MODELLING, PREDICTION AND OPTIMIZATION OF DILUTION ON AUSTENITIC STAINLESS STEEL (AISI 316L) SURFACING OF LOW CARBON STEEL (AISI 1020) USING ROBOTIC ARC WELDING

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"I hereby declare that I have read this thesis and this work is sufficient in terms of concept and quality for the award of a Bachelor of Mechanical Engineering (Design and Innovation)"

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This thesis is submitted to fulfill part of the requirement for the entitlement of Bachelor Degree in Mechanical Engineering (Design and Innovation)

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STUDENT DECLARATION

"I declare that this report is the result of my own work except for the summary and every passage I only have a clear source and references "

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Specially dedicated to my parents for tender support and also to my project supervisor who has fully guided me throughout the course of this research

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ABSTRAK

Permukaan teknologi dengan menggunakan teknik pemendapan kimpal seperti pelapisan, sukar dihadapi, buttering biasanya digunakan dalam pelbagai komponen kejuruteraan untuk meningkatkan kualiti dan kekuatan struktur. Untuk pelapisan keluli tahan karat, pemilihan parameter kawalan proses optimum adalah satu cabaran utama yang akan memberi kesan kepada peratusan pencairan yang secara tidak langsung memberi kesan kepada kualiti pelapisan. Tradisinya, faktor pada satu masa adalah percubaan dan kesilapan kaedah yang bukan sahaja memakan masa tetapi juga bergantung kepada pengetahuan dan pengalaman kakitangan yang terlibat pada masa. Satu percubaan telah dibuat dalam kajian ini untuk menyiasat secara sistematik, pencairan peratusan keluli karbon rendah (AISI 1020) ke atas keluli tahan karat (AISI 316L) dengan menggunakan reka bentuk eksperimen (DOE) metodologi. Dengan menggunakan Kaedah Permukaan Respon (RSM) dengan lima tahap empat faktor utama teknik reka bentuk komposit model matematik telah dibangunkan. Model yang dibangunkan telah disahkan dengan diperiksa untuk kecukupan dan kepentingan dengan menggunakan analisis varians (ANOVA) teknik dan keputusan yang diperolehi telah dibentangkan dan dipersembahkan dalam bentuk grafik untuk membincangkan utama dan interaksi kesan pembolehubah kawalan proses yang terlibat apabila tindak balas.

ABSTRACT

Surfacing technology by applying weld deposition technique such as cladding, hard facing, buttering is commonly used in various engineering components to improve the quality and structural strength. For stainless steel cladding, selection of optimum process control parameters is a major challenge which will affect the dilution percentage that indirectly affects the clad quality. The traditional, one factor at a time is a trial and error method which is not only time consuming but also totally dependent on the knowledge and experience of the personnel involved. An attempt was hence made in this research to systematically investigate, the percentage dilution of low carbon steel (AISI 1020) over Stainless steel (AISI 316L) by adopting the design of experiments (DOE) methodology. By applying Response Surface Methodology (RSM) with five level four-factor central composite design technique the mathematical models were developed. The developed models were verified with checked for the adequacy and significance by applying analysis of variance (ANOVA) technique and the results obtained were tabled and presented in graphical form to discuss the main and interaction effects of process control variables involved upon response. It has been found that Current, Voltage and Torch Speed highly affect the dilution percentage of cladding.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO SURFACING TECHNOLOGY

Surfacing technology by applying weld deposition technique is commonly used in variety engineering components to improve the quality and structural strength. In this technique, welding process carried out to depositing the material on industrial components to develop the surface structure and properties. Material failure due to wear and corrosion in many industries had been critical issues, although the materials undergone surface hardening heat treatment and protective coatings as quality improvement work. These materials will reduced in size after long term service due to wear which no longer can be use unless upgrading works, rebuilding or replacement need to conduct. Weld surfacing is a very efficient and cost-effective work and proven method for depositing high protective coatings and welding consumes low cost of rebuilding work. Weld surfacing effect on the applied components regarding to performance and component life depends upon type of surfacing material and application process.

