MULTI OBJECTIVE OPTIMIZATION OF WASTE ABRASIVE WATERJET ON MECHANICAL PROPERTIES OF HEAT-TREATED A356 USING GREY-TAGUCHI METHOD

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DECLARATION

I declare that this thesis entitled "Multi Objective Optimization of Waste Abrasive Waterjet On Mechanical Properties Of Heat-Treated A356 Using Grey-Taguchi Method" 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 : Valenteno A/L Stivensone______

Date : 17 January 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 : ______________________________

Supervisor Name : Nur Aiman Hanis Binti Hasim___

Date : 15 January 2022_______________

DEDICATION

To my beloved family for raising me and providing me with a lifetime of love and support. To my supervisor Madam Nur Aiman Hanis Binti Hasim and co-supervisor, Madam Nur Farah Bazilah Binti Wakhi Anuar, for mentoring and supporting me during the completion of this thesis.

ABSTRACT

Greensand casting is still widely used in the manufacturing industry because of its low production costs and ease of processing complicated products. The setup of the casting process is critical for achieving quality and efficiency. However, the price of silica sand has doubled in comparison to the typical price in today’s market. Therefore, this study aims to optimize the waste abrasive waterjet parameters (bentonite, coal dust, water) of T6 heat treatment A356 Aluminium alloy using Taguchi based grey relational analysis. Design of Experiment (DOE) was used to plan the parameter of green sand ingredients with waterjet using Grey relational Analysis Method (GRA). The casting and T6 heat treatment process was carried out. After solidification, the A356 Aluminium alloy was tested for tensile strength, hardness, and microstructure. After that, the Grey-Taguchi method was used to analyse the data of mechanical of optimum composition for T6 heat-treated A356 samples acquired from the tests. In addition, an analysis of variance (ANOVA) table summarised the findings. According to the Grey-Taguchi analysis, the ideal green sand composition in tensile and hardness tests is 60% Silica sand and 40% garnet sand, whereas Bentonite, Water, and Coal Dust will be the following the determined parameters. Sample 9 has the highest tensile and hardness value, whereas Sample 1 has the lowest value. In tensile tests, the best green sand composition is 12% Bentonite, 5% Coal Dust, and 6% Water, whereas in hardness tests, the best green sand composition is 9% Bentonite, 6% Coal Dust, and 7% Water. The best green sand composition, as per Grey Relational Grade (GRG) analysis, is 12% Bentonite, 6% Coal Dust, and 6% Water. Based on the ANOVA table, there is a statistically significant relationship between SN ratios and bentonite in the tensile test, however, in the hardness test, there is a statistically significant relationship between SN ratios and coal dust. Finally, with the magnification of an Upright Light microscope, the microstructure of Sample 9 has the highest while Sample 1 has the lowest silicon boundaries region.

ABSTRAK

Proses pengacuan *Greensand* sering digunakan dalam industri pembuatan kerana kos pengeluarannya yang rendah dan kemudahan memproses produk yang rumit. Penyediaan proses pengacuan sangat penting untuk mencapai kualiti dan kecekapan. Walau bagaimanapun, harga pasir silika di pasaran baru-baru ini meningkat dua kali ganda berbanding dengan harga asalnya. Oleh itu, kajian ini bertujuan untuk mengoptimumkan parameter pelelas sisa waterjet (bentonit, debu arang batu, air) dengan proses T6 rawatan haba pada A356 aluminium aloi menggunakan analisis relasi gray berasaskan Taguchi. *Design of Experiment* (DOE) digunakan untuk merancang parameter bahan pasir hijau dengan waterjet menggunakan kaedah Analisis Relasi Gray (GRA). Proses pengacuan dan T6 rawatan haba dijalankan untuk menghasilkan spesimen. Selepas pemejalan, A356 Aluminium aloi diuji kekuatan tegangan, kekerasan, dan struktur mikro. Selepas itu, kaedah Taguchi digunakan untuk menganalisasi data mekanikal komposisi optimum untuk sampel A356 yang dirawat haba T6 yang diperolehi daripada ujian. Di samping itu, jadual analisis varians (ANOVA) merangkum penemuan. Menurut analisis Taguchi, komposisi pasir hijau yang ideal dalam ujian tegangan ialah 60% pasir Silika dan 40% pasir Garnet manakala Bentonit, Air, dan Debu Arang Batu akan mengikuti parameter yang ditentukan. Sampel 9 mempunyai nilai tegangan dan kekerasan tertinggi, manakala Sampel 1 mempunyai nilai terendah. Dalam ujian tegangan, komposisi pasir hijau terbaik ialah 12% Bentonit, 5% Debu Arang Batu, dan 6% Air, manakala dalam ujian kekerasan, komposisi pasir hijau terbaik ialah 9% Bentonit, 6% Debu Arang Batu, dan 7% Air. Komposisi pasir hijau terbaik, mengikut analisis Grey Relational Gred (GRG), ialah 12% Bentonit, 6% Debu Arang Batu dan 6% Air. Berdasarkan jadual ANOVA, terdapat hubungan yang signifikan secara statistik antara nisbah SN dan bentonit dalam ujian tegangan, namun, dalam ujian kekerasan, terdapat hubungan yang signifikan secara statistik antara nisbah SN dan debu arang batu. Akhir sekali, dengan pembesaran mikroskop ‘Upright Light’, struktur mikro Sampel 9 mempunyai yang tertinggi manakala Sampel 1 mempunyai kawasan batasan silikon yang paling rendah.

