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WHY 3D ROUGHNESS?

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Abstract. The paper study intends to answer the following questions:
-Is 3D roughness a necessity or just a caprice of the researchers?
-There are only advantages when choosing to use 3D roughness?
-When, where and why to use 3D roughness?
It shows the maine differences between the two most important methods of measuring the roughness (2D &3D) and a system for measuring the 3D roughness using confocal microscopy and a high precision X-Y coordinate table.

Keywords: *3D roughness, no contact methods, advantages efficient utilization.*

1. INTRODUCTION

Everyone can feel the difference between a rough surface and a smooth, fine surface. This can be done visually or by touch but how can we be making this objective assessment based only solely on our senses?
Very probably different observers will have different opinions on "smoothness" of an area, one of them considering it as very smooth and another "pretty smooth”. Things become more difficult to be compared when roughness of two surfaces obtained by different processing methods. Research engineers were forced to find a method by which to eliminate the subjective factor in assessing a surface roughness which were designed as standards, rules, procedures for measuring the roughness so that if you design a product (e.g. a shaft) contains the sign of roughness Ra 3.2 mean this will be the same for Romania operator but also for Japan and therefore the final result must be identical at least in theory.

Each drawing for the execution of each product should contain references to the roughness and this showing us how important it is this parameter. Roughness correctly chosen not only serves to ensure along with other parameters that characterizes a product (size and dimensional tolerances, terms of shape, conditions relative position, material, heat treatment, protective coverage etc.) a good functioning of the mechanical point of view but you had to, and sure they look good and the final product will look like a long time. It is obvious that the issue is important primarily for parts or side giving the guidance that has contact directly with the user (vision or touch). Is there a direct correlation between surface roughness and production costs which is why designers do not have to exaggerate and to impose to obtain very smooth surfaces with repercussions on the final price of the product but without obtaining any advantage in performance or his lifetime?

Sometimes obtaining a roughness too fine imposed as a guarantor of quality product can shorten the life it. For example, two components are in contact at a relative movements might suggest that if the surfaces are finer then the movement is smoother, but this is not always true because if the process is necessary to see that a surface lubrication May rough would be better and retained longer what oil should be reduced friction.

2. 2D OR 3D ROUGHNESS?

2D roughness measuring method (figure 1) has been (and will) be used for many years to characterize the surface but this method has certain limitations and disadvantages. The most important result of the fact that a surface that comes into contact with another surface will interact in three dimensions and not just two. It says at the outset as a 2D measurement can not provide an accurate representation of surface characteristics. A 3D representation of the areas will give more information about the surface in relation to friction, lubrication, sealing, wear resistance laden supported.

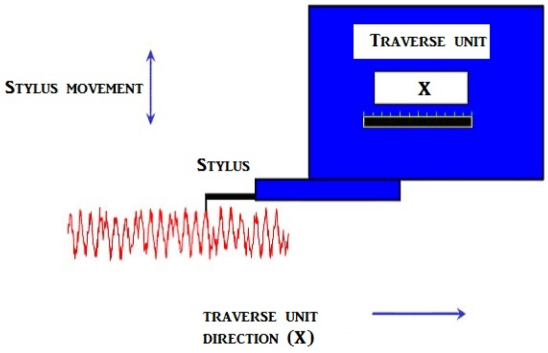

Figure 1

The main advantages of the shift from classical roughness (2D) to 3D roughness (microtopography areas) can include:
- ♦ good viewing area
- ♦ more Statistical Stability
- ♦ better detection and analysis of defects
- ♦ many methods of data representation.

However, there are disadvantages of 3D roughness measurement process, namely:
- ♦ measurement cycles longer
- ♦ large data files
- ♦ visual Subjectivity.

It is obvious that 3D measurement cycle is longer than if only one profile is measured because the surface is usually measured by repeating the practice in several sections of the 2D measurements. This also involves working with larger files and uses an algorithm (software) much more complex and results and presentation are more spectacular and equally useful.

