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MODELLING OF THE VULCANIZATION PROCESS OF THICK-WALLED NATURAL RUBBER ARTICLES

By

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A thesis submitted to the Department of Materials
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in partial fulfilment of the requirements for the degree
of Master of Philosophy

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ABSTRACT

MODELLING OF THE VULCANIZATION PROCESS OF THICK-WALLED NATURAL RUBBER ARTICLES.

By: V.S.C. Weragoda

Chairperson of Supervisory Committee : Dr. P.Y. Gunapala
Co-Supervisor : Dr. N. Munasinghe

A computer-based technique was developed to render the state of cure in thick-walled natural rubber compounds as measured by the oscillating disk rheometer torque. The method was based on a mathematical function derived to replicate the rate of change in the rheometer torque with respect to the curing time and the curing temperature.

The mathematical function was able to trace the temperature related changes in the rheometer curves of different rubber compounds exceptionally well, at a 99.9% level of certainty. This was used to model the vulcanisation process for thick-walled articles through a deterministic simulation approach, which was made it possible to predict the scorch time, curing time, and the time for onset of reversion to a precision within ±5%, as verified against programmed a temperature profile curing in a rheometer.

This study also investigated the variation of the thermal conductivity and the thermal diffusivity of rubber compounds during the curing process, to determine the effectiveness of such variations in estimating the curing time of thick-walled rubber articles. The experiments were carried out using a modified hot wire technique.

The coefficient of variation in the thermal diffusivity was estimated at 20%, and the same for the thermal conductivity was found to be 15%, for the compounds tested. The simulation model showed that this variation was not significant in affecting the curing time.

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LIST OF SYMBOLS

a - Thermal diffusivity (m^2/s)

A - Area (mm^2)

C - Degree of chemical conversion

C_p - Specific heat capacity at constant pressure

G - Gradient (of a curve)

h - Heat transfer coefficient ($Wm^{-2}K^{-1}$)

k_{th} - Thermal conductivity ($Wm^{-1}K^{-1}$)

k_1, k_2, k_3 - Arbitrary constants

M - Rheometer torque

M_L - Minimum torque in rheometer curve

M_H - Maximum torque in rheometer curve

Q - Specific Heat generated (J/m^3)

$\dot{Q}$ - Rate of heat generation (W/m^3)

T - Temperature

t - Time

t_{S1} - Time taken for the rheometer torque to increase by 1dNm from M_L (induction period)

α - State of cure (By rheometer torque or by degree of cross-links)

β_1, β_2 - Parametric constants in the curing rate curve

γ_1, γ_2 - Parametric constants in the curing rate curve

δ_1, δ_2 - Parametric constants in the curing rate curve

ρ - Density (kg/m^3)

χ - Euler's Constant (0.5772)

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