Faculty of Manufacturing Engineering

APPLICATION OF BIO-GLYCOL TO INHIBIT NATURAL PRESSURE LOSS IN AUTOMOTIVE TYPE

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APPLICATION OF BIO-GLYCOL TO INHIBIT NATURAL PRESSURE LOSS IN AN AUTOMOTIVE TYRE

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled “Application of Bio-Glycol to Inhibit Natural Pressure Loss in Automotive Tyre” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is concurrently submitted in candidature of any other degree.

Signature : ……

Name : Raguvaran a/l Jayahkudy

Date : 14/7/2016

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award for the award of Master of Science in Manufacturing Engineering.

Signature : ……..

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Date : 14/7/2016

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DEDICATION

This thesis is dedicated to my beloved parents,

for all the continuous support that you have given to me.

To my beloved friends,

whom never give up in supporting and encouraging me.

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ABSTRACT

Automotive tyre plays an imperative aspect in ensuring safety, economical and performance of a motor vehicle which indeed the only medium that merge the contact between a car and asphalt. According to studies and statistics by giant tyre manufacturers, one of the primary reasons for major road accidents which often leads to loss of life is the catastrophic tyre failure caused by vehicles running with improper tyre pressure due to lack of attention on tyre maintenance. The phenomena where tyre loses pressure naturally and contracts over time is called air permeation, which is identified to be the main cause of tyre to deflate but rarely can be realised by naked eyes. Properly inflated tyres can safe tyre life up to 20% which is equivalent to nine months of its life span, save fuel from 4% to 10%, increase braking efficiency up to 20%, lightens steering system and ease self-steer. Since the day pneumatic tyres were invented, sudden losses of air acts as a major problem associated with tyres and are still being treated by professional tyre researchers. Besides external punctures which cause tyre deflation, other crucial factors which contribute to natural pressure loss are investigated in this study such as the properties of inflated air, pressure leak through mechanical fittings and ultimately excessive tyre operating temperature which promotes air permeability over time. Fundamental experimentation to study the behaviour and characteristic of pressure loss of a normal tyre was conducted in both static and dynamic conditions where they were also tested with and without loaded situation to extract precise data of the pressure loss. It is noticed that a normal tyre losses 5kPa to 10kPa of pressure a month at static condition and 15kPa to 20kPa at dynamic condition. Nowadays, usage of tyre sealants which contains Ethylene Glycol or Propylene Glycol as a countermeasure to curb the issue becomes an ideal solution and current trend but reflects several drawbacks namely on the performance, properties and characteristic of the sealant. In order to improvise the currently available solution, a relevant bio-based additive sealant that tailor to the situation have been initiated using Bio-Glycol as a way forward total solution suiting a wide range of tyres used on domestic cars sequentially sustaining the tyre pressure and further reducing the natural air permeation rate to stop tyre deflation by means of controlling the tyre operating temperature. The proposed solution have been further tested comprehensively in a dynamic condition along other available solution in the market with aid of Tyre Pressure Monitoring System (TPMS), which then leads to the development of a data logging structure of each tyre pressure and temperature using LabVIEW graphical user interface. Concurrently, the physical and chemical properties of the solution have been generated as a validation to reflect its basic performance. Finally, the proposed solution shows promising result in controlling tyre temperature and ultimately reducing tyre pressure loss over time subsequently meeting the standard regulation of a proper tyre sealant.