The conventional method for achieving 3D measurements, whether of roughness, profile, shape, or any other situation that requires measuring controlled movement presupposes space X and Y directions in conjunction with measuring distances (heights) in the direction Z. A very important role in this process plays in coordinated mass movement to ensure very small increments on the Y axis followed by practical measurements which will allow the acquisition of 2D data (an array of points of coordinates x, y, z) allowing the 3D map of the area by three selectable methods as follows:

♦ triangulation
♦♦ B spline surfaces
♦♦♦ Bezier surfaces

As a principle, 3D measurement method can be represented as in Figure 2 where stands out sequential movement Y axis should provide a good locking system during the measurement. In fig.63 is observed all three axes, and movements necessary for completion of the cycle and in this case is replaced by direct palpation scanning laser or other optoelectronic methods (ie noncontact) caresunt preferable for 3D measurement. This time, both motions in the plane (X, Y) are made with two cross-tables and the z-axis measuring element in this case is static.

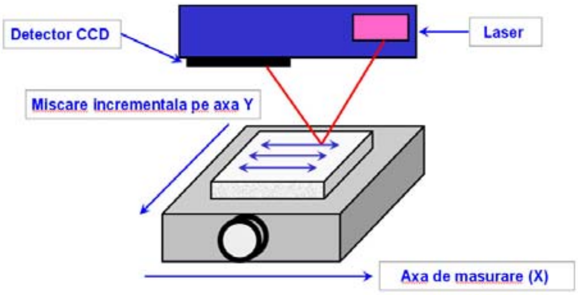

Figure 2

To have a high degree of certainty as regards the results obtained from measurements made by this process must have system tables in two coordinates (X and Y) to ensure that travel on routes such as the imminent impact of the errors that appear after each indexing Y axis to be insignificant. Errors on the 3 axes (ΔX, ΔY, ΔZ) and their effects can be seen in fig. 3.

ΔZ is the difference between the heights of the two consecutive start points Z1 and Z2 measurements. To reduce the effect of this difference in the two coordinate system tables to high precision.

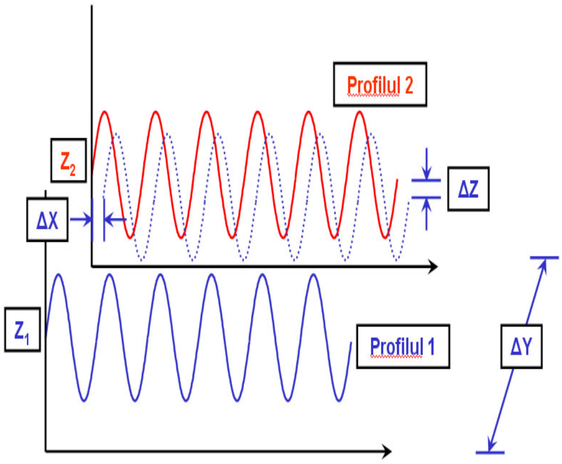

Figure 3

ΔX is the difference between the starting points of measurement. The ΔX is greater the more it will get a distorted microtopography surface. ΔY is a lack of movement on Y axis pitch accuracy, errors can arise from several factors such as the stroke between parts, errors in the mechanism of displacement / indexing step errors when using a mechanism such as screw / nut.

Most electronic devices to measure the roughness of its operation based on measurements made by a measuring head which is in contact with the surface by the very sharp stylus (classical gauges) or opto-electronic elements (non-contact) is moved along the surface of the part. The profile irregularities are is palpated by a stylus or laser beam transmitted through a transducer measuring a mechanism which converts the signal into an electrical signal traveling.

