IMPACT OF POWDER COATING TYPES ON DIMENSIONAL ACCURACY IN OPTICAL 3D SCANNING PROCESS

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DOI: 10.17973/MMSJ.2023_11_2023084

This research article aims to investigate the impact of various types of powder coatings on the resulting dimensional accuracy in the optical 3D scanning process. The experimental study utilises the GOM ATOS II Triple Scan scanner with measuring volume MV100 to conduct a series of measurements. Different powder coatings, varying in composition and application area, are sequentially applied to the measured etalon. The digitised data is then imported into the GOM Inspect software, enabling necessary measurements and result evaluation. This paper leverages engineering knowledge and proficiency with the GOM Inspect metrology software. The anticipated outcomes of this experiment are expected to offer novel insights into the influence of diverse powder coatings on dimensional accuracy. These findings can have practical implications across industries where measurement accuracy is crucial. Furthermore, this research can serve as a foundation for future advancements in the field and provide valuable guidance for selecting the appropriate scanning powder for specific optical 3D scanning applications.

Keywords

3D SCANNING, GOM ATOS, GOM INSPECT, POWDER, COATING

1 INTRODUCTION

Data acquisition of 3D objects has a wide range of application in reverse engineering, quality inspection, and industrial engineering [Raja 2008]. Traditional data acquisition methods are divided into contact and non-contact methods [Feng 2001], [Morovič 2016]. In contemporary manufacturing and engineering practices, achieving high measurement accuracy is of paramount importance for quality control, reverse engineering, and new product development. Optical digitization technology has gained significant prominence as a non-contact method for obtaining precise geometric characteristics of objects without the need for physical contact or causing deformation

[Kurc 2019]. However, the accuracy of optical 3D scanning can be influenced by various factors, among which the type of powder coating, commonly referred to as scanning powder, plays a crucial role. Scanning powders are widely employed in optical digitization processes due to their ability to enhance the surface quality of the scanned part by providing a matte finish. This, in turn, improves the fidelity and accuracy of the resulting digital 3D model. A diverse array of scanning powders is available, exhibiting variations in composition and recommended areas of use. It is important to note that each powder coating type exerts a distinct effect on the dimensional and shape accuracy of the optical scanning process. To ensure reliable and accurate measurements, it is essential to thoroughly investigate the impact of different powder coatings on the dimensional accuracy achieved through optical scanning. Understanding the relationship between powder coating characteristics and scanning accuracy is crucial for optimising scanning protocols and selecting the most suitable powder coatings for specific applications. This research paper aims to address this knowledge gap by comprehensively studying the influence of powder coating types on dimensional accuracy in optical scanning processes. Through rigorous experimentation and analysis, this study seeks to provide valuable insights into the effects of various powder coatings on the accuracy and precision of optical digitization.

The matte layer or powder coating is used for optical 3D scanning when the scanning parts consist of reflectivity, dark, or black surfaces [Medricky 2015], [Medricky 2019]. Polarisation filters and polarisation light techniques are used to eliminate surface reflectivity [Liang, J. 2023], [Zhu 2020].

In a study by *Pereira et al.* [Pereira 2019], the effects of different coating materials on the accuracy of three-dimensional optical scanning were investigated. Coatings of gold, silver, platinum, and carbon were applied using sputtering to enhance the scanned surfaces. Surprisingly, the study revealed that the inherent errors in the scanning process, specifically the registration of multiple point clouds, had a greater impact on accuracy than the choice of coating material. *Maeng et al.* in A Study on Electrostatic Powder Coating for 3D Scanning of Diffused Surfaces, an automatic, electrostatic powder-coating machine was developed, and three different experiments were conducted to compare this system with a laser interferometer and a T-scan 3D scanner. As a result, various characteristics of this new method were ascertained, including its good sensitivity to the different surface states of the bare surface, developer, and electrostatic powder coating. Furthermore, the outstanding scanning performance was verified, and it was demonstrated that this method achieved higher quality compared to traditional methods [Maeng 2015]. Palousek *et al.,* in the paper Effect of Matte Coating on 3D Optical Measurement Accuracy, evaluated a matte coating thickness in the area of 3D optical digitizing. They used two matting materials: chalk spray and titanium coating. Differences between chalk spray and titanium matting material were significant [Palousek 2015]. Franke *et al.,* in a study of process parameters of the atomiser-based spray gun for the application of a temporary matte coating for 3D scanning purposes, found the most suitable process parameters of the spray gun for deposition of matte coating. A mixture of TiO_2 powder and ethanol was used. This coating material was analysed by Phase Doppler anemometry and compared to the deposited coatings [Franke 2022]. Furthermore, Hruboš et al. used a mixture of TiO_2 powder and ethanol, but their study compared the new design of a spray gun with a standard spray gun used for a matte layer. The new design of the spray gun has an atomiser. The matting effect, thickness, and influence of various TiO2 powder particles were investigated in the coating [Hruboš 2022].

