

Application of the Optical 3D Measurement Methods in Sheet Metal Processing

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Abstract

Optical measuring techniques for 3D-coordinate measuring, quality control, component and material testing are gaining importance as industry raises its demands in high technical performance of final products, short production times, low manufacturing costs and overall product quality. In a current turbulent period of the global economic crisis 3D measuring data has become mandatory for the automotive, aerospace, and consumer goods industries.

This article will focus on the industrial application of three different optical measuring techniques which enable high potential for reduction of development times, optimization of production processes and higher product quality: full 3D surface geometry measuring for shape and dimension control of components and tools, 3D strain measuring for material and forming analysis and a dynamic measuring system for 3D motion analysis of machine tools.

Keywords: Optical 3D measurement, quality control, forming limit curve, forming analysis, FE verification

1. Complete 3D surface geometry measuring

1.1 ATOS Triple Scan: 3D-surface measurement

Knowledge of the object's shape and dimensions is historically associated with the measurement branch of the mechanical engineering, but the need for the exact shape knowledge nowadays exists in a vast majority of industrial applications. For example, shape information is important for the accurate position check, modeling of sheet forming moulds and the elastic return control, for shortening of the development time through clay modeling in automotive industry, car airflow (CFD) analysis or the numerical process simulations (CAE), in tool production and try-out (CAD/CAM), in first article inspection and quality control during production (CAQ) or reverse engineering (RE).



Fig. 1. ATOS Triple Scan

Optical fringe projection system ATOS Triple Scan captures the entire component 3D geometry in a dense point cloud as opposed to individual point measurements with the tactile measuring machines. Its main components are two digital cameras (up to 8Mpixel) and a centrally positioned projector (Fig. 1).

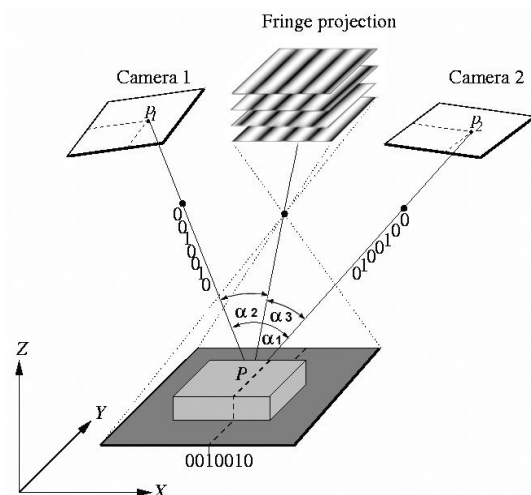


Fig. 2. Fringe projection and triangulation

Projector's role is to help locate the same object point in both cameras by the projection of a fringe pattern (Fig. 2.). Reconstruction of the spatial location of the observed object point is conducted by the

triangulation process. For each image point per calibrated camera one virtual light beam is projected back into space. A point in space where those beams meet is considered to be the reconstructed spatial point position. Compared to conventional fringe projection procedures, the ATOS Triple Scan [1] uses all three viewing angles from the stereo camera and projector (α_1 , α_2 , and α_3 , Fig. 2). This method results in three individual viewing perspectives of the object (3 in 1 sensor). The new approach in combination with the „Blue Light Technology“ makes the sensor more independent of ambient light.

1.2 Case study: tool try-out and wear analysis

While manufacturing sheet metal components, in order to obtain the correct 3D shape the geometry of the stamping, die has to be modified during try-out. This try-out is used to correlate the complex interaction between material, tool and press machine. Because of these modifications (after try-out) final geometries differ from the simulated tool shape and the CAD data model. Heavy forces - like pressure, friction, tight tolerances and vibration - that occur through stamping operation cause changes on tools geometries. Unwanted geometry changes lead to improper manufactured components that cannot be used in later production process. To improve maintenance and repair planning, including preventing production of scrap parts, the wear of tools should be analyzed by comparing the digitized 3D surface and the nominal CAD or measured geometry (figure 3).

