Ain Shams University
Faculty of Engineering

STUDY OF THE INTERACTION FORCES BETWEEN TYRE AND ROAD

BY

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B. Sc. Mechanical Engineering

A THESIS

Submitted in partial fulfilment of the requirements for the degree of M. Sc. In Mechanical Engineering (Automotive Section)

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1996

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Statement

This dissertation is submitted in partial fulfilment for the degree of Master of Science in Mechanical Engineering, to Ain Shams University.

The work included in this thesis was carried out by the author at the laboratories of the department of Automotive Engineering, Ain Shams University from 1991 to 1996.

No part of this thesis has been submitted for a degree or qualification at any other University or institute.

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Acknowledgement

I would like to express my sincere appreciation to my supervisors Prof. Dr. T. A. Nosseir, Dr. A. I. Abdel Aziz and Dr. M. A. Said for their guidance, assistance, encouragement and patience at every stage of this research.

The support of the technicians of the Automotive Dept, Faculty of Engineering, Ain Shams University, is appreciated.

Summary

The object of the present work is to measure and study the interacting forces between the tyre and the road surface in the contact patch in case of small obstacles of different heights and under different tyre operating conditions. To realise this object a test-rig was prepared and equipped with a force dynamometer for measuring both the vertical and the longitudinal dynamic forces in the contact patch. the experimental investigation was designed to obtain the effect of the inflation pressure, the tyre deflection and the obstacle configuration under tyre rolling condition. The rig was also equipped with a data acquisition system, capable of recording the analogue signal and converting it to digital one, was used in collecting and analyses of the acting forces. A module unit was used to supply power and balancing volt to the used sensors. Two main groups of experiments were conducted. The first group was done on a free rolling tyre rotating against a 1.5 m diameter flywheel. The second group was conducting by introducing obstacles of different heights with different centre distance between the obstacle and the dynamometer.

The results of the experimental work were presented as force distribution around the middle of the contact patch. The distribution of the vertical force in case of free rolling shows a small deviation of the peaks towards the leading side of the contact patch. This indicates the correct direction and the value of the rolling resistance. In case of enveloping an obstacle the vertical force distribution shows a concentration in the obstacle zone and relieve of forces in the neighbourhood.

The distribution of the vertical forces far from the neighbourhood is similar to the case of free rolling. The distribution of the longitudinal forces in the contact patch in case of free rolling shows an asymmetric distribution around the lateral axis.

A positive force in the leading side due to the compression of the tyre before interring the contact zone is followed by a negative force in the trailing side due to tread relief . In case of enveloping an obstacle the longitudinal distribution is dependent on both the obstacle height and its circumfrential distance from the dynamometer to a great extent .

Table of Contents

Nomenclature

d	total tyre deflection	[mm]
d_1	tyre deflection due to a flat surface, Appendix (A.2)	[mm]
d_2	extra tyre deflection due to the flywheel curvature, Appendix (A.2)	[mm]
F	calibration force applied to the dynamometer, Appendix (A.1)	[N]
$H_{y2/y1}(\Omega)$	tyre enveloping function, equation (2.1)	
h	obstacle height	[mm]
l	half contact length, equation (2.1)	[cm]
L	distance between obstacle centre and the dynamometer centre	[mm]
L_c	contact patch length, equation (4.1)	[cm]
n	flywheel speed, equation (4.1)	[rpm]
p	tyre inflation pressure	[kPa]
R	flywheel radius	[mm]
r	tyre radius, Appendix (A.2)	[mm]
v	translational velocity	[m/s]
W	tyre total vertical load , equation (4.2)	[N]
w	calibration weights, Appendix (A.1)	[N]

Subscripts

y1	original road surface irregularities, equation (2.1)
y2	filtered road profile, equation (2.1)

Greek symbols

Ω	spatial frequency, equation (2.1)

List Of Figures

CHAPTER (1)

Introduction

The combination of road, tyre, vehicle and driver form one complete interacting system. The characteristics of the vehicle may be described in terms of its performance, handling and ride. The driver response to vehicle vibration, which may be induced by a variety of sources including surface irregularities, aerodynamic forces and vibration of the engine and transmission, is reflected on the performance of the vehicle.

The mechanical characteristics of the tyre in contact with the road must be considered within the vehicle mechanics. The structure of the pneumatic tyres is considered complex. This makes its behaviour unpredictable by a satisfactory theory. An important property of a pneumatic tyre is its ability to cushion a vehicle against road irregularities.

In modern highway vehicles most of the primary control and reacting forces which are applied to the vehicle, with the exception of aerodynamic forces, are generated in the tyre-road contact patch. Thus, it has been said that "the critical control forces that determine how a vehicle turns, brakes and accelerates are developed in the contact patches which has an area not bigger than a man's hand".

A thorough understanding of the relationship between tyre, its operating conditions, and the resulting forces and moments developed at the contact patch is an essential aspect of the dynamics of the total vehicle.
The tyre serves essentially four basic functions :

1) Sustains vehicle load,
2) Transmits the drive force and the braking force to the road surface,