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NUMERICAL ANALYSIS OF TEMPERATURE FIELD IN Nd: YAG. LASER WELDING USING FINITE ELEMENT ANALYSIS

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Abstract: In present study stainless steel 316L grade was chosen for joining using 400w Nd-YAG laser beam welding process. 2D transient thermal-structural numerical simulation model was developed to simulate the complete laser welding process. The effect of each parameter has been studied numerically. The optimized values of process parameters are utilized to get the thermal profiles and heat affected zone using finite element simulations. The finite element calculation of process was carried out by a parametric design language APDL available in the ANSYS finite element code. The temperature values obtained using finite element simulation match reasonably well with an error of 12% hence the developed simulated model can be used to study related parameters.

***Keywords*:** Temperature field; Finite-element analyze; Numerical simulation

INTRODUCTION

Laser beam welding is high power density welding technologies, have been increasingly utilized in industrial manufacturing. Compared to other welding process laser welding process offers a great potential for the new product design. A small heat affected zone is formed by laser welding because in this welding less heat is couples in the work piece.

The word laser stands for 'Light amplification by simulated emission of radiation'. Laser is a coherent and amplified beam of electromagnetic radiation. Laser welding is a non-contact type welding process that there is no direct contact between work piece and laser medium.

In this research work, finite element simulation of Laser beam welding on stainless steel AISI
316 L with different process parameters are performed. Because of its inherent corrosion resistance, austenitic steels, known as 300 series have become cost-effective and have long term applications in many industries sectors including gas, petroleum, petrochemicals, fertilizers as well as power generating plants.

For finite element simulation (FEM), a 3D model is prepared with laser welding boundary conditions. The complete Laser beam welding process is simulated using ANSYS (APDL) 23 to predict the temperature distribution at different locations on butt welded plate. There are three process parameters viz. Welding current, frequency (pulse repetition rate) and pulse width with three levels each (low, medium, high) are taken. Optimization of process parameter is done using TAGUCHI and ANOVA trough MINITAB software. Nd-YAG pulsed laser is used in this work.

METHODOLOGY

To perform the identified investigations, following methodology is adopted:
Step 1: Identification of area of research.
Step 2: Searching research papers
Step 3: Literature review.
Step 4: Problem formulation and deciding about the research objectives.
Step 5: Study of Laser Beam Welding techniques.
Step 6: Identification of different process, performance parameters and other boundary conditions related to the selected welding process.
Step 7: Study of Finite element method to simulate laser beam welding.
Step 8: Simulation of laser welding process with selected boundary conditions.
Step 9: Result analysis to evaluate and compare the process parameters obtained from simulation work.
Step 10: preparation of report.

1.1 FINITE ELEMENT METHOD (FEM)

The finite element method (FEM) or finite element analysis (FEA) is a numerical method for solving problems of engineering and mathematical physics. To solve the problem, it subdivides the given domain into smaller; simpler parts called elements and the point of attachment of the element to other part of structure are called nodes.

1.2 ANSYS Software

مجلة العلوم والتطـــبيقات الهـندسية
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ANSYS is finite element analysis software. Finite element analysis is a numerical method of deconstructing a complex system into very small piece called elements. The software implements equation that governs the behavior of these elements and solves all equations. ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering like:

- Structural
- Thermal
- Fluid, including CFD (Computational Fluid Dynamics)
- Electrical / Electrostatics
- Electromagnetic

1.3 **MATHEMATICAL MODEL**

This part of the finite element simulation of Laser beam welding is heat transfer analysis. In the finite element formulation, this equation can be written for each element as follows

[C (T)] {Ť}+ [K (T)]{T} = {Q (T)}

This analysis requires an integration of the heat conduction equation with respect to time. The Crank – Nicholson/Euler theta integration method is applied to solve these system equations. This element type has a three-dimensional thermal conduction capability. The heat input from the welding laser was modelled by using heat flux as the input for the heat transfer to the work piece. We used 2D cylindrical heat source model in our study.

