EFFECT OF FLY ASH PARTICLE SIZE AND COMPOSITION ON THE PROPERTIES OF ELECTRODEPOSITED NICKEL FLY ASH (NI-FA) COMPOSITE COATING ON ALUMINIUM ALLOY 7075 SUBSTRATE

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **EFFECT OF FLY ASH PARTICLE SIZE AND COMPOSITION ON THE PROPERTIES OF ELECTRODEPOSITED NICKEL FLY ASH (NI-FA) COMPOSITE COATING ON ALUMINIUM ALLOY 7075 SUBSTRATE**

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I hereby, declared this report entitled "Effect of Fly Ash Particle Size and Composition on the Properties of Electrodeposited Nickel Fly Ash (Ni-FA) Composite Coating on Aluminium Alloy 7075 Substrate" is the result of my own research
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Author's Name : NORAMIRA BINTI MD AZMI

Date : 21 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Materials) (Hons). The members of the supervisory committee are as follow:

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(Dr. Intan Sharhida binti Othman)

…….....

(Dr. Mohd Shukor Bin Salleh)

ABSTRAK

Abu terbang dengan tiga saiz zarah yang berbeza dan lima komposisi telah disediakan dan dimasukkan dalam substrat aluminium dengan menggunakan proses pengenapan. Kesan saiz zarah abu terbang dan komposisinya ke atas kekerasan dan kakisan komposit nickel-abu terbang pada AA7075 substrat telah disiasat. Pelbagai abu terbang saiz zarah telah disediakan dengan menggunakan bola pengisaran dengan masa pengisaran berbeza (0jam (seperti yang diterima), 4jam dan 8jam). Kemudian, abu terbang ditimbang mengikut lima komposisi (0g / l (nikel tulen), 10g / l, 30g / l, 50g / l, dan 70g / l) untuk mencari komposisi optimum abu terbang. Dengan nisbah peningkatan zarah halus dan komposisi, kekerasan substrat meningkat manakala kadar kakisan menurun dengan ketara. Terdapat beberapa manfaat yang berpotensi yang boleh diperolehi oleh syarikat pesawat selepas kajian ini selesai. Penambahan kedua fasa zarah ke dalam lapisan komposit akan mengurangkan ketumpatan aluminium yang digunakan, meningkatkan kekerasan, dan juga mengurangkan kadar kakisan.

ABSTRACT

Fly ash (FA) with three different particle sizes and five compositions were prepared and co-deposit into aluminium substrate by using an electrodeposition process. The effects of fly ash particle size and its composition on the hardness, wear and corrosion of electrodeposited Nickel-Fly Ash (Ni-FA) composite coating on AA7075 substrate were investigated. Various FA particle size was prepared by using ball milling with various milling time (0h (as received), 4h and 8h). Then, the FA is weighed to five compositions (0g/l (pure nickel), 10g/l, 30g/l, 50g/l, and 70g/l) in order to find the optimum composition of FA. With the increasing ratio of fine particles and composition, the hardness of the substrate increased, while the corrosion rate decreased considerably. There are some potential benefits that can be gained by the aircraft company after the completion of this study. The addition of second phase particle onto composite coating will reduce the density of the aluminum used, increase the hardness, as well as reduce the corrosion rate.

DEDICATION

Only

my beloved father, Md Azmi bin Ahmad

my appreciated mother, Haslina binti Abdul Shukor

my adored sister and brother, Norazrina, Noramiza, Norazlia, Haizad and Hafiz

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

AA7075	-	Aluminium Alloy 7075
AASHTO	-	American Association of State Highway Transportation Officials
ASTM	-	American Society for Testing and Materials
CMC	-	Ceramic Matrix Composite
DC	-	Direct Current
FA	-	Fly Ash
HMA	-	Hot Mix Asphalt
LOI	-	Loss on Ignition
MMC	-	Metal Matrix Composite
Ni-FA	-	Nickel Fly Ash
PCC	-	Portland Cement Concrete
PMC	-	Polymer Matrix Composite
PSA	-	Particle Size Analyser
SEM	-	Scanning Electron Microscopy
TEM	-	Transmission Electron Microscopy
XRD	-	X-Ray Diffractometer

LIST OF SYMBOLS

h	-	Hour
g/l	-	Gram/liter
kg	-	Kilogram
^{o}C	-	Degree Celcius
GPa	-	Giga Pascal
MPa	-	Mega Pascal
%	-	Percent
g/cm^3	-	Grams per centimetre cube
W/mK	-	Watt per metre Kelvin
J/kgK	-	Joule per kilogram kelvin
μm	-	Micro meter
cm	-	Centimeter
nm	-	Nano meter
mm	-	Millimeter
pH	-	Potential of Hydrogen
Hz	-	Hertz
Å	-	Angstrom
σ_y	-	Yield Strength
wt. %	-	Weight percent
M	-	Molarity
A/dm^2	-	Current density

CHAPTER 1
INTRODUCTION

This chapter describes the introduction of electrodeposited nickel fly ash (Ni-FA) composite coating on aluminium alloy 7075 (AA7075) substrate. In this chapter, background of study, problem statement, objectives, scope, and the significant/important of study are discussed.

