Preface

This book, the second edition, is intended to bridge a gap between the subject of classical vehicle dynamics and the general-purpose computer-based discipline multibody systems (MBS) analysis. Whilst there are several textbooks that focus entirely on the subject, and mathematical foundations, of vehicle dynamics and other more recent texts dealing with MBS there are none yet that link the two subjects in a comprehensive manner.

After 10 years a second edition of this book is indeed timely. Since the first edition there have been notable developments in the understanding and use of active systems, tyre modelling and the use of MBS software.

MBS analysis became established as a tool for engineering designers during the 1980s in a similar manner to the growth in finite element analysis technology during the previous decade. A number of computer programs were developed and marketed to the engineering industry, such as MSC ADAMS™ (*Automatic Dynamic Analysis of Mechanical Systems*), which in this edition still forms the basis for many of the examples provided. During the 1990s MBS became firmly established as part of the vehicle design and development process. It is inevitable that the engineer working on problems involving vehicle ride and handling in a modern automotive environment will be required to interface with the use of MBS to simulate vehicle motion. During the last 10 years several other MBS programmes have become more established, most notably SIMPACK which appropriately receives more coverage in this edition.

The book is aimed at a wide audience including not only undergraduate, postgraduate and research students working in this area, but also practising engineers in industry requiring a reference text dealing with the major relevant areas within the discipline.

The book was originally planned as an individual effort on the part of Mike Blundell drawing on past experience consulting on and researching into the application of MBS to solve a class of problems in the area of vehicle dynamics. From the start it was clear that a major challenge in preparing a book on this subject would be to provide meaningful comment on not only the modelling techniques but also the vast range of simulation outputs and responses that can be generated. Deciding whether a vehicle has good or bad handling characteristics is often a matter of human judgement based on the response or feel of the vehicle, or how easy the vehicle is to drive through certain manoeuvres. To a large extent automotive manufacturers still rely on track measurements and the instincts of experienced test engineers as to whether the design has produced a vehicle with the required handling qualities. To address this problem the book has been co-authored by Damian Harty. At the time of writing the first edition Damian was the Chief Engineer – Dynamics at Prodrive. In the 10 years since the first edition he continued in that role and after a few years working as a Senior Research fellow at Coventry University he moved to his current position with Polaris where he enjoys

the additional challenge of modelling vehicles on wide ranging terrain. With experience not only in the area of computer simulation but also the in the practical development and testing of vehicles on the proving ground Damian continues to help in documenting the realistic application of MBS in vehicle development.

Chapter 1 is intended to document the emergence of MBS and provide an overview of its role in vehicle design and development. Previous work by contributors including Olley, Segel, Milliken, Crolla and Sharp is identified providing a historical perspective on the subject during the latter part of the twentieth century.

Chapter 2 is included for completeness and covers the underlying formulations in kinematics and dynamics required for a good understanding of MBS formulations. A three-dimensional vector approach is used to develop the theory, this being the most suitable method for developing the rigid body equations of motion and constraint formulations described later.

Chapter 3 covers the modelling, analysis and postprocessing capabilities of a typical simulation software. There are many commercial programs to choose from including not only MSC ADAMS but also other software packages such as DADS and SIMPACK. The descriptions provided in Chapter 3 are based in the main on MSC ADAMS; the main reason for this choice being that the two authors have between them 25 years of experience working with the software. The fact that the software is also well established in automotive companies and academic institutions worldwide is also a factor. It is not intended in Chapter 3 to provide an MSC ADAMS primer. There is extensive user documentation and training material available in this area from the program vendors MSC Software. The information included in Chapter 3 is therefore limited to that needed to introduce a new reader to the subject and to provide a supporting reference for the vehicle modelling and analysis methodologies described in the following chapters. As discussed, the emergence of SIMPACK and its growing use by the automotive community has led to additional examples to illustrate the modelling approaches with that software.

Existing users of MSC ADAMS will note that the modelling examples provided in Chapter 3 are based on a text-based format of model inputs, known in MSC ADAMS as solver data sets. This was the original method used to develop MSC ADAMS models and has subsequently been replaced by a powerful graphical user interface (GUI) known as ADAMS/View™ that allows model parameterisation, and design optimisation studies. The ADAMS/View environment is also the basis for customised versions of MSC ADAMS such as ADAMS/Car™ that are becoming established in industry and are also discussed in Chapter 3. The use of text-based data sets has been adopted here for a number of reasons. The first of these is that the GUI of a modern simulation program such as MSC ADAMS is subject to extensive and ongoing development. Any attempt to describe such a facility in a textbook such as this would become outdated after a short passage of time. As mentioned, the software developers provide their own user documentation covering this in any case. It is also clear that the text-based formulations translate more readily to book format and are also useful for demonstrating the underlying techniques in planning a model, preparing model schematics and establishing the degrees of freedom in a system

model. These techniques are needed to interpret the models and data sets that are described in later chapters and appendices. It is also hoped that by treating the software at this fundamental level the dependence of the book on any one software package is reduced and that the methods and principles will be adaptable for practitioners using alternative software. Examples of the later ADAMS/View command file format are included in Chapters 6 and 8 for completeness.

