

EFFECT OF DIFFERENT TYPE OF CAR TO TIRE DEFORMATION

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ABSTRACT

Tire is one of the important part in car which it play an important role in automotive industry. In recent years, much progress has been made in the physical understanding to measure the value deformation of the tire. The objective of this project is to study the effect of the different type of car to tire deformation using FEA software. The structural model of the tire was developed using the computer aided design software SOLIDWORKS. Finite element modeling and analysis was performed utilizing the ALGOR software with one condition that is at normal road. It can be seen that from the result, tire deformation increases when the speed and weight of car increase. Three type of car have been selected in this project that is kancil, proton saga, and Toyota vois. The result of this project is the value of stress von mises and nodal displacement will increase when the tire spins more faster and when the weight of car increase.

ABSTRAK

Tayar merupakan salah satu bahagian yang penting dalam dan ianya memainkan peranan yang penting dalam industri automotif. Dalam kebelakangan tahunan ini, terdapat banyak program telah dibuat dari segi fizikal untuk mengaji nilai perubahan bentuk tire. Objektif projek ini adalah untuk mencari akibat perbezaan beberapa jenis kereta terhadap kadar perubahan tayar dengan menggunakan program Algor. Struktur model tayar ini dihasilkan dengan menggunakan program SOLIDWORKS dan analisis model ini dengan menggunakan program AIGOR dalam satu keadaan iaitu keadaan biasa. Keputusan peningkatan perubahan tayar ini boleh dilihat apabila haklajunya semakin meningkat. Tiga jenis kereta telah dipilih dalam kajian itu iaitu kancil, proton saga, dan Toyota vios. Demi mengira perubahan tayar itu, program Algor digunakan untuk mengaji perubahan tayar itu. Keputusan dalam projek ini adalah semakin berat kereta and tayar itu berpusing semakin besar kadar perubahan tayar itu.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE	i
	SUPERVISOR DECLARATION	ii
	STUDENT'S DECLARATION	iii
	DEDICATION	iv
	ACKNOWLEDGEMENTS	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF SYMBOLS/ ABBREVIATIONS	xiii
1	INTRODUCTION	1
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Objective	2
	1.4 Scopes of project	2
	1.5 Thesis outline	2
2	LITERATURE REVIEW	3
	2.1 Introduction	3
	2.2 History of tire	3

2.3	Tread	4
2.4	Component of tire	6
2.4.1	Tread lug	7
2.4.2	Tread Void	8
2.4.3	Rain Groove	8
2.4.4	Sipe	8
2.4.5	Wear bar	8
2.4.6	Contact patch	9
2.4.7	Bead	9
2.4.8	Side wall	9
2.4.9	Shoulder	10
2.4.10	Inner tube	10
2.4.11	Wheel	10
2.4.12	Valve stem	10
2.4.13	Tire pressure monitoring system	11
2.4.14	Inflation pressure	11
2.4.15	Load rating	11
2.4.16	Wheel alignment	11
2.4.17	Flat	12
2.4.18	Hydroplaning	12
2.5	Tire deformation	13
2.5.1	Deformation under load	13
2.5.2	Tire deformation in motion	14
2.5.3	New approach to reducing rolling resistance	14
2.6	Tire by using Algor	15
3	METHODOLOGY	19
3.1	Introduction	19
3.2	Methodology of the project	19
3.3	Assumption made	21
3.4	Model of tire	21

	3.5	Simulation steps	22
4		RESULT AND DISCUSSION	26
	4.1	Introduction	26
	4.2	Calculation of y-direction force on tire with given velocity and 1000m distance.	26
	4.3	Analysis of tire deformation with different weight and with fit velocity and fit distance.	28
	4.4	Analysis tire deformation with weight of kancil, Proton saga and Toyota vios and with different velocity and same distance.	28
	4.5	Summaries analysis tire deformation of three type of car	31
	4.6	Result of the simulation of tire deformation	33
5		CONCLUSION AND RECOMMENDATION	34
	5.1	Introduction	34
	5.2	Conclusion	34
	5.3	Recommendation	35
		REFERENCE	36
		APPENDIX	
	A	Analysis parameters information	38
	B	Part information	40
	C	Summary	41
	D	Log	43