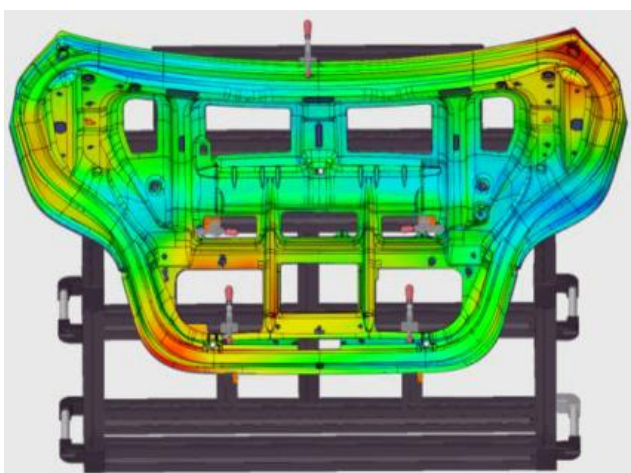


Fig. 3. Full-field comparison of 3D shape between real part and CAD model visualized on CAD

Better option for easily identifying adjusted areas by comparing the measured 3D surface with the nominal CAD surface (figure 4) is to utilize optical 3D digitizing. Nowadays it isn't any more necessary

to update the modified 3D tools surface in the CAD model by morphing or reconstruction. Manufacturing without surface reconstruction today is enabled by CAM systems that even support direct milling on STL datasets. Also, these methods enable copying and rebuilding of broken dies in much shorter time frame.

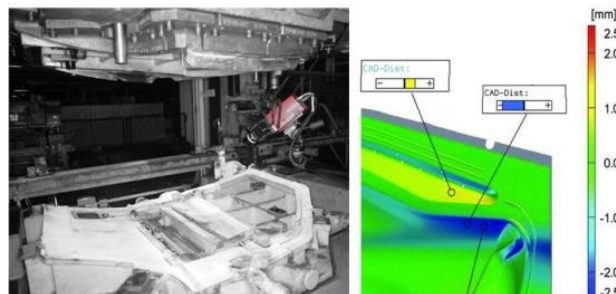


Fig. 4. Measurement of a tool inside a production facility (left) and wear analysis (right)

2. 3D strain measurement

2.1 ARGUS: Sheet Metal Forming Analysis

Sheet metal blank has to be deformed by large forces inside complex tools in order to produce the final component. During that process it is possible that material in some zones gets deformed near or beyond its limit, while component keeps the desired 3D shape. Full-field comparison of the actual sheet metal component geometry and CAD model can check deviation of final geometry, while ARGUS strain measurement system by measuring the strain distribution provides the additional information how the material actually deformed. ARGUS is the non-contact optical system for 3D measurement of deformation, which operates independently of component material. System provides precise and comprehensive 3D coordinates, displacement, and strain results. It is used for the forming analysis of sheet metal components and the validation of numerical forming simulations.



Fig. 5. ARGUS measurement setup

The ARGUS system (Fig. 5.) consists of a handheld camera and notebook, as well as a set of scale bars with encoded measurement targets.

Measuring process is based on the photogrammetric bundle block adjustment (for camera orientation and object point triangulation, Fig. 6.) and digital image correlation. Displacement and strain of any surface size can be determined between two or more deformed component stages. ARGUS forming analysis requires the preparation of the flat original blank with markers that deform together with the metal sheet during stamping (Fig. 5.). On the material surface regular dot pattern is typically prepared by laser marking, etching or printing. After forming, the applied dot pattern is photographed by a user from various directions together with a set of scale bars and encoded measurement targets (Fig. 5., 6).

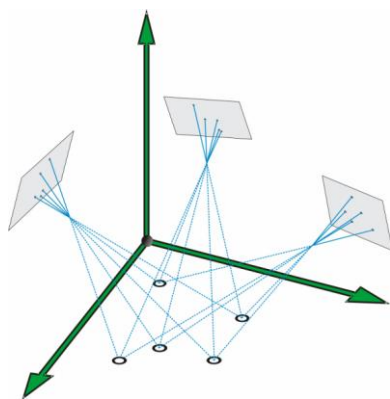


Fig. 6. Photogrammetric triangulation and bundle adjustment

During the optical forming analysis the form and principle strains (major and minor strain) are evaluated. Considering volume constancy of the material the reduction in thickness is calculated. Taking into account the forming limit curve (Fig. 7.), the forming limit diagram is calculated and considered for the evaluation of overstretched areas of the sheet metal component.

