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OPTIČKA DIGITALIZACIJA PROSTORNOG MODELA PROJICIRANJEM KODIRANOG SVJETLA

OPTICAL DIGITALIZATION OF A SPATIAL MODEL BY PROJECTING CODED LIGHT

Tomislav Jurković, Mirko Karakašić, Milan Kljajin

Professional paper

Abstract: *This paper analyzes deviations of a model developed by milling and a CAD model modeled according to its technical documentation. Deviations of model surfaces, dimensional deviations (length, width and height) and deviations of geometric tolerances are analyzed. It is indicated that on the scanned object specific measured values do not meet the appointment requirements in the technical documentation. Errors occurred during the manufacturing, because the selected object is relatively complex and contains many features such as holes, slots, cones and bores. It is noted that 3D scanners can be used to maintain the quality in the production because it is possible to control the resulting errors in geometry, but also for the purpose of reverse engineering and self-control of the production process.*

Keywords: *3D scanning, coded light, surface deviation, optical digitalization*

Stručni članak

Sažetak: *U radu su analizirana odstupanja modela izrađenog na glodalici i CAD modela modeliranog prema tehničkoj dokumentaciji istog. Analizirala su se odstupanja površina modela, dimenzijska odstupanja (duljine, širine i visine) i odstupanja geometrijskih torelancija. Pokazalo se da na skeniranom objektu određene izmjerene vrijednosti ne zadovoljavaju postavljenje zahtjeve u tehničkoj dokumentaciji. Do pogrešaka je došlo prilikom same izrade jer je odabrani predmet relativno kompleksan, sadrži mnogo značajki kao što su provrti, utori, konusi i rupe. Vidljivo je kako se 3D skeneri mogu koristiti za održavanje kvalitete u proizvodnji jer je moguće kontrolirati nastale pogreške u geometriji, ali isto tako i za reverzno inženjerstvo te samokontrolu proizvodnog procesa.*

Ključne riječi: *3D skeniranje, kodirano svjetlo, odstupanje površina, optička digitalizacija*

1. INTRODUCTION

Optical digitalization belongs to modern engineering technologies that find a wide application in reverse engineering, quality control, architecture, art, multimedia and medicine [1]. The purpose of reverse engineering is to manufacture another object based on a physical and existing object for which 3D CAD is not available [2]. Therefore, the application of optical digitalization in reverse engineering has an increasing role and is of high importance in the field of dental prosthetics [3].

3D digitalization systems can be classified according to different parameters [4 ÷ 9], and one of them is according to the application purpose: specialized dental systems and systems of more general purpose. In this paper we used a 3D optical system for general purpose.

On the market there are many 3D digitalizing systems of different technical characteristics [3]. Five systems specialized for extra oral dental 3D digitalization and four for a more general purpose are analyzed [10].

In the paper the latest generation of the ATOS CompactScan scanner is used. This scanner belongs to a group of optical stationary scanners. This scanner works on the photographic principle.

The object is scanned from several angles, and the scans are subsequently combined in order to create a digitized 3D image of the object. Data obtained by scanning are analyzed with *GOM Inspect* software [11].

Fig. 1 shows the model that will be reconstructed. Thus, the dimensions and geometry of real, manufactured model (Fig. 1) are compared with dimensions and geometry from its technical documentation.

2. PROJECTION DIGITALIZING SYSTEM

The scanning process of the model is created by the ATOS CompactScan system [12], (Fig. 1). The system belongs to the family of the third generation of active projection digitizers.

The system consists of a central set of incoherent projector coded light and a convergent configuration of two cameras. CCD chip generates an analog signal that is then transmitted to a computer. The cameras are analog and require the conversion of light intensity to digital signal using ICPCV digitizer [13]. The system is based on the blue light technology.

The projector, which is centrally placed, projects a predetermined raster structure on the surface of the object we want to measure (Fig. 2). This will allow an unambiguous space reconstruction of the surface based on the analysis of snaps taken with the left and right cameras [14]. The determination of object coordinates is carried out by means of triangulation method [15]. To solve the problem of unambiguity, the projector serves as a remedy, i.e. for recognition of identical image sensations of the object measuring point (stereo pairs) in each of the cameras.