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ABSTRAK

Tayar memainkan peranan yang amat penting bagi memastikan pemanduan yang selamat, ekonomikal dan prestasi kenderaan bermotor dimana ianya merupakan satu-satunya medium yang bersentuhan dengan permukaan jalanraya. Merujuk kepada pengkajian dan statistik oleh pengeluar tayar terkemuka, antara faktor utama yang mengakibatkan kemalangan jalanraya sehingga menyebabkan kematian adalah berpunca daripada kenderaan yang beroperasi tanpa tekanan tayar yang betul akibat kelalaian pengguna yang mengabaikan kepentingan tekanan tayar. Fenomena dimana tayar mengalami kehilangan tekanan secara semula-jadi berkadar masa dipanggil kebolehtelapan angin dan ia dikenalpasti sabagai punca utama tayar kempis dimana ia susah untuk disedari dengan hanya memerhati menggunakan mata kasar. Tekanan angin yang mencukupi dalam tayar dapat memanjangkan hayat tayar sehingga 20% (bersamaan dengan 9 bulan), menjimatkan penggunaan bahanapi daripada 4% ke 10%, meningkatkan kecekapan brek sehingga 20% dan meringankan stering dan sistem balasnya. Sejak bermulanya era penggunaan tayar, kehilangan tekanan angin menjadi masalah utama tayar dan masih dalam penyelidikan oleh para pengkaji tayar sehingga ke hari ini. Selain daripada faktor tindakan luar yang mengakibatkan tayar kempis, beberapa punca utama mengakibatkan kehilangan tekanan angin secara semula-jadi telah dikaji antaranya komposisi kandungan angin dalam tayar, kehilangan angin melalui kelengkapan mekanikal dan terutamanya suhu operasi tayar yang tinggi. Eksperimentasi asas bagi mengkaji ciri-ciri sesebuah tayar telah dibuat dalam kedua-dua situasi iaitu statik dan dinamik dibawah pengaruh beban untuk mengekstrak data kehilangan tekanan angin secara tepat dan jitu. Berdasarkan esxperimen tersebut, tayar biasa mengalami kadar kehilangan angin daripada 5kPa ke 10kPa sebulan dalam situasi statik manakala 15kPa ke 20kPa sebulan dalam situasi dinamik. Penggunaan 'sealant' tayar yang mengandungi samaada "Ethylene Glycol" atau "Propylene Glycol" sebagai agen untuk menangani masalah kehilangan tekanan angin tayar amat berleluasa pada masa kini tetapi ia juga terdapat kekurangannya tersendiri dari segi prestasi dan ciri-cirinya. Rumusan baru telah dicipta iaitu 'sealant' berdasarkan bahan tambahan-bio menggunakan "Bio-Glycol"bagi mengatasi kekurangan prestasi 'sealant' tayar yang sedia ada dengan hanya mengawal suhu operasi tayar. Rumusan ini kemudiannya dikaji dalam situasi dinamik bagi mendapatkan perbezaan dengan rumusan yang sediaada dengan bantuan alat yang dipanggil sistem pengawasan tekanan angin tayar (TPMS) yang menjurus kepada ciptaan suatu sistem bagi merekod data tekanan angin dan suhu tayar menggunakan perisian grafik "LabVIEW". Justeru itu, ciri-ciri fizikal dan kimia solusi tersebut telah dikaji sebagai pengesahan kebolehgunaan solusi tersebut. Akhir sekali, solusi yang telah dicipta menunjukkan prestasi yang amat memuaskan dalam mengawal suhu operasi tayar sekaligus mengurangkan kehilangan angin dalam tayar selaras dengan standard yang ditetapkan bagi penghasilan sesebuah 'sealant' tayar.

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LIST OF ABBREVIATIONS

^{o}C	-	Degree Celsius
^{o}F	-	Degree Fahrenheit
%	-	Percentage
A	-	Surface area
ASCII	-	American Standard Code for Information Interchange
ASTM	-	American Society for Testing and Materials
BG	-	Bio-Glycol
BIIR	-	Bromo-butyl
cc	-	Cubic centimetres
cm	-	Centimetre
COM-Port	-	Communication Port
cP	-	Centipoises
D	-	Coefficient of diffusion
EG	-	Ethylene Glycol
FTIR	-	Fourier Transform Infrared Spectroscopy
g	-	Gram
IRTAD	-	Malaysian International Traffic Safety Data and Analysis Group
K	-	Kelvin
kg	-	Kilogram

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km	-	Kilometre
km/h	-	Kilometre per hour
kPa	-	Kilopascal
l	-	Tyre inner-casing material thickness
LabVIEW	-	Laboratory Virtual Instrumentation Engineering Workbench
M	-	Molecules
MIROS	-	Malaysian Institute of Road Safety Research
ml	-	Millilitre
mm	-	Millimetre
MSDS	-	Material Safety Data Sheet
N_2	-	Nitrogen
$\dot{n}''$	-	Rate of outward flux inflation
n	-	Number of moles
NHTSA	-	U.S. National Highway Traffic Safety Administration
NR	-	Natural Rubber
O_2	-	Oxygen
P	-	Pressure
Pa	-	Pascal
PG	-	Propylene Glycol
P_{N2}	-	Permeability of Nitrogen
P_{O2}	-	Permeability of Oxygen
psi	-	Pounds per square inch
Q	-	Permeability
RSD	-	Malaysian Road Safety Department

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S	-	Solubility
SEM	-	Scanning Electron Microscopy
STP	-	Standard Temperature and Pressure
T	-	Temperature
TIC	-	Trinity Inclusive Curriculum
t_m	-	Number of seconds in a month
TPMS	-	Tyre Pressure Monitoring System
V	-	Volume
V_m	-	Volume of mole
wt %	-	Weight percentage

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LIST OF PUBLICATIONS

1. Way Forward to Halt Pressure Loss in Automotive Tyres. *Applied Mechanics and Materials,* 761 (2015), pp.510-514. (SCOPUS Indexed - Published)

2. Air Permeability Investigation towards Automotive Tyre Pressure Sustainability and Life Saving. *ARPN Journal of Engineering and Applied Sciences,* 10 (10), pp.4404-4412. (SCOPUS Indexed - Published)

3. Design of Novel Pressure Replenishing System to Sustain Automobile Tyre Pressure without Human Intervention. *International Journal of Applied Engineering Research,* 10 (10), pp.26295-26306 (SCOPUS Indexed - Published)

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CHAPTER 1

INTRODUCTION

This chapter describes the background of the research and explains briefly the problem statements, objectives and scope of this research. This chapter also includes the organization of the thesis report.

