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3D Measurement of Geometric Characteristics of the Surface

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--***ABSTRACT***--
This study provides a description of a system designed as a new progressive method of measuring and evaluating geometric parameters of surfaces using laser profilometry. The study focuses on a more detailed description of the behavior of these individual parts functioning in mutual interaction as a whole. A method of measuring samples using the triangulation principle is described. The study also measured problematic types of surfaces, such as glossy surfaces, where the use of specific or non-traditional methods of treating these surfaces is partially avoided. The measured and evaluated sample was also created by a progressive technology of material separation using a laser. In the end, the study focuses on the evaluation of the measured profile data of the examined surface.

Keywords *– surface, profile, 3D, progressive method, laser, roughness*

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I. INTRODUCTION

Subtle microgeometric surface irregularities, compared to an ideal surface, are referred to as surface roughness. The development of science, improvement in technical fields and increasing the quality of products using progressive materials force us to precise technical and economic prescribing of production requirements from designers to precisely determined product control to maintain the specified surface roughness. The surface structure of the product has a significant impact on the overall quality of the product. It affects the service life, reliability, strength, fatigue, appearance and sliding properties of the material [1-3].

Research, comparison, use of knowledge of surface roughness and subsequent evaluation of surface roughness leads to an increase in the quality and accuracy of the operation of components, and thus to the efficiency and reliability of the entire equipment. Above all, reliability should be a determining factor for engineers. A reasonable design of the designer will contribute to the selection of the right production technology and the subsequent selection of the conditions of the production process. Improving the surface quality of machine parts reduces the total weight of the component, dimensioned for certain loading conditions. The good quality of the machined surface also simplifies its further processing, engineering or finishing operations, surface treatment which also has an ecological and economic impact on the production of the component. Last but not least, the right demands on the surface roughness will significantly affect the final price. Therefore, it is necessary to choose the roughness as roughly as possible, but at the same time still suitable for the proper function of the surface. The quality of the surface takes into account not only the surface roughness, but also the uncertainty of dimensions, geometric shape and position, and the hardness of the surface of components. This issue of surfaces is investigated by topography, which generally deals with the description of the surface of the examined object. We then call topographic 3D methods those measuring methods, the result of which is the so-called topographic deviation, denoted by (x, y), which is defined as the distance of the point (x, y) from the reference plane. This reference plane is realized either physically during the calibration of the method or is defined by the very principle of the method used. These topographic methods can be divided into contact and optical.

Methods are used to control surface roughness, which can be divided into qualitative and quantitative methods [4-8].

Qualitative methods are based on a subjective comparison of the inspected surface with a sample surface, the roughness of which is known. Only surfaces treated in the same or at least a similar way can be compared, and the result of the inspection is that the inspected surface is smoother or rougher than the sample [9].

The methods quantitatively express the surface roughness numerically. These instruments are based on either optical (non-contact) or tactile measurement. For example, the light cut principle and the interference principle are used in the optical method for determining roughness. Current methods for measuring the roughness of machined surfaces are based on various physical principles [10-14].

II. CHARACTERISTICS OF LPM SYSTEM

The laser profilometer is designed for non-contact characterization of surface geometry (Figure 1). The system makes it possible to measure samples with a maximum weight of 10 kg with a positioning accuracy of 2.5 micrometers per step, each step consisting of 8 micrometers. The sensor resolution is 0.02 mm / pixel. The system also includes LPM view software used to control LPM and evaluate measured data.

