DETERMINATION OF MECHANICAL PROPERTIES FOR LIGHT WEIGHT ENGINE MOUNT HOUSING USING CARBON NANOTUBE ALUMINIUM COMPOSITE

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

by

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Date : 26 JUNE 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.).

The member of the supervisory committee is as follow:

……………………………………

(DR. MOHD SHUKOR BIN SALLEH)

ABSTRAK

Bahan utama untuk tapak pemegang enjin dalam kajian penyelidikan ini adalah CNTs-Al composite dimana adalah campuran aluminium A356, 0.5% “multiwalled carbon nanotube dan 0.5% magnesium sebagai agen kebolehgunaan. Pada asasnya, dalam industri automotif perkembangan ciri-ciri dan teknologi baru semakin meningkat. Oleh itu, adalah sangat penting untuk mempertimbangkan pengurangan berat kereta untuk memberi lebih banyak kecekapan kepada penggunaan bahan api dan juga mengurangkan pembaziran tenaga. Merujuk kepada objektif penyelidikan, kajian ini lebih kepada kekuatan bahan CNTs-Al komposit, proses ‘sand casting” dan juga proses lanjutan iaitu proses rawatan haba T6. Dalam tinjauan kajian lepas, data dan maklumat yang diperoleh menunjukkan kekuatan dan kekerasan CNTs-Al komposit meningkat melalui proses lanjutan. Jadi hasil yang diperolehi membuktikan bahawa dalam analisis kekerasan, mikroskop pengimbasan elektron, mikroskop optik dan ujian kekuatan tegangan menunjukkan CNTs-Al komposit telah meningkatkan kekuatan dan kekerasan mereka selepas rawatan haba T6. Ini kerana mikrostruktur haba aluminium yang dirawat α Al mempunyai kurang dendritik kerana struktur bijirin kecil. Ujian kekuatan tegangan juga menunjukkan peningkatan dalam tegangan dan peratusan pemanjangan CNTs-Al komposit yang dirawat oleh rawatan haba. Oleh itu, tapak pemegang enjin yang baru mempunyai berat kira-kira 0.345 kg jadi ia telah mencapai matlamat utama penyelidikan ini.

ABSTRACT

The research study is use CNTs-Al composite material for the right engine mount which which is A356 aluminium alloy reinforced with 0.5% multi-walled carbon nanotube (MWCNTs) and a premix of 0.5% magnesium (Mg) as wettability agent. Basically, in automotive industry the development of new features and technology are increasing. So with the additional of new features and technology to the car, the additional of weight is gained. Thus, it is very important to consider the reduction of weight car in order to give more efficiency to the fuel consumption and also reduce waste energy. Based on objective of the research, the study is more to the CNTs-Al composite material strength, sand casting process and also secondary process T6 heat treatment process. In literature review, the data and information obtained shows the strength and hardness of CNTs-Al composite is increased through secondary process. So the results obtained has proved that in the analysis of hardness, scanning electron microscope, optical microscope and tensile test shown the CNTs-Al composite has increased their strength and hardness after the T6 heat treatment. This is because the microstructure of heat treated α Al has less dendritic because of grain structure was smalling. Tensile test also shown the increasing of ultimate tensile strength and elongation percentage of heat treated CNTs-Al composite. Thus, the new front lower control arm has the weight about 0.345 kg so it achieved the aim of this research.

DEDICATION

Alhamdulillah, Praise To Allah

I dedicate this report to only

my beloved father, Ghafar bin Harun

my beloved mother, Khamisah binti Hashim

my appreciated siblings, Nurul Hasanah, Nurul Attikah and Nurul Effa Izzati

my kind supervisor, Dr. Mohd Shukor bin Salleh

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

Thank You so Much

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Finally, I would like to give special thanks to my special direct entry family which is my classmate and some supporting UTeM staff who gave me much motivation and cooperation mentally in completing this report. Thanks for the great friendship.

