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METODS OF INTEGRATING MODERN MEASURING DEVICES ON MACHINING SISTEMS

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Abstract: Modern measuring equipment integration (tactile probes and scanners) on CNC machining systems enables the measuring of machining parts directly on the machine, known as on-machine inspection. In on-machine inspection systems tactile and optical probes are used, however, primarily because of the data acquisition speed, it is expected that the non-contact devices (scanners) will take over the primacy. These measuring systems as a result of measuring include a point cloud that requires software processing and generating surfaces, then comparing it to a CAD model with the goal of obtaining measurements. The obtained inspection report should point out the following activities: finishing the part without taking it off the machine or taking a part off the machine and the next processing on other machines, or final control. This paper gives the description of contact and non-contact devices that are used in on-machine inspections, lists the principles and software tools that are used in the acquisition and data processing, and listing the basic advantages and disadvantages. In examples the inspection of prismatic part shoots obtained by milling on the CNC machining center is shown.
Keywords: measurement, on-machine inspection, scanners, CMM, point cloud

INTRODUCTION

The integration of modern measuring equipment (contact and noncontact probes and scanners) on CNC machining systems enables the measurement of milled parts directly on the machine, known as on-machine inspection. These measuring systems as a result of measuring imply a point cloud, that requires software processing and surface generation. Generated surfaces are then compared to the CAD model in order to obtain measuring reports.

In industrial measurement, contact and noncontact devices for inspection are used. Coordinate measuring machine (CMM), the most important representative of noncontact devices, for a long time is considered to be the standard in metrology. On the other hand, optical, noncontact devices for inspection (scanners) are a revolution in inspectional applications for the last decade. In many fields of mid and large scale production processes, devices for scanning in combination with inspection software are becoming the main means for inspection in industry [1] although they are less correct compared with CMM. With their improvement and integration in production, on-machine measuring is possible, without the need for the part to be taken off the machine tool. On the other side, CMM measures point by point, which leads to a relatively low efficiency compared to other methods of optical inspection. This inherent deficiency limits the use of CMM in some cases with high requirements for measuring speed [2].

This paper further gives description to contact and noncontact devices that are used in on-machine inspection, states the principles and software tools that are used in data acquisition and processing, and basic advantages and disadvantages are listed. In an example, the procedure of inspection of prismatic shoot parts obtained by milling on a CNC machining center is shown.

MEASUREMENT PROCEDURES

In the context of integrated inspection, three types of measurement can be differentiated: in-situ measurement, in-process measurement, and on-machine measurement [3].

In-situ measurement encompasses all the measurement techniques which are performed in the machine environment. Here the non-contact techniques are more and more used, as they represent a good compromise between rapidity and resolution. During in-process measurement, the manufacturing process is not stopped, and inspection is carried out simultaneously with part machining. In this case, the measurement is not necessarily the geometry of the part but can be another characteristic such as cutting forces, spindle vibrations, temperature and so on.

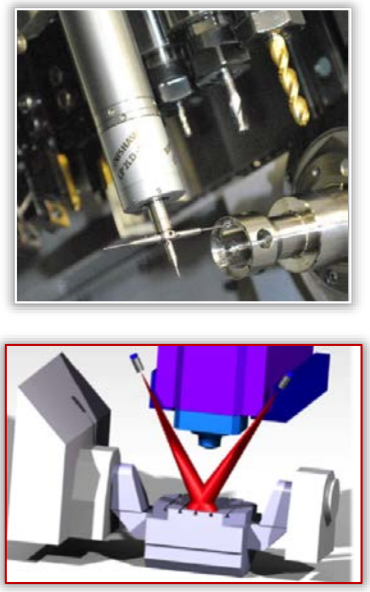


Figure 1. Mesauring devices for on-machine measurement

On the other hand, on-machine measurement (Figure 1) is performed while the part is still located in the machine-tool but while the machining process is stopped. Here, the machine-tool holds the sensor, a touch probe [4], an optical sensor or a combination of different sensors, and allows sensor displacements as on classical CMM. Kako se hardver optičkih skenera svakodnevno usavršava, tako se i njihova tačnost povećava. Iz tog razloga je za očekivati i integraciju optičkih skenera u on-machine sistem inspekcije.

SYSTEMS FOR MEASUREMENT

Data collection systems are divided according to the technical principle they apply to [5]: noncontact and contact. Noncontact devices use mediums like light, sound or magnetic fields, while contact touches the surface of the object using a mechanical probe.

