Precision Engineering 41 (2015) 40–46

Contents lists available at ScienceDirect

Precision Engineering

journal homepage: www.elsevier.com/locate/precision

Roughness variations in cylinder liners induced by honing tools' wear

F. Cabanettes*, Z. Dimkovski, B.-G. Rosén

School of Business and Engineering, Halmstad University, PO Box 823, SE-301 18 Halmstad, Sweden

ARTICLE INFO

Article history:
Received 23 May 2014
Received in revised form 16 January 2015
Accepted 20 January 2015
Available online 29 January 2015

Keywords:
3D surface topography
Automotive motor blocks
Cylinder liner
Plateau honing
Tool wear

ABSTRACT

The manufacturing and finishing (honing) of cylinder liners for the automotive industry is a constant challenge in order to reduce friction losses and oil consumption. A better knowledge of surfaces generated during plateau honing is then required for optimization of the process. Despite a well-known and controlled honing process, variations in surface roughness appear due to honing tool wear and need to be mapped and analyzed. The following paper proposes to map the variations in roughness by using confocal 3D measuring equipment able to inspect any area of a cylinder liner. Six motor blocks, each with five cylinder liners, were evaluated with 20 topography measurements per liner (giving six hundred 3D measurements in total). In addition to standard 3D roughness parameters, tailor made parameters extracting honing texture information are computed. The results show that only a few parameters (Spk, Ssc and Sk) do correlate with the honing tool wear specific to each cylinder. Tailor made parameters indicate similar results. Indeed, as the honing tool wears down, the cylinder liner surface gets rougher plateau or peaks and sharper asperities indicating that ploughing occurs instead of cutting. In future, experimental models could be built in order to perform production and functional optimizations.

1. Introduction

The specifications of components in the automotive industry are strongly ruled by customer and legislation demands. Indeed, engineers are aiming for the production of engines with lower fuel consumption while keeping low emissions [1]. The cylinder liner is one of the engine components with real potential for lowering friction: a recent study by Holmberg et al. [2] showed that the piston assembly is responsible for 45% of the engine friction losses in passenger cars. One of the solutions for reducing friction is to improve and control the surface roughness (such as the Abott curve parameters) of the liners [3–5].

The honing process is commonly used to obtain surfaces with good functionalities for the ring/liner contact (cross hatch pattern and fine surfaces). The honing tool is composed of a number of honing stones which are pressed radially outward. The tool creates a cross hatch pattern (see Fig. 1) by simultaneously rotating and stroking inside the cylinder liner to hone.

Despite a well-known and controlled honing process, spreading of surface roughness cannot be avoided and topography variations do exist at global scales (difference between motor blocks, cylinders) and local scales (top dead center, middle stroke, bottom dead center of the liners).

Most of the studies on roughness variations in production focus on the effect of the honing process parameters such as:

- Honing time and pressure [6–10]
- Stone expansion velocities [11,12]
- Abrasive grit size [10,11,13]
- Abrasive type [12–14]

A few studies focus on the roughness variations inside a cylinder liner [15,16] and the honing tool wear influence is rarely studied since it requires a massive production of liners possible only on real production lines to observe a long term effect.

In the literature, cylinder liner roughness observations are performed on motor blocks from production lines [13,14,17,18], samples produced by laboratory honing machines [8–12,19] or simplified honing test benches [15].

Regarding the observation of the liners, studies have been made using the following techniques:

- Standard techniques by acquiring a few profiles with a stylus measuring on the top dead center [8,10–13,19,20]. Issues with such measurements are the representativeness of the results.

* Corresponding author. Tel.: +33658421263; fax: +33 4 77 43 75 39.
E-mail address: fcabanettes@gmail.com (F. Cabanettes).

http://dx.doi.org/10.1016/j.precisioneng.2015.01.004
0141-6359/

Nomenclature

Sa	areal arithmetic mean height (μm)
Sq	areal root mean square height (μm)
Ssk	areal skewness
Sz	areal maximum height (μm)
Str	areal texture aspect ratio
Sdq	areal root mean square slope
Ssc	areal arithmetic mean summit curvature (1/μm)
Sk	areal core roughness depth (μm)
Spk	areal reduced summit height (μm)
Svk	areal reduced valley depth (μm)
S5p	areal five point peak height (μm)

- Observations by acquiring SEM images or 3D interferometer measurements can be made to study different locations inside the liners [14,17,18]. However they require cutting the motor blocks.
- Observations by acquiring inspection images from CCD cameras do exist [19] and avoid destructive experiments but no standard evaluation of the surfaces can be made.
- 3D topographies can be obtained in a non-destructive way by acquiring series of 2D profiles from a stylus [8,9]. However the technique is time consuming and a few measurements can be made. Therefore statistically robust studies are limited.