2.2 Case study: verification of numerical forming simulations

Optical deformation systems enable extensive analysis of complete products or individual components under the influence of aerodynamic, thermal, or mechanical load. The measured results can be used to optimize production processes and for verification of numerical simulations. During the development of sheet metal trunk lid numerical forming simulation are routinely performed. Necessary inputs for these simulations are material parameters and a large number of boundary conditions. The required material properties such as the forming limit curve (Fig. 7.) or yield curve can also be obtained optically by the ARAMIS system, while shape can be obtained by the ATOS system.

ARGUS software makes it easy to compare deformation results (Fig. 8.) and the FEM analysis (Fig. 9.). In this case [2] numerical trunk lid simulation results were imported into ARGUS where they were aligned and registered into the common coordinate system. Visualization of comparison of major strain (Fig. 8.) distribution on a trunk lid is then obtained by direct comparison with the numerically obtained strains (Fig. 9.). This easy to understand visual representation of the deviations makes it simple to locate areas where improvements of the numerical analysis, boundary conditions or tool geometry have to be conducted.

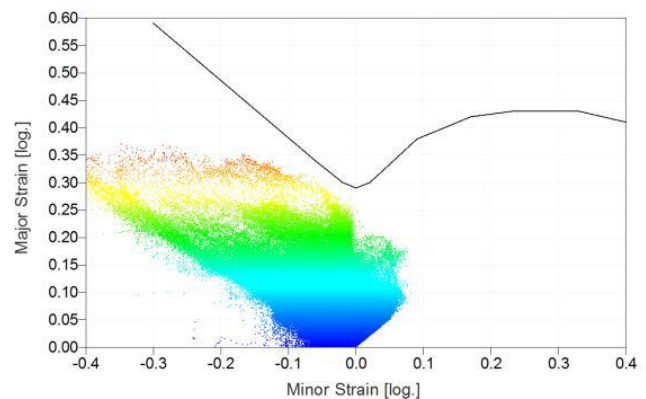


Fig. 7. Forming limit diagram including strain measuring results and FLC

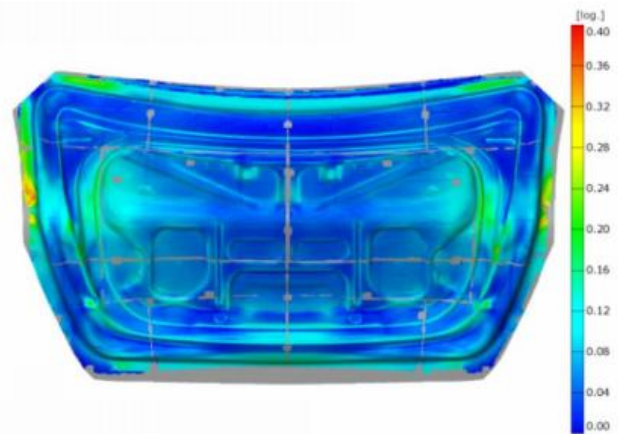


Fig. 8. Major true strain measurement of a trunk lid

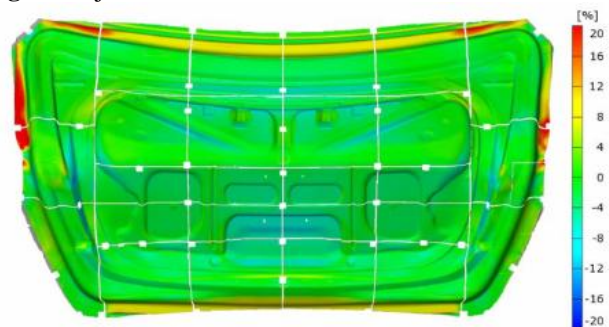


Fig. 9. FEA- measurement comparison of a trunk lid

3. Dynamic 3D movement analysis

3.1 PONTOS: dynamic deformation measurement

Verification of numerical simulation results or investigation of component safety during crash, vibrations, and fatigue or durability tests is impossible without the reliable measurement results. Nowadays, non-contact optical measuring systems for measuring displacements, deformation and velocity are increasingly replacing conventional displacement measurement systems and accelerometers.

