MAHLE GmbH (Ed.)

Pistons and engine testing

VIEWEG+ TEUBNER

MTZ

MAHLE

MAHLE GmbH (Ed.)

Pistons and engine testing

MAHLE GmbH (Ed.)

Pistons and engine testing

With 269 illustrations and 20 tables

VIEWEG+
TEUBNER

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

This book is based on the 1st edition of the German book „Kolben und motorische Erprobung“ edited by MAHLE GmbH.

1st Edition 2012

Editor:
© MAHLE GmbH, Stuttgart 2012

Editorial Office: Ewald Schmitt | Elisabeth Lange

Vieweg+Teubner Verlag is a brand of Springer Fachmedien.
Springer Fachmedien is part of Springer Science+Business Media.
www.viewegteubner.de

Cover design: KünkelLopka Medienentwicklung, Heidelberg
Typesetting: Klementz publishing services, Freiburg
Printing company: AZ Druck und Datentechnik, Berlin
Printed on acid-free paper
Printed in Germany

ISBN 978-3-8348-1590-3

Preface

Dear readers,

The second volume of the MAHLE Knowledge Base, a series of technical books, is both a broader and a more in-depth companion to the first volume, “Cylinder components.” In this volume, MAHLE specialists share their broad, extensive technical knowledge on the subject of the piston, its design, layout, and testing. The many illustrations, graphs, and tables provide a vivid visual overview of the subject, making your work in this area easier every day.

Never before have the requirements that international legislation and customers place on modern engines, and therefore on the piston, been so great, and sometimes so contradictory. That is why you will find so many details about the piston–its function, requirements, different types, design guidelines–as well as about simulating operational durability with finite element analysis, about piston materials, piston cooling, and component testing. Engine testing, however, is still the most important element in the component development program, as is the validation of new simulation programs and systematic development of design specifications. Learn more about it here–with the scientific depth and meticulousness you expect–in the extensive chapter on “Engine testing.”

This second volume of the technical books series is, once again primarily directed to the engineers and scientists in the areas of development, design, and maintenance of engines. However, professors and students in the subjects of mechanical engineering, engine technology, thermodynamics, and vehicle construction, as well as any readers with an interest in modern gasoline and diesel engines, will also find valuable information on the following pages.

I wish you much enjoyment and many new insights from this reading.

Stuttgart, November 2011

Heinz K. Junker

Acknowledgment

We would like to thank all authors for contributing to this technical book.

Dipl.-Ing. Ingolf Binder
Dipl.-Ing. Karlheinz Bing
Dipl.-Ing. Thomas Deuß
Dipl.-Ing. Holger Ehnis
Dr.-Ing. Rolf-Gerhard Fiedler
Dipl.-Ing. Rudolf Freier
Dipl.-Ing. Matthias Geisselbrecht
Dr.-Ing. Wolfgang Ißler
Dipl.-Ing. Peter Kemnitz
Dr.-Ing. Reiner Künzel
Dipl.-Ing. Ditrich Lenzen
Dr. Kurt Maier
Dipl.-Ing. Olaf Maier
Dr.-Ing. Uwe Mohr
Dipl.-Ing. Helmut Müller
Dr. Reinhard Rose
Dipl.-Ing. Wilfried Sander
Dipl.-Ing. Volker Schneider
Dr.-Ing. Wolfgang Schwab
Dipl.-Ing. Bernhard Steck
Peter Thiele
Dr.-Ing. Martin Werkmann

Contents

1 Piston function, requirements, and types

1.1 Function of the piston

1.1.1 The piston as an element of power transmission

In the cylinder of an engine, the energy bound up in the fuel is rapidly converted into heat and pressure during the combustion cycle. The heat and pressure values increase greatly within a very short period of time. The piston, as the moving part of the combustion chamber, has the task of converting this released energy into mechanical work.

The basic structure of the piston is a hollow cylinder, closed on one side, with the segments piston crown with ring belt, pin boss, and skirt; **Figure 1.1**. The piston crown transfers the gas forces resulting from the combustion of the fuel-air mixture via the pin boss, the piston pin, and the connecting rod, to the crankshaft.

