COMPARISON OF DIMENSIONS, SHAPES AND POSITIONS CONTROL USING CMM AND 3D SCANNER

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Abstract:

In this paper, measurements on stainless steel AISI 304 workpiece using Coordinate measuring machine Carl Zeiss Contura G2 and 3D scanner RangeVision PRO are compared and analyzed. Dimensional control is conducted by measuring 11 faces and 9 cylinders. Length, diameter, cylindricity, flatness and parallelism are controlled for features of interest. Using Calypso software on CMM and GOM Inspect software for 3D scanned model are used for creating virtual measurement strategies and dimensional and GD&T control. Deviations of measuring results using both measuring systems are shown and conclusions and recommendations for dimensional control are listed in tables.

Keywords: metrology; CMM; 3D scanning; inspection; measurement

1. INTRODUCTION

The main goal of this paper is to compare the results of measurements on two complex measuring systems with different operating principles, contact and non-contact. The idea is to demonstrate the eventual possibility of using an optical measuring device, which is simpler and cheaper compared to a coordinate measuring machine, as an alternative when measuring deviations from dimensions and shapes. The coordinate measuring machine used to measure metal workpiece for this paper is stationary and very expensive to purchase in small and medium-sized enterprises. As an alternative for dimensional and GD&T control, a 3D optical scanner is used, which is much cheaper and easier to use. The basic characteristics of both complex measuring devices are shown in table 1.

Table 1: The basic characteristics of used measuring devices

CMM Contura G2		3D scanner RangeVision PRO	
Machine weight	1278 kg	Weight	6,5 kg
Workpiece weight	560 kg	Max rotary table load capacity	60 kg
Measuring range – XYZ (mm)	700x700x600	Workpiece dimension range	5-5000 mm
Length measurement error	1,8 µm	Scanning technology	Structured light
Repeatability range of E0	1,4 µm	Resolution	1920 x 1080
Scanning error	2,5 µm	Accuracy, mcm up to	18
Form measurement error	1,8 µm	3D resolution, mm up to	0,04
Single stylus form probing error	1,8 µm	Cameras resolution	6,4 MP

1.1. Workpiece 3D model

The workpiece on which the measurement was performed has its nominal dimensions. Based on the nominal dimensions, a 3D CAD model was created and the surfaces and features that will be measured and controlled were marked (Figure 1).

In the process of measurement and control, the deviation from the nominal measurements that occurs due to the technology of making pieces on the five-axis milling machine DMU60 MonoBLOCK is not taken into account. The measurement was performed on a calibrated coordinate measuring machine, and in relation to these measurements, a comparison of the measurement results obtained on the 3D scanner is made. According to the marked features, table 2 shows the controlled dimensions and shapes.
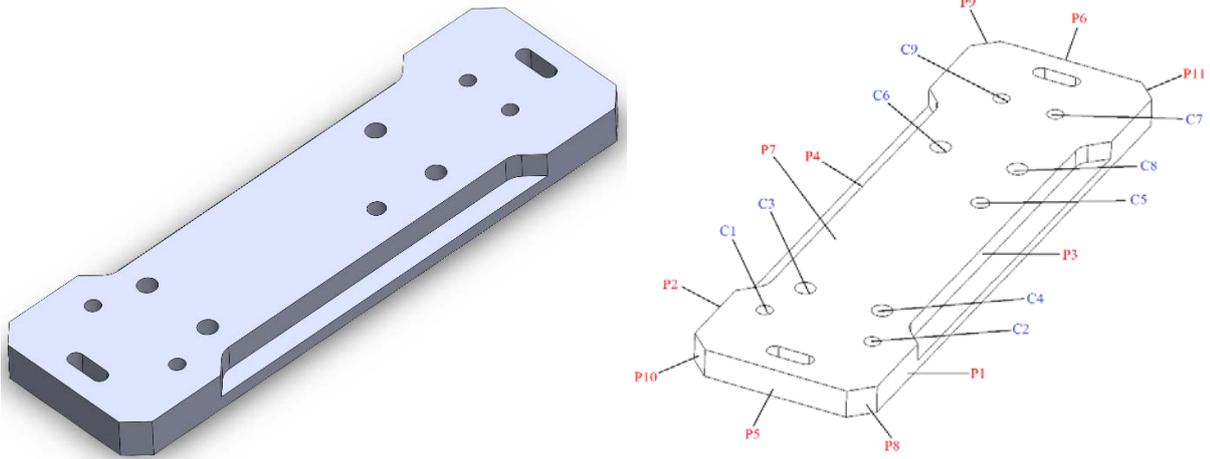
Figure 1: 3D CAD model of workpiece and its features of interest