LIST OF TABLE

Table no.	Title	Page
4.1	Result tire deformation with different weight and fit velocity 20m/s and fit distance 1000m.	28
4.2	Result stress von mises with weight kancil, proton saga and Toyota vios and with different velocity and same distance.	29
4.3	Result nodal displacement with weight kancil, proton saga and Toyota vios and with different velocity and same distance	30

LIST OF FIGURES

Figure no.	Title	Page
2.1	Section of tire.	7
2.2	Tire deform.	13
2.3	Deformation under load.	13
2.4	Tire deformation in motion	14
2.5	Reducing rolling resistance	15
2.6	Revolving 2D meshes with the central axis to form the 3D half FE model for rolling simulation and material distribution of tire in the cross-section view.	16
2.7	Coupling capacitance variation versus horizontal deformation of the tread element.	17
2.8	Resistance variation of the tire impedance. Static tensile load applied along the main direction of a single belt.	18
3.1	Figure for flow chat.	20
3.2	Model with isometric side with tire diameter 0.48 meters and rim diameter 0.36 meters.	21
3.3	Model with XZ side with tire diameter 0.48 meters and rim diameter 0.36 meters.	22
3.4	Model tire in the Algor software.	23
3.5	Mesh model tire in the Algor software.	24
3.6	Model Mesh Settings Screen.	24
3.7	Tire model with given force from x-direction and y-direction	25
4.1	Tire deformation with velocity vs. maximum stress von mises.	31
4.2	Tire deformation with velocity vs. maximum nodal displacement	32
4.3	(a) Result of the simulation of tire deformation; (b) Result of the nodal displacement magnitude;(c) Result value of the strain von mises.	33

LIST OF SYMBOLS/ ABBREVIATIONS

<i>u</i>	Initial velocity, m/s
<i>v</i>	Final velocity, m/s
<i>a</i>	Acceleration, m/s ²
<i>s</i>	Distance, m
<i>m</i>	Mass, kg
<i>F</i>	Force, N
<i>f</i>	Stress, psi, ksi, kPa, MPa
<i>V</i>	Shearing force, lb, kip, N, kN
<i>W</i>	Weight, lb, kip, N, kN
<i>ε</i>	Strain
<i>lb</i>	Pound force

CHAPTER 1

INTRODUCTION

1.1 Background

The automotive industry is the industry involved in the design, development, manufacture, marketing, and sale of motor vehicles. Automotive industry was moving ahead to be an important industry in Malaysia and in the world. Tire is one of the main parts in the car which is always costly. In recent years, much progress has been made in the physical understanding and modelling of the friction behaviour of elastomers at rough and self-affine interfaces [1].

This provides a fundamental physical background for understanding the dynamic contact of tires with road tracks during cornering and braking, especially in the case of cars equipped with Anti-Blocking Systems (ABSs). Deeper insights into the traction mechanism of tires serve as a valuable tool in the development of tread compounds for specific applications, e.g. for dry-, wet- or ice-traction [1].

Furthermore, it may offer useful hints for the understanding of the various wear mechanisms of tire treads under different service conditions, since these mechanisms depend on the sliding conditions. Prediction of traction and wear mechanisms of tires requires detailed knowledge about the contact mechanics of tire treads that operate under slip conditions, considering, for example, tread element deformations during braking or sub-division of the tire footprint in deformation and sliding regions[1].

1.2 Problem statement

As the speed of tire increase, its components tend to grow or deform. This deformation leads to heat generation. This is a normal effect of the deformation of the tire's components due to centrifugal force. The faster the tire spins, the greater its tendency to deform and heat is generated. So that, this study is concentrated on stress of deformation on the tire with different type of car.

