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Original Article

THE USE OF OPTICAL SCANNER IN MEASUREMENTS OF COMPLEX SHAPE OBJECTS

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ABSTRACT

The paper presents the topic of measurements of simple and complex shaped objects. Optical measurement method with the use of laser scanner was presented, as well as the issues of geometry measurements and shape assessment by the use of the strategy of fitting to standard elements. The construction of a reference model for given elements by measuring of malformed elements was shown. The given examples confirmed the usefulness of presented optical method in the assessment of shape compatibility of real element with nominal one, as well as in the assessment of objects' deformation.

Keywords: optical scanner, complex shape elements, reference model, shape compatibility assessment.

INTRODUCTION

Measurements of dimensions and shape of elements are often the basis for assessment of possible objects loadings and elements using up. The analysis of the possibility of using different measurement techniques in measurements of complex shape objects is discussed by many authors [1, 6].

Among issues considered, special attention is paid to the problems of accuracy assessment of used measurement systems in relation to given tasks [3, 4, 7, 10, 11].

A special place in this field is taken by a coordinate measuring technique, where for the geometry description coordinates of points located on the object of researches are used. Typical coordinate systems include, among others, in contact techniques: coordinate measuring machines, measuring arms with contact probes or laser trackers and in contactless systems: optical scanners or computed tomography.

ELEMENTS SHAPE ASSESSMENT BY FITTING THEM TO STANDARD ELEMENTS

In coordinate metrology the analyzed shapes are often compared with simple elements, including the shapes, such as point, line, plane, circle, cylinder, cone, sphere and torus. For elements with a more complex shape the fitting is done using CAD models. In the paper various ways of elements assessment depending on their geometry were presented. First, the elements with a relatively simple construction were considered, then plates with complex spatial geometry, and as a third example elements consisting of many connected profiles were used.

The shape assesment of simple elements

The element, whose shape was assessed, were fusion plates made in a form of simple bars with holes used for bone fusion. Among the considered shapes there are elements presented in Figure 1.

Fig. 1. Fusion plates of simple geometry

In this case, new plates are simple elements with oval or round holes. These holes have chamfers for better fitting of mounting screws; the chamfers are visible in the pictures. Transfer of large forces and bending moments through the whole elements and fitting of plates to bones shape causes significant changes in their geometry. Changes in plates' shapes related to bones' fusion and with loads transferring in case of longest plates is most commonly associated with their curvature. The assessment of the above mentioned deformation is relatively simple. It is harder to change the object geometry spatially. Such a deformation has the element shown in Figure 2.

To assess the plate deformation was used the R-Scan RX2 optical measurement system cooperating with Omega 2025 arm (Fig. 3).

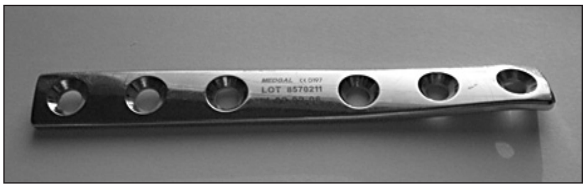

Fig. 2. Spatial deformation of fusion plate

Fig. 3. OMEGA measuring arm of Romer company with R-Scan scanning probe

This system allows to collect point cloud mapping the tested shape with use of a laser scanning probe. Data cleaning and filtering operations allow obtaining information on the size and shape of the measured object. The accuracy of used system and its usefulness in assessment of elements shape was analyzed in works [2, 3, 8, 9]. The tested object is shown in a form of point cloud in Figure 4.

3DReshaper software used for data processing allows, among other, to fit obtained points to certain basic geometric shapes such as: planes, cylinders or spheres. As a result of fitting, the assessment of the actual shape of measured surface can be done (Fig. 5).

