A Review of “Handbook of Railway Vehicle Dynamics” Second Edition
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The second edition of “Handbook of Railway Vehicle Dynamics” book is an edited volume (with 20 self-contained chapters) providing a detailed introduction to the concepts, history, and state of the art related to main issues influencing railway dynamics. The overall flavor of the book tries to balance between fundamental concepts, mathematical analysis, experimental approaches, and practical examples, covering them in sufficient detail that it may be used by practicing vehicle engineers and scientists. For researchers and graduate students who are new to the field of railway vehicles, the editors and authors lay a deep foundation on various key elements such as wheel rail interaction, noise and vibration, aerodynamics, locomotive design, articulation and bogie design, suspension systems, mechanical systems, electrical systems, R&D testing rigs, and simulation strategies.

The topics covered in the book are comprehensive with references provided to other published material for those interested to understand further details in specific topics. The examples provided are international in content but still relevant for the American user. A vast majority of practicing noise and vibration engineers and scientists in the field of rails (the readers of NCEJ of course) would find it rather valuable to understand the interaction of vehicles with tracks.

For users who already own the first edition published in 2006, this book will be a worthy addition as almost all topics are refreshed and updated in the new book to cover advancements in computer tools and data analytics. Also, the second edition has added newer chapters covering design of powered rail vehicles, aerodynamics of rail vehicles, maglev, and the dynamics of the pantograph-catenary system.

After a brief preface and a foreword, all four editors provide a meaningful introduction in Chapter 1. It presents an overview of the key concepts discussed in the subsequent chapters of this book. The authors clearly state that the goal of the book is to cover main areas that impact the dynamic behavior of railway vehicles and to do it by presenting existing solutions in this area from a multidisciplinary perspective.

Chapter 2 (A History of Railway Vehicle Dynamics). The railway train running along a track has a moving interface that connects the vehicle to the track. The dynamics of this complex system has many degrees of freedom. This chapter tells the history of how it all started with empirical engineering of wheelset dynamics more than a century ago and slowly evolved through the development of theoretical concepts to the modern computer application tools. This chapter walks us through how the search for higher speeds in the 1950s drove the need for a more scientific approach to assess risks arising from track/vehicle interaction and the questions of stability. The fascinating evolution of scientific understanding in the areas of wheel/rail geometry, curving, derailment, and hunting, particularly the work done in the 1960s that laid the foundations for the first principles in these areas, is narrated well. The history of unconventional bogie and wheel design evolving over the last 60 years and becoming more acceptable as mainstream design is a valuable slice of history for those in R&D. This chapter also discusses the history of computer simulations.

Chapter 3 (Design of Unpowered Railway Vehicles) provides an introduction to the major design features of unpowered railway vehicles, covering freight wagons and passenger coaches. It explains the main technical characteristics of these vehicles, the terminology used and the design and associated origin of the major vehicle components of car bodies, bogies, running gears, coupling devices and braking systems. This chapter also discusses the materials used in car bodies and the principles for the design of suspensions in detail.

Chapter 4 (Design of Powered Rail Vehicles and Locomotives) provides an introduction to the major design features of all types of powered railway vehicles, including light rail vehicles, passenger trains and locomotives, high-speed trains, freight locomotives and heavy-haul locomotives. The engineering and system analyses for the main components of the above vehicle types and the different traction technologies (electric, diesel, gas turbine, and hybrid) are presented in detail. The major design characteristics and parameters for rail traction vehicles are classified and discussed in terms of their application, thus living up to the purpose of a “handbook.”

Chapter 5 (Magnetic Levitation Vehicles) is a newer addition to the previous edition of this book. The Maglev technology is exciting and not only can achieve medium to high speed but also has the potential to reach super-high speed (several Mach numbers). This chapter discusses the advantages and limitations of maglev trains based on what we know today, and it covers the fundamentals of levitation forces, the maglev system equations and solutions, and classification of maglev in a manner that can be easily understood by beginners. It then dives deeper into the system characteristics, influence of flexible girders on maglev vehicle dynamics with moving loads, the methodology for maglev vehicle dynamics analysis, and simulations of maglev using multibody system analysis software packages.

