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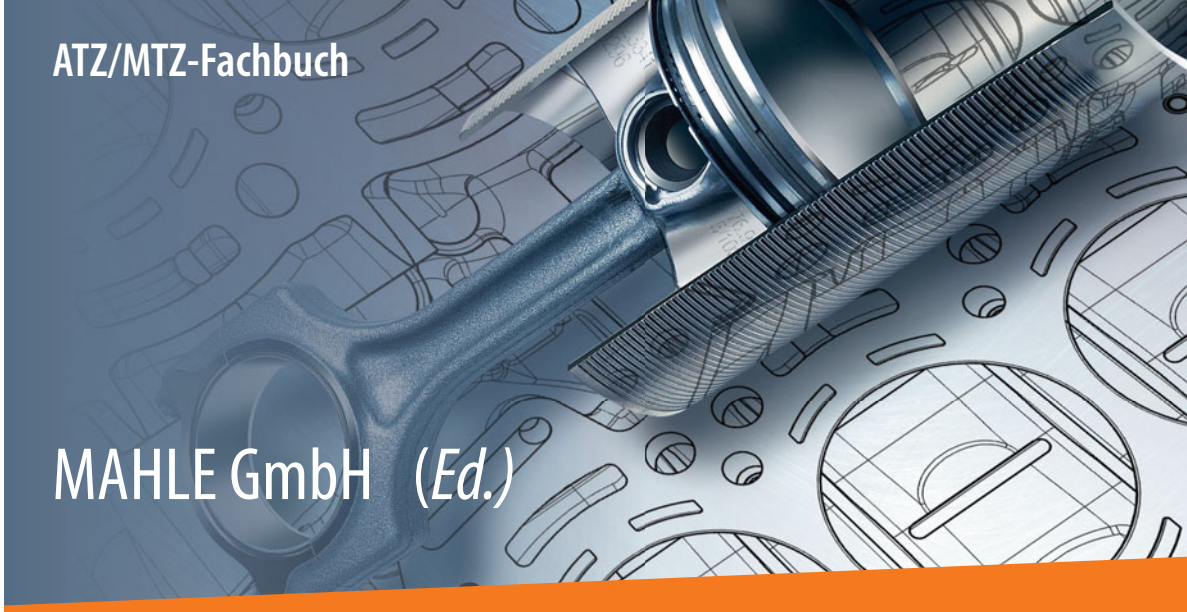

MAHLE GmbH (*Ed.*)

Pistons and engine testing

2nd edition

MAHLE

Springer Vieweg

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MAHLE GmbH
Editor

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Preface

Dear readers,

This is the second revised edition of the second volume of the MAHLE Knowledge Base, a multivolume set of technical books.

The volume “Pistons and engine testing” expands on and adds greater depth to the first volume, “Cylinder components”. In this book, MAHLE experts share their broad-based, extensive technical knowledge of pistons, including layout, design, and testing. The large number of pictures, charts, and tables provide a good visual overview of the entire subject, making your day-to-day work in this field easier.

Never before have such high and sometimes contradictory demands been placed on modern engines, and therefore on their pistons, by international legislation as well as customers. Therefore, the following pages are filled with detailed information on everything to do with pistons: their function, requirements, types, and design guidelines, as well as simulation of operational strength using finite element analysis, and piston materials, cooling, and component testing. Engine testing is, however, still the most important element in component development, as well as for validating new simulation programs and systematically compiling design specifications. In the meticulous scientific depth you have come to expect, you will find out more in the detailed section “Engine testing”.

This second volume in the series of technical books is again primarily intended for engineers and scientists in the fields of engine development, design, and maintenance. 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.

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

Stuttgart, October 2015

Wolf-Henning Scheider
Chairman of the Management Board and CEO

Heinz K. Junker
Chairman of the Supervisory Board

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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 converted into heat and pressure during the expansion stroke. The heat and pressure values increase greatly within a short period of time. The piston, as the moving part of the combustion chamber, has the task of converting part of 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, piston pin boss, and skirt; **Figure 1.1**. The piston crown transfers the compression forces resulting from the combustion of the fuel-air mixture via the piston pin boss, the piston pin, and the connecting rod, to the crankshaft.