Calculation of Heat Flux (Q)

$$Q(r) = \frac{2P}{\pi\sigma^2} e^{\frac{-2r^2}{\sigma^2}}$$

Where

Q(r) = Surface heat flux at radius r

P= Laser power = V*I

I = welding current

V = Voltage

σ= radial distance = 0.0045m

r= beam radius = 0.003m

1.4 **Material properties**

The thermal and mechanical material properties are very important to the successful development of numerical models. In this simulation temperature independent mechanical and structural property are used. The material selected for this simulation is stainless steel 316 L plates.

The Table 5.2 gives the material properties of stainless steel 316L.

Table 5.2: Material properties of SS316L

Melting point	1375-1400K
Young's modulus of elasticity	200GPa
Poisson's Ratio	0.25
Thermal conductivity	16.3 W/mk
Specific heat	0.486 j/gc
Density	8000 kg/m3

1.5 **Modelling and Meshing**

To model the two stainless steel plates of following dimensions are used. Figure 5.6 and 5.7 depict the solid model and wireframe in ANSYS respectively The plates were meshed with tetrahedral mesh elements that can calculate the field variables precisely. The all other portion is meshed with tetrahedral mesh with 0.3 mesh size.

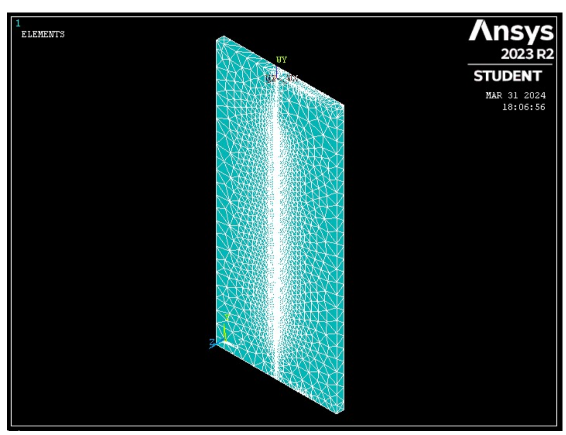

Figure 5.4: 3D meshed model of weld plates

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1.6 **Heat transfer analysis**

For heat transfer analysis finite element simulation model of Laser beam welding is adopted. In the finite element formulation, the governing equation can be written for each element as follows:

$$[C(T)]\{\dot{T}\}+[K(T)]\{T\}=\{Q(T)\}$$

This analysis requires an integration of the heat conduction equation with respect to time. The Crank – Nicholson/Euler theta integration method is applied to solve these system equations. This element type has a three-dimensional thermal conduction capability. The heat input from the welding laser is modeled using heat flux as the input for the heat transfer to the work piece

1.7 SIMULATED RESULTS OF LASER BEAM WELDING PROCESS

The objective of previous chapter is to perform numerical study related to Laser beam plate welding. The simulation is performed with two selected plate with butt welding joint setup using ANSYS APDL. Three input parameters with three levels and output parameter selected to perform the simulation.

A non-linear transient thermal analysis was conducted to obtain the global temperature distribution generated during the welding process at different location of plate. The temperature results of the same are presented in next section. Numerical simulation is done in ANSYS APDL 23 software, cylindrical model is developed for giving the heat flux input for laser welding.

1.8 **Temperature Distribution**

A non-linear transient thermal analysis was conducted first to obtain the global temperature distribution generated during the welding process and the temperature distribution results. Numerical simulation was conducted through ANSYS APDL of laser welding for various laser powers. In our study we are measured the temperature values at different of plate (T1-T9). Simulation is done for three cases for various current values (80, 85 and 90A) and constant voltage (380v) are selected as input parameters, which is shown by figures(6.13 to 6.21), figure (a) represents the temperature contour, (b) time and temperature graph and (c) represents the response of temperature values at various locations at a particular time.