1.1 Background of Study

In recent years, aluminium is used in many applications due to its excellent performance. With an annual consumption of 25 million metric tons, aluminium is the second most commonly used metal in the world after steel (Sleeman et al. 2004). The aluminium is extensively used for ground transport, aerospace, and shipbuilding as aluminium offer a great lightweight material compared to others. This is the reason why the automotive industry is interested in aluminium as the lightness becomes a priority. Table 1.1 below shows the characteristics of aluminium and their importance for different applications.

Table 1.1: Characteristics of aluminium and their importance for different applications (Davis, 1999)

Field of use	Characteristics			
	Lightness	Good heat and electrical conductivity	Resistance to corrosion	Decorative aspects
Transport	1	-	2	2
Building	2	-	2	1
Packaging	3	3	1	1
Electrical	3	1	2	-
Household	2	1	1	2
Machines, appliances	1	2	2	2

(Scale 1: less important, scale 2: important, scale 3: very important)

The durability of the aluminium enable it to be used in many applications and by doing so, the aluminium may come into contact with aggressive environment. To achieve certain strength, aluminium is alloyed with other elements like copper, manganese, magnesium, magnesium-silicon, and zinc-magnesium. Many recent studies have shown that the alloying elements affect the mechanical properties and change the corrosion properties of the aluminium (David, 2016; Sleeman, 2004).

Aluminium has good resistance to atmospheric corrosion and recognised the very good resistance of aluminium in contact with water. Aluminium and the alloys of 1000, 2000, 3000, 5000, 6000 and 7000 series have excellent resistance to atmospheric corrosion in the marine, urban and industrial environments (Sleeman et al. 2004). The corrosion products of aluminium are white. Corrosion is one of the most important limiting factors in life extension of aircrafts.

Corrosion is defined as the deterioration of a material by chemical or electrochemical attack. Corrosion of aircraft structure causes thinning of structure skins resulting to degradation of structural integrity. The several types of corrosion that usually occurs in aircraft structures are uniform, pitting, exfoliation and intergranular corrosion (Baldev et al. 2009). Surface treatment like coating and painting on aluminium alloy is essential in order to prolong the time for the aluminium to corrode.

Aluminium surface treatments have several purposes, including protecting certain alloys if their natural corrosion resistance is insufficient. Literature by Sleeman, (2004) has highlighted that the insufficient corrosion resistance of alloys happen mostly with aluminium-containing alloys of the 2000 and 7000 series. Other than that, surface treatment is used to preserve the surface aspect, in order to avoid pitting corrosion or blackening and modify certain surface properties such as superfacial hardness.

The aluminium is coat with another material to obtain high corrosion resistance and high hardness. Many types of inert particles were used for composite coating, such as carbides, oxides, borides, and nitrides. Over the past decade, most research in nickel coating has emphasized the use of FA as filler in the composite material (Garcia et al. 2001; Panagopolos et al. 2010; Sheng et al. 2003; Viet et al. 2013). FA is the residue from the combustion of bituminous coal. Recycling the FA is one of the alternatives to support green environment in Malaysia.

A combination of two or more materials is defined as composite material. Composite material is being used in high technology application due to the good mechanical properties of the composite. The higher specific strength, stiffness, toughness, wears resistance, and low density of the composite material has overcome the limitations of the monolithic materials. Composite material can be classified into three categories: Metal Matrix Composite (MMC), Polymer Matrix Composite (PMC) and Ceramic Matrix Composite (CMC).

MMCs, as the name implies, have a metal matrix. Metals are mainly reinforced to increase or decrease their properties to suit the needs of design. Addition of FA particles onto the substrate will increase the elastic stiffness and strength, give large coefficients of thermal expansion, and reduce the electric conductivities. The literature by Panagopoulus et al. (2009) has highlighted that the increase of microhardness value of the composite can be attributed to the presence of hard oxides (Al_2O_3 and SiO_2) contained in FA.

Electrodeposited metals are often an ideal means of providing a thin surface coating which has some property superior to that of the substrate. It may, for example, be possible to employ a cheaper or stronger substrate than could otherwise be used and yet achieve good corrosion resistance by applying a suitable electrodeposited coating (Dennis et al. 1993). Electrodeposited nickel is typical of metals which often applied for decorative and protective purposes to cheap mild steel pressings and to die-cast zinc or aluminium alloy components.

It is therefore expected that the incorporation of FA particles in nickel matrix will promote another use of this low cost waste by-product, reducing the cost of aluminium products, and providing higher hardness and corrosion resistance.

1.2 Problem Statement

AA7075 substrate is widely used for aircraft components, especially for stringers and panels. This alloy offers highest mechanical properties compared to other aluminium alloy make the substrate most preferred material for aircraft components. However, AA7075 are sensitive to localize corrosion, such as intergranular corrosion, exfoliation corrosion and

stress corrosion cracking (Wenning et al. 2016). Therefore, surface treatment is required to enhance corrosion resistance of the AA7075.

