# DIAGNOSTICS OF SELECTED SURFACE CHARACTERISTICS WITH LASER PROFILOMETRY

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The paper is focused on the quality evaluation of the surface using the LPM laser profilometer. The measured sample was manufactured by Mitutoyo, Japan with surface roughness 2.94µm. The main goal was proper adujstment of the internal gain of the camera video signal (Gain mode) which affects the quality of the measured data. Measurement and evaluation show that the laser profile mode selection has a significant impact on the obtained data and depends on the type and character of the measured surface.

**KEYWORDS**

profilometry, roughness, laser, non-contact, surface, measurement, technology, parameters

## 1 INTRODUCTION

The surface quality of parts is one of the conditions for their proper function, and significantly influences the component life. Roughness represents the amount of inequality from the ideal shape and arises as a result of:

- Used instruments and related parameters (micro geometric shape and size of the irregularities)

- applied surface treatment (physical and mechanical condition).

In the engineering industry material tends to be intensively stressed during the manufacturing process . During machining, parts of removed material thermally and tension stressed. Machining takes place in primary, secondary and tertiary deformations. Due process in the tertiary area, on a work piece, just beneath the surface, hardness, tension and possibly structure can be changed. State of the work piece after the final finishing of components affects the properties of the final product. In dynamically stressed components such changes have a key influence on the properties of their reliability and durability.

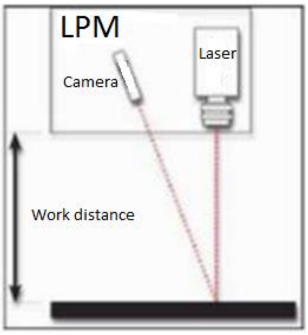


**Figure 1.** Measuring using LPM

## 2 MATERIALS AND METHODS

The laser profilometer (Fig. 2) consists of basic and supplementary parts. The basic part is the mechanical part (supporting frame components with vertical adjustment, the position of the measuring head and programmable specimen feed in axes X and Y), the optical portion (laser beam source, lens and camera with a CCD sensor) and the control portion (PC with operating and evaluation software). Complementary parts include divider picture calibrated with a prescribed roughness socket power strip with surge protection, battery backup power supply with overvoltage protection, external USB drive for data storage.

**Figure 2.** Laboratory of laser profilometry

Optical system forms part of the AVT Marlin camera 131B and 23FM50SP Tamron 50 mm with a visible area of 22 mm x 7 mm. Automated shift portion in the Y axis is realized by means of stepping motors Stan 8MT160-300 in each axis, a length up to 300 mm. The system allows you to measure samples of up to 8 kilogram in the precision setting position of 2.5 micrometer to move. Taking each step consists of 8 microns. Resolution of the sensor is 0.02 mm / PIxel.

Using an experimental system can be measured and evaluated parameters of waviness and roughness of the samples according to EN ISO 4287 and EN ISO 11562 (Ra, Rz, Rq, Rv, Rp, Wa, Wz Wq, Wv, Wp). The results of the evaluation parameters of the profile or profiles measured in the form of raw data can be exported in .csv format that is suitable for further processing experiments in readily available spreadsheet programs.

Transparent image processing and evaluation of experimental data facilitates video splitter Matrox TripleHead2Go Digital-Edition. It is a device for the distribution of one graphical output of the computer to three independent display output (in combination with the use of further graphics output, and selecting the enlarged working area can be obtained from four independent images) such that each monitor is different from the desktop or the application, while graphics performance of computer is not reduced.

| |
|---|
| metals (as measured glossy metal surfaces must be individually assessed options of laser profilometer for a particular application, if necessary, there are methods of coating material, such as application of the spray to a measured surface, which is used to test the crack or the other a glossy surface smoke with candles) |
| stone, ceramics, |
| plastics, |
| rubber, |
| after verification also other materials. |

**Table 1.** Materials measurable by LPM system

### 2.1 *The principle of measurement using LPM*

To view the image of the field captured by the camera of profimeter, AVT SmartView program is used(Fig. 3), which allows in combination with running shift shoot the video appearance of the surface of the measured component. For effective imaging samples LPM system is also equipped with an integrated light. Light consists of four white LED lights. Illumination of the sample with a laser beam or LED light is selected on the measuring head of the system.

