UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SURFACE MODIFICATION OF MILD STEEL USING ALUMINA POWDER CERAMIC PARTICLES AND TIG TORCH WELDING

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in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled " Surface Modification Of Mild Steel Usinf Alumina Powder Ceramic Particles And TIG Torch Welding" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date : 11/01/2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (BMMV) with Honours.

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DEDICATION

Thank you to both my dear parents, Mr Dulah Aspa Bin Rahmat and Mrs Kholifah Binti Md Jais and my siblings for their guidance, support and prayers. My deepest appreciation to my supervisor, Ir. Ts. Dr. Lailatul Harina Binti Paijan who has given me guidance and assistance in preparing this report

ABSTRACT

Mild steel materials are widely used in construction industry for structural components, pipes, oil and gas industry, automotive industry, equipment and machinery. This material has good properties in ductility, machinability and weldability and is a low-cost material. However, it was found that this material has low hardness and wear properties which limit the material's ability for wider applications. The way to overcome this problem is the process of surface modification using TIG torch welding where alumina powder (Al_2O_3) will be used as a coating on mild steel. The process parameter for this works consists of gas flow rate in the range from 20 L/min to 25 L/min and current from 90 A to 120 A. The modified surface produced from the surface modification was characterized using optical microscope, scanning electron microscopy (SEM), hardness tester, X-ray diffraction (XRD) and surface roughness tester. Based on the results, it was demonstrated that the modified surface layer produced maximum hardness of 97.7 HRB with melt layer of 2.0 mm in sample processed under current of 25 L/min. The development of martensite structure contributes to the enhancement of hardness properties. It was found that the intermetallic compound of iron aluminum (FeAl) and iron oxide (FeO_3) were detected from XRD result which indicating the presence of alumina particles in the modified surface layer. Overall, it can be shown that this surface modification can lead to the enhancement on the surface properties with greater surface roughness and hardness qualities, which can be used for wear applications in a variety of sectors.

ABSTRAK

Bahan keluli lembut digunakan secara meluas dalam industri pembinaan untuk komponen struktur, paip, industri minyak dan gas, industri automotif, peralatan dan jentera. Bahan ini mempunyai sifat yang baik dalam kemuluran, kebolehmesinan dan kebolehkimpalan dan merupakan bahan kos rendah. Walau bagaimanapun, didapati bahawa bahan ini mempunyai kekerasan rendah dan sifat haus yang mengehadkan keupayaan bahan untuk aplikasi yang lebih luas. Cara untuk mengatasi masalah ini ialah proses pengubahsuaian permukaan menggunakan kimpalan obor TIG dimana serbuk alumina (Al_2O_3) akan digunakan sebagai salutan pada keluli lembut. Parameter proses untuk kerja-kerja ini terdiri daripada kadar aliran gas dalam julat dari 20 L/min hingga 25 L/min dan arus dari 90 A hingga 120 A. Permukaan diubah suai yang dihasilkan daripada pengubahsuaian permukaan telah dicirikan menggunakan mikroskop optik, mikroskop elektron pengimbasan (SEM), penguji kekerasan, pembelauan sinar-X (XRD) dan penguji kekasaran permukaan. Berdasarkan keputusan, telah ditunjukkan bahawa lapisan permukaan yang diubah suai menghasilkan kekerasan maksimum 97.7 HRB dengan lapisan cair 2.0 mm dalam sampel yang diproses di bawah arus 25 L/min. Perkembangan struktur martensit menyumbang kepada peningkatan sifat kekerasan. Didapati sebatian antara logam aluminium besi (FeAl) dan oksida besi (FeO_3) telah dikesan daripada keputusan XRD yang menunjukkan kehadiran zarah alumina dalam lapisan permukaan yang diubah suai. Secara keseluruhannya, dapat ditunjukkan bahawa pengubahsuaian permukaan ini boleh membawa kepada peningkatan pada sifat permukaan dengan kualiti kekasaran dan kekerasan permukaan yang lebih besar, yang boleh digunakan untuk aplikasi haus dalam pelbagai sektor.

