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Selection of relevant mode of thin and soft parts measurements on machines with multisensor possibility

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Abstract

This paper presents measurements of thin and soft parts that are easily deformable under contact force related to tactile measurement. Few types of such elements, widely used in practice, were chosen and measured on multisensor CMM using low force tactile probe, video probe and chromatic white light sensor. Measurement procedure included aligning of the workpiece based on points measured using different sensors and performing measurements according to multiple-measurement strategy method. Values of repeatability determined for measurement results from different sensors were compared. Differences in obtained repeatability values are significant. Discussion of aftermaths related to use of various types of sensors is also included in the paper.

Soft parts measurement, CMM, multisensor, repeatability, optical measurements

1. Introduction

Over the last decade, several trends have dominated the development of coordinate metrology, one of them is integration of different measuring systems and techniques into one device which can be called multisensory CMM. Systems of this type usually utilize solutions known from classic CMMs combined with optical probing systems such as: laser scanners, video probes or white light sensors. Such devices called Optical CMMs (OCMM) enlarge capabilities of classic tactile machines as well as increase automation and speed of whole measuring process. As the popularity of OCMMs grow, it should come as no surprise that their performance is tested in various aspects to ensure their correct functioning and guarantee appropriate accuracy of measurement. Most often researchers focus on chosen properties of optical probes and different factors which affects their accuracy such as: illumination, autofocus or filtering algorithms [1,2,3]. Another important issue connected with OCMMs is measurement uncertainty estimation for systems of this type [4,5]. The mentioned problem is even more challenging than in case of classic CMMs due to larger number of influencing factors, but also because each utilized probing system has different operating principle and can be characterized by different accuracy [6]. The question about comparability of results obtained using tactile and optical sensors has been examined through measurements of specially developed standards [7] or reference balls made of specially chosen materials [8]. In both cases obtained results showed significant differences depending on the type of probing system used during measurements. Same conclusions can be drawn on the basis of comparison of performance of different OCMMs used in industrial conditions described in [9]. However, in all mentioned cases tests were performed using reference elements most often specially projected for this purpose. This article focuses on checking comparability of results obtained for measurements of workpiece characterized by properties which can be met in normal industrial practice. Element chosen for experiments include thin and flexible parts for which obtaining comparable results for all probing systems included in OCMM can be especially difficult. The following sections include description of research procedure, presentation of obtained results and discussion with particular emphasis put on observed measurement repeatability.

2. Methodology and results

In order to be able to correctly estimate the repeatability with various sensors on a flexible element, a series of measurements was first carried out using a hard deformable element. The experiment was carried out using a matte finish standard sphere with a diameter of 30 mm. The measurement strategy was consisted on designing and measuring six points at different heights of the measuring sphere (Fig. 1). The measurement was carried out 50 times using each sensor – tactile probe, video probe and CFS sensor all of them are factory fitted by the manufacturer. In the case of the video probe, the point measurement was performed using the AutoFocus technique. Based on this, the mean height and standard deviation for chosen points were examined. Obtained results are presented in table (Tab. 1).

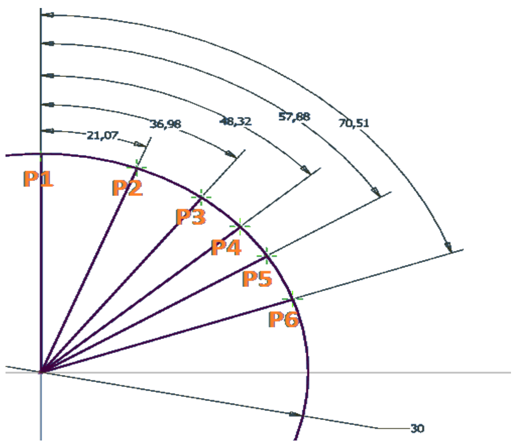

Figure 1. Distribution of measured points on the sphere.

Repeatability of point measurements was assessed using standard deviation. The deviation was determined for each point based on the measurement results. Based on the obtained results, it can be concluded that the smallest standard deviations of the measurement of selected points on the sphere can be obtained for point measurements using the chromatic focus sensor (CFS) head. The average standard deviation for all points is 0.00026 mm. As the results in the table show, similar values are maintained regardless of the point collection angle, defined as the angle between the approach direction (always from the top) and the direction normal to the measured surface. For the video probe, the average standard deviation is 0.0055 mm. The most stable values are obtained for measurements with a small angle of inclination (Point_1, Point_2), when the point measurement angle increases, the value of the standard deviation also increases noticeably. A similar situation can be observed for the tactile probe for which the average deviation is 0.00069 mm. For the last two points (Point_5, Point_6) the standard deviation values are the highest. The next stage of the experiment was to design the measurements of elements susceptible to deformation. For this purpose, plastic elements 44 x 23 x 15 mm with high machining accuracy were used, on which 6 points were chosen in different parts of the element (Fig. 2).

