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Simulation Heat Affected Zone Welding On Aisi 1045 Steel Using Matlab

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Abstract--*In this Research, AISI 1045 steel plate test objects were welded using SMAW welding. A thermal simulation of the welding process (heat input simulation) is performed by entering the maximum temperature distribution on a 140 x 140 mm plate with a thickness of 4 mm, made of AISI 1045 steel. Initially, the plate has temperature limits of 700 °C, 500 °C, above 1300 °C, and below 0 °C. The bottom of the plate is protected by a constant-temperature shield. The test object is then described numerically using the MATLAB program. In this Research, we can use MATLAB to develop a mathematical and numerical model that captures the effect of the heat-affected zone (HAZ) on the mechanical properties of AISI 1045. This model helps in the understanding of how the heat input provided from the welding process influences the mechanical material properties and allows us to optimize the Influence of the process to obtain the desired results. Calculations carried out using the MATLAB application obtained results in the 9th iteration for errors <1%, namely 0.4681%. Considerable heat input results in low tensile strength; this shows that the welded joint, with the electrodes used and the given welding parameters, produced good joint strength.*

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1. INTRODUCTION (Arial 10pt; Bold)

Welding techniques are a critical process in industry, allowing materials to be joined to form intense and complex structures. In sectors such as manufacturing, construction, repair, and others, welding techniques are used to create a variety of products, ranging from vehicles to critical infrastructure.

In the development of the welding industry, knowledge of heat-affected zones is crucial because they can affect the mechanical characteristics and structural strength of the materials being joined. A study was conducted to investigate the impact of heat on HAZ by conducting welding experiments on a particular metal [1]. In this study, MATLAB simulations were used to analyze the effect of heat input during the welding process on the mechanical properties of AISI 1045 steel. AISI 1045 steel is a medium-carbon steel with a carbon content of 0.43-0.50% and belongs to the medium-carbon steel group.

This specification steel is widely used as an automotive component, for example, for gear components in motor vehicles. AISI 1045 steel is a plain carbon steel with a carbon content of 0.45%. Steel of this specification is widely used as a component of gears, shafts and bearings. In this application, the steel must have good wear resistance because, given its function, it must withstand wear from rubbing against the chain [2].

In general, wear resistance is directly proportional to hardness. Analyze the mechanical properties of various potential V angles and the factors that cause residual stress in the Shielded Metal Arc Welding process or in manual arc welding of low-carbon steel using experimental methods. The results of previous Research tests showed that the highest tensile strength occurred at a potential of 45 ° and a current of 100 A. The largest residual voltage occurred at an angular potential of 60° and a current of 100 A, while the smallest residual voltage occurred at a potential of 40° and a current of 100 A. current 80 A. [3].

Some welding processes with varying welding parameters use numerical methods in SolidWorks. The simulation results show that Gas Metal Arc Welding produces low residual stress. [4]. The residual stress analysis of the steel plate was performed with PWHT. The analysis was carried out by experimental methods and numerical analysis with the ANSYS program. The results showed PWHT can affect residual voltage. Stress relief begins to occur at temperatures above 400ºC and stabilizes at 600ºC. [5].In actualization in the life of AISI 1045 steel used in the shaft component of the garbage shredding machine, for example, and splicing is carried out using a welding process for design, it requires knowledge of the mechanical properties of steel and its resistance to heat caused by the welding process.

Therefore, to study the effect of the welding process on the mechanical properties of steel, especially the heat input, experiments were carried out in MATLAB on the area of Influence of welding heat on the mechanical properties of AISI 1045 steel.

2. METHODOLOGY

Understanding the heat-affected zone (HAZ) in the welding industry is crucial because it can affect the mechanical properties and structural strength of the material being welded. To investigate the effect of heat on HAZ, an experiment involved welding a metal material.

Therefore, in the welding process, efforts to increase weld strength should receive primary attention. One parameter that can affect weld strength is heat input. Heat input is related to the regulation of current, voltage, and welding speed.

