

Application Note: 3D Motion Analysis

Optical measuring technology for dynamic analysis of press machines

Measuring system: PONTOS

Keywords: sheet metal forming, process optimization, MFU, analysis of guides, tilt and machine stiffness, dynamic machine tool behavior, metal forming, joining, pressing, cutting, bending, drawing

Dynamic production processes have a major impact on the quality of finished parts during metal forming with machine tools. Machine stiffness, deviation of guides and drives as well as centering and angular positions all play a key role in this regard.

Tool service life can be increased considerably by carrying out analyses with the PONTOS non-contact stereo camera system for optical dynamic 3D deformation measurement. As a result manufacturing processes can be optimized and costs reduced.



GOM mbH
Mittelweg 7-8
38106 Braunschweig
Deutschland
Phone +49 531 390 29 0
Fax +49 531 390 29 15
info@gom.com

GOM International AG
Bremgarterstrasse 89B
8967 Widen
Schweiz
Phone +41 5 66 31 04 04
Fax +41 5 66 31 04 07
international@gom.com

GOM France SAS
10 Quai de la Borde - Bât A2
91130 Ris Orangis
Frankreich
Phone +33 1 60 47 90 50
Fax +33 1 69 06 63 60
info-france@gom.com

GOM UK Ltd
Business Innovation Centre
Coventry, CV3 2TX
Großbritannien
Phone +44 2476 430 230
Fax +44 2476 430 001
info-uk@gom.com

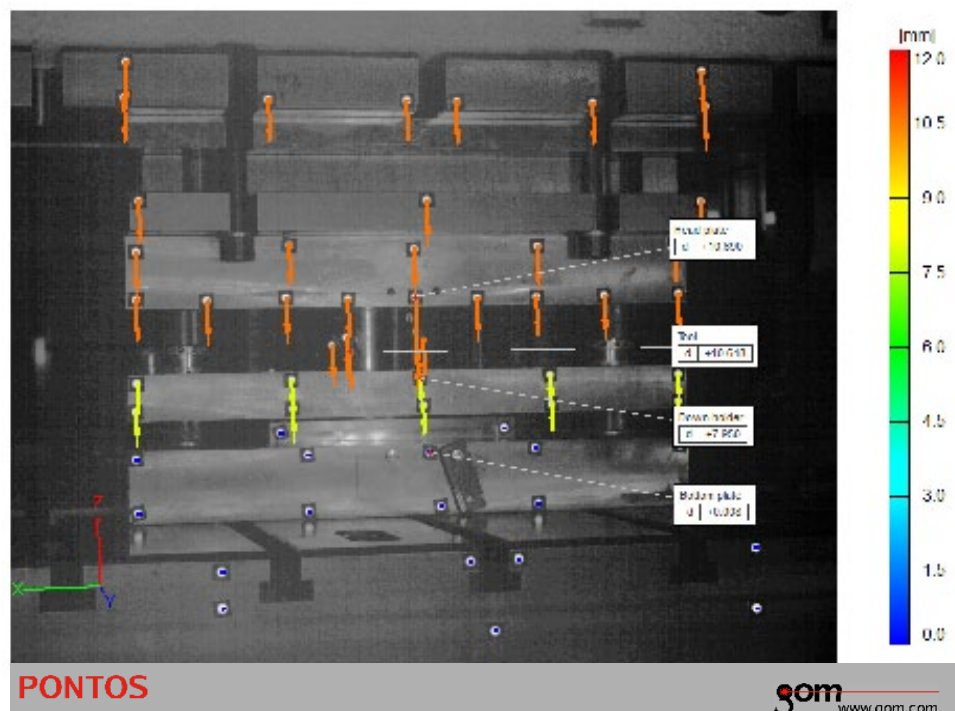
GOM Branch Benelux
Interleuvenlaan 15 E
3001 Leuven
Belgien
Phone +32 16 408 034
Fax +32 16 408 734
info-benelux@gom.com

3D motion analysis / component development (Machine tools, process optimization)

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Some forming manufacturing processes require further analysis methods in addition to the knowledge already in place. Optical 3D measurement allows the shape and dimensions of forming tools and sheet metal parts to be inspected during tool try-out. However, successful production depends on more than tool geometry, since, as tool try-out shows, it is sometimes not possible to produce optimal parts despite modifications of tool surfaces.

