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Quantification of cylinder bores almost 'zero-wear'

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ABSTRACT

Despite the importance of wear evaluation during initial stages of engine life, low wear rates require the use of very accurate measurement techniques. Topography analysis has been widely used to evaluate almost 'zero-wear'; however, the lack of uniformity in the determination of a reference height for comparison between worn and unworn surfaces can completely change the results, making them unreliable. In this work, a heavy duty diesel engine was tested in dynamometer during 100 h and relocated topographies were obtained before and after the test. Volume losses were computed by comparing bearing area curves from *worn* and unworn surfaces using different reference heights. Although most works consider valleys or core as a reference, it is shown that both references can result in underestimation of wear. A new methodology for almost 'zero-wear' measurement based on the analysis of bearing area curves is proposed. Additionally, the variation of 3D functional parameters is investigated for evaluation of almost 'zero-wear'.

1. Introduction

Machine lifetime, performance and reliability are closely related to wear. In internal combustion engines, the critical parts in terms of friction and wear are piston and ring assembly, cylinder bore, bearings and valve train [1–3]. According to the literature [3,4], about 40% of friction losses in internal combustion engines are due to the contact between cylinder bore and piston rings/piston skirt. Alternating loads in a wide range of speed and temperature give rise to variable lubricating regimes and wear mechanisms in the referred tribosystem [1,5,6]; therefore, minimizing wear of cylinder bores is not a trivial task. The wear of cylinder bores can decrease the volumetric efficiency of the engine and increase blow-by, oil consumption, pollutant emissions and power losses [7–9]. Also, it can cause axial wear scratches [10] that can harm the hydrodynamic support of piston rings, increasing even further the contact metal-to-metal and, therefore, wear.

Although the cylinder bore surface topography plays an important role in terms of reduction of friction and wear [11–20], the wear process itself can change the surface of the cylinder so that several works have been published trying to qualitatively correlate topographical changes and wear [21–26]. Sreenath proposed that the initial stages of wear comprise both surface smoothening and filling of the valleys by wear debris [21]. Horng et al. showed that the *unworn* surface is transformed into a beneficial surface having many small valleys during running-in [22]. Jeng et al. used a theoretical model based on Johnson translatory system to describe changes of surface topography during running-in [23]. Pawlus suggested that the assessment of the amplitude parameter – which is proportional to the sum Spk+Sk+Svk [1] – before and after engine test is a promising technique to monitor wear [24]. Zhu applied fractal geometry to characterize worn surfaces during initial wear stages [25]. Kovalev et al. [26] estimated 'zero-wear' taking into account the variation of real contact area.

When the engine reaches the end of its wear life, more than 99.9% of its mass would have remained [1]. Due to the heavy weight of engine blocks and cylinder liners, weight loss measurements are infeasible to estimate wear of cylinder bores. The gauging procedure can be used to measure engine wear depth by evaluating the bore diameter before and after wear; however, the method is significantly affected by distortions in the cylinder bore [27]. Thin layer activation methods allow the estimation of wear of cylinder bores by collection of radioactive wear debris from retrieved lubricant [28]; however, the technique does not inform the region in which wear occur. More precise results for wear measurement of cylinder bores during initial stages of wear can be obtained by the evaluation of surface topography changes. Gara et al. proposed that wear volume could be computed by evaluating bearing ratio parameters before and after engine test [29]. Several researchers calculated volume changes for almost 'zero-wear' based on the comparison of bearing area curves from *worn* and

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Nomenclature

Rdq	root mean square slope of the assessed profile
Sdq	root mean square slope of the assessed surface
Sk	core height (μm)
Smr1	areal material ratio for peaks (%)
Smr2	areal material ratio for dales (%)
Spk	reduced peak height (μm)
Svk	reduced dale height (μm)
Vm(p)	material volume at a material ratio given by "p" (μm3/μm2)
Vmp	peak material volume of the scale-limited surface at "p" (μm3/μm2) – The default value for "p" is 10%

unworn topographies [27,30–34]. To compare different bearing area curves, a common reference height must be assumed. Jeng [30] used an external reference height to relocate measurements before and after pin-on-disk bench tests; however, when analyzing the wear in cylinder bores, no external reference is available and the reference height must be taken from the topography itself.