1.3 Objective

The purpose of this project is to study the effect of different type of car to tire deformation using FEA software.

1.4 Scopes of project

The scope of the projects is limited to:

- i. The weight of car range from 8800N to 22000N.
- ii. Using normal size tire 15 inch.
- iii. Using normal road only.

1.5 Thesis Outline

Chapter 1 is discussed the introduction of the project, problem statement, scopes of project, objective and the thesis outline. Chapter 2 is discussed about the literature review which done by other research about the tire. Chapter 3 is discussed about the simulation set-up, its assumption and drawing. Chapter 4 is discussed about the result and discussion regarding the analysis of the FEA software. Chapter 5 is discussed about the conclusion and future recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Tire deformation causes a change of the spacing between the steel wires inside the tire carcass and this change is translated into an impedance change of that region of the tire. By measuring such an impedance change, our approach enables to determine the deformation of the tire. Experimental results support the feasibility of our approach and are reported and discussed in this paper[2].

Tire, are ring-shaped parts, either pneumatic or solid (including rubber, metals and plastic composites), that fit around road wheels to protect them and enhance their effect. Pneumatic tires are used on many types of vehicles, such as bicycle, motorcycles, cars, trucks, earthmovers, and aircraft. Tire enable better vehicle performance by providing traction, braking, steering, and load support. Tire form a flexible cushion between the vehicle and the road, which smooths out shock and makes for comfortable ride[2,3].

2.2 History of tire

The earliest tires were bands of iron (later steel), placed on wooden wheels, used on carts and wagons. The tire would be heated in a forge fire, placed over the wheel and quenched, causing the metal to contract and fit tightly on the wheel. A skilled crafter,

known as a wheelwright, carried out this work. The tension of the metal band served the purpose of holding or "tying" the wooden spokes of the wheel together, hence the term "tire". In addition to tying the spokes together, the tire also provided a wear-resistant surface to the perimeter of the wheel. As wheels changed over time, the term "tire" continued to be used for the outer band even when it no longer served the purpose of tying the spokes together [4].

The word is "probably" or "perhaps" the wheel's "tire", an obsolete version of "attire". *Tire* is the older spelling, but both were used in the 15th and 16th centuries (for a metal tire); *tire* became the settled spelling in the 17th century but *tyre* was revived in the UK in the 19th century for pneumatic tyres, possibly because it was used in some patent documents, though many continued to use *tire* for the iron variety. *The Times* newspaper was still using *tire* as late as 1905[4].

The first practical pneumatic tire was made by the Scot, John Boyd Dunlop, in 1887 for his son's bicycle, in an effort to prevent the headaches his son had whilst riding on rough roads (Dunlop's patent was later declared invalid because of prior art by fellow Scot Robert William Thomson). Pneumatic tires are made of a flexible elastomer material, such as rubber, with reinforcing materials such as fabric and wire. Tire companies were first started in the early 20th century, and grew in tandem with the auto industry. Today, over 1 billion tires are produced annually, in over 400 tire factories, with the three top tire makers commanding a 60% global market share[4].

2.3 Tread

The tread is the part of the tire which comes in contact with the road surface. The tread is a thick rubber, or rubber/composite compound formulated to provide an appropriate level of traction that does not wear away too quickly. The tread pattern is characterized by the geometrical shape of the grooves, lugs, voids and sipes. Grooves run circumferentially around the tire, and are needed to channel away water. Lugs are that portion of the tread design that contacts the road surface. Voids are spaces between

lugs that allow the lugs to flex. Tread patterns feature non-symmetrical (or non-uniform) lug sizes circumferentially in order to minimize noise[5].