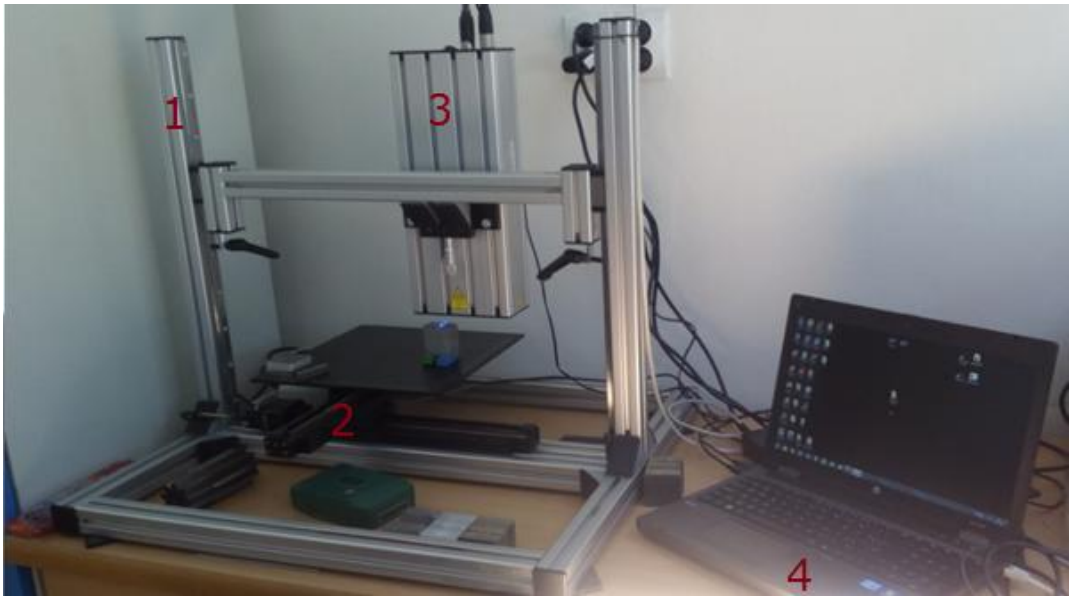

Fig. 1 LPM laser profilometer assembly

We used the LPM View program (Figure 2) to display the image of the area captured by the system profilometer camera. For efficient sampling, the LPM system is also equipped with an integrated light, which consists of four white LED lights. The illumination of the sample with a laser beam or LED light is selected in the software part of the system before the surface measurement.

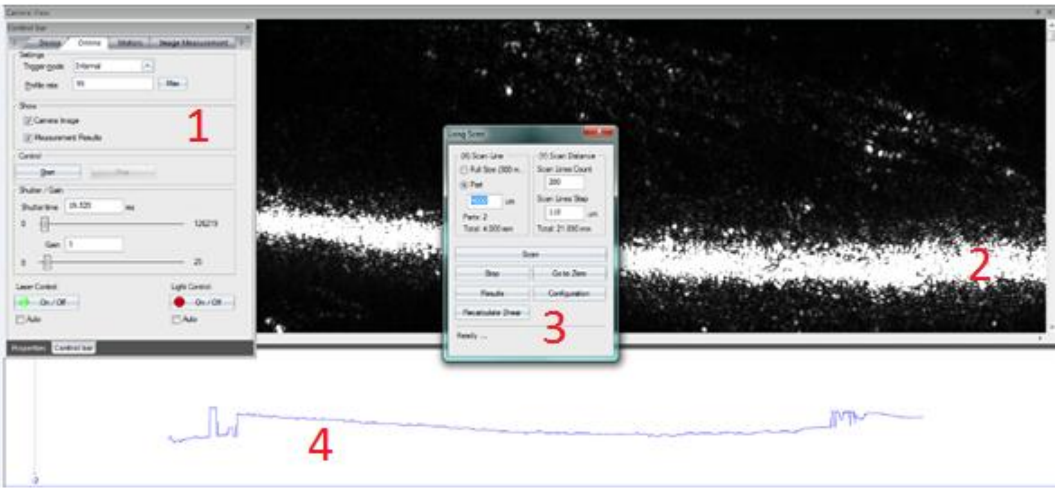

Fig. 2 LPM View software for measuring experimental samples

1 - Window for setting measurement parameters with a laser profilometer. In this window, the live mode of the camera is started and the operating mode of the profilometer (Gain) and the time for which the sample is to be taken (Shutter Time) are set. The correctness of the settings of these parameters determines the quality of the measured data,

2 **-** Real laser image window on the surface of the measured sample (Camera view). Displays the image provided by the device in Camera image mode. The image can be enlarged and reduced as well as shifted.

3 **-** Click on the Roughness and waviness window to open the Long Scan window. In this window, the parameters of the size of the measured part of the surface are set, i. width, length and also step size of stepper motors in micrometers. This window starts the scanning of the measured surface where it is visible in which phase the measurement of roughness parameters is located.

4 **-** Surface profile window. This window shows the last measured profile in the Measurement results mode. When the cursor stops, the current cursor position value is displayed at the current position. Values are displayed in millimeters.