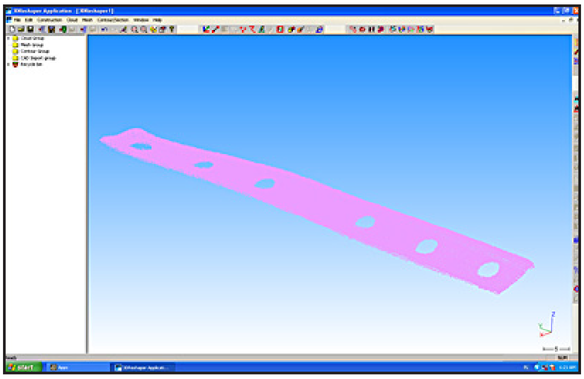

Fig. 4. Point cloud mapping the geometry of tested object

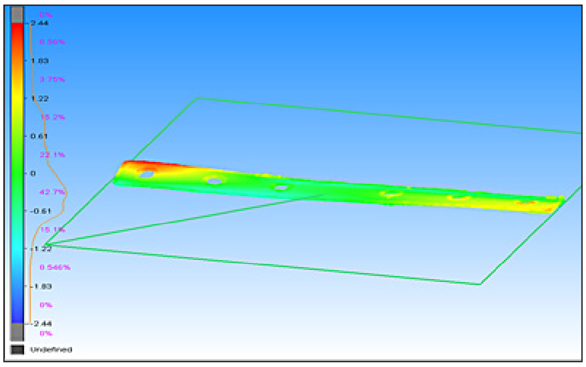

Fig. 5. The shape element assessment with the use of best fit plane according to the least squares method

Deformation values in certain points are presented in a form of a map. Distance values of measurement points and their distribution on the whole object can be read using the scale shown in a form of a graph in the left side of the diagram.

The shape assesment of complex geometry elements

Aside from objects of relatively simple shapes, there is also a separate group of elements of complex spatial geometry. Examples of spatially shaped elements taken into consideration are presented in Figure 6.

The considered elements have smooth holes, threaded with different diameters and different angles of hole axis in relation to the face plane.

Particular plates of similar geometry may differ in small details, such as additional undercuts in the concave part (Fig. 7).

Fig. 6. Complex geometry elements

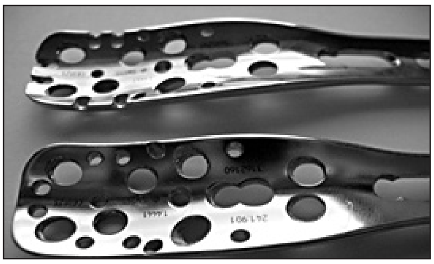

Fig. 7. Differences in elements shape

The plates tested had visible scratches. However, they do not change the elements' geometry significantly. To assess the shape change of such complex surfaces the optical scanner with 3DResaper software was used, as in the case discussed previously. The measuring system used allows for tested shape assessment in relation to the reference model. The standard shape can be obtained from the CAD model of the element or by measuring of the under-formed element. The way of model building based on the measurement and the element shape assessment is presented in the following part of this paper.

Building of a reference model

The first phase of the element shape assessment is to obtain the reference model. Because of the absence of the source CAD model, the model built on the basis of standard part measurements was adopted as a standard. Point cloud scanned on the plate is shown in Figure 8.

Due to the high reflectivity of the measured surface, during measurement appears some scatter of measurement points that requires their cleaning from noises. Points cleaned from noises allow to construct the model by applying appropriate triangle mesh on them (Fig. 9).

Models built in accordance with the presented method can be used not only to the element geometry assessment, but also as a basis for strength calculations carried out for example by finite elements method. Different software use various ways to build a mesh based on the point cloud [5].

The shape assessment by comparison with a model

The element, whose shape we compare with the standard is scanned also in the first step, then the data are filtered and in the next step the elements are fitted to each other (Fig. 10).

Elements fitting according to the Gaussian procedure are the basis for the plate surface shape assessment. The visualization of shape change is