Dynamic processes also have a major impact on the quality of finished parts during metal forming with machine tools and can be analyzed successfully with real-time 3D deformation measurement systems.

The PONTOS optical deformation measurement system can be used to analyze the dynamic behavior of forming machines. The stereo camera system visualizes any deviation in guides and drives as well as in centering, angular positions and machine stiffness.

Bolster plate deflections can be measured and stroke position adjusted. This increases tool service life and optimizes manufacturing processes so that costs can be reduced.

Dynamic deformation measuring system

The portable PONTOS optical measuring system measures the spatial coordinates and displacement of individual measurement points. The system typically consists of a stereo camera sensor, tripod and computer (Fig. 1). The points or areas on the object to be measured are identified with self-adhesive and temperature-stable markers before the measuring process is carried out (Fig. 2).



Fig. 1: PONTOS system for optical dynamic 3D analysis, sensor, tripod, computer, (typical measurement set-up)



Fig. 2: PONTOS consumables, self-adhesive markers

The PONTOS measuring head is freely positioned on a tripod in front of the measuring object. The system can be flexibly triggered and records images for one or plenty load conditions. The stereo camera system makes it possible to determine any number of markers within the measuring volume simultaneously with maximum precision and accuracy (Fig. 3 and 4). The PONTOS system is virtually self-monitoring, since calibration accuracy is checked at every measurement.

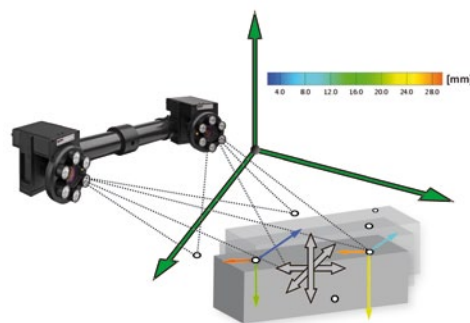


Fig. 3: PONTOS measuring principle, spatial 3D online measurement of marker positions and displacement, 3D displacement vectors



Fig. 4: Online deformation measurement of a wind power plant. The PONTOS system enables analysis of vibrations, frequencies, torsion, bending, speed, acceleration and trajectories

Thanks to use of high-speed cameras, the system can also be used to measure fast processes and motion sequences, e.g. during component testing in wind tunnels and in crash-test stands (Fig. 5).

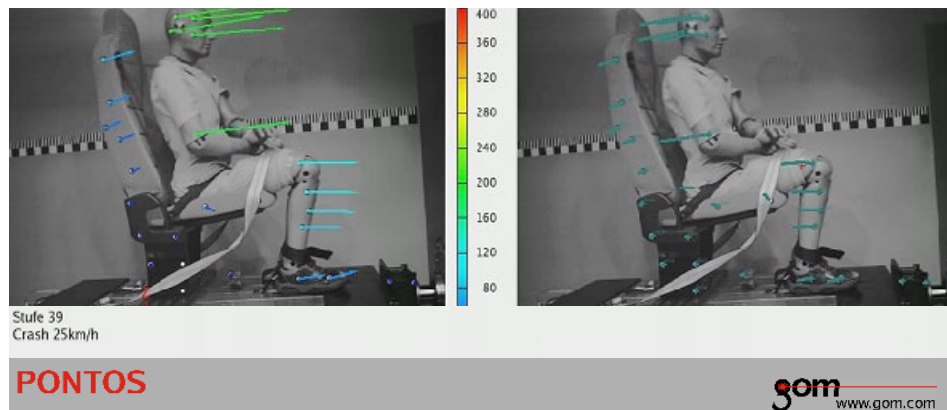


Fig. 5: PONTOS high-speed deformation measurement in a crash-test stand. Online analysis of displacement vectors and trajectories.

Positions and movements of complex parts that cannot be directly measured (e.g. concealed blanks or tool tips), are measured by means of adapters. Any group of points can be defined in advance as an adapter and calibrated accordingly (Fig. 6).