Figure 3 shows the window with the measured roughness values of the measured surface, which was automatically generated by the LPM software. This window allows the export of the measured data to the mentioned formats and also the creation of a graph of the profile of the measured surface and the generation of a 3D model of the measured sample (4). The 3D model can also be composed of exported profiles in specialized programs working with spatial graphs such as. MS Excel or Microcal Origin.

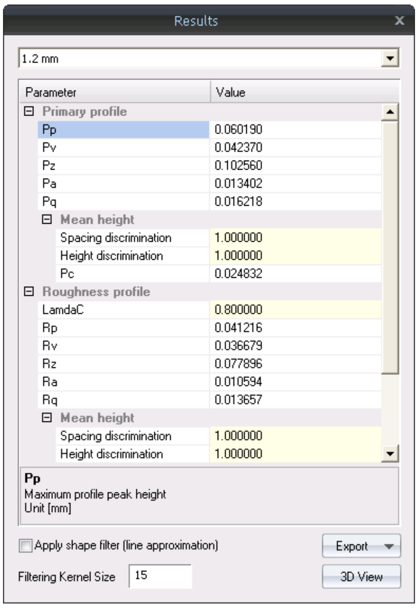

Fig. 3 Dialog box with measured parameters of surface profile roughness and corrugation

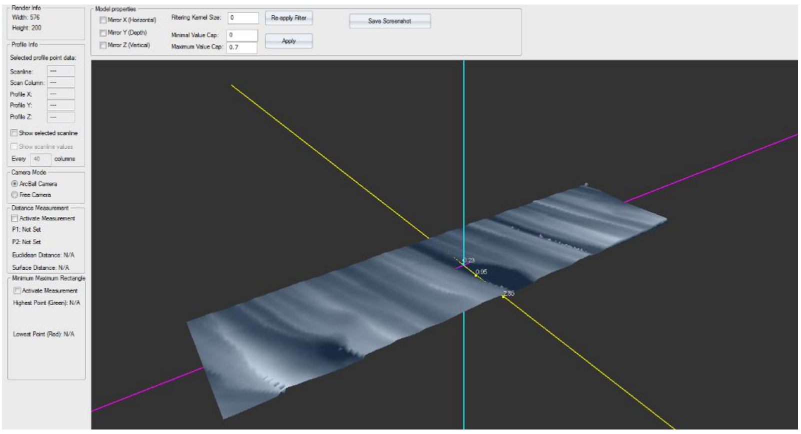

Fig. 4 Created 3D model of the surface profile

III. MEASUREMENT OF GLOSSY SURFACES

The main part of the experiment was to determine the suitability of using a non-contact LPM laser profilometer to measure glossy surfaces. To measure the glossy surface using laser cutting technology, they made a sample of stainless steel with the standard designation A 304. We chose the A 304 material because it shows a very shiny surface during laser cutting, which was the main requirement for this sample. The sample has the same dimensions as samples made with AWJ except for the thickness, which is 5 mm, because this cutting technology is used for cutting rather thinner materials up to 12 mm thick. Sample A 304 was measured with a Mitutoyo SJ 400 contact roughness meter to determine the Ra roughness parameter reference value and a LPM non-contact laser profilometer. From these measurements, a graphical dependence of Ra on the measurement step rate is constructed, which shows the differences of the Ra parameter values measured by the contact and non-contact method.

A TruLaser 3040 machine from TRUMF was used to make the sample (Figure 5). The TruLaser 3040 setup parameters for A 304 sample division are shown in Table 1.

Fig. 5 TruLaser 3040 from TRUMPF

Tabuľka 1 Parameters of the TruLaser 3040 machine when dividing the A 304 sample using a laser

Parametre strojov	Antikorová oceľ (A304)
Výkon lasera	3200W
Rezná rýchlosť	2,1 m/min
Max. hrúbka rezania	12 mm
Šírka rezu - škáry	0,2 mm
Ohnisková vzdialenosť	4,5 mm
Priemer fókusovaného lúča priemer lúča na tryske	2,3 mm
Druh a tlak pomocného plynu	Dusík - 17 Bar
Priemer dýzy	2,3 mm

In this part of the experiment, the roughness parameter Ra was evaluated, which in practice is sufficient data to verify the suitability of the LPM non-contact laser profilometer. The evaluation of Ra took place in three surface zones. In the smooth zone, in the middle zone and in the rough zone. The measured surface was transversely divided into three parts a, b, and c (Figure 6). First, the smooth (longitudinal, Step 1) part was measured by three measurements in parts a, b, c. This was followed by the measurement of the middle (Step 2) and rough (Step 3) parts of the surface divided into zones a, b, c.).