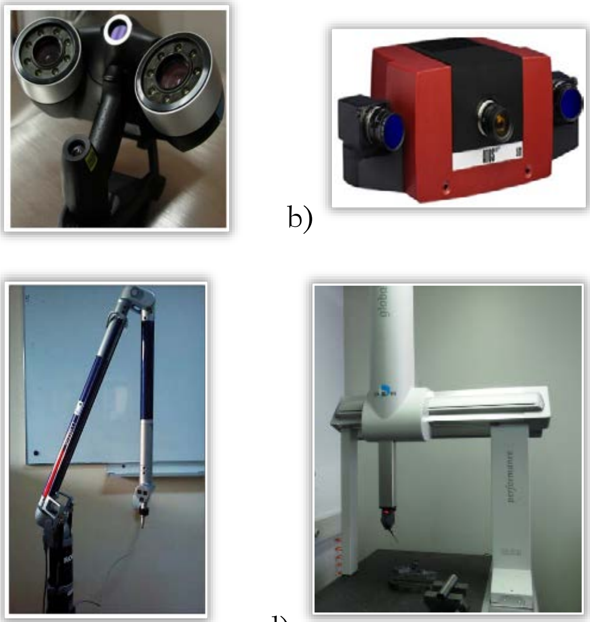
— Non-contact systems for measurement

Noncontact scanning systems (sceners) are becoming more present in the industry every day. These systems allow a significant reduction in manufacturing costs, mainly due to the important decrement in the inspection time. They enable obtaining a great amount of data that provides very good levels of quality in results. In spite of the well-known advantages that these systems offer, there are also some difficulties, such as the undefined and nonstandardized accuracy when compared with traditional inspection systems based on touch-trigger probes [6]. Noncontact scanning systems range across laser scanners (Figure 2-a), structured light scanners (Figure 2-b) and industrial CT scanners. All of them capture the "shape" of the part so that measurements can be made and analyzed using inspection software.

— Coordinate measuring machines

Coordinate Measuring Machines (CMM) are widely employed in most areas of modern advanced manufacturing industry, as well as in many other fields that require high quality dimensional inspection. CMM can be performed in two main varieties: portable and stationary CMM. Portable CMM (Figure 2-c), which typically are stationed on an arm or are observed by a tracking device. They are manually operated, and lower accuracy than stationary CMMs, but also come at a much reduced cost. Use of portable CMM requires a lot less training, can be used on very large parts without requiring complex set up, and it is easy to add additional portable CMM.

Stationary CMM (Figure 2-d), are typically very large installations - gantry, bridge and horizontal systems - that are highly accurate, expensive and much slower compared to other methods. These CMM have zero portability and the part being measured has to be ported to the CMM itself (in-situ measurement). A number of different physical configurations exist for the mechanical structure of the stationary CMM; these include: cantilever, moving bridge, fixed bridge, horizontal arm, gantry, and column mechanical structures. The tip of the probe in the CMM is usually a ruby ball. Probes can be single or multiple tip. The most common probe design is the touch-trigger type, which actuate when the probe makes contact with the item's surface. Stationary CMM have the disadvantage of being fixed in one place, being very slow and quite costly. Secondly, data capture is slow.



a) b) c) d)

Figure 2. Laser and Structured light scanner, Portable and stationary CMM [7]

PRINCIPLE OF INSPECTION WITH 3D SCANNING

Computer aided inspection (CAI) presents the new technology that allows measuring by comparing the deviations of the physical part from its nominal (ideal) 3D CAD model. Process CAI starts from a generated CAD model and a physical part that is measured. The part is firstly scanned by any measuring device (CMM or optical device). The obtained point cloud (STL, TXT, etc.) is, if required, preprocessed and processed using CAD and/or CAI software, ie. the surface model of the part is generated. CAI software ddoes the comparisons of the nominal CAD part with the surface model and calculates the desired deviations of the real part compared to the ideal CAD model [8].

The result of scanning presents a point cloud, a file that contains a set of XYZ coordinate points in a 3D coordinate system. The point cloud of the measured part, obtained with the use of optical scanners commonly contains a large amount of data of the points from the surface (up to a few millions) that are subsequently processed. With the use of CMM a point cloud is obtained with less (user defined) data, and usually contains less irregularities.

The deviations (errors) of the point cloud, that occur during scanning and that should be corrected with preprocessing include: sampling density, noise, outliers, misalignment and missing data [9]. Subphases within preprocessing are filtrating point clouds and data-point reduction [10]. Segmentation of the point cloud is a process that also occurs in some inspection systems. Segmentation can be described as a process of data division of the results of 3D scanning (point cloud) on meaningful regions, or the process of extraction of important elements from the point cloud [11].

