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APPLICATION OF NON-CONTACT PROFILOMETER IN AUTOMATED PRODUCTION

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Abstract: The main thesis of this paper was to briefly describe the measurement technique using a non-contact laser profilometer. This paper is divided into several parts, where in the introduction, in the theoretical analysis, we described the necessity of using control mechanisms in automation. Then, in the second chapter, we have developed the technology of measurement with a profilometer and its application in scientific work and in practice. In the experimental part, we have defined the application of a profilometer in laboratory conditions on an automated line in the measurement of a part printed with a 3D printer. Finally, we evaluated the advantages and disadvantages of this device compared to mechanical measuring devices.

1 Introduction

Today, almost all mass production is automated because it is cheaper, more accurate, and requires fewer people. Increasing productivity and the desire to gain a competitive advantage are usually the main reasons many companies initiate an automation project. Other reasons for automation may not be due to "thinking about the future" but rather the presence of current specific reasons - such as a hazardous work environment or high labor costs. Some companies automate processes to reduce production time, increase production flexibility, reduce costs, eliminate human error, or address a labour shortage [1].

Automation solutions usually focus on some or all of these economic and social factors. In this way, the general purpose of production automation can be assigned: to replace human labour and optimize work. In a broader sense, the goals of process automation include [2]:

- Reducing the production of operators.
- Increasing the number of products.
- Expanding the range of products.
- Multiplication of production.
- Increasing production reliability.

Benefits generally attributed to automation include higher production rates and productivity, more efficient use of materials, better product quality, improved safety, shorter workweeks, and shorter lead times. Higher output and higher productivity are two of the most important reasons for using automation. Despite high quality claims from good human workmanship, automated systems typically perform a production process with less variability than human workers, resulting in better control and more consistent product quality. Better process control also means that materials are used more efficiently, resulting in less waste [3].

The use of state-of-the-art measurement and control mechanisms is also a given. One of these technologies is also non-contact measuring systems such as (sensors, profilometers or camera systems). Today these control mechanisms have much more complex functions than in the past. They are used as a control algorithm, as a transformation element between the measured variable and the evaluation unit, or as an element of product quality control in automated production [4].

The principle of these measuring devices is that the measured object enters the measuring zone of the device, the device performs the measurement, and since there is no mechanical contact between the object and the measuring device, high reliability and repeatability of the measures is ensured. Such devices are maintenance-free and do not wear out quickly thanks to the non-contact measurement, which is an excellent advantage for manufacturing companies [5].

2 Principle of non-contact measuring with the profilometer

The profilometer consists of a laser emitter, cylindrically arranged lenses, a light-sensitive receiver lens with a large aperture and a high-resolution CMOS (Complementary Metal-Oxide Semiconductor). The principle of this measuring device is that the laser radiation from the measuring head emits a blue light beam that irradiates the measured surface. The reflected light is projected onto a light-sensitive CMOD sensor and generates a 2D and 3D profile of the measured workpiece, which can then be examined [6].

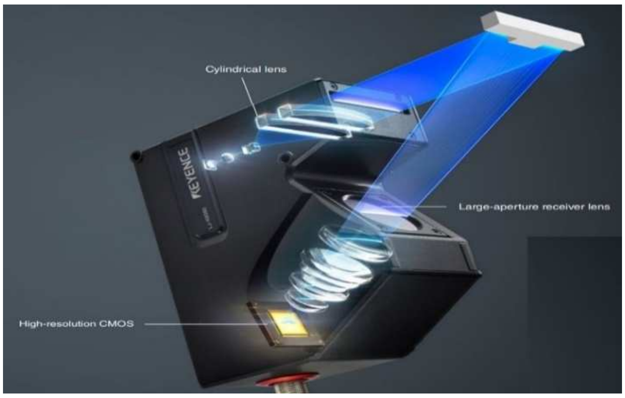

Figure 1 2D/3D Profilometer Keyence [7]

As a measuring instrument, the profilometer is very accurate, as it is supposed to identify and quantify surface elements on a very small scale. Surface roughness is categorized in degrees from "N12" to "N1" according to ISO 4287 and is based on the maximum height difference between microscopic slopes, peaks and valleys to an accuracy of 1 micron [8].

