UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN ANALYSIS OF INTERMETALLIC COMPOUND, Ni_3Al FOR AUTOMOTIVE INDUSTRY

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfilment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

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DECLARATION

I declare that this thesis entitled " Design Analysis Of Intermetallic Compound For Automotive Industry" results from my own research except as cited in the references. Therefore, the thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : 

Name : Mageanragopi A/L Jayagopi

Date : 17.01.2022

APPROVAL

I hereby declare that I have read this thesis, and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature : J. J. S. Anand.

Supervisor Name : Prof. Ts. Dr. Joseph Sahaya Anand

Date : 15/1/2022

DEDICATION

I would like to dedicate the abundant amount of effort that I have put in this report to those who helped me throughout the thesis progress for PSM 2. Firstly for my supervisor Prof. Ts. Dr. Joseph Sahaya Anand has guided me well from initial stage until the end of this thesis by giving me a lot of information regarding the topic. Secondly, I would like to dedicate this report to my parents, who supported me by giving moral support during the thesis progress and been understanding my situation. Last but not least, my classmates, whoever helped me start up with several chapters and give me motivation while doing the thesis, I would dedicate this report for them.

ABSTRACT

Intermetallic compound is a compound that combines two metals but with unique properties compared to their individual properties and the application of intermetallic compound in this thesis is on automotive industry. One of the main parts of a car is the car chassis which requires a strong and highly strenghten material that can withstand heavy force or load. In the early stage of automotive industry, the material used to build the car chasis was carbon steel and followed by aluminium and titanium according to industry evolution. Eventhough those materials used for car chassis consisting alot of advantages compared to others, there are some drawbacks in using those materials. In order to avoid the disadvantages, a new material should be replaced with them and this thesis discusses how This research paper will consist of the properties, structure and the possibility of material replacement with intermetallic compound. Compared to carbon steel and aluminium, nickel aluminide performed well in most mechanical test, corrosion test and fatigue analysis. The proposed nickel aluminide consisting lesser weight with the density of 6 g/cm3 which is an unique property compared with other metals. Nickel aluminide also consist of ability to withstand higher temperature also higher oxidation together with higher strength and this makes the nickel aluminide to be the best material to be used as raw material for car chasis. Mechanical tests such as tensile testing, Vickers microhardness test were taken in order to gain its mechanical properties while corrosion test for its chemical properties as where rust free material is an important aspect for automotives. The microhardness value increased when the annealing temperature increase while decrease in elongation percentage. The nickel aluminide sample also chemically etched under placed under Scanning Electron Microscope(SEM) and optical microscope to view the microstructure and grain structure of the sample. There were changes in microstructures when the annealing temperature changes also the sample placed under X-Ray Diffraction(XRD) to analyze the crystal structure. The CAD modelling of car chasis were anlayzed under fatigue analysis with different materials and controlled constraints. The result of strength and displacement had been obtained under different annealing temperature and based on the result the nickel aluminide withstands higher temperature compared to other materials. As for the average results the ultimate tensile strength the maximum value recorded was 84.838 MPa which is for non-heated sample of $\mathbf{Ni_3Al}$ maximum hardness was 134.93 MV at 600°C annealed temperature.

ABSTRAK

Sebatian antara logam ialah sebatian yang menggabungkan dua logam tetapi mempunyai sifat unik berbanding sifat individunya dan aplikasi sebatian antara logam dalam tesis ini adalah pada industri automotif. Salah satu bahagian utama kereta ialah casis kereta yang memerlukan bahan yang kuat dan sangat kuat yang boleh menahan daya atau beban yang berat. Pada peringkat awal industri automtif, bahan yang digunakan untuk membina casis kereta adalah keluli karbon dan diikuti oleh aluminium dan titanium mengikut evolusi industri. Walaupun bahan yang digunakan dalam industri automotif mempunyai banyak kelebihan berbanding yang lain, terdapat beberapa kelemahan dalam menggunakan bahan tersebut. Untuk mengelakkan keburukan, bahan baru harus diganti dengannya dan tesis ini membincangkan bagaimana Kertas penyelidikan ini akan terdiri daripada sifat, struktur dan kemungkinan penggantian bahan dengan sebatian antara logam. Berbanding dengan keluli karbon dan aluminium, nikel aluminida menunjukkan prestasi yang baik dalam kebanyakan ujian mekanikal, ujian kakisan dan analisis keletihan. Nikel aluminida yang dicadangkan terdiri daripada berat yang lebih rendah dengan ketumpatan 6 g/cm3 yang merupakan sifat unik berbanding dengan logam lain. Nikel aluminida juga terdiri daripada keupayaan untuk menahan suhu yang lebih tinggi serta pengoksidaan yang lebih tinggi bersama-sama dengan kekuatan yang lebih tinggi dan ini menjadikan nikel aluminida menjadi bahan terbaik untuk digunakan sebagai bahan mentah untuk casis kereta. Ujian mekanikal seperti ujian tegangan, ujian mikrokekerasan 'Vickers' telah diambil untuk mendapatkan sifat mekanikalnya manakala ujian kakisan untuk sifat kimianya kerana bahan bebas karat merupakan aspek penting untuk binaan casis kereta. Nilai kekerasan mikro meningkat apabila suhu penyepuhlindapan meningkat manakala peratusan pemanjangan berkurangan. Sampel nikel aluminida juga terukir secara kimia di bawah diletakkan di bawah Scanning Electron Microscope(SEM) dan mikroskop optik untuk melihat struktur mikro dan struktur butiran sampel. Terdapat perubahan dalam struktur mikro apabila suhu penyepuhlindapan berubah juga sampel diletakkan di bawah Belauan Sinar-X (XRD) untuk menganalisis struktur kristal. Pemodelan CAD casis kereta telah dianalisis di bawah analisis keletihan dengan bahan yang berbeza dan kekangan terkawal. Hasil kekuatan dan anjakan telah diperoleh di bawah suhu penyepuhlindapan yang berbeza dan berdasarkan keputusan nikel aluminida menahan suhu yang lebih tinggi berbanding dengan bahan lain. Bagi keputusan purata kekuatan tegangan muktamad nilai maksimum yang dicatatkan ialah 84.838 MPa iaitu bagi sampel tidak dipanaskan **Ni_3Al** kekerasan maksimum ialah 134.93 MV pada suhu sepuh 600°C.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my family members for giving me abundant of moral support during this journey of PSM 1 as where I had to struggle with searching for information and getting stress with the progress of my information collecting process, some of my family members been with me and giving me moral support and understand my situation. Secondly, I would like to thank my supervisor Prof. Ts. Dr. Joseph Sahaya Anand for giving me a lot of companions while in the process of settling down the whole report and also guided me with the topic. He has been giving me a lot of inputs regarding the topics and helped me to gain information from accurate resources in internet while, his clear explanation every single subtopic helped me a lot to finish this PSM 1 report.