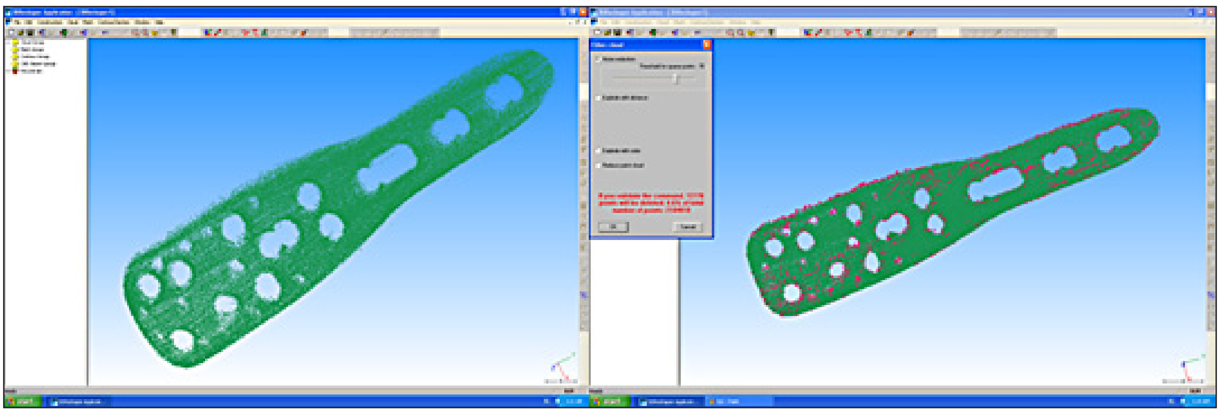

Fig. 8. Point cloud mapping the standard element and the process of its filtering

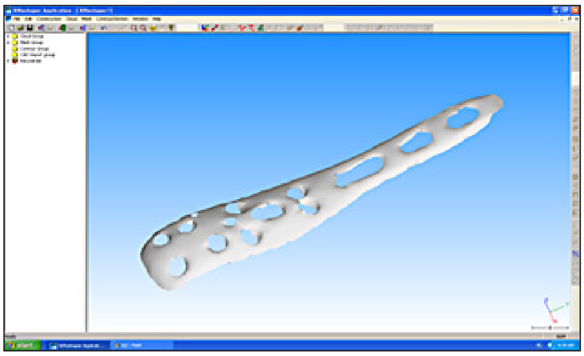

Fig. 9. Element face plane model

possible, as in the case of a simple geometry element, in the form of a map. Values of deviations in certain points can be presented in a form of labels, in which are given points coordinates (x, y, z), components of shape deviation in given directions and its value.

For compared elements obtained from measurements differences between shape of face planes in the area out of holes were up to 0.16 mm, which was the accuracy limit value of used measurement system. This allows to conclude that there are no significant differences in the geometry of assessed complex shape elements.

THE GEOMETRY ASSESSMENT OF MULTI CELLS ELEMENT

As an example of an element with a complex geometry we may take the window profile which has a form of two to eight cells, which differ in wall thicknesses. Such a construction guarantees good thermal insulation, and therefore low heat transfer coefficient. Plastic profiles have also an excellent acoustic insulation. Since the PVC profiles usually have low stiffness, the most suitable method to measure their geometry is to use optical methods. The high complexity of the shape of concerned element makes it very difficult to measure it as a whole body, due to the lack of possibility to map inner cell surfaces over the whole object length. Figure 12 shows the tested object and the effect of its digitization with visible fitting of the cylinder to one of the external open cells with the use of 3DReshaper software.

An alternative method for body measurements is performance of measurements and comparisons in cross-section.

It is possible here to use the comparison with the CAD model (Fig. 12) or performance of dis-

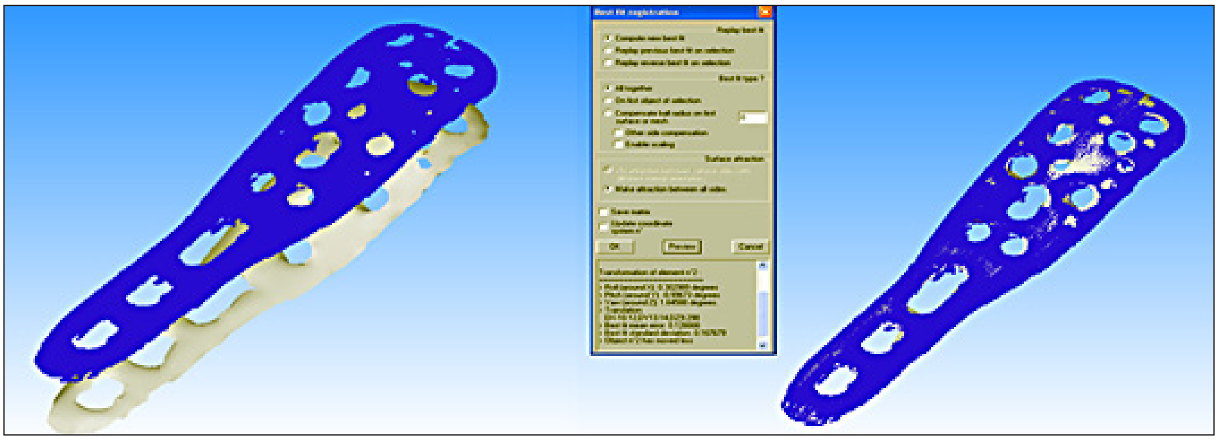

Fig. 10. Reference model and a cloud representing the tested element – elements' fitting

