# MULTI SCALE MORPHOLOGICAL METROLOGY OF PISTON-RING-TEXTURED CYLINDER LINER ASSEMBLY IN RELATION TO THEIR TRIBOLOGICAL PROPERTIES

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**Abstract**:
The authors overviewed the broad measurement and quality control problem of one of the fundamental part of the engine in context of tribological requirements. In field of design and manufacturing engines, engineering is very wide subject not frequently treated in term of multi-process of multi-functional surfaces on multi-scale with multi-sensor metrology. In case of tribological analysis of piston-ring / cylinder liner (C.L.) interface, the surface's topography characteristics of contacting solids reveal different fundamental tribological regimes: Boundary, Elasto-Hydro-Dynamic (E.H.D.) Hydrodynamic and recently postulated µ E.H.D. lubrication. Therefore, one can expect for concerned surfaces of different morphologies and scales the most suitable metrological sensors and devices.

**Keywords**: multi-scale, texture, topography, measurements, tribology

## 1. INTRODUCTION

The optimization of internal combustion engines to be placed in the context of ecology and the economy today, forced the engine manufacturers progress in the fields of sustainability, reliability, effectiveness of fuel and emissions of gaseous pollutants. Generally surface finishing process is that, which using specific adopted means and manufacturing procedure for final part application providing high-value for producer. Principal industrial constraints are: simplicity, duration and fidelity of the manufacturing process, non negligible being duration (s) life tool (s) and simplicity control quality. In this paper for simultaneous didactic, economic and metrological reasons surfaces finished by honing (abrasive) and LASER (ablative) cf Fig.1 & Fig. 2, process mostly controlled and widespread engines (C.L some countries or companies call this Cylinder Sleeve) cylindrical surfaces are selected **[11]**.

Fig 1 View of typical four cylinder liner engine block of modern car and focus on honed –laser textured surface.

This manufacturing method is approached from the perspective of morphology to understand and optimize the some contradictory tribological function of the (C.L.- piston ring interface) as high anti-galling properties, low leak, less wear and friction of the interfaces and of course less of oil consumption. This is in wide, very competitive, insidious area of terrestrial, marine, aviation, transport construction machinery context.

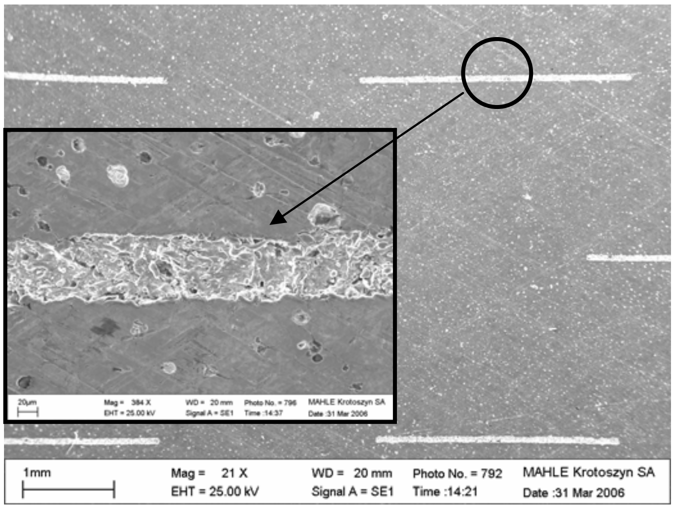


Fig.2. SEM view of honed and wide LASER linear cavities orthogonally to oriented to piston movement

The dimensional range to be considered in metrology is varying from a few millimeters to meter diameter. If only the number of engines for civil light weight land vehicles products in 2009 through the world is taken into account, it's over 50 million cars **[13]**, which is about 0,5 billion of (C.L.) per year. The finishing manufacturing process is based on two body abrasion, by means of a head of honing with abrasive stones requiring for morphology characterization very sophisticated multi-sensor, multi-scale metrological control quality strategy due to the multi-functions of different (C.L.) areas and according to their applications.