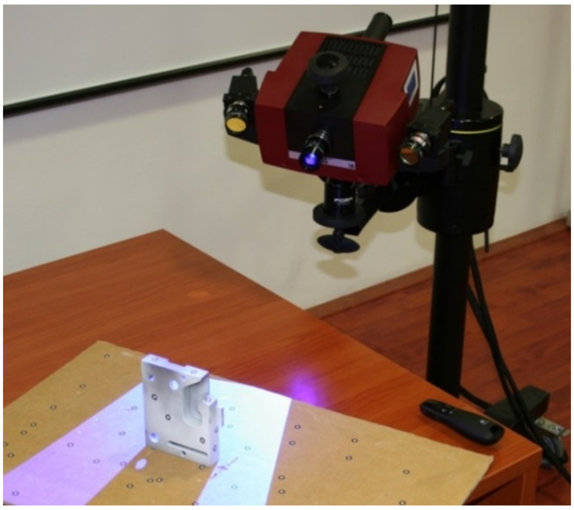

Figure 1 Scanning the selected element, apropos the back surface

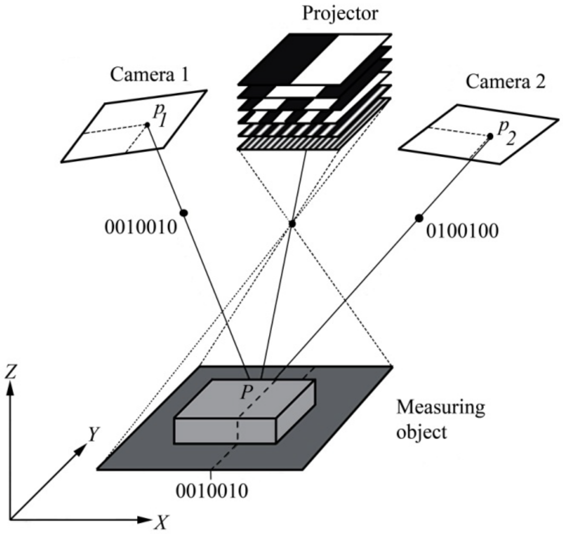

Figure 2 The principle of operation of the projection sensor [14]

3. THE PROCESS OF OPTICAL DIGITIZING OF A SPACE MODEL

In this paper the model presented on Fig. 1 is reconstructed. Dimensions of this model are compared with the dimensions given in its technical documentation. Scanning of the model is done on the 3D scanner in the Industrial Park Nova Gradiška d. o. o. In order to obtain a 3D digital model, scanning is performed from several different angles. By means of scanning, a cloud of points is obtained, from which the resulting polygon mesh is created. After placing the object in the best position, scanner starts to collect information.

For objects with highly specular transparent surfaces, grooves and holes do not provide a sufficient contrast to cameras, so powder needs to be used to reduce the reflection. After scanning and the application of powder, light is removed from the object.

On the scanned object the nomination of reference points is carried out (Fig. 1). The geometry of the reference points is dimensionally defined and they have a high contrast (white circles on a black background). Reference points serve as connection points for individual measurements, and allow for the individual measurements transformation into a common coordinate system.

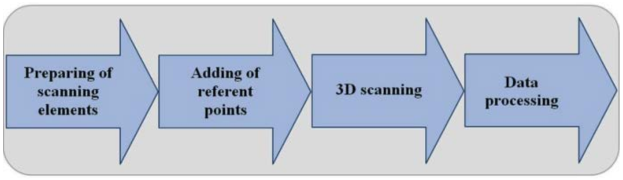

Figure 3 The order of operations during the optical digitalization of an element

Time scanning of an object depends on its complexity. When an object is more complex, the scan should be repeated several times from different angles. Due to the large number of slots, holes and cones, twenty scans are carried out for this object. The entire scanning process is shown in Fig. 3.

4. ANALYSIS OF DEVIATION SURFACES AND DIMENSIONS OF CAD MODEL AND THE MODEL OBTAINED AFTER OPTICAL DIGITIZING

In the paper deviations of a model developed by milling and a CAD model modeled according to its technical documentation are analyzed. In order to analyze the deviations of these two models, the model made by milling was scanned using a 3D scanner. Deviations of model surfaces, dimensional deviations (length, width and height) and deviations of geometric tolerances are analyzed. For comparison and analysis of the results the GOM Inspect software was used [11].