Treads are often designed to meet specific product marketing positions. High performance tires have small void ratios to provide more rubber in contact with the road for higher traction, but may be compounded with softer rubber that provides better traction, but wears quickly. Mud and snow (M&S) tires are designed with higher void ratios to channel away rain and mud, while providing better gripping performance. When installing new tires, you should try and replace all four at once. Installing just two new tires on the front or rear will encourage under steer or over steer. Depending on the vehicle and position of the new tires. With front wheel drive cars the rear tires usually wear very slowly whereas the front tires that do most of the work wear out. If only two new tires are being bought it is important to fit the new tires at the rear. There are several good reasons for this:

1. The rear tires would age and perish otherwise and they need moving up-front to be used up so they do not become brittle and crack .
2. Less weight can be on the rear tires (especially with smaller cars) and grip will be weaker; by having newer tires at the rear more grip is available, and over steer risk will be reduced. It also have more control over the front two wheels, and can afford to have the lesser tires in situ there.

Not moving the rear wheels to the front can cause blowouts as one can end up with antique tires that still look excellent. Actually gain traction when it is cold, whereas, other tires lose traction on the ice and snowy roads[6,7, and 8].

2.4 Component of tire

A modern pneumatic tire is a complicated composite construction made up of strong, light polymer fibers in a matrix made of a carbon-reinforced mixture of elastomeric polymers-rubber. Specialized adhesives help bond rubber and reinforcing cords into a light, doughnut-shaped structure called a carcass[3,4].

The tread area of a radial-tire carcass is reinforced with a number of polymer or steel belts. A flat band of rubber that forms the traction surface is bonded onto the carcass with heat and pressure. Two steel wire hoops connected to the tread area by relatively thin side-walls clamp the tire onto the wheel[3,4].

The tire contact-area shape depends on the tire cross section shape and structure. The relationship between tire contact area and tire deflection is nearly linear. Tire deflection is the most important variable governing the area of contact between the tire and the roadway. If inflation pressure and load are varied simultaneously, the contact area will remain effectively constant[3,4].

The vertical component at any point is equal to the inflation pressure of the tire plus the bundle (tire structural characteristics, tire driving, braking torque, tire side forces and tire velocity, etc.)[3,4]. Section of tire shown in Figure 2.1.

