1 Introduction

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The principal aim of this handbook is to present a detailed introduction to the main issues influencing the dynamic behaviour of railway vehicles, and a summary of the history and the state of the art of the analytical and computer tools and techniques that are used in this field around the world. The level of technical detail is intended to be sufficient to allow analysis of common practical situations, but references are made to other published material for those who need more detail in specific areas. The main readership will be engineers working in the railway industry worldwide and researchers working on issues connected with railway vehicle behaviour, but it should also prove useful to those wishing to gain a basic knowledge of topics outside their specialist technical area.

1.1 STRUCTURE OF THE HANDBOOK

The topics covered in this handbook are the main areas that impact the dynamic behaviour of railway vehicles and are intended to present the existing solutions in this area from a multidisciplinary perspective. These include the numerical and tribological analysis of the wheel-rail interface, general railway vehicle design and architecture, suspension and suspension component design, simulation and testing of electrical and mechanical systems, interaction with the surrounding infrastructure and noise and vibration generation. The handbook is international in scope and draws examples from around the world, but several chapters have a more specific focus, where a particular local limitation or need has led to the development of specific techniques or tools.

For example, the chapter on longitudinal train dynamics and vehicle stability expands upon the longitudinal train dynamics chapter in the first edition and mainly uses Australian examples of the issues related to longitudinal dynamics on their heavy-haul lines, where very long trains are used to transport bulk freight. Similarly, the issue of structure gauging largely uses the UK as a case study, because it is there that historic lines through dense-population centres have resulted in a very restricted loading gauge. The desire to run high-speed trains in this situation has led to the use of highly developed techniques to permit full advantage of the loading gauge to be taken.

The history of the field is presented by Alan H. Wickens in Chapter 2, from the earliest thoughts of George Stephenson about the dynamic behaviour of a wheelset through the development of theoretical principles to the application of modern computing techniques. Professor Wickens was one of the modern pioneers of these methods and, as director of research at British Rail Research, played a key role in the practical application of vehicle dynamics knowledge to high-speed freight and passenger vehicles.

Chapters 3 and 4 set out the basic structure of railway vehicles. In Chapter 3, Anna Orlova, Roman Savushkin, Iuriii(Yury) Boronenko, Kirill Kyakk, Ekaterina Rudakova, Artem Gusev, Veronika Fedorova and Nataly Tanicheva outline and explain the basic structure of the railway coaches and wagons and the different types of running gear that are commonly used. Chapter 4 covers the design of powered railway vehicles and locomotives. Maksym Spiryagin, Qing Wu, Peter Wolfs and Valentyn Spiryagin explain the type and structure of locomotives in service and the
different types of traction system used. Magnetic levitation vehicles are described in Chapter 5 by Shihui Luo and Weihua Ma. MagLev technology has been around for some time but does not yet seem to have achieved full commercialisation. The likely trends are explored in Chapter 5.

Chapter 6 explores the detail of the key suspension components that make up the running gear of typical railway vehicles. Sebastian Stichel, Anna Orlova, Mats Berg and Jordi Viñolas show how these components can be represented mathematically and give practical examples from different vehicles. The key area of any study of railway vehicle behaviour is the contact between the wheels and the rails. An understanding of all the forces that support and guide the vehicle pass through this small contact patch and of the nature of these forces is vital to any analysis of the general vehicle behaviour. The equations that govern these forces are derived and explained by Jean-Bernard Ayasse, Hugues Chollet and Michel Sebès in Chapter 7. They include an analysis of the normal contact that governs the size and shape of the contact patch and the stresses in the wheel and rail, and also the tangential problem, where slippage or creep in the contact patch produces the creep forces which accelerate, brake and guide the vehicle. The specific area of tribology applied to the wheel-rail contact is explained by Ulf Olofsson, Roger Lewis and Matthew Harmon in Chapter 8.