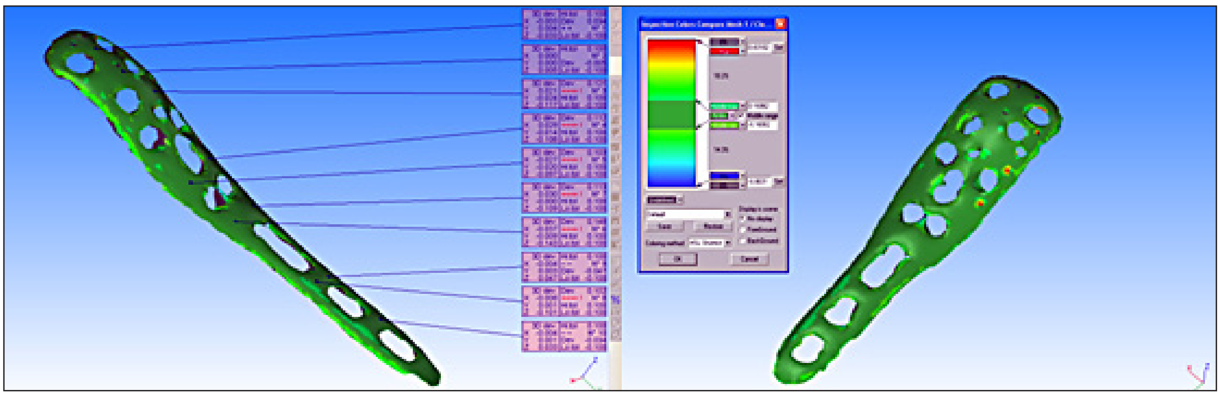

Fig. 11. Results of the element shape assessment by the comparison to the model

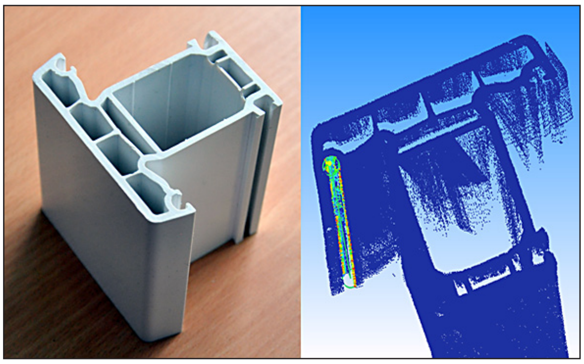

Fig. 12. T window profile and the point cloud representing thereof

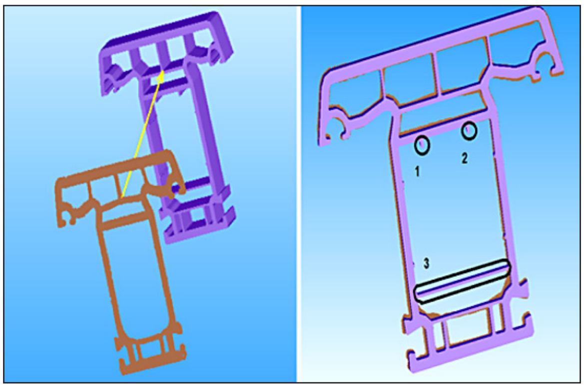

Fig. 13. Fitting of the section to the CAD model

tance measurements of selected points. A preliminary assessment lets to note differences in shape (fragments marked with no. 1, 2, 3) and wall thicknesses of the measured element in relation to the model (3DReshaper).

To measure wall thicknesses for each cell GOM Inspect software was used. GOM Inspect software enables, among others, to:

- review and process 3D point clouds,
- 3D control and mesh process realization.

The data processed in the system can be derived from white light scanners, laser scanners, computed tomography and coordinate machines.

Elements fitting in the front and side view realized in GOM system are shown in Figure 14.

