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Industrial application of Computerized Tomography

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Introduction

In many enterprises measuring and quality checking tasks occur, which presently cannot be solved or can only be solved with difficult conventional measuring procedures. On account of this:

- the derivative of geometry data for complex shapes and therewith connected
- the inspection of complex shapes (comparison of physical model and CAD-model).

In 1998 the *Anwenderverbund Volumenabtasten* (user network volume scanning) was created by the Fraunhofer Institute for Manufacturing Engineering and Automation in Stuttgart, for the handling of such questions. Other companies involved in this are BMW, Bosch, Daimler-Benz-Aerospace, Porsche, Bombardier-Rotax and Stihl.

In particular the following tasks should be processed with Bombardier-Rotax in Gunskirchen, Austria:

- derivative of geometry data of a cylinder head for current simulations in the water channels.
- inspection of a motorcycle cylinder.

Surface and volume-oriented measuring procedures

For the tasks mentioned, surface-oriented measuring procedures can

Surface-oriented measuring procedures:

- Tactile measurement (CMM)
- Laser triangulation
- Structured lighting

Principle:

- Measuring point must be visible

Volume-oriented measuring procedures:

- Computerized Tomography (CT)
- Ultrasonic
- CGI (destroying)

Principle:

- Digitizing a series of sectional views
- The sectional views completely contain the geometry information

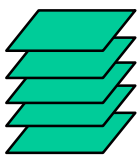

Figure 1: Surface and volume-oriented measuring procedures

only be used with great difficulty, since all points of the cylinder head or the motorcycle cylinder, which need to be measured, are not visible from the outside (see figures 3 and 6). For this reason CT is used in these cases.

Processing of CT Measuring Data

With the industrial computer tomography a series of 2D image slices is attained. With commercially available evaluation software, in each 2D image contours can be extracted and 3D-point clouds can be calculated from them.

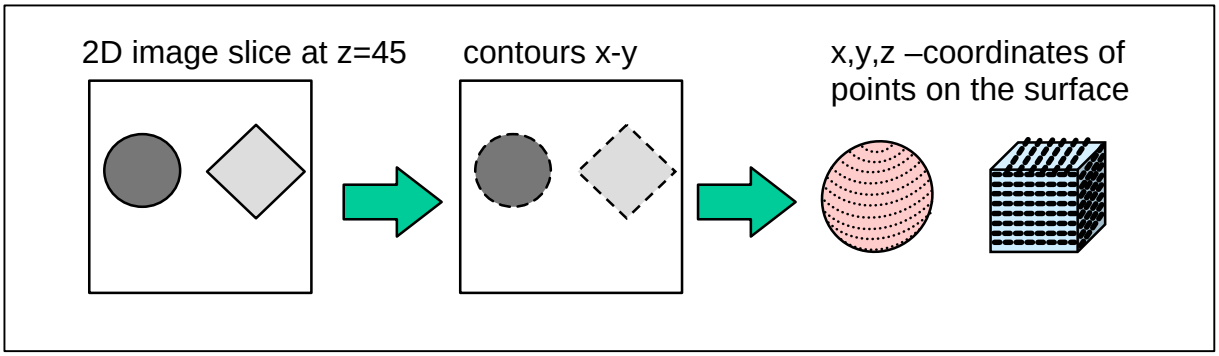

Figure 2: Processing of CT measuring data

Derivative of geometry data of a cylinder head for simulation in the water channels.

Figure 3: Cylinder head

In order to execute a flow simulation, the geometry data of the water channels should be collected from the cylinder head, as represented in figure 3. The water channels consist exactly of the internal cavities of the cylinder head.