2 MATERIALS AND METHODOLOGY

Optical 3D scanning is a non-contact measurement technique that enables the capture and analysis of the geometry and dimensions of objects in a three-dimensional space. This technology utilises various optical principles, such as structured light projection, laser triangulation, or fringe pattern projection, to acquire data points from the surface of an object. The collected data is then processed to generate a digital representation of the object in the form of a 3D model. Optical 3D scanning offers several advantages over traditional measurement methods, including its ability to capture complex shapes, high measurement accuracy, and non-destructive nature. It has found applications in diverse fields such as industrial design, reverse engineering, quality control, and medical imaging [Vagovský 2015].

The experiment involved utilizing a variety of scanning powders to investigate the subject under examination. A total of 10 distinct types of matting powders were employed, each possessing unique characteristics such as shelf life, intended application areas, and methods of surface application. In order to maintain confidentiality regarding the manufacturer's products, the powders were designated with specific codes: "CHP" denoted chalk powder, while "DoA" represented duration of action followed by a corresponding numerical value indicating the duration in hours. Notably, "P" indicated permanent, "TD" referred to titanium dioxide, "Eco" signified environmentally friendly, "G" was used for airbrush application, and "U89" was a distinct chalk powder variant from those used previously. The following matting powders were used in the experiment:

- **sample no. 1 – CHP DoA 2**
- **sample no. 2 – CHP DoA 6**
- **sample no. 3 – CHP DoA 6G**
- **sample no. 4 – CHP DoA 24**
- **sample no. 5 – CHP DoA Eco**
- **sample no. 6 – CHP DoA 0**
- **sample no. 7 – CHP DoA P**
- **sample no. 8 – CHP DoA X**
- **sample no. 9 – CHP DoA P U89**
- **sample no. 10 – TD TiO2**

Prior to commencing the optical digitization process, a critical step was to select an appropriate measuring volume to ensure the desired and utmost accuracy in the experiment's results. The primary focus in this selection was on the size of the part to be subsequently digitized. Additionally, to achieve precise scanning of individual objects, careful consideration was given to the spacing of measured points that the chosen measuring volume could capture and scan effectively. Consequently, the measuring volume MV 100, capable of scanning individual points with a spacing of 45 µm, was deemed the most suitable and accurate option available for implementation at the faculty. Setting the parameters for the digitization itself represented a pivotal aspect of the experiment. To achieve this, the ATOS Professional software was employed. The scanning parameters were configured in a step-by-step manner, addressing exposure time, image quality, and resolution progressively. The exposure time played a crucial role in determining the duration for which the scanner sensor gathered information from the scanned part. A longer exposure time resulted in capturing more light, which directly impacted the scan result. The ATOS Professional software allowed for the specification of three distinct exposure times. The first option (1) was intended for optimal lighting conditions and well-prepared surfaces. The second option (2) catered to parts with inferior surface finishes, such as darker or shinier surfaces. The third option (3) was designated for parts with the most challenging surface properties.