Chapter 6 (Suspension Elements and Characteristics). The rail vehicle suspension is the set of elastic elements, dampers and associated components that connect the wheelsets to the car body, through the bogie frames. In this chapter, the various suspension elements used in rail vehicles, namely coil springs, rubber springs, air springs, leaf springs and hydraulic dampers are introduced, and their main characteristics are explained. It describes the mathematical representation of various suspension elements and dampers and how they are designed to have certain force-displacement characteristics, or force-velocity characteristics, to guarantee running safety and to provide good ride characteristics to the vehicle. It also covers guides, traction rods and bump stops. The car body to bogie connection is discussed with illustrative pictures providing practical insight to this area. Although this chapter touches a little bit on how to apply stiffness assumptions for the elastic elements in the various model packages, it would have been more beneficial for beginners in modeling, if this was expanded a bit more. Also, there could have been a discussion on how stiffness changes with speed. These minor deficiencies are mitigated through a comprehensive reference list that includes 59 published works in this area.

Chapter 7 (Wheel Rail Contact Mechanics). The key area of any study in of railway vehicle behavior is the contact at the wheel rail interface. The basics of wheel rail contact and all the forces that are transferred from the vehicles to the wheels through a small contact patch are meticulously described. It takes us through the fundamentals of Hertzian contact and the tangent problem, including the different expressions of creep forces which accelerate, brake and guide the vehicle. The discussion pivots to contact mechanics in the context of railways. The concepts of conicity, gravitational forces and safety criteria are explained through the application lens. This chapter also provides an overview for wheel-rail contact force modeling within vehicle dynamics software.

Chapter 8 (Tribology of the Wheel Rail Contact). The wheel-rail interface of a railway system is an open system where contact conditions vary constantly due to foreign material contamination in the interface. It is exposed to dirt and particles and natural lubrication, such as high humidity, rain, and leaves, all of which can alter the contact conditions and influence the contact forces. This chapter gives an overview of the wheel-rail interface contact mechanics, including the size and shape of the contact, levels of contact stress and friction-creep relationships. The surface damage mechanisms such as wear, plastic deformation and rolling contact fatigue, as well as how they interact, are described. The potential of friction modification to optimize energy consumption, noise management, and wear reduction are discussed. Flange lubrication, top-of-rail friction modifiers, and leaves causing slippery conditions, among others, are discussed. Practical tips for lubricator system selection and positioning are provided. Challenges associated with maintaining the various lubrication systems to function as designed are touched upon. Considering that this is a subject of intense research and practical application in day-to-day operations of any railway system, the chapter is too short at 20 pages and leaves the reader wanting more.

Chapter 9 (Track Design, Dynamics and Modeling). This chapter presents the dynamics and modeling of various track structure and the interaction of tracks and vehicles. The tracks are an essential structure on which trains operate. The running rails are the main component of the tracks that function to guide train wheels to move forward along the direction of the track, carry the wheel loads and distribute the load across track components. The track design, service condition, and dynamic behavior have significant influences on the stability and ride comfort of trains. This chapter focuses on the dynamics and modeling of various railway track structures, as well as the interaction between track and train. The interaction between track and train is explained through vehicle-track coupled dynamics theory and wheel-rail coupling model. The most typical and commonly used dynamics models for ballasted track and slab track are described in detail, with emphasis on the equations of motion of track components. Models for impact loads, harmonic loads, random track irregularities and the comparisons of track irregularity power spectrums for high-speed railways worldwide are presented. The models for harmonic loads discuss rail corrugation and wheel polygon for high-speed railways. The power spectral density for random track irregularities in American, German, and Chinese track systems is compared. Finally, an example of developing a vibration-attenuated track system for an urban rail transit application using the vehicle-track coupled dynamics theory is presented. This dives into the design scheme, dynamic modeling, and experimental validation of full-scale dynamic tests for a vibration attenuation track and a floating slab track under harmonic loads.