Research on the effect of welding process heat input on the mechanical properties of AISI 1045 steel: An experimental study and numerical analysis, it can be concluded that the heat input of the welding process affects the mechanical properties of AISI 1045 steel. Considerable heat input results in low tensile strength. Good heat input parameters are 80 A current, 20 V voltage, and a welding speed of 2 mm/s, which can produce a tensile strength of 428 MPa. [1].

All specimens tested do not break in the weld area, indicating that the welded joint with the E7018 electrode and the provided welding parameters produces a strong joint

.

A heat input that is too large causes excessive penetration in the weld area, while a heat input that is too small can result in poor weld penetration and weld defects. Proper heat input can also minimize thermal contractions, residual stress, and distortions in welded products. Therefore, the strength of the welded joint depends on the heat input setting.

2.1 Specimen Preparation and Welding

At first, 9 AISI 1045 steel specimens with a thickness of 4 mm were machined using hand grinders and benchwork tools to facilitate welding. The shape of the weld joint was chosen as a single V butt joint with an angle of 60 °, as shown in Figure 1, based on Polymachine Journal, Volume 17, Number 1, February 2019 3.

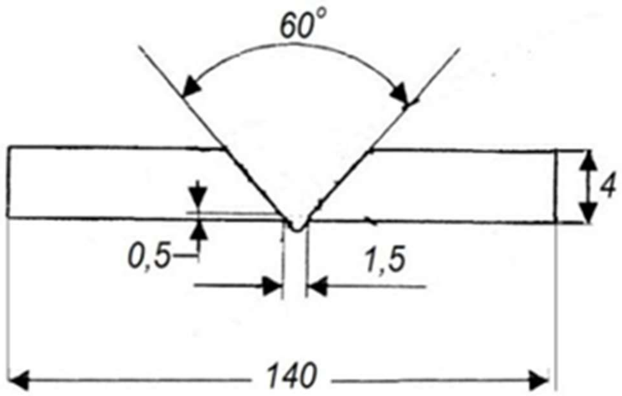

Figure 1. V-groove Butt Weld Joint

Welding is done using a shielded metal arc welding machine or a manual arc welding process. DC and polarity using E7018 electrodes with a size of Ø3.2 x 330 mm. In potent V welding, the process starts with root welding, then the filler or filling process is carried out, and the last step is capping welding, namely closing welding at a constant welding speed of 2 mm/s.
The welding parameter settings are shown in Table 1.

Table 1. Welding Parameters

No. Spec	***Current (A)***	***Voltage (V)***
1,2,3	80	20
4,5,6	90	25
7,8,9	100	28

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The heat input in welding is calculated by the following formula

$$H = \frac{E.I.60}{V} \tag{1}$$

Where :
H = Heat input (Joules/mm)
E = Welding voltage (Volts)
I = Welding current (Amper)
V = Welding speed (mm / s)

In the simulation of calculations using the numerical method of elliptic differential equations. The elliptic method or Liebmann method, as described in the study title, is used to examine the trend in heat distribution in AISI 1045 steel plates, using the following formula.

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0 \tag{2}$$

$$T_{i,j} = \frac{T_{i+1,j} + T_{i-1,j} + T_{i,j+1} + T_{i,j-1}}{4}$$

$$T_{i,j}^{new} = \lambda T_{i,j}^{new} + (1-\lambda) T_{i,j}^{old}$$

$$(\varepsilon_a)_{i,j} = \left| \frac{T_{i,j}^{new} - T_{i,j}^{old}}{T_{i,j}^{new}} \right| 100\%$$

Error value calculation formula.

In this study, a thermal simulation of the welding process (heat input simulation) was performed by specifying the maximum temperature of the heat distribution on a 140 x 140 mm plate with a thickness of 4 mm made of AISI 1045 steel. At first, the plates had temperature limits of 700°C, 500°C, above 1300°C, and below 0°C. The bottom of the plate is insulated and maintained at a constant temperature. All four sides of the plate have temperature measurement points. Building a mathematical model for heat distribution on plates is one part of the Research process.

