# DEVELOPMENT OF A MATHEMATICAL MODEL TO RELATE THE AGEING PARAMETERS TO HARDNESS AND TENSILE STRENGTH OF AL 6063 ALLOY

Selvarathinam Sivanujan

218010G

Master of Science (Major Component of Research)

Department of Materials Science and Engineering
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# DECLARATION

I declare that this is my own work and this Thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: *UOM Verified Signature* Date: 30/08/2023

The above candidate has carried out research for the Master of Science (Major Component of Research) Thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. GIP De Silva

Signature of the Supervisor: Date: 30/08/2023

*UOM Verified Signature*

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# ABSTRACT

Deformations, failures, and the wearing-off effect are common in Al 6063 structures due to their low strength and hardness, respectively. Industries have age-hardened Al 6063 alloy to improve its properties to a specified level depending on the components being produced. Industries do trials before production and check to see if the product has achieved its required levels of properties. This trial-and-error method is time-consuming, and further, it is not acceptable from an engineering perspective. For this reason, industries are looking for a model that will provide an accurate prediction of the hardness and tensile strength for the parameters associated with aging.

In this research, a mathematical model was developed to predict the most efficient combination of aging parameters to achieve the required tensile strength and hardness of Al 6063. The model was developed based on the experimental tensile strength and hardness values for the 25 combinations obtained by varying aging time and temperature at five levels. Tensile strength and hardness were measured using the universal tensile testing machine and the Vickers hardness tester, respectively. Further, the model was developed using the SPSS statistical software and validated with data sets obtained from the literature. For the purpose of finding the most efficient combination of tensile strength and hardness, the model was developed as a computer program based on the Python programming language.

In addition to the development of the model, the influence of precipitate size distribution on the tensile strength and hardness variation of Al 6063 alloy with aging temperature and time was investigated. Micro-structures were observed, and precipitate types were identified using a scanning electron microscope and an energy dispersive spectrometer (SEM/EDS). The precipitate size distribution was determined based on SEM images using MIPAR image analysis software. Beyond the peak age stage, a significant increase in the percentage of precipitates larger than 1.5 µm and a decrease in the percentage of precipitates smaller than 0.75 µm were accompanied by a decrease in tensile strength and hardness.

**Keywords**: aluminum 6063, age hardening, hardness, tensile strength, precipitate size distribution, mathematical modeling

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# LIST OF ABBREVIATIONS

| **Abbreviation** | **Description** |
|---|---|
| ANOVA | Analysis of Variance |
| BSD | Backscattered Electron Detectors |
| DSC | Differential Scanning Calorimetry |
| EDS | Energy Dispersive Spectroscopy |
| FEA | Finite Element Analysis |
| NN | Neural Network |
| RSM | Response Surface Methodology |
| SEM | Scanning Electron Microscopy |

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