The following paper proposes to map the roughness variations of cylinder liners due to the honing tool wear. A non-destructive and fast acquisition technique is used to obtain 3D topographies from motor blocks picked out of a real production line. The confocal measuring equipment is able to scan any area of a cylinder liner from passenger cars meaning that statistically reliable data can be obtained to observe the influence of the honing tool wear on cylinder liners' surface topography.

2. Materials and methods

2.1. Motor blocks

The motor blocks used in this study are from the production line of the Volvo T5 [21] 2.5 l petrol engine (254 hp) with 5 cylinders (see Fig. 2). The cylinders have a total length of 140 mm and an inner diameter of 83 mm. The process studied is the plateau honing which is performed with stones containing diamond abrasives.

Every 2 days, one motor block was picked out of the same production line (see Fig. 3). In 10 production days a total of 6 motor blocks were picked out. The interval for picking out blocks provides a complete scan over the entire honing tools life. As a consequence a reliable mapping of the surface roughness spreading can be obtained.

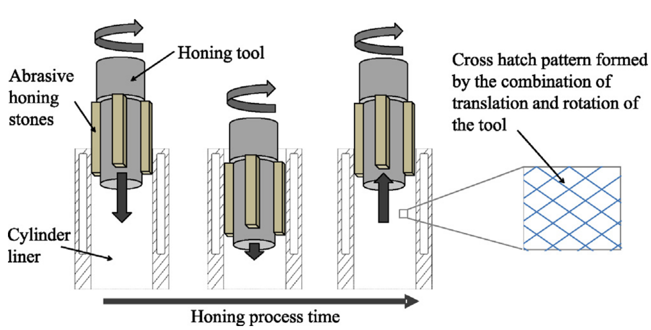

Fig. 1. The honing process forming a cross hatch pattern.

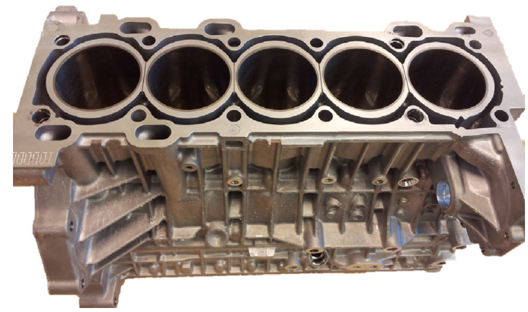

Fig. 2. One of the motor blocks studied with 5 cylinder liners.

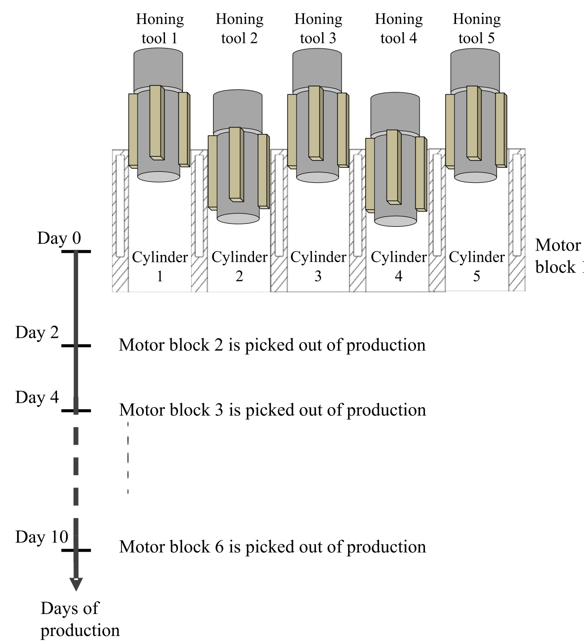

Fig. 3. Procedure of picking motor blocks out of the production line.

2.2. Measuring equipment

For this study, an optical 3D surface measuring system is used (see Fig. 4): the μsurf® cylinder [1] is based on the confocal principle and allows automated cylinder liner inspections by positioning the optical objective according to depth (axial direction of the liner) and angle (circumferential direction of the liner). The methodology for acquiring 3D measurements (area: 1 by 1 mm, lateral resolution: 0.95 μm, vertical resolution <10 nm) is presented in Section 2.3.

2.3. Measuring methodology

20 measurements per liner are performed in order to have statistically reliable results. Furthermore, different angular and depth positions are chosen inside the liner to perform a representative scan. Each cylinder from each block is measured according to the following measuring pattern:

- 4 angular positions in the circumferential direction of the liner are chosen as shown by Fig. 5 (0°, 90°, 180°, 270°).
- 5 depth positions in the axial direction of the liner are chosen as shown by Fig. 5 (10 mm, 40 mm, 50 mm, 60 mm, 70 mm). More measurements are performed in the middle of the liner since the

[1] Nanofocus AG, Germany, http://www.nanofocus.de