Table 1

Contact method	**Optical method**
Possible damage to the surface	No surface damage
geometry measurement	Optical path measurement
The stylus can brake	The optical transducer can't brake
Insensitive to tilt of the part surface	They are allowed only limited tilts
Relatively low speed	They can be very fast
Can be used to measure physical parameters but also for measurement geometry	Only the optical path
Calibration of roughness is acceptable on all scales	Difficult to calibrate by standard
Influence of temporal and spatial / dynamic effect	Influence spatial / geometric effects

3. PRESENTATION OF MEASUREMENT RESULTS

3D measurement data collected for a series of 2D measurements to be imported by a specialized soft-ware bearing in mind that these are primary data that is unfiltered, etc. are not smoothed. One possible and very common way of presenting the results can be seen in Figure 4.

In this case was considered an area of 0.8 mm square and the difference between the highest peak and deepest valley is 12 µmm. The color code can be attached to the approximate height of its surface in different areas. After filtering and removing the first inclination may be a result of the measurement is perpendicular to the surface was ruin to achieve a representation as in the same picture.

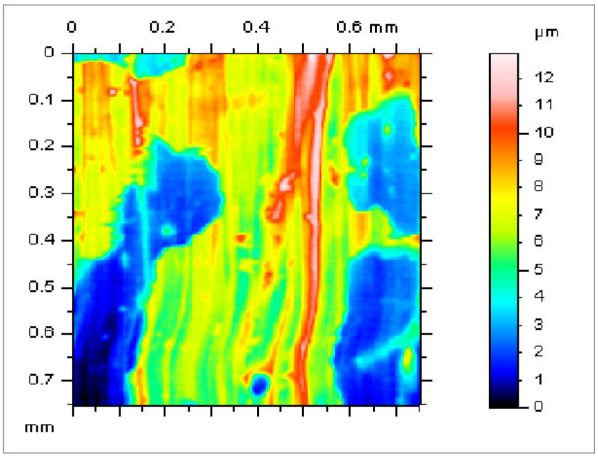

Figure 4

The true spatial representation of measurement results providing the most detailed and excellent perception of relief(figure5)

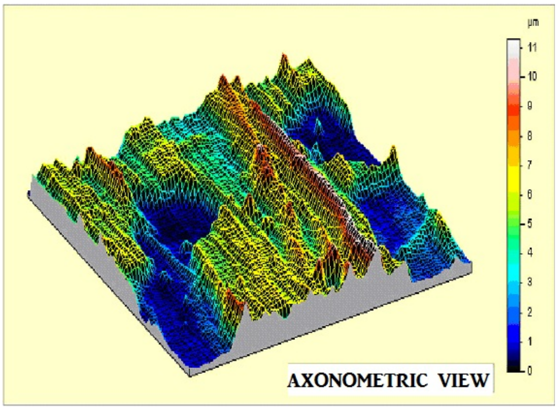

Figure 5

Other variants of the presentation of measurement results are those where the surface appears as a photo simulation (figure 6) or a continuous axonometric view to outline (figure 7).