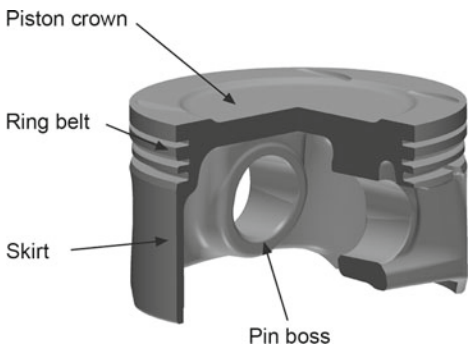

Figure 1.1: Gasoline engine pistons for passenger cars

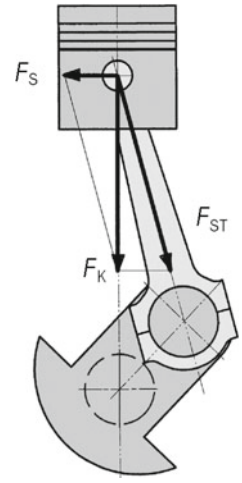

Figure 1.2: Forces on the piston

The gas pressure against the piston crown and the oscillating inertial forces, referred to in the following as the inertia force, of the piston and the connecting rod constitute the piston force F_K; **Figure 1.2**. Due to the redirection of the piston force in the direction of the connecting rod (rod force F_{ST}), an additional component arises–following the force parallelogram–, namely the lateral force F_S, also known as the normal force. This force presses the piston

MAHLE GmbH (Ed.), *Pistons and engine testing,* DOI 10.1007/978-3-8348-8662-0_1,

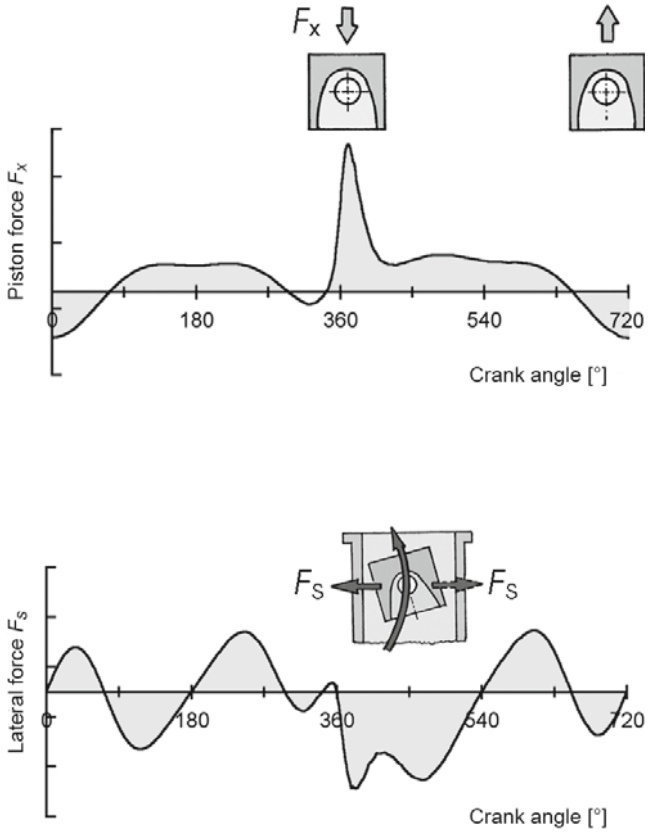

Figure 1.3:
Force curves

skirt against the cylinder bore. During a combustion cycle, the lateral force changes direction several times, which presses the piston from one side of the cylinder bore to the other, due to the existing piston clearance. **Figure 1.3** shows the piston force and lateral force curves as a function of the crank angle.

1.1.2 Sealing and heat dissipation

As a moving and force-transmitting component, the piston, together with the piston rings, must reliably seal the combustion chamber against gas passage and the penetration of lubricating oil under all load conditions. It can fulfill this task only if a hydrodynamic lubricating film is present between the piston rings or skirt and the cylinder bore. The stoppage of the piston at the two dead center points, where the lubricating film isn't fully functional, is particularly problematic. The piston rings must remain functional over very long running periods. Average sliding speeds are typically 10 to 12 m/s.

In four-stroke engines, the piston crown also supports the mixture formation. For this purpose, it has a partially jagged shape, with exposed surfaces (such as the bowl rim) that absorb heat and reduce the load capacity of the component. In two-stroke engines with