УДК 667.021.1

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# CONFOCAL LASER SCANNING MICROSCOPY IN ESTIMATION OF SURFACE STATE

*В статті представлено доцільність використання конфокального лазерного скануючого мікроскопа OLYMPUS LEXT OLS3100 для оцінки стереометрії поверхонь деталей. На основі якісного аналізу з використанням зображень структур проведено дослідження геометрії поверхні після триботехнічних випробувань. Зображення поверхні конструкцій, отриманих за допомогою конфокального лазерного скануючого мікроскопа дозволяють проводити комплексну оцінку форми поверхні і аналіз змін, що відбуваються в процесі перетворення поверхневого шару.*

*Ключові слова: контроль, лазерне сканування, мікроскоп, структурі поверхні*

*This work presents the suitability of an OLYMPUS confocal laser scanning microscope LEXT OLS3100 for assessing stereometry of interacting surfaces of components. Characteristics of the microscope have been provided by giving basic technical data and measuring possibilities. The assessment of the shape of the surface geometrical structure has been carried out based on a qualitative analysis using images of structures. The surface structures analysed underwent previous tribological tests. The assessed images of a surface obtained with the use of a confocal laser scanning microscope originated from scanning and simulation of topography. In addition, the image of a non-interacting structure (prior to tribological tests) has been compared with images obtained from other devices enabling surface stereometry to be recorded in the form of images of surfaces. The images of surface structures obtained with the use of a confocal laser scanning microscope have proved useful in assessing surface shape and in the analysis of changes occurring during transformation of the surface layer.*

*Keywords: control, laser scanning, microscope, structure of surface*

## Introduction

The tribological characteristics of interacting components of a machine are mostly determined by the characteristics of the surface layer of these components [3, 7, 9]. These characteristics, in turn, are mainly determined by the surface stereometry, i.e. the outer part of the surface layer. The stereometric shape of a surface is defined as the surface geometrical structure (SGS) which is a collection of surface micro-unevenness that are the marks of machining or effects of wear. The basic elements that describe SGS include surface roughness, waviness and isotropy – lay of machining marks, shape deviations and surface defects [2].

Because the condition of a surface determines performance characteristics of interacting surfaces, it is important to make a correct selection of methods and tools for assessing stereometric characteristics of a surface. Metrological measurements of the surface topography should, to a largest possible extent, reflect the actual structural shape, enabling in turn an adequate assessment to be carried out of the operating characteristics of frictional pairs. The assessments of SGS characteristics (including roughness, lay etc) are performed based on a quantitative and qualitative analysis.

The widening of knowledge of SGS shape and development and use of new ways of its assessment (quantitative and qualitative) has become possible owing to e.g. accurate computer-aided measurement devices. New programme-related possibilities of surface analysis in a spatial system (3D) have been created, which, given the increased accuracy of measuring devices, enables SGS components to be observed in a nanometric scale and to be described by means of a number of parametric and non-parametric values [1, 4, 8].

This study presents the possibilities of using an OLYMPUS LEXT OLS3100 confocal laser scanning microscope for a qualitative assessment of SGS.

One of the basic methods of a qualitative evaluation of the surface layer condition is by analysing a surface image. Images – photographs should be taken so that they enable a qualitative assessment of general SGS characteristics (roughness and lay) to be conducted. Visible and possible to identify should also be the marks of wear and potential defects [5, 6].

## Characteristics of a confocal laser scanning microscope

An OLYMPUS LEXT OLS3100 confocal laser scanning microscope, due to the use of advanced technological solutions, enables very accurate and repeatable measurements of the surface stereometry. The accurate three-dimensional measurements results from the horizontal resolution of 0.12 μm and vertical resolution of 0.01 μm, obtained by combining a laser light with a wave length of 408 nm (violet optical system) with a confocal optical system [10, 11].

The confocal optical system, comprised of e.g. an apochromatic lens and a round confocal lens stop, prevents aberrations related to the use of a light source that emits short waves (408 nm), thus providing a very high accuracy of microscopic measurements of surface profiles. In addition, the microscope is characterised by the magnification range of 120-14400 times and the possibility of performing measurements without any prior surface preparation.

A LEXT confocal laser scanning microscope enables the following observation methods of inspected surfaces to be used [10, 11]:

a) brightfield observation method – information on the colour may be obtained from the brightfield observations where they can be used to observe defects on colourful filters or locate corrosion spots on metal,

b) DIC method (*Differential Interference Contrast*) – observation using DIC enables detection of very small scratches or defects with a height of several nanometers which could not be detected in brightfield observation,

c) laser confocal observation method – observation applying a very large resolution that cannot be obtained for conventional microscopes and which is possible through the use of a laser light with a wave length of 408 nm and a confocal optical system,

d) DIC confocal laser observation method – a combination of the previously described b and c methods.

e) The microscope in question offers therefore more possibilities compared to the traditional scanning microscope so it seems appropriate to use it in surface layer transformation tests.