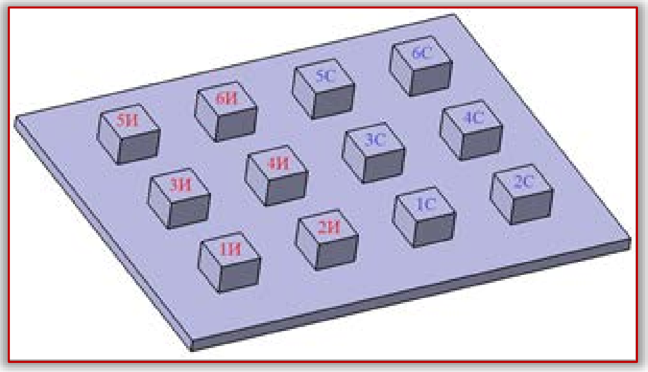
The purpose of the surface processing phase is generating the surface model from a preprocessed point cloud [12]. In geometrical modelling, surfaces are generated either with the procedure of fitting based on the data-points or with poligonal fitting.

CAI software performs the comparison of the nominal (ideal) model with the surface model and calculates the desired deviations. Softwares for measuring can be naturally classified as contact and noncontact. Some of the commercial softwares for contact measuring are: FARO CAM2, Hexagon PC DMIS, Verisurf, BuildIt!, Delcam PowerInspect. Commercially available software products for noncontact measuring are: Geomagic Qualify, Rapidform XOV, Innovmetric Polyworks, as well as GOM Inspect. GOM Inspect contains the basic tools for preprocessing and processing of point clouds, while allowing users inspection while creating measuring reports that contain recordings, pictures, tables, diagrams, text and graphic, or they are in PDF format.

EXAMPLE OF INSPECTION WITH 3D SCANNING

The procedure of inspection of vertical shoots of parts obtained by milling (Figure 3-a) using noncontact software package GOM Inspect is shown below. The shoots were measured (scanned) on a coordinate CNC measuring machine, and afterwards scanned using the optical scanner.

a)

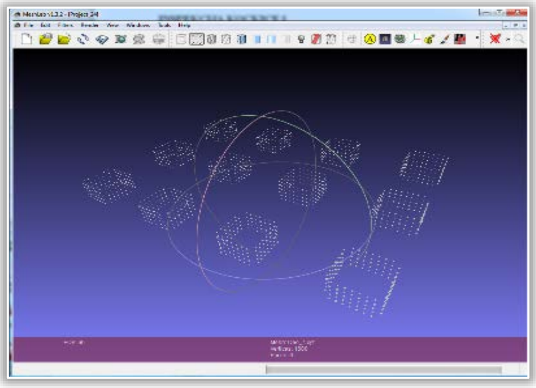


b)

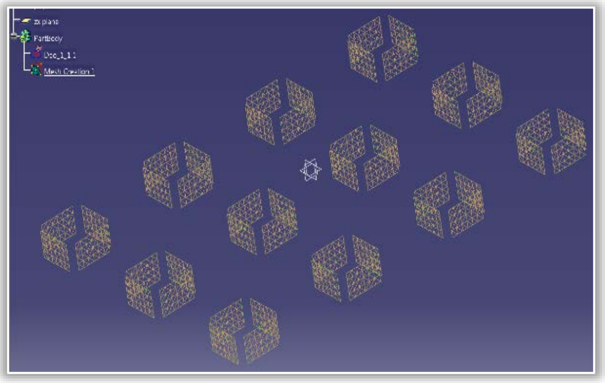
Figure 3. The part after milling and the CAD model of the part

— **Scanning on CMM and point cloud preprocessing**

The measurement of the shoots is done on the CNC measuring machine DEA GLOBAL Silver Performance. Every vertical surface of the shoot is scanned through the matrix 5x7 points, so 35 points by one surface is obtained (Figure 4-a).



a)



b)

Figure 4. XYZ file imported to MeshLab and the triangulated point cloud in CATIA

For the measuring results to be imported from CMM to the software for noncontact measuring GOM Inspect, it is needed to transform them into a format that the program can recognize (STL format). With the use of the software MeshLab and CATIA, the triangulated (STL) point cloud file (Figure 4-b) is obtained, that will be used for surface generating and measurement in GOM Inspect. As the point cloud contains only measuring surfaces, and the points are uniformly distributed, there was no need for additional preprocessing.