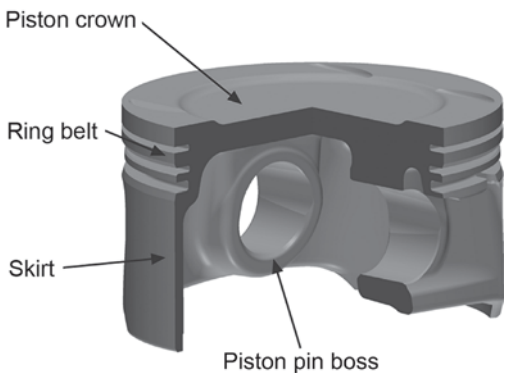

Figure 1.1: Gasoline engine pistons for passenger cars

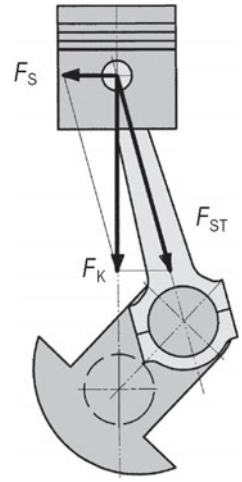

Figure 1.2: Forces on the piston

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 FK; **Figure 1.2**. As a result of the redirection of the piston force in the direction of the connecting rod (rod force FST), an additional component arises–following the force parallelogram–, namely the lateral force FS, also known as the normal force. This force presses the piston

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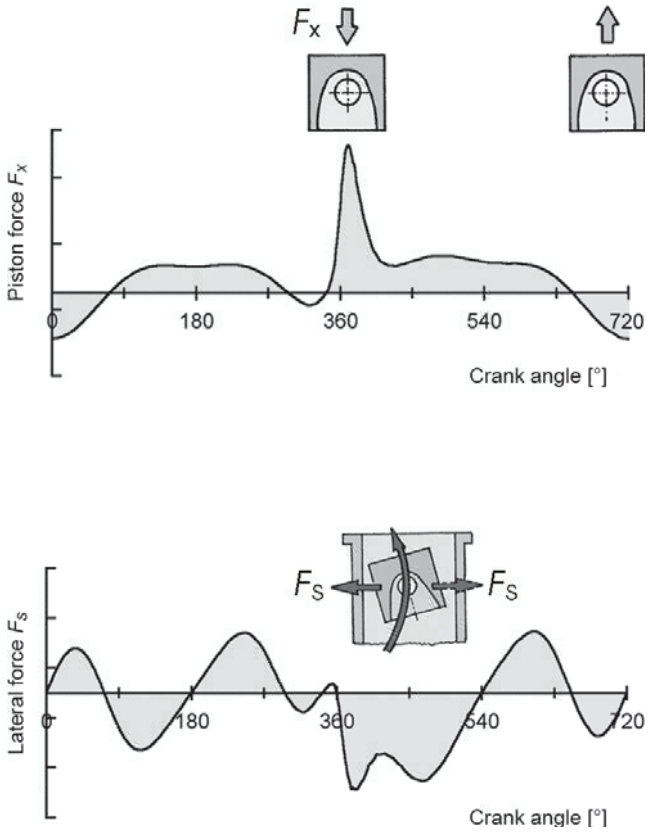

Figure 1.3:
Force curves

skirt against the cylinder bore. During an operating cycle, the lateral force changes direction several times, which presses the piston from one side of the cylinder bore to the other. **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 power-transmitting component, the piston, together with the piston rings, must reliably seal the combustion chamber against gas passage and the penetration of lubricating oil in all load cases. A prerequisite is that the materials, geometries, and surfaces are carefully matched. Long piston service life requires good wear behavior, which in turn requires that the running partners are sufficiently supplied with lubricating oil. The oil-retaining capacity of the components due to their surface structure, particularly that of the cylinder, plays a decisive role. This is particularly challenging near the dead center points of the piston, because the hydrodynamic lubricating film is less significant here and mixed friction predominates. 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