Table 2: The controlled dimensions and shapes

Controlled dimensions and shapes	Features
Length	P1, P2; P3, P4; P5, P6; P1, P3; P2, P4
Diameter	C1, C2, C3, C4, C5, C6, C7, C8, C9
Cylindricity	C1, C2, C3, C4, C5, C6, C7, C8, C9
Parallelism	P1, P2; P3, P4; P5, P6; P8, P9; P10, P11
Flatness	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11

2. CMM MEASUREMENT

In the process of preparing measurements on a coordinate measuring machine, the first task is to position the work piece on the work table of the machine. With the help of electromagnetic devices, the piece was positioned on the work table in a position that allows unhindered movement of the measurement probe and measurement without the possibility of collision between the piece and the probe (Figure 2).

Figure 2: Workpiece positioned on CMM

In the measurement process, two approaches were used: manual and automatic. Using manual measurement, controlling the probe with a joystick, a certain number of points on each plane of interest were measured. Measurement results were obtained after manual measurement was conducted, without creating automatic and standardized measurement methods on the coordinate measuring machine. When it comes to cylinders, cylindricity and radius were controlled by manual measurements, using the VAST XT measurement probe. Several points were measured inside each cylinder, at two different heights, , thus achieving the conditions for creating an automatic measurement strategy for each of the cut parts of the cylinders. An automatic measurement strategy was created for each of the cylinders, which executes two circle paths at two different heights inside the cylinders (Figure 3a). Several parameters were defined under the circle path automatic strategy settings: speed: 5 mm/s, number of points for each circle: 50, start height: 1 mm, target height: 3 mm.

After the planes and cylinders have been measured, using the Form and Location option, within the Calypso software, the features to be controlled are created. For measurement and control, the default Least Square method of measurement and control was used (Figure 3b).

Manual and automatic strategies were conducted and results for dimensional and GD&T control were obtained.
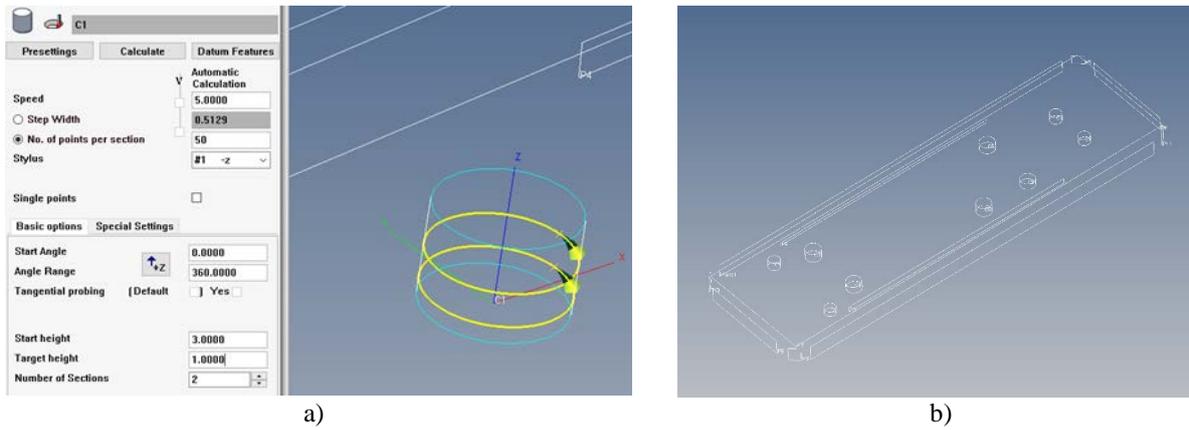
a)   b)