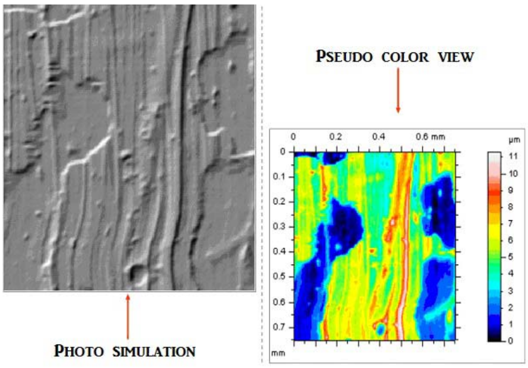

Figure 6

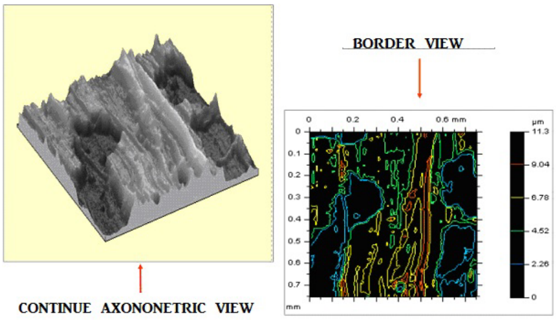

Figure 7

4. 3D ROUGHNESS PARAMETERS

Three-dimensional roughness parameters are very useful and are designed to better characterize the degree of surface finish and implicitly its performance. However, in most cases only technical documentation indicated roughness parameter to be controlled is required in a 2D parameter called Ra (roughness average) and because the 3D parameters are not well enough known but perhaps also because to be measured is necessary modern equipment to offer this possibility. With the new roughness parameters, design engineers have not only can view as many controlled elements and details on the surface but may even like to think of the design phase to its functionality.

There are different aspects of the functionality of a surface, the most important role in a certain direction and less important in the other direction of course technology. Thus, for some areas are more important that they ensure a good seal when the others are important aspects of friction, wear during running-in procedure and so on.

The following table indicates which the most frequently met situations are when 3D parameters recommended and what relevance they may have.

Table 2

Function	Ampli-tude	Spatial	Hybrid	Functi-onal
Lubrication	▲	▲	■	■
Seals	▲	■	▲	▲
Friction	▲	▲	▲	▲
Rigidity	▲	■	■	▲
Slip	▲	▲	■	▲
Electrical contact	▲	▲	▲	▲
Fatigue	▲		●	▲
Stress	▲		■	▲
Reflectivity	▲	■	▲	▲

Where: ▲- very relevant
■- quite relevant
●- little relevant

The 3D roughness parameters are usually divided into five major categories as follows:

-♦ amplitude (height) parameters
-♦♦ spatial parameters
-♦♦♦hybrid parameters
-♦♦♦♦ functional parameters
-♦♦♦♦♦ feature parameters

The names of 3D parameters defined in ISO 25178 starts with S for surface or V for volume. They do not reflect filtering conditions and do not have P (primary), R (roughness) or W (waviness) prefixes like the 2D parameters

Table 3: Height parameters

Para-meter	Name	Equation
Sq	Root mean square (RMS) height (*standard deviation of the height distribution*	$S_q = \sqrt{\frac{1}{A}\iint_A Z^2(x,y)dxdy}$
Ssk	Skewness *symmetry of the height distribution*	$Ssk = \frac{1}{S_q^3}\iint_a (Z(x,y))^3 dxdy$
Sku Kurtosis	*spread of the height distribution*	$S_{ku} = \frac{1}{S_q^4}\iint_a (Z(x,y))^4 dxdy$
Sa arith-metic height	Sz maximum height (*peak-to-valley*)	$S_a = \frac{1}{A}\iint_A \lvert Z(x,y)dxdy \rvert$
Sz	Maximum height (peak-to-valley	
Sp maxi-mum peak height	Maximum peak height(*from reference plane*)	

♦♦Spatial parameters

PARAMETER	NAME
Sal	autocorrelation length
Str	texture aspect ratio
Std	texture direction

♦♦♦Hybrid parameters

Sdq	Root mean square gradient
Sdr	Developed interfacial ratio

♦♦♦♦Functional parameters

Para-meter	Name	Equation
Smr (c)	areal material ratio	
Sdc (mr)	inverse areal material ratio	
Sxp	extreme peak height	$Sxp = Sdc(50\%) - Sdc(2.5\%)$
Vv (mr)	void volume	$Vv(mr) = \frac{K}{100\%}\int_{mr}^{100\%}[Sdc(mr) - Sdc(q)]dq$
Vm(mr)	Material volume	$Vv(mr) = \frac{K}{100\%}\int_{0}^{mr}[Sdc(q) - Sdc(mr)]dq$
Vmp	Hill material volume	$Vmp = Vm(10\%)$
Vmc	core material volume	$Vmc = Vm(80\%) - Vm(10\%)$
Vvc	core void volume	$Vvc = Vv(10\%) - Vm(80\%)$
Vvv	dale void volume	$Vvv = Vv(80\%)$

