UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS OF CAST METAL MATRIX USING CAD TOOLS

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

by

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Design and Analysis of Cast Metal Matrix Using CAD Tools**

SESI PENGAJIAN: 2009/10 Semester 2

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The member of the supervisory committee is as follow:

……..

(EN. TAUFIK)

ABSTRACT

This project presents the new design of cast metal matrix automotive wheel using simulation of low pressure die casting. By using CATIA, a 3-dimensional model of new automotive wheel design is developed as the master pattern. As an approach to simulate the actual casting process, casting simulation tool is used to introduce the cast metal matrix material with composition of aluminium A356 alloy and 20wt% SiC particles into the cast wheel. Then, the finite element model of the wheel is built and solved by using ANSYS, followed by a discussion on the casting simulation using AnyCasting software. Finally, a scaled-down rapid prototype model is produced to represent the master pattern for casting.

ABSTRAK

Projek ini mempersembahkan rekaan baru roda kereta matriks logam tuangan dengan menggunakan simulasi tuangan tekanan rendah. Dengan menggunakan CATIA, satu model 3-dimensi roda rekaan baru telah dihasilkan untuk dijadikan pattern untuk simulasi process tuangan. Sebagai satu pendekatan, alat simulasi proses tuangan telah digunakan untuk memasukkan komposisi matriks logam tuangan yang mengandungi aloi aluminium A356 dan 20wt% butiran kecil SiC ke roda tuangan tersebut. Seterusnya, sebuah model unsur terhingga dibina dengan menggunakan ANSYS. Keputusan simulasi menggunakan perisian AnyCasting dan ANSYS dibincangkan untuk mengenalpasti kerosakan tuangan. Akhir sekali, sebuah model prototaip yang dikecilkan dihasilkan untuk menunjukkan paten tunggal bagi process tuangan.

DEDICATION

I dedicate this report to my parents, my mentors, and my friends. Without their patience, understanding, support, and most of all love, the completion of this work would not have been possible.

ACKNOWLEDGEMENT

First and foremost I offer my sincerest gratitude to my supervising lecturer, Mr. Taufik (Lecturer of Manufacturing Engineering Faculty – Department of Manufacturing Design), who was abundantly helpful and offered invaluable assistance, support and guidance to me in completing my final year project. He has supported me throughout my research with his patience and knowledge whilst allowing me the room to explore and work in my own way.

I would also like to express my appreciation to the technicians in Manufacturing Engineering laboratory for assisting me in the fabrication of the scaled-down prototype model of the actual product.

Special thank also to all my friends and course mates in UTeM; Mr. Lee Weng Sum and Mr. Timothy Paul Anak Beruin for sharing their invaluable knowledge and assistance. Without them my project would not have been successful.

I would also like to convey thanks to Ms. Liew Shwu Jin for her assists and advices in solving the problems I faced in my final year project.

Finally, I wish to express my love and gratitude to my beloved family members for their support, understanding and endless love, throughout the duration of my final year project at UTeM.

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LIST OF ABBREVIATIONS

2D	-	Two Dimensional
3D	-	Three Dimensional
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CATIA	-	Computer Aided Three-dimensional Interactive Application
FDM	-	Fused Deposition Modelling
FE	-	Finite Element
FEA	-	Finite Element Analysis
MMC	-	Metal Matrix Composite
RP	-	Rapid Prototype

CHAPTER 1
INTRODUCTION

1.1 Project Background

Cast metal Matrix, or metal matrix composites (MMC's), an evolutionary composite material for reinforcement and weight reduction in casting products, has showed significant success in industries such as automotive, aerospace and electronics for the past 10 years (Kaczmar et al., 2000; Sala, 2002). By adding in sufficient reinforcement, the mechanical properties of soft metal alloys can be greatly enhanced. Improvement on the yield strength and tensile strength can be clearly seen after the metal alloys are being reinforced (Kaczmar et al., 2000).

In designing and producing a new product, time and cost are inevitably the main constraints that urge manufacturer to find new ways to lower manufacturing cost together with increased productivity (Edwards, 2004). Hence, computer aided engineering (CAD) tools show its advantages in making the lead time of design process shorter and reduce the cost of producing prototype by efficiently create and modify the 3-D model (Carman & Tigwell, 1998; Materialise, 2009).

Conventionally, the design of cast metal matrix involves fabricating the physical specimens for analysis on the microstructures of casting and study on their mechanical behavior (Clegg & Lim, 1997; Jasmi, 2001; Sala, 2002; Vijayaram et al., 2006; Yamagata et al., 2008). It not only requires longer lead time but also higher

manufacturing cost. Therefore, this has come to a demand in a new method of producing cast metal matrix in a cheaper and faster way.

Modern 3-dimensional modeling, analysis and simulation tools play an important role in reducing the lead time and the cost of design process. Casting simulation tools such as ProCAST has replaced the conventional method of designing and analyzing of cast metal matrix (Taufik et al., 2009). Also, numerical techniques like finite element method is applied to do modeling of composites solidification process, which helps the manufacturing industries to study the casting parameters such as temperature history (Vijayaram et al., 2006; Taufik et al., 2009).