Figure 3: a) Automatic circle path strategy, b) Defined characteristics for the control

3. 3D SCANNING PROCESS AND VIRTUAL MEASUREMENT

3.1. RangeVision PRO scanning

Based on earlier research, in the process of 3D scanning, with the optical 3D scanner RangeVision PRO, there is a problem of surface reflection and color of the workpiece. The workpiece, made of stainless steel AISI 304 material, is glossy and it is necessary to reduce the influence of that factor on the scanning process. Using a powder spray, a white color powder layer was applied to the work piece, which allowed to obtain better scanning results. The workpiece was positioned on the rotary table of the 3D scanner (Figure 4).

Under the settings in the software ScanCenter, few 3D scanning parameters were defined: the number of scans: 16 and, inner scanning domain and the type of white light projection of the scanner. After the scanning procedure was carried out, also in the ScanCenter software in the postprocessing phase, unwanted surfaces on and around the model were removed, scans were registered and connected to the coordinate system, and a 3D virtual model was created in .STL format (Figure 5).

The meshed virtual model consists of over 20 million triangles. Without simplifying the model, a realistic metrological model was created and prepared for virtual metrology inspection.

Figure 4: RangeVision PRO 3D scanner and workpiece prepared for 3D scanning
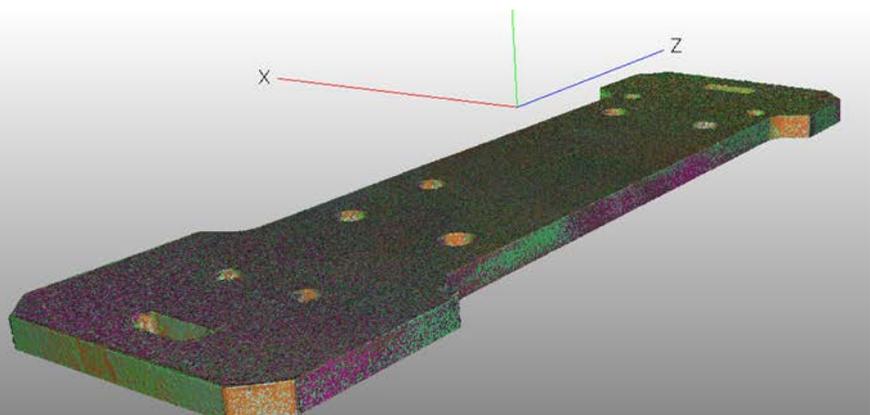

Figure 5 – Virtual scanned model

3.2. GOM Inspect control

Dimensions and GD&T control of the scanned model was performed in the GOM Inspect software. GOM Inspect is the gold standard in virtual metrology that complies with ISO and ASME standards.

The meshed model, created by 3D scanning, is positioned in the virtual environment of the software and the coordinate system is determined using the Pre-Alignment tool. Based on the features defined for control in this work, planes and cylinders were created that correspond to those that were controlled on the coordinate measuring machine. The same surfaces and cylinders are marked with the same labels and are controlled in the same order as in the Calypso software (Figure 6).
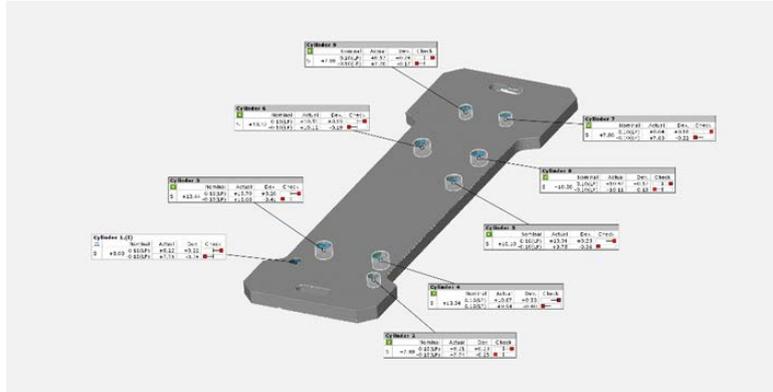

Figure 6 - GOM Inspect dimensional and GD&T control

Contrary to the Calypso software, the algorithm that allows us to create features in the GOM Inspect software, such as approximated planes and cylinders, uses the Gauss method. GD&T analysis was performed, including planarity, parallelism and cylindricity as well as two-point distances and diameter control and measured results were obtained.

