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CALIBRATION CERTIFICATION OF ATTRIBUTE CHECK FIXTURES FOR TUBE MANUFACTURING USING STRUCTURED LIGHT 3D SCANNERS

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Abstract To make production of correct parts without rework and prevention the scrapping of good parts, manufacturers of tubes for automotive industry rely on attribute check fixtures. Fixtures are intended to answer the question does the product conform to the dimensional specifications and tolerances. In this paper the methodology for calibration certification of attribute check fixtures for tube manufacturing using structured light 3D scanners is presented. Sample preparation, 3D scanning, processing of point cloud and generation of measurement reports are described. GOM Inspect software was used to process meassuring data ang measured results generation. A large amount of recorded measuring points with high accuracy of measurement ensures that certification pass only fixtures that meet the requirements defined by the documentation. Based on measuring results, accredited laboratories may issue calibration certificates. The presented methodology is a valuable tool for calibration certification of attribute check fixtures for tube manufacturing. The methodology presented in this paper can be applied for calibration certification to all other types of gages, fixtures and jigs.

Keywords: Calibration; attribute check fixtures; polygonal model; 3D digitizing; measurement; ATOS.

1. INTRODUCTION

Three dimensional coordinate metrology is one of the foundations of modern product quality concepts [1]. Universal applicability and the possibility of high degree of automation has ensured that this measurement technology has a primacy for more than 30 years. The CAD data is the absolute authority for advanced manufacturing compliance. Modern metrology software provides interface between CAD models and measuring devices in real-time. Conventional coordinate measuring machines (CMM) are performing measurements based on set of points obtained by touching the measuring object [3]. The measurement result depends on the selection and number of measuring points.

Many applications require fast and efficient in-proces control and the use of expensive sophisticated devices is inadequate. The most obvious examples come from the automotive industry, where entire product series are controlled by simple fixed devices – gages and fixtures [4]. Precision tubes for the automotive industry must meet the highest performance requirements, especially in terms of geometric accuracy [4]. In-Vehicle attribute check fixtures forms a template that precisely coordinates the locations of components throughout the entire product, as well as their respective assembly points, so that every part goes exactly where it's supposed to go [5]. If the tube fits into the

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

cavity, the part is correct; if it does not fit, it is not correct. A well-designed and -constructed fixture makes the process run smoothly [6-11].

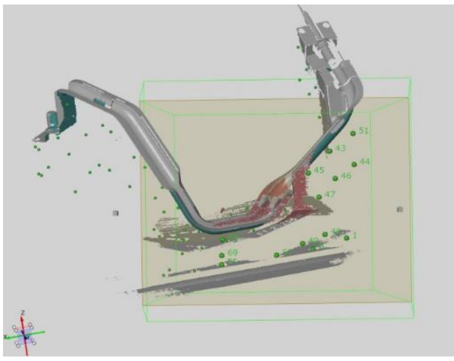
Modern 3D scanning technologies provide the possibility of 3D digitization of the entire surface of an object with a very high accuracy of the position of each recorded point [12]. The 3D scan consists of millions of measurement points and represents a faithful digital copy of a real physical object [13]. Since application of 3D scanning allows for full insight into the current state of configuration of these tools, in this paper the methodology for calibration certification of attribute check fixtures for tube manufacturing using structured light 3D scanners is presented.

2. ACQUISITION PROCEDURE

A full-contour fixture makes contact with the tube along its entire run, end-to-end (Figure 1a). The body of the fixture checks most of the contours and features. Additional hardware, such as the items located at each end and in the middle of the tube, are used for verifying the locations of specific tube features.

Sample preparation, 3D scanning, processing of point cloud and generation of measurement reports are described in the folowing sections.

(a)



(b)

Figure 1. Attribute check fixture: (a) physical model, and (b) actual data obtained by 3D digitzing

2.1. 3D Digitizing

Opposite to CMM, 3D scanner captures dense set of points, called Point Cloud, on visible surfaces of objects that are subject to 3D scanning [10]. In other words, the point cloud is a set of points whose positions in the space are determined by measurement.