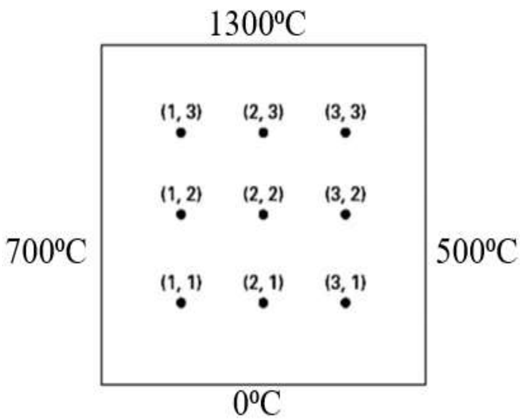

Figure 2. Boundary Condition

The area of Influence of heat in the resulting welding process is the relationship of the heat input of the welding process.

2.2 Welding Procedure

In the welding industry, the Shielded Metal Arc Welding (SMAW) method is often a tough choice for combining strong materials such as AISI 1045 steel. AISI 1045 steel, known as medium-carbon steel, offers the strength and toughness required for a wide range of industrial applications, from machine building to construction.

The SMAW welding process on AISI 1045 steel begins with meticulous material preparation. The steel surface should be cleaned of dirt, such as rust or oil, to ensure optimal welding results. Then,

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selecting welding electrodes is an important next step. For AISI 1045 steel, E7018 electrodes are often chosen because their characteristics match those of medium-carbon steels.
After preparation is complete, light the bow. The arc-ignition process must be carried out carefully and precisely to avoid defects in the weld finish. When the arc is formed, the welder must pay attention to the welding position specified for the work. Then, using appropriate techniques, such as consistent and uniform welding movements, the material is heated with an electric arc to form a strong connection.

During the welding process, heat control is significant. The welder must ensure the material's temperature is controlled to avoid distortions or unwanted structural changes in AISI 1045 steel. After welding is complete, the final result must be carefully inspected. These inspections aim to ensure there are no defects such as cracks, porosity, or unexpected metal buildup that could reduce the strength or reliability of the structure.

By following these steps and paying attention to critical factors such as electrode selection, arc ignition technique, heat control, and inspection of the final result, the SMAW welding process on AISI 1045 steel can produce strong, reliable joints in accordance with industry safety and quality standards.

3. RESULT AND DISCUSSION

In this study, testing was conducted in MATLAB by entering a calculation formula to obtain the correct results.

3.1 MATLAB Calculation Simulation

The simulation was carried out using MATLAB with the Liebman method. The Liebman method is commonly used to solve heat equations in systems with complex heat distribution. In this study, the Liebman method is used because the breakdown of the heat distribution system within the area of Influence of the welding heat is very complex.

```
%HEAT DISTRIBUTION BY THE LIEBMAN METHOD


for i=1:9;
    for j=1:9;
      T(i,j)=0
   end
end


%BOUNDARY CONDITIONS
T(:,1)=700 ; %left border
T(:,j)=500 ; %right border
T(1,:)=1300 ; %Upper limit
T(j,:)=0 ; %Lower limit


lamda = 1.5


while(1)
for j=2:6
for i=2:6
    T_old(i,j)=T(i,j);
    T(i,j)=(T(i+1,j)+T(i-1,j)+T(i,j+1)+T(i,j-1))/4;
    T(i,j)=lamda*T(i,j)+(1-lamda)*T_old(i,j)
```

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```
    end
end

error=dot((((T(i,j)-T_old(i,j))/T(i,j))*100),...
(((T(i,j)-T_old(i,j))/T(i,j))*100))
if error<=1
break;
end
end
```

Enter the parameters of the data that has been obtained into the MATLAB program. The simulation results are shown in Figure 3.

1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
700	0.9457	0.9971	0.9714	0.8709	0.6276	0	0	0	500
700	0.7685	0.7661	0.7074	0.5762	0.3558	0	0	0	500
700	0.6507	0.5877	0.4987	0.3828	0.2169	0	0	0	500
700	0.5348	0.4190	0.3329	0.2415	0.1297	0	0	0	500
700	0.3611	0.2403	0.1725	0.1186	0.0619	0	0	0	500
700	0	0	0	0	0	0	0	0	500
700	0	0	0	0	0	0	0	0	500
700	0	0	0	0	0	0	0	0	500
0	0	0	0	0	0	0	0	0	0

Figure 3. MATLAB Simulation Results

The calculation is carried out at the highest temperature of 1,300 degrees Celsius to the lowest temperature of 700 degrees Celsius. The temperature is the area of Influence of heat on the welding obtained. Then, the simulation using the MATLAB application yielded results in the 9th iteration with an error of <1%, or 0.4681%. This approach can be used to determine the contribution of each heat source, enabling the resulting heat distribution to be observed.

3.2 Grid Analysis Results MATLAB

To get the result of a simulated grid in a given MATLAB heat equation, create a MATLAB script or function that implements its numerical solution. One method for solving partial differential equations like this is the elliptic method, also known as the Liebmann method.

