UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CONCEPTUALISATION OF MODULAR AIRLESS TYRE USING TRIZ AND PUGH METHOD

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Conceptualisation of Modular Airless Tyre Using TRIZ And Pugh Method" is the result of my own research except as cited in references.

Signature : .....

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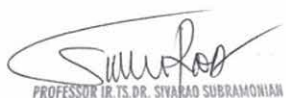
APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:



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(PROFESOR IR. DR. SIVARAO A/L SUBRAMONIAN)

ABSTRAK

Tayar ialah komponen bulat berbentuk cincin bagi kenderaan yang bersentuhan dengan tanah. Tayar berfungsi untuk memastikan kenderaan bersentuhan dengan tanah dengan memberikan daya tarikan yang diperlukan dan mengekalkan beban kenderaan. Tekanan inflasi mempunyai kesan pada cengkaman dan kemungkinan tayar pneumatik letupan dan menyebabkan ketidakstabilan kenderaan. Oleh itu, tayar tanpa udara sedang dibangunkan sebagai tindak balas kepada keperluan yang semakin meningkat untuk tayar yang lebih selamat untuk menangani masalah tayar pneumatik. Walau bagaimanapun, tayar tanpa udara sedia ada mengalami kesukaran untuk diubah suai selepas ia dikeluarkan, serta kekurangan kebolehsesuaian. Projek ini mempersembahkan konsep baharu pembangunan tayar tanpa udara modular kereta menggunakan penyepaduan teori penyelesaian masalah kreatif (TRIZ) dan kaedah Pugh. Analisis fungsional digunakan untuk mengenal pasti dan menganalisis interaksi komponen tayar tanpa udara. 39 parameter kejuruteraan, 40 matriks percanggahan prinsip inventif digunakan untuk menjana penyelesaian. Kemudian, 40 penyelesaian prinsip inventif yang dikenal pasti diperhalusi kepada strategi penyelesaian khusus yang digunakan untuk membina konsep tayar tanpa udara modular. Kekurangan kebolehlarasan tayar tanpa udara adalah disebabkan oleh interaksi yang tidak mencukupi antara jejari, hab dan cincin luar. 40 prinsip inventif, termasuk #1 Segmentasi, #6 Universality, #28 Ganti Sistem Mekanikal dan #34 Menolak dan Menjana Semula Bahagian, diperhalusi menjadi strategi penyelesaian khusus yang digunakan untuk menjana empat lakaran konsep inovatif baharu. Pemilihan konsep Pugh digunakan untuk menilai dan menentukan konsep akhir tayar tanpa udara modular. Keputusan menunjukkan bahawa konsep 2 menduduki tempat pertama dan mempunyai nilai kedudukan tertinggi antara 4 konsep yang dihasilkan.

ABSTRACT

Tyre is a circular, ring-shaped component of a vehicle that comes into contact with the ground. Tyre functions to keep the vehicle in contact with the ground by providing the required traction and to maintain the vehicle's load. Inflation pressure has an impact on grip and the likelihood of a pneumatic tyre blowout and induce vehicle instability. Thus, airless tyres are being developed in response to a growing need for safer tyres to address pneumatic tyre issues. However, existing airless tyre have difficulty to be modify after it has been manufactured, as well as its lack of adaptability. This project presents the new concept of car modular airless tyre develop using the integration of theory of creative problem solving (TRIZ) and Pugh methods. Functional analysis is used to identify and analyse the interactions of airless tyre components. The 39 engineering parameters, 40 inventive principles contradiction matrix are used to generate the solutions. Then, the identified 40. inventive principle solution are refined into specific solution strategy that is used to build the concept of modular airless tyre. The lack of adjustability of airless tyre is attributed to insufficient interaction between the spoke, hub, and outer ring. 40 inventive principles, including #1 Segmentation, #6 Universality, #28 Replace Mechanical System, and #34 Rejecting and Regenerating Parts, are refined into specific solution strategies that are used to generate four new innovative conceptual sketches. Pugh concept selection was used to evaluate and determine the final concept of modular airless tyre. The results shows that concept 2 ranked the first and has the highest-ranking value among the 4 concepts generated.

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DEDICATION

I dedicate my research work to my family, friends, supervisor and final year project panels for giving me assistance, continuous support and encouragement throughout the process. Thank you so much.