The quality of the scanned images was governed by the quality parameter, offering two settings: "High" and "More Points." The "High" setting generated high-quality 3D points, but in certain cases, gaps could appear on surfaces with intricate shapes. Conversely, selecting "More Points" automatically generated a larger number of 3D points and placed them on complex surfaces to minimize gaps. The final step involved defining the scan resolution, presenting a choice between "Fast scan" (Half resolution) and "Full resolution The "half resolution/fast scan" option facilitates scanning at a reduced resolution of 2.5 megapixels, resulting in significantly faster scanning times. On the other hand, the "Full resolution" setting enables scanning at the highest camera resolution possible, which is 5 megapixels. After careful consideration, the following parameters were chosen for the scanning process: exposure time - option number 2, quality - High, and resolution - Full resolution. These settings were deemed most appropriate to achieve the desired level of accuracy and completeness in the digitization of the subject.

3 EVALUATION OF DIMENSIONAL ACCURACY

However, before the optical digitization process was carried out, there was an effort to find a suitable method with which it would be possible to compare individual values obtained from optical digitization. Inspection of the deposited layer of scanning powder on a confocal microscope was chosen as a suitable method. The measurement was carried out only with the use of matting powder, specifically CHP DoA P U89. The problem in evaluating the thickness of the measured layer of scanning powder was caused by the uneven application on the examined sample. The scanning powder layer looked like isolated islands at 20x magnification. Repeated measurement in order to achieve a more uniform layer of scanning powder had the same result - the deposited layers were isolated from each other. Therefore, the thickness of the applied layer was determined by measuring the so-called peaks that represented a layer of opacifying spray on the sample. The measurement was performed on the sample from the second experiment, where we had a larger view from the confocal microscope and more data from which we calculated the arithmetic mean. Finally, we obtained the individual peak sizes, from which we determined the thickness of the matting powder layer using the arithmetic mean. Based on the sizes of the individual peaks, which represent the thickness of the applied layer of matting spray, we calculated the arithmetic mean, which gave us the average height of the matting powder coating. This value reached 14.13 µm. However, the obtained value of the applied layer is not authoritative and cannot be taken as the exact obtained value of the applied layer. This method proved to be unsuitable for obtaining data on the thickness of the deposited layer of scanning powder. The main problem was that the deposited layer of scanning powder at 20x zoom was not continuous, which prevented obtaining the desired transition between the area of the sample with the deposited layer and without the opacifying powder. This problem was caused by the application of the scanning powder with a spray head, which created isolated islands on which the powder was trapped. The suggestion of applying a thicker anti-reflective layer and observing a wider area of the sample appeared to be a suitable solution to this problem. Therefore, the same measurement process was performed on another sample where the scanning powder was applied for a longer time. Unfortunately, despite these adjustments, the results achieved were the same as in the previous case, and thus it was still not possible to reliably determine the thickness of the applied layer of scanning powder. Figure 1 illustrates the measurement results obtained from a confocal microscope, revealing distinct islands of the applied anti-reflective powder on the measured sheet metal sample.

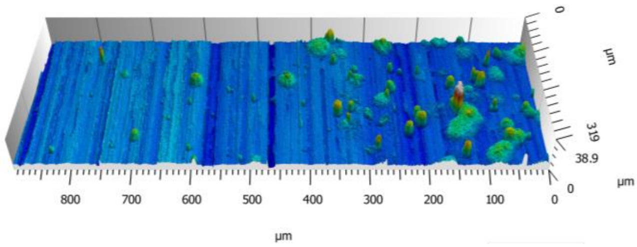

Figure 1 The surface of the measured sample inspected with a confocal microscope

After conducting 3D optical digitisation on the selected part, a ø17 mm etalon, the results were evaluated using GOM INSPECT software. The software provided data that were recorded in tables, enabling further analysis of values such as the arithmetic mean, minimum, and maximum measurements. The subsequent section presents these tables, accompanied by Boxplot graphs illustrating the range of measured values corresponding to each type of scanning powder utilised. Table 1 presents the measured values of the scanning powder layer thickness on the cylindrical surface of the etalon. It is evident from Table 1 that the lowest layer thickness was achieved with sample n. 10.

