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EXPERIMENTAL CHARACTERISATION AND HYPERELASTIC MODELLING OF THE MECHANICAL BEHAVIOUR OF ARENGA PINNATA – SILICONE BIOCOMPOSITE

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ABSTRACT

The increasing awareness about global climate change issues has slowly led to the use of natural fibres in composite materials as an alternative to synthetic fibres since the latter produces harmful gases upon burning. This concern has motivated the study to produce a new soft biocomposite material by employing a natural fibre; Arenga pinnata fibre (AP) as a filler for silicone rubber. Silicone rubber is known to possess high flexibility and elasticity, nevertheless silicone rubber exhibits weak strength. To improve this, AP fibre which possess good seawater resistance was added into silicone rubber. The interfacial adhesion between the silicone rubber and the AP fibre were also investigated since both possessed hydrophobic and hydrophilic properties respectively. Therefore, the main aims of this study are to investigate the physical and mechanical properties of the Arenga pinnata – silicone biocomposite (APSil) and to model its deformation behaviour using hyperelastic constitutive model. The specimens were prepared with 0wt%, 4wt%, 8wt%, 12wt% and 16wt% of filler compositions. Physical tests: swelling test, moisture absorption test and density test were carried out to investigate its physical properties. Uniaxial tensile test, compression test, and dynamic mechanical analysis were also conducted to compare the mechanical properties of both soft (silicone) and hard (epoxy) biocomposites. Morphological analysis on the fractured specimens after tensile test was conducted using Scanning Electron Microscope (SEM). Since this material is soft, hyperelastic constitutive models; Mooney-Rivlin, Yeoh and Polynomial models were also adopted using Excel Solver and polynomial regression method (PRM). A new mathematical modelling; the Modified Polynomial model was also developed to accurately describe the tensile deformation behaviour of the soft materials. It was found that the density and moisture absorption intake showed a steady increment as the filler content increased. The highest water intake recorded was 3.26% (16wt%). Besides, result displayed the swelling properties of Arenga pinnata – silicone biocomposite was enhanced as the filler composition is increased. Pure silicone rubber (0wt%) shows the highest swelling rate (283.27%) in comparison to 16wt% specimen which possesses the lowest swelling rate (146.84%). Comparing both soft and hard materials, both materials demonstrated different mechanical behaviour. However, it is interesting to find from the tensile test that a gradual increment of filler content had improved its stiffness property. Results from compression tests and dynamic mechanical analyses also revealed that the increment of filler addition had enhanced both soft and hard biocomposite as its compressive strength and thermal properties increases. The SEM images also indicated that all specimens (soft and hard) possessed good filler-matrix bonding and the AP fillers were well distributed. Through numerical study, the new Modified Polynomial hyperelastic model showed the best performance (R^2 up to 0.9998) to accurately curve fit the experimental data of all specimens as compared to Mooney-Rivlin, Yeoh and Polynomial models. Therefore, it can be concluded that this study has successfully achieved the aims to investigate the effect of the addition of Arenga pinnata fibres into silicone rubber mechanically and numerically. It could also be determined that the addition of AP filler has significantly improved the chemical, stiffness and thermal properties of the material. This has contributed significantly to the knowledge about Arenga pinnata – silicone biocomposite and soft materials as well. Its material constants have also been successfully quantified using the Modified Polynomial model accurately and the mechanical properties of hard (epoxy) and soft (silicone rubber) biocomposite have been well distinguished.

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CHAPTER ONE
INTRODUCTION

1.1 Background

Over the past few years, we have been experiencing global warming phenomena which lead to heart breaking issues such as the melting of ice in the Arctic that causes the extinction of animals like polar bears. One of the huge contributors to this climate change is the large amount of carbon dioxide (CO_2) emissions in the atmosphere. The burning of plastic and synthetic fibres including glass fibres, carbon fibres, Kevlar, and nylon have emitted these anthropogenic CO_2 gases as the gases accumulated and trapped within the earth atmosphere. This has eventually caused the rise of temperature of the earth. Due to this, the awareness has increased among researchers by promoting the use natural fibres in composite materials which are CO_2 neutrality [1-3] instead of using synthetic fibres to help reduce the amount of CO_2 emissions.

"Biocomposite" material is the term used for a composite material that is either the matrix, reinforcement or both derived from a biological origin [4]. Thus, the employment of natural fibre as filler or reinforcement in composite material has become famous as to replace the synthetic fibre for a greener material. Natural fibres also exhibit unique characteristics over synthetic fibres in terms of low density, cheaper, bio-degradability property and most of all, they can be obtained easily as they are abundant in nature [5-6]. Besides that, natural fibres are safe to be used compared to synthetic fibres which can cause harm to our skin and lead to environmental problems [7]. Some of the natural fibres already known by researchers are kenaf, oil palm, flax, jute and others which have been employed extensively in composite materials to investigate its potential in replacing the man-made fibres [4,8]. Some of the studies have also fabricated a hybrid composite that combines both synthetic and natural fibres [9,10] in order to overcome the weaknesses in natural fibres.

"Arenga pinnata", "Ijuk" or "Arenga saccharifera" is one of the growing attentions in the study of potential natural fibres for composite materials. Arenga pinnata (AP) is a multipurpose plant as almost all parts of the tree can be utilised [11]. They are traditionally used in the making of ropes for ship cordages, roofs, brooms and