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UTeM	–	Universiti Teknikal Malaysia Melaka
MMC	–	Metal matrix composite
PMC	–	Polymer matrix composite
CMC	–	Ceramic matrix composite
EEV	–	Efficient energy vehicle
CNTs	–	Carbon nanotubes
SWCNTs	–	Single-wall carbon nanotubes
MWCNTs	–	Multi-wall carbon nanotubes
Al	–	Aluminium
Al_2O_3	–	Aluminium oxide
CNTs-Al	–	Carbon nanotubes aluminium
SiC	–	Silicon carbide
Cbn	–	Carbon nitrade
SEM	–	Scanning Electron Microscope
VHN	–	Vickers Hardness Number

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Sumio Ijima of the NEC laboratory, Japan in 1991 is the first person discover about carbon nanotubes (CNTs), during soot observation between two carbon electrodes generated by electric discharge by using high resolution transmission electron microscopy (TEM). Ijima studied C60 molecules that had been discovered in the 1970s by Harold Kroto and Richard Smalley. Kroto and Smalley found that carbon atoms would spontaneously be assembled into molecules of specific forms under the right conditions for arc-discharge. However the discovery of CNTs was accidental, as shown by Ijama's discovery, under difference experimental condition, carbons atoms can self-assemble into CNTs.

According to Khalid and Ibrahim (2013), CNTs reportedly have extremely large aspect ratios, great surface area and high mechanical strength. The tensile strength is 100 times higher than steel. These make CNTs good candidate as fillers in composite materials including ceramic, metal and polymer composite to realize desirable consumer products. Moreover, CNTs are also good joining agents due to their unique electrical, mechanical and thermal properties. Min F.Y (2004) indicated that a small percentage addition of CNTs can dramatically improve the electrical, mechanical and thermal properties of the materials.

Metal matrix composite is one of the most widely composite materials uses in this industry. Recent development in the field of CNTs have led to a renewed interest in exploring the CNTs-aluminium metal matrix composite (CNTS-AMMC). By done this CNTs and aluminium alloy combination, the car part especially in fabricating engine mount parts will lead to not only lighter component parts, but also have high chemical stability and good wear resistance parts.

This bring a great advantages to automotive industry which now meet the industry demand to produce Energy Efficient Vehicles (EEV) which represents a good alternative for conventional cars that are lighter, less polluting and more fuel-efficient vehicle Ahmed Elmarakbi (2015). This demands need the industry to produce more light automotive parts but having more on mechanical properties such as high strength which can withstand a lot stress form the engine and improving the parts life wear.

The studies will based on designing and fabricating the lighter automotive parts by using CNTs-Al composite, and comparing its microstructural and statistical analysis with the original automotive parts. Characterization of the samples is tested in variable type of characterization such as optical microscopy, scanning electron microscopy, and as well as hardness test and tensile test. Therefore, the behaviors of the samples will be justified.

1.2 Problem Statement

There are being increasingly strict fuel economy requirements in automotive industry while consumers are demanding advanced electronic system, entertainment and improved interior comforts which adds unnecessary weight B.F Schultz (2012). To overcome those challenge the researchers are turning to light-weight metals as suggested by M. Kim *et al.* (2011). William Joost (2012) state that, lightweight materials is one of important technology that can result the improvement of fuel efficiency of the vehicle by 6-8% for each 10% reduction weight of vehicle while the vehicle performance characteristics are maintained. Therefore, composites material have attracted the attentions of the researchers due to its good mechanical properties. In this research, CNTs-Al composite which is A356 aluminium alloy reinforced with 0.5% multi-walled carbon nanotube (MWCNTs) and a premix of 0.5% magnesium (Mg) as wettability agent are selected to produce light weight of automotive parts with good mechanical properties (M.S Salleh *et.al*, 2019).

Various of MMC are uses in making automotive parts for example in making bearing surfaces and cylinder liners, automakers uses silicon carbide (SiC), aluminium oxide (Al_2O_3), graphite-reinforced micro and nano MMC to increase the parts wear resistance. Composites containing micron-scale reinforcements also known as monolithic alloys are used in producing connecting rods provide ultrahigh strength and modulus. Then, aluminium, magnesium alloys and high strength steel are used in cylinder, valves bodies, cases and channel plates Wiyao L.A. (2015). Furthermore, for high thermal conductivity parts likes brake components, automakers uses combination of micro and nano MMCs reinforced with high conductivity carbon or cubic boron nitride (cBN) powder.