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TABLE OF CONTENTS

CHAPTER 4: RESULTS AND DISCUSION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
ANP	-	Analytic Network Process
ARIZ	-	Algorithm of Inventive Problem Solving
3D	-	3 Dimensional
AL	-	Aluminium
CAD	-	Computer-Aided Design
CAGR	-	Compound Annual Growth Rate
CEC	-	Cause-And-Effect Chain
FAM	-	Functional Analysis Model
ME	-	Mechanical Elastic
PU	-	Polyurethane
PFD	-	Problem Formulation Diagram
QFD	-	Quality Function Deployment
RSM	-	Response Surface Methodology
TRIZ	-	Theory of Innovative Problem Solving

LIST OF SYMBOLS

°C	-	Degree Celsius
ρ	-	Rho
kg/m^3	-	Kilogram Per Cubic Metre
MPa	-	Mega Pascal
mm	-	Millimetre
kWh	-	Kilowatt-Hour

CHAPTER 1

INTRODUCTION

This chapter describe the introduction of modelling of a tyre suspending system for bachelor's degree project 1. This chapter go through the project's background of study, problem statement, objectives, scope, significant/important of study, organization of report as well as summary.

1.1 Background of Study

The comfort and safety of driving a vehicle are mostly determined by the components of the car suspension system's proper operating conditions and symbiosis. A shock absorber, a spring, and, most crucially, a tyre makes up a vehicle's suspension system. Drivers have been less mindful of the necessity of their tyres as vehicles have become more sturdy, reliable, and stylish. Tyres have come a long way in terms of safety, performance, and wear, however they still require more care than the majority of automobile components. (Sassi et al., 2016).

A tyre is an important component of any vehicle. Rubber members are used in tyres to provide cushioning as well as clearance for the vehicle. The rubber part is secured to the rim of the wheel. A tube is put inside a tube tyre, whereas a tubeless tyre does not have one. A tyre is a circular component that is installed on the rim of a wheel to transmit the vehicle's load from axle to rim (Abhishek & Kumar, 2020).

A vehicle's suspension system attaches the frame to the road. The primary aim of the suspension system is to increase a vehicle's overall performance as it rolls down the lane. The suspension system also assists in the absorption of road bumps, ensuring a healthy and enjoyable ride. Spring, shock absorbers, bars, linkages, and, most significantly, tyres make up the suspension system.

Tyres plays a variety of roles in a car's safety; they can both avoid and trigger accidents. If tyres are faulty or worn, they may play a significant role in car accidents. Faulty tyres are more skid on wet roads, increasing the risk of a punctured or blowout, which could result in a serious car accident.

Currently, tyre manufacturers are dealing with the increasing mountain of bald tyres that are defiling the landscape and come up with to recycle them or finding solutions for the tyre that long lasting and can be recycled. Airless tyres are currently being developed by companies including Michelin and Bridgestone, which means they are not pneumatic. Airless tyre strives for output standards beyond those possible with traditional pneumatic technology. Airless tyre has pneumatic-like load carrying capability ride comfort and will not fail due to a lack of air pressure because it does not have a pressurised air cavity inside the tyre.

Maintenance-free, strong impact resistance, the ability to function with a partially broken tyre, and use in harsh terrain are all advantages of airless tyre. In the case of an airless tyre, shaping the pressure and energy losses is limited to choosing the right support structure and material design. General airless tyre concept shown in Figure 1.1 have the following components: a tread, a shear beam (analogue to the carcass in a pneumatic tyre) or an elastic ring, a deformable supporting structure, and a rim. The rim and tread of the tyre serve the same purpose as those of traditional pneumatic tyres. The shear beam may have a core, solid or of a certain geometry) sandwiched between two low-deformation-modulus membranes (Hryciów et al., 2020).

