CHARACTERIZATION AND MODELING OF THERMO-MECHANICAL BEHAVIOR OF SOLID TIRES WITH GRAPHITE AS A HEAT TRANSFER ENHANCER

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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.

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Abstract

The solid resilient tire construction consists of three layers namely tread, cushion and base. The cushion or the middle layer provides a comfortable ride but also needs to reduce the heat buildup when the tire is subjected to heavy loads. Repeated loading on the cushion compound causes heat generation due to hysteresis and combined with the heat due to friction from tread needs to be relived promptly to reduce the risk of tire damage. The aim of the study is to enhance the thermal properties of the cushion compound of the solid tire using Sri Lankan vein graphite powder as a filler.

This study reports mechanical, chemical and thermal properties of vein graphite powder sourced from Bogala mines, Sri Lanka. Five varieties of graphite powder samples were chosen to investigate their potential for application and each were characterized through Thermal Constant Analyzer, Differential Scanning Calorimetry, and Ultrasonic pulse-echo method. The ultrasonic method was adopted to obtain measurements of the Poisson's ratio (ϑ), Young's modulus (E), and Shear modulus (G) of the graphite powder samples. Highest value of thermal conductivity, volumetric heat capacity, and thermal diffusivity was reported from the grade of graphite powder possessing larger particle size.

The study also focused on the improvement of the mechanical, curing, and thermal properties of vein graphite filled cushion compounds. The results showed a decrease in tensile strength with the graphite powder content. Maximum torque and the cure time were not significantly changed with the graphite particle content. Furthermore, results revealed a 66% of increase in thermal conductivity at the 10% of graphite particle addition to the compound relative to the unfilled cushion compound. It was observed that tensile strength decreased (with increased hardness) due to low interfacial adhesion and air gaps present between graphite particles and the compound. Furthermore, Dynamic mechanical analysis was performed on the vein graphite filled solid tire compounds to investigate the interaction between graphite and the polymer matrix.

Next, an empirical equation, derived from the relationship between theoretical and experimental thermal conductivity values, was established to model the for graphite-

filled solid tire compound. This equation is a valuable tool for estimating thermal conductivity within the 0-10% graphite filler loading range. Then, a comprehensive tensile test and thermal conductivity test simulations were carried out using Abaqus software and compared the obtained results with experimental data, which was observed to have reasonable correlation.

Dedication

To my loving husband Hashira ❤️

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List of Abbreviations

Abrasion Resistance Index	ARI
Aluminum Nitride	AIN
American Society for Testing and Materials	ASTM
Carbon Black	CB
Carbon Fiber	CF
Carbon Nanotubes	CNT
Coarse Flakes of Radial	CFR
Coarse Striated-Flaky	CSF
Conductive Graphite	GT
Cure Rate Index	CRI
Definitions of Differential Thermal Analysis	DTA
Degree of Graphitization	DG
Deutsches Institut für Normung	DIN
Differential Scanning Calorimetry	DSC
Electrically Conductive Adhesive	ECA
Energy Dispersive X-Ray	EDX
Energy Dispersive X-Ray Spectroscopy	EDS
Expanded Graphite	EG
Finite Element Analysis	FEA
Force – Displacement	F-D
Four-Node Linear Heat Transfer Quadrilateral Element	DC2D4
Full Width at Half Maximum	FWHM
Graphene Oxide	GO
Graphite Nanoplatelets	GNP
Graphite Nanoplatelets	GNP
Graphited Fiber	GF
Liquid Crystal Polymer	LCP
Moving Die Rheometers	MDR
Multiwalled Carbon Nanotubes	MWCNT

Natural Rubber	NR
Needle-Platy Graphite	NPG
Negative Temperature Coefficient	NTC
Non-Destructive Testing	NDT
Oscillating Disc Rheometers	ODR
Poly (Vinyl Alcohol)	PVA
Polydimethylsiloxane	PDMS
Polyester Resin	PR
Polyimide	PI
Polymeric Matrix Composites	PMC
Polystyrene Sulfonate	PSS
Polyvinylidene Fluoride	PVDF
Radial Single-Walled Carbon Nanotube	RSWCN
Reduced Graphene Oxide	RGO
Rubber Process Analyzer	RPA
Scanning Electron Microscope	SEM
Shiny-Slippery-Fibrous	SSF
Specific Gravity	SG
Specific Heat Capacity	SHC
Styrene Butadiene Rubber	SBR
Thermally Reduced Graphite Oxide	TRGO
Thermally-Exfoliated Graphite Oxide	TEGO
Thermo Gravimetric Analysis	TGA
Three Dimensions 8-Node Brick Element	C3D8
Three Dimensions 8-Node Brick Hybrid Element	C3D8H
Ultra-High Molecular Weight Polyethylene	UHMWPE
Ultrasonic Testing	UT
Urethane Acrylate Non-Ionomer	UAN
Vinyl Acetate	VA
X-Ray Diffraction	XRD