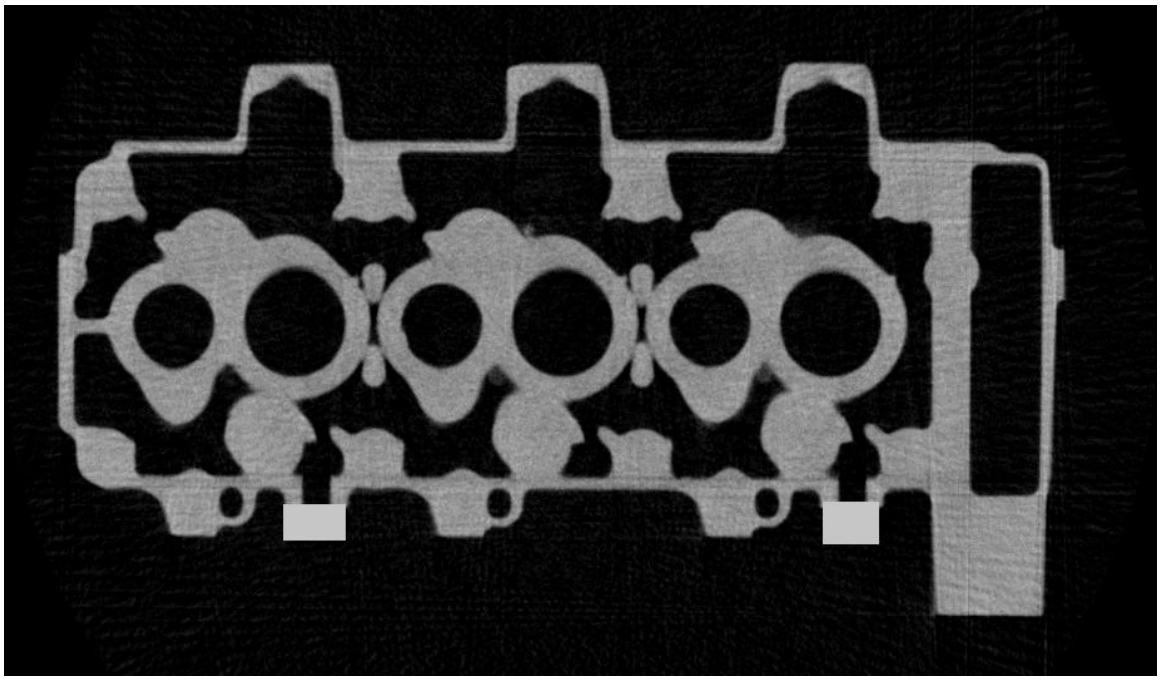

Figure 4: With CT digitized grey value image at z=24

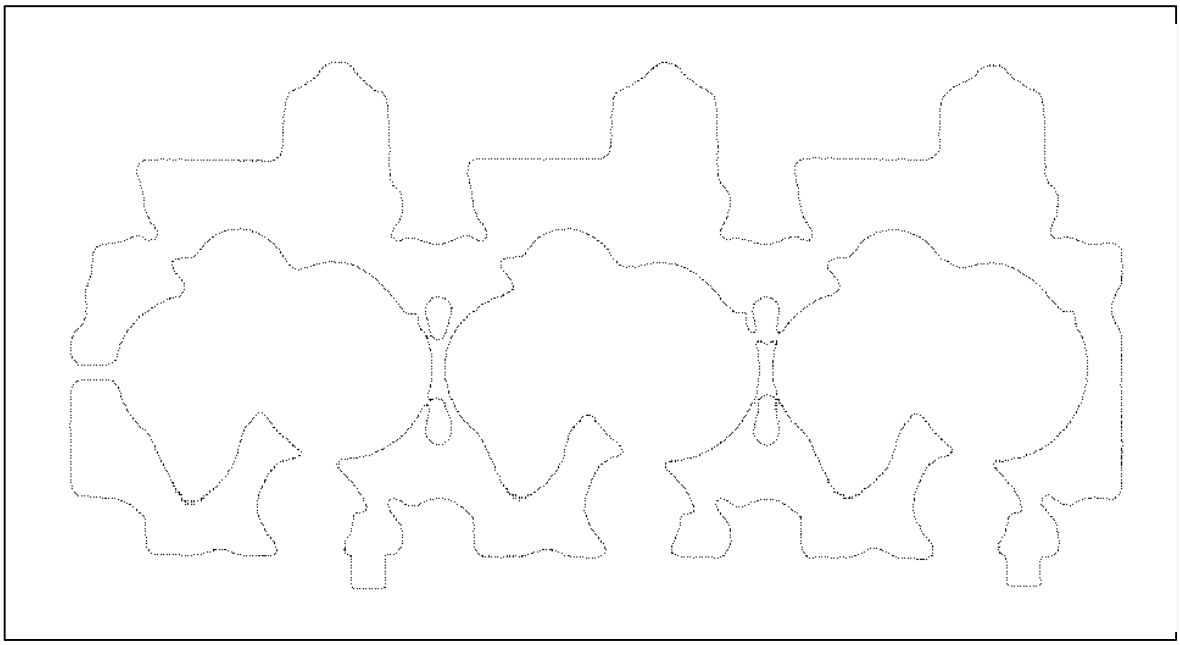

Figure 5: Interior contours by grey value image processing

For this case 150 2D image slices of the cylinder head were scanned with CT (see figure 4) and in each 2D image the contours were calculated (see figure 5).

From the contours triangulated 3D-point clouds of the cylinder head and the water channels could be calculated with commercially available software for grey value image processing (s. figure 6 and figure 7).