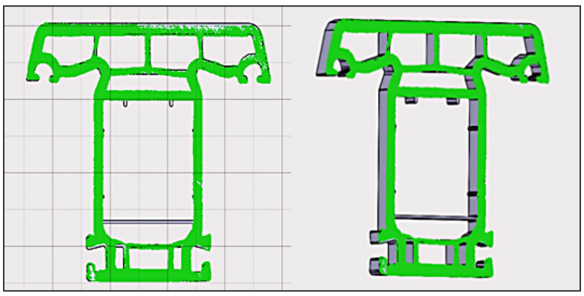

Fig. 14. Elements fitting in GOM system

Measurement of cell wall thicknesses

Measurements of wall thicknesses will be referenced to the nominal geometry as shown in Figure 15. Figure 16 presents exemplary measurements results and their visualization in relation to the external dimension of the profile.

In Figure 15 the nominal dimensions are marked with numbers 1–12. The obtained measurement results of certain characteristics are summarized in Table 1 and 2.

All the obtained wall thicknesses are larger than nominal values what results in greater rigidity of the profile.

CONCLUSION

The optical measurement method using laser scanner presented in the paper has proven to be an effective tool in measurements of objects of different shape complexity. The presented examples have proven its high usefulness in both the assessment of conformity of a real element shape with nominal element and the assessment of objects deformation caused by wear and tear. The use of different programs to results assessment expands possibilities of the used measurement systems. Laser scanner in connection with an appropriate data processing system is a tool that enables measuring variable curvature elements, which are very difficult or impossible to be measured using conventional measurement systems.

REFERENCES

1. Gąska A., Olszewska M.: Porównanie różnych urządzeń metrologicznych wykorzystywanych w zastosowaniach biomedycznych, Postępy Nauki i Techniki, 06, 2011, 155-163.
2. Juras B., Sładek J., Szewczyk D.: Możliwość identyfikacji błędów kształtu przy wykorzystaniu skanera optycznego, czasopismo Pomiary Automatyka Kontrola, 01, 2012, 112-114.
3. Juras B., Szewczyk D.: Dokładność pomiarów realizowanych skanerem optycznym, Postępy Nauki i Techniki, 07, 2011, 29-36.
4. Ostrowska K., Szewczyk D., Sładek J.: Wzorcowanie systemów optycznych zgodnie z normami ISO i zaleceniami VDI/VDE, Czasopismo Techniczne, 26, 2012, 167-179
5. Sitnik R. Karaszewski M.: Optimized point cloud triangulation for 3D scanning systems. Graphics & Vision International Journal, 17, 2008.

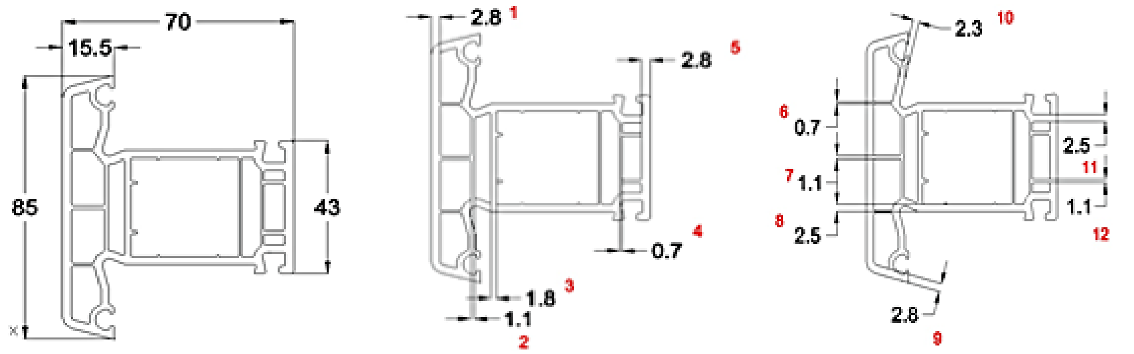

Fig. 15. Nominal dimensions of measured element: external dimensions and thicknesses of selected walls

