The Effect of Nd:YAG Laser Beam on Aluminum Surface Coated with Fe-SiC

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Physics

Faculty of Science
Universiti Teknologi Malaysia

November 2013

I dedicate this work

To the sole of my dear parents

Whose love, kindness, patience and prayer have brought me this far
To my friends
For their love, understanding and support through my endeavour

To my siblings
For their endless laughs and tears

ACKNOWLEDGEMENT

First and foremost, my unlimited and sincere appreciation goes to the Lord of the seven heavens and earth ALLAH (SWT) for His endless mercies, blessings and guidance through from birth till now and forever. Alhamdullahi Robi Alamin.

First my sincere appreciation goes to my supervisor Professor Dr. Noriah Bidin for her continued guidance, support and encouragement to ensure this work is a successful.

My earnest appreciation also goes to all my friends particularly my dear friend Mohd Shafiq bin Shaharin that contributed to this successful project.

I shall forever be grateful to the soul of my parents, my siblings, their families and my Imam for their unending support, financially; morally, spiritually and emotionally. To them I am highly indebted and words alone cannot describe my gratitude. I pray to ALLAH (SWT) make you reap the fruit of your labour on me, Jazakum Allau Khyran.

ABSTRACT

Laser ablation on aluminium base coated with Fe-SiC is reported. A q-switched Nd:YAG laser was employed as a source of energy. The fundamental wavelength of the laser beam is 1064 nm with output energy of 100 mJ and pulse duration of 10 ns. The laser was conducted in repetitive mode with frequency rate of 1 Hz. The laser was focused to induce plasma formation. Pure aluminium plate was employed as a substrate for laser ablation. Metal element iron (Fe) and ceramic material silicon carbide SiC were selected to be as laser ablation elements. Both of the elements were mixed together in a ratio of 2:1 (Fe:SiC). Two step deposition techniques were chosen in this work to predeposite the aluminium substrate. The substrate was painted with cohesive material gum before powder spray coating on it. The predeposit aluminium was then exposed with focused laser at various numbers of pulses (1 – 13 pulses). The created material was examined via scanning electron microscope (SEM), x-ray diffraction (XRD) machine and microhardness Vicker HV machine. The microstructure of the created surface was examined via SEM and the results showed the effect of homogenized resolidified area. The plasma temperature is much higher than the melting point of the laser ablation material Fe and SiC thus immediately after plasma interaction with coating materials most of them are melted. The fluid flow over the surface and resolidified during cooling. However the melting temperature between Fe, SiC and Al are different, this allows new composite formation during quenching. The formation of such new composite is identified through XRD analysis. Inherently, several new composites are revealed such as Al-Fe-Si, SiAl and Fe-Si. The formation of such new composite is also indicators for the increment in the strength of the created materials. This is validated by measuring the hardness of the created material. Apparently, the hardness of the modified surface is confirmed to be two times greater than the original substrate.

ABSTRAK

Laser ablation keatas aluminium yang disalut dengan Fe-SiC dilaporkan. Q-suis Laser Nd:YAG di gunakan sebagai sumber tenaga. Panjnag gelombang asas alur laser ialah 1064 nm demgan tenaga keluaran 100 mJ dan tempoh denyut 10 ns. Laser dikendalikan dalam mode ulangan dengan kadar frekensi 1 Hz. Laser difokuskan untuk mengaruhkan pembentukan plasma. Plat aluminium tulin digunakan sebagai subsrat yang hendaki dialoikan. Unsur logam seperti besi fed an bahan seramic seperti silicon karbid dipilih sebagai unsur aloi. Kedua-dua unsur dicampurkan bersama dalam nisbah 2:1 (Fe:SiC). Teknik dua langkah deposisi dipilih dalam kerja ini untuk pra-deposit substrat aluminium. Substrat disapu dengan bahan lekatan seperti gam sebelum dihemburkan dengan salutan serbuk campuran keatasnya. Pra-deposit aluminium kemudianya di dedahkan dengan laser focus pada pelbagai bilangan denyut (1 -13 denyutan). Bahan aloi diperiksa melalui mikroskop imbasan electron SEM, mesin pembelauan sinar-X, XRD, mesin kekerasan Vicker HV. Mikrostruktur permukaan aloi di periksa melalui SEM dan keputusannya menunjukkan kawasan kesan pembekuan semula yang homogen. Suhu plasma adalah jauh lebih tinggi berbanding dengan takat cair bahan aloi Fe dan SiC serta Al, oleh itu selepas plasma bertindak dengan bahan-bahan tersebut, mereka terus menjadi cair. Ceair kemudian mengalir diatas permukaan dan membeku ketika penyejukkan. Walaubagaimanpun disebabkan suhu lebur antara Fe, SiC dan Al berbeza, ini memberi kesempatan untuk pembentukan komposit yang baru ketika penyejukan. Pembentukan komposit baru seperti itu dikenalpasti melalui analisis XRD. Ternyata beberapa komposit baru ditemui seperti A-Fe-Si, Si-Al, Fe-Si. Pembentukan komposit baru seperti itu juga merupakan petanda pertambahan kekuatan bahan aloi. Ini ditentusahkan melalui pengukuran kekerasan bahan aloi. Kekerasn permukaan yang diubahsuai terbukti dua kali lebih keras daripada subsrat asal.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Laser radiation has great importance in many applications, such as the scientific and industrial applications. The invention of laser has led to a scientific and technological revolution which included the conventional and modern industries, laser helped in bring about tremendous developments for many sciences and application fields and has become one of the modern science achievements (Miglore, 1996). Laser material processing is an advanced and highly efficient manufacturing method. It has been applied into almost all fields of engineering, military, industry, and communication (Majumdar and Manna, 2003). In this work, the effect of laser beam characteristic on the Aluminum alloys and use this laser as a tool to improve the Aluminum Alloys characteristics were studied.