Table 1 Measured values of measuring the cylindrical surface of the etalon

Type of scanning powder	Minimum value of the matting layer [mm]	Maximum value of the matting layer [mm]	Arithmetic diameter of the matting layer [mm]
1 - DoA 2	0,030	0,036	0,033
2 - DoA 6	0,045	0,047	0,046
3 - DoA6G	0,015	0,020	0,017
4 - DoA24	0,058	0,069	0,063
5 – DoA Eco	0,019	0,020	0,020
6 – DoA 0	0,013	0,019	0,016
7 - DoA P	0,029	0,030	0,030
8 - DoA X	0,020	0,033	0,026
9 – DoA P U89	0,015	0,016	0,015
10 -TD TiO_2	0,010	0,012	0,011

With the help of Boxplots, we can graphically better see the range of individual layers of scanning powders used in a given experiment. As written in the text before, the thinnest deposited layer of scanning powder was achieved using sample no. 10, i.e. titanium dioxide. The thickness in this case was 0.011 mm. Similarly low values, which belonged to the lowest values in this experiment, included the values measured using sample no. 3, sample No. 6 and sample No. 9. The thickest layer of scanning powder was achieved with sample No. 4, CHP DoA 24 The thickness of the scanning powder layer reached an average value of 0.063 mm, which is a value that is significantly different from the other measured values. We also achieved a high value of the thickness of the anti-reflective layer using sample No. 2.

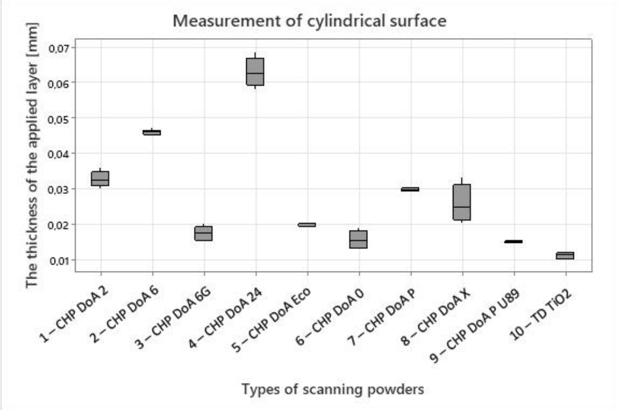

Figure 2 Measured values of the thickness of the applied layer for the measurement of the cylindrical surface

In addition to analyzing the thickness of the applied layer, the provided images also offer insights into the type of scanning powder used. Specifically, it allows us to distinguish between permanent and temporary matting powders, the latter being subject to evaporation during the scanning process. This distinction is discernible through the variance of values observed in individual measurements. Permanent anti-reflective products demonstrate minimal variation within their value range. For this experiment, samples numbered 5, 7, 9, and 10 were employed as permanent scanning sprays. Conversely, temporary preparations exhibit higher dispersion among the measured values. Table 2 presents the data concerning the radius of circles formed by cutting the measured etalon 3 mm away from the global coordinate system in the direction of the Y axis. These observations shed light on the behavior of different scanning powders during the experimental process.

Table 2 Measured values of the thickness of the deposited layer on a circle at a distance of 3 mm from the global coordinate system

Type of scanning powder	Minimum value of the matting layer [mm]	Maximum value of the matting layer [mm]	Arithmetic diameter of the matting layer [mm]
1 - DoA 2	0,040	0,043	0,040
2 - DoA 6	0,057	0,058	0,057
3 - DoA 6G	0,016	0,020	0,017
4 - DoA 24	0,079	0,090	0,084
5 - DoA Eco	0,020	0,021	0,021
6 - DoA 0	0,015	0,020	0,018
7 - DoA P	0,032	0,034	0,033
8 - DoA X	0,023	0,037	0,030
9 - DoA P U89	0,015	0,015	0,015
10 – TD TiO_2	0,010	0,012	0,012

This table shows the values of the diameter, minimum and maximum values of the radius of the circle for the scanning powders used in the experiment. Compared with the values in Table 1, it is clear that the average values of the radius of the circle, created at a distance of 3 mm from the global coordinate system in the Y axis, are higher than the values of the matting layer when measuring the cylindrical surface. These values increased exponentially with respect to Table 1, which means that the layer thickness values with values lower than 0.020 mm increased in the order of thousandths of millimetres, while the samples with higher values of the thickness of the applied matting layer showed an even more significant increase. This is evident from sample number 4, where the value of the thickness of the applied layer increased from 0.063 mm to 0.084 mm.