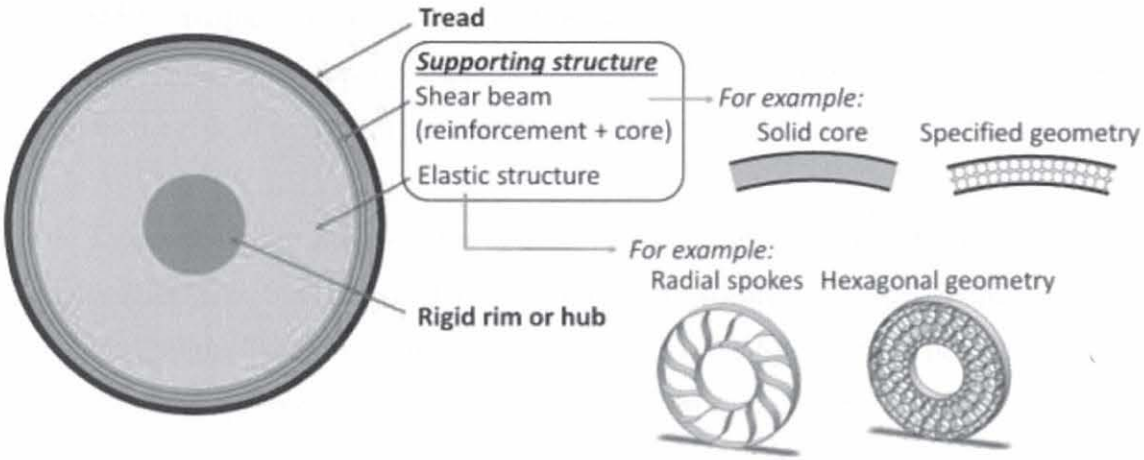

Figure 1.1: General concept of airless tyre (Hryciów et al., 2020)

1.2 Problem Statement

Numerous elements might cause or enhance the likelihood of a tyre failure (puncture or blowout). When a tyre's internal air pressure drops suddenly or gradually, such an unpleasant event can occur at any time. This pressure drop hinders the tyre from performing its primary function, which is to support the vehicle's weight. As a result, the driver is unable to maintain on a safe and straight path, that usually results in a dangerous car accident.

Pneumatic tyre has several flaws, the most significant of which being its vulnerability to air pressure fluctuations. Differences in air pressure have an influence on tyre performance and substantially alter passenger ride comfort. The chance of a blowout on the road is undeniably the most alarming of all the risks.

Inflation pressure affects both grip performance and the danger of tyre blowout failure. A large variance in inflation pressure diminishes grip and, because of the reduced rigidity, can cause vehicle instability even on dry roads. Tyre blowouts can happen as a result of heat generated by massive tyre deformations caused by severe underinflation (Jansen et al., 2016).

Attempts have been made to build flat proof that may provide the same mechanical qualities as the air trapped inside the tyre since the beginning of the twentieth century. There

is no need for periodic maintenance to refill the tyres with air and maintain an acceptable internal pressure with the revolutionary technology of airless tyres. This technique minimises the risk of punctures and greatly improves the vehicle's safety.

To deal with the situation, the concept of flat-proof tyre was born out of a growing desire for safer tyres. Several tyre manufacturers company brought it back to the tyre market. Innovative designs like those proposed by Bridgestone and Michelin are popular because of their non-hazardous behaviour and high stability (Sassi et al., 2016).

As the source of hazard in pneumatic tyre is mainly due to their dependence on air, by introducing the concept of airless tyre such limitations can be avoided. This disadvantage of puncture can be removed by introducing airless tyre that have improved handling and increased surface traction. However, one of the most major disadvantages of the airless tyre is that once created, it cannot be changed and lack of adjustability. A new set of airless tyres would be required if the vehicle required a different quiet setting. When a car hits speeds of above 50 mph while creating a lot of noise, vibrations become pleasant (Kalahastimath, 2021).

1.3 Objectives

The primary objectives of this work are to:

i) Identify and analyse the interactions of the airless tyre system's core components

ii) Generate the concept of modular airless tyre employing TRIZ methodology

iii) Determine the final concept using Pugh concept selection

1.4 Scope

The scope of this project focused on the conceptualisation process where TRIZ approach is used as concept generation while Pugh method is used for concept selection. The interactions of car's airless tyre core components are identified and analysed using functional analysis. Then, the conflicts between good and bad feature of airless tyre components are matched using contradiction matrix. Later, based on the identified inventive principles, specific solution strategies are developed, which are used to construct the conceptual sketch of a modular airless tyre. Next, Pugh method is used to evaluate the concept generated where a final concept of modular airless tyre is made from the evaluation. This study does not involve system level design and detail design.

1.5 Significant/Important of Study

In terms of safety, durability, and wear, tyres have come a long way, but requires more attention than majority of the car components. Extreme under-inflation can cause increased tyre wall flexing and heat build-up within a tyre, which can lead to a disastrous tyre failure. Blowouts are caused by a combination of factors like vehicle speed, tyre pressure, and load. To improve vehicle protection, these factors necessitate both well-known design improvements and the quest for new wheeled mover design solutions, one of which is the use of wheels with airless tyre. Airless tyre has pneumatic characteristics with pneumatic tyre such as load carrying capacity and ride comfort, and it cannot be punctured because it does not have pressurised air cavity. This work looks forward to that new concept of modular airless tyre might be a benchmark study when developing modular airless tyre. The new concept hopes to solve lack of versatility issues of the current airless tyre.

1.6 Organization of The Report/Thesis

This section includes a summary of each chapter's material.