Lecture Notes in Applied Mechanics Vol. 6

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System Dynamics and Long-Term Behaviour of Railway Vehicles, Track and Subgrade

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Series Editor
Prof. Dr.-Ing. Friedrich Pfeiffer

Springer-Verlag Berlin Heidelberg GmbH

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ISBN 978-3-642-07864-4 ISBN 978-3-540-45476-2 (eBook)
DOI 10.1007/978-3-540-45476-2

Library of Congress Cataloging-in-Publication Data

System dynamics and long-term behaviour of railway vehicles, track and subgrade /
Karl Popp and Werner Schiehlen (eds.).
p. cm. – (Lecture notes in applied mechanics ; v. 6)
Includes bibliographical references and index.

1. High speed trains–Dynamics–Congresses. 2. Railroads–Track–Dynamic–Congresses.
I. Popp, Karl. II. Schiehlen, W. O. (Werner O.) III. series

TF1450 .S97 2002
625.1–dc21 2002029220

http://www.springer.de

Originally published by Springer-Verlag Berlin Heidelberg New York in 2003
Softcover reprint of the hardcover 1st edition 2003

Cover design: design & production GmbH, Heidelberg
Typesetting: Digital data supplied by author

SPIN: 10885949 62/3020xv-5 4 3 2 1 0 – printed on acid-free paper

Preface

High speed ground traffic is strongly competitive to air traffic in densely populated areas like Europe or Japan. During the last decades, completely new technologies for high speed railway vehicles were developed. The primarily goals have been to achieve travelling speeds from 250 to 350 km/h and to guarantee safety of the passengers. In Germany these goals were met by the ICE train service starting in 1991. However, certain phenomena were not considered thoroughly during the development of high speed systems: track response, rail and wheel corrugation and noise generation. It turned out that there was a challenge for interdisciplinary research bringing together civil and mechanical engineers dealing with railway problems.

In 1996 the Deutsche Forschungsgemeinschaft (German Research Council) accepted the proposal initiated by Professors K. Knothe (Berlin), P. Meinke (Stuttgart) and K. Popp (Hannover) for a Priority Programme devoted to *System Dynamics and Long-Term Behaviour of Vehicle, Track and Subgrade.*

The aims of the Priority Programme were to contribute to a better understanding of the dynamic interaction of vehicle and track and the long-term behaviour of the components of the entire system. So far, the approach has been to increase speed, traction and axle-load by optimizing sub-systems. However, the entire system has revealed new limitations: settlement and destruction of the ballast and the subgrade lead to deterioration of the track; irregular wear of the wheels cause an increase in overall load and deterioration of passengers' comfort; damage of the running surfaces of the rail and the wheel becomes more frequent.

The research was based on four main issues. Non-linear behaviour of the ballast was investigated experimentally in laboratories and simulated by new material-laws and multi-particle computer models. The coupling of the track-model and the subgrade was defined using various methods. Phenomena occurring in the contact area of wheel and rail were numerically and experimentally analyzed, also by using a virtual measurement device on the moving train. Dynamic models of the entire system were thought to explain the phenomenon of polygonalization of the wheels. It was expected that the interdisciplinary and fundamental research will result in physical explanations and subsequently will lead to engineering developments which will allow long-lasting solutions.

All the aforementioned engineering problems have been investigated in the Priority Programme SPP 1015 with research activities financially supported by the Deutsche Forschungsgemeinschaft (DFG) from 1996 to 2002. The research comprised 22 interconnected projects conducted at 16 German universities and research institutions. The research activities were organized in the following sections:

- Vehicle Dynamics (coordinator: P. Meinke, Stuttgart)
  - Wavy wear pattern on the tread of railway wheels (E. Brommundt, Braunschweig)
  - Distributed numerical calculations of wear in the wheel-rail contact (K. Frischmuth, Rostock)
  - Modeling and simulation of the mid-frequency behaviour of an elastic bogie (K. Popp, Hannover)
  - Rotor dynamics and irregular wear of elastic wheelsets (P. Meinke, Stuttgart)
  - System dynamics of railcars with radial- and lateralelastic wheels (W. Schiehlen, Stuttgart)
- Contact, Friction, Wear (coordinator: B. Zastrau, Dresden)
  - Model-based validation within the rail-wheel-subgrade modeling (D. Söffker, Duisburg)
  - Friction and wear of tractive rolling contacts (L. Deters, Magdeburg)
  - Experimental analysis of the cyclic deformation and damage behavior of characteristic wheel and rail steels (K.-H. Lang, Karlsruhe)
  - On the numerical analysis of the wheel-rail system in rolling contact (B. Zastrau, Dresden)
- Track Dynamics (coordinator: K. Knothe, Berlin)
  - Monitoring the dynamics of railway tracks by means of the Karhunen-Loève-Transformation (E. Kreuzer, Hamburg-Harburg)
  - Measurements and modelling of resilient rubber rail-pads (K. Knothe, Berlin)
  - Combined modelling of discretely supported track models and subgrade models - Vertical and lateral dynamics (K. Knothe, Berlin)
  - The dynamics of railway track and subgrade with respect to deteriorated sleeper support (R. Lammering, Hamburg)
  - Model-based investigation of the dynamic behaviour of railway ballast (K. Popp, Hannover)
- Subgrade Dynamics (coordinator: G. Gudehus, Karlsruhe)
  - Experimental and numerical investigations on the track stability (R. Katzenbach, Darmstadt)
  - Simulation of the dynamic behavior of bedding-foundation-soil in the time domain (O. v. Estorff, Hamburg-Harburg)
  - Numerical model and laboratory tests on settlement of ballast track (G. Gudehus, Karlsruhe)
  - Experimental investigation and numerical modelling of soils and ballast under cyclic and dynamic loading (H.-G. Kempfert, Kassel)

- Rigid body dynamics of railway ballast (T. Pöschel, Berlin)
- Track settlement due to cyclic loading with low minimum pressure and vibrations (W. Ruecker, Berlin)
- 3D-simulation of dynamic interaction between track and layered subground (S. Savidis, Berlin)
- Dynamic behavior of railway track systems analyzed in frequency domain (G. Schmid, Bochum)

This book contains the scientific results of the Priority Programme as presented at the Concluding Colloquium held at the University of Stuttgart, Germany, March 13 - 15, 2002. Additionally, the earlier concluded projects are also included in this volume as well as an introduction with review and outlook, and a benchmark study.

The following experts in the field were invited to join the Colloquium to present survey lectures on related research topics:

- H. P. Lang: Experience from high-speed traffic
- R. D. Fröhling: Track and subgrade loading
- P. Pointner: The wheel-rail-contact and its effect on wear and rolling-contact-fatigue-cracks
- R. M. Goodall: Active suspension technology and its impact upon vehicle/track interaction

Three of their contributions have been included in this book, too. In summary, this book represents a final scientific report of the DFG Priority Programme SPP 1015.

Finally, we would like to thank the Deutsche Forschungsgemeinschaft (DFG) for the financial support and, in particular, to its representative, Dr.-Ing. Jürgen Hoefeld, for his continuing interest in the Programme. We acknowledge the excellent work of the section coordinators, Professors G. Gudehus, K. Knothe, P. Meinke and B. Zastrau who arranged for the fruitful cooperation within the Programme. And last but not least we thank our coworkers Dipl.-Ing. T. Meinders and Dipl.-Ing. H. Kruse for their most valuable help during the preparation of the Concluding Colloquium and the preparation of this Proceedings Volume.

Hannover, May 2002
Karl Popp

Stuttgart, May 2002
Werner Schiehlen

Contents