For this project, a new design of cast MMC automotive wheel using aluminium A356 as binding material (matrix) and Silicon Carbide particles (reinforcement) will be developed and analysis will be conducted on the product using simulation of CAD tools. The simulated analysis results will be compared with the experimental results obtained from the previous studies.

1.2 Problem Statement

Cast Metal Matrix has proven to be effective and reliable in casting automotive products such as connecting rods in weight reduction and reinforcement (Sala, 2002). In the previous studies, actual cast specimens or products are needed to be fabricated in order to analyze the mechanical properties of cast metal matrix such as impact strength and yield strength. This leads to higher cost consumption and longer lead time in the design stage of new product development. The effectiveness of implementing CAD and casting simulation tools in the design of cast metal matrix has yet to be proven. The study on the impact of Cast Metal Matrix design parameters such as gating system, cooling channel design, flow pattern and solidification are necessary to predict the quality of final casting product.

1.3 Objectives

The aims of this paper are:

- To study the design parameters of producing cast metal matrix using CAD tools.
- To design and analyze a cast MMC automotive wheel using CAD and casting simulation tools.
- To propose the new design of cast MMC wheel.

1.4 Scope of Project

The research project will focus primarily on the design, analysis and simulation of the 3D model of the cast metal matrix wheels. Other aspects such as actual casting process and parameters will not be discussed in this project. Various tools such as CATIA, Solidworks, AnyCasting and ANSYS will be used for the 3D modeling, casting simulation and structural analysis. As an approach, a combination of A356 alloy (matrix) and 20wt% of SiC dispersion particles (reinforcement) will be used as the material of wheel design in one of the casting simulators, AnyCasting to simulate the low pressure die casting process of cast wheel. The structural analysis of new MMC wheel design will be focused on the part performance which includes stress/strain distribution, deformation and thermal strain. Finally, a scale-downed rapid prototype model of the cast wheel will be produced to represent the master pattern for casting process.

1.5 Organisation

The organization of this report is as follows: Chapter 2 describes the literature review of the related journals and papers of previous researches conducted by other parties. Chapter 3 discusses the methodology of the project using the CAD tools. First the 3D models of wheel design and gating system components are produced using CATIA and Solidworks respectively. After that, the properties of MMC material is introduced into the simulation model using AnyCasting software. Then, the finite element model is constructed and solved using ANSYS via the static structural analysis. A brief description of the design process of the cast metal matrix is also included in this chapter. Chapter 4 presents the detailed simulation studies carried out for new MMC wheel design. An analysis on the flow pattern, air entrapment, and impurities prediction of low pressure die casting simulation and the structural behavior of the product were discussed in this chapter as well. Lastly, the results and findings of the study are concluded in chapter 5.

1.6 Gantt Chart for PSM 1 & 2

No.	Task		Week																														
			PSM 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PSM 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14
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9	Preparation for presentation PSM 1	Planning																															
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10	Presentation for PSM 1	Planning																															
		Actual																															
11	Design of Gating System	Planning																															
		Actual																															
12	AnyCasting Simulation	Planning																															
		Actual																															
13	ANSYS – Static Structural Analysis	Planning																															
		Actual																															
14	Result analysis and discussion	Planning																															
		Actual																															
15	Report writing for PSM 2 (Final report)	Planning																															
		Actual																															
16	PSM 2 report submission	Planning																															
		Actual																															

CHAPTER 2
LITERATURE REVIEW

2.1 Cast Metal Matrix/Metal Matrix Composites (MMCs)

A metal matrix composite is one of the composite materials consists of a binding metal (matrix) and one/more than one reinforcement material in the form of either particle, fibre, or layer (Callister, 2003). Cast metal matrix is a type of MMC produced by the casting process. Ductile metals, such as aluminium, magnesium, titanium and their alloys, have been popular matrices for MMCs applied in industries such as aerospace, automotive, defence and construction (Clegg & Lim, 1997).

2.1.1 Aluminium and Aluminium Alloys

In accordance with Degarmo et al. (2003), aluminium is the most important nonferrous metal that has principal uses in transportation, construction, electrical applications, containers and packaging, consumer durables, and mechanical equipment. Pure aluminium is soft and ductile and has a specific gravity of 2.7, which is a relatively light weight metal compared to steel (specific gravity 7.85). Due the low density properties of pure aluminium, alloying process is favoured in acquiring greater strength in non-electrical applications. The low melting point of aluminium (approximately 660°C) makes the alloying process easier (Callister, 2003).

