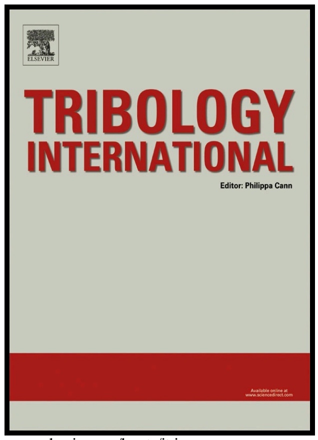

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Development of a Test Method for a Realistic, Single Parameter-Dependent Analysis of Piston Ring versus Cylinder Liner Contacts with a Rotational Tribometer

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Abstract

A rotational tribometer as well as a corresponding test method for measuring friction and wear under pure sliding conditions were developed for the purpose of single parameter analysis of piston ring to cylinder liner contacts. Using this rotational tribometer and applying the developed test method, such analyses were carried out at a high level of precision and under close-to-engine conditions within a wide range of relevant operation parameters of internal combustion engines. In order to validate the test method, the friction and wear of a compression piston ring running against a honed cylinder liner were studied. In this paper, the influence of the test parameters contact temperature, ring load, test duration and sliding speed on the friction and wear behavior of a hard chrome-plated piston ring against a thermally sprayed, iron-based cylinder liner coating (NANOSLIDE®) was analyzed. The friction and wear study at low, medium and high combustion chamber pressures, low to high sliding speeds as well as at moderate to high contact temperatures will be discussed exemplarily. The obtained wear results show very good correlation to engine durability tests.

Keywords:
Rotational tribometer, Combustion engine, Piston ring, Cylinder liner, Single parameter-dependent analysis

1. Introduction

Fuel economy is the major driving force behind the increase in the performance of modern combustion engines. Driven by legal regulations of a progressive reduction of CO_2 emissions, the combustion engine is in need of continuous fuel consumption optimization. Thus, fuel consumption is reduced by consistent downsizing, while simultaneously increasing the combustion chamber pressure and supercharging enhances engine performance. Moreover, the fuel consumption of gasoline engines is reduced further by direct fuel injection. The corresponding increase in the power density of combustion engines, however, results in higher mechanical and thermal stresses on engine components [1]. This also requires increased wear resistance within the frictional contacts of the engine components.

Additionally, frictional losses in terms of mechanical losses account, apart from thermodynamical losses, for a great share of fuel consumption [2–4]. Depending on the engine type and operating conditions, up to 50% of these frictional losses are due to piston assembly friction [2, 3, 5]. In particular, the frictional contact between the piston rings and cylinder liner plays a central role due to the fact that a substantial amount of friction losses within a combustion engine is linked to the piston ring package. In order to meet these increased requirements for mechanical and thermal stability technologically, heavy gray cast cylinder liners have been replaced by thin iron-based, thermally sprayed liners [6, 7] and aluminum pistons have been replaced by steel pistons [8]. Furthermore, new piston ring coatings have been developed [9–11] and optimized in terms of friction and wear resistance.

In the real operation of combustion engines, the piston ring assembly is stressed by a wide range of variable load factors. It is therefore the intention to analyze processes such as piston ring dynamics as well as the friction and wear behavior of piston rings running against cylinder liners by means of advanced simulation models. Another objective is to pre-select engine components during the concept phase with regard to design and materials. For this reason, substantial knowledge bases as well as a more detailed single parameter-dependent understanding of friction and wear processes are required. For this purpose, a rotational tribometer was developed in cooperation with Phoenix Tribology Ltd. as well as a corresponding test method measuring friction and wear.

2. Previous work

In the past, a holistic approach was practiced in order to provide a fundamental understanding of the interactions of the piston ring and cylinder liner surfaces as well as the engine oil in terms of friction and wear [4, 12]. Priest [12] derived methods for optimizing the piston assembly tribology by analyzing wear and lubrication at the piston ring face and cylinder bore interface. Scherge et al. [13] analyzed the wear mapping of piston rings by using the radionuclide-technique. An overall understanding of the wear and friction behavior of the piston ring and liner contact was the main goal of the previous named research.

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