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Finally, I want to express my appreciation to my family and friends who did everything they could to support me by encouraging me to keep working on this project and providing financial assistance to help us cover all of the costs associated with completing this research.

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LIST OF SYMBOL AND ABBREVIATION

SDAS	-	Secondary Dendrite Arm Spacing
LSC	-	Low Superheat Casting
Al	-	Aluminium
GRG	-	Grey-Relational Grade
GRA	-	Grey-Relational Analysis
SSM	-	Semi Solid Metal
AWJ	-	Abrasive Waterjet
MA	-	Metaheuristic Algorithms (MA)
AMC	-	Aluminium Matrix Composite
RSM	-	Response Surface Method
IP	-	Injection Pressure
MIG	-	Metal Inert Gas
EDM	-	Electrical Discharge Machining
ANOVA	-	Analysis of Variance
MRR	-	Material Removal Rate
DOE	-	Design of Experiment
$\sigma\sigma$	-	Tensile Stress
P	-	Load or Force
A	-	Area
L	-	Load (gf)
d	-	Average Diagonal

$Y_i(n)$	-	The value of grey relation
$\min y_i^0(n)$	-	The minimum value
$\max[y(n)]$	-	The maximum value
Δ_{oi}	-	Deviation Sequence
Δmin	-	Comparison Sequences Minimum Values
Δmax	-	Comparison Sequences Maximum Values
ξ	-	Identification Coefficient
n	-	Number of Response Characteristics
$\gamma 1$	-	Required Grey Relational Grade
MPa	-	Mega Pascal
HBR	-	Hardness Scale of Rockwell Hardness

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CHAPTER 1

INTRODUCTION

1.1 Background

A356 aluminium casting alloys have been generally utilized in automotive and aerospace industries to give progress on those concerns because of their colossal castability, weldability, corrosion resistance and high strength-density proportion or also known as a ratio. Generally, the microstructural of A356 aluminium alloy features considerably controlled mechanical properties. The as-cast microstructure of A356 comprises of course dendritic structure, permeable structure, and non-uniformly distributed Si phase (Manochehrian et al., 2019). The mechanical properties of A356 aluminium casting alloy have been improved by using the T6 heat treatment method. Thus, it consists of good castability that can be used to fabricate complex casting designs where lightweight, pressure tightness and excellent mechanical properties needed (GECU et al., 2018).

T6 heat treatment is a method for improving the mechanical properties of Al-Si castings. The T6 heat treatment includes a solution heat treatment, soaking and ageing, and the parameters typically did in industry, are those proposed by ASTMB917 and ASTMB91 standards. The solution heat treatment at a temperature of 540oC, with local times that may fluctuate somewhere in the range of 6 hours and 12 hours, and then artificially ageing at 155oC between 3 hours and 5 hours (Menargues et al., 2015). The precipitation hardening through heat treatment will encourage the alloying components in the form of fine coherent particles of Mg2Si and Al2Cu inside the grains during the ageing stage to solidify the alloy. The long span solution heat treatment can modify the morphology of the Si stage into a spheroidal shape and thus change the properties of the aluminium alloy (L.Y.Pio, 2011). In the casting industries, it is regularly indicated that a casting segment ought to be solution treated for 6 hours at 540oC (Menargues et al., 2015).