In order to full-fill its task to verify the geometry of attribute check fixtures on the basis of the point cloud and polygonal model, measured results must be an order of magnitude more accurate than the machine used to manufacture the part. The measurements shown in this paper were performed using an optical measuring system ATOS (Advanced TOpometric Sensor) [13].

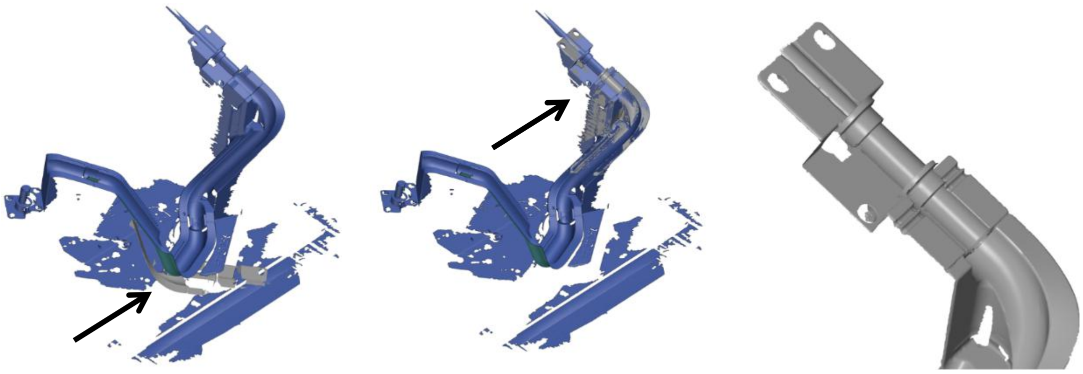
2.2. Model Preparation

GOM Inspect software was used to process meassuring data ang measured results generation. GOM Inspect is advanced state-of-the-art dimensional metrology software [2]. It enables fast accurate work

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

comparing the digital world to the physical world while meeting today's strict demands of quality control.

3D scanning allows adding areas that have been missed to scan or have been modified/upgraded (Figure 2). A new scan needs to be aligned to the old one, since it is in the arbitrary position (Figure 2a). Alignment is carried out through areas that are common to both scans (Figure 2b). In this way, one project can contain different positions of moveable elements (Figure 2c).
The software GOM Inspect has many features to process a polygonal mesh. However, it is very important that the polygonal mesh is unprocessed, as the filling of holes, decimations, and similar interventions on the mesh make changes onto original mesh and introduce unmetered assumptions. The only changes are permissible in terms of removing unnecessary data (Figure 2c).



(a) (b) (c)

Figure 2. Model preparation.

2.3. Model Transformation

The model obtained in the previous step is in an arbitrary position in the space. In order to be usable for measurement, it is necessary to transform it to the coordinate system CAD model through the procedure called alignment. There is the initial alignment or prealignment and the main alignment.

Using the function Prealignment, software prealign the actual data to the nominal data (CAD) regardless of the start position. The more structured a component is, the faster the software finds a solution for the alignment. For flat or rotationally symmetric components, the software needs a longer search time. Prealignment is required before any further alignment or inspection. The function Local Best-Fit With Tolerances aligns actual data to nominal data via a best fitting with defined tolerance limits. Figure 3a shows on top the CAD data and below the measured actual part. The actual data is not prealigned yet. The question is whether the built-in part fits into the CAD data. The CAD and the actual elements are interwoven (Figure 2). Figure 3b shows the result of prealignment. The local best-function function requires defining the area of the model by which the match will be performed (Figure 3c). The result of the alignment with the tolerance definitions (Upper limit +0.2 mm and Lower limit -0.2 mm) is shown in Figure 3d.