Based on application above, the previous studies shown many types of MMC materials uses in automotive industry. However, up to date, not many work has been done to explore the CNTs-Al composite uses in the automotive industry. Thus, there are strong needs to investigate this materials purposely for automotive applications.

1.3 Objectives

The objectives are listed below:

1. To fabricate an engine mount housing by using powder CNTs-Al composite.
2. To investigate the microstructural evolution of the fabricated parts in T6 heat treatment.
3. To analyze the mechanical properties of the fabricated part before and after T6 heat treatment.

1.4 Scope of the Study

The scopes of study for this project is to study the lightweight CNTs-Al composite of the right engine mount material types. . In this research, the focus more on strength for the CNTs-Al composite materials. The type of right engine mount vehicle is Nissan Altima, so the design must follow the specification of Nissan Altima right engine mount. The part are fabricated by using sand casting. The actual weight of Nissan Altima right engine mount is 0.39kg. So the new part fabricate must have weight approximately below 0.39kg.

Then, there will be a comparison between the non heat treated and heat treated samples. The heat treated sample will focused to the T6 heat treatment. The sample will be justify after the result from the mechanical and microstructure analysis are obtained.

1.5 Project Outlines

The project outlines are as below:

(a) Chapter 1 represent the introduction about my project conducted which is background of study, problem statement, objectives, scope of study and project outlines. In this chapter, it explains clearly about how the subtopics being connected and influence each other in this project.

(b) Chapter 2 represent the literature review on the background, basic information and facts about my project. By understand the basic concept, how the experiment and test will be conducted as well as the research method early, so it may enhance the progress of this project.

(c) Chapter 3 represent the methodology used to conduct this project. This chapter included the flow of the experiment and test being conducted, the planning of the research and the sources of data collected.

(d) Chapter 4 represent the result and discussion about the project. This chapter will present the data received from the research and stressing the significance as well as significance of findings of this projects.

(e) Chapter 5 represents the conclusion about the whole study, recommendation for the future research as well as sustainability development, complexity and life-long learning for his project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the fundamental of CNTs-Al composite will be discussed. This chapter is divided into some subchapters which in section 2.2 will be discussed about aluminium alloys including cast and wrought alloys and aluminium alloys (A356). In section 2.3, will be discussed about composite. Then, in section 2.4 will be discussed about CNTs due to its categories, mechanical properties and synthesis of CNTs. Metal matrix composite (MMC), and CNTs-Al will be discussed in section 2.5. Next, in section 2.6 will elaborated more about metal casting process and sand casting. In section 2.7 topic about thixoforming process will be discussed. Furthermore, in section 2.8 will be elaborated more about heat treatment which are include T6 heat treatment, solution heat treatment, quenching and artificial aging. Moreover, in section 2.9 will be discussed about tensile testing while in section 2.10 will covered about hardness testing. In section 2.11, will be discussed about energy efficient vehicle (EEV).

2.2 Aluminium alloys

Karacan *et al.* (2010) state that aluminum and it alloys are used in numerous field regardless in light metal industry, as that of many other industries in this century and in daily life. The reasons aluminum and it alloys are commonly use is because of they have high heat conductivity and high electrical conductivity but low density make they are easy to use.

However, there still some disadvantages of aluminium and it alloys aside from the advantages list before which is they have low abrasion resistance and have poor surface properties.

For some Al alloys, in addition of alloys and using heat treatment for heterogeneous microstructures, attractive mechanical properties are created. A.S. Anasyida *et al.* (2010) think that it is conceivable that the addition of alloying elements will influences the wear properties of Al, as it strengthens through hardening precipitation and dense solution. Some of the alloying elements are Ce, Cr, Cu, Fe, Mn, Ti, Zr, and Zn which are put together to this alloys. These alloying elements either form compound or dissolve inside the microstructure.

Throughout the years, various studies have been carried out by researchers to evaluate the specific consequence of intermetallic particles and additions to individual alloys have on corrosion defects in Al alloys, which emerges from opposing and inter-granular type corrosion regarding to G. Svenningsen *et al.* (2006). In circumstances where the corrosion appearances of component intermetallic have been thoroughly characterized, intermetallic have been found to show a complex behavior, for example, active and/or noble. In an investigation directed by Birbilis and Buchheit (2004), they categorized the intermetallic formed in Al alloys, based on their presence active or passive, their corrosion current and corrosion potentials. In conclusion, they demonstrated that Al3Ti and Al20Cu2Mn3 had the lowest corrosion level, while Mg2Si and MgZn2 had the utmost corrosion level.