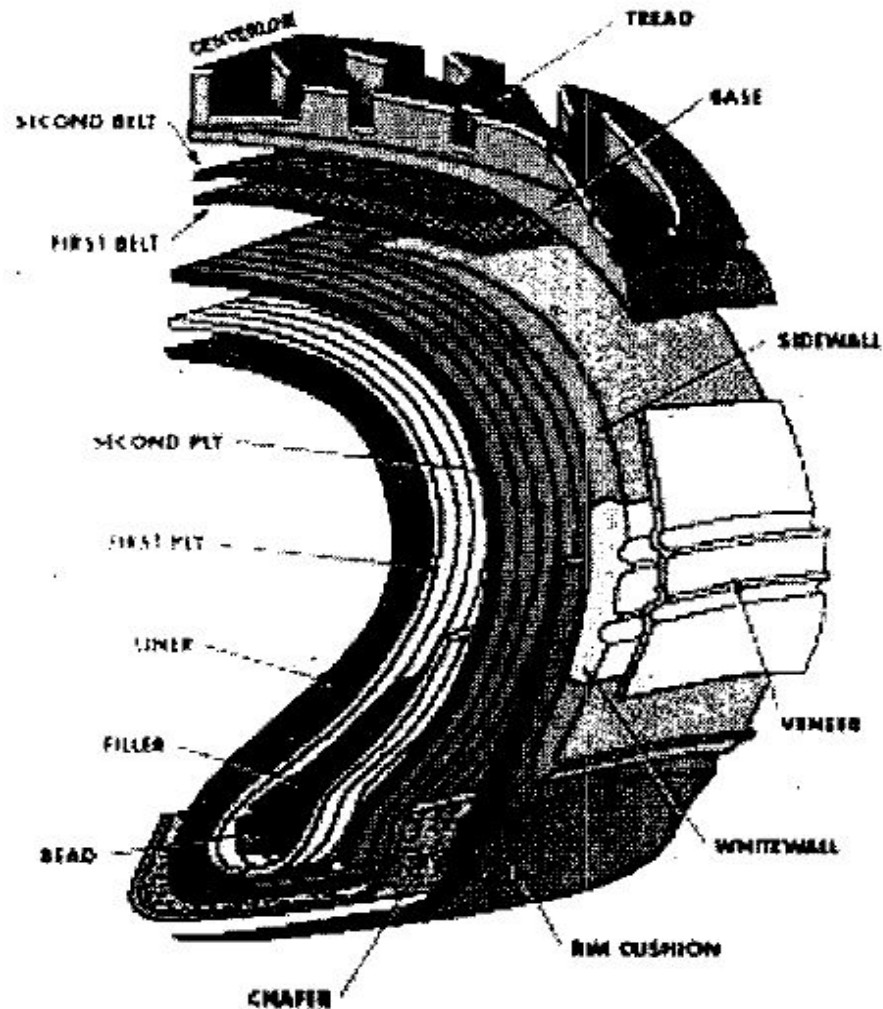


Figure 2.1: Section of tire[3].

2.4.1 Tread Lug

Tread lugs provide the contact surface necessary to provide traction. As the tread lug enters the road contact area, or footprint, it is compressed. As it rotates through the footprint it is deformed circumferentially. As it exits the footprint, it recovers to its original shape. During the deformation and recovery cycle the tire exerts variable forces into the vehicle. These forces are described as Force Variation[9].

2.4.2 Tread Void

Tread voids provide space for the lug to flex and deform as it enters and exits the footprint. Voids also provide channels for rainwater, mud, and snow to be channeled away from the footprint. The void ratio is the void area of the tire divided by the entire tread area. Low void areas have high contact area and therefore higher traction on clean, dry pavement[9].

2.4.3 Rain Groove

The rain groove is a design element of the tread pattern specifically arranged to channel water away from the footprint. Rain grooves are circumferential in most truck tires. Many high performance passenger tires feature rain grooves that are angled from the center toward the sides of the tire. Some tire manufacturers claim that their tread pattern is designed to actively pump water out from under the tire by the action of the tread flexing. This results in a smoother ride in different types of weather[10].

2.4.4 Sipe

Tread lugs often feature small narrow voids, or sipes, that improve the flexibility of the lug to deform as it traverses the footprint area. This reduces shear stress in the lug and reduces heat build up. Sipes also provide greater traction in icy conditions[10,11].

2.4.5 Wear Bar

Wear bars are raised features located at the bottom of the tread grooves that indicate the tire has reached its wear limit. When the tread lugs are worn to the point that the wear bars connect across the lugs, the tires are fully worn and should be taken out of service[10].

2.4.6 Contact Patch

The contact patch, or footprint, of the tire, is merely the area of the tread which is in contact with the road surface. This is the area which transmits forces between the tire and the road via friction. The length-to-width ratio of the contact patch will affect steering and cornering behavior[12,13].

2.4.7 Bead

The bead is that part of the tire which contacts the rim on the wheel. The bead is reinforced with steel wire, and compounded from high strength, low flexibility rubber. The bead seats tightly against the two rims on the wheel to ensure that a tubeless tire holds air without leakage. The bead fit is tight, to ensure the tire does not shift circumferentially as the wheel rotates. The width of the rim in relationship to the tire are a factor in the handling characteristics of an automobile because the rim supports the tire's profile[13].

2.4.8 Side Wall

The sidewall is that part of the tire that bridges between the tread and bead. The sidewall is reinforced with rubber and fabric plies that provide for strength and flexibility. The sidewall transmits the torque applied by the drive axle to the tread in order to create traction. The sidewall, in conjunction with the air inflation, also supports the load of the vehicle. Sidewalls are molded with manufacturer-specific detail, government mandated warning labels, and other consumer information, and sometimes decorative ornamentation[13].

