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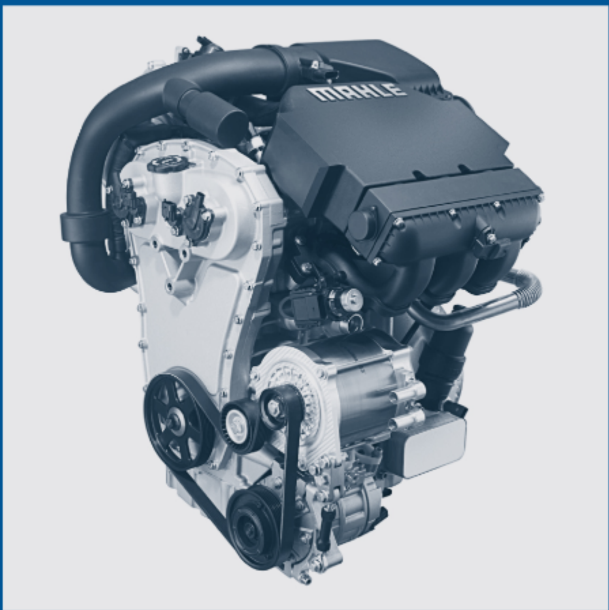
# Advanced direct injection combustion engine technologies and development

## Volume 1: Gasoline and gas engines

Edited by Hua Zhao

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# Preface

Over the last decade, significant progress has been made in the development of direct injection internal combustion engines. It may have been by coincidence that direct injection technology was developed and applied almost simultaneously to spark ignition (SI) gasoline engines and light-duty diesel engines in the mid-1990s, but the direct injection technology had been adopted in both engines for the same reason – to increase the efficiency of internal combustion (IC) engines for automotive applications while improving their performance. However, the route to growth and market penetration has proved more haphazard in the case of direct injection SI engines, owing to relatively high cost, lower than expected gains in fuel economy and full load performance, their complexity and the requirement for a lean $NO_x$ aftertreatment system. In comparison, the high-speed direct injection (HSDI) diesel engine has achieved remarkable commercial success due to its excellent fuel economy and good performance characteristics.

With heightened concern over the greenhouse gas effect, imminent $CO_2$ emission targets in Europe and Japan, and new fleet vehicle fuel consumption requirements in the US, direct injection gasoline engines are staging a comeback, mainly through downsized boosted operations in the short term and stratified charge and/or controlled autoignited combustion in the medium term. In the meantime, HSDI and heavy-duty (HD) diesel engines are facing the challenge of meeting ever more stringent emission legislation across the globe, but without deteriorating fuel economy. It is therefore timely that the state of the art with respect to current direct injection combustion engines and their development needs should be presented and discussed in a single book so that researchers and practising engineers can 'stand on the shoulders of giants' in developing future high-efficiency and low-emission combustion engines. One particular strength of this book is its wide-ranging but balanced coverage of the fundamental understanding and applied technologies involved in DI combustion engines and the complementary contributions by both practising engineers and academic researchers.

This book is divided into two volumes, the first dealing with gasoline and gas engines, and the second discussing diesel engines. In Volume 1, following an overview of the history and principles of high-efficiency direct injection gasoline engines, approaches to achieving better fuel economy from such engines are presented. These include a discussion on stratified charge combustion for part-load operations in Chapter 2, downsized engines through turbocharging in Chapter 3, lean-boost and exhaust gas recirculation (EGR) boost for further engine downsizing in Chapters 4 and 5, and autoignition combustion for simultaneous reduction in NO and fuel consumption in Chapter 6. Chapter 7 illustrates the use of computational fluid dynamics (CFD) in the design and optimisation of direct injection gasoline engines. Chapter 8 reviews direct injection compressed natural gas (CNG) engines that have been developed for commercial vehicles. Chapter 9 has been written to reflect the experience of the world's most successful bio-fuel market in Brazil. Finally Chapter 10 provides an up-to-date summary of advanced optical techniques and their applications to the development of gasoline engines.

Volume 2 starts with a survey of HSDI diesel engines developed over the last decade, which sets the scene for the following chapters. Chapter 2 provides an overview of state-of-the-art fuel injection systems for light-duty diesel engines. The fundamentals of mixture formation, combustion and emissions from HSDI diesel engines are presented in Chapter 3. This is complemented by a detailed discussion on the effect of multiple injections on diesel combustion and emissions in Chapter 4. Air management and turbocharging technologies are crucial to the diesel engine's performance and emissions, and they are the subject of Chapter 5. Chapter 6 presents and discusses some advanced concepts for future light-duty HSDI diesel engines. With the incorporation of a more sophisticated fuel injection system, turbocharging, EGR, and regenerative and active aftertreatment systems in modern diesel engines, Chapter 7 introduces the concept and example of a model-based control and engine management approach to illustrate how such a complex system can be controlled and optimised.

In the second part of volume 2, following an overview of current heavy-duty diesel engines in Chapter 8, the evolution and development in the fuel injection system for heavy-duty diesel engines is described in Chapter 9. Chapter 10 gives an excellent presentation on the turbocharging technologies for heavy-duty diesel engines by one of the major turbocharger manufacturers. Chapter 11 presents results of a series of experimental and CFD studies carried out on a single-cylinder heavy-duty diesel engine using multiple injections and combustion chamber designs. Part II concludes with a detailed description of the systematic process in the design of heavy-duty diesel engines in Chapter 12.

Part III of Volume 2 discusses exhaust emission abatement, diesel combustion diagnostics and modelling. Fuel reforming is an interesting topic in that it offers the potential to generate on-board hydrogen for not only better combustion but also the opportunity for improving the performance