Table 1. Results of points measurement on sphere.

Name	Std. Dev. / mm	Name	Std. Dev. / mm
Point_6_CFS	0.00035	Point_3_CFS	0.00024
Point_6_OPT	0.01435	Point_3_OPT	0.00289
Point_6_TAC	0.00116	Point_3_TAC	0.00069
Point_5_CFS	0.00030	Point_2_CFS	0.00020
Point_5_OPT	0.00842	Point_2_OPT	0.00199
Point_5_TAC	0.00091	Point_2_TAC	0.00042
Point_4_CFS	0.00023	Point_1_CFS	0.00022
Point_4_OPT	0.00366	Point_1_OPT	0.00167
Point_4_TAC	0.00038	Point_1_TAC	0.00057

The part coordinate system was determined once, using the tactile head. Then, the procedure consisted in measuring each point with three available measuring heads in two settings was repeated 50 times. Based on this, repeatability was estimated for each point for each of the three probes.

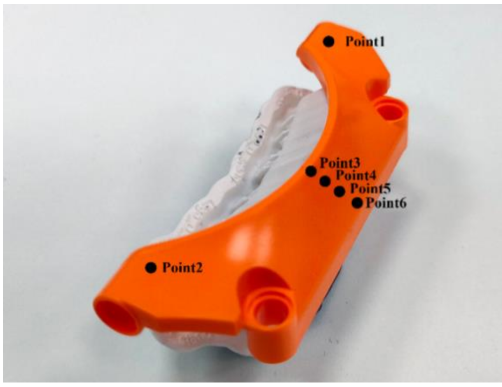

Figure 2. Distribution of measured points on plastic element.

Analyzing the obtained data, it can be concluded that in the case of measurements of points 1-2, where the direction vector in the direction of the z axis is close to k = 1, the best results are achieved for the tactile probe and CFS. Analyzing the next points 3 - 6, it can be concluded that the most repeatable results can be obtained with the CFS probe. For the same points measured with the tactile probe, the results reach poor values of repeatibility (at the level of 0.4 mm). This is due to the deformation of the object when a contact force of the measuring probe is applied, which results in incorrect determination of the direction vectors of the point. As a result, the measured point can be corrected by the incorrect value of the radius of the measuring tip, which makes the repeatability of the measurement low. Analyzing the results using the video probe, it can be concluded that the performance characteristics of the AutoFocus point acquisition system depend on the direction vector of the point and the reflectivity and roughness of the measured object.

Table 2. Results of points measurement on thin and soft part.

Name	Std. Dev. / mm	Name	Std. Dev. / mm
Point1_TAC	0.00026	Point4_TAC	0.37826
Point1_OPT	0.00292	Point4_OPT	0.01781
Point1_CFS	0.00039	Point4_CFS	0.00765
Point2_TAC	0.00049	Point5_TAC	0.36977
Point2_OPT	0.00332	Point5_OPT	0.00898
Point2_CFS	0.00071	Point5_CFS	0.00670
Point3_TAC	0.37690	Point6_TAC	0.37671
Point3_OPT	0.00377	Point6_OPT	0.00358
Point3_CFS	0.01044	Point6_CFS	0.00564

3. Conclusion

Based on the results obtained, it can be concluded that measurements using the CFS probe will in most cases be the best choice. Due to the non-contact nature of the measurements, it is possible to acquire points on a free and deformable surface with very high precision. An additional advantage of this method is resistance to various types of reflections and surface roughness. The disadvantages of this technology include the limited possibility of measuring elements with a complicated shape due to the nature of the measurement, thus requiring frequent reorientation of the measurement element to access the measurement surface. The use of the video probe, as in the case of the CFS probe, allows for non-contact measurement, thanks to which the measurement of a flexible element is possible. In the case of this head, point measurement using the AutoFocus system may in some cases result in point acquisition with lower accuracy. The advantage of this measuring head is the continuous preview of the measured object and the ability to select the appropriate magnification, thanks to which it is possible to pick a point from a given measurement window very precisely. The use of the tactile probe for measurements guarantees the highest accuracy in most cases. This head gives a lot of freedom when measuring solid elements. hard to deform due to the possibility of building various types of tip assemblies, thanks to which it is possible to measure a component with a complex shape in a limited number of workpiece settings. As shown in the experiment, the measurement of deformable elements may however cause some difficulties with the use of this technology, which results in the deterioration of the accuracy of point acquisition on a free-form surface.

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