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CALCULATION PROGRAM FOR STEEL WELDABILITY BY CONSIDERING THE HEAT AFFECTED ZONE (HAZ) WIDTH OF WELDED JOINT

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The program makes the welding process more accurate with welding parameters used, more time saving, and low-cost operation, and it can also improve the welding operator's metallurgy knowledge. Good weldment depends on the skill and experience of the operator's. This program includes the chemical elements content of the steel, the diameter of the electrode; electric current; electric voltage, welding speed; metal thickness will be welded and heat input. Visual Basic package program used to create the program. The study aims to create the program for determining the width of heat affected zone based on welding parameters. This research may simulate the heat-affected zone dimension based on the heat input temperature from arc welding.

Keywords: steel; weldability; calculation program; carbon equivalent; weld parameter

INTRODUCTION

Weldability of high strength steel involves protective gases, welding voltage, welding current, protective gas flow rate, and chemical elements contained [1]. High heat input produces coarse martensite weld metals and lower toughness than low heat inputs with the same filler metals [2, 3]. The main welding parameters to produce suitable fillet beads include root openings, travel speed, and minimized heat input [4]. Hebda and Sady created a Software to estimate steel weldability based on (i) Tremlett, (ii) Det Norske Veritas (DNV), (iii) International Institute of Welding (MIS), (iv) Poland Standard (PNs), (v) Kihara and Suzuki, (vi) Hardness of sub-hardening zone based on Coe's formula, (vii) Hot crack susceptibility, (viii) Preheating temperature according to Seferian [5]. The increasing heat input leads to lower bainite formation and reduces the hardness of microstructure [6]. The profile of HAZ hardness test result can be used to assess the weldability [7]. Un-defect weld joint can be obtained based on appropriate current, polarity, and torch angle [8]. Facing HAZ always has a lower hardness than base and weld metal [9].

Based on the previous studies, the problem formulation is "how to create the program to determine of HAZ width of steel welded joint."

Crack consists of hot (UCS) and cold crack (P_{cm}) [10].

$$UCS=230C+190S+75P+45Nb-12{,}3Si-5{,}4Mn-1 \qquad (1)$$

UCS > 30, then crack possibility is high. If UCS = 10 – 30, welding could still be controlled,

$$P_{cm}=C+\frac{1}{20}Mn+\frac{1}{30}Si+\frac{1}{60}Ni+\frac{1}{20}Cr+\frac{1}{15}Mo+\frac{1}{10}V+5B \qquad (2)$$

If P_{cm} < 0,23 %, the weld strength will be low. Moreover, if P_{cm} > 0,35 %, the metal does not possess any toughness to deal with cold cracking. P_{cm} = 0,25–0,30 % is highly recommended.

Weldability of steels obtained using (C, CE) plotted in Gaville Diagram (Figure 1), and expressed by the following formula, [11].

The International Institute of Welding (IIW) and Polish Standards (PNS):

$$CE\,/\,\% = C+\frac{Mn}{6}+\left(\frac{Cr+Mo+V}{5}\right)+\left(\frac{Ni+Cu}{15}\right) \qquad (3)$$

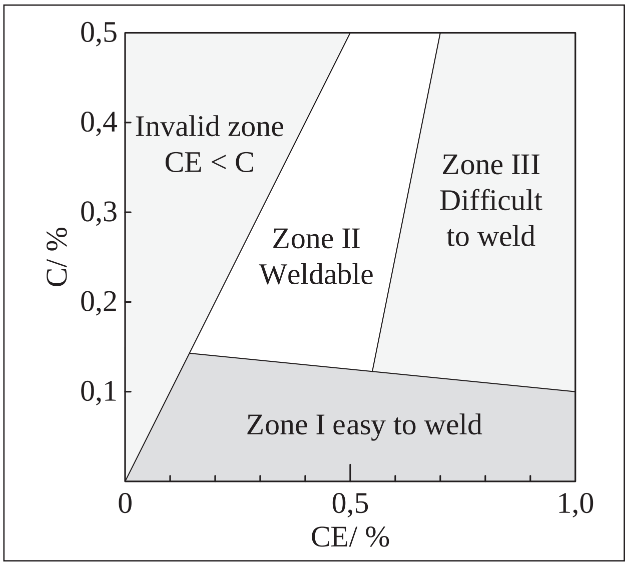

Figure 1 Graville Diagram [11]

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Det Norske Veritas formula for steels with yield strength not exceeding 300 MPa,

$$CE = C + \frac{Mn}{6} \leq 0,32 \quad (4)$$

Det Norske Veritas formula for steels with yield strength more than 300 MPa,

$$CE = C + \frac{Si}{24} + \frac{Mn}{10} + \frac{Cr}{5} + \left(\frac{Ni + Cu}{40}\right) + \frac{Mo}{4} + \frac{V}{14} \leq 0,37 \quad (5)$$

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$$CE = C + \frac{Mn}{6} + \left(\frac{Cr + Mo + V}{5}\right) + \left(\frac{Ni + Cu}{5}\right) \leq 0,45 \quad (6)$$

