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QUALITY INSPECTION OF FREE-FORM SURFACE PARTS

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Abstract: Free-form surface parts have been widely used in many industrial areas, such as aerospace, automobile, shipbuilding, etc. Inspection of freeform parts can be carried out using inspection based on CAD model machined parts. This type of inspection, based on the CAD model, is known as the CAD inspection. The purpose of applying this kind inspection is to meet the complex requirements of the machined freeform parts. The inspection of free-form surfaces is a difficult process due to their complexity and irregularity. In this paper, one parts with free-form surfaces were analysed. A systematic approach to the analysis of geometry has been carried out, which involves the development of surface models of objects using the technique of reversible engineering (RE). After that, a comparison of the geometry of digitized models was made. After a comparison of the geometry and the analysis of the obtained results, it was confirmed that this approach influences a significant improvement in the efficiency of the control of the production process.
Keywords: Free-form surfaces, laser scanner, reverse engineering, inspection

1. INTRODUCTION

Inspection of freeform parts implies determination deviations of certain parameters and then comparing them with nominal values. The inspection plays an important role in industrial production because it ensures product quality. Measurement methods are generally divided into two categories: contact measurements and non-contact measurements . Although both methods of measurement are widely used in data acquisition in measurement or reverse engineering (RE), it has been shown that each technique has its own characteristics and limitations, which lend them to particular applications [1]. Tactile coordinate measuring machine (CMM) methods are widely used for dimensional metrology because of their high accuracy. The generation process of initial set of points is very time-consuming on complex machined parts if applied to RE [2]. The measurement speed, about a maximum of 60 points per minute and the accessibility limitation of CMMs represent a serious disadvantage that may involve declining industrial competitiveness [3]. An alternative approach is represented by non-contact digitisation of surfaces based on optical techniques, for example laser scanning. A triangulation method is applied on a measured surface to obtained point cloud data at 3D laser scanner. The benefits of this method of measurement to generate a large number of points in a short time. This makes it a common choice in RE applications and quality control methods of freeform surfaces [4].

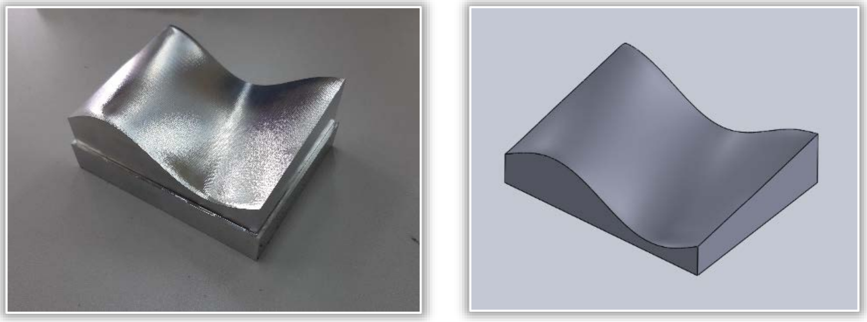
However, the free-form surfaces have been widely applied in many industrial areas. It is difficult to measure or inspect them because of their complex geometry. To improve the efficiency and accuracy of measurement of free-form surfaces, an inspection procedure is presented in this paper for measurement of free-form surface parts based on CAD model. This type of inspection, based on the CAD model, is known as the CAD inspection.

2. MATERIALS AND METHODS

This section discusses the methodology of inspection of free-form surfaces and presents a workipiece and measuring equipment.

— Measured workpiece and equipment

Figure 1a shows the analysed object, i.e. a workpiece with a free-form surface. The workpiece is made of aluminium alloy Al 7075 (AlZnMgCu1.5), characterized by high mechanical properties, as well as very high fatigue and corrosion resistance.



(a) (b)

Figure 1. a) measured workpiece, b) CAD model

Its mechanical characteristics include tensile strength (560 MPa), Rp0.2 (500 MPa), elongation-stretch before ultimate failure (7%) and hardness (150 HBW) [5]. This workpiece has been obtained by the machining (milling) method. The linear machining strategy was generated in SolidCAM, while the tool used was Hoffman Garant®, code 202480. The sample was created at the EMCO Concept Mill 450 machining centre, at machining parameters generated as follows: a feed rate of 600 mm/min and a spindle speed of 5000 rpm.