I was stucked in between the progress of chapter two which is the literature review and that is where my supervisor guided me well with coping up with the struggle. No man said success will not come without struggle, so I have faced a lot of hardship in personal while accomplishing this psm. Somehow, with the help of family and my supervisor, I had bounce back to the track that I should be to finish this report and the presentation.

Finally, I would like to thank my fellow classmates for also giving me moral support and some guidelines on developing subtopics and elaboration. At this moment, I would like to thank the almighty for driven my forces to accomplish this report even though I was not in a stable condition via mentally and physically. I'm proud of myself in accomplishing this project report and I hope this report have fulfilled the criteria that have been given.

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LIST OF SYMBOL AND ABBREVIATION

mm	-	Millimeter
Ni3Al	-	Nickel Aluminide
NiAI	-	Nickel Aluminide
FeAI	-	Magnesium Aluminide
NiTi	-	Nickel Titanium
g/cc	-	Gram per cubic centimeter
B2(CsCI)	-	Superstructure of a compound
nm	-	Nanometer
K	-	Kelvin
Li_2(cP4)	-	Packets in crystal structure
IC-221M	-	Nickel based cast alloy
IN-713C	-	Nickel based superalloy
°C	-	Degree celcius
AI_2O_3	-	Aluminium Oxide
NiA_20_4	-	Nickel Aluminium Oxide
Ni_3AlB	-	Boron doped Nickel Aluminide
NiO	-	Nickel Oxide
Fe_3AI	-	Magnesium Aluminide
Y_2O_3	-	Yttrium(III) Oxide
GPa	-	GigaPascal
Å	-	Angstroms

$a0$	-	Lattice parameter
kgf	-	Kilogram-force
HV	-	Hardness Value
icorr	-	Corrosion Current

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CHAPTER 1

INTRODUCTION

1.1 Preliminaries

Chapter 1 is the introduction for the thesis as where the background study provides few information on the title and follows it, problem statement, which is the initial step on the research. Based on the problem statement and background study, the objective is developed and following the objective scope of the project was stated on information regarding what is really this research is going through about and some important elements regarding the topic of this thesis.

"Design analysis of intermetallic compound for automotive industry" is the title of this thesis. The main goal is to analyse an intermetallic compound to be replaced with current materials used to build in the automotive industry. Car chasis is the main part that is going to be having material replacement with the intermetallic compound thus, nickel aluminide would be the intermetallic compound that is been analysed as a replacement material for the wheel hub.

1.2 Background of Study

Automotive industry leads today's world with a lot of innovation in the transportation that people get utilized with. A lot of new inventions and technology have been comprised under this industry to deliver elevated automobile services for the community. Transportation is one of the basic needs for us in these days as it gives people to have their own access and freedom to services and jobs that they are seeking for also increase in

demand of automobile leads to great development in roads which makes easier for people to get connected with each other's too. Over past few years, the technology development in automobile leads to various difference in car's models and over time new technologies were introduced in the car system such as, auto-cruise system, abs system and the others. In this order, there were some changes in building materials of cars to create lightweight vehicles to provide higher top speed compared to existing car models. On the other hand, increasing the fatigue strength can also be said as strength of car also been focused in the past few decades to increase the safety of the driver and passengers. These two things brought us to the material replacement and introduction of new alloyed elements into car manufacturing. Initially, only two main raw materials were used in automotive industry to create the chasis of a car: steel, aluminium, and titanium.

