STUDY ON WEAR PERFORMANCE OF HEAT TREATED THIXOFORMED ALUMINIUM ALLOY

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

by

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I hereby, declared this report entitled "Study on Wear Performance of Heat Treated Thixoformed Aluminium Alloy" is the results of my own research except as cited in reference.

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Author's Name : SITI HAJAR BINTI AZHAR

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APPROVAL

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

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ABSTRAK

Banyak komponen industri yang diperbuat daripada aloi aluminium LM27 atau A357 tertakluk kepada industri automotif dan aeroangkasa terutamanya aloi aluminium. Disebabkan oleh keadaan ini, laporan ini adalah untuk menyiasat prestasi haus aloi aluminium berbentuk thixoform selepas rawatan haba terutamanya T6. Rawatan haba T6 terdiri daripada tiga langkah: yang pertama ialah rawatan penyelesaian di mana aloi dipanaskan selama 8 jam pada 540°C, yang kedua ialah pelindapkejutan selama 5 minit dalam suhu bilik, dan langkah terakhir ialah proses penuaan di mana aloi dipanaskan selama 4 jam pada 160°C untuk membolehkan pemendakan berlaku. Tambahan pula, parameter untuk penyiasatan ini termasuk masa dan kelajuan kacau semasa penuangan bahan suapan. Penyiasatan ini akan menganalisis perbezaan dalam prestasi haus aloi aluminium antara thixoforming dan konvensional casting, menilai penggunaan rawatan haba semasa proses thixoforming mempengaruhi prestasi haus dan mengenal pasti penilaian mikrostruktur aloi aluminium dalam thixoforming dan konvensional casting. Walau bagaimanapun, penggunaan zarah yang dirawat haba, suntikan zarah dan sistem kacau meningkatkan kebolehbasahan dalam cair aluminium. Untuk mengkaji prestasi haus, ujian haus akan dijalankan di bawah pin pada cakera dengan standard ASTM G99. Saiz butiran matriks LM27 diiktiraf oleh mikroskop pengimbasan elektron (SEM) dan analisis XRD untuk data mengenai struktur dan fasa kristal.

ABSTRACT

Many industrial components made of aluminium alloys LM27 or A357 are subjected to automotive and aerospace industry especially aluminium alloys. Due to this situation, this report is to investigates the wear performance of thixoformed aluminium alloy after heat treatment especially T6. The T6 heat treatment consists of three steps: the first is a solution treatment in which the alloy is heated for 8 hours at 540°C, the second is a 5 minute quenching in room temperature, and the final step is an ageing process in which the alloy is heated for 4 hours at 160°C to allow precipitation to occur. Furthermore, the parameters for this investigation include stirring time and speed during feedstock casting. This investigate will analyse the differences in wear performance of aluminium alloys between thixoforming and conventional casting, evaluate the use of heat treatment during thixoforming process influences wear performance and identify the microstructure evaluation of aluminium alloy in thixoforming and conventional casting. However, the use of heat-treated particle, injection of particles and the stirring system improved the wettability within the aluminium melt. In order to study the wear performance, wear test will be conducted under pin-on-disc with ASTM G99 standard. LM27 matrix grain size is recognised by electron scanning microscopy (SEM) and XRD analysis for the data on crystal structure and phase.

DEDICATION

For my parents,

my beloved father, Azhar bin Musa

my true loved mother, Siti Zaiton binti Yusoff

Thank you for the moral support, money, cooperation, understanding and encouragement,

To all my friend who always help me during the process of this study,

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Last but not least, my appreciation goes to those who have helped me directly and indirectly in completing this report. I am very thankful that a lot of people have support and inspire me to carry out this report,

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LIST OF ABREVIATIONS

AA	-	Aluminium Association
Al	-	Aluminium
CoF	-	Coefficient of Friction
CS	-	Cooling Slope
Cu	-	Copper
DSC	-	Differential Scanning Calorimetry
EDM	-	Electrical Discharge Machining
Fe	-	Iron
HPDC	-	High Pressure Die Casting
Mg	-	Magnesium
Mn	-	Manganese
SEM	-	Scanning Electron Microscopy
Si	-	Silicone
SIMA	-	Strain-induced Melt Activation
SIT	-	Stirring Integrated Transfer-heat
SSM	-	Semisolid Metal
SSMP	-	Semisolid Metal Process
UNS	-	Unified Numbering System
UTS	-	Ultimate Tensile Strength
XRD	-	X-ray Diffraction
YS	-	Yield Strength