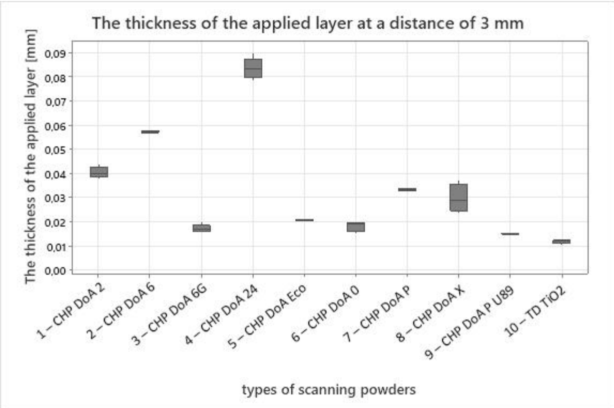

Figure 3 Graph of the thickness of the applied layer at a distance of 3 mm from the coordinate system

Table 3 contains the recorded measurements of the radius of the circle, which was created by the cut of the measuring gauge 6 mm away from the global coordinate system in the direction of the Y axis. The recorded values of the diameter of the radius of the measured circle in Table 3 are lower than those in Table 2 and approach the values of the diameter of the cylinder radius, which are listed in Table 1.

Table 3 Measured values of the thickness of the deposited layer on a circle at a distance of 6 mm from the global coordinate system

Type of scanning powder	Minimum value of the matting layer [mm]	Maximum value of the matting layer [mm]	Arithmetic diameter of the matting layer [mm]
1 - DoA 2	0,030	0,035	0,032
2 - DoA 6	0,042	0,044	0,043
3 - DoA 6G	0,015	0,020	0,017
4 - DoA 24	0,055	0,066	0,060
5 - DoA Eco	0,019	0,020	0,019
6 - DoA 0	0,011	0,018	0,014
7 - DoA P	0,031	0,032	0,032
8 - DoA X	0,021	0,032	0,026
9 - DoA P U89	0,014	0,015	0,014
10 - TD TiO_2	0,010	0,012	0,012

Using graphic visualization, it is clear which scanning powders created thinner or thicker layers. Based on the observation of the graph, it can be concluded that the best results were achieved when using scanning powders for samples No. 3, No. 5, No. 6, No. 9 and No. 10, similarly to the previous cases. The same applies to the thickest measured layer, which was achieved by sample No. 4 with a size of 0.060 mm.

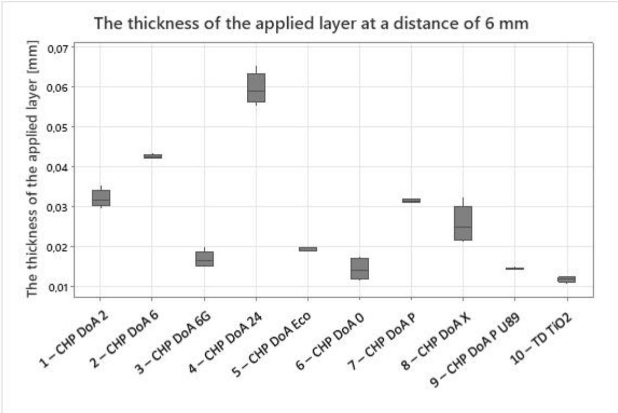

Figure 4 Graph of the thickness of the applied layer measured at a distance of 6 mm from the coordinate system

