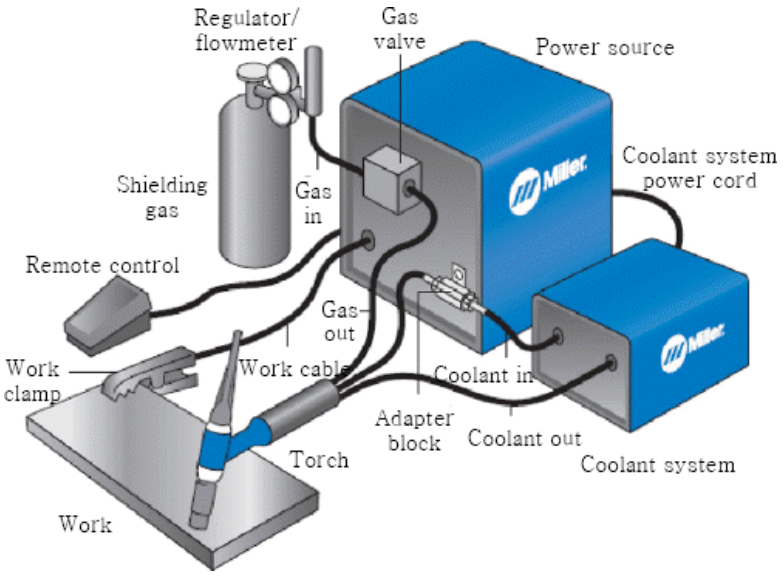

Fig 1. Block diagram of Manual TIG Welding [8]

Electric arc: There are three possible means of carrying out TIG welding. Every stage is having its own applications depending upon the requirement. The bead is having unique relation with temperature and many more functions.

TIG welding applications are for varying range of thickness but value is constraint till 10 mm for better benefits. It is used for horizontal as butt weld .Direct current reverse polarity is highly used among operation and is highly used for welding carbon, alloy and stainless steels, NI and Ti alloys. Cu alloys, contains Al in significant amount, will be carried out welding by this type of polarity. Direct current electrode positive is mean for welding with shielding gas, it is having strong implications of removing or cleaning impurities. It may also be used for TIG welding Mg alloys. Alternating current is most often preferred to take benefit of cleaning and most suitable no. welding applicable on the joint and good bead formation. Most are using this on Al alloys for better surface accuracy.

Literature Review

Literature survey is the important part of any project work. A large volume of literature is available in journals and books on this manual and automated TIG welding and various parameters affecting residual stresses in it. Following are some of the literature worth mentioning to get the direction of work and relevance to a large extent.

Vishnu et al. [10] It is concluded from the paper that welding parameters like welding current, heat flux and voltage are important parameters for finding the residual stress and by controlling these parameters, its optimization can be done. This study performs the simulation of welding and finding the effect of distribution of residual stresses along the boundary so as to minimize it and apply the same for maintaining and optimizing it.

Kumar et al. [11] this paper finds the result of welding with taking temperature as input. Various graphs are plotted while taken care about the cooling rate and its effect on the properties of the material. HAZ and various temperature field are formed on the study and studied various effects and modification after temperature is applied as input.

Jang et al. [12] The sustained stress condition under normal operation that may drive stress corrosion cracking is typically dominated by residual stresses in the vicinity of welds. Tensile stress on the surface is a necessary condition and a primary driving force for initiation of stress corrosion cracks. The rate of the subsequent SCC growth is to a large extent governed by the residual stress profile through the material.

Zinn et al. [13] this paper focuses on the use of simulations for welding and heat treatment. It presents the validation of welding and heat treatment on a simple part. Transient temperature and strain measurements are performed during welding. Residual stress measurements are performed both after welding and after heat treatment. Comparisons between experimental and simulated results show fairly good agreement. Using this experimental set-up, it has been seen that the model is sensitive to buckling when releasing the plate from the fixture. The possibility of buckling makes the model highly sensitive to the initial conditions. The buckling tendency causes problems in the simulation and the experimental set-up is therefore less suitable no. for validation of the models.

Jeyaprakash et al. [14**]** this studied the effect of various parameters related to mechanical properties of the material to the quality of the weld produced. It is also finding heat flux, current, voltage, young modules and various parameters on the quality of the weld. It also indicate various parameters effecting it from the point of cooling rate and other parameters effected it.

Withers et al. [15] TIG welding is widely used process and highly applicable for producing both types of ferrous family and in this study various parameters related to the welding are taken care and effects of it's on the material quality is studied. Al alloy is used as specimen and various parameters are varied to find its effect on the welding strength and its mechanical properties.

Owen et al. [16] This study literally deals with the automation in the field of welding to advance the techniques and find out the most optimized form which is having more quality, require lesser time and maintain the production rate as well. This atomization of welding is done with taken care about the effect of it on the quality of the material. Uniformity and welding speed, torch inclination are important parameters studied.