Surfacing technology can be classified according to the purposes of the technique used and its application. Surfacing can be categorized into few types, which are cladding, hardfacing and buttering. Cladding process is depositing a material layer over a base metal mainly for corrosion resistance. Austenitic stainless steel shows very excellent corrosion resistance surfacing alloy and together with good high temperature properties.

In industries, this material used to cladding of boilers, pressure vessel components, chemical and petrochemical industries and also food industries .Hardfacing process mainly applied for wear resistance, whereby hard material is deposited over softer or more ductile material. Surfacing alloy, martensitic steel which high carbon contain used in hardfacing shows excellent abrasive wear and thermal shock resistance and moderate corrosion resistance. These alloys are used for metal-to-metal wear application and widely used for hardfacing of steel mill rolls. Buttering process usually carried out on worn out components by rebuild it to required size through depositing material layer by welding so that can use it back into service.

1.2 PROBLEM STATEMENT

In this thesis, the material surfacing of austenitic stainless steel AISI 316L carry out onto the low carbon steel AISI 1020 base plate. Cladding method applies in this project through weld deposition technique by using robotic arc welding. During this process, the percentage of dilution of the base metal over weld bead penetration should minimize by regulating the process variables. By developing the mathematical models, the prediction and optimization of the dilution percentage need to investigate.

1.3 OBJECTIVES

1. To investigate and study the relationship between the process variables and dilution during Austenitic Stainless Steel AISI 316L surfacing to develop mathematical models by using Robotic Arc Welding
2. To predict and compare the developed model for optimization of dilution.

1.4 SCOPE

In order to fulfill the objective of this thesis, a study to understand the theory and controlling of percentage dilution in weld surfacing should carry out in this project. Hence, the literature review on welding process and basic operation of the robotic arc welding should study. Importantly, application of design of experiment methodologies to develop mathematical models for prediction of responses and optimization should understand well.

CHAPTER 2

LITERATURE REVIEW

2.1 SURFACING TECHNOLOGY

Surfacing technology by applying weld deposition technique is commonly used in variety engineering components to improve the quality and structural strength. In this technique, welding process carried out to depositing the material on industrial components to develop the surface structure and properties. Material failure due to wear and corrosion in many industries had been critical issues, although the materials undergone surface hardening heat treatment and protective coatings as quality improvement work. These materials will reduced in size after long term service due to wear which no longer can be use unless upgrading works, rebuilding or replacement need to conduct. Weld surfacing is a very efficient and cost-effective work and proven method for depositing high protective coatings and welding consumes low cost of rebuilding work. Weld surfacing effect on the applied components regarding to performance and component life depends upon type of surfacing material and application process (R.Arulmani and Sunil Pandey, 2004)

2.2 CLADDING METHOD

Cladding technique can be classified as a process of depositing a thick layer of metal with relative thickness by using appropriate filler metal on a low carbon steel base metal. Cladding process over carbon based or low alloy steel can be conduct in few methods including weld overlaying, explosive bonding, roll bonding and "wallpapering". "Wallpapering" is well known as sheet lining method whereby thin corrosion resistant metal sheet alloys are edge welded to the carbon based steel structure. Commonly, weld overlaying method widely used in surface cladding of fabricated steel structures which mainly for achieving a corrosion resistant surface and treating worn out parts. In industrial applications, cladding process used for boiler and pressure vessel components, chemical and petrochemical industries and also food industries. Types of stainless steels widely used as cladding material due to excellent corrosion resistance combined with good high temperature properties.(James F. Jenkins. P.E.)