4 ANALYSIS OF MEASUREMENT RESULTS

In the previous chapter, the data were evaluated in the metrology software GOM Inspect, which showed us how individual scanning powders affect the dimensions of the digitized part. Measurements were performed on the cylindrical surface of the etalon, on a circle created at a distance of 3 mm from the global coordinate system and at a distance of 6 mm from this coordinate system. In addition to measuring the radius of this circle, we also performed measurements of cylindricity and circularity, which allowed us to determine the uniformity of the deposited layer. The entire scanning process was carried out at the Center of Excellence for 5-axis machining CE5AM at the Faculty of Materials Technology in Trnava of the Slovak Technical University in Bratislava, while we used the measuring volume MV100. A total of 5 measurements were performed for each scanning powder. During the measurement, we followed the same procedure of applying the anti-reflective layer, where we used a screen to eliminate the initial splash of the spray both at the beginning and at the end of the process. We applied the spray to the measured sample using a rotary table, turning the table around its axis. We applied this procedure to all scanning powders to ensure the same conditions for all samples examined. If we focus on dimensional accuracy, we achieved the best results in the thickness of the applied layer with sample No. 10, which is titanium dioxide. The thickness of the layer reached a value of 0.011 mm and the highest recorded value did not exceed 0.013 mm. It is also important to mention that the applied anti-reflective layer achieved the best cylindricity values of all samples. The method of applying the sample using an airbrush also contributed to these results, which allowed us to regulate the amount of the sprayed mixture. With scanning powders that are applied by spray, such a possibility of regulation is not available, and this is also reflected in the obtained results. Among the samples that are applied by spray, it is necessary to mention sample No. 9, which is a developer, and sample No. 6, which is a temporary scanning powder. With sample No. 9, we achieved an average thickness of the applied layer of 0.015 mm, while sample No. 6 reached a value of 0.016 mm. The difference between each sample is negligible in terms of scanner accuracy, so we consider these samples to be equally effective. A significant difference between the two samples is that sample No.9 is permanent and must be cleaned from the surface later, while sample No.6 is temporary and disappears by itself from the surface of the scanned object after a certain period of time.

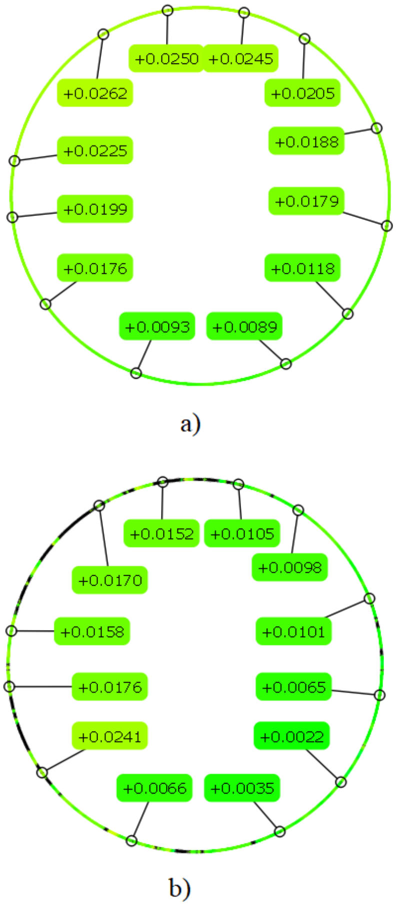

Figure 5 Inspection section created on: a) the first digitization of the etalon, b) the fifth digitization of the etalon

Figure 5 illustrates that the evaporation of the scanning powder affects the thickness of the anti-reflective layer at different places around the entire circumference of the created circle. When comparing Figure 5 a) and Figure 5 b), a significant difference in the thicknesses of the applied anti-reflective layer can be observed. It is therefore clear that the favourable measured values of the matting layer thickness of this sample are partly due to the fact that during scanning the powder layer evaporated, which led to a decrease in the value of the arithmetic mean of the thickness of the deposited layer. At the same time, it is important to note that after the fifth scan of the part, the required layer of scanning powder did not remain on the surface to create a sufficiently high-quality digital image, which caused unscanned spots on the etalon, which can also be seen in Figure 5 b) as black spots. This indicates that even though the thickness of the scanned layer was lower, it was manifested by an increase in the cylindricality. Therefore, it is important to note that the use of scanning powders with such evaporation effect and fast sublimation process is suitable under certain conditions when it is difficult to remove the permanent scanning powder from the surface of the scanned part. An example of such use could be the scanning of textile material, where permanent scanning powder could damage the scanned component, or with historical objects, where subsequent cleaning could damage the digitized object. In such cases, the use of an evaporating matting powder would be necessary and would bring significant advantages. Visually clearer comparison of the evaporative effect on the mentioned sample no. 6 is shown in Figure 6. This Figure compares just the digital image constructed in the first scan and the digital image in the fifth scan of the same etalon.

