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Smoothness and plateauness contributions to the running-in friction and wear of stratified helical slide and plateau honed cylinder liners

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ABSTRACT

Cylinder liner surface has a great influence on frictional and wear performances of combustion engines during the running-in period. Two surface texture anisotropies produced by plateau honing (PH) and helical slide honing (HSH) processes (which consist of 50° and 130° cross-hatched grooves, respectively) are commonly used in automotive industry for thermal combustion engine cylinder liners. They are generated by a three stages process. The first stage, rough honing, removes enough material to obtain the desired cylindricity. The second step, finish honing, generates the honed texture which consists of grooves with a specific cross-hatch angle. The third stage permits to reduce the surface peaks and therefore allows varying plateau superficial roughness amplitude.

This paper is devoted to studying the influence of respectively smoothness and plateauness on honed surface wear and friction performances during running-in. For that, HSH and PH textures are generated using different final honing stage durations in order to obtain different levels of surface peak clipping. Then, friction, wear and surface topography evolution were analyzed during running-in tests on a reciprocating ring-liner tribometer under mixed lubrication regime. The results show that the superficial surface roughness generated by helical slide honing has a very low contribution into friction. This is promising for the honing process optimization, in which the third stage can be significantly reduced or avoided.

1. Introduction

In the automotive industry, face to a stringent legislation for the limitation of harmful polluting emissions, manufacturing improved efficiency vehicle engines is a major objective [1]. Several experimental and numerical studies showed that cylinder liner texture influences significantly on engine functional performances (friction, wear, oil consumption, etc.) [2–4]. Different stratified honing techniques (plateau honing, helical slide honing, slide honing, etc.) are used in industry [5].

The main differences between the processes are generally due to the produced surface smoothness (surface roughness), plateauness (plateau and valleys ratio or/and anisotropy (cross-hatch angle)) [5,6]. A study based on a numerical hydrodynamic contact model explained the choice of honing cross-hatch of these industrial processes [7]. It determined two optimal ranges of crosshatch angles (25–60° and 115–140°) in hydrodynamic lubrication regime for lower friction performances. Other studies confirmed these results [8–11].

Two industrial processes plateau honing (PH) with a cross-hatch angle of 50° and a helical slide honing (HSH) with a cross-hatch angle of 130° are interesting for their frictional performance. These very widely used processes are a succession of three honing stages [5,6,12,13]. The first stage often categorized as rough honing establishes the form of the bore. The so called “finish honing” creates the basic surface texture of the hole which is the second operation. For plateau (PH) and helical slide honing (HSH), the final finishing stage is mainly used to generate plateauness surfaces (with smooth plateaus and quite deep valleys) that resemble to running-in surfaces and hence significantly reduce wear of the liner surface [14]. This also enables to obtain a smoother surface in which, according to Horng and Lee [15], large valley are transformed to many small valleys. However, after running-in engine test, it has been shown that the wear of HSH surface is reduced as compared to a plateau honed surface [5].

Concerning the surface topography, Mezghani et al. [1,4] demonstrated, in the case of PH process that smooth texture with lower plateau roughness and valley depth contributes to reduce frictional performances of honed surfaces. Nevertheless, it has been shown, through numerical studies that helical slide honed surfaces are less sensitive to the plateauness i.e., to superficial roughness [6]. The plateau/valleys ratio can be maintained quite high without increasing friction coefficient in mixed lubrication regime [10,6]. Moreover, the reduced roughness topography of HSH surface, compared to plateau honed is mainly due to the high honing duration during the last stage [5,16,17].

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Nomenclature

S_{pq}	root-mean square of the superficial plateau roughness of cylinder surface after plateau honing (μm)
S_{vq}	root-mean square of the valleys depth of cylinder surface after plateau honing (μm)
μ_D	lubricant viscosity, Pa s
v	mean sliding velocity during friction and wear tests
F_N	normal contact force between ring and liner surface
F_T	tangential contact force between ring and liner surface
l_y	contact width between ring and liner surface
HSH	helical slide honing or helical slide honed (surface)
PH	plateau honing or plateau honed (surface)
COF	coefficient of friction
S	Sommerfeld number $S = \mu_D v / (F_N / l_y)$

In this paper, the influence of smoothness and plateauness of PH and HSH surfaces on friction is revealed during running-in process. Then, PH and HSH surfaces with different roughness and plateau/valleys ratios were generated by varying the third honing stage duration. Theirs frictional performances, wear and surface topography evolution have been compared experimentally using a linear-ring tribometer.