2.2.1 Weld Cladding Technique

Welding is one of technique usually applied for cladding process. Usually, weld overlaying concept used to clad over metal surface with filler material through welding process. Gas metal arc welding (GMAW) is one of welding types which widely used in many industrial operations. The gas metal arc welding process parameters influencing the weld bead geometry of the weldment to obtain good weld quality. Even though welding method applied for cladding process, there is a huge different in between cladding and welding a joint in terms of percentage of dilution. The properties and composition of cladding are highly influenced by dilution obtained. Controlling the dilution percentage in cladding very important, specifically low dilution is highly recommended. At the low dilution, the deposit composition of two different metals will be closer to that of the filler metal and corrosion resistance of cladding will also be improved (T.Kannan and N.Murugan, 2006)

2.3 ROBOTIC ARC WELDING (GMAW)

Gas metal arc welding can be explained as welding process that produces deposition of melted metals through heat to the welding arc between workpiece and feeding filler metal electrode (consumable). The wire electrode which release from reel continuously by an automated wire feeder will feed through welding torch with internal contact tip. Welding arc which transfer heat will create internal resistive power to melt the filler wire. Welding arc is concentrated with heat from the melting filler electrode end towards molten weld pools and transferring process of molten metal takes place to weld pool. Shielding gas mixtures act as protective agent to prevent contaminants at atmosphere to the molten weld pool and electrode wire. Generally, application of automation in arc welding, process parameters should well categorized and established in robotic welding system. In robotic welding system, welding procedure selection must be perfectly applied to ensure perfect bead quality obtained (I.S.Kim et al., 2002)

Figure 2.1: Arc welding robot (GMAW),(UTeM,FKP Laboratory)

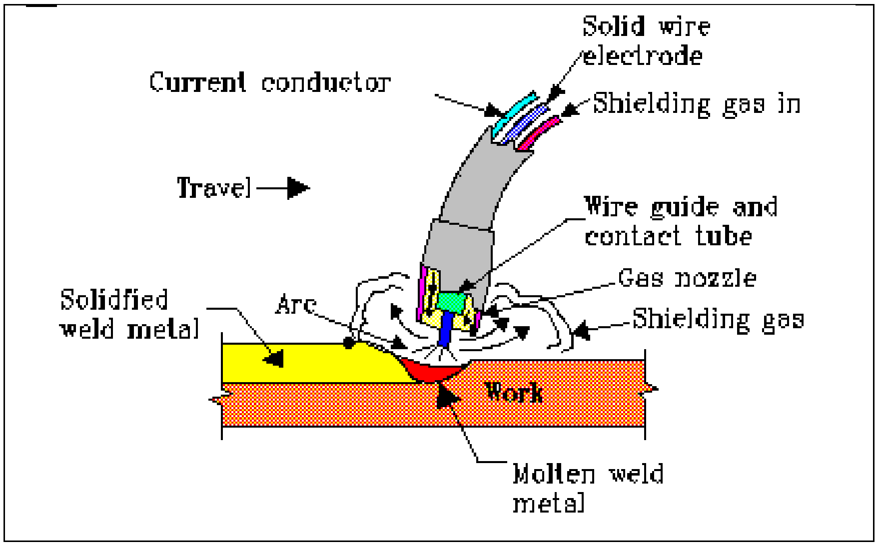

Figure 2.2: GMAW welding (MIG welding)

2.3.1 Welding current

Welding current is the most influencing process variable in arc welding. The current flow rate will controls the depth of fusion, electrode burn off rate and geometry of the weldment.

2.3.2 Welding voltage

Voltage differentiates the electrical potential between the welding wire tip and molten weld pool surface. It determines the weld reinforcement and shape of the fusion area. High welding voltage produces flatter, wider and less deep of weld penetration rather than low welding voltages. Optimum arc voltage produces maximum depth of penetration.

2.3.3 Welding speed

Welding speed can be classified as travelling rate of the electrode along the workpiece or travelling rate of workpiece under the electrode along the welding point. Some statements generally can be made regarding speed of travel. Increasing the travelling speed by maintaining arc voltage and current constantly will reduce the width