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Effects of cylinder liner surface topography on friction and wear of liner-ring system at low temperature

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ABSTRACT

The experiments were carried out using an Optimol SRV5 oscillating wear tester under lubrication. Specimens were cut from gray cast iron cylinder liners honed and/or plateau honed with diamond or ceramic stones. Counter-specimens were cut from chromium-coated compression ring. Short time tests of 30 min duration were conducted at a temperature of −20 °C, with a stroke of 3 mm. In addition, for a few sliding assemblies, durations of tests at the low temperature were extended to 24 h. For comparison, similar tests for a smaller number of sliding pairs were carried out at a temperature of 80 °C. Before and after tests cylinder liner surface topographies were measured by a white light interferometer Talysurf CCI Lite. It was found that the changes of liner height and frictional resistance at the low temperature were smaller from those tested at the elevated temperature. Two-process textures tested at the low temperature led to a smaller final coefficient of friction, compared to one-process surfaces; opposed results were obtained at the high temperature.

1. Introduction

The contact between a cylinder liner and a piston ring is a substantial source of friction, about 40% of the total losses [1]. In conditions of starved lubrication, a high temperature reduces the oil viscosity [2] causing collisions of surface peaks and then higher friction and wear. A high temperature promotes tribochemical reactions on the surfaces in contact [3]. Tribological tests were carried out on a plate against a ball under lubrication by oils without additive package [4]. The friction force was found to be proportional to an oil temperature. Higher viscosity of oils under boundary lubrication led to the lower friction resistance [5,6] due to the higher oil film thickness (a thicker fluid film leads to better lubrication). Cavdar [7] studied the influence of oil temperature on the boundary lubrication. The results showed that higher temperature (150 °C) led to the increased friction and wear rate than smaller temperature (50 °C). Sliding wear tests were carried out using a pin-on-disc tester to investigate the influence of oil temperature on sliding wear [8]. An increase in temperature of the SAE40 lubricant increased wear rates.

For hydrodynamic lubrication, the higher the oil viscosity, the higher values of friction were observed [9]. The mean effective friction contribution of the piston assembly is proportional to the square root of the lubricant viscosity [10]. When diesel engines operated under high temperatures, lubricant viscosity was increased due to evaporation of the light compounds and oil oxidation [11]. The fuel consumption of a vehicle depends on the friction. Therefore there is a trend towards the application of low viscosity engine lubricants, for obtaining improved fuel economy through the reduction of frictional losses. However because metal-to-metal contact severity is much increased when lubricant viscosity is reduced, improvements in wear resistances of cylinders and piston rings by a friction-reducing surface treatment or the use of friction modifier additives will be necessary [9,12] if a low viscosity lubricant is used.

The cylinder surface topography affects frictional losses of an internal combustion engine [11]. Spencer et al. [13] studied experimentally a top compression ring in contact with different cylinder liners using a Plint reciprocating tribotester. Smoother cylinder liner surface provided lower friction. Similar findings were obtained by other researchers [14–16]. Increase in height of cylinder liner surface caused an increase in an oil film thickness [15] following by larger oil consumption.

However, too smooth smoothness of a cylinder liner surface has the inclination to seizure. It is believed that plateau honed texture ensures good sliding properties of a smooth topography, like small wear, low coefficient of friction, and a great ability to maintain oil. Plateau honed surfaces are the first examples of two-process textures [17–20]. The linear wear level of cylinder liners with two-process textures was smaller compared to those with one-process surfaces characterized by the same

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Table 1
Parameters of cylinder liner surfaces.

Liner designation	Sq, μm	Sz, μm	Sk, μm	Svk, μm	Spk, μm	Sal, mm	Str	Spd, 1/mm^2	Spq, μm	Svq, μm	Smq, %
ID1	1.55	13.5	3.75	1.84	1.79	0.018	0.012	435	–	–	–
ID2	2.95	17.5	6.34	5.06	2.12	0.038	0.074	160	–	–	–
IC1	0.95	6.2	2.1	1.2	0.66	0.02	0.019	780	–	–	–
IC2	1.85	12.6	4.45	2.65	1.33	0.023	0.02	540	–	–	–
IID1	0.3	3.3	0.46	0.8	0.21	0.014	0.018	1621	0.19	1.53	94
IID2	0.52	4.5	0.61	1.51	0.25	0.016	0.014	1242	0.22	1.48	83
IID3	0.8	6.1	0.95	1.8	0.3	0.017	0.013	830	0.25	1.65	72
IIC1	0.46	4.2	0.8	0.95	0.23	0.016	0.02	1320	0.28	1.05	86
IIC2	0.75	5.5	1.1	1.35	0.28	0.017	0.016	921	0.31	1.1	75
IIC3	0.5	4.5	0.68	1.26	0.22	0.015	0.016	1154	0.27	1.8	90
IIC4	0.8	6.4	0.92	1.7	0.27	0.016	0.019	886	0.32	1.9	74