The measuring device used in this research was the manual coordinate measuring arm (MCAx 20+) with an integrated laser scanner MMDx100, multisensor measuring system. Table 1 indicates the major configurations of Nikon MCAx multisensory system.

Table 1. Specification of MCAx multisensory system

Specifications of the Nikon MCAx20+ articulated arm with a Nikon MMDx100 handheld laser scanner				
Measuring range	Point repeatability	Volume length accuracy	Laser accuracy	Laser scanning system accuracy
2000 mm	0.023	± 0.033 mm	0.01 mm	0.048 mm

— **Free-form surface inspection**

Products with freeform surfaces have been widely used in many industrial areas. Geometric accuracy of machined parts with freeform surfaces significantly influence at their function. Therefore, it is important to inspect the geometry of freeform surfaces and ensure that the accuracy requirements have been met [4]. To perform this procedure, it is necessary to acquire all the geometrical and dimensional information on the parts in a very fast way. The procedure required to achieve complete, simple and fast quality control is shown at Figure 2 [6]:

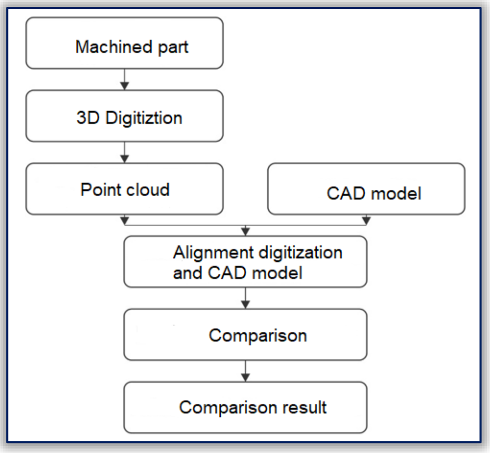


Figure 2. Procedure of CAD inspection

3. RESULTS AND DISCUSSION

Special software packages, which are sometimes dedicated to other graphic applications, make it possible to perform some comparisons between surfaces. The graphic presentation of the results includes several forms [6]:

- color map of regions,
- measurement points in color and
- color deviation vector.

Computer-based inspection of a freeform surface is often conducted by sampling the measurement points on the manufactured surface and comparing these measurement points with the CAD model. The measurement points include also deviations of location and orientation. An example of a color map of the observed geometric deviation of the workpiece is shown in Figure 3. Main advantages of presenting results in this form include quick and simple analysis of the quality of the machining parts, conventional geometric shapes and especially parts with free-form surfaces.

Numerical form deviations of randomly selected points on the surface of the machined part is shown in Figure 4. This kind of comparison gives a better overview of the nominal CAD model, while, on the other hand, in the case of a smaller number of measuring points, a smaller level of deviation is observed.

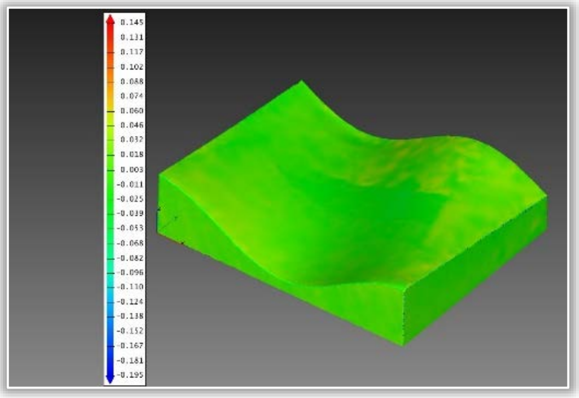


Figure 3. The color map of the observed geometric deviation-global compare (Focus Inspection 10.0)

