APPLICATION OF FINITE ELEMENT ANALYSIS (FEA) TO ANALYZE THE EFFECT OF DIFFERENT ELECTRODE SIZE IN MIG WELDING PROCESS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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FACULTY OF MANUFACTURING ENGINEERING
2010
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Application of Finite Element Analysis (FEA) to Analyze the Effect of Different Electrode Size in MIG Welding Process

SESJI PENGAJIAN: 2009/10 Semester 2

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ABSTRACT

This thesis presents a finite element method in numerical study of two dimensional transient heat conduction to determine the temperature distribution by using MSC Patran software. The execution of the analysis was done by using MSC Patran software where its shows area that have been affected by heat and area that was free from distortions. This method was functional with the usage of temperatures to calculate the heat development and distribution. The analysis implementation was on the stainless steel plate AISI 304L during welding process with using OTC DR 4000 Robot Welding. Three sizes of electrodes with three different voltages were use in this study to analyze their effect to the MIG welding process. The effect of microstructure changes in welded 304L stainless steel induced by the processes of welding was investigated in the experiment using metallography method. The hardness test was carried out for the weld joint at the weld metal area, heat affected area and base metal area to know the properties of stainless steel after welding.
ABSTRAK

DEDICATION

I dedicated this report for my parent, my supervisor and my friends. Without their patience, understanding, support, and most of love, the completion of this work would not have been possible.
ACKNOWLEDGEMENT

Alhamdullillah, praise to Allah Almighty for His blessing and His love for giving me a chance to complete this project. I wish to thank University Teknikal Malaysia Melaka because give me the good facility and environment to do this project.

My deepest gratitude goes to my Project Supervisor, En. Mohd Shukor Bin Salleh, for his technical and moral support in the initiation and successful completion of the research. His valuable criticism, fruitful discussion and continuous guidance were the source of great inspiration to me. Special thanks to all the technical staff in laboratory and workshop in FKP especially Mr. Safarizal bin Madon and Mr. Fakhrulnaim bin Ibrahim for their continuous and kind assistance.

Last but not least I am very grateful to my family and friends for their support and patience during the studies. Without their support, this thesis could not have been completed. I dedicate my report to them for their love, guidance, sacrifice and encouragement.
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<td>2 Dimension</td>
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<td>3-D</td>
<td>3 Dimension</td>
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<td>EDM</td>
<td>Electric Discharge Machine</td>
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<td>FE</td>
<td>Finite Element</td>
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<td>Finite Element Analysis</td>
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<td>HAZ</td>
<td>Heat Affected Zone</td>
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<td>Hydrochloric Acid</td>
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<td>HNO₃</td>
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CHAPTER 1
INTRODUCTION

1.1 Introduction

Fusion welding processes are widely used for fabrications in many engineering applications such as aerospace, automotive and shipbuilding industries. A Metal Inert Gas (MIG) welding process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. The heat source causes highly non-uniform temperature distributions across the joint and the parent metals. Therefore, the thermal expansion and contraction during heating and subsequently cooling as well as material plastic deformation at elevated temperatures result in inevitable distortions and residual stresses in the joint and the parent metals, which greatly affects the fabrication tolerance and quality (Michaleris et. al, 2000). In current industrial practice, welding processes are developed largely based on trial and error experiments incorporating with engineers knowledge and experience of previous similar designs. Simulation tools based on Finite Element (FE) method are very useful to predict welding distortions and residual stresses at the early stage of product design and welding process development (Gery et al., 2005).

Metal Inert Gas (MIG) is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. The wire is fed to the arc by an automatic wire feeder, of which both push and pull types are employed, depending on the wire composition, diameter and welding application. The temperatures that generated in MIG are relatively low (Messler, 2000).
Consequently, this method is suitable only for the thin sheets and section of less than 6mm, otherwise incomplete fusion may occur. The operation is easy to handle and is used very commonly for welding ferrous metals in thin sections. Pulsed arc systems are used for thin ferrous and nonferrous metals. This process is suitable used for welding most ferrous and nonferrous metal and is used extensively in the metal fabrication industry. Because of the relatively simple nature of the process, the training of operators is easy. The process is versatile, rapid and economical and welding productivity is double that of the SMAW process. This GMAW process is currently one of the most popular welding methods, especially in industrial environments. It is because the GMAW process can be automated easily and lends itself readily to robotics and to flexible manufacturing systems (Kalpakjian and Schmid, 2006).