```
%GRID ANALYSIS RESULTS
x0=0; xf=1;
y0=0; yf=1;
nx = 101; ny = 101; %checking for ref book

x=linspace(x0,xf,nx);
y=linspace(y0,yf,ny);
dx=x(2)-x(1);
dy=y(2)-y(1);

T=zeros(nx,ny);%preallocation matrix
```

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```
kmax = 1e5;%number of iteration,
%try until the result gives a constant value or a graphic
%A higher number of iterations makes a better result
%I suggest using k=10000 (it may take more CPU time, but gives a good result

for k = 1:kmax % perfom iterative calculation
   for i = 2:nx-1
      for j = 2:ny-1
         T(i,j)=((dy^2*(T(i+1,j)+T(i-1,j)))+(dx^2*(T(i,j+1)+T(i,j-1))))/(2*(dx^2+dy^2));
      end
   end
   T(:,1)=700; %Left BC
   T(:,ny)=500; %Right BC
   T(1,:)=1300; %Top BC
   T(nx,:)=(4.*T(nx-1,:)-T(nx-2,:))/3; %Neumann BC
end

Figure (1)
imagesc(x,y,T)
title('Profile Temperatur in square plate')
Xlabel('x-axis')
ylabel('y-axis')
colormap jet
colorbar
```

The MATLAB trend grid simulation results are shown in Figure 4.

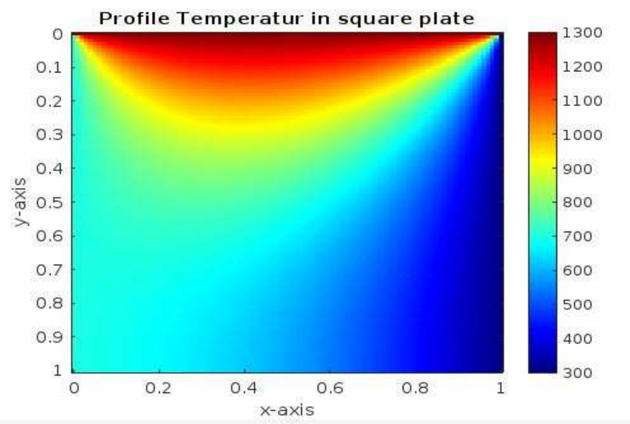

Figure 4. Grid Analysis Results MATLAB

The grid simulation results show the trend of the heat-influence area (dark yellow) at 1000ºC. The red area shown in the picture is the welding area, while the blue area is the plate area after the heat-affected zone.

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The dark yellow grid indicates an area of heat Influence, where heat input is strongly influencing the material's mechanical properties. By conducting simulations in MATLAB, parts can be observed at each point in the heat-affected area, allowing the distribution of heat to be determined.

Simulations carried out in MATLAB to examine trends in heat-affected regions can serve as an initial analysis step to determine at what temperature conditions the mechanical properties of steel change.

4. CONCLUSION

After a trial analysis of the MATLAB simulation results, the calculation was performed using the Liebman method. In the 9th iteration, the results showed an error of < 1%, or 0.4681%.

The numerical method for elliptic differential equations, with MATLAB simulation, can be used as an alternative for analyzing heat transfer problems in heat Influence area Research.

The effect of heat input from the welding process on the mechanical properties of AISI 1045 steel. A numerical analysis study. It can be concluded that the heat input of the welding process, especially the heat Influence area (HAZ), affects the mechanical properties of AISI 1045 steel. Considerable heat input results in low tensile strength.

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