

MAHLE GmbH (Ed.)

Pistons and engine testing



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With 269 illustrations and 20 tables



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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

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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 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.

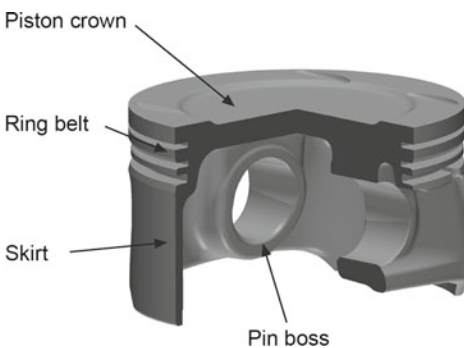


Figure 1.1: Gasoline engine pistons for passenger cars

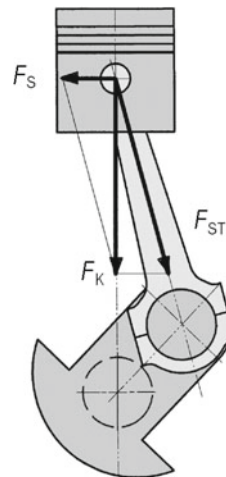


Figure 1.2: Forces on the piston

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

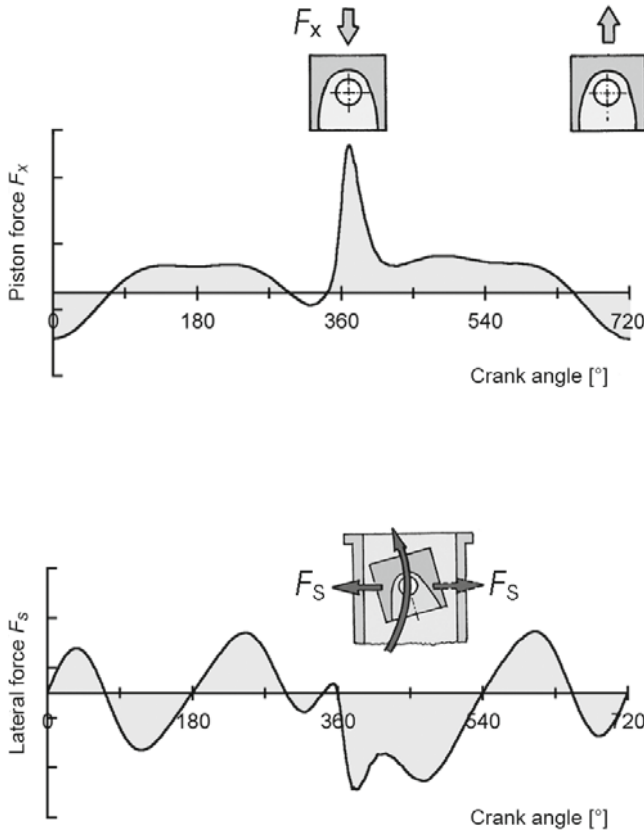


Figure 1.3:
Force curves

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