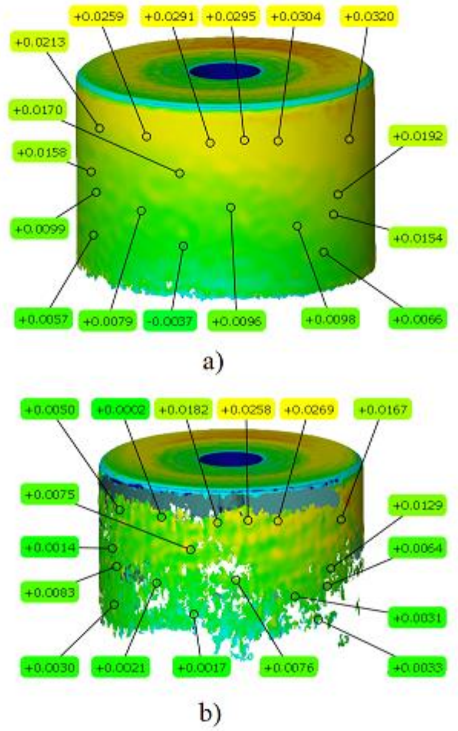

Figure 6 Colour map of deviations: a) for the first etalon scan, b) for the fifth etalon scan

It is clear from Figure 6 a) that the surface is relatively uniformly covered with scanning powder, in contrast to Figure 6 b), where a large part of the scanning powder is evaporated. This indicates that the use of evaporative scanning powders has its limitations also in terms of scanning speed. The evaporation effect compared to permanent scanning powders is shown in Figure 7. This figure shows permanent scanning powders as sample no. 9 and no. 10, which are compared to *DoA 0* evaporating scanning powder. It is possible to observe the decreasing thickness of the applied matting layer, while with permanent scanning powders the measured values do not differ much from each other and the dispersion between them is minimal.

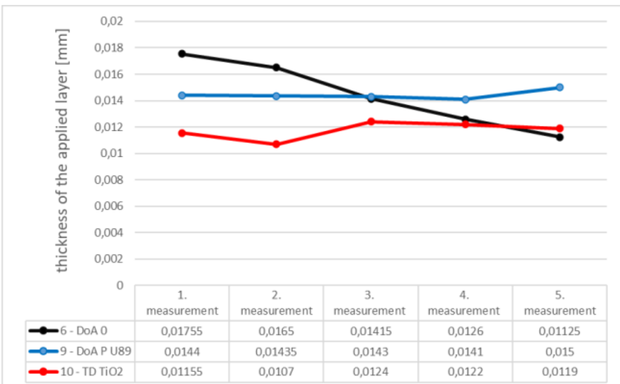

Figure 7 Comparison of the behaviour of permanent scanning powders and temporary scanning powders

This powder is similar in composition to DoA 6 scanning powder, but it is applied to the sample using an airbrush. According to information from the manufacturer, the sublimation time of this scanning powder should be between 6 and 10 hours. However, during an etalon digitization using this very sample, the scanning powder layer sublimated in less than 1 hour. Faster sublimation of scanning powder can be caused by various factors. One of the possible factors may be inappropriate environment during scanning and ambient conditions. However, the conditions were the same for all scanning sprays, so it is necessary to look for other causes that could have caused this situation. The most likely factor that affected the sublimation is the storage of the scanning powder. Improper storage can affect powder stability and cause faster sublimation. Due to these facts and the detected lack of scanning powder, it is not possible to compare the obtained results of this sample and it is necessary to exclude it from further analysis. We achieved the thickest layer of applied scanning powder using sample no. 4, *DoA 24*. This scanning spray is temporary, with a sublimation time of up to 24 hours. This capability enables the digitization of objects, which can take several hours. However, the thickness of the applied layer of this scanning powder approached the limit of one tenth of a millimeter. It is important to note that these values were obtained when cutting at a distance of 3 mm from the global coordinate system, and the average layer thickness of this scanning powder reached a value of about 0.063 mm over the total area of the cylinder. This value is the highest among the compared samples. I would recommend using this scanning powder only when digitizing parts that do not require high dimensional accuracy.