After alignment of the CAD model with the model obtained by scanning, analyzing of the surface deviation took place. With the *Surface Comparison* tool sensing deviation of particular points and sections of model was performed.

For the analysis of surface deviations the measuring scale with precision tolerances of 0.2 mm was used. In Fig. 4, the gray areas on the model are displayed. These areas are not measured in the analysis of surface deviations, because they exceed the set limits.

The upper surface of the model is mostly marked in green which means that it is a deviation in the range of 0 to 0.035 mm. The front face and the individual cylindrical surfaces and slots are marked in yellow and in those parts the range of deviation is 0.035 to 0.09 mm. The big difference in the deviations in certain surfaces of the model is the result of a fault that occurred during the manufacturing stage. During the manufacturing of complex parts with a lot of features, such as this part, faults are possible during manufacturing (Fig. 4). This

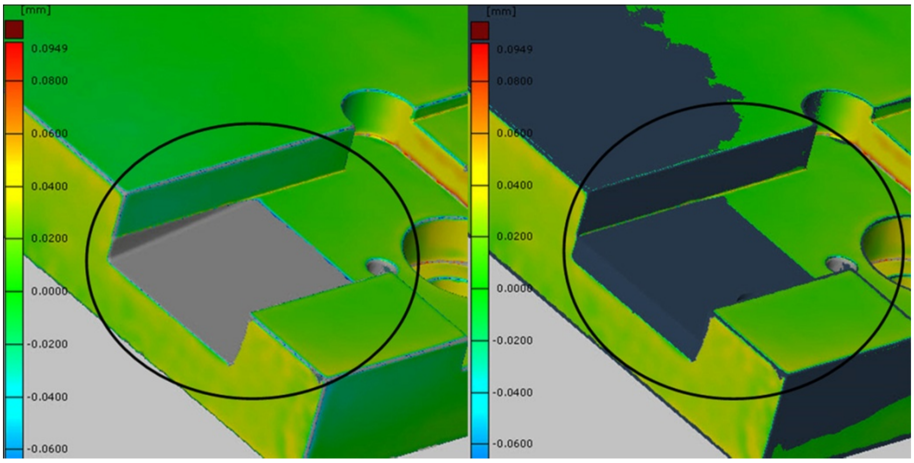

Figure 4 Manufacturing fault

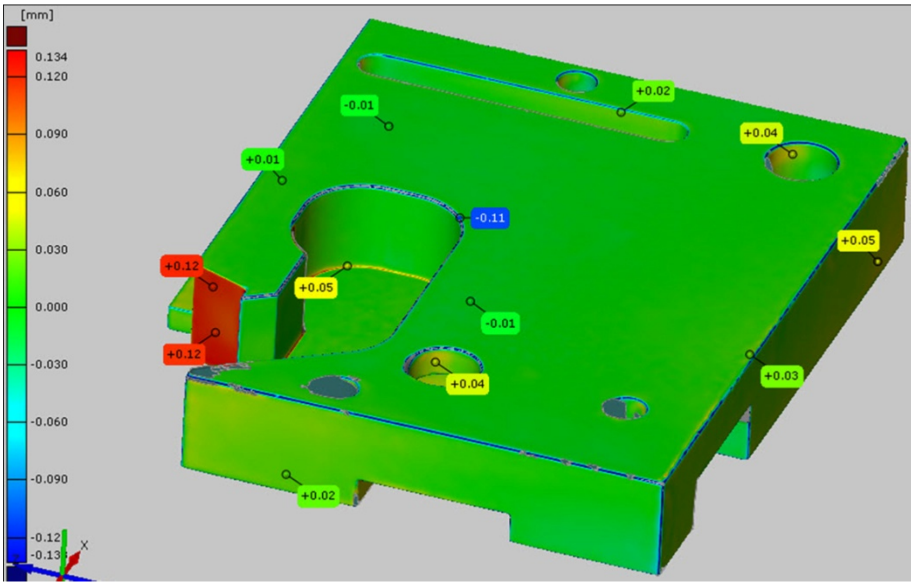

Figure 5 Deviation in particular points on the surface

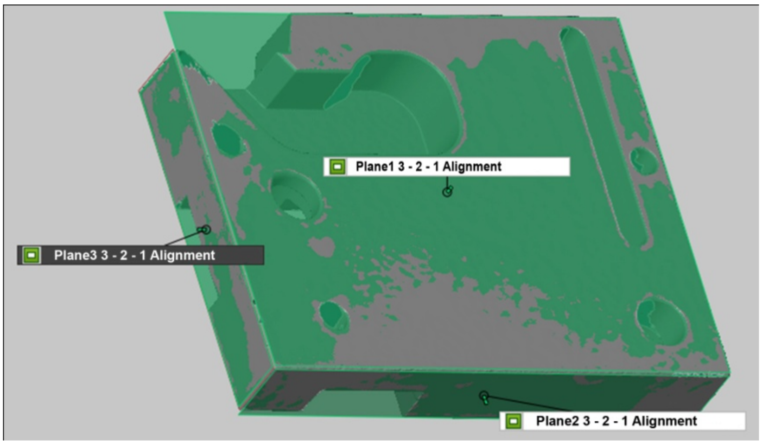

Figure 6 3 - 2 - 1 alignment by set planes

example shows that 3D scanners can be used to maintain the quality in the manufacturing because it is possible to control the resulting faults in geometry. If it is a larger series, after generating NC code and making the first model, the scanner can be used as a self-control unit in the manufacturing process.

The previous analysis is not precise enough and is used only as a visual representation. In Fig. 4 it is not known what the exact amount of deviation for the desired point of observation is. In order to carry out an analysis on specific points of the surface, it is necessary to see dimensional cards.

Fig. 5 shows cards with the amounts of deviations, onto which values at certain points were entered. It is evident that the maximum deviation is 0.12 mm, which is presented in red color. This analysis of surface was achieved using the principle of 3 - 2 - 1 alignment.

For analysis of the geometrical tolerances reference planes are necessary. Three additional planes are constructed as a basis for the model alignment. The first plane is set on the upper surface and by a Gaussian function its optimal position is obtained. On this plane there are set points Z1, Z2, and Z3. Then, the second plane is defined by the lateral surface of the model. On this plane there are set points Y1, and Y2. Point X is set on the third plane. This plane is set on the front side of the model. Based on these points, as in the previous case, the 3 - 2 - 1 alignment was carried out. Fig. 6 shows this procedure.

After alignment reference elements were made, i.e. A and B bases. On the basis of A and B the tolerance of perpendicular and tolerance of placement will be checked.