LIST OF SYMBOLS

%	-	Percent
lb	-	Pound
kg	-	Kilogram
g/cm^3	-	gram per centimetre cube
N/mm^2	-	Newton per millimetre square
lb/in^2	-	Pound per inch square
mm	-	millimetre
˚F	-	Fahrenheit
°C	-	Celsius
µm	-	micrometre
N	-	Newton
Hz	-	Hertz
kHz	-	kilohertz
kN	-	kilonewton
rpm	-	revolution per minutes
mm^3/Nm	-	millimetres cubes per Newton meter
m/s	-	meter per seconds

CHAPTER 1

INTRODUCTION

This chapter highlights the introduction of this research work, including the background, problem statement, objective, scope, and significance of the study. This report has carried out a study on the fatigue behaviour of the heat-treated thermoformed aluminium alloy.

1.1 Background

Thixoforming is one of the methods that have been used in Semisolid Metal (SSM) processing. This method has become more popular as a way to make things in the last few years because people are more interested in making things with semisolid metal. Thixoforming is also a three-step process. It starts with making a material with an open globular microstructure, then heating that material to the temperature needed for moulding, and then moulding the material in a die-casting press (Abdelgnei et al., 2021). Furthermore, this process is most usually utilised to create complicated aluminium car components, which is a distinct benefit. Furthermore, there is a strong demand for the development and implementation of models and numerical software tools that enable for the precise prediction of semisolid casting processes to be established (Koke & Modigell, 2003).

Aluminium alloy is the most commonly used material in the vehicle sector, according to (Nelaturu et al., 2020). It is also used to make engine components such as pistons, engine blocks, and cylinder heads. Furthermore, aluminium alloy LM27 is widely used in the aerospace and defence industries due to its high strength-to-weight ratio, excellent castability to nearly perfect shape, and wear resistance. As an added bonus, the thixoforming technique yields a high-quality object at a cost comparable to or less than that of traditional forming procedures such as casting or forging. Semisolid processing must achieve high surface quality, complicated near-net shape components, and thinness sections that require minimal finishing to outperform die-casting while keeping key die-casting advantages such as tight dimensional tolerances and fast production rates.

Semisolid slurry processing is dependent on the nondendritic microstructure and thixotropic behaviour of it is semisolid slurry, since they reduce porosity and segregation in the conventional casting process, respectively. Electromagnetic stirring, strain-induced melt activation (SIMA), stirring integrated transfer-heat (SIT), cooling slope casting (CS), and mechanical stirring are all prominent methods for generating thixotropic behaviour in the semisolid state (Abdelgnei et al., 2021). There is a lot of evidence that heat treatment can improve the properties of aluminium alloys. T5 heat treatment, as well as changes to T5 heat treatment, is especially good at improving the strength and hardness of aluminium alloys.

1.2 Problem Statements

The usage of aluminium and its alloys have increase in many application and industries over the decades. The automotive industry is the largest market for aluminium castings and cast product. aluminium is widely used in other applications such as aerospace, marine engine and structure. The applications grow as industry seek new ways to save weight and improve the performance. However, another aspect has become critical importance is the achievement of quality and the wear performance on the material. Therefore, in the past, the developments have focused on quality factors that the properties of the aluminium not in aluminium alloy LM27.

Semisolid casting is a method of producing castings with very low porosity and excellent mechanical properties. Therefore, with the existence of these benefits, there are still many successful commercial uses for semi-solid cast aluminium components. However, this technique has failed to achieve the widespread commercial application in its early days. Even though, the fact that semisolid cast aluminium components have numerous successful commercial applications, the process has yet to attain the widespread commercial application envisioned in its early days. On the other hand, this thixoforming approach can result in fewer casting flaws, such as macro isolation, shrinkage, and porosity. These gains are sufficient to motivate additional research into thixoforming formation processes. Additionally, heat treatment can be utilised to improve certain materials' mechanical qualities (Salleh et al., 2014). This means that further study into the thixoforming process is needed to show that it has the potential to be more beneficial in a variety of industries while maintaining high product quality, and that it might potentially reach the consumer market and have a greater impact on society world in general.

