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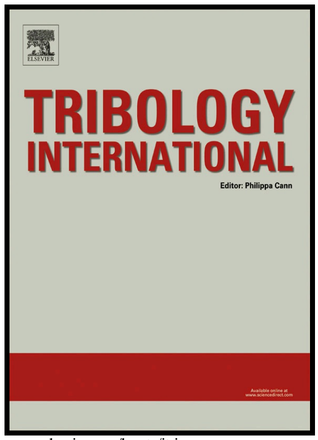


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# Experimental and simulative research advances in the piston assembly of an internal combustion engine

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**Abstract**

The piston assembly is the most complex tribological system within the internal combustion engine. In order to fully exploit its optimization potential a high level of system understanding is required. Therefore, in this paper experimental studies of two single cylinder engines are combinded with CFD-simulation of the piston ring pack. The introduced measurement and simulation techniques enable a holistic approach to the investigation of the tribological conditions of the piston assembly.

The results – like the comparison of crank-angle resolved oil film thickness to the piston assembly friction measurement – illustrate the implications of design parameters of the piston assembly on the functional parameters friction, oil consumption, blow-by, wear and acoustics and thereby permit purposive system optimization.

*Keywords:* Piston assembly, Lubricating oil film thickness measurement, Floating liner engine, CFD piston rings

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## 1. Introduction

In 2009 the EU member states have committed themselves to reduce the emission of polluting greenhouse gases, especially $CO_2$, by at least 20 % by 2020 compared to 1990. Therefore emissions of 95 g $CO_2$/km are the limit for new registrations of motorcars as of 2020 [1, 2]. Compared to the determined average value of 126.7 g $CO_2$/km by the EEA (European Environment Agency) [3] in 2013, the automotive industry is faced with tremendous economic and technical challenges, as a study of the IKA (Institute for Automotive Engineering, RWTH Aachen) shows [4]. Hence the reduction of $CO_2$ emissions and the related fuel consumption is the key task in the development of modern combustion engines.

A technical method to attain these target values, is to improve the mechanical efficiency. According to Holmberg [5] between 4.3 and 7.8 % of the fuel energy is dissipated by the friction between the piston assembly and the cylinder liner. Accordingly, the optimization of the piston assembly provides a good opportunity for the development of improved future engines.

To exploit the potential for improvement, a detailed knowledge of the tribological processes is essential. Due to the constantly changing conditions like viscosity, velocity and pressure, the piston assembly is one of the most complex tribological systems inside the internal combustion engine [6]. In addition to the friction, the design of the piston assembly significantly influences the oil consumption and blow-by losses. Furthermore, wear and acoustic effects have to be taken into account, especially with the contact alteration of the piston. The major challenge in optimizing the piston assembly is thus to find measures that optimize the friction without influencing other tribological phenomena unfavourably.

An evaluation of new design features with regard to effects on the friction-force is not sufficient for an effective improvement of the system piston assembly. In fact, the development of innovative components requires the holistic examination of all influences on this tribological system.

## 2. Theoretical basics

In this paper, effects of a component variation – preload of the oil scraper ring – on the piston assembly friction, blow-by gas flow and the lubricating oil film thickness are investigated. The latter is crucial for friction, oil consumption and wear.

So far little research has been done on dependencies between all these phenomena on the piston assembly. In many publications only individual effects, such as the study of friction and wear behavior at a tribology test rig [7] have been investigated. Interactions between the tribological behavior and other effects, such as changes in blow-by that occur during the combustion cycle, have not been analyzed yet.

During the strokes the boundary conditions like viscosity, velocity and pressure change and the piston assembly passes states from boundary friction to hydrodynamic friction, as shown in Figure 1. The hydrodynamic friction represents a significant contribution to the friction losses, which is defined by the product of actual friction force and relative speed. The piston stops for a very short period of

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