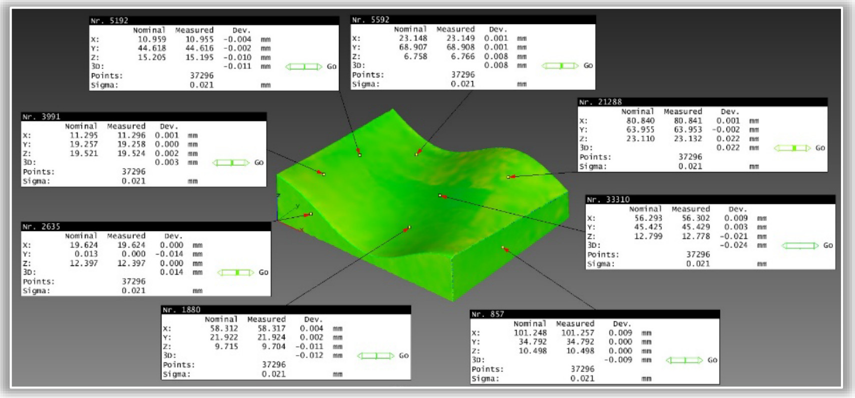
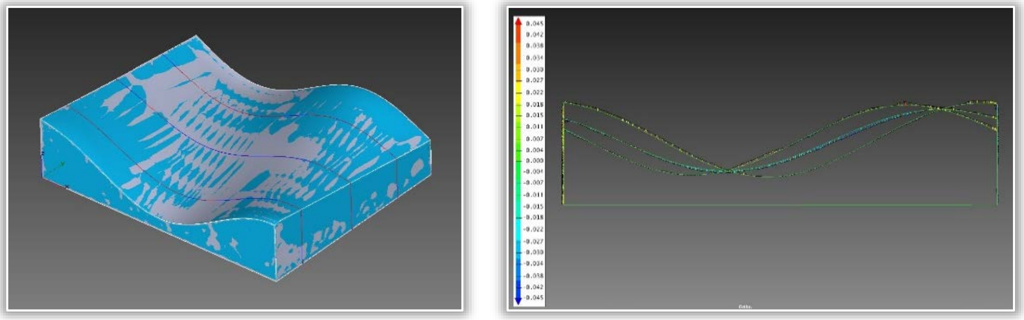


Figure 4 Numerical form deviation of randomly selected points

Evaluating the deviation in the cross-section implies the determination of the vector of deviations whose intensity corresponds to the level of deviation (Figure 6). This form is less transparent from the visual aspect, but, on the other hand, it gives a better insight into the value of deviations in certain areas. The deviations were analyzed in three sections (Figure 5).



(a) (b)

Figure 5. a) section planes, b) sections compared

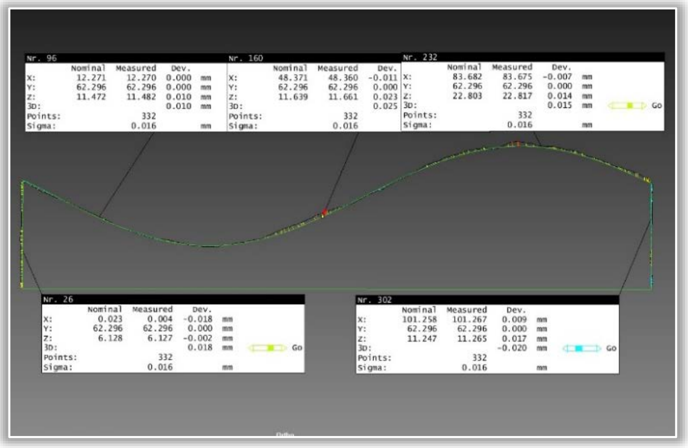


Figure 6. Evaluation of the deviation in the cross-section Y=62 mm

Geometric deviations of surfaces are attributed to many phenomena that occur during machining, both deterministic and random in character. These phenomena with their consequent machining errors can be described in space domain. In coordinate measurements of free-form surfaces, spatial data is obtained providing information on machining and on geometric deviations in the spatial aspect. If a measurement is to take into consideration the form deviation without reference to the datum features, the procedure of fitting the data to the CAD model must be performed. Then, the local geometric deviations determined only represent surface irregularities which can be divided into three components of different lengths: form deviations, waviness, and roughness of the surface. Spatial coordinates of each measurement point include all three components at different proportions. The components connected with the form deviations and waviness are surface irregularities superimposed on the nominal surface, most often deterministic in character. The component connected with random phenomena, including the surface roughness, is irregularity of high frequency [4].

4. CONCLUSION

This paper described techniques for the inspection of machined parts with free-form surfaces. Computer-based inspection of freeform surfaces is often conducted by sampling the measurement points on the manufactured surface and comparing these measurement points with the CAD model of the ideal design surface and its profile tolerance. The method was tested on the machined part shown in Figure 1. Based on the method presented in this paper, it is possible to locate areas on machined parts with the greatest geometric deviations. After the geometry comparison and the analysis of the obtained results, it has been confirmed that this approach leads to significant improvement in the efficiency of the production process control.

Note:

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