The principle laser surface engineering applications can be divided into three broad areas as shown in (Figure 1.1).

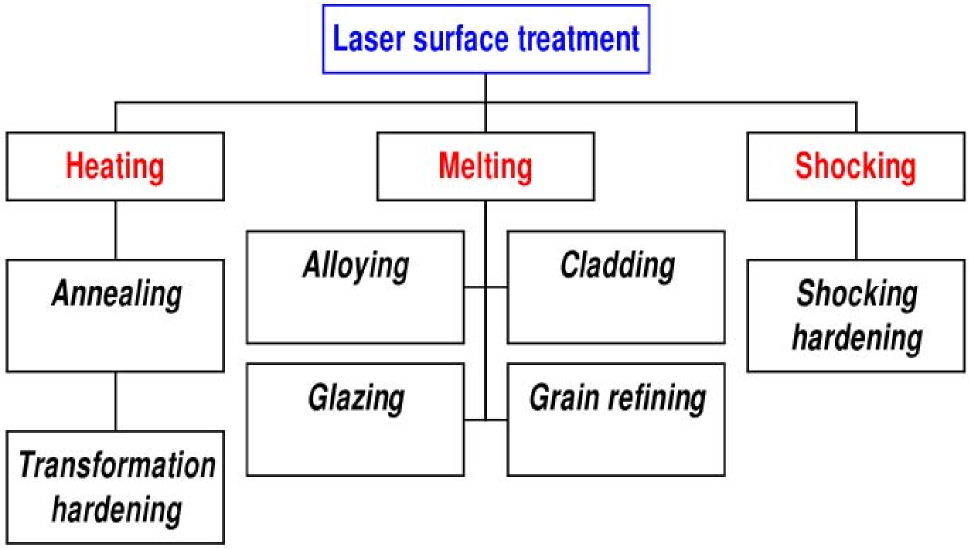

Figure 1.1 Methods of laser surface treatment of materials (Muthu, 1979)

The modification of the surface of any alloy by heat treatment or surfacing techniques provides a solution to the compromise, allowing the specification of the bulk material to be dictated by strength or economic constraints, and the surface only to be tailored for wear, corrosion resistance or other properties desirable for its service use.

There are many techniques to achieve the modification of the materials and alloys surfaces as (Welis, 1978):

Thermal treatments

- Induction hardening
- Flame hardening
- Laser hardening
- Spark hardening
- Electron hardening

Thermochemical diffusion treatments

- Carburizing (gas, liquid, pack)
- Carbonitriding (gas, liquid)
- Nitrocarburising (gas, liquid)
- Nitriding (gas)

Mechanical treatments

- Peening
- Fillet rolling

Laser beam technology has led to the possibility of localized modifications to the microstructures of a range of materials. Such modifications can lead to improve service properties in the surface layers of a component, while leaving the bulk properties essentially unchanged. There are number of mechanisms by which these changes can be brought about, but all depend on the ability to manipulate the laser beam accurately, and on the high power density of the beam. The common advantages of laser surfacing compared to alternative processes are: Chemical cleanliness and cosmetic appearance, minimal heat input, since the source temperature is so high, transformation occurs so quickly and the heat input to the part is very low. This reduces the distortion and the heat-affected zone is very small, no post machining required, non-contact process, ease of integration

Iron aluminides possess several attractive properties motivating significant research and development efforts over the past years (Liu et al., 1998). Iron aluminides (Fe_3Al and FeAl) show excellent surface properties and resistance to oxidation and sulfidation in aggressive environments (Tortorelli *et al.,* 1994; Tortorelli *et al.,* 1995; Tortorelli *et al.,* 1996; Liu et al., 1998 and Banovic et al., 1999). Due to their excellent properties and cost considerations, appropriate compositions of iron aluminides could find applications as coatings on more traditional higher-strength materials with inferior corrosion resistant properties at higher temperatures and/or wear resistance at ordinary temperatures.

1.2 Problem statement

Aluminum is widely used in industry due to its low cost, light weight and excellent formability. But it has weakness like low strength, easy wear, tear and corrosion. The laser alloying method is used to strengthen the aluminum surface normally work for the whole bulk which involves a lot of energy and time consuming. This method applied by melting the substrate surface, and then injecting powder of the alloying material into the melt portion. The most important advantage of this process is the possibility of modifying the properties within a thin surface layer without affecting the properties of the bulk material. In this work we introduced a Q-switch Nd :YAG laser to control and achieve the desired surface properties.

1.3 Research objectives

The purpose of this study was to alloy aluminum surface with Fe-SiC using a Q-switched Nd:YAG laser. In attempt to achieve this goal, the following tasks will be performed:

1. To expose an aluminum target coated with Fe-SiC at different number of pulses
2. To observe the change in microstructure by SEM
3. To analyze the formation of new composite by XRD
4. To measure the microhardness of the samples by hardness machine

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