The Taguchi method is used uniquely for single response optimization issues. To overcome this downside, the Grey-Taguchi strategy is utilized for solving interrelationships among the different reactions. In correlation with other improvement techniques, for example, the response surface method (RSM), the Grey-Taguchi method allows examination for several factors simultaneously with the least possible number of experiments and however yield reproducible outcomes with sufficient exactness. This technique focuses on the effect of individual factors and investigates a linear relation and is applied in the screening of trials (Shirasangi et al., 2021a). Moreover, the Grey-Taguchi methodology requires a smaller number of experiments (Gul et al., 2020). This method doesn't represent the cooperation impact and quadratic terms, thus give no data about the non-linear behaviour of the system (Shirasangi et al., 2021a).

Analysis of variance (ANOVA) is a statistical method that chooses whether the mean estimation of at least two groups is different. It is also a tool for decision making to recognize any variations in the average daily practice of groups of objects tested (Vishwanatha et al., 2021). The ANOVA method is used to also determine the most important process parameter in obtaining the highest tensile and hardness values, as well as the overall percentage of each parameter's effect. To forecast the analytical value of process parameters, the study of variance (ANOVA) was used. It aids in determining how independent parameters influence the output parameter. By comparing the mean square against a measure of exploratory errors at explicit certainly stages, ANOVA assists in casually measuring the critically and cooperation of every principal factor (Chandran et al., 2020).

Greensand casting is considered as a role as perhaps the most antiquated manufacturing processes which goes back 4000BC. Some books express that the Shang Dynasty in China (1600-1046 BCE) utilized clay moulds and surprisingly the popular Houmuwu ding (1300BC) was made utilizing clay mouldings. Greensand projecting is one of the fundamental and raw processes of any manufacturing industry. The word “GREEN” in Greensand casting alludes to the moisture present in the wet sand or can state as clay used for the process (Ranade et al., 2020). The Greensand mould casting process is one of the famous casting processes to create ferrous and non-ferrous castings. the crude material of sand mould is effectively accessible and reusable thus, 70% casting is being made by the sand-casting process. The sand mould has great porousness, hardness and strength which makes it more appropriate for castings. The casting quality relies upon the physical, chemical and mechanical property of the mould. These properties fluctuate with sand molecule shape and size, compound structure, combination temperature and cover restricting property (Sadarang et al., 2020).

The waterjet cutting produces sludge in the type of slime comprising of the garnet sand, particles of the cut metal and water. This is called a waste of abrasive waterjet. The average execution waterjet cutting machine produces at least 200g of dry waste each moment. The piece and properties of the waterjet cutting metal waste tends to be depicted as extra fine and almost uniform weighty sand with high substances of residue portion, with iron, silicon and aluminium oxides winning its synthetic structure (Skanavi & Dovydenko, 2018).

1.2 Problem Statement

Greensand casting is still widely used in manufacturing industries because it has low production cost and easy to process complex products. However, in today's market, the price of silica sand has been risen to double compared to the standard price. To overcome this problem, the waste from abrasive waterjet is introduce, so that it can help to reduce the usage of silica sand. In manufacturing industries that use the casting process still have not started to use abrasive waste to produce moulds because they do not aware of it. They intended to use silica sand because it provides better quality products. Since silica sand has a high market, the prices also will keep on increasing and this can affect the prices of outcome product as well. Therefore, abrasive waste is a better solution to help reduce the usage of silica sand. Several quality tests have been run on A356 aluminium casting alloy to make sure that the properties and qualities of the outcome results are the same as using 100% of silica sand.

1.3 Research Objective

The aim of the study is to optimize the waste abrasive waterjet parameters (bentonite, coal dust, water) of heat treatment A356 Aluminium alloy using Taguchi based grey relational analysis. The following objectives are as follows:

a) To develop a design of experiment with different composition of Greensand with waste abrasive of waterjet by using Grey Relational Analysis Method.

b) To investigate the microstructure of the heat-treated A356 Aluminium alloy samples.

c) To analyze the mechanical of optimum composition for heat-treated A356 Aluminium alloy samples.

1.4 Scope of Research

The scope of this research**:**

- Develop a design of the experiment by 3 levels (bentonite, coal dust and water) by Taguchi Method for the mixture of silica sand and waterjet abrasive waste.

- Using the Taguchi method is used to identify the optimum grey relation grade by an orthogonal array.

- To analyze the behaviour of T6 heat-treated A356 Aluminium alloy by tensile test and hardness test for different composition by using ANOVA.

- To analyze the morphology microstructure for T6 heat-treated A356 Aluminium alloy for a different composition.