Chapter 4 addresses the modelling and analysis of the suspension system. An attempt has been made to bridge the gap between the textbook treatment of suspension systems and the MBS approach to building and simulating suspension models. As such a number of case studies have been included to demonstrate the application of the models and their use in the vehicle design process. The chapter concludes with an extensive case study comparing a full set of analytical calculations, using the vector-based methods introduced in Chapter 2, with the output produced from MSC ADAMS. It is intended that this exercise will demonstrate to readers the underlying computations in process when running an MBS simulation.

Chapter 5 addresses the tyre force and moment generating characteristics and the subsequent modelling of these in an MBS simulation. As a major area of importance it deserves to be the largest chapter in the book. Examples are provided of tyre test data and the derived parameters for established tyre models. The chapter concludes with a case study using an MBS virtual tyre test machine to interrogate and compare tyre models and data sets. Since the first edition new tyre models such as the FTire model from Gipser and the TAME Tire model from Michelin have become established and therefore receive a more extended coverage in this edition.

Chapter 6 describes the modelling and assembly of the rest of the vehicle, including the anti-roll bars and steering systems. Near the beginning a range of simplified suspension modelling strategies for the full vehicle is described. This forms the basis for subsequent discussion involving the representation of the road springs and steering system in simple models that do not include a model of the suspension linkages. The chapter includes a consideration of modelling driver inputs to the steering system using several control methodologies and concludes with a case study comparing the performance of several full vehicle modelling strategies for a vehicle handling manoeuvre.

Chapter 7 deals with the simulation output and interpretation of results. An overview of vehicle dynamics for travel on a curved path is included. The classical treatment of understeer/oversteer based on steady state cornering is presented followed by an alternative treatment that considers yaw rate and lateral acceleration gains. The subjective/objective problem is discussed with consideration of steering feel and roll angle as subjective modifiers. The chapter concludes with a consideration of the use of analytical models with a signal-to-noise approach.

Chapter 8 concludes with a review of the use of active systems to modify the dynamics in modern passenger cars. The use of electronic control in systems such as active suspension and variable damping, brake-based systems, active steering systems, active camber systems and active torque distribution is described. A final summary matches the application of these systems with driving styles described as normal, spirited or the execution of emergency manoeuvres.

Appendix A contains a full set of vehicle model schematics and a complete set of vehicle data that can be used to build suspension models and full vehicle models of varying complexity. The data provided in Appendix A were used for many of the case studies presented throughout the book.

Appendix B contains example Fortran Tire subroutines to supplement the description of the tyre modelling process given in Chapter 5. A subroutine is included that uses a general interpolation approach using a cubic spline fit through measured tyre test data. The second subroutine is based on Version 3 of the Magic Formula and has an embedded set of tyre parameters based on the tyre data described in Chapter 5. A final subroutine 'The Harty Model' was developed by Damian at Prodrive and is provided for readers who would like to experiment with a new tyre model that uses a reduced set of model parameters and can represent combined slip in the tyre contact patch.

In conclusion it seems to the authors there still remain two camps for addressing the vehicle dynamics problem. In one is the practical ride and handling expert. The second camp contains theoretical vehicle dynamics experts. This book is aimed at the reader who, like the authors, seeks to live between the two camps and move forward the process of vehicle design, taking full advantage of the widespread availability of convenient digital computing.

There is, however, an enormous difficulty in achieving this end. Lewis Carroll, in *Alice through the Looking Glass*, describes an encounter between Alice and a certain Mr H Dumpty:

> *'When* I *use a word', Humpty Dumpty said, in rather a scornful tone, 'it means just what I choose it to mean—neither more nor less'.*
>
> *'The question is', said Alice, 'whether you* can *make words mean so many different things'.*

There is a similar difficulty between practical and theoretical vehicle dynamicists and even between different individuals of the same persuasion. The same word is used, often without definition, to mean just what the speaker chooses. There is no universal solution to the problem save for a thoughtful and attentive style of discussion and enquiry, taking pains to establish the meanings of even apparently obvious terms such as 'camber' – motorcycles do not have any camber by some definitions (vehicle-body-referenced) and yet to zero the camber forces in a motorcycle tyre is clearly folly. A glossary is included in Appendix C, not as some declaration of correctness but as an illumination for the text. In this edition a new appendix has been added. Appendix D lists some of the test procedures defined by the International Standards Organisation that are used to validate the handling performance of a new vehicle.

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