Heat input is defined by current, voltage and welding speed [12] for shielded metal arc welding ranges (0,6 – 4,3) kJ/mm and is formulated as follows [13]

$$H_{net} = \frac{60 \times E \times I}{1000 \times S} \quad (7)$$ with,

E = Voltage across arc/ Volts
I = Current range/ Ampere
H_{net} = heat input/ kJ/mm.
S = Travel speed/ m/second. HAZ width (y) can be obtained using the following equation [10, 14]

$$y = \left(\frac{1}{T_P - t_o} - \frac{1}{T_m - T_o}\right) \times \left(\frac{H_{net}}{(2\pi e)^{0,5} \times \rho \times C \times t}\right) \quad (8)$$

with:
T_p = Peak temperature/ ºC.
t_o = Plate temperature/ ºC.
T_m = Melting temperature of base metal/ ºC.
T_o = Base metal original temperature/ ºC.
π = 3,14.
e = Brigg number (2,7….)
ρ = Density of base metal/ kg/m^3
C = Specific heat capacity/ (J/kg·°C).
t = Metal thickness/ mm

Increasing distortion is mostly due to increased heat input, cost, and time. [6].

Aim of this study is creating calculation to determine the HAZ width of steels welded joints. To achieve the aim of this research need to do the following,

1. Determine the susceptibility to hot and cold cracks of steel to be welded.
2. Steel weldability determined based on carbon equivalent and carbon elements contained in the steel.
3. Obtain the relation between welding parameters and the width of heat affected zone

METHODOLOGY

The calculation step program follows the flow-chart shown in Figure 2.

The first step. Start and prepare the program and proceed with designing the program workflow and arranged in the flowchart diagram.

The second step. Compile a database of metal-based on the chemical which will be welded based on the chemical content and mechanical properties. Classify the steel based on the chemical contained.

The third step. Calculate the carbon equivalent and plot into Graville diagram at points (CE, C). From this point, it concluded that steel could be welded or not.

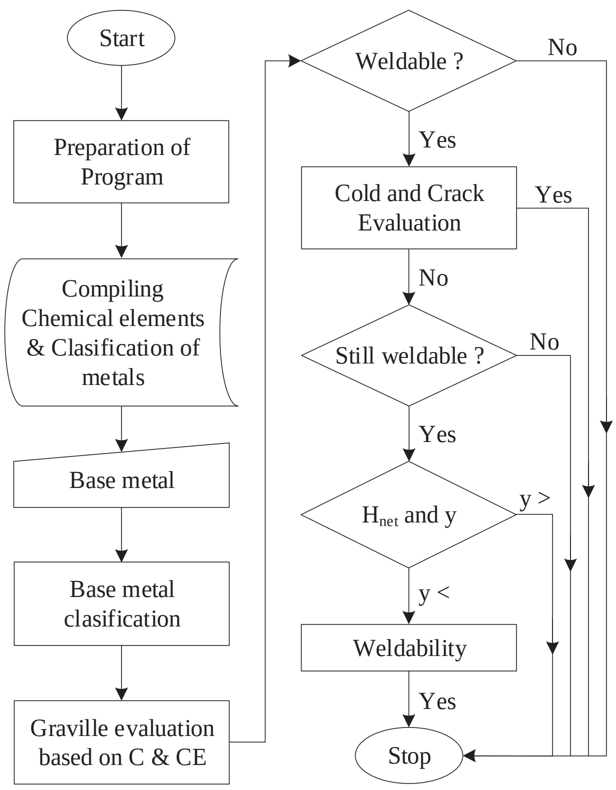

Figure 2 Flowchart for calculation

The third step. Calculate the carbon equivalent equivalent and plot into Graville diagram at the coordinate points (CE, C). From this point can be concluded whether steel could be welded or not. If he metal could weld, the process continues to the crack (cold and hot) evaluation step. If the metals not be welded, the process stops.

The fourth step. Evaluate cold and hot crack. If there is no crack, the process continues to evaluate the heat input. Nevertheless, if the crack occurs, the process stops.

The fifth step. Evaluate heat input. If y <, then the process continues to weldable. If y >, the process stops – also.

RESULTS AND DISCUSSION

W Welding parameters involved in this program arranged, including chemical content, electrodes diameter, electric currents, electric voltages, travel speed, metal thickness to be welded, and heat input.

By plotting (CE, C) in Graville Diagram, it can show whether steel is weldable or not. Weldability involves hot and cold cracks, and both depend on the chemical element content of base metals.

Electrode diameter is affected by steel thickness, current, and voltage.

CONCLUSION

Based on research has been done can be concluded as follows:

1 The results obtained allow the program to determine hot and cold crack susceptibility of steel to be weld.
2 This program can predict weldability using carbon equivalent (Tremlett, Det Norske Veritas, International Institute of Welding and Polish Standards) with carbon elements in the steels welded through the Gaville Diagram.
3 The program can predict the width of the heat affected zone based on heat input, electric voltage, electric current, travel speed, electrode diameter, and welded plate thickness.

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Note: The responsible for English language is lector from Diponegoro University