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LIST OF SYMBOLS AND ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
PVD	-	Physical Vapor Deposition
CVD	-	Chemical Vapor Deposition
TIG	-	Tungsten Inert Gas
SEM	-	Scanning Electron Microsopy
XRD	-	X-ray Diffraction
Al_2O_3	-	Alumina Powder
ASTM	-	American Society for Testing and Materials
ASTM	-	American Society for Testing and Materials
MPa	-	Megapascal
GPa	-	Gigapascal
°C	-	Degree Celsius
GTAW	-	Gas Tungsten Arc Welding
GMAW	-	Gas Metal Arc Welding
SMAW	-	Shielded Metal Arc Welding
Al	-	Aluminum
Zn	-	Zinc
MAB	-	Manganese-Aluminium- Bronze
MIG	-	Metal Inert Gas
PAW	-	Plasma Arc Welding
WC	-	Tungsten Carbide
Ti	-	Titanium
Si	-	Silicon
C	-	Carbide

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CHAPTER 1

INTRODUCTION

1.1 Background

Mild steel is often used in engineering, making specific shapes to build convenience tools for humans. The purpose of mild steel is to create products in the industry widely, making it one of the most popular steels. Its uses in today's society are structural steel, signage, cars, furniture, fences, etc.

The usage of a material created by surface treatment can produce hardness from the start. Surface treatment improves wear, abrasion, corrosion, oxidation, and indentation resistance. Heat treatment is included in the surface treatment class for this treatment. Metal coatings can be used as a surface treatment in a variety of ways to improve a material's mechanical, electrochemical, and thermal performance. The procedure utilized is very dependent on the material used and the desired layer of substance or depth of surface treatment. Although metal and non-metal coating techniques are a vast subject with several advanced technological methods, there are some fundamental concepts and practices that, if understood, can lead to a better understanding of the surface coating process.

In addition, this surface treatment can also change the shape of the structure. Such changes occur as a result of the process of metallography. This metallography is to see the condition on the surface of the finished material. The purpose of this study was to look at the possibilities produced from hard materials by using alumina powder and surface melting techniques in TIG welding. An electric arc provided directly to the surface area maintains the tungsten electrode and the sample. This work aims to develop and characterize a hard surface layer through the solidification of alumina powder to a mild steel surface by the TIG torch coating technique.

1.2 Problem Statement

There are problems encountered in mild steel is due to its resistance to corrosion and low tensile strength, which breaks faster than other steels when under tension. The coating should be done on mild steel to enhance the hardness and surface properties of the material. This coating reinforcement is done to extend and widen the application of mild steel into various applications. As a result, this coating reinforcement can withstand high resistance of the material to hardness and wear properties.

1.3 Objective

The main objective is:

1. To develop a modified surface layer by depositing alumina particles into mild steel using TIG torch process at various current, pulsed, and argon gas flow rate parameters for modified surface layer.
2. To determine the effect of alumina particles for development of hard surface layer on hardness, melt depth, microstructural and surface roughness.

1.4 Scope of project

1. The use of alumina powder functions as a coating reinforcement for mild steel. The parameters used in this study are current (90 – 120 A), pulse-TIG is constant (5 pulse/sec) and gas flow rate (15 – 25 L/min).
2. The hardness tester, optical microscope, scanning electron microscopy, and X-ray diffraction will be used to characterise the changed surface. and surface profile-meter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Carbon steel is a type of mild steel. Another name for mild steel is low carbon steel, because of the total of carbon 0.05% to 0.35% that found in mild steel (Gidado, U. et al., 2020). Therefore, mild steel is valuable for structural materials in buildings, the machining industry, kitchenware and others. There are two properties present in mild steel namely chemical and physical.