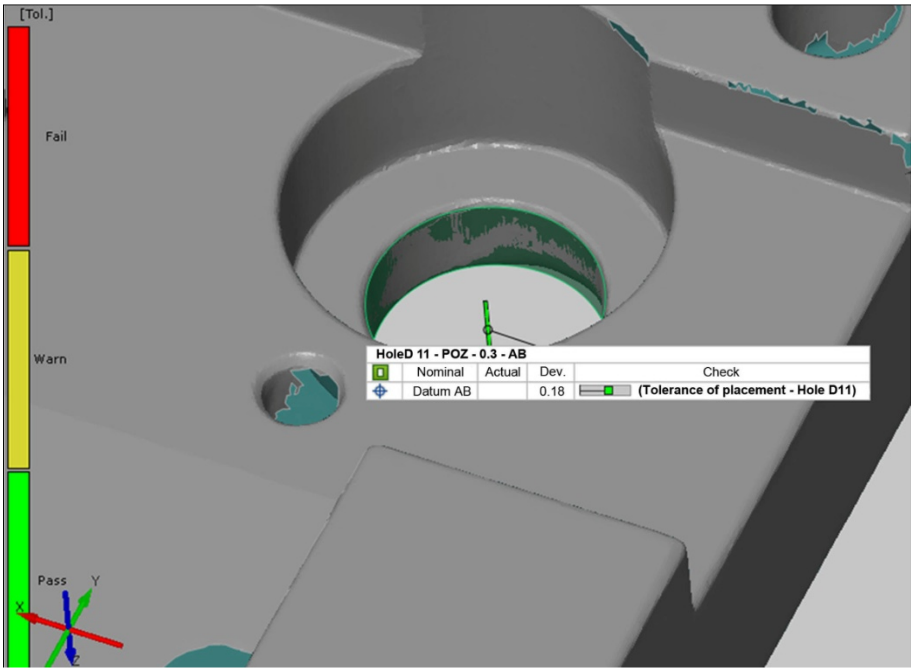

Figure 7 Hole control of diameter of 11 mm

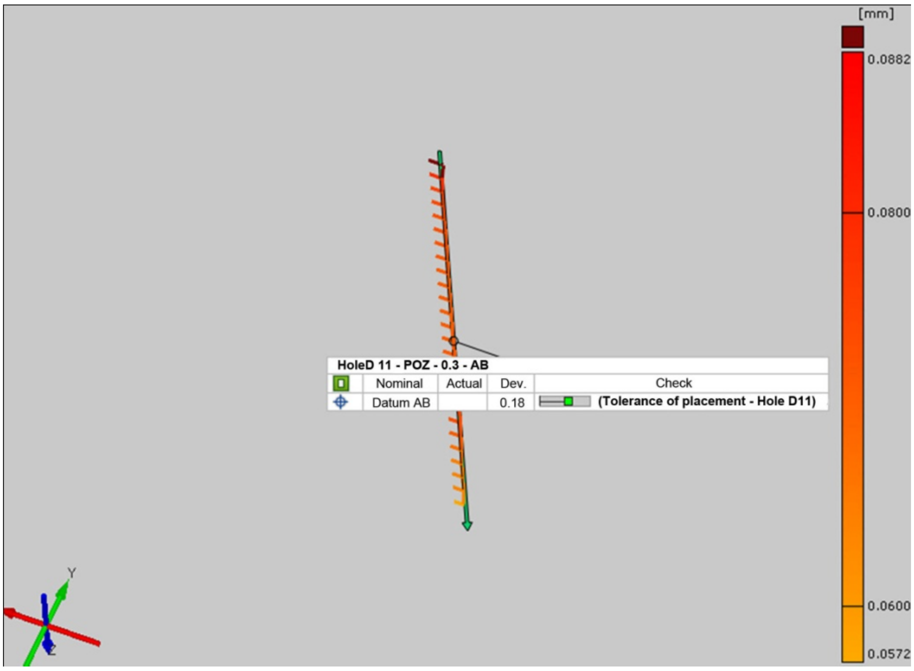

Figure 8 Vector representation of deviation center of the circle

Control results of placement tolerance of the hole are shown in Fig. 7. It is evident that the center of the circle is within the set tolerances. The center of the circle must be within two parallel planes at a distance of 0.3 mm, which are symmetrically arranged with respect to the theoretically correct position of the reference plane A and the reference plane B. The maximum deviation from the center of the circle is 0.18 mm, which is more than satisfactory. Vector representation of the hole center deviation is shown in Fig. 8.

Furthermore, the perpendicular tolerance of the upper surface was checked. In Fig. 9, which is separated from the technical drawing, it is possible to see that the default perpendicular tolerance on the surface is 0.02

mm. Tolerated surface must be within two planes, which are arranged at a distance of 0.02 mm and perpendicular to the bases A and B.

After assigning the required parameters, i.e. after defining the reference plane and tolerance in relation to the aforementioned, results can be read.