Furthermore, the mechanical stirring is the technique that involve in casting. Prabu et al. (2006) discovered that increasing the stirring speed and time improved particle distribution. The results of the hardness test also revealed that stirring speed and time had an effect on the composite's hardness. After 10 minutes of stirring at 600 rpm, the homogeneous hardness values were reached.

1.3 Objective of Study

i. To analyse the differences in wear performance of aluminium alloys when undergoes thixoforming and conventional casting process.
ii. To evaluate the influence of process of heat treatment on process wear performance.
iii. To identify the microstructural evaluation of aluminium of the thixoformed product alloy under thixoforming and conventional casting process.

1.4 Scope of study

The scope of this project is to investigate the wear performance on a T6 heat treated thixoformed aluminium alloy LM27. In this project, aluminium alloy LM27 is chosen as the primary material that will investigate. This material is suitable for casting and thixoforming process. Moreover, in thixoforming process, it will use a mechanical stirring as a stirring method for produces feedstock because this method is simple and easy to handle without any extra precautionary steps. Then, after the casting and thixoforming process the material will undergo the T6 heat treatment. In order to examine the effect of the T6 heat treatment, the material will be test on wear testing using ASTM G99 to investigate the wear performance. In addition, it will be using X-ray diffraction (XRD) to check the phase and composition of the aluminium alloy LM27. Moreover, to identify the microstructure, surface morphology and worn surface after wear testing of casting and thixoforming it will be using Scanning Electron Microscopy (SEM-EDX).

1.4 Significant of Study

This study helps to analyse and examine the effect of heat treatment in thixoforming process effect on the wear performance of an aluminium alloy LM 27. This study also will analyse the comparison between thixoforming and normal casting processes.

1.6 Organisation of The Report

The outline of the project demonstrates an overview of the elements in each of these chapters that emphasize the main scope of the chapter. The outline is split into five chapters which is it include introduction, literature review, methodology result and discussion and conclusion and recommendation.

Chapter one reviews the introduction on this project which includes a background, problem statements, scope, objective of the project. Chapter two is devoted to all the theories and literature review where studies and research are related to the project obtained from the journal and article. Chapter three explains the research methodology. This chapter is the most crucial part which includes brief explanation all methods and techniques used in the project. Then, result and discussion in chapter 4. All the results will be collected and analyse after running the test through microstructure testing (SEM), XRD test, and wear test then the effect of heat treatment T6 on the aluminium alloy LM 27 will be discuss. Lastly, in chapter 5, the conclusion and recommendation about the research are examined. It contains the overall conclusion regarding discoveries of objective and new suggestion for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter explains the content, steps, and every point that are related to the study. The data gathered from the article, journal, published literature, books, magazines etc, it focusses on the LM27 Aluminium alloy undergoing thixoforming process. This section explores the Aluminium Alloy LM27 material, including its thixoforming method and characteristics. This chapter also covers wear testing and its impact on the thixoforming process, heat treatment and the microstructure of the material.

2.1 Aluminium

The presence of aluminium oxide at high temperatures reveals that aluminium is an electronegative metal with a significant demand for oxygen. Aluminium has low density, which is approximately 2.7%, it has high mechanical strength, which may be attained through alloying and heat treatment, and its relatively strong resistance to corrosion in its purest form are the three primary characteristics that make aluminium valuable. Moreover, it good thermal and electrical conductivity, reflectivity, high ductility, low operating costs, magnetic neutrality, high scrap value, and non-toxic and colourless corrosion products make it desirable in the chemical and food processing industries. The features of the metal are increased through various treatments (P.G. Sheasby and R. Pinne, 2001).

In addition, aluminium's malleability is one among its most valuable characteristics. Often, it can successfully compete with less malleable, less expensive materials. The metal can be cast using any technique familiar to foundrymen. It may be rolled to any thickness, even foils thinner than paper. A sheet of aluminium can be stamped, drawn, spun, or roll-formed. Additionally, the metal may be pounded or forged. Drawn from rolling rod, aluminium wire can be stranded into any size or type of cable. Metal can be extruded into an almost infinite variety of profiles or shapes (J.R. Davis, 2001).