**Assessment of SGS condition with the use of a confocal laser scanning microscope**

To evaluate the suitability of a confocal laser scanning microscope for analysing surface stereometry, measurements of the geometrical structures of sample surfaces were carried out. A qualitative assessment was performed based on the images in the spatial system (3D) of three structures of sample surfaces. The samples were subjected to tribological tests and the interface of the working surfaces during tests was conformal, i.e. distributed over the entire interacting surface of samples. One of the analysed structures originated directly from finish machining and it was a non-interacting surface, while the remaining two underwent tribological tests: along the path of friction of 1000 m and 2000 m. The conditions occurring during tribological tests were assumed as constant. Samples with counter samples were interacting in a lubricating medium, i.e. machine oil and the values of operating parameters were as follows: relative motion speed – 2.9 m/min (0.05 m/s), load – 600 N (theoretical pressures in the interacting area: 2 MPa).

Friction distance | **a)** | **b)**

0 m

1000 m

2000 m

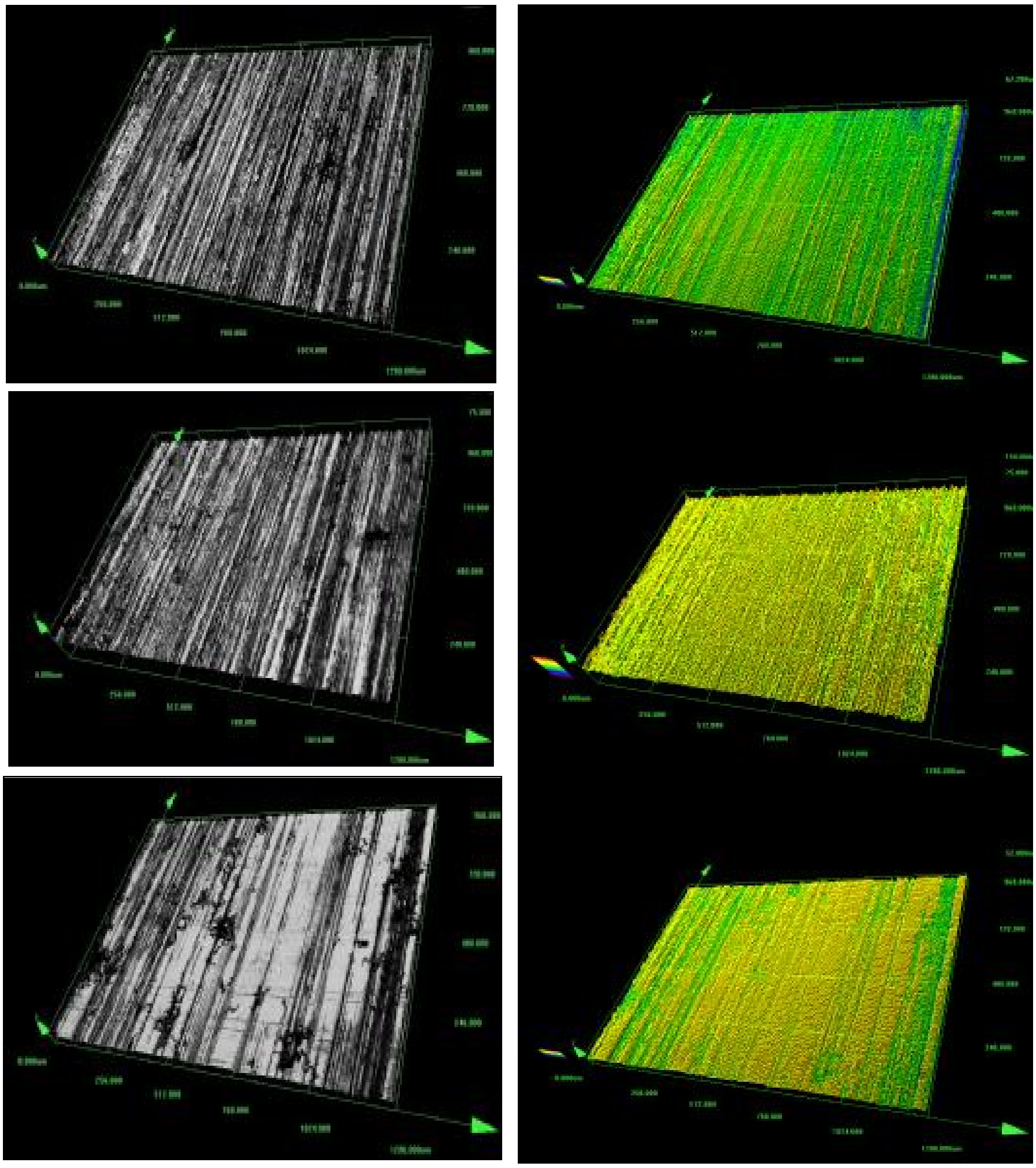


**Fig. 1. SGS 3D images with various paths of friction obtained from a confocal laser scanning microscope by: a) scanning (actual image), b) computer simulation (virtual image)**

Figure 1a shows the actual images of surface topography obtained from a confocal laser scanning microscope whereas figure 1b presents images from computer simulation based on performed measurements.

The images presented are characterised by high detail of surface stereometry, which results from a high microscopic resolution. The nature of changes in SGS condition that can be observed is that the non-interacting surface of the analysed sample is free from signs of tear – the surface bears only the signs of machining. In the remaining figures, the said signs can be observed as bright spots. The signs of tear are particularly visible for images of structure with a path of friction of 2000 m. This is also true for images from computer simulation (fig. 1c).

The quantity and size of machining signs/marks and wear are clear and easy to identify. Images obtained from a confocal laser scanning microscope provide large amount of information on the shape of the surface geometrical structure.

In addition, to obtain a comprehensive assessment of the metrological possibilities of using a confocal laser scanning microscope for analyses of the surface stereometry, an image of the non-interacting surface structure of a sample (prior to tribological tests) was compared with images obtained from other measuring devices, enabling surface stereometry to be recorded in the form of images of analysed surfaces. The image obtained from a confocal laser scanning microscope was compared in a three-dimensional system (3D) with the image of a surface obtained from a Talyscan 150 measuring device (fig. 2), and in a flat system (2D) with the image of a surface obtained from a conventional optical microscope (fig. 3).

a)

b)

