

**Surface Morphology Information by Image Analysis Method****Zdravecká Eva\*, Ondáč Miroslav**

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**Abstract:** The surface is an important component of many technical parts to ensure tribotechnical functions. Development of new types of coatings and their deposition methods provides technically exploitable coatings with good tribological properties. In experiments in addition to conventional parameters such as friction coefficient, temperature, etc. are analyzed the surface properties in friction and wear area before and after the tribological tests using different methods and analysis. The paper deals about the possibilities of image analysis methods, using the Matlab Image Processing Toolbox, obtained by SEM for coatings based on DLC/CN to document the morphology of the surface before the tribological test. By the geometric properties modifications and applications of a wider spectrum of sophisticated operations and algorithms in image analysis have been made about the surface morphology of coatings analyzed.

**Keywords:** image processing, SEM, DLC, morphology, particle.

**INTRODUCTION**

A variety of analyses can be used for the complex characterization of the tribological mechanism of contact. These are analyses of micro- and macro-mechanical effects, chemical effects and material transfer. Recently, tribological behaviour has begun to be analyzed at the molecular level - nanomechanical effects [1].

After mutual body contact, the traces remain on both bodies. These tracks contain key information on contact process. Individual wear mechanisms leave a characteristic morphology to identify the prevailing type of wear.

The comparison of functional surfaces before and after tribological testing plays an important role. An interaction analyses in tribological contact is essential to optimize the properties of two contact surfaces with a view to achieving the desired friction and prediction of wear. Characteristic properties of layers applied to the base material and their behaviour in tribo-contact with other material can be ascertained by various test methods and experiments. In order to achieve optimal results, it is also necessary to investigate the parameters of the coating technology in order to achieve the desired coating quality (homogeneity, density, porosity, etc.) Digital image processing follows analyses of selected carbon-based coatings and their impact on wear resistance.

DLC (Diamond like Carbon) layers are a group of coatings with a wide range of properties depending on composition and structure. Using a variety of deposition techniques, it is possible to create a wide range of surface layer properties modifications. For the production of DLC layers, industrial-scale techniques are based on PVD (Physical Vapor Deposition) and PACVD (Plasma Activated Chemical

Vapor Deposition). The most widely used PVD methods include cathodic arc evaporation and magnetron sputtering. Evaporated or sputtered is the cathode formed by the carbon target, and argon is generally used as the working gas.

To prepare the coatings by PACVD methods the most commonly applied discharges are RF (radio frequency capacitive and inductive); DC (direct-current pulsed) and microwave, where hydrocarbon gases (acetylene, methane, etc.) are used. The most commonly applied at PACVD methods. The deposition temperature of the layers varies from room temperature up to 250 °C (grafting may occur at higher temperatures). The great adaptability of PVD processes allows the application of a wide range of metallic materials, alloys, semiconductors, superconductors polymers, and the preparation of various types of composites [2,3].

Other parameters that determine the properties of the DLC layers include, in addition to the carbon / hydrogen ratio, the amount and type of carbon-to-hydrogen bonds, the  $sp^3$ ,  $sp^2$  and  $sp^1$  bond concentrations, or whether the layers are doped with

other elements. The amorphous nature of the DLC coating opens up a wide range of application by doping with number of different alloying elements [4].

Due to structural variability and biocompatibility and low wettability, the carbon based layers are suitable for applications in biotribology and medicine, such as implant coatings, biosensors, and biochips. Amorphous DLC films are also used in medicine for vascular prostheses, contact lenses, surgical needles, screws, etc. [5].

Due to complexity of friction, it is complicated to find a direct correlation between surface roughness and friction. Many things such as ambient temperature, humidity, wear, speed and test duration can affect friction coefficient of a material and surface roughness is also one of them.

The surface roughness is influenced by many factors such as the growth defects in sputter-deposited a-C films, films, close voids, flake formation, overcoated particles and those due to the coarse columnar morphology. Flakes are generated when some foreign particles are at the substrate surface before the coating starts to grow, or they are built into the growing coating. The paper deals about the possibilities of image analysis methods using the Matlab Image Processing Toolbox for coatings based on DLC/CN to document the morphology of the surface obtained by SEM.

## MATERIALS AND METHODS

The analyzed a-C coating was deposited on CoCr base material by sputtering in a vacuum chamber from a carbon target by a UVNIPA-1-001 device [6]. DLC layers were deposited at low temperature. Nitrogen and argon were added during the deposition process into the working chamber. The coatings were deposited on polished CoCr substrates with  $R_a = 0.05 \mu\text{m}$ . At different contents of Ar and N, the nanocomposite particles of  $\beta\text{-C}_3\text{N}_4$  or nanocrystalline diamond particles were formed in the amorphous matrix as well as different surface morphology. Particle

detection, their shape and morphology in coating analysis is a tool for optimizing the coating process and achieving a surface layer with improved properties.