EXPERIMENTATION AND FEM METHODOLOGY

The fixture is working a model which rotates by the chain drive connected on a gear which is fixed on a shaft. The chain is connected through the gear mounted on the shaft of motor, as the motor shaft rotates the chain rotates which drive the main shaft, resulting corresponding motion of two pinions which rotates the ring gear and the fixture start rotating in circular motion.

The no of teeth in gear are 97 that of 10 in pinion providing a gear ratio of 9.7, due to smaller gear ratio the rotation per minutes (RPM) reduces providing a velocity of 40 inch per minute, more over this RPM is too high for the welding process hence a speed regulator is attached in addition to again reduce the RPM and to get approximately 8-12 inch per minute RPM which is necessary for the welding.

Fig 4. Fixture of automated TIG welding for circular section

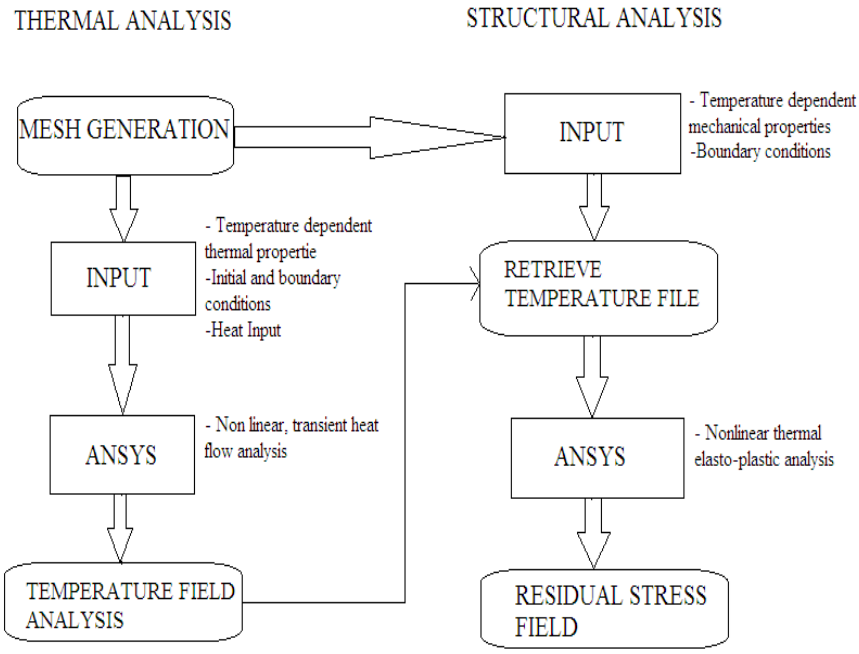

Fig 5. Working Methodology

Modeling

The study indicates two important parameters to be considered while applying TIG welding on circular sections:

First one indicates the relation of carrying out operation manually versus automatic and second benefit of carrying out simulation instead of experimentation for better productivity and optimization.

Modeling is being done in APDL.

Plane is selected as per conveyance depending upon problem type.

Problem Definition

A FEM analysis is used for finding transient thermal analysis and Elastic- Plastic analysis of welding, due to application of heat and surrounding temperature some residual stress induced in the field which is too harmful and decrease its hardness and many more drawbacks of the material.So it is advised to remove that problem not by experimentation which will consume more time and resources, but by simulation of the welding.

Material Used

SS316 material is used in this present study. Grade 316 is the standard molybdenum-bearing grade, 304 can also be considered but first is having good corrosion resistant properties as compared to second; mainly in chloride field it's having more application. It is used in industrial applications like brakes, automobile parts and aircraft parts. This material also has good welding properties. Post treatment is not required in this type of welding. Many researchers prefer this for enhancing application and used for sensitization. Grade 316H, having more amount of carbon can be used for high temperature field to carry out welding. If we have to take into account toughness and stability then austenite form of SS can also be

used. But that is must be used with alloys like Si.

Material Properties

Material used in this welding is not as carbon but its form SS316 is used because of most applications of this material now days. Young modules, Elasticity, Ductility and many properties are being studied and taken from research papers. These parameters are used as inputs in this model. Pipe material Stainless Steel SS316

Results

The axial residual stresses at the outer surface of the pipe are predicted at different sections 45^0, 90^0, 180^0 and 270^0 from the weld start position. The pipe on which the analysis is done as shown in figure no. 1.

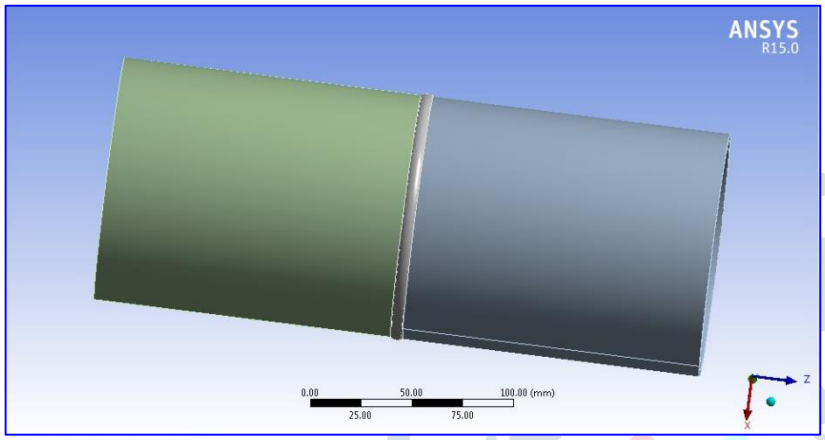

Fig 7. Graphical representation of welding pipe

The axial residual stresses are found as the compressive and tensile in nature as shown by the residual stress contours in the figur no. 2. The compressive residual stresses are found on or near the weld bead area and the tensile residual stresses are found away from the weld bead area.

