UNIVERSITI TEKNOLOGI MARA

METAL INJECTION MOULDING OF ALUMINIUM ALLOY SWARF USING PALM STEARIN AS A STANDALONE BINDER

SARAH BALQIS BINTI YUSSOFF

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science
(Mechanical Engineering)

College of Engineering

March 2023

ABSTRACT

Aluminium alloy swarf (AAS) is by-product obtained from the automotive manufacturing industry. It is conditioned and pulverised to be remade into another part via metal injection moulding (MIM) in this work. MIM usually produces complex, intricate, and high-quality parts in large quantities (10,000< units). Thus, carving a clear path for recycling aluminium alloy through MIM is in value added territory. Not to mention that aluminium MIM in general has yet to be commercialised as this is still an on-going research due to the intriguing properties of aluminium in the efforts to be sintered. Moreover, as palm stearin (PSr) has successfully been used in singularity instead of the common practice of using a system of binders, this work takes two steps more along the path of greener manufacturing. This is because aluminium and PSr themselves have relatively low melting ranges (~400°C-700°C and ~55°C-70°C, respectively) which lowers the typical working temperature of injection moulding. Subsequently, the standalone PSr binder is capable of providing pseudo-plasticity which is a substantial factor in the succession of injection moulding. Mainly, this work aims to characterise AAS powder through planetary ball milling purged with inert gas (argon) for manufacturing via MIM. The average particle size is ~13 µm, due to the gas gauging down the chamber temperature, resisting agglomeration. The powder produced are irregular in shape and generally bulky, with a broad distribution of particle sizes. These characteristics assists in particulate interlocking, contributing to green part strength. Next, the pulverised AAS (PAAS) is mixed with 100vol% of PSr to form feedstock with three powder loadings (63 vol%, 65 vol% and 67 vol% PAAS). However, only the 65 vol% of PAAS is selected for further work since it provided the highest packing density with consistent fluidity as pressure increases. Consequently, the PAAS feedstock is successfully injected within 65°C to 70°C with a corresponding injection pressure of 300 kPa to 400 kPa. Lastly, comes the binder removal and consolidation of PAAS particulates through thermal debinding and sintering, respectively. This is where the effects of different heating rate and soaking parameters for both thermal debinding and sintering are varied and evaluated. The proposed ideal thermal debinding heating rate should range between 0.3 to 0.5 ºC/min, with holding duration kept within 30 to 120 minutes and soaking temperature between 420ºC to 550ºC. While for sintering, heating rate should range between 1 to 3 ºC/min, holding duration kept between 50 to 80 minutes, and holding temperature within 575ºC to 580ºC. As such, working samples for further research work or testing can be produced as the plausibility of particulate consolidation is apparent.

ACKNOWLEDGEMENT

Alhamdulillah, I have reached the final part of my master's research study and I thank Allah SWT for getting me here. I could not have done so without my very dedicated, understanding and kind supervisor Nor Hafiez Mohd Nor (Assoc. Prof. Dr. Ts.), as well as my also dedicated and kind co-supervisor Hazran Husain (Ir.).

Not to forget the laboratory (Heat Treatment, Advanced Materials, Metal Injection Mouldings, Material Science, and etc) technicians and staffs involved in making my research journey a lot smoother all around; a thousand gratitude to you all. A special thanks to the head of the MIM lab for the inspiring path of greener manufacturing.

I wrote this thesis with a strong message to remind myself and everyone that is connected to me that as long as we are alive, there is always time to learn and new things to discover.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Throughout the world, waste management is a crucial area that needs to be improved, especially today with the rapid growth of the industry due to high consumer demands. Thus, Malaysia aims in supporting the United Nations Environmental Program (UNEP), including managing waste from production processes. Do take note that in this work, the waste is collected specifically from engine block finishing processes, where it in turn tends to have less to virtually no contamination aside from lubricants. Moving on, current wastes from machining processes such as grinding, milling, boring etc. also known as metal swarf are collected for bulk sales with affordable prices. The aforementioned bulk sale of swarf is mostly dominated by recycling companies, along with the procurement of larger portions of unwanted parts. Most big companies that can afford to operate and maintain furnaces will continuously salvage their metal scrap to recycle it themselves since metals do not degrade in value; one of which includes one of the major automotive companies in this country, Perodua Sdn. Bhd. Alternatively, there are smaller companies, who could not afford to purchase, operate, or maintain furnaces, who would ultimately sell off all their metal scrap, and swarf.

Generally, recycling companies would turn all types of swarf, metal swarf included, into briquettes by a low-pressure compaction process. From briquetting, precious lubricants can be recycled and scrap inventory is optimised, which aids cost reductions. Non-metal matters are used as fuel burners while metal matters are briquetted to ease transport and inventory take-up before they are re-melted into ingots or billets. However, other than briquetting melting and moulding into bulks, billets, or ingots, it can be completely replaced into producing high quality and complex parts right after scrap production. Hence, this research focuses on waste materials produced in-situ of machining processes, also known as swarf, to be subjected to numerous steps to be reproduced via metal injection moulding (MIM) in yielding complex and tight tolerance metal parts of its best quality and characteristics. The final product would be