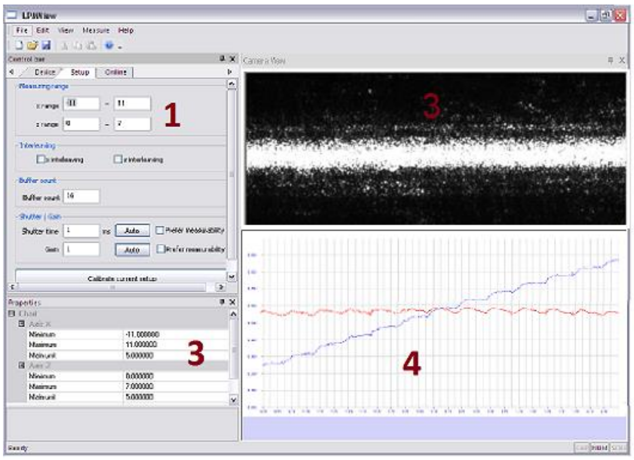


**Figure 3.** Software LPM View (1-box setup and run a profilometer evaluation, 2-window real image of the scanned camera, 3-graph window displayed data, 4-captured data)

At position 2 (Fig. 3) there is a measurement of the profile window with a preview sample with visible laser line. The preview window is suitable for the construction of the image sensed as a result of setting the image brightness less adapted to high intensity laser beam.

At position 4 (Fig. 3) it shows the current measured profile. Stacking a series of profiles of the measured system LPM allows a 3D model of the measured object, which is shown in (Fig. 4). The model is also possible to stack the export profile in specialized programs working with spatial graphs such as MS Excel or Origin Microcal.

### 2.2 *Software for observation of samples*

Observation of the sample was used software LPM view (Figure 3). To view the image of the field captured by the camera of profimeter, AVT SmartView program is used (Fig. 4), which allows in combination with running shift shoot the video appearance of the surface of the measured component. For effective imaging samples LPM system is also equipped with an integrated light. Light consists of four white LED lights. Illumination of the sample with a laser beam or LED light is selected on the measuring head of the system.

### 2.3 *Measurement metodology using LPM*

**Important steps prior to measurement:** (LPMView User guide, 2015).

1. Set the engine to the starting position (axis X, Y)
2. Sharpen CCD camera. Turn on the laser and start a live camera mode. Using a micrometer feed sample set so that the laser line is in the camera image. The camera is out of focus when the laser line is visible along the length of a camera view and is located in the lower part.
3. Set ShutterTime the camera. Length of the exposure period is important to the scanning, but in terms of obtaining a higher quality signal to the measurement profile. Due to the variety of scanned materials and surfaces can be re-experiment by changing the exposure time and confronting quality profile by using the tool live profile. The ideal profile would be the least noisy (still without fluctuations in value), the ideal laser line, the live image from the camera should be as continuous as well as the closest possible.

### 2.4 *Place and conditions for carrying out of experiment*

The experiment was realized on Faculty of Manufacturing Technologies in the Roughness Measurement Laboratory at the Department of Process Production in Prešov. Measurement of the surface roughness parameters was performed on the optical measuring system intended for the surface parameters control.

The system uses laser profilometry based on triangulation principle. When this using this principle, laser line is projected on measured surface at an angle , which is then captured using a digital camera placed perpendicular to the scanned surface (Fig. 2).

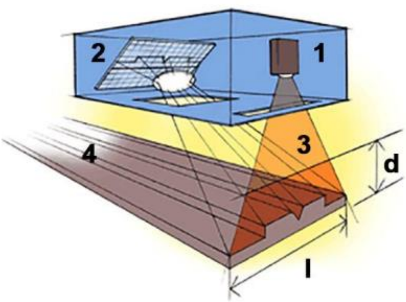


**Figure 4.** Schemes to measure the LPM 0.
1- CCD camera, 2-laser light source, 3-laser light on the surface, 4-measured surface, C operating range profilometer, d-working distance, l- measuring range

### 2.5 *Software equipment*

**Base programs:**

- Operating System Microsoft Windows 7,

- MS Office (for data export to Excel).

**Utilities:**

- LPMView - used for communication with the laser profilemeter,

- AVT SmartView - camera preview and creating graphical documentation,

- Test feed - management and testing XY displacement,

- Microsoft Excel - graphical processing of exported data.