## 2. MORPHOLOGICAL NORMATIVE APPROACH

There are a large number of parameters conformed to 2D or 3D characterizations with respectively more than 80 and 50 normalized settings in standards ISO 13565 2 and ISO 13565-3 **[1, 2]** topographic measures and even more than 50 other settings in proposal. Looking for efficiency and simplicity of morphological description, the correlations have been done between certain settings families of $R_k$ and $R_q$ **[11]** to consider relevant quantities of honing types (C.L.) engines. In this case, $R_{vk}$ and $R_{pk}$ standard settings are in relation to so called Abbott-Firestone or bearing curve (cf Figure 3) commonly used to evaluate the morphology of (C.L.) engines. This diagram as integration of profile height distribution shows and quantifies "plateau" areas and the honing scratches responsible for various reasons of"local pressures" distribution and lubricant "reservoirs"

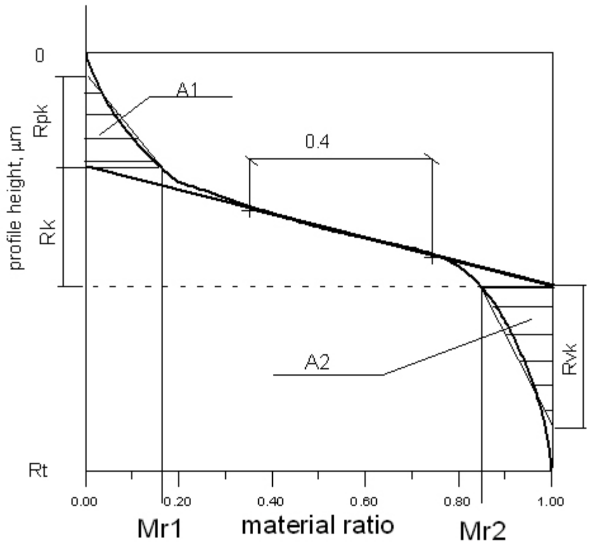


Figure 3. Abbott-Firestone curve or bearing curve (presented above parameters are specified in ISO standards 13565 2 and ISO 13565-3

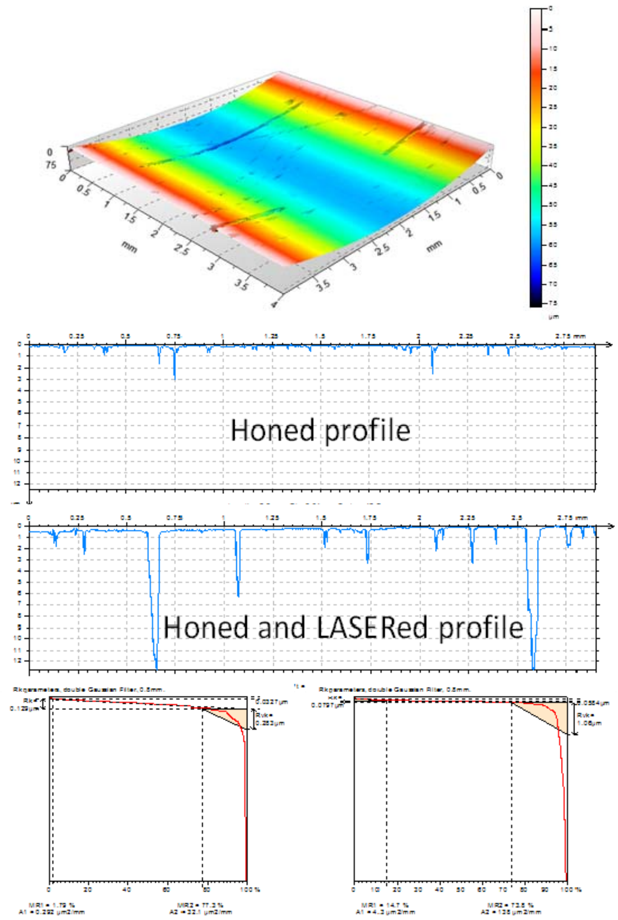


Fig.4. 3D isometric view of (C.L.) part, profiles of honed and laser cavity areas and respective Abbott-Firestone curves

conditioning tribological performance of the (C.L.). One can easily imagine what is stated for LASER cavity texturing (cf Fig. 4) that simple characterization by set of $R_{k}$, $R_q$ $R_{vk}$ and $R_{pk}$ parameters even completed by bearing curve is no more sufficient.