The Scanning Electron Microscope (SEM) uses a focused beam of high energy electrons to generate various signals on the surface of solid samples. Signals which originate from interaction electron-sample provide sample information, including external morphology (structure), chemical structure, and crystalline structure. The specimen must be firmly stored in the microscope chamber. Samples must be stable in vacuum in the order of  $10^{-5}$  to  $10^{-6}$  Pa [7]. SEM is one of the most extensive analytical tools for surface analysis. Together with the additional EDS detector, it is possible to identify elements of the entire periodic system. SEM advantages include high image resolution, fast object identification, good depth of field, etc. Among the disadvantages can be included the need for vacuum, the possibility of the damage of the sample, the size limitation results in the cutting of samples, etc. [8].

Image analysis is a tool that characterizes the structure of the material (shape, quantity and distribution of individual components) so that mutual relationships and arrangements could be found between the properties of the structure examined [8]. Digital image processing and analysis is a continuously growing area in the theoretical and practical aspects of use in several areas. Wide availability of microcomputer systems, price reduction, and rising power make a significant contribution to digital computing and image analysis. Image processing requires appropriate hardware, software, and specific algorithms [10].

One of the possibilities to obtain the surface morphology information before the tribological examination is the use of the Matlab system and its toolbox for image processing and analysis. Using the Matlab system, a DLC/CN coating deposited by the PVD method was analyzed (Figure 1).

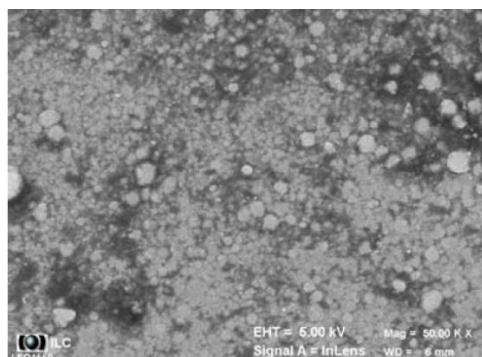
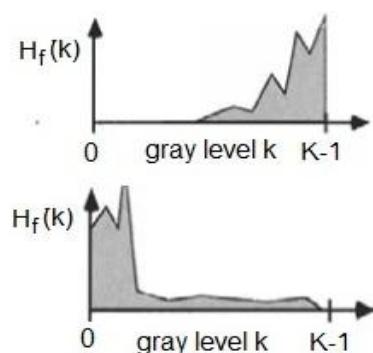


Fig-1: Analyzed a-C coating

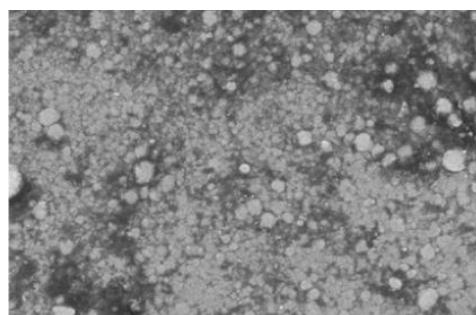


**Fig-2: Histogram of gray level distribution of dark and lighter image [9]**

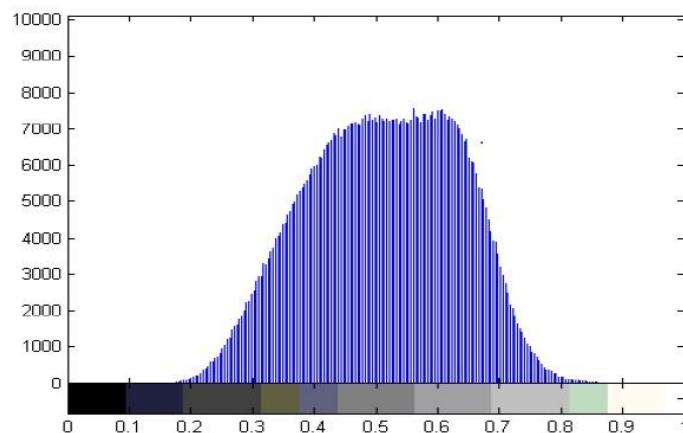
#### Improving contrast

Image brightness control and contrast enhancement are often used in image analysis. Improved image quality is achieved by aligning its gray scale and histogram verification (Figure 2). The histogram, intensity distribution is estimated in the

image by multiple addition of the brightness in the gray level. The image after the contrast adjustment gives a relatively low contrast image (Fig. 3 and 4) or better quality in terms of its further processing. (Figure 5 and 6) [9].