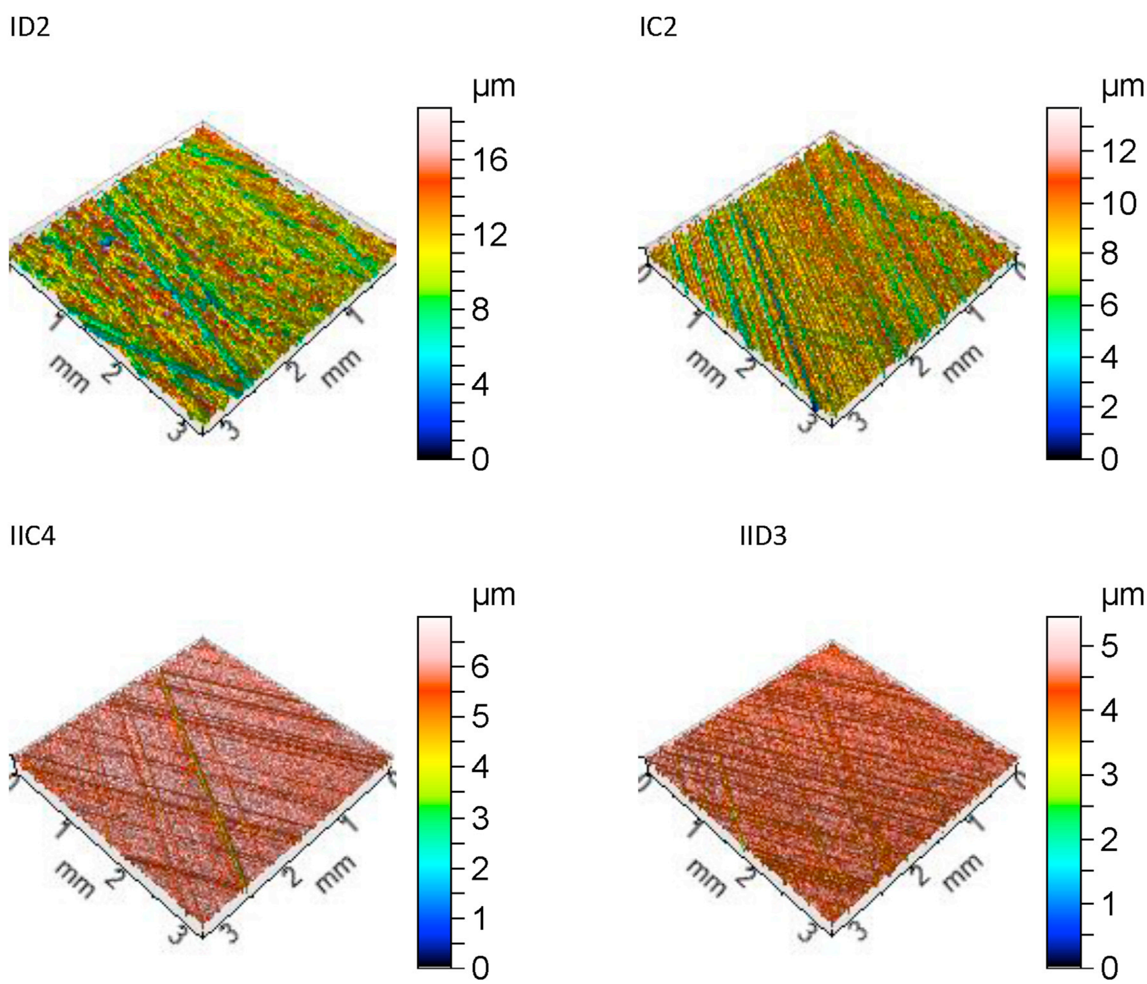

Fig. 1. Isometric views of one-process ID2 and IC2 and two-process IIC4 and IID3 surfaces of cylinder liners.

mean roughness height [21]. Smoother plateau honed cylinder liner surfaces was proven beneficial for friction reduction compared to a typical standard plateau honed cylinder liner with a typical ring pack [22]. Similar results were obtained by Yousfi et al. [23]. The frictional resistance of a cylinder-ring system can also be improved by cylinder texturing [11,24–26].

The cylinder liner surfaces typically operate at high temperatures. However, during winters, the air temperature in many places is low, which affects the initial temperature inside the cylinders. This work aims to study experimentally effects of cylinder liner surface topography on friction and wear of piston ring-liner assembly at a low temperature (−20 °C).

2. Experimental details

The experiments were carried out using an Optimol SRV5 oscillating wear tester under lubricated conditions. SRV testers were previously used for the study of a co-action between the piston ring and cylinder liner [27–29]. The tester Optimol SRV5 was extensively described in Ref. [29]. SAE 15 W/40 mineral oil was a lubricant. The volume of oil in a container was 18 ml. Specimens were cut from cylinder liners made of a gray cast iron of 130 mm diameter, and 218 HB hardness. As the results of honing and/or plateau honing various surface textures of cylinder liners were obtained. Counter-specimens were made from chromium-coated compression rings. Tests were conducted at temperature −20 °C, with a