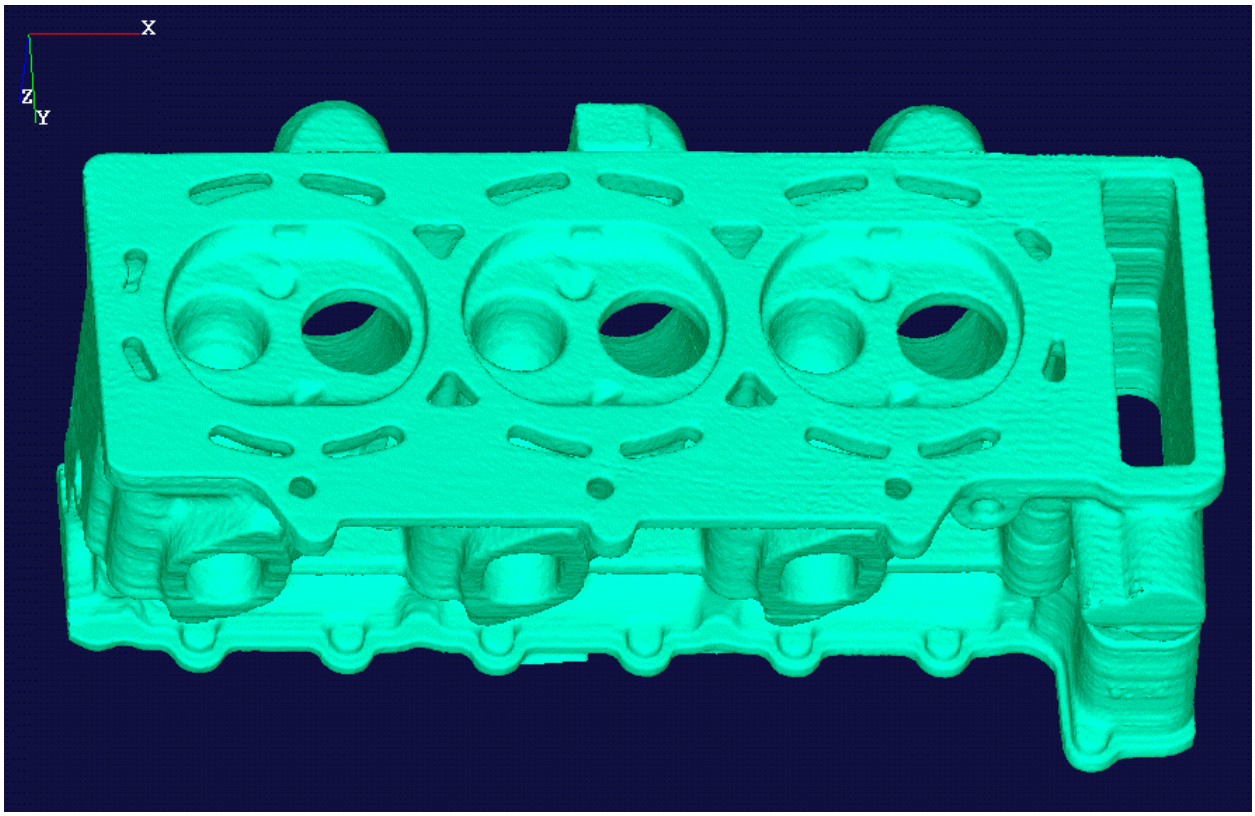

Figure 6: Reconstructed 3D-model (triangulation) of the cylinder head

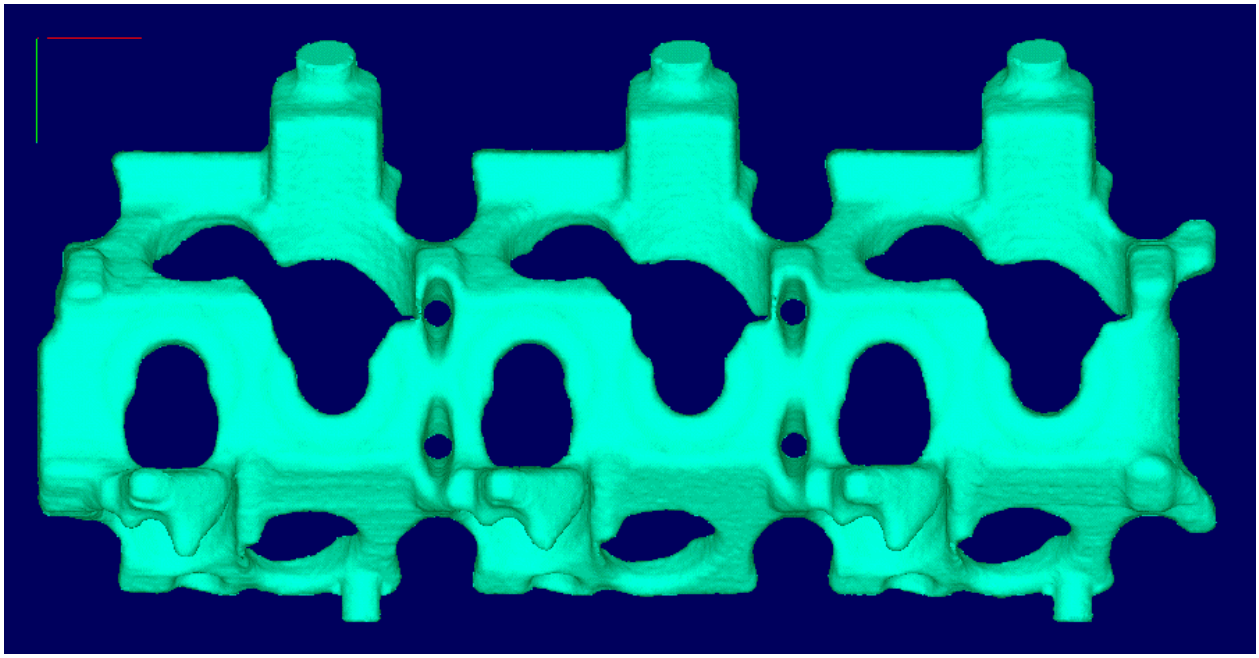

Figure 7: Reconstructed 3D-model (triangulation) of the water channels

With the triangulated 3D-point clouds of the water channel the flow simulation was executed.