1.1 Background

Automotive tyres are basically made of natural and synthetic rubber and their hybridization provides comfort, as well as ensures safety in different types of road conditions and operational temperature. The only medium that transfers the whole lot of vehicle load onto the road is the tyre. As tyres are supported by the wheels, they provide a cushion between the road and the vehicle suspension. Besides, they also provide traction for both acceleration and braking; resist lateral forces for safe cornering, stability and better handling. With the assistance of the air pressure inside them, tyres are responsible in providing support for the overall weight of a vehicle as claimed by Haraguchi (2006).

Automobile tyres naturally undergo gas escapism due to several causes, which then require regular inflating to replace the air loss and to sustain proper tyre pressure. Tyre pressure drops mainly due to pressure loss or air escapism from the tyre. Beside tyre quality and tyre materials, improper tyre pressure is the main factor that leads to catastrophic tyre failure and eventually resulting in major road accidents as stated by Dosjoub (1988) and Litchfield (2001). Furthermore, Sivarao et al. (2009) clarify that every

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20 kilopascal pressure drop in a tyre is equivalent to adding a virtual 70 kilogram person into the car which indirectly results in excessive tyre wear and serious road accidents due to poor control and stability of the car. Micro molecular gases can easily escape to the atmosphere from a pressurized vessel through the interface fittings and absorption through porous materials. Sivarao et al. (2009) found that an automobile tyre naturally releases about 10kPa to 20kPa of pressure every month regardless of tyre brand used. Excessive tyre operating temperature is noticed to be one of the primary factors affecting natural tyre pressure loss which is also known as air permeation (Karmarkar et al. 2010).

Therefore, tyre sealants are widely used by vehicle owners not only to seal any external punctures but also used as a laminating medium to reduce pressure loss through the tyre. Most of the sealants produced are glycol-based; they either use Ethylene Glycol or Propylene Glycol which act as heat transfer fluids to reduce the air loss from the tyre by means of controlling excessive tyre operating temperature. A totally new Bio-based additive sealant using Bio-Glycol which is derived totally from corn has been initiated as a solution to improvise currently available sealant performance by controlling excessive tyre operating temperature and ultimately reducing tyre pressure loss. Nevertheless, this proposed solution is non-toxic and fully bio-degradable. Besides, it has non-petroleum content and corrosion inhibited sealant which downsizes the performance gap between the tyre sealant using Ethylene Glycol and Propylene Glycol thus suiting a wide range of tyres used on domestic cars.

1.2 Problem Statement

Under inflated tyres lead to excessive load concentrated on it. Investigations by giant tyre manufacturers reveal that underinflated tyres are virtually overloaded in the

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absence of passengers in the car thus increasing the fuel consumption, reducing braking efficiency and tyre life. The improper tyre inflation hazard does not stops here; it goes a step ahead where the excessive heat generated due to the overloaded condition between the road is dissipated to the tyre. This heat accumulation then leads into the fatigue region and exposes the tyre to the risk of explosion hence resulting in accidents due to loss of control (Abdullah et al., 2013). Since automobile tyres are not able to sustain pressure for a longer period due to natural pressure losses, tyre sealants have become a popular solution and are in demand nowadays. The usage of glycol-based tyre sealants for the purpose of sustaining tyre pressure has begun since 1969. Two primary types of glycol based tyre sealants are either from Ethylene Glycol or Propylene Glycol. Unfortunately, both these glycol reflect several drawbacks namely on the performance, properties, cost and characteristics of the sealant (Dianyi, 2007). Ethylene Glycol based sealant contains a high toxicity level which is harmful to users but it is cheap and performs better than Propylene Glycol. On the other hand, Propylene Glycol contains lower toxicity level but is expensive and performs less efficient than Ethylene Glycol. Since, controlling excessive tyre temperature has high potentials in sustaining tyre pressure, a scientific approach is to be formulated to investigate systematically with elements involving experimentation, optimization, and validation in order to provide the industry with an improvised outcome in tyre sealant quality.

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