Chapter 10 (Gauging Issues). Gauging is a technique that ensures that the rail vehicle fits in the infrastructure and can pass through it safely at the designed speed. This chapter provides a brief overview of the principles of gauging used to test compatibility between trains and structures on railway networks. It touches static gauges and swept envelopes. It provides enough context, guidance, and references to understand the relationship between vehicle movements induced by vehicle elements such as suspensions and its relationship to clearance on a given infrastructure at running speeds. This is covered for both new systems and legacy alignments. The chapter covers traditional clearance calculation techniques and practical risk-based clearance calculations. It considers conventional and tilting trains and the critical analysis cases from a clearance perspective.

Chapter 11 (Railway Vehicle Derailment and Prevention). This chapter focuses on railway vehicle derailments that are caused by wheel-rail and vehicle-track interaction and the safety criteria. The mechanisms and the common contributing factors are discussed in detail. It includes flange climb derailment due to gauge widening, rail rollover and track panel shift. Vehicle parameters such as lateral instability, vehicle body resonances, wheel design, longitudinal in-train forces, and vehicle overspeed are also discussed. An overview of how to assess and predict derailment is also presented. The most useful section for practitioners in this section is the discussion on different strategies to prevent derailment including wheel rail profile optimization, friction management, vehicle design, and continued maintenance of gauge, among others.

Chapter 12 (Rail Vehicle Aerodynamics). The aerodynamic drag is an important parameter for high-speed trains and looks at ways to optimize the interaction of a rail vehicle with its surrounding environment when moving at high speeds. This chapter provides a brief introduction to the evolution of higher speeds in the railway transportation sector and the need for optimizing aerodynamic performance. This is particularly important for vehicle safety and passenger comfort in severe conditions through tunnels or when there is significant change in surrounding flow field due to strong winds in open environment such as long-span bridge, high-rise bridge and embankments. This chapter explains the use of wind tunnels and computational fluid dynamics to improve the understanding of the effects of aerodynamics on the dynamic behavior of railway vehicles. It looks into research methods of aerodynamics for rail vehicles such as wind tunnel test, moving-model test, real-vehicle test, and numerical simulation. The properties of exterior flow structure of rail vehicles are discussed, including the characteristics of vortex structure, wake flow, flow field at rail vehicle crossing, flow field under cross-wind, test case of single train passing through the tunnel and trains passing each other in the tunnel. The vehicle dynamics simulations use representative load conditions such as drag force, lift force, side force and corresponding moments to simulate real world operating conditions. The chapter also includes a section on evaluation of aerodynamic indexes for rail vehicles that discusses the assessment standards for aerodynamic loads for track alignment in both open air and tunnel situations and even includes a paragraph on safe distance for human bodies such as track workers at the line side and passengers on a platform.

Chapter 13 (Longitudinal Train Dynamics and Vehicle Stability in Train Operations). Longitudinal train dynamics is important in heavy-haul railways; very long and heavy trains lead to extremely high coupling forces. The primary focus of this chapter is to help the readers understand how to model and analyze longitudinal train dynamics from rolling resistance and braking systems perspectives. The modeling of longitudinal train dynamics needs to consider input forces such as traction, dynamic braking, propulsion resistance, curving resistance, gravitational components and pneumatic brake models. It also needs to consider the vehicle connections such as draft gear and wagon connections that form the basis of the coupling forces. Different draft gears and wagon connections are discussed in detail. This chapter gives a comprehensive and systematic approach to deterministically modeling draft gears. The fast methods for assessing wagon dynamic interactions and stability on train routes are treated in detail with discussion on lateral coupler angles, wheel unloading and climb on curves due to lateral components of coupler forces, rail vehicle body and bogie pitch due to coupler impact forces, and rail vehicle lift-off due to vertical components of coupler forces. This chapter also provides a brief discussion on the longitudinal passenger comfort standards and train crashworthiness topics. The interesting element in the passenger comfort acceleration discussion is the different ride comfort limits used for seated versus standing passengers in Australia.