2.1 The state of art

As mentioned earlier, one of the non-contact measurement systems is also a profilometer. A profilometer is a special metrological measuring device that is used to measure the height differences of measuring objects. In technical articles, we can find many examples of the use of this device, such as Leroux et al., whose article focused on the use of a 3D profilometer in the identification of the surface of the paper, where he was able to identify the inscription on the papers printed by laser printer thanks to the ultra-precise microbalance [9]. Mital et al., in their article, use a profilometer for surface roughness identification in waterjet machining [10]. Sun et al., in turn, proposed an algorithm for evaluating the quality (machinability) of the surface texture of tools using a profilometer [11]. Chen et al. came up with the idea of inspecting the surface of gears on clutch wheels using halogen illumination and a CMM-based profilometer [11]. Arezki et al. used accurate profilometer measurements on several ultra-precision measuring machines to evaluate innovative optical aspherical and free-form surfaces [13]. In turn, Oezcan et al. presented an interesting proposal in their work using a camera system and a profilometer to develop a 3D measurement scheme for analyzing the failure of concrete specimens and their porosity [14]. Fiorentini et al. had an even more interesting idea in their study, in which they used a 3D laser profilometer to measure the surface of an asphalt road in order to measure the surface texture of the asphalt exposed to vehicular traffic and environmental erosive influence after each day [15].

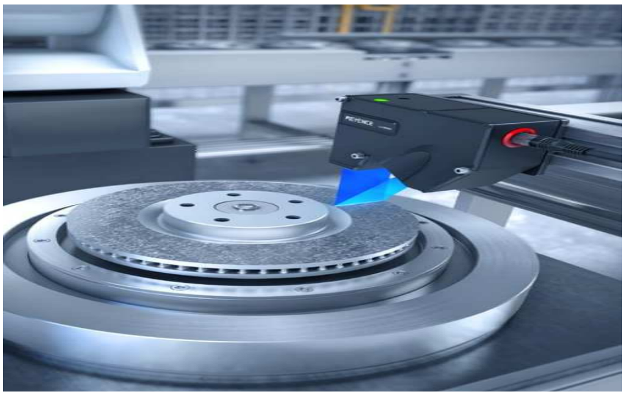

Figure 2 Measurement process with profilometer [7]

3 Application of profilometer in laboratory conditions

The measurement procedure in this article consists of the implementation of a profilometer on an automated line set up under laboratory conditions. The measurement object was a part printed with a 3D printer, which serves as a stabilizing element of the robot arm. The part is made of PLA filament for black 3D printers, which can lead to partial measurement errors for the profilometer caused by the absorption of light by the ink.

Figure 3 shows the measuring head of the LJ-X8400 profilometer from Keyence. This profilometer uses the principle of laser triangulation with a light source, a blue semiconductor laser with a wavelength of 405 nm. The spot size of the laser radiation is approximately 275 mm x 249 µm at a reference distance of 380 mm.

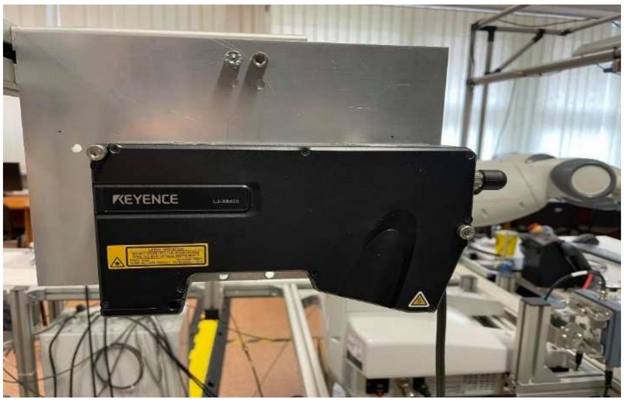

Figure 3 Profilometer Keyence LJ-X 8400

The raw profilometer data is transmitted using a software algorithm that determines the type of element and measures the width of the measured object and the clear distances. The algorithm first uses the difference between adjacent data points to detect a sudden profile change. Sudden changes in surface profile indicate the presence of an element. The object data goes through a second algorithm to classify the object. Data identified as overlap or gap is passed to a third algorithm for width estimation.

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Figure 4 Pallet with measured workpiece on automated line

Before the component itself could be measured, a trigger had to be installed on the line, in our case an optical laser sensor. The 48.6 x 48.6 x 7.2 mm workpiece was placed on a prefabricated pallet that served to interrupt the laser beam from the trigger as it moved along the line, informing the profilometer to begin measuring the part. After the pallet passes the sensor, the laser beam is reconnected to the light-sensitive reflective surface, causing the profilometer to complete the measurement.

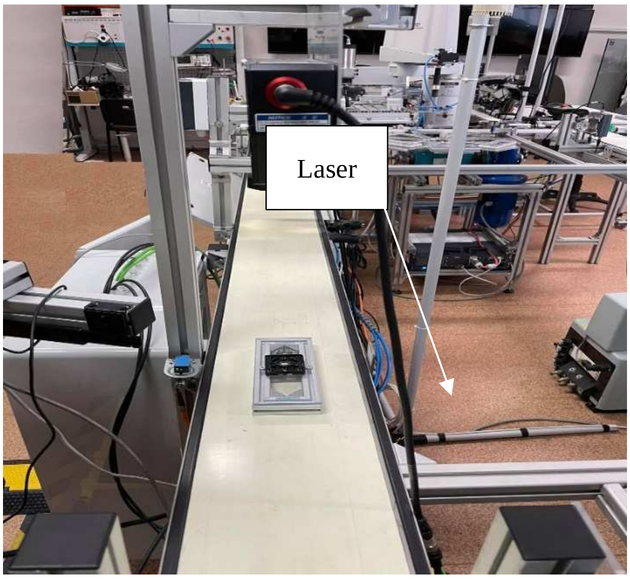

Figure 5 Measurement process of a workpiece with a profilometer on an automated line

