1 Introduction

Simon Iwnicki

CONTENTS

I. AIMS

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 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.

Although in the very earliest days of the railways (as described in Chapter 2) an individual was responsible for all aspects of the design of a railway, for most of the historical period of railways the vehicles (or rolling stock) have been under the control of mechanical engineers whereas the track has been seen as the domain of civil engineers. The focus of this book being on the vehicles would tend to put it firmly in the mechanical domain, but in fact, in recent years this rather artificial divide has been lessened as engineers have been forced to consider the railway as a system with the wheel–rail interface at its centre. Increasing use of electrical and electronic components to power, control (or in some cases replace) the basic mechanical components has brought electrical, electronic, mechatronic and control engineers into the teams. The development of equations that represent the complex interactions between a vehicle and the track and of computers able to provide fast solutions to these equations has relied upon the expertise of software engineers and even mathematicians.

The topics covered in this handbook are the main areas which impact on the dynamic behaviour of railway vehicles. These include the analysis of the wheel–rail interface, suspension and suspension component design, simulation and testing of electrical and mechanical systems, interaction with the surrounding infrastructure, and noise generation. Some related areas, such as aerodynamics or crashworthiness, are not covered as they tend to use different techniques and tools and have been extensively developed for road or air transport and are reported on elsewhere.

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 new techniques or tools. For instance, the chapter on longitudinal dynamics mainly uses Australian examples as the issues related to longitudinal dynamics cause most problems in heavy haul lines such as those in Australia where very long trains are used to transport bulk freight with extremely high axle loads, sometimes on narrow gauge track. Similarly, the issue of structure gauging largely uses the U.K. as a case study, because here the 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 issue of standards has been a tricky one due to the vast number of different organisations who set and control railway standards. It has not been possible to provide comprehensive guidance in this area but typical examples of the application of standards have been brought into the handbook where appropriate. For example, AAR Chapter XI standards for derailment in the U.S. and UIC518 for limits on wheel–rail forces in the E.U. are presented. It should be stressed that these are intended only as illustrative examples of how the results of vehicle dynamic analyses can be used, and those with responsibility for safety should check carefully what the relevant current standards are for their work.

II. STRUCTURE OF THE HANDBOOK

The history of the field is presented by Alan 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 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. In Chapter 3, Anna Orlova and Yuri Boronenko outline and explain the basic structure of the railway vehicle and the different types of running gear that are commonly used. Each of the relevant components is described and the advantages and disadvantages of the different types explained.

The key area of any study of railway vehicle behaviour is the contact between the wheels and the rails. All the forces that support and guide the vehicle pass through this small contact patch, and an understanding of the nature of these forces is vital to any analysis of the general vehicle behaviour. The equations that govern these forces are developed by Hugues Chollet and Jean-Bernard Ayasse in Chapter 4. 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 Olofson and Roger Lewis in Chapter 5. The science of tribology is not a new one but has only recently been linked to vehicle dynamics to allow effective prediction of wheel and rail wear, and examples of this from the Stockholm local railway network are presented.

Although the main focus of railway vehicle dynamics is traditionally on the vehicle, the track is a key part of the system and in Chapter 6 Tore Dahlberg clearly explains the way that track dynamics can be understood. The contribution of each of the main components that make up the track to its overall dynamic behaviour is also presented. Chapter 7 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 in this chapter he explains these philosophies and techniques.

Of fundamental concern to all railway engineers is the avoidance of derailment and its potentially catastrophic consequences. Huimin Wu and Nicholas Wilson start Chapter 8 with some statistics from the U.S. that show the main causes of derailment. They go on to 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.

Longitudinal train dynamics are covered by Colin Cole in Chapter 9. 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 between vehicles. This chapter also covers rolling resistance and braking systems.

Chapter 10 deals with noise and vibration problems, which have become of greater concern in recent years. David Thompson and Chris Jones 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 influence of vehicle design considered.

In Chapter 11, R. 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. Oldrich Polach, Mats Berg, and Simon Iwnicki have joined forces in Chapter 12 to 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. Material in 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.

Chapter 13 takes these principles into the field and describes the main test procedures that can be carried out during the design or modification of a vehicle, or as part of an acceptance process to demonstrate safe operation. Julian Stow and Evert Andersson outline the range of transducers available to the test engineer and the ways that these can be most effectively used to obtain valid and useful data. The necessary filtering, corrections, and compensations that are normally made are explained, and data acquisition system requirements are covered. The chapter includes examples of the most commonly carried out laboratory and field tests.

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 and instrumentation can be easily installed. Weihua Zhang and his colleagues at Southwest Jiaotong University in China operate what is probably the most important roller rig in the world today and they outline the characteristics of this and other roller rigs and the ways in which they are used. Chapter 14 also reviews the history of roller rigs, giving summaries of the key details of examples of the main types. Chapter 15 extends the theme to scale testing, which has been used effectively for research into wheel–rail contact. In this chapter P. D. Allen describes the possible scaling philosophies that can be used and how these have been applied to scale roller rigs.

In compiling this handbook I have been fortunate in being able to bring together some of the leading experts in each of the areas that make up the field of railway vehicle dynamics. I and my coauthors hope that this handbook, together with its companion volume, *Road and Off-Road Vehicle Dynamics*, will be a valuable introduction for newcomers and a useful reference text for those working in the field.

Simon Iwnicki
Manchester