Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
3rd DAAAM-ICAT

ANALYSIS OF ALIGNMENT PROCEDURES FOR CONTACTLESS INSPECTION OF RAPID MANUFACTURED PARTS

MINETOLA, P[aolo]; CALIGNANO, F[laviana] & IULIANO, L[uca]

Abstract: *Rapid Manufacturing processes are employed for tool-less fabrication of complex freeform custom-made geometries of unique pieces or low volumes productions in short times. When multiple copies of the same product are rapid manufactured, the parts must be inspected for quality. Different inspection alignment on contactless scan data of a rapid manufactured part are analyzed in this work, putting in evidence that an inaccurate or inattentive definition of the part reference system can lead to incorrect evaluations of real part deviations.*
Key words: *rapid manufacturing, contactless inspection, reference system, alignment*

1. INTRODUCTION

As well as other products, Rapid Manufactured (RM) parts have to be inspected to assess their quality in terms of dimensions and geometrical tolerances.

The CAD model or STL file of an RM part cannot be used as reference for the inspection, because it does not represent accurately the real geometry of the final product. Deviations between the virtual model and the final real piece are a consequence of additive process tolerances and finishing operations. The approval of the customer is often granted on the real piece and not on its virtual model.

For this reason Reverse Engineering (RE) techniques have to be used to digitize the real geometry of the customer-granted RM part in order to obtain a reference model for quality control of the copies. The use of optical scanners and contactless inspection procedures is slightly replacing traditional pointwise contact measurements in quality control of freeform geometries and complex parts (Gao et al., 2005; Savio et al, 2007). Although 3D scanners are not as accurate as Coordinate Measuring Machines (CMMs), they are suitable for the inspection of RM parts, which generally do not have tight tolerance requirements. Moreover contactless digitizing does not require the use of any fixture and potential deformation of plastic parts by probe tip contact is avoided.

As regards pointwise inspection of RM parts, another problem cannot be disregarded: the surface roughness and finish affect the measurements results since the contact of the probe tip is influenced by the staircase effect of the surface. Depending also on the approaching direction, the probe tip can slip from one stair step (layer) to the following one during the contact and the measure could be inaccurate. Such problem is avoided by using contactless digitisers for quality control of RM parts.

High density point clouds allows to inspect the whole surface of the part instead of some scattered points only. Quality control results, among other factors, depend on the accuracy of the contactless digitizer used, but also on the definition of the part reference system for the inspection alignment.

The aim of this paper is to put in evidence that particular attention have to be paid in the definition of the part reference system in contactless inspection, particularly if the scanning device accuracy is low. Similar works could not be found in technical literature, since the use of contactless scanners for inspection of rapid manufactured parts is quite a recent issue.

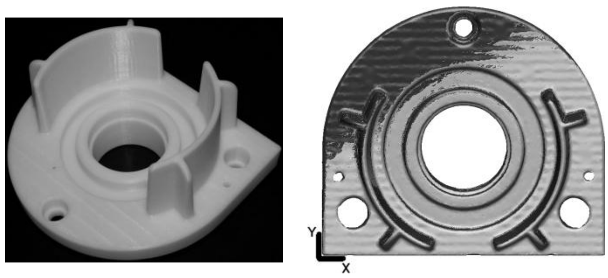
2. METHODOLOGY

An RM part was selected as case study and two different optical scanners were employed for the inspection activity. Different inspection alignments were defined on the two scan data by selecting different points for the calculation of the same Cartesian reference system.

Then the differently aligned scan data were first compared one to another to compute the deviation of the whole point cloud. In addition, fifty scattered scan points were selected for each different alignment and their Cartesian coordinates were used as nominal values for the inspection by a CMM.

2.1 Case Study

The rapid manufactured part (figure 1a) selected as case study is a holder for a hydraulic cylinder. The holder was manufacture by Fused Deposition Modelling (FDM) on a Stratasys Dimension Elite machine using a layer thickness of 0.178 mm of ABS plastic. The overall dimensions of the part are 107 x 93.7 x 60.5 mm and its surface was not finished nor polished after fabrication not to alter the staircase effect.



(a) (b)

Fig. 1. RM part selected as case study (a) and superposition of the two alignments of ATOS scan data (b)

2.2 Contactless Digitising

Two different optical scanners were used for contactless digitising the case study. The former is the structured light scanner ATOS (Advanced TOpometric Sensor) Standard produced by GOM GmbH. It has a declared accuracy of 0.05 mm and it was calibrated for a working area of 200 x 160 mm. The ATOS Standard digitizes up to 400,000 points per single scan in less than 10 seconds.

The latter is the laser triangulation scanner Vivid 900 (Vi-900) by Konica-Minolta. The device has a declared accuracy of 0.08 mm and it was used with the tele lens for a scan area of 111 x 84 mm. The Vi-900 digitizes up to 300,000 points per single scan in less than 5 seconds.

According to authors' experience, the ATOS Standard performance in terms of accuracy and reproducibility is better than that of Vi-900 (Iuliano et al., 2005).

2.3 Reference System Definition

Contactless inspection involves the comparison of one point cloud with the theoretical CAD/STL model or a reference point cloud. Before the comparative analysis, the compared objects have to be aligned one to another.

In quality control of mechanical components, the requirements in terms of features' location and tolerances are set by the designer with respect to a unique fixed reference system, which has to be reproducible. A Cartesian reference system is very often used in inspection and it can be defined by the 3-2-1 alignment rule (plane, vector and origin point to define the directions of the three coordinates and the origin of the reference system).