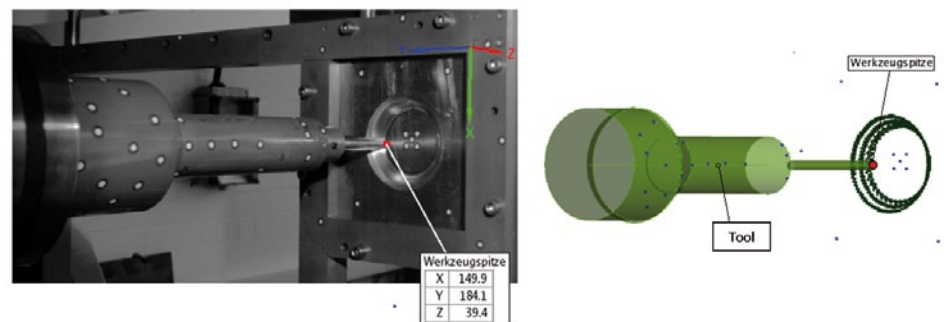


Fig. 6: PONTOS measurement of tool tip movement using an adapter (group of calibrated points), visualization via primitives.

Since measurements are taken online, the PONTOS software can also automatically evaluate the recorded high-speed images in a real-time deformation analysis. Various report options are available for evaluating the positions and displacements of the measuring points. 3D displacement vectors and diagrams are used to monitor deformations such as torsion, bending, deflection, etc., in real time and to investigate structural vibrations, speeds and accelerations. Measurement results and analysis can be exported as PDF files or as images, videos, worksheets and diagrams (Fig. 7).

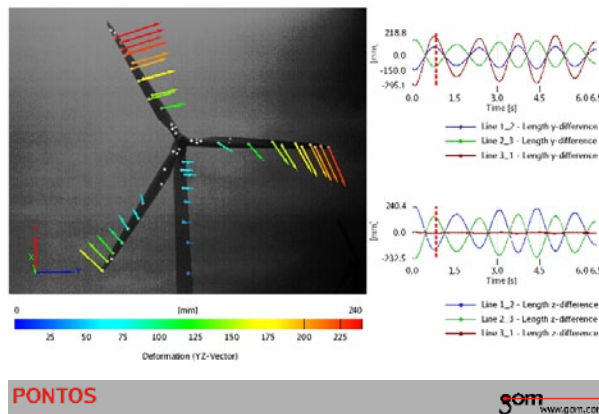


Fig. 7: PONTOS measurement report, the 3D displacement vectors can be visualized in the real camera image for each deformation step. In addition, real-time analyses can be produced in the form of diagrams and videos.

Typically, it takes one person just under an hour to set up the PONTOS system and apply markers to a medium-sized measuring object. The variable system can be quickly and flexibly adapted to different sizes of measuring field, with possible dimensions ranging from a postcard to a wind power plant. The optical PONTOS system for dynamic 3D analysis thus replaces conventional extensometers, LVDTs and accelerometers. PONTOS is a completely new system that is also deployed to measure velocity.

Dynamic analysis of metal forming machines

Metal forming is one of the most complex production processes due to the multiple forming steps and progressive dies it involves. Knowledge about the material properties of the metal blanks used in the forming process plays a vital role in the manufacture of high quality metal components, as does geometric precision and the high-quality surface finish of the manufacturing dies. Special expertise is needed above all to adjust the machine parameters, for example to apply the right settings for blankholder force, the stroke length and force of the ram, die cushions and drawing punches.

It may therefore take some time before a new metal part complies with the required manufacturing quality. In addition, the costly forming tools may have an untypically short service life, with the result that too many of the manufactured parts prove to be of inferior quality. These problems are not always caused by defective forming tools, whose shape and dimensional accuracy can be inspected quickly with optical 3D scanning. Tool wear is influenced not only by process parameters (pressing force, ram stroke, die cushion pressure, etc.) but also by the static and dynamic interactions between the press and the tool (bending, vibration, ram return stroke, etc.). Further problems can often only be resolved by analyzing the dynamic forming process on the forming press while it is in operation.

However, it is difficult to analyze its rapid and complex movements with the required precision using conventional measuring systems. For this task optical measuring systems offer a clear advantage. The PONTOS system can take detailed measurements of the complex and rapid sequences that typically occur in forming processes.