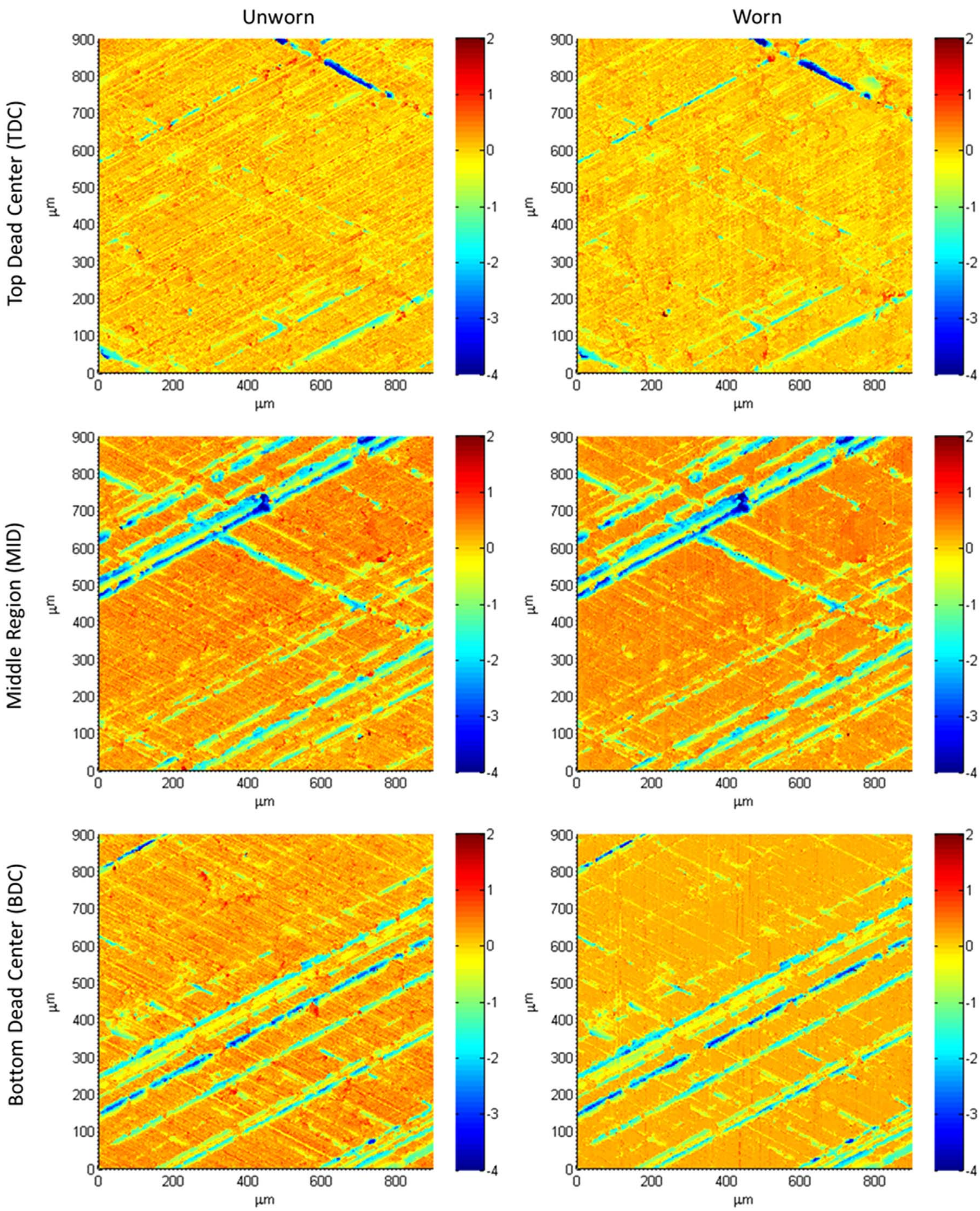

Fig. 1. Relocated topographies from rear side obtained before and after engine test.