♦♦♦♦♦Feature parameters

PARAMETER	**NAME**
Spd	density of peaks
Spc	arithmetic mean curvature of peaks
S5p	five-point peak height
S5v	five-point pit height
S10z	ten-point height
Sda	closed dale area
Sha	closed hill area
Sdv	closed dale volume
Shv	closed hill volume

In order to obtain a surface micro-topography, “altitude” (coordinate Z) of each surface point is measured. This can be achieved by the different methods like auto-focusing method, which implies the movement of an element (lens) on the Z axis direction. The described con-focal method eliminates this inconvenience of the need for the existence of moving elements. The method is based on the axial chromatic of the objective lens and the principle is shown in figure 8 Practically, a white light source is imaged by an objective lens with extended axial chromatism on a series of monochromatic point images in the measurement space. When the measured sample intercepts the measurement space at point M, a single of the monochromatic point images is focalized at M. Due to the confocal configuration, only the wavelength λ_M will pass through the spatial filter with high efficiency, all other wavelengths will be out of focus (figure 8).

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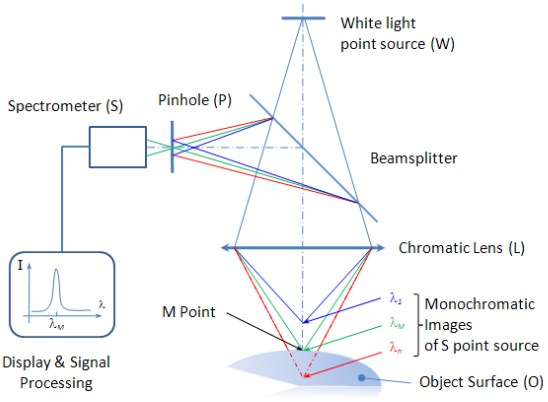

Figure 8

5. Results

INCDMTM Bucharest have made a functional model of 3D roughness using confocal microscopy that are in laboratory tests (figure 9).

Figure 9

The mechanical system includes
- The base
- Vertical frame
- Z axis displacement sub-assembly

Actuators

- Controlled displacement systems X and Y axes Sensors (Transducers) - First, the Z axis (an optical system based on confocal method which in conjunction with a very precise coordinates in two tables provide XYZ coordinates of points measured, necessary and sufficient data for computing system to recreate a virtual and accurate copy of the scanned area of optical pen (measuring head)) Since the XY axes and movements (two coordinates table) are equally important inductive transducers are used to quantify the two-way movements with precision micrometric strictly required for such measurements.

Electrical system: electronic processing and control block consists mainly of:
- The command and supply;
- The amplification, filtering, measurement;
- The results are displayed;
- The interface with other systems.

The calculation: Working with a PC is a sine qua non condition for the realization of such equipment to measure 3D roughness. By means of a data acquisition boards collect information from incremental transducers in X and Y table and collect the signal from the voltage controller (0-10V) offered by optical head responsible for measuring distances on the z axis, signal proportional to the distance to the surface roughness which is measured.

Data output: the results of measurements are the measurement report which may include a 3D representation of the surface, numerical coordinates and / or 2D graphics (roughness) in any selected section

Technical specifications

Measuring range	X Axe	30 mm
	Y Axe	min. 5 mm
	Z Axe	±150 µm
Transducer	X Axe	Incremental
	Y Axe	Incremental
	Z Axe	Optic modular confocal
Measuring direction		whatever
X axe straightness		5 µm/30 mm
Y axe straightness		Max. 2 µm/5 mm
Repositions repetability axa Y		max. 0,5µm
Measuring speed		1 mm/s
Measuring force		0 N
Cut-off		0,25; 0,8; 2,5 mm
Digital output		RS-232C interface
Electric supply		220V,50Hz

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