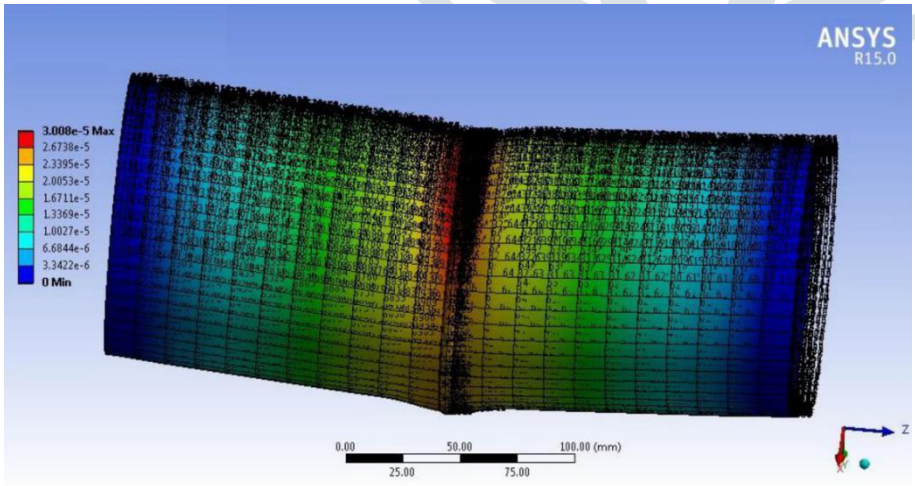

Fig 8. Stress acting on the pipe joint

The axial residual stresses on or near the weld bead is around 150 Mpa that is compressive in nature ans the axial residual stresses away from the weld bead area around 20 mm from the weld bead area is around 350 Mpa that is tensile in nature which is the main cause of the fracture that might be the fatigue fracture, cold cracking or can be the other.

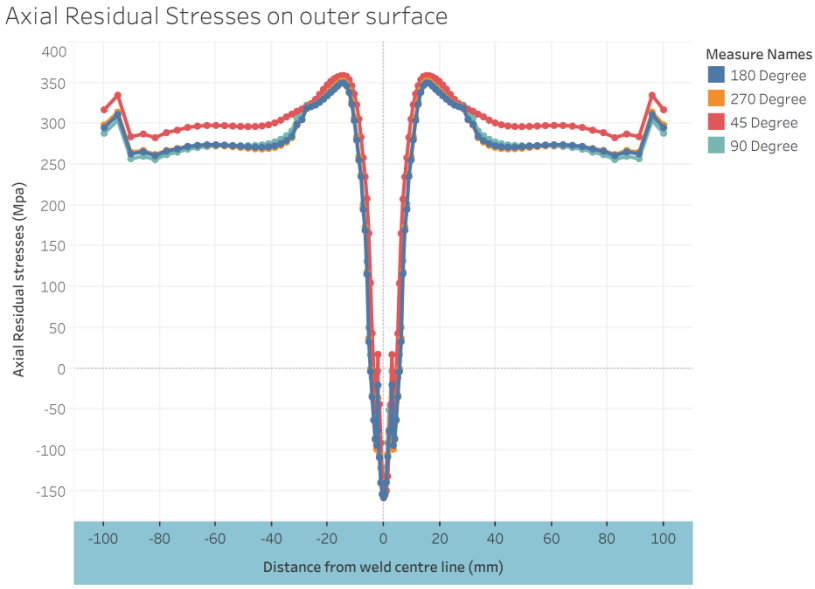

Fig 9. Axial residual stresses on the outer surface of the pipe

Conclusion

The study indicates two important parameters to be considered while applying TIG welding on circular sections:

First one indicates the relation of carrying out operation manually versus automatic and second benefit of carrying out simulation instead of experimentation for better productivity and optimization.

The following conclusions were made:

Thermal and structural analysis is being performed in simulation to obtain residual stress graphs in the SS316 material and following conclusions are listed below:

1. The heat flux is calculated from the experimentation of TIG welding on pipe and that input works as inputs for the simulation modeling.
2. Simulation saves time, money and increase productivity and for optimizing the welding process to minimize residual stress field w.r.t various parameters.
3. Temperature field and structural field show the relation between stress with temperature and other mechanical properties.
4. Current, voltage and other parameters being varied so as to vary heat flux to minimized the stress field and optimizing the process.

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