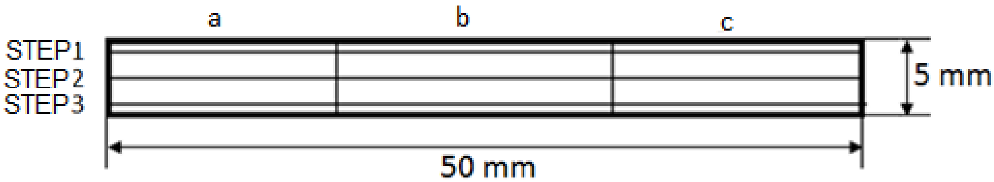

Fig. 6 Measurement of sample A 304 with Mitutoyo SJ 400 contact roughness tester

Fig. 7 Measurement with contact roughness meter Mitutoyo SJ 400 sample A 304

Figure 7 shows the glossy surface profile of sample A 304 measured at the factory using a laser cutting technology in the LPM software window. The surface of the sample is very glossy, which can be seen on the profile curve, which has a stepwise course caused by the reflection of laser light from the measured surface back to the CMOS camera (Figure 8).

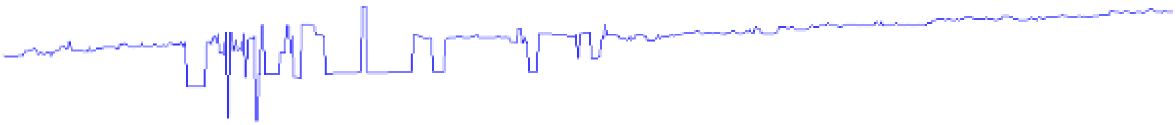

Fig. 8 Sample profile curve A 304 created by LPM view software

Figure 9 shows a graph of the measured values by the contact and non-contact method of sample A 304. The green curve represents the reference roughness values Ra measured by the contact roughness meter Mitutoyo SJ 400. The red curve represents the roughness values Ra measured by the non-contact laser profilometer LPM. The red curve confirms the lack of measurement by laser profilometry, while the gloss of the surface caused the reflection of the laser from the sample surface into the CMOS camera, which caused a sharp increase in the values of the roughness parameter Ra i. measurement error, which can be explained as unwanted glare from the camera sensor. This measurement error can be partially eliminated for some surfaces by deleting bias values from the exported tables. With this type of very glossy surface, it will not be possible to solve this because the roughnesses shown by the red curve are several times higher than the actual roughness value.

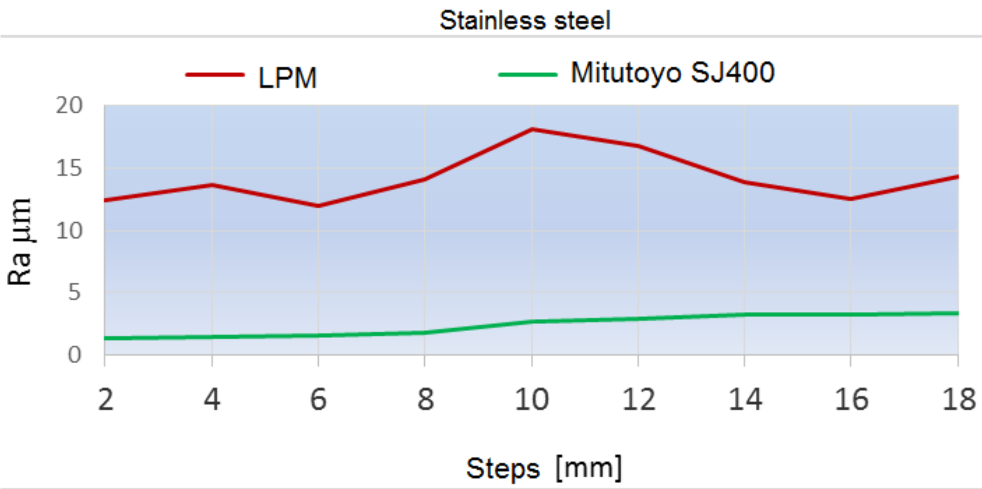

Fig. 9 Graph of measured values by contact and non-contact method of laser samples

IV. CONCLUSION

Figure 10 shows a 3D model of a scanned sample made of stainless steel. The 3D model was created by stacking a series of measured profiles with LPM view software. The image shows the places where the largest reflections of laser light from the surface of the sample to the CMOS camera occurred in a red circle. The LPM view software evaluated these reflections as the largest surface irregularities and evaluated them as a sharp increase in Ra values.