— **Scanning with scanners and point cloud preprocessing**

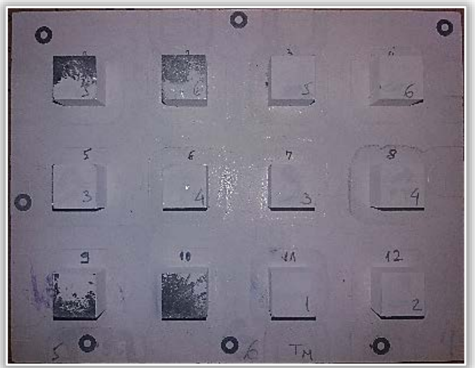
Vertical shoots are scanned using Structured light scanner ATOS II.

As the parts are made from reflective surfaces (aluminum), it was not possible to scan them, so they were dusted with NORD-TEST, Endringprufsystem, Entwickler U 89, and then scanned (Figure 5-a).

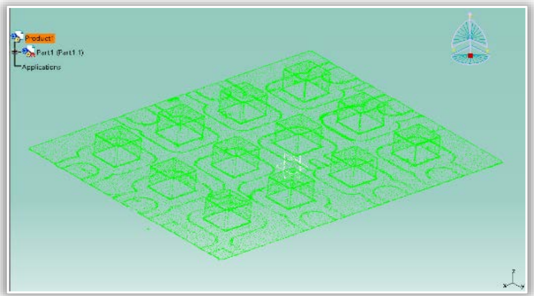
On Figure 5-b the point cloud obtained using scanner model ATOS II is shown, imported in CATIA. The characteristics of the point cloud are: number of triangulated surfaces (facets): 141098; point count: 71490; cloud radius: 117,974 mm and cloud dimensions: 183,555x145,075x30,539 mm.

Surfaces of interest for measurement are side surfaces of the shoot, so only they are viewed. On the cloud there was no points outside the range, and the errors on the mesh are mostly on the edges of the shoot. On Figure 6, the characteristic mesh deviations are shown.

The lack of scanned points on edges and transition surfaces is shown on Figure 7-a. This lack is further complicated with triangulation (Figure 7-b). This way a part without clearly defined edges is obtained (Figure 7-c). As GOM Inspect sets fitting levels on the inner segmented surface part, there was no need for edge pulling.



a)



b)

Figure 5. The dusted part and the obtained point cloud using scanner ATOS II

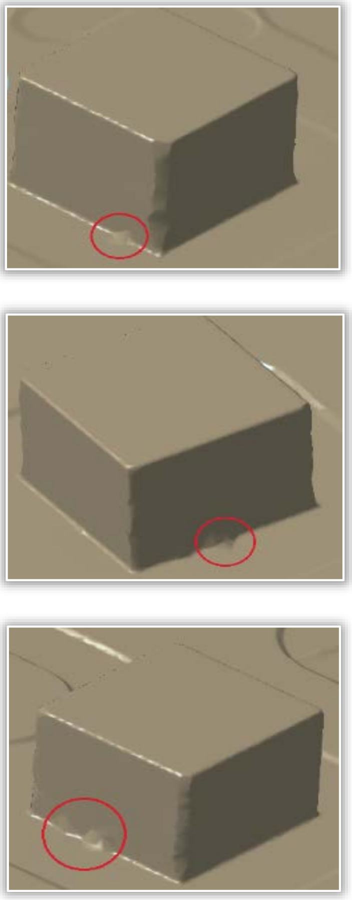
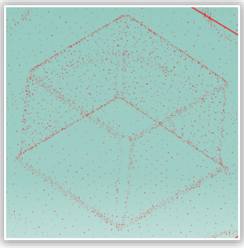
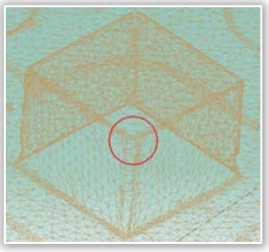


Figure 6. Irregularities on the triangulated cloud point



a)



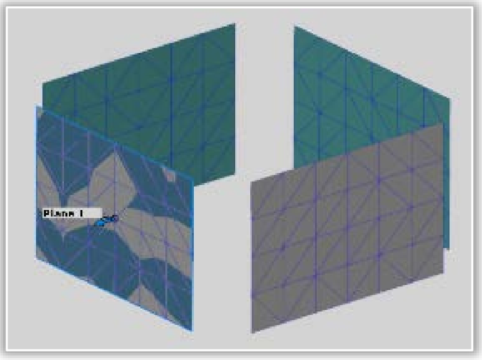
b)

c)

Figure 7. Triangulated point cloud and edge irregularities

— **Edge generating and measurement in GOM inspect**

For measurement to be done, it is needed to import the CAD model (Figure 3-b) in GOM inspect, and then import the STL point cloud file. After the alligment of the CAD model with the point cloud, surface generating is done. Surface generation is done over fitting planes (Fig 8.). GOM Inspect gives the option of choosing two methods of fitting, Gauss's method (that is used here) and Chebychev's.



