

UNIVERSITI TEKNOLOGI MARA

**EXPERIMENTAL-NUMERICAL
ANALYSIS OF LEUCAENA-
SILICONE BIOCOMPOSITE ON
PHYSICAL-MECHANICAL
PROPERTIES**

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ABSTRACT

Natural fibre composites have become popular for their ability to support sustainable and economic growth by using renewable resources and lowering environmental impact. These composites, made by combining different materials, are designed to have specific desirable properties. Therefore, this study focuses on creating an innovative silicone biocomposite by reinforcing Leucaena fibre into silicone rubber. The research defines in two main stages which are experiments and mathematical modelling. Despite the lack of reliable data on reinforcing Leucaena into silicone rubber, specimens were carefully prepared with fibre compositions ranging from 0wt% to 16wt%, following appropriate fabrication standards. Comprehensive physical and mechanical tests were conducted to evaluate the properties of the new material, including its density and tensile behaviour under uniaxial load. The tests performed included the Density Test (ASTM-D792), Uniaxial Tensile Test (ASTM-D412) and Compression Set Test (ASTM D394). These tests were conducted to provide a thorough understanding of the material's performance under various conditions. As the materials exhibit hyperelastic behavior, three hyperelastic material models (Neo-Hookean, Mooney-Rivlin, and Ogden) were employed to quantify the material parameters. This study utilized a predictive approach employing the MATLAB Neural Network Tool (nntool) to construct an artificial neural network (ANN) with three inputs (weight, load, and elongation) and outputs (material constants: C_1 , C_2 , μ , and α). The network successfully predicted the material constants of the Ogden model. Testing results showed a consistent increase in specimen density with the rise in fibre content. The quantified tensile properties of this newly introduced Leucaena-silicone biocomposite ranges from 30.30 kPa to 38.90 kPa (Neo-Hookean), 42.30 kPa to 47.10 kPa (Mooney Rivlin) and 5.40 kPa to 55.90 kPa (Ogden). Thus, tensile test results demonstrated improved material properties and increase specimen stiffness with higher fibre content supported by numerical analysis. The Coefficient of determination, R^2 , aided in selecting the best curve fitting in hyperelastic modelling with the Ogden model exhibiting the highest R^2 value (0.99903), indicating its excellent agreement with experimental data. Besides, the percentage difference of prediction between experimental and ANN is 0.11% (Neo Hookean). The artificial neural network efficiently predicted the optimum trained network through various trials, achieving satisfactory coefficients of correlation (R) for training, testing, validation and overall. In conclusion, this study significantly advances the understanding of Leucaena-silicone biocomposites by combining experimental and numerical analyses to evaluate and predict material properties. The findings contribute to the development of sustainable materials with improved mechanical performance. The predictive model established in this research will aid future studies in efficiently determining material constants, promoting further innovation in biocomposite materials.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Composite material is combination of two or more materials that can macroscopically viable to form materials with specific properties (perfect bonding) and enhanced performance [1]. The composite has unique properties because the different materials used in it work together [2]. In other words, composite materials are formed by combining the complete structures of more than one material [3]. One of composite material is fibre reinforced polymer (FRP) which is the fibre can be selected from synthetic fibre such as carbon fibre, glass fibre and aramid fibre. The polymer act as a matrix. While for matrix material consist of polymer, metal and ceramic [2].

Biocomposite materials are the fibre used from the natural resources such as Kenaf, sugar palm, wood and waste materials. A biocomposite is a blend of natural fibres and matrices, including thermoplastic and thermoset polymers [3]. Besides, biocomposite help in decreasing environmental impact and improved mechanical properties since its biodegradable. Other than that, biocomposite can be as alternative for used in industrial field in order to fabricate any kind of products. Manufacturers find biocomposites appealing due to their flexibility in processing, high level of stiffness that can be tailored to specific needs and their affordability when considering the volume of material used. Recently, there has been increased research on biocomposites among researchers [4]. This is due to the characteristics of biocomposites which are capable of making a significant impact in various sectors such as construction, manufacturing and automotive. In addition, the use of biocomposites in the food packaging industry can replace conventional plastics which are often made from fossil-based materials. Environmental advantages are provided by bio-polymers due to their biodegradability, fewer greenhouse gas emissions, and derivation from renewable resources [5].

The natural fibre growing in the interest and utilisation in various fields as it has biodegradable properties, low cost, high availability and low density. On the other hand, the natural fibre is becoming new substituents for conventional fibre such as carbon Kevlar, carbon fibre and glass fibre. Therefore, the dependency of non-renewable