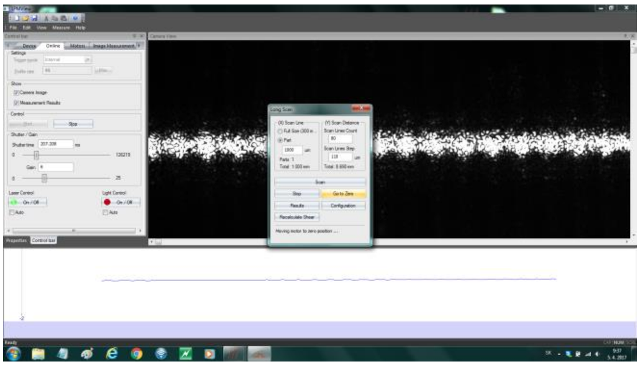

**Figure 5.** Sample Measurement Software Parameters

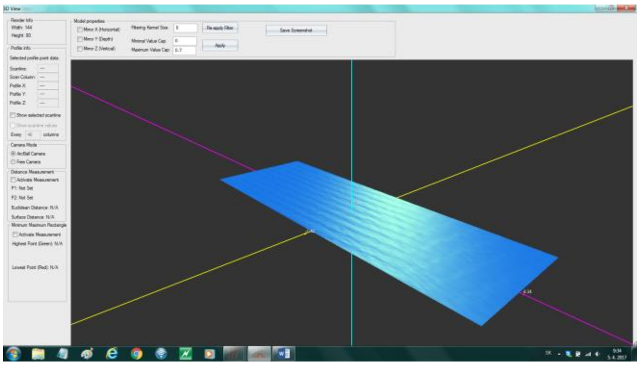

**Figure 6.** Camera preview of measured sample

## *2.6* Conditions for carrying out the experiment

Measured material was the precision reference specimen. It was manufactured by Mitutoyo company in Japan and is designed for calibration and evaluation of the measurement accuracy of the device for measuring surface roughness.

| Country of manufacture | Japan |
|---|---|
| Manufacturer | Mitutoyo |
| Ra | 2,94 microns |
| Rmax(Ry) | 9,3 microns |

**Table.2** Reference speciemen


**Figure 7.** Precision reference specimen

## 3 THE MEASURED VALUES

In the present experimental part of this study, it is performed the practical measurement using precision reference specimen. By evaluating the surface roughness, Ra parameter was observed - mean arithmetic deviation of the profile.

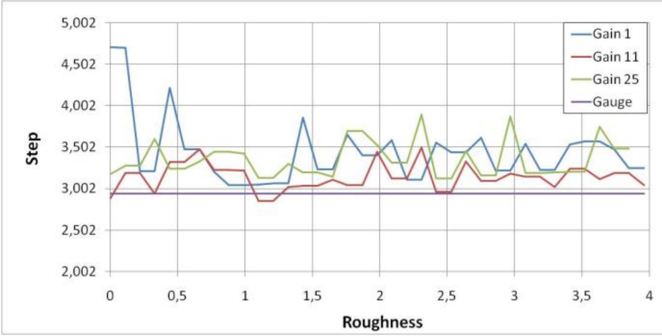


**Figure 8.** The graph of the measured values

| Step | 0 | 0,11 | 0,22 | 0,33 | 0,44 | 0,55 | 0,66 | 0,77 |
|---|---|---|---|---|---|---|---|---|
| Gain 1 | 4,707 | 4,703 | 3,211 | 3,211 | 4,214 | 3,473 | 3,473 | 3,201 |
| Gain 11 | 2,878 | 3,191 | 3,191 | 2,942 | 3,321 | 3,321 | 3,478 | 3,223 |
| Gain 25 | 3,174 | 3,274 | 3,274 | 3,6 | 3,238 | 3,238 | 3,238 | 3,443 |
| Step | 0,88 | 0,99 | 1,1 | 1,21 | 1,32 | 1,43 | 1,54 | 1,65 |
| Gain 1 | 3,04 | 3,04 | 3,05 | 3,065 | 3,065 | 3,855 | 3,234 | 3,234 |
| Gain 11 | 3,223 | 3,217 | 2,849 | 2,849 | 3,018 | 3,039 | 3,039 | 3,107 |
| Gain 25 | 3,443 | 3,422 | 3,13 | 3,13 | 3,298 | 3,197 | 3,197 | 3,148 |
| Step | 1,76 | 1,87 | 1,98 | 2,9 | 2,2 | 2,31 | 2,42 | 2,53 |
| Gain 1 | 3,651 | 3,402 | 3,402 | 3,583 | 3,109 | 3,109 | 3,558 | 3,438 |
| Gain 11 | 3,041 | 3,041 | 3,446 | 3,123 | 3,123 | 3,496 | 2,959 | 2,959 |
| Gain 25 | 3,697 | 3,697 | 3,53 | 3,313 | 3,313 | 3,893 | 3,125 | 3,125 |
| Step | 2,64 | 2,75 | 2,86 | 2,97 | 3,08 | 3,19 | 3,3 | 3,41 |
| Gain 1 | 3,438 | 3,614 | 3,221 | 3,221 | 3,541 | 3,223 | 3,223 | 3,537 |
| Gain 11 | 3,331 | 3,091 | 3,091 | 3,183 | 3,142 | 3,142 | 3,018 | 3,239 |
| Gain 25 | 3,452 | 3,161 | 3,161 | 3,869 | 3,186 | 3,186 | 3,194 | 3,204 |
| Step | 3,52 | 3,63 | 3,74 | 3,85 | 3,96 | | | |
| Gain 1 | 3,574 | 3,574 | 3,474 | 3,248 | 3,248 | | | |
| Gain 11 | 3,239 | 3,113 | 3,19 | 3,19 | 3,045 | | | |
| Gain 25 | 3,204 | 3,744 | 3,484 | 3,484 | 4,165 | | | |