2.2 Aluminium Alloy

Aluminium is one of the most adaptable, affordable, and attractive metallic materials for a variety of function, from soft, highly ductile wrapping foil to the most demanding engineering application. Aluminium is the special mix of qualities supplied by aluminium and its alloy. (J.R. Davis, 2001). Aluminium alloy was exhibit intermediate strength and good ductility. Aluminium alloys have intermediate strength and ductility. There are various types of aluminium alloys, including wrought aluminium and aluminium alloy. They were created with a four-digit numerical system. Copper, magnesium, zinc, silicon, manganese, and lithium are the primary alloying elements. Aluminium alloys are classified according to the principal alloying ingredients. Copper for series 2XXX, manganese for series 3XXX, silicon for series 4XXX, magnesium for series 5XXX, magnesium and silicon for series 6XXX, zinc for series 7XXX, and additional elements for series 8XXX are the major alloying components. (Ambroziak and Solarczyk, 2018).

Bguthrie (2020) has been reported that aluminium alloys have been created specifically for the casting technique used to create the pieces. Materials of the 300, 400, and 500 series are found in cast alloys. The 300 series are the most prevalent cast alloys. The most popular High Pressure Die Casting (HPDC) alloys (380, 383, 384) are composed of Si, Cu, Fe, and Mn, with Mg being strictly limited. The most popular aluminium alloys for sand casting, gravity casting, and low-pressure casting are 356 and 357, which contain 6% and 7% Si, respectively.

2.2.1 Properties of Aluminium Alloy

Aluminium and aluminium alloy are melted and remelted regularly as needed for the casting of ingots or billets for subsequent fabricating procedures such rolling, extruding, drawing, or forging and also for recycling. Aluminium does not ignite or catch fire as it is being melted nor does it emit smoke or toxic gases. Bguthrie (2020) has stated that 90% of aluminium casting are Al-Si alloys. The most important reason for alloying silicon with aluminium is to improve casting by making the molten metal more fluid. Therefore, fluidity increases with increasing silicon content, and extremely high silicon alloys are wear resistant.

2.2.2 Application of Aluminium Alloy

Aluminium alloys are economical in many applications. They are used in automotive industry, aerospace industry, in construction of machine, appliances, and structures, as cooking utensils, as cryogenic applications, and in innumerable others areas. Moreover, aluminium alloys, as well as other modern materials used in vehicles of the future, such as hybrid and electric vehicles, show an extraordinary tendency to use particularly modern recycling techniques and techniques in order to maximize the amount of seamless, rare, expensive and scarce materials reused and re-used to create new vehicle models, but also other technical systems. This is above all possible by the conquest of processes by which the compounds and alloys based on aluminium are relatively easy to disintegrate and obtain relatively pure elements and compounds for the subsequent production cycles

2.3 Aluminium Alloy LM 27

LM27 is a versatile alloy that can be utilised for a variety of purposes. It is easy to cast, therefore it may be used for the majority of general-purpose castings requiring moderate mechanical qualities, such as general engineering components, home and office equipment, domestic fittings, electrical tools and switch gear, and automobile engine and transmission parts.

According to Kumar et al. (2016), the matrix is composed of commercial-grade aluminium alloy LM27 with 7.53 wt. % Si and boron carbide with particle sizes between 100 and 20 nm (m). Coarse (100 m), medium (50 m), and fine (20 m) reinforcements are employed to span the entire range. As a flux, potassium titanium fluoride and boron carbide were introduced in equal amounts. This made the boron carbide simpler to adhere to the aluminium alloy.

Table 2.1: Composition of LM27 aluminium alloy

Element	Cu	Si	Mn	Zn	Mg	Sn	Ni	Fe	Ti	Pb	Al
wt%	1.5–2.5	6–8	0.2–0.6	1.00a	0.35a	0.1a	0.3a	0.5a	0.2a	0.2a	Balance

wt%: Percentage weight.
[a] maximum amount.

2.4 Semi-Solid Processing

Metal alloys are formed between the solidus and liquidus temperatures during semisolid metal (SSM) production. This is a well-known way of fabricating metal objects. It must have a solid near-globular grain microstructure surrounded by a liquid matrix, as well as a substantial area where the transition from solidus to liquidus occurs. This is what the approach needs to function properly. Semisolid metal (SSM) processing is a relatively new method of producing metal that has recently gained popularity. SSM processors do not utilise the same tools as those that employ other forms of metal shaping. As starting materials, they use either solid metals (solid state processing) or liquid metals (casting) (Guan et al., 2012).