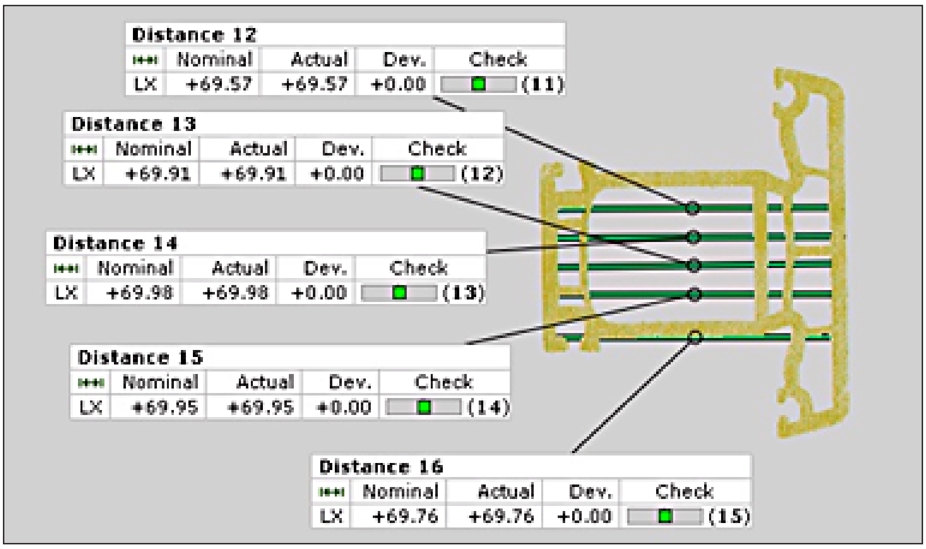

Fig. 16. Height measurement with links

Table 1. Presentation of results of external dimensions measurements

Element name	CAD value [mm]	Value point cloud [mm]					Average
		measurement 1	measurement 2	measurement 3	measurement 4	measurement 5	
Base width	43	42.91	43.03	42.92	43.01	42.71	42.92
Peak width	85	84.71	84.76	84.79	84.66	84.72	84.73
Peak height	15.5	15.12	15.47	15.73	15.66	15.39	15.48
Profile height	70	69.89	69.91	69.98	69.95	69.76	69.90

Table 2. Presentation of results of wall thicknesses measurements

Element number	CAD value [mm]	Value point cloud [mm]					Average
		measurement 1	measurement 2	measurement 3	measurement 4	measurement 5	
1	2.8	3.07	2.81	2.93	3.07	2.94	2.96
2	1.1	1.47	1.59	1.54	1.42	1.43	1.49
3	1.8	2.17	2.14	2.24	2.28	2.27	2.22
4	0.7	0.97	1.01	1.04	0.98	0.94	0.99
5	2.8	3.09	3.06	3.18	3.27	3.15	3.15
6	0.7	1	0.98	1.09	1	0.99	1.01
7	1.1	1.44	1.51	1.56	1.49	1.46	1.49
8	2.5	2.82	2.75	2.73	2.7	2.73	2.75
9	2.8	3.03	3.08	3.06	2.92	3.11	3.04
10	2.3	2.63	2.65	2.63	2.66	2.62	2.64
11	2.5	2.91	3.04	3.2	3.01	3.12	3.06
12	1.1	1.51	1.61	1.59	1.49	1.49	1.54

6. Sładek J., Gawlik J., Ryniewicz A., Krawczyk M., Kupiec R.: Metrologia współrzędnościowa w inżynierii produkcji a dokładność pomiaru i dokładność wytwarzania, Inżynieria Maszyn, 3, 2010, 20-34.
7. Sładek J., Gąska A., Olszewska M., Ostrowska K., Ryniewicz A.: Metoda oceny dokładności pomiarów realizowanych za pomocą ramion pomiarowych wyposażonych w optyczne głowice skanujące. Mechanik, 2, 2012, 133-139.
8. Sładek J., Ostrowska K., Gąska A., Gacek K., Kmita A.: Model matematyczny opisu dokładności Współrzędnościowych Ramion Pomiarowych. Inżynieria Maszyn, 14(2), 2009. 7-18.
9. Sładek J., Ostrowska K., Gąska A.: Modeling and identification of errors of coordinate measuring arms with use of metrological model. Measurement, 46, 2013, 667-679.
10. Sładek J., Sokal G., Kmita A., Ostrowska K.: Wzorcowanie Współrzędnościowych Ramion Pomiarowych (WRP). Acta Mechanica et Automatica, 1(2), 2007.
11. Sładek J.: Dokładność pomiarów współrzędnościowych. Wydawnictwo Politechniki Krakowskiej, pp. 495, Kraków 2011.