Chapter 14 (Noise and Vibration from Railway Vehicles). This chapter discusses the sources of noise and vibration and the methods to control them from the perspectives of both wayside effects and train interior performance. The theory of rolling noise generation from the wheel rail interaction is discussed. Equations for contributions to rolling noise from rail and wheel surface roughness, wheel dynamics, and track dynamics help with understanding the fundamentals of noise generation mechanisms. It also discusses various methods to control rolling noise. This includes managing surface roughness at the wheel rail interface, optimizing the wheel design and the use of wheel dampers, building low-noise track structures, and the use of noise barriers. Other types of environmental noise and vibration sources from trains including impact noise and vibration from wheel flats, rail joints, switches and crossings are discussed briefly with potential mitigation strategies. Mechanisms of squeal noise generation at sharp curves and strategies to mitigate them are discussed in some detail. Aerodynamic noise can be louder than wheel rail rolling noise in high-speed trains. Methods to measure, predict, and control aerodynamic noise are discussed in this chapter. Vehicle interior noise, including both airborne and structure-borne noise, are covered. Ground-borne noise and vibration generation mechanisms and control measures such as track treatments and vehicle design are also discussed in detail. Finally, vibration comfort inside trains is treated with a discussion on the effects of vehicle design elements such as bogies, suspensions, traction mechanisms, and carbody structure.

Chapter 15 (Active Suspensions). Until recently, vehicle dynamics has been exclusively a mechanical engineering discipline using passive suspensions. This chapter discusses the relatively recent inroads made by advanced controls technology into the world of railways suspensions. The active suspensions technology opens a new avenue for manipulating vehicle dynamics, and this chapter describes primarily three applications. (1) Tilting trains for high-speed trains that allows to maintain higher speeds through curves. This is widely used on high-speed trains. (2) Active secondary suspensions to maintain good ride quality on high-speed trains or less-well-aligned track. (3) Active primary suspensions to improve stability during the kinematic mode and also ensure desirable performance on curves for wheelsets with solid axles. For axles with independent rotating wheels, the active primary suspensions have the potential to improve stability and help avoid wheelset running on flanges. This chapter covers the concepts, equations, strategies and methods for assessing different control configurations. It also describes design challenges with illustrative example. Overall, this chapter provides a good overview of the current state of the art and the risks and opportunities afforded by this technology.

Chapter 16 (Dynamics of Pantograph-Catenary System). Pantograph-catenary interaction is a critical aspect of electric train infrastructure with overhead catenary system. It is one of the three fundamental physical factors that determine the maximum train speed for such a system, the other two being track geometry and rolling stock capabilities. The design and health of the pantograph-catenary system also impact the reliability and maintainability of the mainline railway operations. This chapter provides a good description of the main problems affecting the design of the pantograph and of the overhead equipment. It introduces to the modeling and simulation techniques used to investigate pantograph-catenary interaction problems. The measurement and testing techniques both in laboratories and the field to qualify pantographs are discussed. The main types of damages and failure affecting the pantograph-catenary system and condition monitoring of the system are discussed. The emerging long-term trends to improve the system performance and life cycle costs are also discussed, and the considerations include active/semi-active pantograph control, continuous monitoring of the overhead contact lines status, and analysis of pantograph aerodynamics using computational fluid dynamics.