**Fig-3: Low contrast image**



**Fig-4: Histogram - low contrast image**

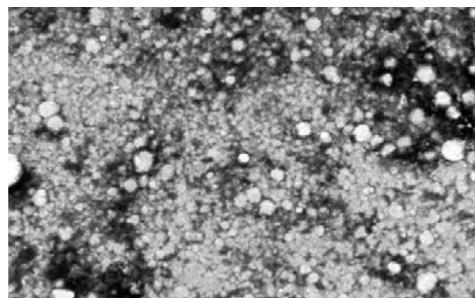


Fig-5: SEM image after adjusting the contrast

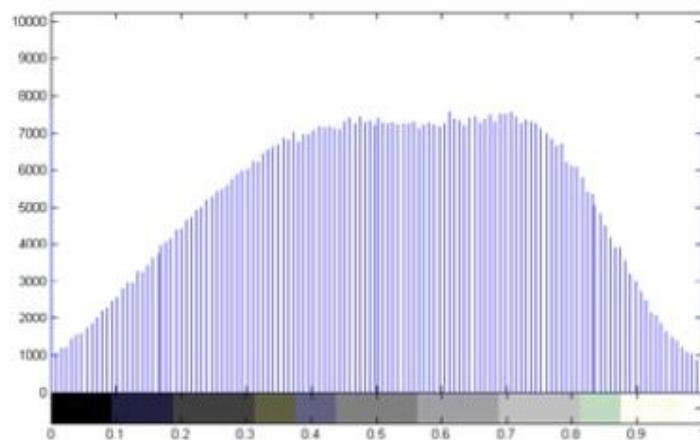


Fig-6: Histogram - after adjusting the contrast

#### Edge detection

Interface detection provides the identification of position, object scope, or interest area: ROI. Edge is generally a local change of one area to another [6]. The Matlab IP toolbox allows you to apply multiple edge detection methods: Prewitt, Roberts, Sobel (Figure 7), Canny (Figure 8) with advanced parameter options that have a significant impact on the output quality page. [10-12]. Edge detection by Sobel is realized by spatial 2D convolution of image operations. It represents a

simple and effective way of detecting the interface in the image. Among the drawbacks we can include its sensitivity to noise, "strong" edges that are not suitable for some applications. Canny detection is designed with detector optimization that meets three performance criteria, which are: revealing non-existent edges, minimizing edge distances and detecting a real edge, minimizing the response to the actual image, i.e., ensuring the detection only at the interface



Fig-7: Edge Detection – Sobel

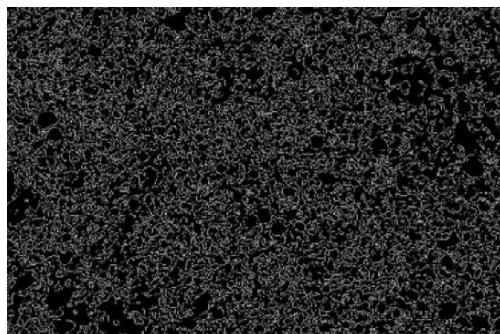


Fig-8: Edge Detection – Canny

#### Morphological imaging operations

Morphological image processing is a set of operations in which the object structure is modified within the image. Erosion, dilation, opening and closure are among the four basic operations [6]. Application of morphological image processing has a wide use in

several areas such as filtering, segmentation and shape recognition. Morphological image processing can be performed on binary images [8]. By commands in Matlab, objects were suppressed in the image in two steps, according to the specified criterion - size (Figures 9 and 10).

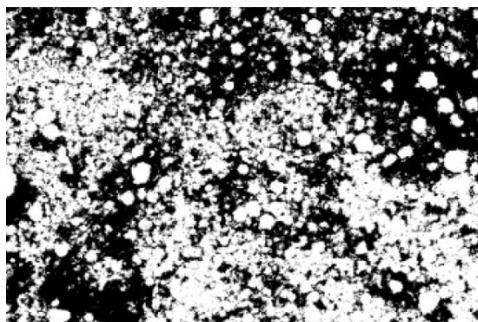


Fig-9: Object identification

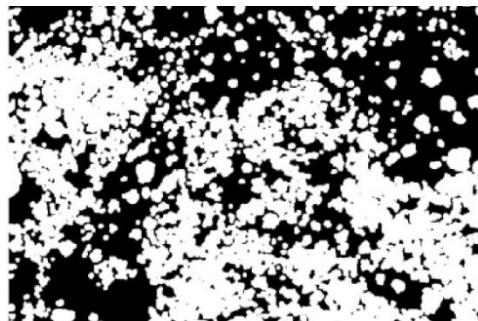


Fig-10: Eliminating Objects - Step 2

#### Image filtering and object identification

Matlab IP Toolbox supports application of different types of filters. The choice of the filter type depends on the geometric properties of the image, the quality and the desired outputs. Image filtering for noise

suppression was performed using a median filter (Figure 11). Surface morphology imaging (Figure 12) is a useful tool for improving visualization of surface changes and interpreting the results of tribo-processes.