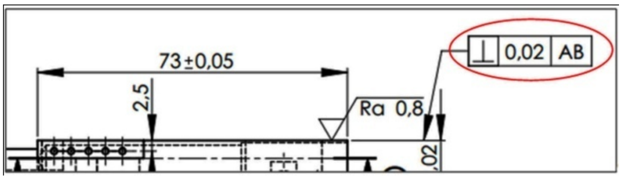

Figure 9 Representation of the default perpendicular tolerance

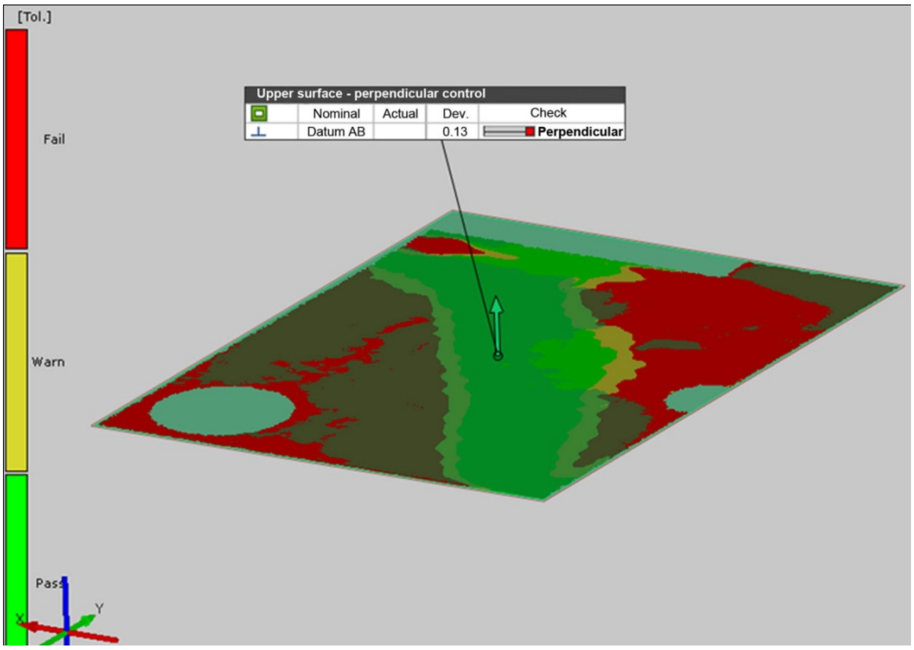

Figure 10 Representation of results of controlling perpendicular tolerance

In Fig. 10 it is possible to see that the upper surface does not satisfy the perpendicular condition. Tolerance is 0.02 mm and the actual maximum deviation is 0.13 mm.

5. CONCLUSION

The paper presents an analysis related to the verification of geometry and dimensions of an object manufactured on a milling machine, according to dimensions and tolerances of the technical documentation. Some dimensions on scanned object do not meet the appointed requirements in the technical documentation. It can be concluded that the errors occurred during the manufacturing, because the object contains many features such as holes, slots and cones. From that reason this object is complex. During checking of geometrical tolerances (perpendicular tolerance and placement tolerance) there was an almost negligible deviation from set points. Maximum deviation from the placement tolerance of the analyzed hole is 0.18 mm, and the default tolerance of placement in relation to the reference planes is 0.3 mm. When checking perpendicular tolerance of the upper surface, in some parts deviations are 0.13 mm which is the maximum deviation. Allowed deviation is 0.02 mm.

Geometrical deviations can be caused by faulty manufacturing, but not necessarily. Deviations may occur during constructing the A and B bases, related to the referent planes in the computer program *GOM Inspect*. These bases are connected to some other, previously defined planes. In such cases, it would be desirable to make full scan parts of an object that may affect the measurements. This would result in better scanning of holes, in order to capture the entire contour of the holes. It would be better to generate a cylinder with set A and B bases in its center.

Except for the measurements, these scanners can be used for reverse engineering. Certain elements can be reconstructed, and based on scanned models it is possible to create CAD models. However, not every automated process or software can generate a CAD model from an existing scanned models. For this reason, progress can be, apart from the 3D scanning technology, expected in the development of software that is closely related to this area.

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Author contact:

Mirko Karakašić, PhD, Assistant Professor
J. J. Strossmayer University of Osijek
Faculty of Mechanical Engineering in Slavonski Brod
35000 Slavonski Brod, Croatia
E-mail: mkarakas@sfsb.hr

Milan Kljajin, PhD, Full Professor
J. J. Strossmayer University of Osijek
Faculty of Mechanical Engineering in Slavonski Brod
35000 Slavonski Brod, Croatia
E-mail: mkljajin@sfsb.hr

University North
42000 Varaždin, Croatia
E-mail: mkljajin@unin.hr