Inspection of a motorcycle cylinder

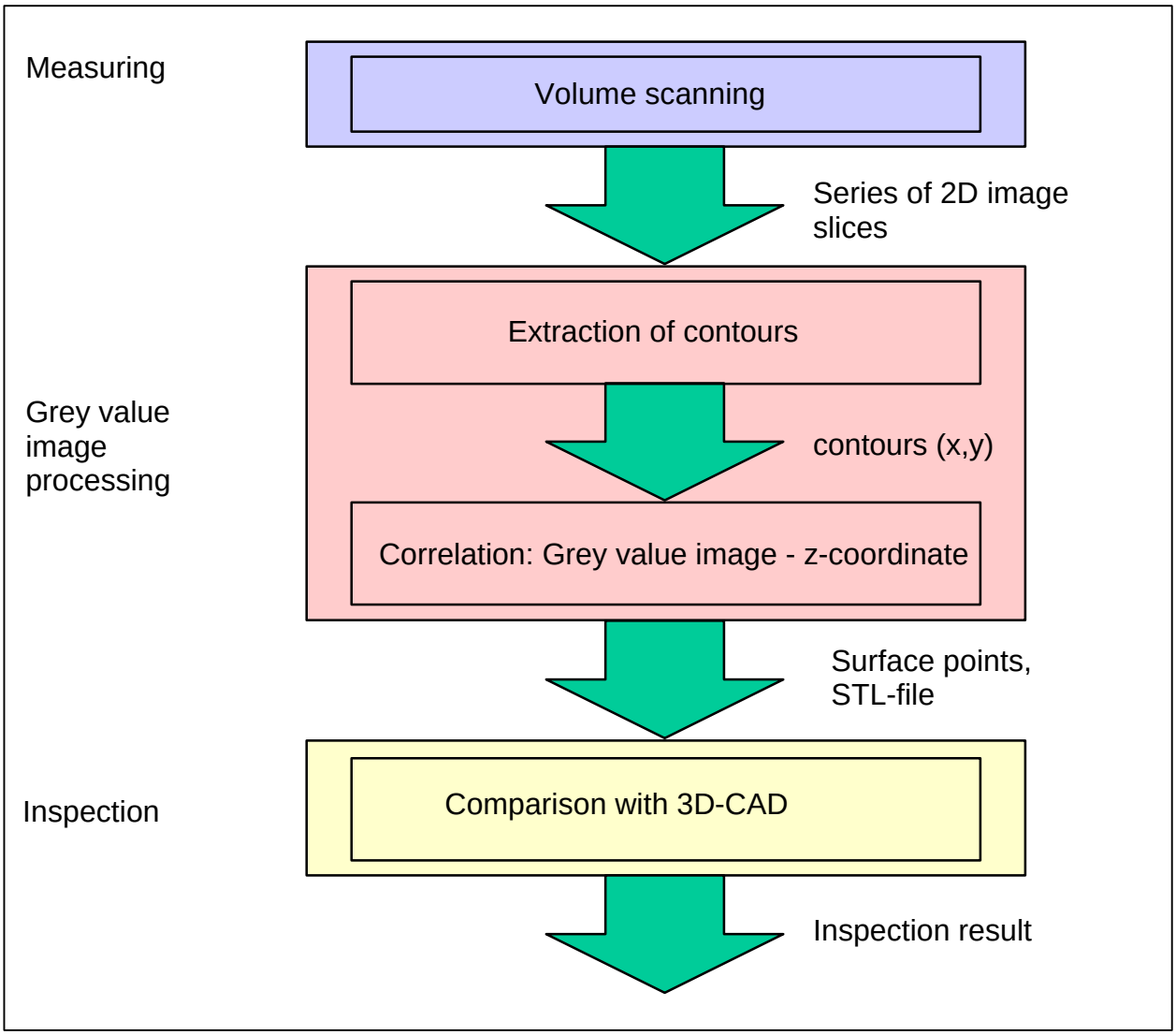

Figure 8: Process Chain Inspection

Likewise CT can be applied for the inspection of complex shapes. Here a 3D CAD-model (see. figure 9) and a motorcycle cylinder cast out of it formed the basis and the physical model and the CAD-model should be compared.

For this case 500 2D image slices of the cylinder head were scanned with CT (see figure 10) and in each 2D image the contours were calculated (see figure 11).