After the measurement, the data about the workpiece is sent to the software of the company Keyence LJ-X Terminal Software, where the measured parts are displayed in 3D format. With the help of this software, we can measure height differences of individual components in serial production by determining standard values based on given input height conditions, and the profilometer then measures the difference of these parameters on other components.

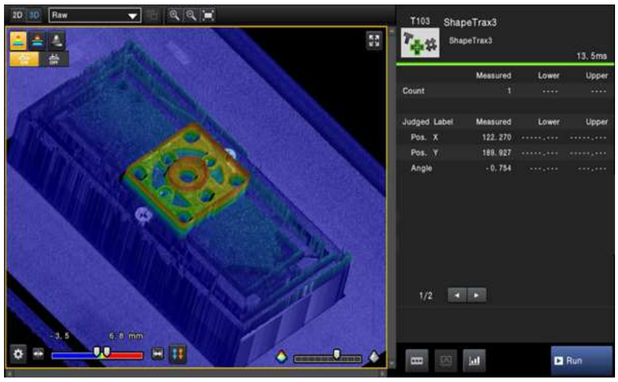

Figure 6 Measured workpiece in the software interface

The zero reference surface for measuring a part is the surface of the pallet on which the part is placed. Figure 6 shows that the software distinguishes the height distribution of the part based on colour differences, with the blue colour representing negative values and the red representing positive values. When identifying defects in production, we can use this device to quickly identify either machining defects or, as in our case, 3D printing defects. The X and Y position data as well as the angle are the reference points for the profilometer for the next measurement. The software also gives us the option of directly measuring the dimensions of individual elements of the workpiece to better identify height differences in the mould.

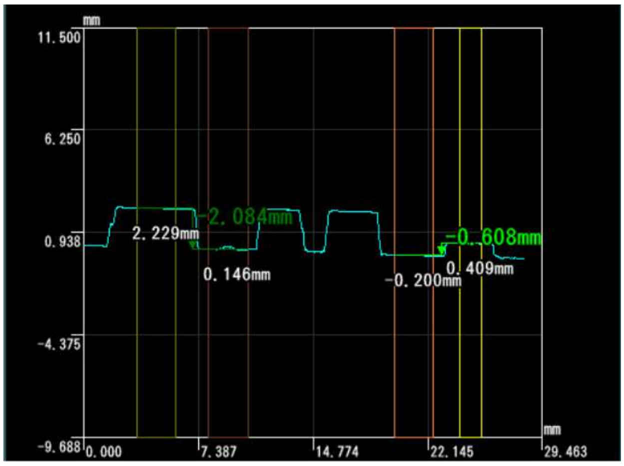

Figure 7 Measurement of height differences on the workpiece

3.1 Evaluation of profilometer application

The non-contact gage, instead of a needle used in a light gage, uses an advantage over mechanical gages, namely, the elimination of wear on the contact surface of the gage with the measured component. The advantages and disadvantages of using a non-contact profilometer can be summarized in the following points.

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Advantages:

- No damage to the sample surface.
- Ability to measure smaller roughness with high accuracy.
- Fast measurement and high repeatability.
- Simultaneous observation of the surface image and height profile.
- The ability to produce a fully focused, high-resolution image that competes with SEM (3D colour laser microscope images).

Disadvantages:

- The limited size of the measurement target.
- The limited measurement of some surfaces (reflections, colour absorption of light etc.).
- The limited to fixed measurement only in one place (immobility).

4 Conclusion

As we can see, the automation of various production processes increases the speed of the tasks performed. Moreover, in this way, it is possible to eliminate the human factor, the number of frequent errors is significantly reduced, which allows improving the quality of the process. Thanks to the development of new technologies, production automation also contributes to the improvement of control mechanisms, such as the non-contact profilometer LJ-X8400.

As shown in the article, non-contact (laser) profilometers are the best choice for automated production, because thanks to their long-term stability and speed, it is possible to do without technical service for a long time, which is the main criterion for the functionality of the automated line. Furthermore, thanks to the high measurement accuracy and easy-to-use software, the application of this device are very simple. For automated production, this device offers the possibility of quick identification of defects by measuring the profile of the workpiece and then analysing the height differences. In this article, we have evaluated all the advantages and disadvantages of this device and can recommend it without the slightest doubt for the manufacturing sector.

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