Application Example: Reverse Engineering

Use of optical measuring technology in the ceramics industry

Measuring system: ATOS
Keywords: Reverse Engineering, Tool and Moldmaking, Quality Assurance, Ceramic Castings, Contraction Ratio Analysis, CNC-Milling

Ever more complex components, more sophisticated technical requirements, new materials and shorter product cycles pose new challenges and tasks for the ceramic industry as development times are continuously being shortened. Optical 3D measuring technology can provide advantages in all stages of product development of a ceramic product, e.g. during tool and mold development as well as during the production process.

Today modern, innovative companies use optical 3D measuring technology for faster construction of forming tools, for geometry and dimensional checks during first article inspection and to create backup copies of try-out tools. In the ceramic industry, capturing of the actual shape of a product is of utmost significance, as dry and firing shrinkage must be completely understood so that the related deformation during the production process can be compensated.
Reverse Engineering / Model & Form Making

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Optical 3D Digitization System
The ATOS 3D Digitizer is based on the principle of triangulation. The sensor unit projects different fringe patterns onto the object to be measured. These patterns are then recorded by two cameras. Based on the optical image equations (calibration), the computer automatically calculates the 3D coordinates for each camera pixel of the scanned surfaces with very high precision. Individual measurements are automatically transferred to a common object coordinate system using previously applied reference points. During each measurement, the software checks online for system calibration, sensor movement or any ambient changes that might affect the measurement.

The ATOS sensor head can be positioned manually on a tripod and is, due to its robust design, built to perform also in harsh and adverse production environments. The ATOS 3D optical digitizer is mobile and can easily be adapted to specific measuring tasks and object sizes within a few minutes by interchangeable lens sets. Due to this flexibility, the ATOS system is able to measure objects of various sizes, from filigree injection-molding components to a complete aircraft. Robots or multiple-axes motion units are available for automated measurement.
**Reverse Engineering / Design**

Hand-made models, such as visualization models or oversized models, in which the contraction ratio has already been implemented, can be quickly scanned completely capturing all freeform surfaces using optical digitizing (Fig. 1). The measured data is initially available as point cloud or polygon mesh which can subsequently be mirrored, inverted or scaled in the ATOS software (Fig. 2).
Depending on the requirements e.g. for import into CAD-systems the ATOS measuring data can be reduced using curvature-based algorithms without any quality loss in order to minimize the data volume (Fig. 3). In addition, any arbitrary sections, such as axes parallel, along radii or splines and basic primitives can be created and exported as IGES (Fig. 4, 5).

For the actual surface reconstruction special software packages (e.g. RapidForm, Geomagic, Polyworks, Pointmaster, Icem-Surf, etc.) are available where NURBS-surfaces can be constructed directly on the polygon mesh. Thus, surfaces can be mathematically described whose conventional creation in normal CAD systems can be very time-consuming.

Today, a number of CAD programs, such as Catia, ProE, etc., as well as tool and moldmaking systems, such as Tebis, Visi and Delcam can also import and effectively process the ATOS measuring data in their original data quality and native resolution. Consequently, the designer can now work independently from the metrology engineer taking all necessary information for surface reconstruction from the high resolution scan data.
**Reverse Engineering / Moldmaking**

When developing forming tools in the ceramics industry the appropriate dry and firing shrinkage for the corresponding materials being used must be taken into account. Each contour of the form must be differently enlarged by a defined percentage (allowance) in order to obtain a product with the correct shape and size. Not only is the material property vital for obtaining a suitable product, but also the geometry (shrinkage resistance) and, above all, a correct technical design.

If the visualization model or the oversized model has been previously digitized, a smooth route into CAD/CAM is now possible. The CAD data for models and forms can be derived by means of surface reconstruction of the scanned data (reverse engineering) using respective software packages (Fig. 6-8).

Fig. 6: Surface reconstruction using ATOS measured data (curve net).