Shielding gases are necessary for gas metal arc welding to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The choice of a shielding gas depends on several factors, most importantly the type of material being welded and the process variation being used. Pure inert gases such as argon and helium are only used for nonferrous welding; with steel they do not provide adequate weld penetration (argon) or cause an erratic arc and encourage spatter (with helium). Pure carbon dioxide, on the other hand, allows for deep penetration welds but encourages oxide formation, which adversely affect the mechanical properties of the weld. Its low cost makes it an attractive choice, but because of the reactivity of the arc plasma, spatter is unavoidable and welding thin materials is difficult. As a result, argon and carbon dioxide are frequently mixed in a 75%/25% to 90%/10% mixture (Craig, 1991). Generally, in short circuit GMAW, higher carbon dioxide content increases the weld heat and energy when all other weld parameters (volts, current, electrode type and diameter) are held the same. As the carbon dioxide content increases over 20%, spray transfer GMAW becomes increasingly problematic, especially with smaller electrode diameters (Craig, 1991).
Most applications of gas metal arc welding use a constant voltage power supply. As a result, any change in arc length (which is directly related to voltage) results in a large change in heat input and current. A shorter arc length will cause a much greater heat input, which will make the wire electrode melt more quickly and thereby restore the original arc length. This helps operators keep the arc length consistent even when manually welding with hand-held welding guns. To achieve a similar effect, sometimes a constant current power source is used in combination with an arc voltage-controlled wire feed unit. In this case, a change in arc length makes the wire feed rate adjust in order to maintain a relatively constant arc length. In rare circumstances, a constant current power source and a constant wire feed rate unit might be coupled, especially for the welding of metals with high thermal conductivities, such as aluminum (Lincoln, 1997).

Electrode selection in MIG is based primarily on the composition of the metal being welded, but also on the process variation being used, the joint design, and the material surface conditions. The choice of an electrode strongly influences the mechanical properties of the weld area, and is a key factor in weld quality. In general, the finished weld metal should have mechanical properties similar to those of the base material, with no defects such as discontinuities, entrained contaminants, or porosity, within the weld. To achieve these goals a wide variety of electrodes exist. Depending on the process variation and base material being used, the diameters of the electrodes used in GMAW typically range from 0.7 to 2.4 mm, but can be as large as 4 mm. The smallest electrodes, generally up to 1.14 mm are associated with the short-circuiting metal transfer process, while the most common spray-transfer process mode electrodes are usually at least 0.9 mm (Craig, 1991).
1.2 Project Background

A fusion weld like MIG produce several distinct microstructural zones in pure crystalline of stainless steel metal. This different zones correlate reasonably well with various transformations on appropriate phase diagrams except for where resulting structures deviates from equilibrium significantly (e.g martensite in steels). The fusion zone (or weld metal in a metal) is the portion of the weld that melted during welding, having been heated to above the temperature where melting just begins for the material being welded. The heat-affected zone HAZ is the portion of the base material that was not melted but whose properties were altered by the heat of welding through some phase transformation or reaction. The unaffected base material is the portion of the base material wherein the welding heat did not exceed the minimum required to affect it structure or properties. The weld zone encompass the fusion, partially melted and heat-affected zone, since this is the region where base material properties are effected by welding.

For this reason, the research of using the different heat input in welding the stainless steel metal was conduct to know their effect to the welding area. One of the purpose of this research is to know the properties of the weldments metal. The another purpose is to know the distortion of the welded two welded steel. The distortion in a weldment can arise when thermally induced stresses are unrestrained.

There are three fundamental dimensional changes taking place during welding can cause distortion in weld fabricated structures or weldment:

(a) Transverse shrinkage that occurs perpendicular to the weld line,
(b) Longitudinal shrinkage that occurs parallel to the weld line and
(c) Any angular change that consist of rotation that occurs around the weld lines.

This project experimental data was compared to finite element analysis (FEA). This FEA consists of a computer model of a material or design that is stressed and
analyzed for specific results. It can be used in new product design, and existing product refinement. A company is able to check if a proposed design is able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

1.3 Problem Statement

Welding is one of major and principal activities in today’s industrial applications. The performance of these industries as regards productivity, meeting delivery schedule, the product quality, etc. depends very much on the structural design and welding technology adopted in these area as well as the distortion control measures implemented during fabrication. In the entire welding process plays a very important role as far as productivity and quality of the end product is concerned. Weld induced distortion is one major problem areas in industrial applications. The problem become acute in case of thin wall fabrication. Like in the shipbuilding industry, the naval vessel with weight restriction are using more and more high tensile steels leading to the use of thinner plates. Unless suitable distortions rendering them unaccepted without fairing. Hence the welding techniques and the associated weld distortion problems encountered in shipbuilding industries are very typical and they are to be dealt with from a view point of shipbuilding requirements. The welding and structural design engineers in shipyards thus face a real challenge to deliver a distortion free product and to minimize the post weld fairing requirements. During the MIG welding, the uniform temperature distribution during the thermal cycle, incompatibility strains lead to thermal stresses. These incompatible strains due to the dimensional change associated with solidification of the weld metal, metallurgical transformations and plastic deformation are the main source of the residual stresses and distortion in this welding. The effect of the weldment has influence on the brittle fractures, fatigue crack propagation and structural instability strength. Traditionally, welding analysis used non destructive procedure or experimental