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

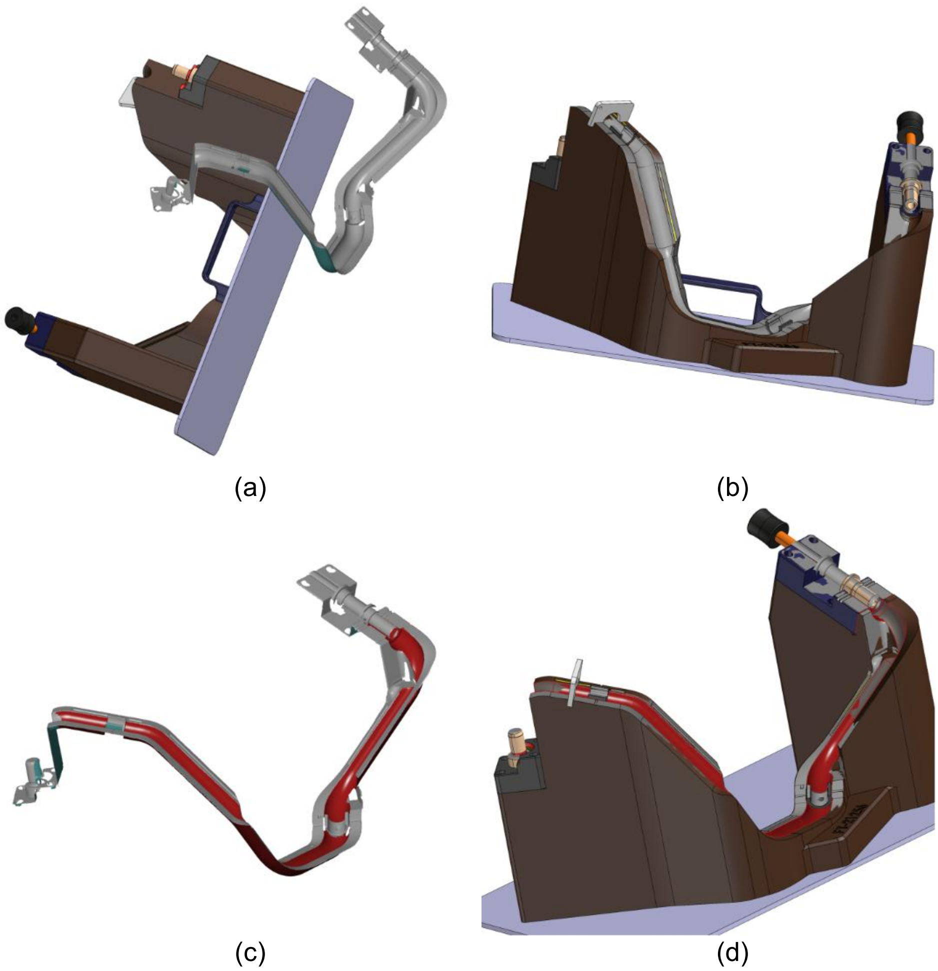


Figure 3. Alignment of nominal (CAD) and actual (digitized) data:
(a) relative position of nominal and actual data before prealignment,
(b) relative position of nominal and actual data after prealignment,
(c) zones of actual data used for main alignment,
(d) relative position of nominal and actual data after best-fit alignemnt.

2.4. Feature Extraction

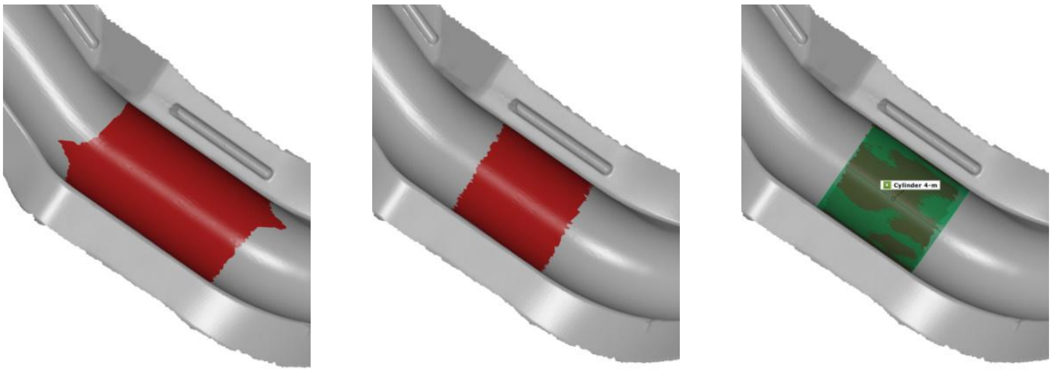
A measuring principle is a simple way to create actual elements. The software creates the actual elements based on the nominal elements (CAD data). During this procedure, the software links the actual element to the nominal element. In addition, the measuring principle contains the information, in which way the software creates and links an actual element.