- Characteristics of pure aluminium (Ahmad & George, 2000) :
  - easily formed, machined, and casted
  - although not found free in nature, aluminium is an abundant element in the earth's crust
  - low density
  - corrosion resistant
  - non-magnetic
  - non-combustible
  - highly reflective
  - heat barrier and conductor
  - malleable

- Properties of pure aluminium (Degarmo et al., 2003) :
  - Density/Specific Gravity (g/cm^3 at 20°C) = 2.70
  - Melting Point (°C) = 660
  - Specific heat at 100 °C, $cal.g^{-1}K^{-1}$ ($Jkg^{-1}K^{-1}$) = 0.2241 (938)
  - Thermal conductivity (W/mK) = 237
  - Thermal emmisivity at 100°F (%) = 3.0

Conventionally the mechanical strength of aluminium is enhanced by cold work and by alloying them with some of the principal elements such as copper, magnesium, silicon, manganese, and zinc (Callister, 2003). However, both of these processes tend to reduce the corrosion resistance of aluminium.

An important feature of aluminium and its alloys (and other non - ferrous alloys) is that the fatigue strength aluminium alloys continues to fall with increasing stress cycles, unlike ferrous alloys that exhibit finite fatigue endurance strength, and this must be accounted for in design process.

MMC system of aluminium alloy matrix reinforced by SiC dispersion particles has further strengthened the aluminium alloys. In the previous studies of Kaczmar et al. (2000), results showed that the increase of SiC 10.7mm dispersion particles has improved the yield and tensile strength of Al-4.5%Cu-1.5%Mg alloy (Figure 2.1a & b).

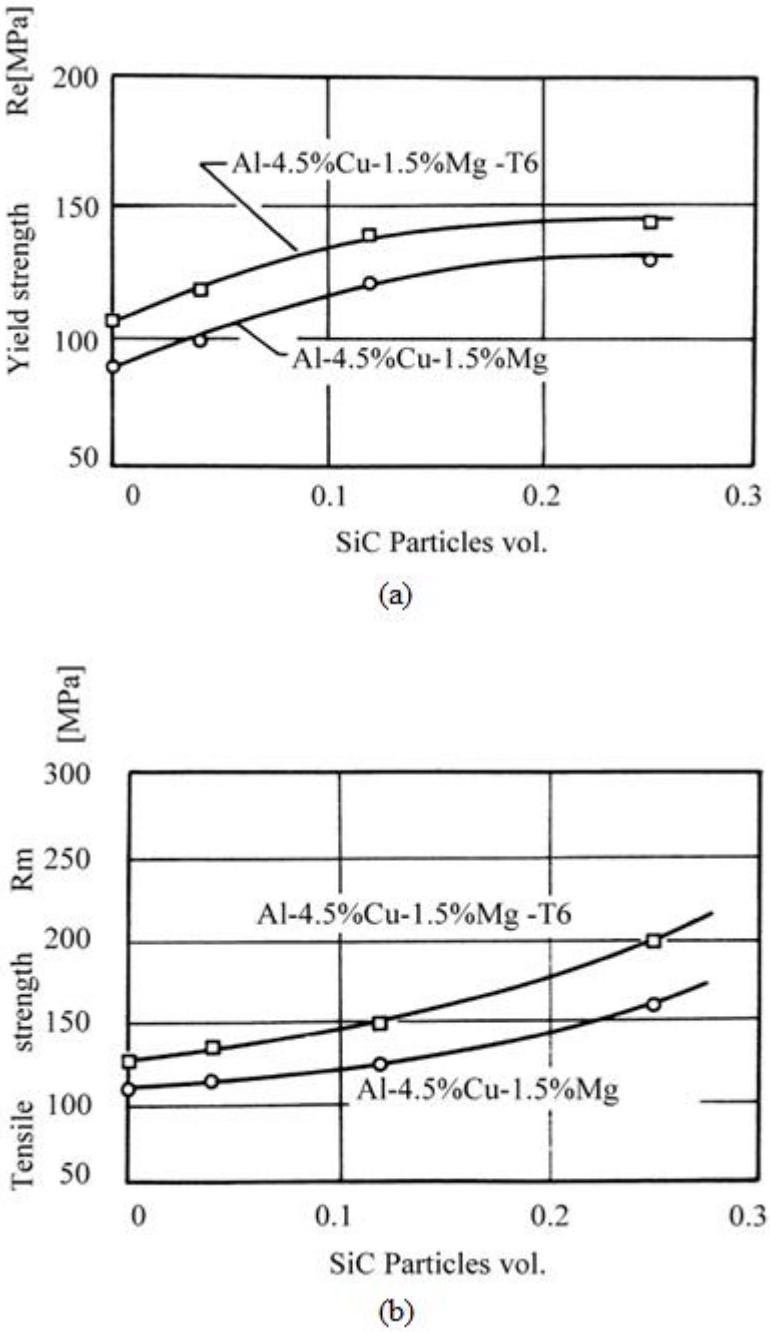

Figure 2.1: (a) The yield Re and (b) the tensile strength Rm of composite materials on an Al-4.5% Cu - 1.5%Mg matrix reinforced with SiC dispersion particles of 10.7mm diameter (Kaczmar et al., 2000).