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COMPARATIVE STUDY OF DIFFERENT OPTICAL COORDINATE MEASUREMENT SYSTEMS

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Abstract *Geometric inspection of complex parts is of great interest in industrial production. Coordinate measuring machines (CMM) are widely used because they are flexible and have a high accuracy. They are often used for inspection of prismatic parts and freeform surfaces. The CMMs are relatively slow and allow generating a certain number of points at the surfaces. Faster measurement can be achieved with non-contact optical measurement systems (OMS), 3D scanners. These measurement systems offer several advantages like fast acquisition of points at the surface of the part, high density of points, independence of measurement results from rigidity of part, fast and easy access to the surfaces of the complex part. Compared to coordinate measuring machines, these measurement systems are less accurate. Also, the procedures of accuracy test for non-contact measurement systems and shape of standards are not strictly defined. The aim of this paper is to present a comparative analysis of two 3D portable and handheld scanners based on laser triangulation. For this purpose, two calibrated artefacts were used and two test parts were designed. The result of this analysis can be used for the selection of an optimal measurement system for a specific measuring task.*

Keywords *accuracy, digitalization, contactless measurement systems*

1. INTRODUCTION

Striving to reduce the total production costs, strict requirements are set for coordinate metrology. Coordinate measuring machines (CMMs) are the most common measurement systems in industrial metrology, especially in aerospace, automotive, die/ mold industry [1]. The CMMs with contact probes can measure up to 200 points/s with the maximum speed of 150 mm/s [2]. The CMMs are relatively slow and allow generating a certain number of points at the surfaces.

Faster measurement can be achieved with non-contact coordinate measurement systems. These measurement systems offer several advantages like fast acquisition of points at the surfaces of the part, high density of points, independence of measurement results from rigidity of part, fast and easy access to the surfaces of the complex part [3]. Inspection of complex parts and freeform surfaces requires high performance of scanners, accuracy first of all. Optical measurement systems reduce measurement time, but, in comparison to CMMs, these measurement systems are less accurate [4]. The process of determination of laser scanner accuracy is not clearly defined and it is necessary to perform various comparison tests.

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Giganto at all [5] compared different measurement systems based on laser triangulation, conoscopic holography, and structured light techniques for Geometric Dimensioning and Tolerancing (GD&T) verification of selective laser melting parts. Barbero and Ureta [6] analyzed the accuracy of different optical measurement systems based on the surfaces obtained from point clouds. Five digitization systems are considered with three calibrated artefacts and two test parts. Al-Ahmari and Aalam [7] focused their study on two laser triangulation scanners mounted on a CMM and an Articulated measuring arm. Design of Experiment (DOE) is used to optimize surface parameters in the process of reconstruction of complex parts. Toth and Živčak [8] compared the quality of scanned data at two different scanners. A comparative study included a dimensional and geometrical inspection of the special design of a test part. The part was produced by additive technology. Guerra at al [9] compared a structured light scanner, a photogrammetry based scanner, and a laser scanner. Additively produced step gauges were used for comparison of these measurement systems.

This paper presents a methodology of comparative analysis of two 3D portable and handheld scanners based on laser triangulation. For this purpose, two calibrated standards were used and two test parts were designed. Result of this study can be used to analyze dimensional and geometric accuracy of the analyzed measurement systems.

2. MATERIAL AND METHODS

Optical measurement systems were divided into five categories, i.e., the systems based on triangulation, ranging, interferometry, structured light, and image analysis [10]. 3D laser scanners based on triangulation method are the most commonly used for laboratory research and modern industry inspection. In this research two portable handheld laser scanners were analyzed (Figure 1-2).

The MMDx100 laser line triangulation scanner is integrated at a Nikon MCAx portable coordinate measuring arm (CMA) with six degrees of freedom (DOF). A portable arm can be mounted at the magnetic stand or tripod. The Creaform Handyscan scanner is a manual scanner without a stand. This scanner with seven red laser lines and a camera identifies target points placed near the object. The advantage of these scanners is the ability to generate high density point clouds at the surfaces of complex parts for a short time.

Fig. 1. An MMDx100 laser scanner integrated at articulated measuring arm

Fig. 2. An Creaform Handyscan 700 laser scanner

Table 1 indicates the major configurations of the scanners compared.