5 CONCLUSIONS

This experiment aimed to investigate the effect of different types of powder coating on the dimensional accuracy of cylindrical part in the process of optical 3D scanning. In addition, the study focused on determining the extent to which the selected powder coating could affect the dimensional and shape accuracy of the selected part, the etalon. The used material of the etalon was hardening steel 17 042. The thickness of the powder coatings was measured using an optical 3D scanner GOM ATOS II Triple SCAN with a measuring volume of MV100. To ensure consistent results, the digitization process was performed under the same scanning conditions. These types of scanning powders were used, and an important aspect was the uniform application of the powders to obtain relevant results. A rotary device was used to apply the powder and a sieve was used to prevent initial spatter. This procedure was repeated for all types of powder coatings, taking five measurements for each. A given type of matting powder was applied 1 time to the scanned etalon. After the digitization process, measurements were taken in the GOM Inspect system and the results were evaluated. To speed up the evaluation process, the parametric nature of the software was used, enabling automatic measurements on subsequent digitized models. The experiment revealed that the choice of scanning powder significantly affected the dimensional accuracy. Although there are many anti-reflective products available, only a limited number were examined in this study. Among the tested samples, sample no. 10 the least impact on dimensional and geometric accuracy with the ability to compete with sample no. 9 and sample no. 6. These samples also showed excellent shape accuracy values. Other scanning powders gave average values ranging from 0.02 mm to 0.033 mm, suitable for specific situations as intended by the manufacturer. Sample no. 4 showed the weakest values, primarily used for larger parts where the requirements for dimensional accuracy are lower. Based on the conducted experiments, it can be conclusively asserted that titanium dioxide (TD TiO_2) demonstrated the most favorable outcomes, resulting in the lowest thickness of the applied coating, measuring 0.011 mm. Conversely, the least desirable outcome was observed with *CHP DoA 24*, which exhibited a significantly higher thickness of the applied coating, measuring 0.063 mm. During the examination of *CHP DoA 6G* scanning powder, anomalies showing errors in the digitization process arose, which were subsequently confirmed by sample analysis. This faulty scan spray, a matting compound applied with an air gun, showed sublimation in less than an hour instead of the expected 6 hours. Such behavior can be attributed to factors such as improper storage. Measurements were evaluated on the cylindrical surface of the etalon, with cuts made at distances of 3 mm and 6 mm from the global coordinate system. The experiment revealed higher values of the layer thickness in the section at a distance of 3 mm from the coordinate system compared to the section at a distance of 6 mm. This discrepancy can be attributed to the deposition method, where the scanning powder was applied at an angle. Unfortunately, an alternative way of applying the anti-reflective layer to the cylindrical and front surfaces of the etalon could not be implemented. Finally, the obtained layer thickness results were compared with the manufacturer's specifications. The values of the thickness of the applied layer exceeded the values provided by the manufacturer of the scanning powder. This discrepancy may be influenced by the manual application method used instead of an automated process, as well as potential differences in environmental conditions specified by the powder coating manufacturer. In conclusion, this experiment clarified the significant influence of powder coating types on the dimensional accuracy of optical 3D scanning. It emphasized the need for careful consideration of powder deposition methods and highlighted the importance of selecting appropriate scanning powders based on the required accuracy requirements.

ACKNOWLEDGEMENTS

This work was supported by the Operational Programme Integrated Infrastructure, funded by the European Regional Development Fund, project “Development of new progressive cutting tools for machining parts produced by WAAM additive manufacturing technology to reduce the number of cutting tools when machining parts from different types of materials” (ITMS2014+: 313011BWQ8).

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