For this reason the 3-2-1 alignment was used to define the reference system on the scan data of the case study. Three points were selected on the top plane of the central hole for the Z plane, two points on the front face for the X axis direction and one point on the side face for the X axis origin (figure 1b).

The issue with high density scan data is that each feature is defined by several points, so the definition of the reference system in the 3-2-1 alignment could be influenced by which point is selected. Of course the influence is also related to the accuracy of the optical scanner and to the quality of the resulting point cloud.

To deeply investigate this aspect, the 3-2-1 alignment was replicated twice on the ATOS scan data (157,682 points) and twice on the Vi-900 data (222,098 points) by selecting different points on the aligning features (top plane, front face and side face) each time. Therefore, as result of the Cartesian reference systems replication, four differently aligned point clouds were available for comparison: ATOS data first alignment, ATOS data second alignment, Vi-900 data first alignment and Vi-900 data second alignment.

3. RESULTS

3.1 Scan data comparison

The difference between the four aligned point clouds can be visually checked by super-positioning one to another (figure 1b). The four aligned point clouds were compared in couples by means of Rapidform 2006 software to compute the reciprocal distances. The results of the comparative analysis are shown in table 1.

3.2 CMM inspection

To further investigate and validate the results of software comparisons, fifty scattered points were selected on similar locations of each aligned point cloud. Their Cartesian coordinates were used as nominal values for the planning of pointwise inspection of the real RM part on a Dea Iota CMM using a probe tip diameter of 2 mm.

The alignment of the real RM part on the CMM was performed by the 3-2-1 rule by hitting the points on the same aligning features used for the point clouds alignment. The CMM measurements were replicated three times and the CMM alignment was changed each time only after having completed the inspection of the fifty points of the four aligned point clouds. The results of ATOS data inspection are shown in table 2, those of Vi-900 data inspection in table 3.

Reference	Compared	Mean Distance	Standard Deviation
ATOS data 1st Alignment	ATOS data 2nd Alignment	0.07 mm	0.04 mm
ATOS data 1st Alignment	Vi900 data 1st Alignment	0.49 mm	0.39 mm
ATOS data 1st Alignment	Vi900 data 2nd Alignment	0.61 mm	0.46 mm
ATOS data 2nd Alignment	Vi900 data 1st Alignment	0.48 mm	0.39 mm
ATOS data 2nd Alignment	Vi900 data 2nd Alignment	0.61 mm	0.46 mm
Vi900 data 1st Alignment	Vi900 data 2nd Alignment	0.21 mm	0.14 mm

Tab. 1. Results of aligned point cloud comparisons

Fifty points of ATOS scan data		1st Alignment	2nd Alignment
1st Measure	Mean Distance	0.27 mm	0.25 mm
	Std. Deviation	0.26 mm	0.25 mm
2nd Measure	Mean Distance	0.28 mm	0.27 mm
	Std. Deviation	0.28 mm	0.28 mm
3rd Measure	Mean Distance	0.28 mm	0.27 mm
	Std. Deviation	0.27 mm	0.27 mm

Tab. 2. Results of CMM Measurements on ATOS data

Fifty points of Vi-900 scan data		1st Alignment	2nd Alignment
1st Measure	Mean Distance	0.29 mm	0.41 mm
	Std. Deviation	0.22 mm	0.31 mm
2nd Measure	Mean Distance	0.28 mm	0.39 mm
	Std. Deviation	0.21 mm	0.31 mm
3rd Measure	Mean Distance	0.27 mm	0.43 mm
	Std. Deviation	0.19 mm	0.28 mm

Tab. 3. Results of CMM Measurements on Vi-900 data

4. CONCLUSIONS

The results of the software comparisons between the aligned point clouds (table 1) are confirmed by the CMM inspection of the fifty scattered points (table 2 and table 3). The mean distance between all points of the two alignments of ATOS data is 0.07 mm. Such value is lower than the layer thickness of the FDM process. Due to the staircase effect of the part surface, contact inspections by CMM (table 2) show no difference for the two alignments of ATOS data.

On the contrary, the mean distance between all points of the two aligned Vi-900 point clouds computed by Rapidform software is 0.21 mm (table 1). Contact pointwise measurements by CMM confirmed a difference between the two alignments for Vi-900 data (table 3). With respect to software comparison results (table 1), lower values for the differences between the ATOS data and Vi-900 data were obtained in the fifty points inspection by CMM (table 2 and table 3): this is probably due to the staircase effect that influences contact measurements.

On the whole, both software comparisons and CMM inspection of differently aligned point clouds demonstrate that the selection of the points on reference features during the definition of the same part reference system can influence the results of non contact quality control, leading to incorrect evaluations. The influence is more evident if the accuracy and quality of the scan data is worse, as for the Vi-900 device in the selected case study.

5. REFERENCES

Gao, J.; Folkes, J.; Yilmaz, O. & Gindy, N. (2005). Investigation of a 3D non-contact measurement based blade repair integration, *Aircraft Engineering and Aerospace Technology: An International Journal*, Vol. 77, pp. 34-41

Iuliano, L. & Minetola, P. 2005. Rapid Manufacturing of Sculptures Replicas: A Comparision between 3D Optical Scanners, *Proceedings of CIPA XX International Symposium*, Torino (Italy), pp. 384-389

Savio, E.; De Chiffre, L. & Schmitt, R. (2007). Metrology of Freeform Shaped Parts. *Annals of the CIRP*, Vol. 56, No. 2 pp. 810–835