1.3 Problem Statement

Aluminium become the pick for the luxurious cars while titanium becomes the pick material for high profiled sports also muscle cars meanwhile steel been utilized for normal budget and saloon cars. Cars like BMW, Benz, Volvo, Audi is built with aluminium while Ferrari, Lamborghini cars are built with titanium, which can also differ with the price of those brands. According to Andrew et al (2006), steel is cheap and heavy while aluminium and titanium are little bit costly but lightweight and non-ferrous metals that will not undergo any rusting process. According to the density level, steel having 7.87 g/cc while aluminium is 2.69 g/cc. This makes the inertia of a car increase if the built material is steel, leading to increment in friction between ground and tires. This leads to lower speed of a car if steel is used as a built material for a car while usage of aluminium avoids these issues, but the problem is aluminium is abit high in price and same goes to titanium which is also more costly compared two of these materials.

According to a recent study, for past 20 years the vehicle's weights have been significantly increased as for every year the vehicles weight is increasing 16 kilograms. In this case, reducing weight and the concern of safety is important in order to avoid this situation as we all know, more weight on a car leads to more fuel consumption and lower top speed and some other problems regarding a vehicle's motions. On the other hand, in the seek of reducing the weight, we should look up for the safety concerns that a vehicle consists of as where it avoids the driver and passengers from being safe in any cost of accidents or crashes. Usage of steel in car chassis may increase the weight of a car as the raw materials weigh more than aluminium, which is the alternate material chosen by some automobile companies such as Ford and Tesla. Comparing aluminium in safety purpose, it is safer according to drivealuminium.org, as it has better energy absorption, larger overall size and larger crush zones.

Somehow the usage of aluminium might be questionable when we look up into the price of it as according to Maw.I (2018) Dr.Jody Hall, vice president of automotive market division of SMDI says that gaining lower mass with aluminium would be a great thing. Still, for the relatively small difference compared to steel, it would be costly to be used as built material for car chassis. This same goes with titanium as it is also high in cost even though it is known for its high corrosion resistance, light weight, and strength.

Therefore, to solve all this problem that have been seen in automotive industry for decades, new advanced material can be developed and for that the design analysis is studied on intermetallic compound **NiAl** for the possibility to be used as replacement for existing raw materials to decrease the body weight without reducing the safety.

1.4 Objective

The objective of this project are:-

I. To study the intermetallic aluminides for automotive applications using research papers, journals, article and other source of data.

II. To design an intermetallic material in terms of their structural and chemical properties that can be suitable for automotive applications. (car chasis).

III. To analyse their mechanical and physical properties for the designing aspects.

1.5 Project Scope

There are various types of intermetallic compounds available and can be innovated according to the applications. Every single compound consists of its own properties that will not be suitable for many applications. Restrictions occurs upon the selection of type of intermetallic compound that can be used as a raw material for a car chassis build thus the scope of this project laid on only one intermetallic compound which is classified as **NiAl** and **Ni_3Al** which is known as nickel aluminides.

Mechanical properties of the intermetallic compound is the important data that will accumulated through the experiment that will be carried on and here in the properties, there will be main three points that will be focussed on which are hardness, tensile strength and toughness of the materials. In this case, for the chemical properties corrosion studies will be carried on in order to gain the compound's chemical properties which is Tafel exploitation plot. A compound lattice structure is plays another important role for its properties and studying the structure of those two intermetallic compound is very important as where X-Ray Diffraction analysis will be carried in the seek of finding and analysing the grain structure of **NiAl** and **Ni_3Al**.

On the other hand, SEM which is known as Scanning electron microscope will be used to findout the strucutre of the compound and visibly it can provide a clear vision on the compound structure. Compouter Aided drawing software will be a part of this research as where, designing the car chassis with the intermetallic compound and some other related drawings would be drawn in the drawing or desinging software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Design analysis is a process regarding decision making which comprises developing product model which can be resulted in an actual product. According to Mogahzy (2009) This includes analytical tools which are derived from mathematics, basic sciences, engineering fundamentals and statistics which will be utilised in developing a product model. Design is about the conceptual solution while analysis is meant to be problem investigation Larman (2004). Design analysis have been carried in various scope of research to gain the meter of evolution in a model and also to find out the mechanical strength of materials via several tests and data collected from tertiary source. The scope of analysis is wide as where the analysis carried based on several industries and one of them is automotive industry. In automotive industry, the role of intermetallic compounds are very important as where it is a part of car manufacturing system to be build material for the vehicles. Intermetallic compounds is a compound that is formed by combination of two or more metals which having its own unique structure, composition and properties (Ali, 2020). The characterisitcs of the intermetallic compound which makes it suitable for high temperature applications it consists of great demand in recent years (Kobayashi, 2004). In the need of higher fuel efficiency, environmental regulations and weight minimisation also demand of customers makes the automotive companies to develop new materials and modify the existing materials then doing reasonable material selection (Mekonen Asmare Fentahun, 2018).