Over time, rubber degrades. Ford has recommended that tires be replaced when they are 6 years old to prevent sudden failure, even if the tire looks undamaged. In tropical climates, such as in Singapore, tires degrade sooner than in temperate climates. Tires on seldom-used trailers are at the greatest risk of age-failure but some tires are

built to withstand idleness. This is usually done by using nylon reinforcement. In the past rayon was used in tyres but it ages quite badly[14].

2.4.9 Shoulder

The shoulder is that part of the tire at the edge of the tread as it makes transition to the sidewall[14].

2.4.10 Inner Tube

Most bicycle tires, some motorcycle tires, and many tires for large vehicles such as passengers, semi trucks, and tractors are designed for use with inner tubes. Inner tubes are torus shaped balloons made from a material initially impervious to air leakage. The inner tubes are inserted into the tire and inflated to retain air pressure[14].

2.4.11 Wheel

Tires are mounted to wheels that bolt to the drive hub. Automotive wheels are either made from pressed and welded steel, or composite of lightweight metal alloys, such as aluminium or magnesium. These alloy wheels may be either cast or forged[13,14].

2.4.12 Valve Stem

The valve stem is a tubular rubber shape with a metal valve used to inflate the tire with air. Valve stems usually protrude through the wheel for easy access for inflation. Tires are inflated through a valve, typically a Schrader valve on automobiles and most bicycle tires, or a Presta valve on high performance bicycles. The rubber in valve stems eventually degrades. Replacement of the valve stem at regular intervals reduces the chance of failure[15].

2.4.13 Tire Pressure Monitoring System

Tire pressure monitoring systems are electronic systems which monitors the tire pressures on individual wheels on a vehicle, and alarms the driver when the pressure goes below a warning limit. There are several types of designs to monitor tire pressure. Some actually measure the air pressure, and some make indirect measurements, such as gauging when the relative size of the tire changes due to lower air pressure. These systems are becoming mandatory in countries such as the United States[15].

2.4.14 Flation Pressure

Tires are specified by the vehicle manufacturer with a recommended inflation pressure, which permits safe operation within the specified load rating and vehicle loading. Most tires are stamped with a maximum pressure rating (for USA only). For passenger vehicles and light trucks, the tires should be inflated to what the vehicle manufacturer recommends, which is usually located on a decal just inside the driver's door, or in the vehicle owners handbook[15].

2.4.15 Load Rating

Tires are specified by the manufacturer with a maximum load rating. Loads exceeding the rating can result in unsafe conditions that can lead to steering instability and even rupture. For a table of load ratings, see tire codes. Replacing a tire on a vehicle with one with a lower load rating than originally specified by the vehicle manufacturer will often render the insurance invalid[16].

2.4.16 Wheel Alignment

When mounted on the vehicle, the wheel and tire may not be perfectly aligned to the direction of travel, and therefore may exhibit irregular wear. If the discrepancy in alignment is large, then the irregular wear will become quite substantial if left

uncorrected. A wheel alignment is the procedure for checking and correcting this condition through adjustment of camber, caster and toe angles. These settings also affect the handling characteristics of the vehicle[16].

2.4.17 Flat

A flat tire occurs when a tire deflates to the point where the metal of the wheel rim comes to ground level. This can occur as a result of normal wear-and-tear, a leak, or more serious damage. A tire which has lost sufficient pressure to cause it to become distorted at the bottom will impair the stability of the vehicle and may further damage the tire if it is driven in this condition. The tire should be changed and or repaired before it becomes completely flat. Continuing to drive a vehicle with an absolutely flat tire will likely result in damaging the tire beyond repair, possible damage to the rim and vehicle, and will put the occupants, and other vehicles in danger. A flat tire or low pressure tire should be considered an emergency situation, requiring immediate attention to rectify the problem[16].

2.4.18 Hydroplaning

Hydroplaning, also known as aquaplaning, is the condition where a layer of water builds up between the tire and road surface. Hydroplaning occurs when the tread pattern cannot channel away enough water at an adequate rate to ensure a dry footprint area. When hydroplaning occurs, the tire effectively "floats" above the road surface on a cushion of water - and loses traction, braking and steering, creating a very unsafe driving condition. When hydroplaning occurs, there is considerably less responsiveness of the steering wheel. The correction of this unsafe condition is to gradually reduce speed, by merely lifting off the accelerator/gas pedal. Hydroplaning becomes more prevalent with wider tires[16].