Temperature values are measured at particular locations; for this purpose particular nodes are selected in ANSYS APDL of those locations. In General post processing, result viewer shows the temperature values at particular nodes number which depicted in table 6.20

1 For case 1

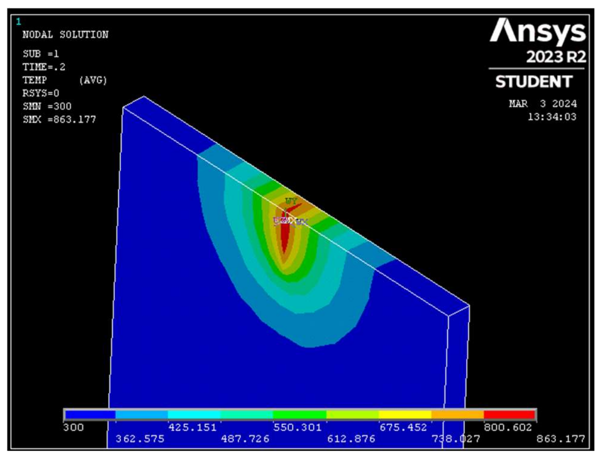

Figure 6.13 (a) Temperature contour after welding

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For case 2

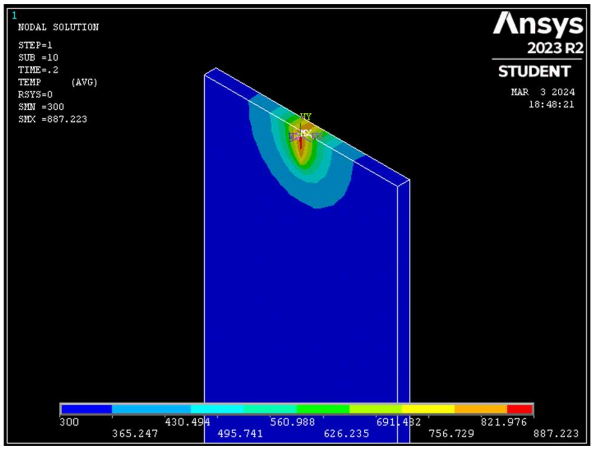

Figure 6.14(a) Temperature contour of after welding

For case 9

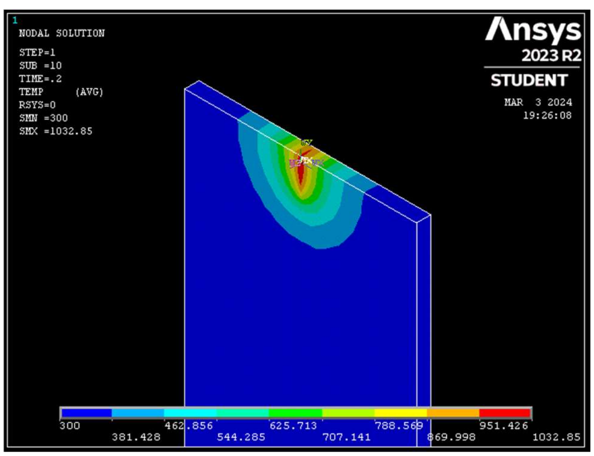

Figure 6.21 Temperature contour of after welding

Table 6.20 Response table of temperature at different nodes at particular time:

Simulation No	Temperature at three location	Node no	Temperature (k)	Stress
1	T_1		863.177	
2	T_2		867.223	
3	T_3		910.712	
4	T_4		920.107	
5	T_5		945.945	
6	T_6		971.783	
7	T_7		976.481	
8	T_8		1004.67	
9	T_9		1032.85	

CONCLUSIONS

The objective of this work is numerical investigation and optimization of process parameters during laser beam welding of SS 316 L plate. To achieve this total 9 experiments are conducted according to Orthogonal array L9 (33). In this work two performance parameters (Temperature and tensile strength) are investigated by varying the three process parameters (welding current, frequency, and pulse width). The optimum parameters values found which would yield maximum temperature and tensile strength.

Simulated studies of Laser beam welding of SS 316 L plate material has been conducted in previous chapter. Current chapter contains comparative evaluations, future scope and conclusion of the current work..

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