**Table 3.** Measured values

Roughness precision reference specimen: Ra = 2,94 µm

Average measurement data Gain 1: $\overline{Ra} = 3{,}44$µm
Average measurement data Gain 11: $\overline{Ra} = 3{,}10$µm
Average measurement data Gain 25: $\overline{Ra} = 3{,}38$µm

## 4 MEASUREMENT RESULTS

The goal of this study was to evaluate the measured of sample surface using a laser profilometer, which was constructed of components available on the market at the Department of manufacturing processes. The sample was produced with a surface roughness with a value of 2.94 microns. The sample surface is glossy which caused a slight interference reflections. It had a slight effect on the measured data.

In the present experimental part of this study, it is performed the practical measurement using precision reference specimen in order to test the measurement accuracy of developed device by comparison of measured data with the standard. By evaluating the surface roughness, Ra parameter was observed - mean arithmetic deviation of the profile. Surface roughness was measured in 40 steps with a step size of 0.11 mm at three levels of the Gain modes. The best mode with the cleanest preview in the dialog box for the sample was Gain

11 mode and Shutter time 161,2ms. From the measured values the arithmetic mean of the resulting roughness was calculated. Measured values for the roughness of the precision reference specimen are shown in Table. 2.

In order to determine the suitability of adjusting the profile parameters with respect to the type and character of the measured surface, the measurement was carried out at three levels of the profilometer Gain 1, Gain 11 and Gain 25. Using the measurement results, it is possible to determine which of the Gain modes is the most appropriate for a given type of material. Figure 8 shows the dependence of the surface roughness measured on the surface roughness of the precision reference spicemen at three levels of the Gain profile mode. Figure 7 illustrates the measured values for the arithmetic mean deviation Ra. As it can be seen, by comparing the meanings of the measured values and the value of the precision reference specimen we found differences in Gain 1, the average roughness value was 3.44 µm.

Using Gain 11 mode the average roughness value was 3.10 µm and using Gain 25 mode the average roughness was 3.38 µm. The largest deflection of the measured values occured in Gain 1 mode with the average deflection of roughness value 0.5µm and in Gain 25 mode with the average deflection 0.44µm. The smallest deflection occured in Gain 11 mode indicating that it is optimal to set the gain mode to the middle level of the mode range for the measured type of the surface.

Slight deflection in the measured values was caused by the gloss of the surface of the precision reference specimen. The surface gloss led to the reflections of the laser light to the CCD camera, resulting to the jumps in the measured data and it influenced the overall average of the measured values. It is obvious from the evaluation of the measurements that the profile mode adjustment has a significant impact on the measured data quality.

## 5 CONCLUSION

Surface roughness is a characteristics that affects the durability and reliability of components, energy loss, wear resistance, tribological properties, etc. In terms of machining technology of machine parts, surface roughness is one of the standard criteria for assessing their quality. Surface roughness significantly influences the course of physical and chemical phenomena in the operation parts, friction, sealing efficiency, operational reliability, durability and economy of devices.

According to the specifications of the standard ISO 4287 and EN ISO 11562 software LPMView in cooperation with a laser profilometer allows to perform a comprehensive assessment of the machined surface. As we found out in this practical measurements, also our laser profilometer allows comprehensively evaluate the measured surface. However, it is necessary to define the use of the operating mode Gain by different types of surfaces which will be the subject of further research and development.

By the non-contact roughness measurement system at the Department of operation of production processes we are able to measure a wide range of soft and hard surfaces, which is a major advantage of the device. Also, the measurement is limited by the size and weight on the sample. Therefore, as part of research and development system for the contactless measurement and evaluation of surface roughness are trying the topic of surface roughness measurement to expand and improve this facility. The advantage of the proposed system is mainly the speed of measurement and processing of the measured values, further advantage is favorable price. Disadvantage is the geometry of the measured surface, which must be satisfactory, and that is, the shape of the measured object may not be very curved or oval. Non-contact system for measuring the roughness at the Department of operation of manufacturing process is not able to measure all the objects and parts, but is merely an extension and improvement of methods for measuring the roughness of machined surfaces.

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