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Finite Element Method & Simulation of Robotic TIG-welding

Tapasya Gaikwad

Mechanical Department, GGSP

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Abstract -Robotized welding is one of the most important robot tasks used in manufacturing industry. The operator usually performs the programming of the robot manually, i.e. by jogging the robot arm to each coordinate pose in space. Programming can, however, be made more accurate by the use of simulation, using so called Computer Aided Robotics. Simulation can also be a powerful tool to evaluate and control welding heat effects, such as unwanted stresses and deformation. The objective of this thesis was to develop a simulation tool and a method by which robot trajectories, temperature histories, residual stresses and distortion can be analyzed and optimized off-line. This was performed by integrating robot simulation software with finite element analysis software. A special interface was created allowing information exchange between the two software programs. The method was used to program welding trajectories both for planar plates and for a part of an aerospace component. The trajectories were downloaded to the finite element analysis software where temperature and residual stress prediction were performed. Good agreement was found between the programmed robot trajectory, and the actual trajectory and only small adjustments were necessary. Temperature measurements were performed using both thermocouples and infrared imaging. Good agreement was also found between the results using these two methods. The method developed provides a powerful tool to construct and optimise robot trajectories and welding process parameters off-line.

***Key Words*:**Robotic, TIG, Welding, Optimise,FEM

1.INTRODUCTION

Manual TIG–welding is, on the contrary, one of the most common welding processes in the aircraft industry. This is due to high product requirements for materials with high heat and corrosion resistance, with good fatigue properties and with low weight.

The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

The objective of this research is to develop and validate a simulation tool for the TIG welding process. The tool shall be capable of simulating torch paths, predicting temperature histories, residual stresses, and deformation, thus making it possible to optimise welding sequences and fixture solution prior to manufacture. Of particular interest is whether or not sufficiently complex models can be developed, that can be used industrially in the design and production engineering phases.

2.Principle of TIG welding

Three different alternatives of current can be used namely; direct current (DC) with a positive electrode, DC with a negative electrode or alternative current (AC). AC is mainly used for the welding of aluminium and magnesium since cleaning of the oxide layer on the surface can in this way be achieved. DC with a negative electrode is used for most other materials, including thick plates of aluminium. Pulsed and non-pulsed currents can be used. A non-pulsed current is most common. The use of a pulsed current has some advantages, such as increased penetration.

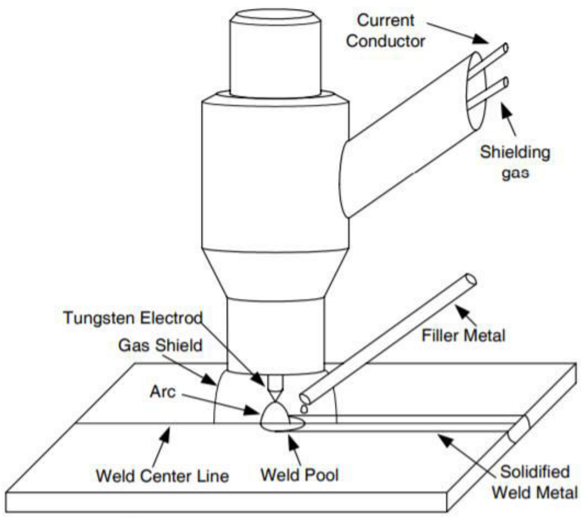

Figure 1: *Principle of Tungsten Inert Gas (TIG) welding.*

2.2 Residual stresses and distortion

Residual stresses are self-balanced internal stresses, which exist in the component without any external loads and can be classified as macro stresses and micro stresses. In the melted weld pool stresses are released and can be assumed to zero. During the solidification of the melted weld pool the metal starts to shrink and to exert stresses on the surrounding weld metal and HAZ.