While creating any feature using Gausian Best-Fit, the software squares the deviations of the selected points or polygons to the possible fitting element, adds up the quadratic deviations, and changes the possible fitting element until the sum is the smallest. Then, the software creates the fitting element. Parameter of the Gaussian method is measuring point outliers – measuring points which will eliminated during calculation. Because we use digitized data, software operates on large number of points, and, to the Gaussian distribution, the values are: (a) 1 sigma = approx. 68.3 % of all points, (b) 2 sigma = approx. 95.4 % of all points, (c) 3sigma = approx. 99.7 % of all points, ... If All points are selected, the software considers all selected points and does not eliminate the measuring point

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

outliers.

By measuring the principle, the software automatically determines the area on the model to fit the cylinder. However, the selected area may be greater than that which is actually cylindrical (Figure 4a). For this reason, the tool indicates the length at which the cylindrical area should be selected (Figure 4b). The cylinder fitted in this way is shown in Figure 4c.

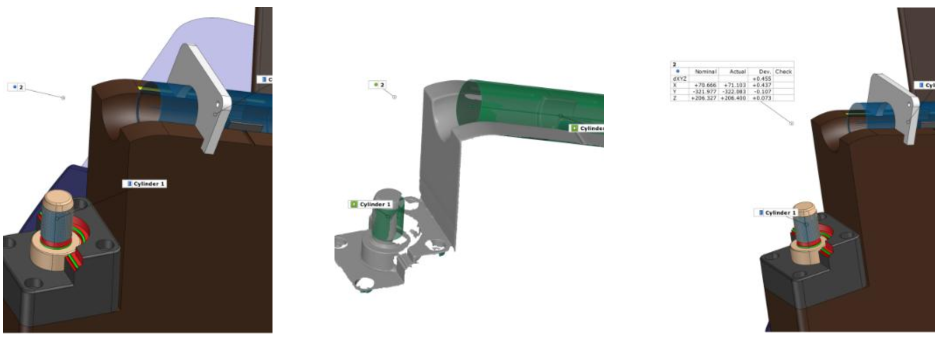


(a) (b) (c)

Figure 4. Cylinder extraction based on measurement data:
(a) area of actual data selected by measuring principle,
(b) user corrected area of actual data, and
(c) „actual cylinder" fitted based on user corrected area of actual data.

2.5. Control Point Construction

The control points are constructed as intersections of the tube straight line segments or features of the device (Figure 5). For example, point 2 is obtained as a intersection of the cylinders 1 and 2. Cylinder 1 is a feature at which the end of the tube is placed, and the cylinder 2 is a straight line segment of tube. Using the function Referenced Construction, software creates actual elements in the same way as the nominal elements are created. In other words, the software reproduces the way of construction on the actual data.



(a) (b) (c)

Figure 5. Procedure for control point construction:
(a) construction of features on nominal data, (b) features constructed on actual data using measuring principle (fitting element), and (c) construction of intersection point on nominal data and on actual data using measuring principle (referenced construction).