2. Experimental procedure

2.1. Honing experiments

Stratified honing experiments have been carried out on an instrumented vertical honing machine with an expandable tool (NAGEL no. 28-8470) (Fig. 1). The considered part is a crankcase that consists of four lamellar gray cast iron cylinder liners for diesel engines. First, during the rough honing stage, all of the process parameters are similar for all the honed bores. Then, for the finish stage, two different kinematics are used: a plateau honing kinematic with a cross-hatch angle of 50° and a HSH one with a cross-hatch angle of 130°. To obtain that, two different couples of rotation speed and axial speed have been used. For plateau honing process (PH) a high rotational velocity is used whereas for the helical slide honing process (HSH), the axial speed is increased. During the final stage, in order to generate different roughness levels and plateauness ratios [4,6], the surfaces are honed with HSH and PH kinematics using a hydraulic expansion at different honing durations (from 0 to 25 strokes). All the other working variables were kept constant. The details of the most important applied process condition are represented in Table 1.

The honed crankcases were first cut in order to extract rectangular portions with dimensions of 140 mm (length) × 110 mm (width) × 35 mm (height) (Fig. 2) of honed bores, in order to facilitate optical measurements and to carry out more easily tribological tests and surface topography measurements.

2.2. Tribological tests

Friction and wear tests are carried out once for each honing configuration at temperature of 27 ± 2 °C through a reciprocating ring-liner tribometer driven by a slider–crank mechanism with a stroke length of 80 mm (Fig. 3). The contact surface is lubricated using 10W40 semi-synthetic oil (μ_D equal to 0.08 Pa s at 40 °C). The total wear test duration is 120 min where additional amount of lubricant is added (2–3 ml) every 20 min. The normal force and engine velocity used for these tests are 100 N and 174 rpm (the average linear velocity equivalent to 0.46 m/s) respectively.

Friction tests are undertaken in mixed lubrication regime at two load levels 50 N and 100 N and three different reciprocating

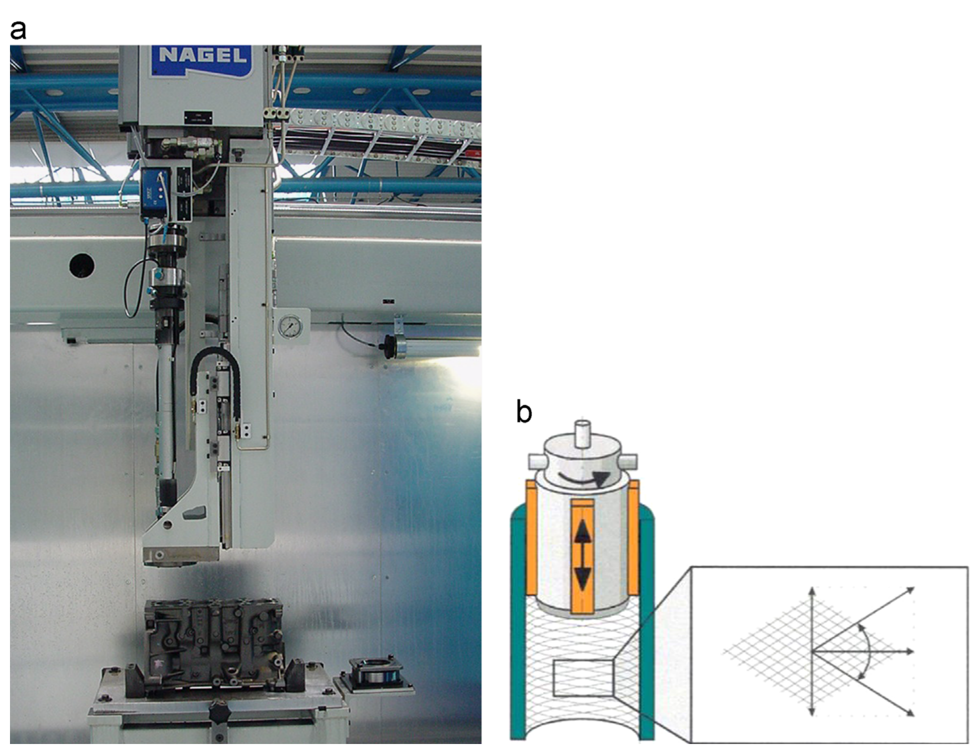

Fig. 1. (a) Vertical honing machine with an expansible tool, and (b) schematic representation of a honing head and its motion.