Table 1. Specification of scanners

MMDx100	
Accuracy	10 μm
Min. point resolution	65 μm
Max. frame rate	150 Hz
Stripe width	100 mm
Max. points per stripe	1000
Accuracy comb. with MCAx arm	48 μm
Light source	1 laser crosses
Handyscan 700	
Accuracy	30 μm

Resolution	50 µm
Scanning area	(175x250) mm
Measurement rate	480 000 measur./s
Volumetric accuracy	0,02 mm+0,06 mm/m
Light source	7 laser crosses

Calibrated artefacts like a gauge block, a cylinder, and a sphere are widely used in the industry. Comparison process and evaluation of scanners is based on the verification of two calibrated artifacts and two test parts (Figure 3). Chosen artefacts and test parts with set geometric features and freeform surface represent samples which cover a series dimensional and geometrical tolerances. Also, the scanned surfaces of test parts were compared to CAD models. Anti-reflection coat in spray form was applied to shiny surfaces of analyzed objects.

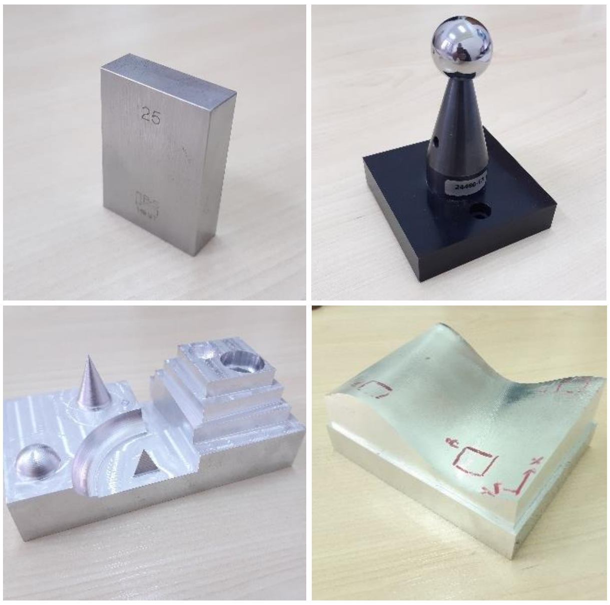

Fig. 3. Objects to be measured

A calibration process of used scanners was performed before digitization of objects. Because of the manual nature of the digitizing process, it is difficult to maintain consistency, even if the process is performed by the same operator. However, dispersion of values is bigger if scanning is done by a different operator. Considering this influence, analyzed objects are digitized by the same operator under the same strategy of scanning and the same alignment process. After the digitization process, raw point clouds are cleaned. Also, this process includes manually removing point clouds which do not belong to a part of object surfaces. Software Focus inspection and Geomagic control were used for processing point clouds and analyzing deviations. The digitization process was performed under controlled laboratory conditions.

3. RESULT AND COMPARISON

The calibrated artefacts were defined with their corresponding certified values and uncertainties. Their accuracy is much higher than accuracy of analyzed measurement systems and serves as reference. A gauge block and a sphere (Fig. 2) were used for determination of a systematic error of scanners and enabled to compare their accuracy. The obtained deviation is presented as the difference between the measured value and value accepted as a reference (Table 2). The digitization of artefacts was repeated tree times and obtained values presented a mean.

Table 2. Values of dimensional devaiations

Digitization systems	Gauge block length deviation (mm)	Sphere diameter deviation (mm)
MMDx100	0.0259	-0.0105
HandyScan 700	0.0484	-0.0367

Dimensions of the complex test part are not established and they are not calibrated. These test parts are used to test scanners in real conditions in practice. A digitized surface of test parts was compared to CAD models. Comparison results are shown in Figures 4-7.
Comparison of scanned surfaces and the CAD model was performed by the best-fit algorithm of alignment. Comparison based on numerical form deviation and global deviation using color maps allows quick and easy analysis of generated deviation by both scanners (Figure 4). Form deviations in the cross-section enable a better insight into the value of deviations in certain areas (Figure 5).