In this research, FA particles co-deposited in nickel matrix are used to investigate the effect of these particles on the properties of the AA7075 substrate since the FA is one of the most inexpensive and low density reinforcement available among other type of reinforcement.

It is known that MMC coating layer using micro-and nano-sized particles has lead technological interest to the production of new composite materials with improved and well-controlled properties. Ni-FA composites have been investigated to the greatest extend and successfully commercialized for the protection of friction parts, combustion engines and casting moulds.

However, the reports on the effect of FA particle size and composition on the hardness and corrosion resistance of electrodeposited Ni-FA composite are very limited. Therefore, this research will be focused on the effect of FA particle size and composition on the hardness and corrosion resistance of electrodeposited Ni-FA composites coating on AA7075 substrate.

1.3 Objectives

The objectives of this project are:

1) To study the effect of FA particle size on the hardness and corrosion of electrodeposited Ni-FA composite coating on AA7075 substrate.

2) To investigate the effect of FA composition on the hardness and corrosion of electrodeposited Ni-FA composite coating on AA7075 substrate.

3) To examine the relationship between FA particle size and FA composition on the properties of electrodeposited Ni-FA composite coating on AA7075 substrate.

1.4 Scope

In this project, various sizes of FA particles will be prepared from the ball milling process. Then, the FA particles will be co-deposited in the nickel matrix at various sizes and various compositions using electrodeposition process. The effect of various FA particle sizes and various FA compositions on hardness, and corrosion of Ni-FA composite coating will be studied in this research.

Various FA particle size will be prepared by using ball milling with various milling time (0h (untreated), 4h and 8h). The FA is crush to reduce the particle size and in case of agglomeration. Then, the FA is weighted to five compositions (0g/l (pure nickel), 10g/l, 30g/l, 50g/l, and 70g/l) in order to find the optimum composition of FA.

AA7075 will undergo surface pre-treatment using mechanical pre-treatment (grinding and polishing) and chemical pre-treatment (alkaline cleaning, acid cleaning, and zincating) before proceed to coating process. Nickel and AA7075 will be used as anode and cathode respectively in the electrodeposition process. The electrolyte is prepared by using nickel watts bath and mix with various FA particle sizes and compositions.

The range size and characterization of the FA particles is carried out by using particle size analyser (PSA) and scanning electron microscopy (SEM). Then, the characterization of the coating is done by using SEM and X-Ray Diffraction (XRD). The effect of FA particle size and composition on the coating of AA7075 substrate is investigated using Vickers hardness test and Tafel technique corrosion test.

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1.5 Significant/Important of Study

There are some potential benefits that can be gained by the aircraft company after the completion of this study. The addition of second phase particle onto composite coating will reduce the density of the aluminum used, increase the hardness, as well as reduce the corrosion rate. Therefore, the performance of the FA particle will increase the hardness and corrosion resistance of the AA7075 for aircraft component.

1.6 Organization of the Report

This report consists of five chapters. Chapter 1 covers the introduction of the research. This chapter discusses the background of study, problem statement, objectives, scope and significant/ important of study. Problems are identified through literature reviews of several related journals and articles. This is followed by objectives to be achieved throughout the study and scope which narrows down the area of the study. The impact of the study to the aircraft component is also revealed.

Chapter 2 consists of literature review part. This chapter covers the basic theories regarding the research topic and the previous studies from journal, book and the internet. The current FA particle size and its composition used by the researchers are explained. The basic principles of electrodeposited composite coating on AA7075 substrate are also comprised. Lastly, the methods for conducting the experiment and proposing alternative FA particle size and its composition are described.

Chapter 3 contains the methodology part. This chapter explains the flow of the whole project that has been done, starting from literature review to presentation of the final year project. All progress has been divided into eight basic phases which consist of literature review, identifying materials, chemical, process, characterization and testing used, sample preparation, surface pre-treatment, electrodeposition process, characterization of the coating, mechanical testing, report submission and presentation.

Chapter 4 contains of result and discussion part. This chapter is most important as it provide the finding of the project. The result of various FA particle size after grinding will be shown in this chapter. The characterization of Ni-FA coating on AA7075 using SEM and XRD also will show here. The values of hardness and corrosion of 15 samples after the mechanical and chemical testing will be compared and discuss further in this chapter.

Chapter 5 contains the conclusion and recommendation part. In this chapter, all the findings based on the result stated in chapter 4 will be concluded. The conclusion made is based on the objectives, to conclude the effect of FA particle size and composition on the hardness and corrosion on AA7075 substrate. The optimum amount of FA co-deposit in the nickel matrix also will be state here.

1.7 Summary

The background of study, problem statement, objectives, scope, and significant/ importance of study has been discussed in this chapter. In the next chapter, literature review from several journals will be discussed more deeply to gain more understanding about the project.