The stereo camera PONTOS system enables optical point tracking in time by measuring their spatial coordinates and calculating displacements of the individually marked measuring points. Self-adhesive ultra-light markers are easily manually applied to the object surface in the area of interest. Any number of markers can be tracked simultaneously with high precision and accuracy (Figure 10).

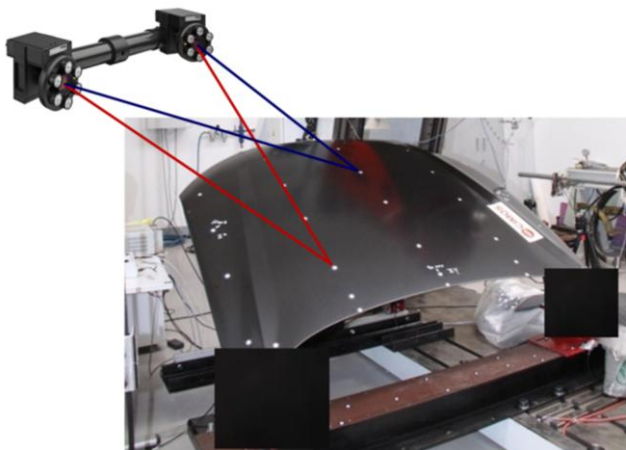


Fig. 10. PONTOS measurement setup

3.2 Case study: Head impact test

Pedestrian safety is one of the requirements why CIMOS has in 2002 turned in into the global development of pedestrian protection systems and in the development and production of the active hood hinges. Purpose of active safety systems is to protect the pedestrian from the serious injuries. Activation of the safety system should increase hood deformation area thus reducing the injury by absorbing the impact energy. Active system we analyzed consists of the car hood, special hood hinges with activators, acceleration sensors and the control unit. Measurements in CIMOS [3] were conducted with the measurement system PONTOS HS with the frequency of 500Hz with the full resolution of 1,3 Mpixel. Cameras were attached

to the 1,2m stable carbon fiber frame and fixed approximately 2,5m above the bonnet.

On the measured car bonnet retro reflective self-adhesive markers were attached. Additional points were attached to the reference frame, which served as the static reference. After the activation process ended, head model was deployed with onto the partly opened car hood, aimed at the predefined location (Fig. 11.). Recording of the image pairs was triggered (via the analog connection) together with the head deployment unit. Measuring results were bonnet displacements and velocity, as well as the HIC factor.

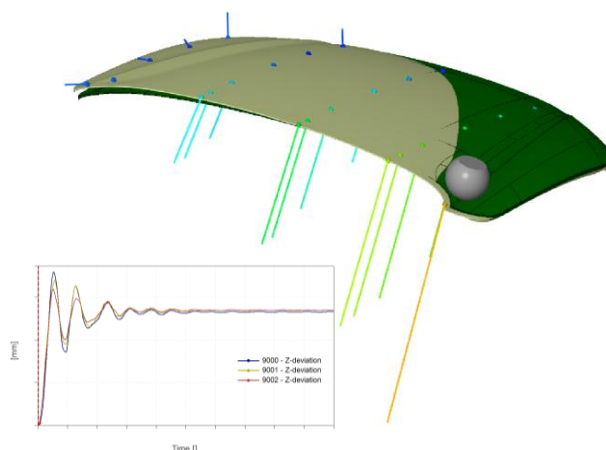


Fig. 11. PONTOS measurement results

4. Conclusion

Shorter product cycles and cost optimization today force companies to be more efficient in their development, first article inspection and production process optimization. The presented 3D digitization and deformation measurement systems were developed with the industrial requests in mind. With over 3000 installations around the world, presented systems are daily utilized in process optimization, cost reduction and the reduction of development times.

5. References

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