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

3. RESULTS

The control of the geometry of the attribute check fixtures starts from the assumption that with the position of the control points check we can precisely check the compliance of the fixtures with the requirements expressed by the technical documentation. By the procedure described, we obtain a total deviation of the control point constructed on the basis of actual data with respect to the corresponding point on the nominal data, as well as deviations in the direction of the coordinate axes (Figure 6). A large number of measuring points allows to determine the field of deviation of real pieces in relation to engineering ideas – CAD model (Figure 7).

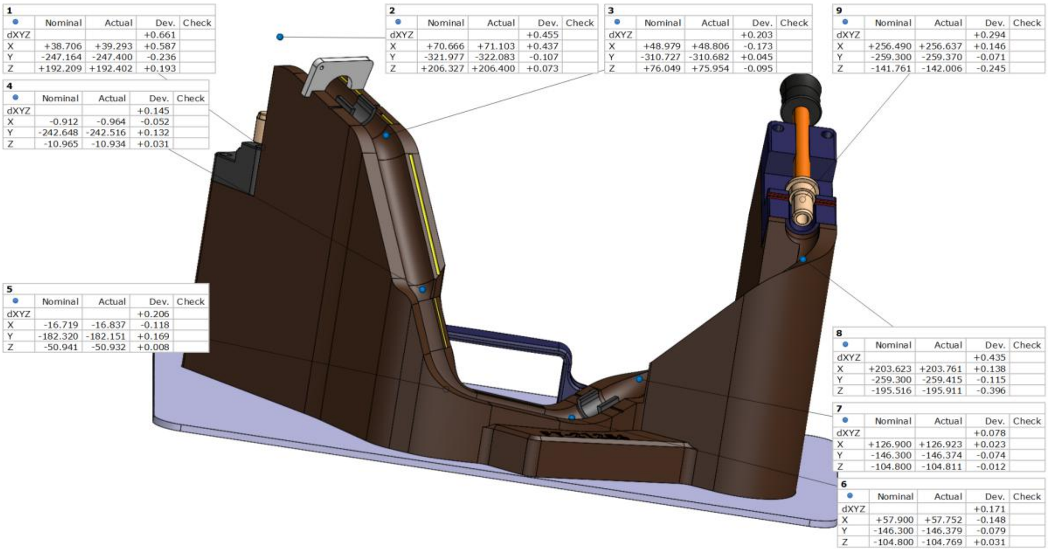


Figure 6. Measurement results for control points.

Figure 7. Deviation field of digitized surface in reference to CAD model of attribute check fixture.

2018, Volume 2, Issue 2, 48-55, DOI 10.6723/TERP.201812_2(2).0007

Based on these measurements, accredited laboratories may issue appropriate calibration certificates [16]. Calibration certificates issued by Lotric Metrology DOO are available for their users online via the portal MEOL – Measurement On Line (logging with user name and password) [17].

4.CONCLUSION

A part is only as good as its inspection. Fixtures allow the evaluation of many data points in a quick and rational manner. A check fixture is a quick-to-use and easy-to understood tool that ensures the part is built to the customer's requirements.

The paper presents a new approach for calibration certification of attribute check fixtures on the basis of the point cloud and polygonal model captured by structured light 3d scanners. Sample preparation, 3D scanning, processing of point cloud and generation of measurement reports are described. A large amount of recorded measuring points with high accuracy of measurement ensures that certification pass only fixtures that meet the requirements defined by the documentation. Based on presented results, the methodology presented is a valuable tool for calibration certification of attribute check fixtures for tube manufacturing.

In addition to the primary task, to enable validation and certification of attribute check fixtures for tube manufacturing, this procedure also provides the documentation of the device. Thanks to the dense point data, it is possible to monitor the wear and damage of the fixtures over time. The methodology presented in this paper can be applied for calibration certification to all other types of gages, fixtues and jigs (component, assembly, acceptance, variable data, SPC, hot stamp, go/no-go, automated, process, and hand-held gages, assembly, robotic weld, spot weld, mig weld, riveting, hemming, bonding, CMM inspection, drill, and laser fixtures (hot stamp), drill jigs, ...) [6-9, 14].

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