Chapter 17 (Simulation of Railway Vehicle Dynamics). Considering that railway vehicle dynamics are evaluated primarily using computer simulations, this is a very important chapter for application engineers as it talks about the tools available to perform detailed analysis. This chapter provides an overview of the modeling avenues available to characterize railway vehicle dynamics and discusses how simulations can be validated. It starts with the fundamentals of vehicle-track interaction and the first principles of equations of motions. Major multibody simulation packages available for modeling vehicle dynamics are discussed. Typical vehicle dynamics computational tasks such as stability, ride characteristics, and curving are discussed in detail with examples of applications.

Chapter 18 (Field Testing and Instrumentation of Railway Vehicles). This chapter provides an overview of situations in which the dynamics data may require empirical data from testing. It looks into common techniques and equipment used, both in the laboratory and for conducting vehicle testing on track. Common transducers such as accelerometers, strain gauges, force-measuring wheelsets, and vehicle speed and position measurements are discussed. This chapter also discusses numerical tools for wheel and rail shape measurements. Static and dynamic tests in the laboratory and the field environment that are used for validation and acceptance of the rolling stock are presented. The target audience for this chapter is both modeling community and the application test engineer in the field of railway vehicle dynamics.

Chapter 19 (Roller Rigs). Computer models have limitations when the input parameters do not accurately capture key variables. Particularly, new vehicle designs that strive to maximize sustainability goals such as low fuel consumption would benefit from empirical data generated in controlled test conditions. The roller rigs are very relevant for such scenarios. This chapter discusses the history of roller rig testing and provides a summary of twelve major roller rig test facilities from across the globe. The summary analyzes capabilities to test wheel-rail contact, adhesion, traction and braking, wear and roller contact fatigue, derailment and curving, noise and vibration, component performance, and environmental conditions. The size of test specimens such as full vehicle, bogie, single wheelset and single wheel that can be handled by these facilities is also discussed. For four facilities, there are detailed technical overview of the research objectives, configuration overview, and specification. The operational modes and application of these four facilities are also discussed in detail. Finally, the experimental methods and errors are also discussed. Overall, this chapter demonstrates the value of sophisticated test facilities and where they can complement the analysis capabilities of advanced computer simulations. It also does a good job explaining the changes in vehicle response in a roller rig due to kinematic and geometric differences compared to running the rail on track.

Chapter 20 (Scale Testing Theory and Approaches). The main obstacles for the widespread use of full-scale roller rig facility are the high costs and the substantially limited use to test the first prototypes of real vehicles. However, scaled testing facilities can help get insights into specific phenomenon much more efficiently. This chapter describes the use of reduced-scale test benches for simulating different aspects concerning railway vehicles. It provides a history of the development of simulators and discusses the strategies for scaling at three facilities, one each in Germany, France, and UK. Generally, this chapter provides a good flavor of bench tests and how they are customized for specific tests. Dynamic track simulator, tribology studies and Hardware in the Loop applications are typical applications for scaled prototype tests that are covered in this chapter.

Chapter 21 (Railway Vehicles Dynamics Glossary). The contributors to this handbook are truly international experts from across nations and regions, and inevitably, there is quite a bit of variation in the technical and operational terminology used by different railway systems. For the American audience, here are some notable differences in the terminologies between American-based conventions and the British-backed development: "rail" and "railway, " "truck" and "bogie, " "train line" and "brake pipe, " "warp" and "track twist, " "subgrade" and "roadbed, " "crosstie" or "tie" and "sleeper."

Personally, I have found this book valuable as it covers the concepts and applications of railway vehicle dynamics in a comprehensive way. It lives up to its title of being a handbook as the various contributors bring in diverse angles to the topic of vehicle dynamics and the editors have done a neat job of compiling them in a cohesive manner. Because the book presents concepts, equations, practical testing techniques, modeling details, and real-world examples, it can serve as learning material for application engineers that are beginning in the field and as a handy reference for experienced professionals.

No practice questions or exercises are given at the end of each chapter, and thus, it would be impossible to use it as a textbook. Nevertheless, this is perhaps the best reference book out in the market with up-to-date content for serious professionals and students in the field of railway vehicle dynamics.

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