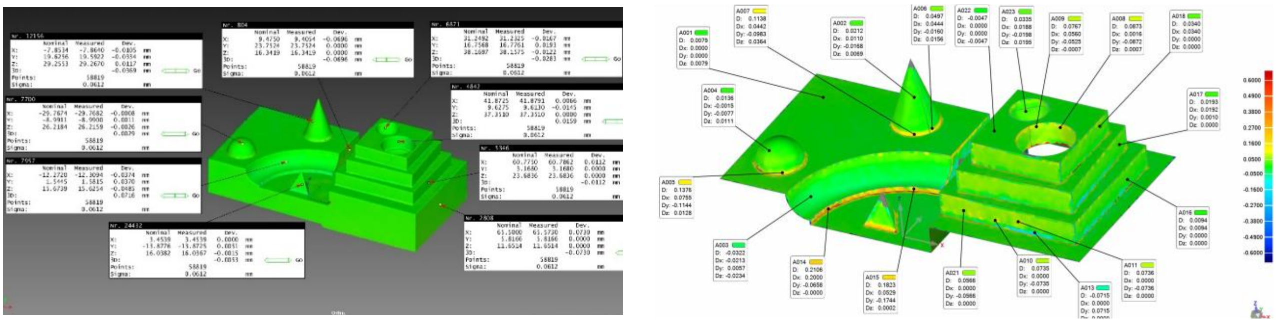

Fig. 4. Deviations between the scanned surface and CAD model of the prismatic test part (MMDx100 left, HandyScan 700 right)

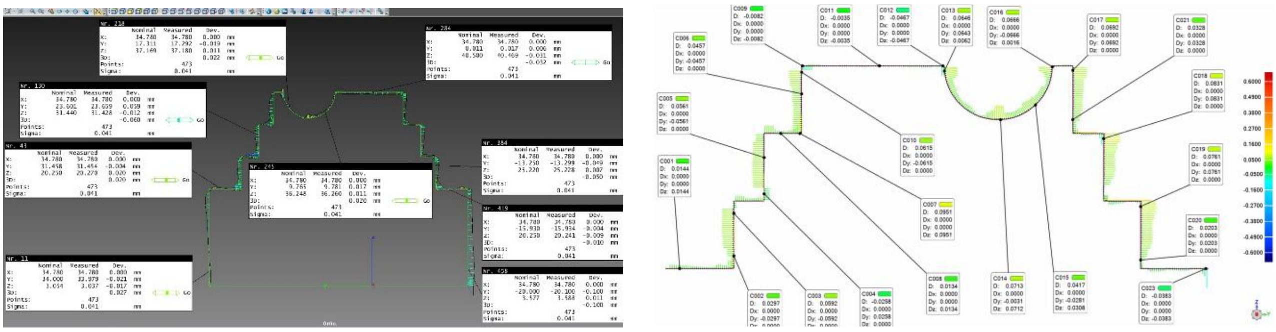

Fig. 5. Evaluation of deviations in the cross-section of the prismatic test part

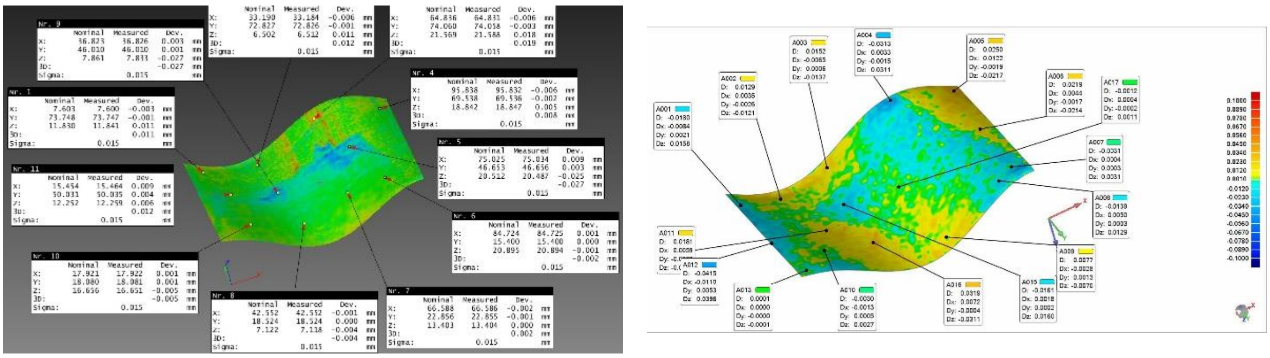

Fig. 6. Deviations between the scanned surface and CAD model of the freeform test part