## NOMENCLATURE

| | Parameters ISO 13565-2 | |
|---|---|---|
| $S_{sk}$ | Skewness parameter | [-] |
| $S_{Ku}$ | Kurtosis parameter. | [-] |
| $R_k$ | Depth of roughness of the central part | [µm] |
| Rpk | Reduced peak height | [µm] |
| Rvk | Valleys reduced depth | [µm] |
| Mr1 | Upper material ratio | [%] |
| Mr2 | Lower material ratio | [%] |
| A1 | "Volume of the restovers" | [-] |
| A2 | "Volume of lubricant reserve" | [-] |
| Rt | Total height of the ISO adjusted profile | [µm] |

The holistic approach of (C.L.) interface based on 40 years of tribological investigations of Laboratory of Tribology and Dynamics of Systems and their academic and industrial partners research in metrology and manufacturing to treat that problem as a whole dynamic system which requires a multi-physic and multi-scale analysis of morphological, rheological, physical and chemical aspect of dynamic interfaces **[3-7, 12]**.

## 3. CONCLUSIONS AND PROSPECTS

The introspection that follows is limited to the morphological approach of the surface texture knowing that different fundamental tribological lubrication regimes: Boundary, Elasto-Hydro-Dynamic (E.H.D.), Hydrodynamic and play various transitional roles in different parts of (C.L.). Recently has been postulated µ-E.H.D. lubrication due to specific morphology within the cavity as shown on Fig.5. **[8-10]**. Therefore, if one can make obvious and prove existence of µ-E.H.D. lubrication multi-scale and multi–physics have to be developed due to micro-fluid mechanics never postulated for (C.L.) piston ring tribological interfaces. Consequently the others morphological descriptors like $S_{sk}$ and $S_{Ku}$ parameters which allow to correlate parameters of cavities patterns forms, directions, density, spatial distribution to a tribological functions and their performances can be developed.

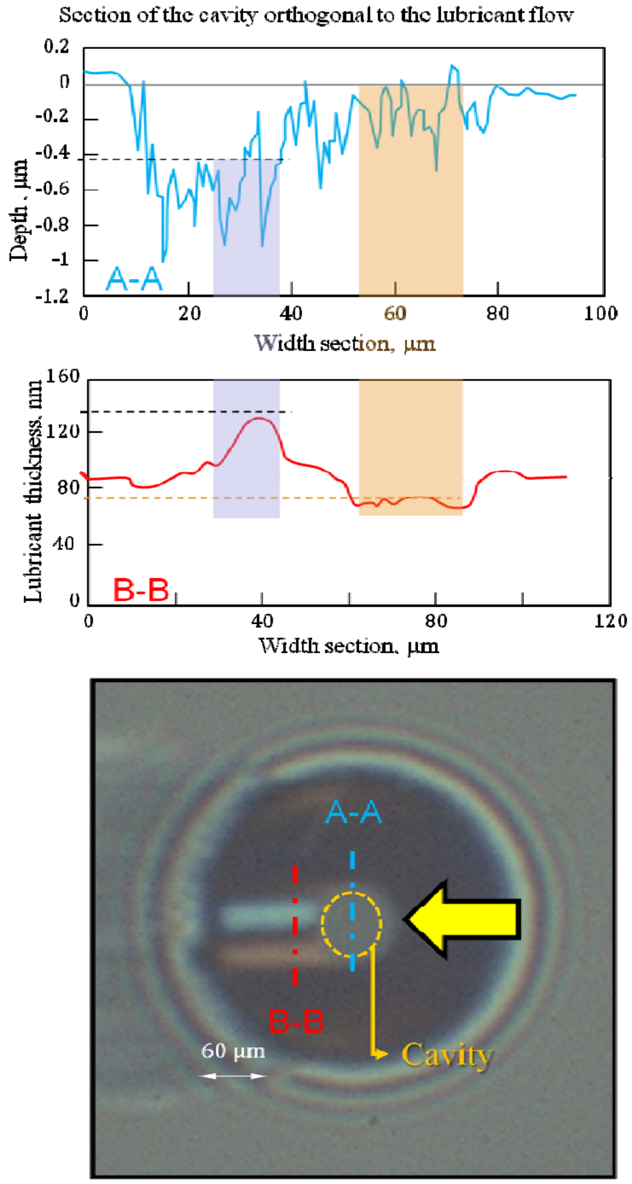


Fig. 5 Measured profile in-cavity morphology from confocal 3D microscopy (top) and related film thickness (middle) deduced thanks to multi-beam interferometry visualization (bottom)

The topography of surfaces can be discussed qualitatively and measured quantitatively in carrying out comprehensive reviews of characteristics produced by specific tools of mathematical morphology analysis, descriptive statistics, fractals treatment, wavelet or Karhunen-Loève, Fourier transforms, spectral analyses and multi-scale-based data.