R. Pinner *et al.* (2001) state that, aluminum in its pure state is a relatively soft metal with a tensile strength of 90 N/mm2 (13,000 lb/in2) and a yield strength of only 34.5 N/rrnn2 (5,000 lb/in2). Through the improvement of wide range of alloys, in any case, extremely differed ductility and strength can be accomplished, and this has led the numerous uses of today either in industries or daily life. For example, the uses of ductile material for drink container and very thin foil material in packaging industry. Other application are the uses of highly conductive alloys for electrical application and relatively low-strength alloys for building construction industry. Meanwhile in automotive and aerospace industry, the high strength of aluminium alloys are used for aircraft and armored vehicles.

2.2.1 Cast alloy

Murthy *et al.* (2014) describes that aluminuim and its alloys are cast able and the quality factor is essential in choosing the casting process. The numerous casting methods that can be utilized are die casting and sand casting. For large scale of relatively small sized parts die casting is the one which is most appropriate.

Besides, aluminium cast alloys are likewise classified by the same system with the wrought alloy. Strength is improved with the equivalent mechanism, other than strain solidifying and is classified in indistinguishable way from that of either heat fixable or non-heat fixable ones.

According to Davis (2001) in United States, the Aluminum Association system is best known. Casting configurations are depicted by a three digit system and decimal value. The decimal .0 relates to cast alloys limits. Decimals .1, and .2 are about ingot structures, which subsequent to melting and processing should result in complying casting requirements. Tables 2.1 shows the strength of various range of some cast aluminium alloy.

Alloys families for throwing arrangements incorporate the accompanying:

- 1++.+: Controlled pure compositions
- 2++.+: Alloys with the main alloy material is copper.
- 3++.+: Alloys with the main alloy material is silicon. Other alloy material are specified.
- 4++.+: Alloys with the main alloy material is silicon.
- 5++.+: Alloys with the main alloy material is magnesium.
- 6++.+: Not used
- 7++.+: Alloys with the main alloy material is zinc. Other alloy material are specified.
- 8++.+: Alloys with the main alloy material is tin.
- 9++.+: Not used

Table 2. 1 Various ranges of strength cast aluminum alloys

Alloy system	Tensile strength range	
	MPa	ksi
Heat treatable sand cast alloys		
Aluminium-Copper (201–206)	353 – 467	51 – 68
Aluminium-Copper-Nickel-Magnesium (242)	186 – 221	27 – 32
Aluminium-Copper-Silicon (295)	110 – 221	16 – 32
Aluminium-Silicon-Copper (319)	186 – 248	27 – 36
Aluminium-Silicon-Copper-Magnesium (355, 5% Si, 1.25% Cu, 0.5% Mg)	159 – 269	23 – 39
Aluminium-Silicon-Magnesium (356, 357)	159 – 345	23 – 50
Aluminium-Silicon-Copper-Magnesium (390, 17% Si, 4.5% Cu, 0.6% Mg)	179 – 276	26 – 40
Aluminium-Zinc (712, 713)	241	35
Non-heat treatable die cast alloys		
Aluminium-Silicon (413, 443, F temper)	228 – 296	33 – 43
Aluminium-Magnesium (513, 515, 518, F temper)	276 – 310	40 – 45
Non-heat treatable permanent mold cast alloys		
Aluminium-Tin (850, 851, 852, T5 temper)	138 – 221	20 – 32

2.2.2 Wrought alloy

Murthy *et al.* (2014) indicate that wrought aluminium is an as-formed aluminum alloy that has been mechanically worked to obtain a better grain structure and a better physical quality. They are forged and extruded products. The ANSI and the Aluminum Association have set up the aluminum classification numbering system. This classification system uses codes to deliver facts about the condition of heat treatment and the alloying material involved.

In the United States, the Aluminum Association System is best known. Their alloy identification system uses various nomenclatures for wrought alloys, but categorize alloys into categories for simplification. Tables 2 shows the strength of several of range of some wrought aluminium alloys.