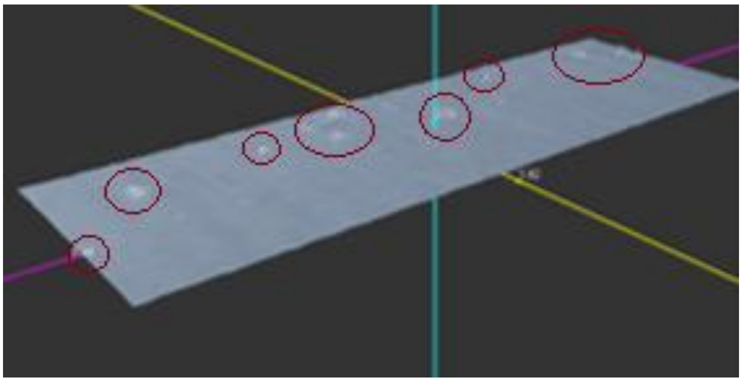

Fig. 10 Generated 3D profile of sample A 304 made by contactless laser profilometer

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REFERENCES

[1]J. Liu, E.H. Lu, H.A. Yi, M.H. Wang, P. Ao, A new surface roughness measurement method based on a color distribution statistical matrix, Measurement, 103, (2017) 165-178. doi: 10.1016/j.measurement.2017.02.036.
[2]C. Kang, H.X. Liu, Small-Scale Morphological Features on a Solid Surface Processed by High-Pressure Abrasive Water Jet, Materials, 6, 8, (2013) 3514-3529. doi: 10.3390/ma6083514.
[3]C. Lu, Study on prediction of surface quality in machining process, J. Mater. Process. Technol., 205, 1-3, (2008) 439-450. doi: 10.1016/j.jmatprotec.2007.11.270.
[4]J. Raja, B. Muralikrishnan, S. Fu, Recent advances in separation of roughness, waviness and form, Precis. Eng.-J. Int. Soc. Precis. Eng. Nanotechnol., 26, 2, (2002) 222-235. doi: 10.1016/S0141-6359(02)00103-4.
[5]T. Das, K. Bhattacharya, Refractive index profilometry using the total internally reflected light field, Appl. Optics, 56, 33, (2017) 9241-9246. doi: 10.1364/AO.56.009241.
[6]Bass, M., aj. Handbook of optics. Vol. I. Fundamentals, techniques & properties. 2nd ed. New York, McGraw – Hill, 1995.
[7]Bass, M. aj. Handbook of optics. Vol. II. Devices, measurement & properties. 2nd ed. New York, McGraw – Hill, 1995.
[8]Dyson, J. Interferometry as a measuring tool. Machinery Publishing, 1970.
[9]West, Charles M. Holografická interferometrie. New York, John Wiley & Sons, 1979.
[10] Hrabovský, M.; Bača, Z.; Horváth, P. Koherenční zrnitost v optice. Olomouc, Vydavatelství Univerzity Palackého, 2001.
[11] Guenther, Robert D. Modern optics. New York, John Wiley & Sons, 1990.
[12] Menn, M. Practical Optics. San Diego, Elsevier academic press, 2004, ISBN 0-12-490951-5.
[13] Mitaľ, G – Ružbarský, J.: Bezkontaktné meranie a vyhodnocovanie drsnosti opracovaných povrchov pomocou laserovej profilometrie. In: ARTEP 2016. Košice: TU, 2016 S. 00-1-00-7. - ISBN 978-80-553-2474-6
[14] KOLNEROVÁ, M.: Povrchy povlaků – mikrogeometrie. [online]. Liberec: Technická univerzita v Liberci - Katedra strojírenské technlogie. Oddelení tváření kovů a plastů. 2010. [26.1.2016]. Dostupné na internete: <http://www.ksp.tul.cz/cz/kpt/obsah/vyuka/stud_materialy/spt/povrchy%20povlaku.pdf>.

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