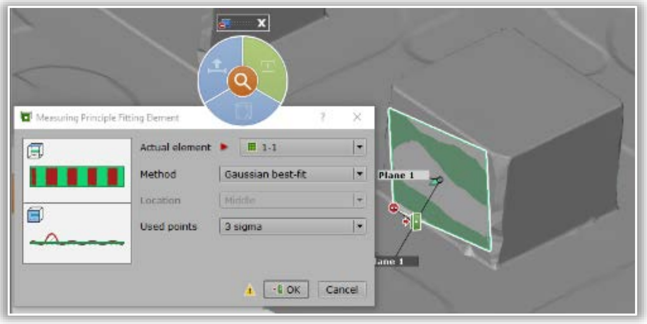
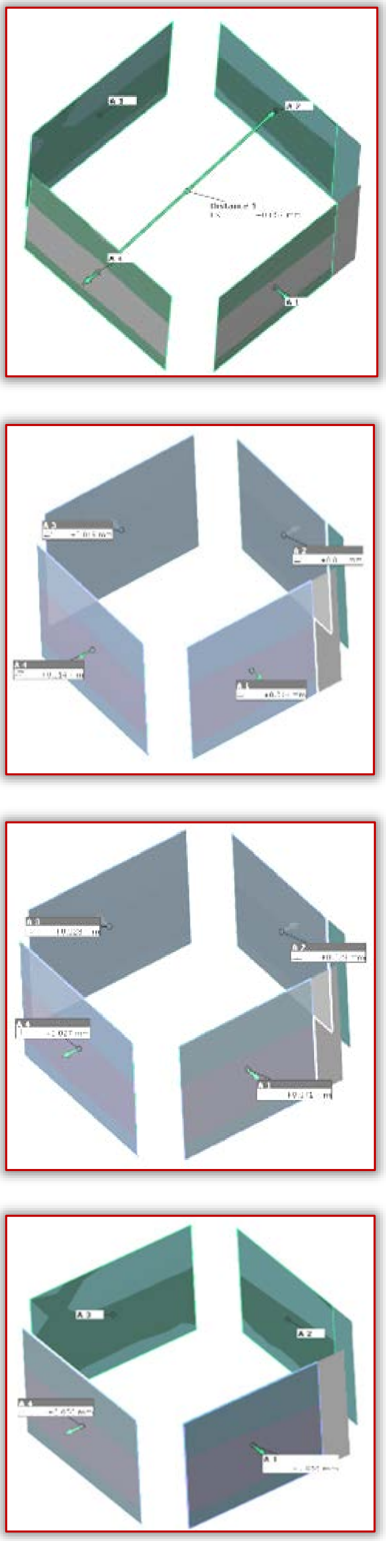


Figure 8. Creating of Fitting Plane CMM cloud and point cloud from the scanner

After creating of fitting planes, software measurement is done by comparing the CAD model with the fitting planes. On Figure 9-a. the measured linear deviation distance LX and distance LY is shown. Also the deviation from form and orientation is shown: flatness (Figure 9-b), prependicularity (Figure 9-c) and parallelism (Figure 9-d).



a) b) c) d)

Figure 9. Measured linear deviation and deviation from the shape and position

CONCLUSIONS

Modern measurement equipment is more present in manufacturing industries, so it can be said that the measuring machine coordinates have become the standard and that the manufacturing and documentation are adjusting to the coordinate measuring machines in a great deal.

On the other hand, the non-contact (optical and laser) measuring systems are more intensively developed. Their advantage in inspectional applications is faster measurement, larger count of measuring points, the possibility of measuring flexible materials, as well as the possibility of on-machine measuring. These measuring systems as a result include a point cloud, which requires the processing and generating of surfaces for the purpose of measuring and control.

The purpose of this paper is systematization of the knowledge bound for computer aided inspection (CAI). Measuring procedures are listed, and the importance of research on this subject on the modern (on-machine) measuring is mentioned. Contact and noncontact systems and devices for measurement are described. Mentioned are the principles of inspection by 3D scanning, as well as problems that can occur during preprocessing and processing of the obtained point cloud. Also the commercial software for contact and noncontact measurement are listed. On a concrete example the whole process of CAI is shown. Scanning of the part is done using CMM and a scanner. Obtained point clouds are preprocessed. Using the GOM Inspect software, generating of measuring systems, measuring of linear deviations as well as deviations from the form and orientation are done.

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