Fig. 7: Surface reconstruction using ATOS measured data (NURBS surfaces).

Fig. 8: Surface reconstruction using ATOS measured data (rendered surfaces).
Quality Assurance / First Article Inspection
Capturing of the actual contour is of vital significance in tool and moldmaking, as properly fitting items come from “wrong” molds which compensate shrinkage and deformation during production process and de-molding.

For first article inspection and quality control, the ATOS measuring data of digitized components can be directly compared with the original measured data or CAD master data (Fig. 9). Such a full-surface nominal/actual comparison can be used to quickly determine whether defined tolerance limits have been maintained, or to control which areas of a component have been deformed.

The measured data and the CAD model are therefore imported into the ATOS inspection software. After the alignment to the CAD coordinate system (e.g. RPS registration, 3-2-1, Best-Fit), any deviation can be immediately visualized using a color plot of the entire component surface and easily and quickly interpreted (Fig. 10).

Fig. 9: Measurement of a glazed sink of a pre-production series using the ATOS 3D measuring system.

Fig. 10: First sample inspection of items from a pre-production series (full-surface nominal/actual comparison with the master data).
Defined points can be just as easily individually calculated according to the principle of conventional coordinate measuring machines (Fig. 11). For documentation and further processing 3D reports or tables can be generated, and the results and deviations can be exported to various formats such as Excel, HTML, Word, 3D Viewer, etc. (Fig. 12).

**Fig. 11:** First sample inspection of items from a pre-production series (defined measuring points nominal/actual comparison with the master data).

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**Fig. 12:** First sample inspection of items from a pre-production series (export tables of defined measuring points with tolerance limits).
Reverse Engineering / Adaptation of Tools during Pilot Production

Based on the differences between CAD data and measurements of first samples derived from the forming tools, necessary modifications which may be required during pilot production can be completed efficiently.

Any manual modifications made during tool try-out or production startup phase can be immediately updated into the CAD model with the aid of ATOS-3D digitization and surface reconstruction.

In this phase, manual modified areas can be detected by means of a nominal/actual comparison between the CAD model and the actual component enabling the CAD to be modified to reflect the true form (Fig. 13 - 16). This method guarantees that the actual status of the tool will constantly be recorded and is also available as a CAD data record for all CAD/CAM processes.

Fig. 13-16: Exemplary presentation of tool / mold development with adaptation.
Archiving / Product Variants
Digitization during pilot production also enables for permanent archiving of all various forms and process stages of a product. This provides access to variants which might be no longer present (Fig. 17). Meshes of the various model states can then be compared and areas may be combined. This allows product variants and modified products to be created quickly and easily at any time. ATOS 3D digitization of older tool and mold depots also permits classic products to be quickly adapted and refabricated.

![Fig. 17: Archiving of model variants.](image)

Tool Duplication using 3D Measuring Data / Digital Data Backup
In the ceramics industry the die for duplicating the forming tools represents a decisive factor. Apart from adapting tools the ATOS 3D digitizer is also used at this stage of the process chain for a digital data backup of the functioning tools in case of loss or damage.

A lot of CNC programs and controllers can now generate and machine milling paths directly on digitized point clouds or meshes (Fig. 18, 19). In this manner, broken dies can be duplicated quickly and easily even without having any previous surface reconstruction performed at all.

![Abb. 18, 19: CNC-milling path generated directly on ATOS measuring data.](image)
Quality Assurance / Final Inspection for Production

With the use of macros, the ATOS 3D measurement system is also well-suited for use in final inspection of components (Fig. 20). Based on a single measurement, the flatness of surfaces (Fig. 21), angles, slopes, tap bank inclination, valve position, etc. can be analyzed (Fig. 22, 23).

Fig. 20: ATOS measurement on a glazed sink for final inspection during production.

Fig. 21: Measuring report (flatness of plane).

Fig. 22: Measuring report (angles, inclination).

Fig. 23: Measuring report (valve position).