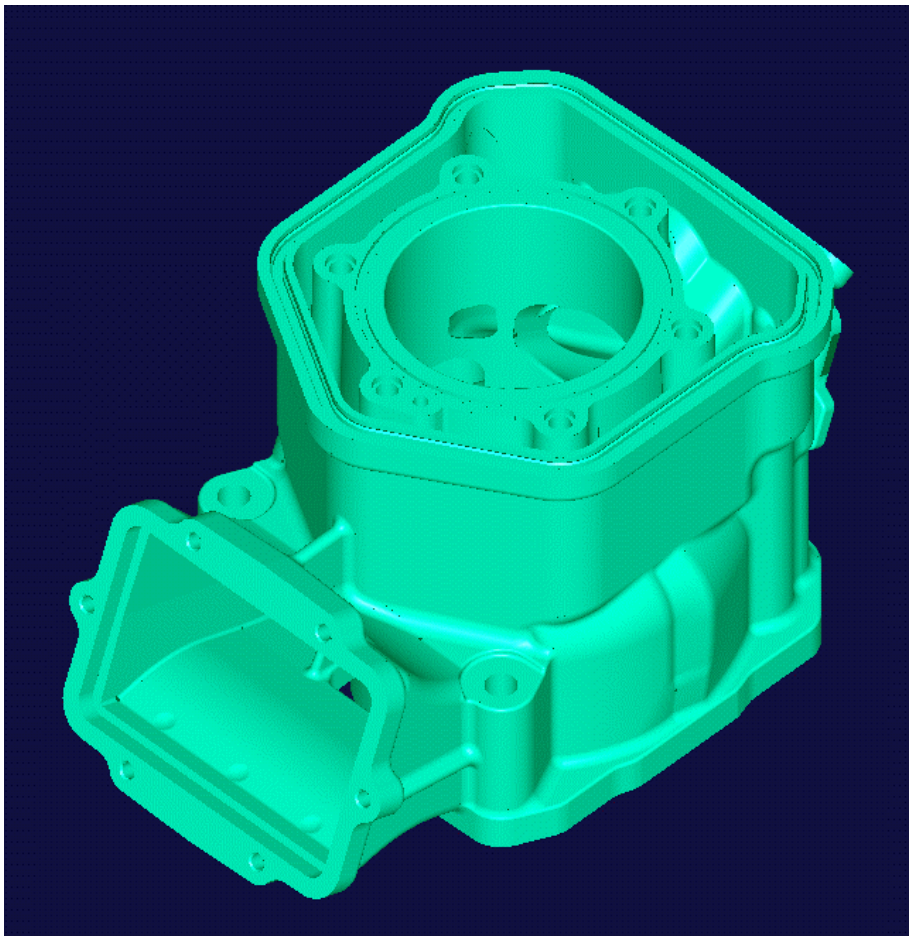

Figure 9: CAD-model motorcycle cylinder

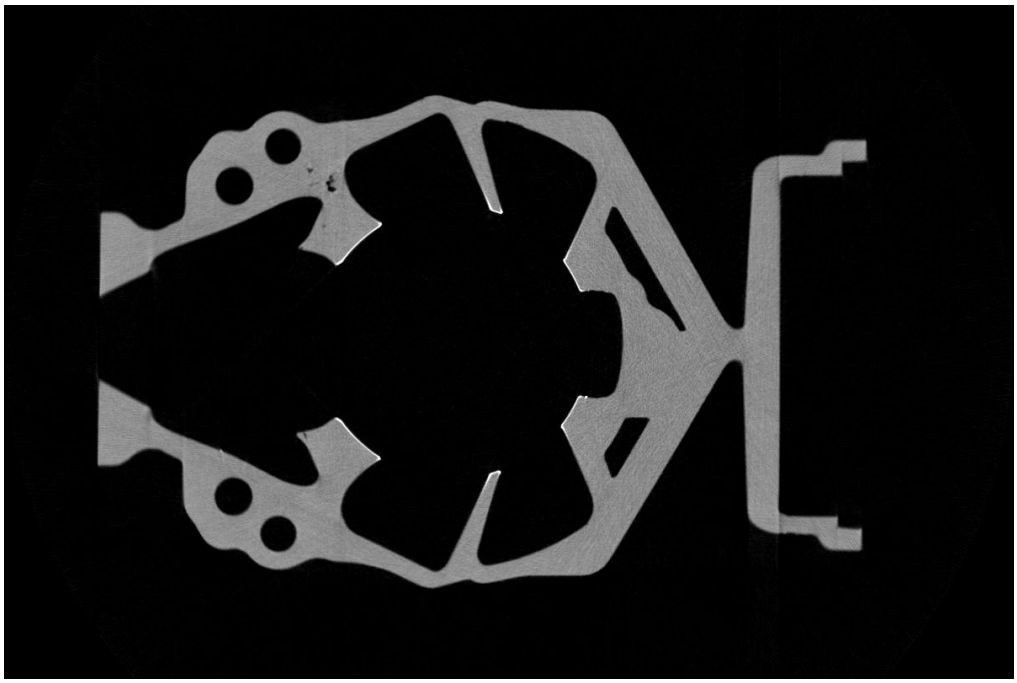

Figure 10: 2D image slice motorcycle cylinder

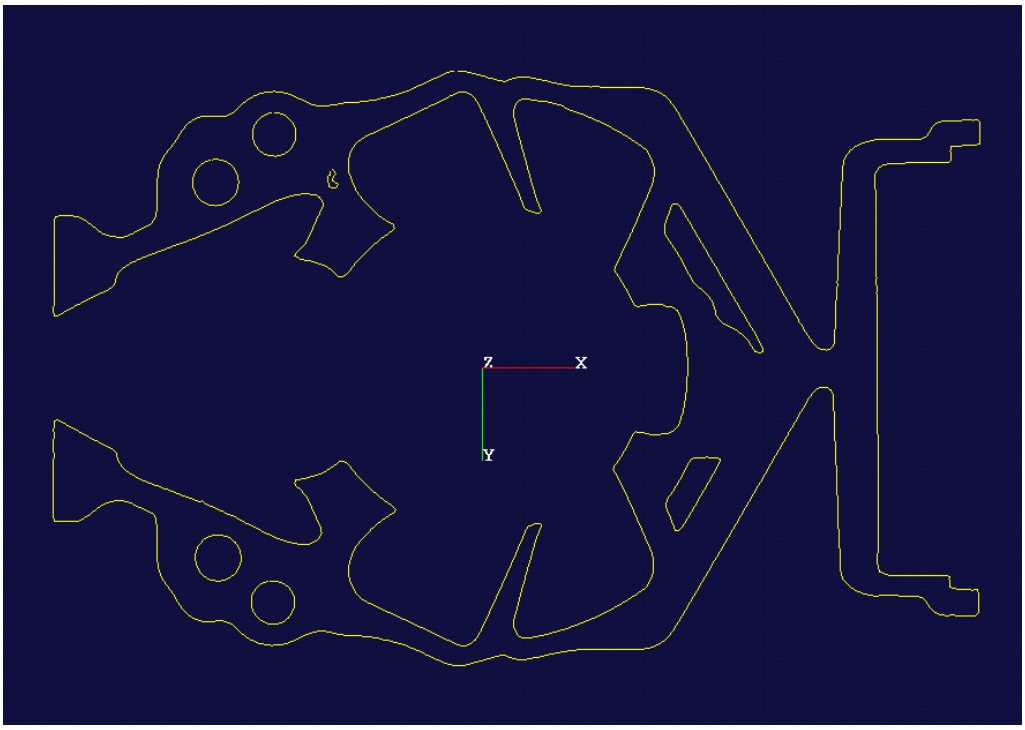

Figure 11: Contours motorcycle cylinder

A 3D point cloud could be calculated from the contours by grey value image processing. With CT however, no coordinate system is adjustable – in contrast to tactile measuring. Before the calculation of the deviations between the point cloud and the CAD-model, the point cloud must be aligned to the CAD-model (see figures 12 and 13).

