AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

MECHANICAL PRODUCTION DEPARTMENT

Development of technique(s) for cladding of metal-ceramic composite layer on metallic surface(s)

A Thesis submitted in partial fulfillment of the requirements of the

M.Sc. in Mechanical Engineering

By

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B.Sc. Mechanical Engineering, Design and Production Department

Ain Shams University, 2019

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STATEMENT

This thesis is submitted as a partial fulfillment of M.Sc. degree in Mechanical engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Abstract

Steel coating to enhance corrosion and wear resistance has been a research focus for a long time. Laser cladding of low carbon mild steel with Aluminum Silicon Carbide metal matrix composite and Aluminum Molybdenum carbide metal matrix composite has been investigated in this thesis. Laser cladding process was implemented using a 4.4 kW (Nd:YAG) laser cladding machine with multi powder hopper feeding system Laser power and laser scan speed has been changed to form the experimental matrix. Laser power was changed from 0.9 kW to 1.2 kW with step 0.1 kW. Laser scan speed was chosen to be 0.9 m/min to 1.1 m/min with step 0.1 m/min.With maintaining spot diameter constant, preheating temperature, standoff distance, carrier gas flow rate and powder feed rate at values of 4 mm , 400 °C, 12 mm , 2 $l/min.$, 1.8 l/min respectively .

Clad geometry aspects have been investigated through different laser energy densities. Clad height, width, penetration are measured geometry aspects that were measured on the cross section of the samples using microscope. SEM and EDX analysis were implemented on three samples from each clad material at different energy density range to check the diffusion layer formation. Mechanical and chemical properties of the different clad layer material have been investigated at laser energy density of 25.48 $\mathrm{J/mm^2}$ in which full clad layer was obtained.

Results showed that clad geometry gets better forming clad layer with the increase of energy density and a slight increase in clad layer quality has been observed at the Al-SiC clad. Wear results has shown that Al-SiC has the best wear resistance while Al-Mo2C was the worst. Corrosion resistance results showed that Al-Mo2C has the best corrosion resistance and Al-SiC was lower but both still better than uncl1added mild steel.

Key words:

Laser cladding, MMC, Wear, corrosion, clad geometry

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Chapter 1: Introduction

Mild steel is a commercial common use material in all heavy industries such as automotive industries, steel structures and production lines and machinery. Such commercial common use of mild steel is due to several properties that make it the most economical alternative. The main property of mild steel is its mechanical and chemical properties within its cheap price. It is known for its excellent mechanical properties combined together such as hardness, tensile, stiffness and strength.

One of the major drawbacks of mild steel is its low corrosion resistance that limit its use in any corrosive environment such as pumps and navy machinery. Also the second drawback of mild steel in mechanical applications is its low wear resistance in relative motion applications.

Overcoming such drawbacks have been the focus of this research to solve them combined by enhancing the wear and corrosion resistance. Getting such combined property can be found in metal matrix composites by mixing a corrosion resistant base metal such as aluminum with a high wear resistance ceramic material such as Silicon Carbide and Molybdenum Carbide. Steel coating with such composite on the contact surface of wear and corrosion is the solution of the above-mentioned drawbacks.

Several methods of coating can be used in such process such as hot dipping, thermal spraying using plasma, frictional surfacing and laser cladding. Laser cladding has been chosen to be used in this research for several aspects such as ease of controlled mixing of the metal matrix composite by multi feeding system and precise control of the mixture percentage and controlling the energy density applied in the process by controlling the CNC controlled robot.

The process was done using a laser cladding machine in the National Laser center in CSIR, Pretoria, South Africa. Cladding materials were powder

supplied from the metallurgy lab in the National laser center and the substrate material was mild steel sheets with thickness of 10 mm cut according to the experimental procedures.

Chapter 2: Literature review

2.1. Steel properties and applications

Low carbon mild steel is one of the most common industrial material. It is the fundamental component of structures like bridges, buildings etc. It is widely used in storage tanks, ship building (1). In addition, it is used commonly in mechanical applications such as vehicles and due to excellent mechanical properties combined together such as hardness, tensile, stiffness and strength (2). As shown in **Figure 2-1** ranges of tensile strength of different materials indicate that steel is in the top range of tensile strength materials among the metals, which make it unique in mechanical applications. Machinability and formability of steel is one of the main mechanical aspects that make steel on the top of the most used metal in sheet metal manufactured products (3).

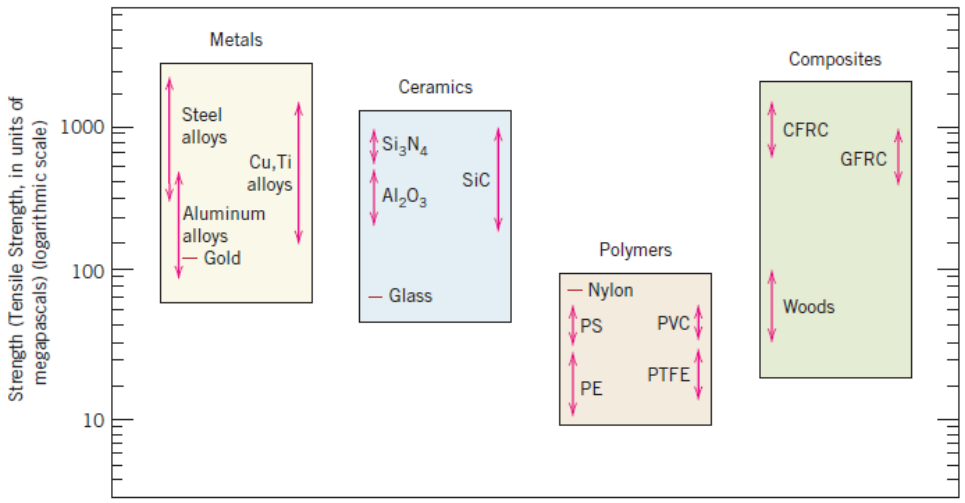

Figure 2-1 Bar chart of room temperature strength (i.e., tensile strength) values for various metals, ceramics, polymers, and composite materials (2).