2.5 Tire deformation

As the speed of a tire increases, its components tend to grow or deform. This deformation leads to Heat generation. This is a normal effect of the deformation of the tire's components due to centrifugal force. The faster the tire spins, the greater its tendency to deform. And the more it deforms, the more heat is generated[5]. Tire deform shown in Figure 2.2.

But for tires driven at high speeds, controlling heat levels is critical. Engineers must find ways to control tire growth so that heat levels are confined to acceptable[5].

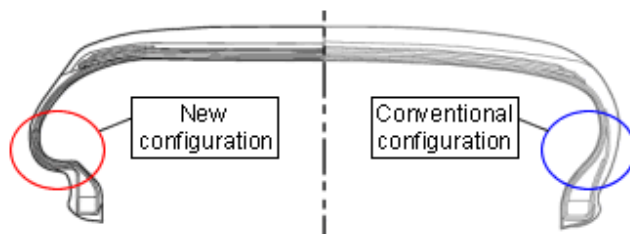


Figure 2.2: Tire deform[5].

2.5.1 Deformation Under Load

Changing the direction of deformation allows for increased eccentric deformation and reduces the amount of circumferential bending deformation in the tread portion of the tire. That reduces energy loss and also reduces tread wear[5]. Deformation under load shown in Figure 2.3.

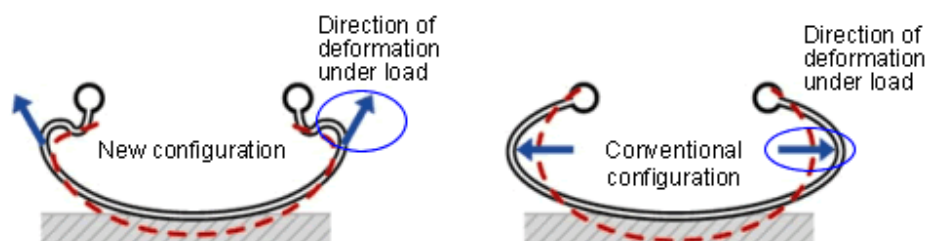


Figure 2.3: Deformation under load[5].

2.5.2 Tire Deformation in Motion

Two kinds of deformation occur in tires in motion shown in Figure 2.4.[5]. The eccentric deformation occurs mainly as a shift in the center of rotation and the tread deformation and energy loss are minimal. The circumferential bending deformation occurs mainly in the tread portion and the energy loss is large.

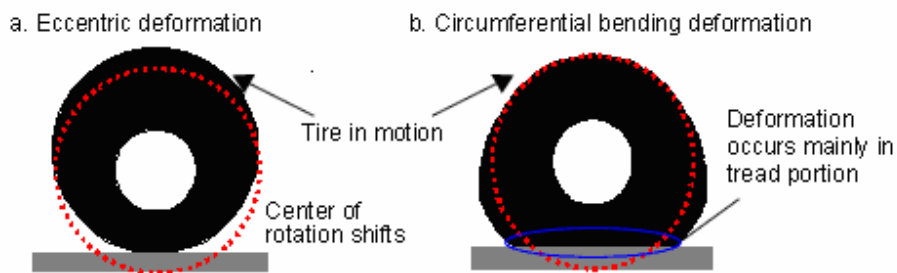


Figure 2.4: Tire deformation in motion[5].

2.5.3 New Approach to Reducing Rolling Resistance

Bridgestone's new design technology allows for reducing rolling resistance by increasing eccentric deformation and minimizing circumferential bending deformation in a tire in motion. That reduces tread deformation and energy loss[5]. Reducing rolling resistance and new configuration results in smooth and minimal deformation shown in Figure 2.5.