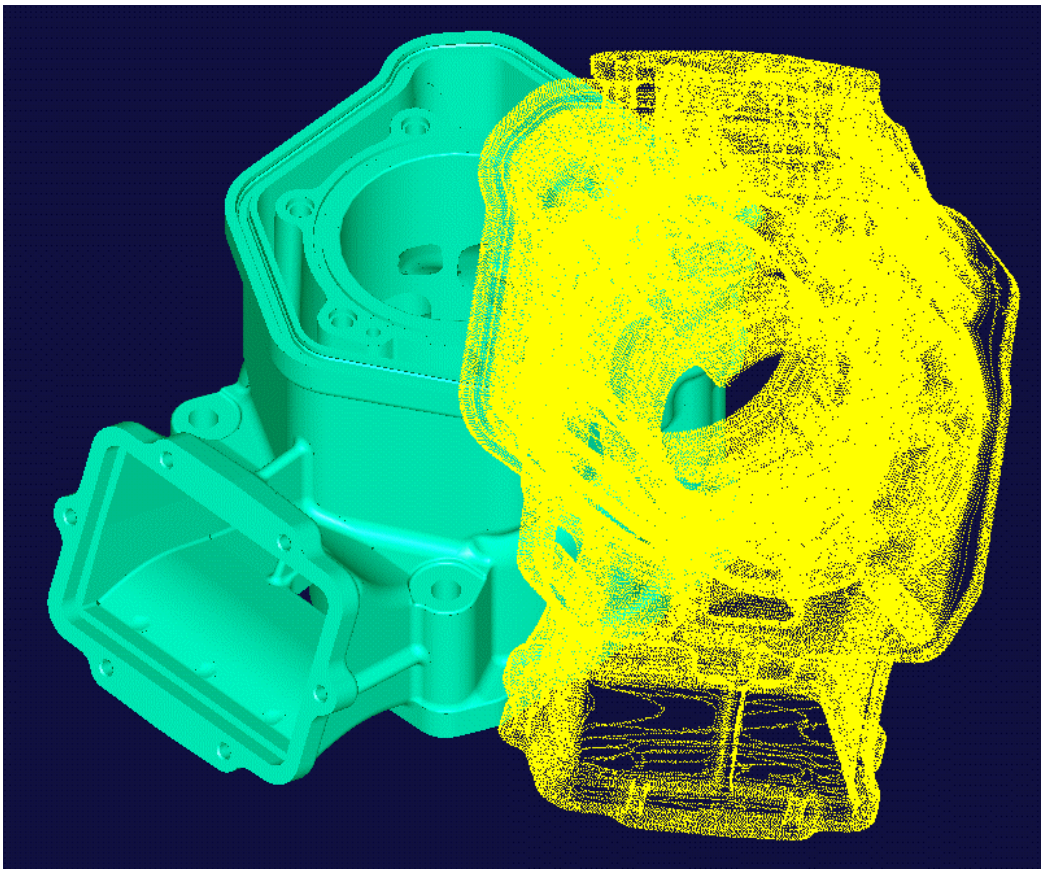

Figure 12: Point cloud and 3D-CAD-model

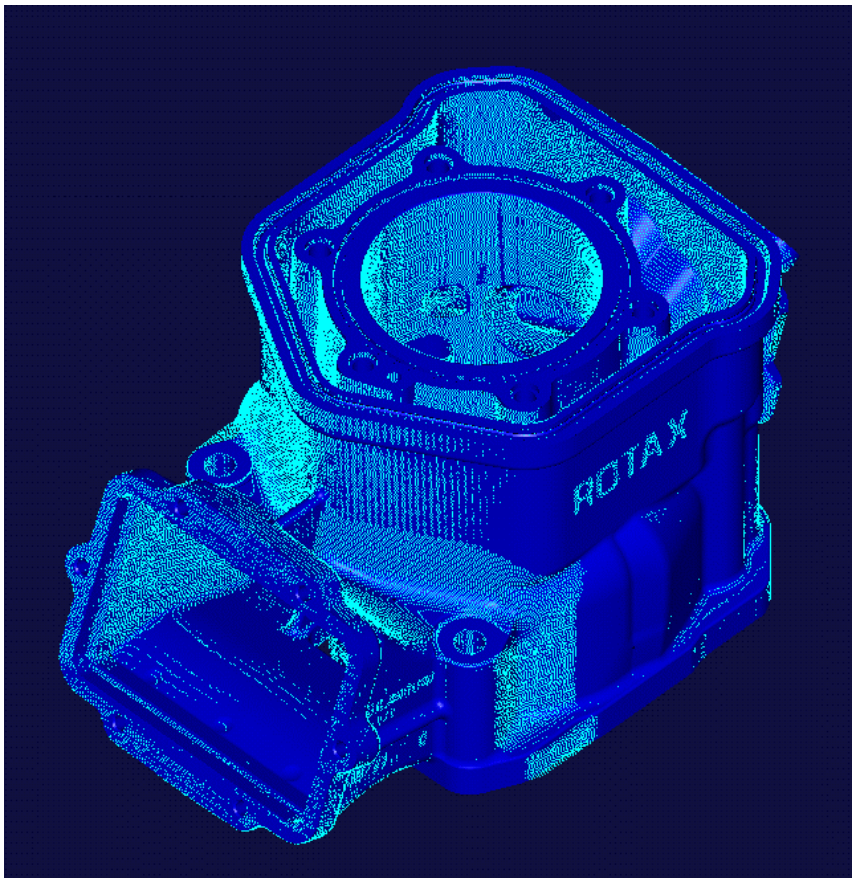

Figure 13: CAD-model and aligned point cloud

For the alignment (registration) of the point cloud, fitting elements like cylindrical drillings, plane side panels, etc. in the point cloud were calculated and assigned to the appropriate geometric elements in the CAD-model. This could be done with commercially available software.