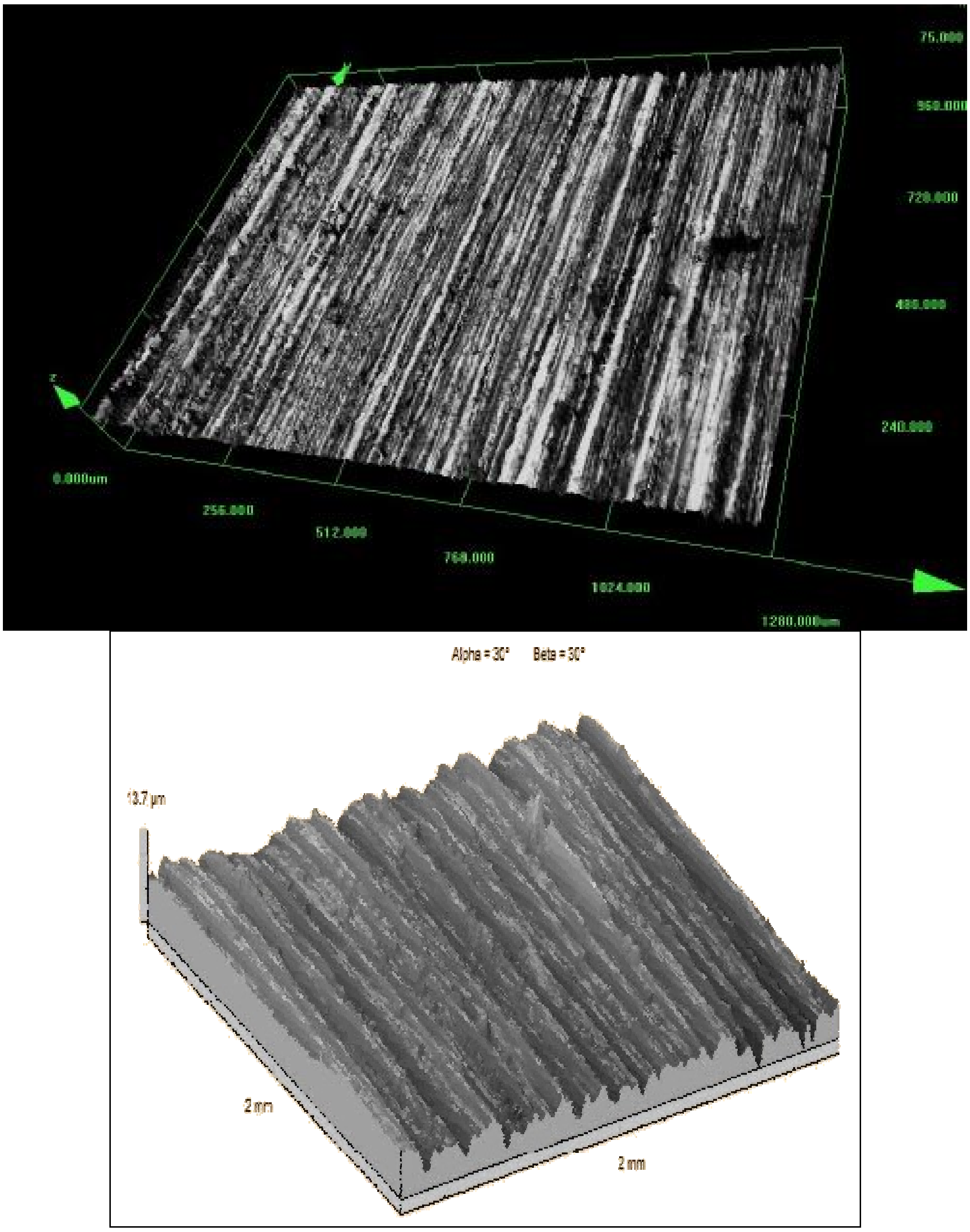
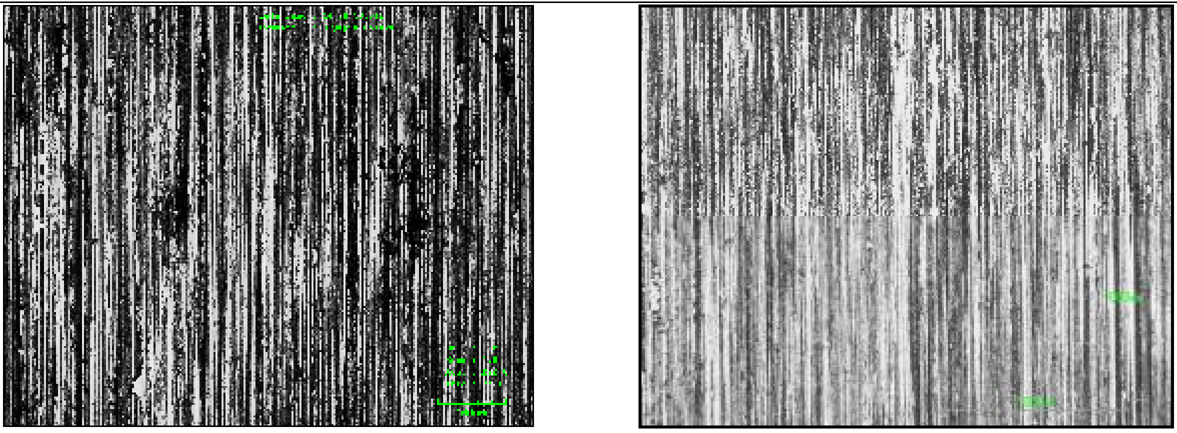



**Fig. 2. SGS images in 3D system after machining (without interacting) obtained from: a) confocal laser scanning microscope, b) measuring device**



a) b)

**Fig. 3. SGS images in 2D system after machining (without interacting) obtained from:**
**a) confocal laser scanning microscope, b) conventional optical microscope**

Surface structure images shown in figures 2 and 3 obtained with the use of a confocal laser scanning microscope are clearer and have greater contrast than the compared images obtained from traditional measurements. They provide more information on the details of stereometry and thus on the existing changes in the surface layer of interacting elements.

As shown by the comparison, the microscope is principally suitable for very accurate micro- or even nanometric analyses of surfaces. In the cases where the structure of a surface in a micro scale is not important from a point of view of desired tribological features, it is not necessary to use a confocal laser scanning microscope and it is sufficient to use conventional measuring devices for analyses instead.

**Summary**

Based on the conducted analyses, a confocal laser scanning microscope has been demonstrated in this study to be highly suitable for conducting tribological tests. Surface structure images obtained with the use of this microscope proved useful for a qualitative assessment of the surface shape and therefore tribological characteristics themselves, as well as being useful in the analysis of changes occurring during transformation of the surface layer.

Such an accurate representation of the surface stereometry may be useful in metrology of textured surfaces, i.e. surfaces which are intentionally formed micro-geometrically. In such cases, it is important to obtain the repeatability of SGS and the said microscope would be very suitable for such assessments.

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Надійшла 14.11.2012 р.
Рецензент: д.т.н. Шалапко Ю.І.