The chemical properties of mild steels are mixed with other materials. Often steel is easily exposed to oxides around it, because it is this oxide that will damage the steel so that it can rust and be able to destroy the steel, this allows the occurrence that will be similar to mild steel if left untreated. With the addition that a mixture of other chemicals is able to make mild steel resistant to rust, for example, a popular mixture used on mild steels is chromium because of its effectiveness against exposure to the atmosphere is able to protect corrosion from occurring. Apart from that other element have their own advantages if added in mild steel.

The physical properties of mild steel are suitable for use in industrial places due to the quality of mild steel (Li et al., 2018). Mild steel is divided into several types of by looking at its grade according to their own suitability such as ASTM 1010, ASTM 1020, ASTM A36, ASTM A516, and others. Table 2.1 shows the physical properties found in mild steels which have high tensile strength, high impact, weldability, ductility and so on in industrial use.

Table 2.1 Physical properties of Mild Steel (Mohamed, D.M. et al., 2018)

Density	7850 kg/m^3
Ultimate Tensile Strength	400 – 550 MPa
Yield Strength	250 MPa
Young's Modulus	200 GPa
Melting Point	1450 °C
Thermal Conductivity	50 W/mK

2.2 Surface modification

The purpose of surface modification is the modification of surface properties to improve performance in the biological environment while maintaining the bulk properties of the material. It also increases the specificity of the material to specific cells or ligands to reduce unwanted adhesions/reactions. There are two ways to change the surface structure by thermal and mechanical methods. Often thermal processes are associated with localized heating and controlled cooling to unwanted microstructures.

Adequate shielding of molten metal pools with inert or inactive gases in Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW) and electron beam welding results in cleaner deposits than Shielded Metal Arc Welding (SMAW) and gas welding. Dilution lowers the sediment by mixing the coating material with the molten base metal. Increased liquefaction changes the composition of the deposit, reducing its mechanical properties and performance. During deposition, less dilution is better. The melting depth of the substrate during the test determines the liquefaction. Deeper substrate liquefaction dilutes and lowers sediments (Dwivedi et al., 2018).

Therefore, the quantity of heat provided for melting the substrate during welding and thermal spray operations determines the degree of melting during deposition (welding, spray). Higher the energy density of the process (such laser and plasma arc welding), the less heat needed for substrate melting and dilution (Dwivedi et al., 2018).

2.2.1 Process of surface modification

Surface composition and microstructure are essential factors in improving and extending the material's usability. Mechanical interactions with its environment, such as friction and subsequent wear, and chemical impacts like oxidation and corrosion, are all controlled by the properties of thin layers on the surface, which may differ from bulk and can be chemically microstructurally modified. Surface alloying and coating processes range from basic paint application to complicated electro-plating, nitriding, boron, and surface diffusion treatments. Unfortunately, due to equilibrium solids solubility restrictions, limited solid-state permeability, and bulk material grain development, many standard surface treatments have limitations (Dwivedi et al., 2018).

2.2.1.1 Laser cladding

Laser cladding is a procedure that incorporates the application of manufacturing processes such as coating, prototyping, and repair (Tamanna et al., 2019), and the development of metallurgical solids with these techniques. This laser cladding is utilised on a daily basis in industries such as metallurgy, aerospace, and energy (Chang et al., 2022). Laser cladding works in the same way as arc welding in that it melts the surface and adds material to it in the shape of a wire, strip, or powder. This laser cladding can frequently improve corrosion resistance (Y. Liu et al., 2021).

Dwivedi (2018) found that, high energy density allows quick melting of thin substrate and coating layers, reducing laser cladding heat input. Due to the rapid cooling rate, decreased heat input refines the grain structure and reduces substrate metal dilution (<1%) and thermal damage. An inert gas barrier may protect the molten weld bead from ambient gases during laser cladding. Figure 2.1 shows the process performed in laser cladding on a plate in which the laser is removed from the nozzle. The metal powder will be added to it through the opening of the annulus, whose axis is parallel to the laser beam. The powder will be injected into the gas stream on the plate. Argon will be used as a conveying and gas shield.