The track on which railway vehicles run is clearly a significant part of the dynamic system, and Wanming Zhai and Shengyang Zhu present the dynamics and modelling of various railway track structures in Chapter 9, as well as the interaction between track and train. Chapter 10 covers the unique railway problem of gauging, where the movement of a railway vehicle means that it sweeps through a space that is larger than it would occupy if it moved in a perfectly straight or curved path. Precise knowledge of this space or envelope is essential to avoid vehicles hitting parts of the surrounding infrastructure or each other. David M. Johnson has developed computer techniques that allow the gauging process to be carried out to permit vehicle designers and operators to ensure safety at the same time as maximising vehicle size and speed, and he explains the philosophies and techniques in this chapter.

The avoidance of derailment and its potentially catastrophic consequences are of fundamental concern to all railway engineers. In Chapter 11, Nicholas Wilson, Huimin Wu, Adam Klopp and Alexander Keylin explain how railway vehicle derailment is prevented. They explore the main causes and summarise the limits that have been set by standards to try to prevent these occurrences and cover the special case of independently rotating wheels and several possible preventative measures that can be taken.

In Chapter 12, Hongqi Tian explains the use of wind tunnels and computational fluid dynamics to improve the understanding of the effects of aerodynamics on the dynamic behaviour of railway vehicles.

Longitudinal train dynamics are covered by Colin Cole in Chapter 13. This is an aspect of vehicle dynamics that is sometimes ignored, but it becomes of major importance in heavy-haul railways, where very long and heavy trains lead to extremely high coupling forces. This chapter also covers rolling resistance and braking systems.

Chapter 14 deals with noise and vibration problems. David Thompson, Giacomo Squicciarini, Evangelos Ntotsios and Luis Baeza explain the key issues, including rolling noise caused by rail surface roughness, impact noise and curve squeal. They outline the basic theory required for a study in this area and also show how computer tools can be used to reduce the problem of noise. The effect of vibrations on human comfort is also discussed, and the effect of vehicle design is considered.

In Chapter 15, Roger M. Goodall and T.X. Mei summarise the possible ways in which active suspensions can allow vehicle designers to provide advantages that are not possible with passive suspensions. The basic concepts from tilting bodies to active secondary and primary suspension components are explained in detail and with examples. Recent tests on a prototype actively controlled bogie are presented, and limitations of the current actuators and sensors are explored before conclusions are drawn about the technology that will be seen in future vehicles.

Computer tools are now widely used in vehicle dynamics, and some specialist software packages allow all aspects of vehicle-track interaction to be simulated. In Chapter 17, Oldrich Polach,
Mats Berg and Simon Iwnicki explain the historical development and state of the art of the methods that can be used to set up models of railway vehicles and to predict their behaviour as they run on typical track or over specific irregularities or defects. The material of previous chapters is drawn upon to inform the models of suspension elements and wheel-rail contact, and the types of analysis that are typically carried out are described. Typical simulation tasks are presented from the viewpoint of a vehicle designer attempting to optimise suspension performance, and the key issue of validation of the results of computer models is reviewed.

In Chapter 18, Julian Stow outlines the key aspects of field testing, including the procedures typically used during the acceptance process to demonstrate safe operation of railway vehicles. An alternative to field testing is to use a roller rig on which a vehicle can be run in relative safety, with conditions being varied in a controlled manner. In Chapter 19, Paul D. Allen, Weihua Zhang, Yaru Liang, Jing Zeng, Henning Jung, Enrico Meli, Alessandro Ridolfi, Andrea Rindi, Martin Heller and Joerg Koch summarise the characteristics of the main types of roller rig and the ways in which they are used. Chapter 19 also reviews the history of existing roller rigs, summarising the key details of examples of the main types. Chapter 20 extends the theme to scale testing, which has been used effectively for research into wheel-rail contact. In this chapter, Nicola Bosso, Paul D. Allen and Nicolo Zampieri describe the possible scaling philosophies that can be used and how these have been applied to scaled roller rigs. In Chapter 21, Tim McSweeney provides a glossary of terms relevant to railway vehicle dynamics.