4. RESULTS COMPARISON

After the process of measurements, the results of both measurements were compared, contact on a coordinate measuring machine using the Calypso software and non-contact using the ScanCenter and GOM Inspect software. All controlled dimensional and GD&T characteristics results are reprezented numerically in Table 3.

Table 3: Numerical representation of all controlled dimensional and GD&T characteristics results

Characteristic	Feature	CMM (mm)	3D scanner (mm)	Characteristic	Feature	CMM (mm)	3D scanner (mm)
Flatness	P1	0,073	0,1	Parallelism	P1, P2	0,0168	0,12
	P2	0,0156	0,07		P3, P4	0,0775	0,53
	P3	0,0748	0,21		P5, P6	0,0230	0,28
	P4	0,0099	0,17		P8, P9	0,0262	0,06
	P5	0,0064	0,29		P10, P11	0,0797	0,13
	P6	0,0037	0,22	Length	P1, P2	96,5921	94,8
	P7	0,0764	0,33		P3, P4	72,0340	70,88
	P8	0,0014	0,16		P5, P6	305,3988	305,20
	P9	0,0009	0,23		P1, P3	13,3354	12,08
	P10	0,0443	0,19		P2, P4	13,1722	11,81
	P11	0,0038	0,11	Diameter	C1	8,0386	7,76
Cylindricity	C1	0,1096	0,28		C2	7,9982	7,74
	C2	0,0642	0,30		C3	10,4484	10,03
	C3	0,0662	0,41		C4	10,4299	9,94
	C4	0,0871	0,44		C5	10,0357	9,75
	C5	0,2550	0,41		C6	10,4044	10,12
	C6	0,0304	0,27		C7	7,9092	7,63
	C7	0,2292	0,25		C8	10,2593	10,11
	C8	0,3421	0,34		C9	8,0373	7,70
	C9	0,0623	0,26				

5. SUMMARY

Analyzing the measurement results and comparing the results obtained by measuring on a coordinate measuring machine and a 3D scanner, it is possible to observe quite large deviations in certain characteristics.

It is important to note that the measurements were made on a very precise, accurate and calibrated coordinate measuring machine and on a 3D scanner that has less accuracy and does not have a standardized calibration method. In addition, one of the disadvantages of 3D scanning was that the workpiece had to be treated with a powder spray, which was an additional factor that added error into the measurement process itself.

Observing the deviation from flatness, we can notice that the deviation values range from 0.027 mm for the smallest surfaces to 0.2836 mm for the largest surface. The result is the influence of a small number of points that were measured on the CMM and based on which the flatness was controlled and the Gaussian method used to create the surfaces in the virtual measurement. For the deviation from cylindricity, the smallest value is 0.0021 mm, while the largest is 0.3529 mm. The values of deviations from parallelism range from 0.0338 mm to 0.4535 mm and smaller deviations are clearly visible for smaller surfaces.

As far as dimensional control is concerned, the deviations are significantly greater. They range in length from 0.1988 mm to 1.7921 mm and from 0.1493 mm to 1.4699 mm. In length measurements, the largest dimensions have the smallest deviations. As for deviations in diameter measurements, at maximum nominal diameters of 10 mm, deviations of half a millimeter are very large.

It is possible to conclude that 3D scanning can be used to control workpieces that have very large permitted tolerances and deviations from nominal measurements, but with more precise and accurate measurements, especially when controlling the internal dimensions of cylinders, it is impossible to get the desired results.

6. REFERENCES

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