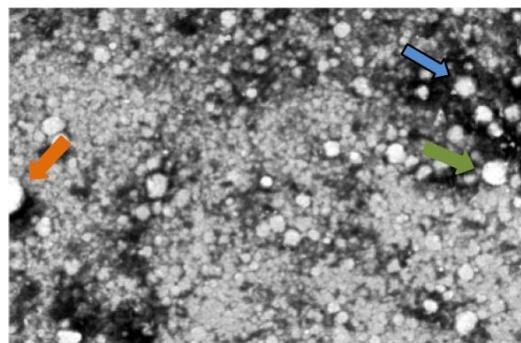


Fig-11: Median filter

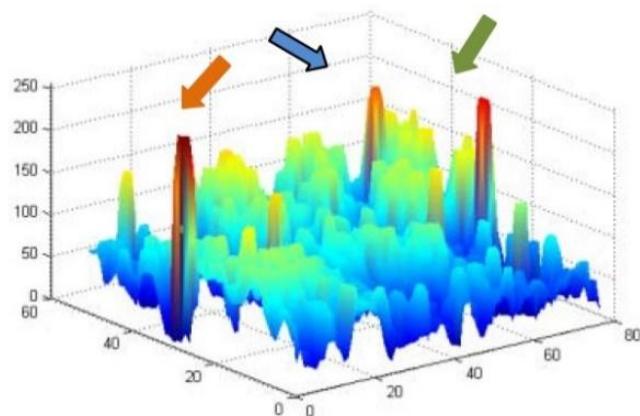


Fig-12: Surface Morphology

To reduce noise and to improve particle identification for further processing (such as particle size, orientation, etc.) that contains a DLC layer after a tribological test with a UHMWPE flat sample, the

image filtration method with detection was used. The pretreatment of the UHMWPE particle after the tribological test is shown in Figures 13- 15.

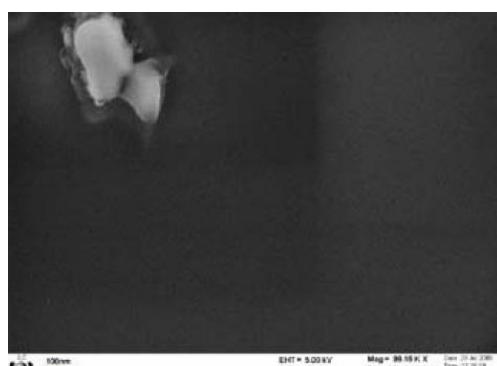


Fig-13: Particle of counterbody (UHMWPE) after tribological test

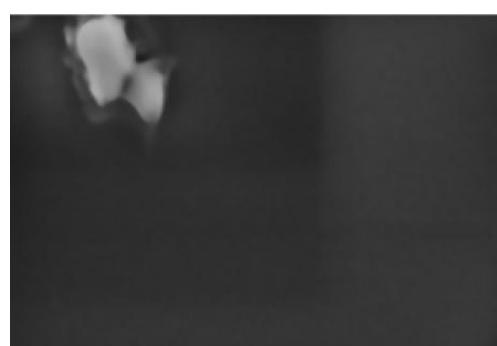


Fig-14: Improving the interface to identify geometric characteristics



**Fig-15: Particle identification for further processing and analysis**

## CONCLUSION

Preprocessing, processing, and image analysis is an extensive problematics, and selected analyses present only some of its options. The use of computing techniques in the field of microscopy and digital image processing is nowadays a matter of course and with the ever increasing performance of hardware and software also a qualitatively and quantitatively useful tool. Images obtained by microscopy provide a wide range of information. Image limitations and optical noise provide the need for image enhancement through techniques and procedures for its processing.

Particle interface detection, their orientation, shape, and surface morphology information in coating analysis using image analysis tools can bring not only improvement of the properties of surface layers and optimization of the deposition process to achieve a surface layer with improved properties but also an improvement in functional surface analysis after wear with the goal of identifying the predominant wear mechanism, which can provide key information in the area of prediction of wear.

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