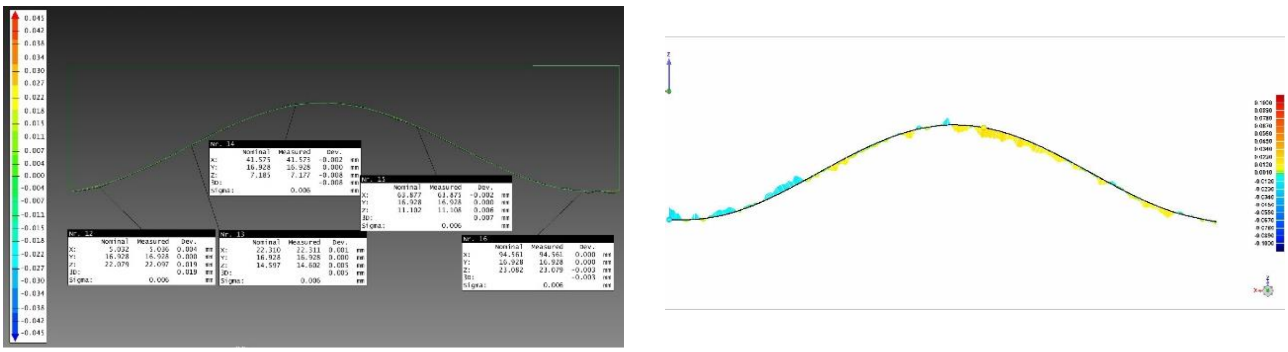

Fig. 7. Evaluation of deviations in the cross-section of the freeform test part

Quality of digitization used objects is dependent on a variety of factors. Some of them come from the scanner (sensitivity of sensor, calibration), then from the object (geometry, rigidity, roughness of surface, shiny surfaces), then from ambient conditions (lighting, dust, temperature,

humidity) and the operator's ability. Both scanners were used at the same laboratory conditions by the same operator.
Deviations obtained at the calibrated artifacts can be used for determination of systematic error of scanners. Based on the deviation obtained at the two difference scanners (Table 2), it can be concluded that the MMDx100 scanner has shown smaller deviations. The values of these deviations range between -0.0105 mm and 0.0259 for MMDx100 scanner by Nikon, respectively -0.0367 mm and 0.0484 mm for Handyscan 700 by Creaform.
The test parts with a set of geometric features and a freeform surface are not calibrated. They can serve for comparison of scanners in terms of distribution of points, quality of mesh, digitization in the area of edges and holes. Deviations obtained at the test parts are shown in table 3.

Table 3. Deviations obtained at the test parts

	MMDx100	HandyScan 700
Prismatic test part	(-0.07÷0.07) mm	(-0.07÷0.09) mm
Test part with freeform	(-0.03÷0.02) mm	(-0.04÷0.03) mm

4. CONCLUSION

The inspection process in different areas has encouraged the development of different measurement systems. The main goal of digitization systems is to generate and save object information for the purpose of dimensional and geometric analysis. The contactless digitization systems have their own standards and verify accuracy in accordance with manufacturers' procedures. To compare the performance process of different measurement systems and their accuracy is demanding. Metrological performance of contactless measurement systems is presented with different parameters which are difficult to compare with each other. In the case of an unambiguous approach, it is possible to make comparison of characteristics.
In this study two different laser scanners were compared. A comparison was performed in terms of accuracy and quality of digitalization of complex parts. For this purpose, two calibrated artefacts and two complex test parts were used. Based on the result, it can be concluded that the MMDx100 laser scanner demonstrated better accuracy than the Handyscan 700. Compared to MMDx100, the Handyscan 700 has better acquisition speed. Some of the surfaces of complex parts are difficult to access and they require more passes for scanning, which increases the noise in the point cloud. Based on the surface optimization algorithm, the Handyscan 700 scanner avoids the creation of multiple scans at the same area.

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