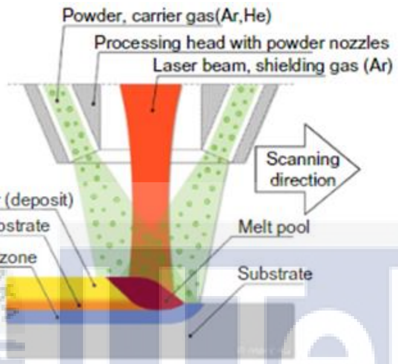

Figure 2.1 Schematic drawing of the laser cladding process head (Zhu et al., 2021)

2.2.1.2 Ion implanting

The introduction of nitrogen ions into a substance is known as ion implantation. An ion source, a high voltage source, a vacuum system, an accelerator tube, a target box, and an electronic system are the two primary components of an ion implantation system. The quadrupole lens, deflector magnet, and sweeper are all included as extra components. The ion dose is determined by the ion current size, the target region, and the length of implantation. The sweep file is bounded by a window, and behind the window is a metal clip holder in good electrical contact condition. (W. Liu et al., 2022).

2.2.1.3 Thermal spraying

This method can be used to coat a wide range of materials and components in order to give resistance to wear, corrosion, cavitation, corrosion, abrasion, and heat. Thermal spraying can also give electrical conductivity or insulation, lubrication, high or low friction, sacrificial wear, chemical resistance, and other surface qualities (Iqbal et al., 2020). The projection of small soft particles onto a cleaned and prepared surface, where they adhere to form a continuous layer, is common to all thermal spraying procedures. The interplay of heat and kinetic energy leads the particles to flatten or "splash" onto the surface and on top of one another, resulting in a thick coating of successive layers.

According to Iqbal et al (2020), thermally sprayed zinc-based alloys are often employed to safeguard steel buildings because of its high durability in seawater and lower electronegativity than steel, allowing it to act as a sacrificial anode. Assume, however, that the coating is subjected to high humidity or hostile species such as chloride or sulphate ions. The Zn in the solution will dissolve, resulting in a thinner protective layer and localised corrosion. This is meaningless when Al-based alloys are employed for corrosion prevention. A well-known thermal spraying method for the deposition of zinc-based compounds is wire arc.

In general, corrosion is slowed in zinc and aluminium alloys by two different protection mechanisms: passivation due to the formation of aluminium oxide, which protects the surface from corrosive elements, and acting as a sacrificial anode due to the electropositive nature of the zinc, which extends the service life of the substrate.

2.3 Type of welding

The fusion between two metal metals is known as welding, and it is done between metal and metal that is joined together by means of heat, pressure or both forming a join as the parts.

2.3.1 Shielded metal arc welding (SMAW)

SMAW welding is a kind of heat-shielded arc welding created by an electric arc between the electrode's end and the metal to be welded (Munawar et al., 2018). The SMAW is a tool that can connect joint structures, repair work, and maintenance. This process is widely used in industry because it is simple to use.

Munawar et al. (2018) discovered in his publication that SMAW welding has an impact on mechanical properties with heating treatment on S45C steel. The higher the heating temperature, the more powerful the material. Heating temperature changes are well known to induce a change in the hardness value of the material; the higher the given temperature, the larger the hardness value of the material. The difference in metal structure between a specimen that had not been heated and a specimen that had been heated at 150 °C, 250 °C, and 300 °C was then assessed using microstructure testing. The microstructure was discovered after 3 seconds of sanding, polishing, and etching with a 5% sulfric acid solution.

There is a structural change in microstructure when the primary composition of a microstructure consisting of ferrite, martensite, and pearlite changes either in proportion or distribution. The difference in microstructure resulted in a change in tensile, impact, and hardness strength. The ratio of ferrite composition in specimens without heating treatment is more than that of heat treatment up to 300 °C. With each rise in heating temperature, the material's hardness and toughness (impact) diminish, but its tensile strength increases.