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These stresses remain in the material after welding and result in unwanted distortion. A typical example of distortion is given in figure 8. The stress level in the solidification area is proportionately low, but the stress level in the weld area increases and can be as high as the yield limit of the base material, which can cause unwanted fractures. Stresses in a welded plate are usually divided in two directions, transverse and longitudinal to the weld.

Longitudinal residual stresses can arise from different causes. The most common cause is the longitudinal contraction of the weld as it cools down. Another cause is superimposed by opposing transformation processes. Transverse residual stresses are generated by the transverse contraction of the weld during the cooling phase. It can also be generated indirectly due to the longitudinal contraction

2.3 General Principles of Finite Element Modelling of Welding

All FEA problems are defined in terms of initial and boundary conditions. A typical type of initial condition for a welding application is the initial temperature that, in most cases, is set to room temperature. Examples of the most important boundary conditions are fixture forces, and heat transfer coefficients between the part and its surroundings.The second method is to use a surface distribution to simulate the arc. Here the energy source heat flux depends on the distance from the centre of the arc.The material properties that have to be included in the proposed simplified model when temperature simulations are to be performed are specific heat, heat conductivity, density, liquidus and solidus temperature. The conductivity is usually temperature dependent. Weld pool convection is a complex phenomenon that is difficult to simulate.

3. CONCLUSIONS

In this the a method and a simulation tool by which robot trajectories can be defined and thermal, residual stress distributions can be predicted on parts with complex shapes have been developed. The method was evaluated on a piece of an aerospace component where robot weld paths were defined off-line and automatically downloaded to a Finite Element Model, where temperatures and residual stress distributions were predicted. The temperature predictions were compared with experimental measurements using both thermocouple and infrared emission measurements and good agreements were found. No residual stress distributions have as yet been validated but measurements using neutron spectroscopy have been performed which are to be compared with corresponding predictions..

2.4 FEM-modelling in the present study

The welding paths, including initial weld velocities, were exported from the CAR model to the finite element software where predictions of temperature histories, residual stresses and fixture reaction forceswere performed. The same CAD/CAM model as in the CAR model was imported to and meshed with the FEA software. The commercial FEA program MARC, from MSC Software, was used. In paper I a model with solid elements was created. Since this type of model is computationally very expensive, a small part of the component had to be selected for modelling. The model was divided by a non-uniform mesh with higher densities close to the weld path (where the highest temperature gradients were assumed to occur),fig.2 Eight-node brick elements were used. In next a shell model of the whole section of the aerospace part was created, see fig.3

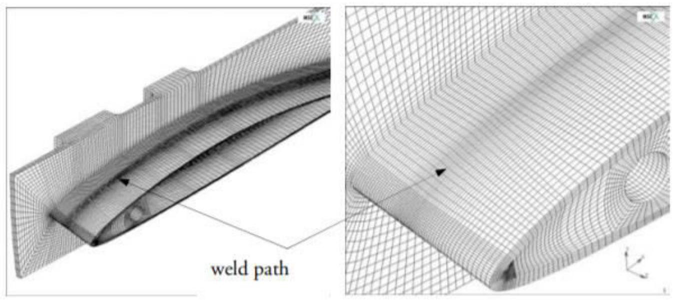

Fig.2 The non-uniform mesh used in paper one. Note the higher densities along the weld path

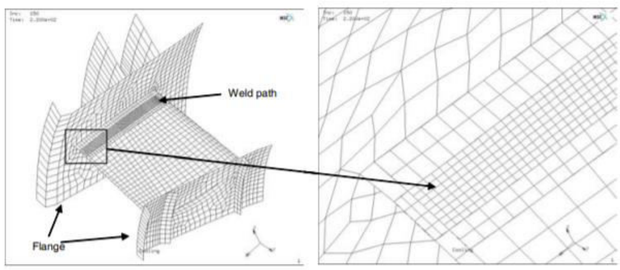

Fig.3 Shell model of aerospace component. Note the higher densities along the weld path

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