Preface

The operational properties of the road vehicle are the result of the dynamic interaction of the various components of the vehicle structure possibly including modern control elements. A major role is played by the pneumatic tyre.

"The complexity of the structure and behaviour of the tyre are such that no complete and satisfactory theory has yet been propounded. The characteristics of the tyre still presents a challenge to the natural philosopher to devise a theory which shall coordinate the vast mass of empirical data and give some guidance to the manufacturer and user. This is an inviting field for the application of mathematics to the physical world".

In this way, Temple formulated his view on the situation almost 50 years ago (Endeavor, October 1956). Since that time, in numerous institutes and laboratories, the work of the early investigators has been continued. Considerable progress in the development of the theory of tyre mechanics has been made during the past decades. This has led to better understanding of tyre behaviour and in its role as a vehicle component. Thanks to new and more refined experimental techniques and to the introduction of the electronic computer, the goal of formulating and using more realistic mathematical models of the tyre in a wide range of operational conditions has been achieved.

From the point of view of the vehicle dynamicist, the mechanical behaviour of the tyre needs to be investigated systematically in terms of its reaction to various inputs associated with wheel motions and road conditions. It is convenient to distinguish between symmetric and anti-symmetric (in-plane and out-of-plane) modes of operation. In the first type of mode, the tyre supports the load and cushions the vehicle against road irregularities while longitudinal driving or braking forces are transmitted from the road to the wheel. In the second mode of operation, the tyre generates lateral, cornering or camber, forces to provide the necessary directional control of the vehicle. In more complex situations, e.g. braking in a turn, combinations of these pure modes of operation occur. Moreover, one may distinguish between steady-state performance and transient or oscillatory behaviour of the rolling tyre. The contents of the book have been subdivided according to these categories. The development of theoretical models has always been substantiated through experimental evidence.

Possibly one of the more difficult aspects of tyre dynamic behaviour to describe mathematically is the generation of forces and moments when the tyre rolls over rough roads with short obstacles while being braked and steered in a time varying fashion. In the book, tyre modelling is discussed while gradually increasing its complexity, thereby allowing the modelling range of operation to become wider in terms of slip intensity, wavelength of wheel motion and frequency. Formulae based on empirical observations and relatively simple approximate physical models have been used to describe tyre mechanical behaviour. Rolling over obstacles has been modelled by making use of effective road inputs. This approach forms a contrast to the derivation of complex models which are based on more or less refined physical descriptions of the tyre.

Throughout the book the influence of tyre mechanical properties on vehicle dynamic behaviour has been discussed. For example, handling diagrams are introduced both for cars and motorcycles to clearly illustrate and explain the role of the tyre non-linear steady-state side force characteristics in achieving certain understeer and oversteer handling characteristics of the vehicle. The wheel shimmy phenomenon is discussed in detail in connection with the non-steady-state description of the out-of-plane behaviour of the tyre and the deterioration of ABS braking performance when running over uneven roads is examined with the use of an in-plane tyre dynamic model. The complete scope of the book may be judged best from the table of contents.

The material covered in the book represents a field of automotive engineering practice that is attractive to the student to deepen his or her experience in the application of basic mechanical engineering knowledge. For that purpose a number of problems have been added. These exercises have been listed at the end of the table of contents.

Much of the work described in this book has been carried out at the Vehicle Research Laboratory of the Delft University of Technology, Delft, The Netherlands. This laboratory was established in the late 1950s through the efforts of professor Van Eldik Thieme. With its unique testing facilities realistic tyre steady-state (over the road), transient and obstacle traversing (on flat plank) and dynamic (on rotating drum) characteristics could be assessed. I wish to express my appreciation to the staff of this laboratory and to the Ph.D. students who have given their valuable efforts to further develop knowledge in tyre mechanics and its application in vehicle dynamics. The collaboration with TNO Automotive (Delft) in the field of tyre research opened the way to produce professional software and render services to the automotive and tyre industry, especially for the *Delft-Tyre* product range that includes the *Magic Formula* and *SWIFT* models described in Chapters 4, 9 and 10. I am indebted to the Vehicle Dynamics group for their much appreciated help in the preparation of the book.

Professors Peter Lugner (Vienna University of Technology) and Robin Sharp (Cranfield University) have carefully reviewed major parts of the book

(Chapters 1 to 6 and Chapter 11 respectively). Igo Besselink and Sven Jansen of TNO Automotive reviewed the Chapters 5-10. I am most grateful for their valuable suggestions to correct and improve the text. Finally, I thank the editorial and production staff of Butterworth-Heinemann for their assistance and cooperation.

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Rotterdam,
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Note on the third revised impression

In this new edition, many small and larger corrections and improvements have been introduced. Recent developments on tyre modelling have been added. These concern mainly camber dynamics (Chapter 7) and running over three-dimensional uneven road surfaces (Chapter 10). Section 10.2 has been added to outline the structure of three advanced dynamic tyre models that are important for detailed computer simulation studies of vehicle dynamic performance. In the new Chapter 12 an overview has been given of tyre testing facilities that are designed to measure tyre steady-state characteristics both in the laboratory and over the road, and to investigate the dynamic performance of the tyre subjected to wheel vibrations and road unevennesses.

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