After the alignment the deviations between the point cloud and the CAD-model could be computed. Figure 14 shows a special region of the CAD-model and the point cloud and the deviations. Depending upon the size of the deviations to the point cloud the CAD-model is differently colored. Since the Rotax writing was not contained in the CAD-model in figure 14, but attached with the manufacturing of the tooling, particularly large deviations can be detected there.

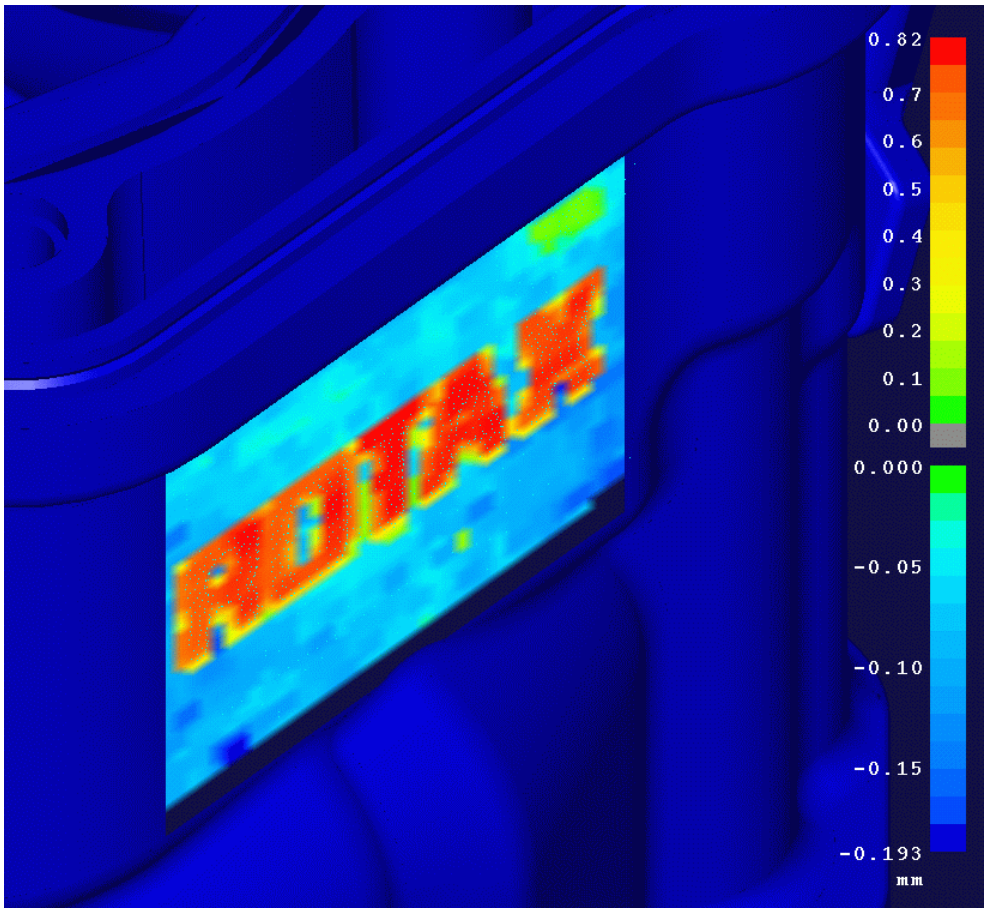

Figure 14:Deviation between point cloud and CAD-model

Summary and result

With the application of CT, new process chains for measuring and test functions of complex components could be established. The CT compared with conventional measuring procedures, offers the following advantages:

- During the digitizing only small interactions are necessary.
- Contrary to surface-oriented measuring procedures, with CT internal structures of complex components are completely entered.
- From the 2D image slices, triangulated point clouds can be reconstructed in substantially short operating time .
- Due to the reconstruction on the basis of 2D image slices, CT can also solve complex tasks like the determination of internal cavities (water channels).

At present further industrial application of the CT are being examined by the Fraunhofer Institute for Manufacturing Engineering and Automation in Stuttgart, as well as the companies involved to the *Anwenderverbund Volumenabtasten* are supported during the testing, evaluation and introduction of new technologies and process chains.

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