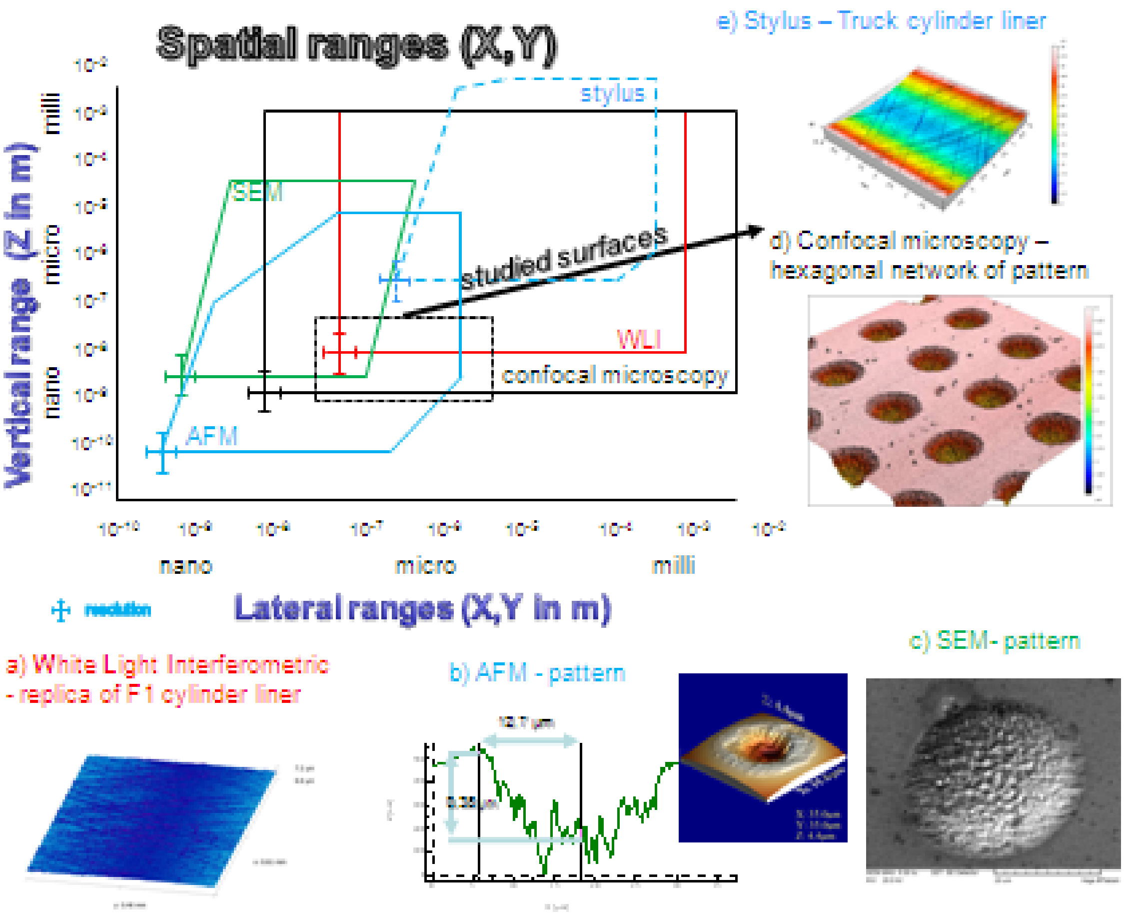


Fig.6 Multi-sensor 3D metrological techniques for different ranges and morphological types of cylinder liner surfaces characterizations

In every cases the motifs analysis with spatial, morphological, gradient, Laplacian, Sobel, Gabor, Gaussian filtering operators have to be used very with awareness. In the search for compromise between the scope of the topic and space to scan, it has been the extraction of relevant elements in the context of the design, manufacture and sustainability.

Despite, the sum searches since decades improvement is always sought and this by new texturing of surface **[8, 10]**. Different processes are envisaged in order to elucidate creating “local lift” and/or “debris trapping” roles in various schemes of lubrication regime of the (C.L.), or piston ring. Motivated by new technologies of manufacturing, combining different techniques of morphology generation and taking into account the State of the art of the Tribology in the context of (C.L.), it attempts to modeling and experiments with textured surfaces. This constitute prospective phase of preliminary results in the find the most appropriate morphology for (C.L.)/piston ring interfaces. It can be achieved only combing multi-physics, multi-scale, multi-sensor approaches.

## 4. ACKNOWLEDGEMENTS

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