Measuring objective

In order to investigate root causes and optimize the metal forming process based on a hydraulic press, it was necessary to look at two different issues. The first involved static machine stiffness analysis, to measure the bend and tilt of the cross-beam and machine bed as well as of the machine frame when force was applied to a narrow area of the press. The task was to measure deformation caused by centralized and decentralized component positions.

This was to be followed by online analysis of a real punching process in order to test dynamic machine stiffness. The aim was to analyze not only the bend factor of rams, drawing punches and die but also the speed and any vibrations on blankholders, drawing punches and die. The ram return stroke was of special interest.

Measuring procedure

The mobile, optical PONTOS system can be easily integrated into existing test environments and was freely positioned on a tripod in front of the press (Fig. 8). The self-monitoring system generates reliable and precise data even under critical working conditions, as found in a production environment.



Fig. 8: PONTOS measurement set-up in the production environment.

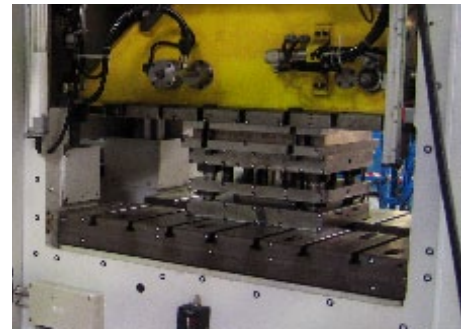


Fig. 9: Preparation for PONTOS system measurements, the components that are to be included in static and dynamic deformation measurement are labeled with self-adhesive markers.

Self-adhesive markers were applied to the individual components such as machine frame, press bed, cross-beam, rams, drawing punches, blankholders and die (Fig. 9).

The hydraulic press was then set to a specific starting position and a measurement was taken, which represented the reference state for the subsequent displacement measurements. This was followed by static and dynamic machine analyses.

Measuring results of static machine stiffness

It took one person under an hour to prepare and perform the actual measurements. Evaluation and analysis can be carried out immediately on site on the basis of the images obtained, and subsequently varied at any time when required.

Extracts from the static load analysis are shown in graphical format below. A centered load produced hardly any tilt, whereas a decentralized load of 10% from the center caused a noticeable tilt in the press bed and cross-beam. To compensate rigid body movement, the press bed was assumed to be stable (Fig. 10). Analog measurements were taken of the obvious discrepancy between the feed forces and actual impact forces and synchronized with the optical deformation measurements. The PONTOS software makes it possible to record analog force signals and synchronize them with the optical measurement data. This guarantees that deformations are measured against the correct input parameters, since feed forces may diverge greatly from the actual impact forces.

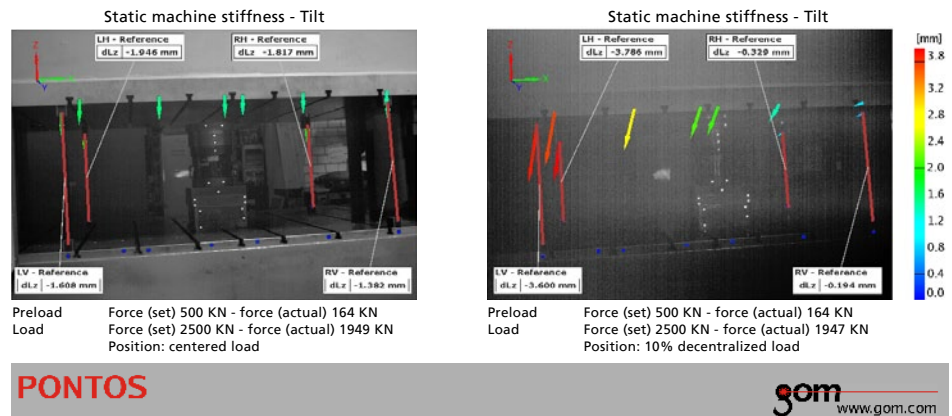


Fig. 10: Static deformation analysis, tilt of press bed and cross-beam with centered (left) and 10% decentralized load (right). To compensate rigid body movement, the press bed was assumed to be stable.

Analog measurements were taken of the obvious discrepancy between the feed forces and actual impact forces and synchronized with the optical deformation measurements.

Static load analysis also measured press bed bending (Fig. 11).

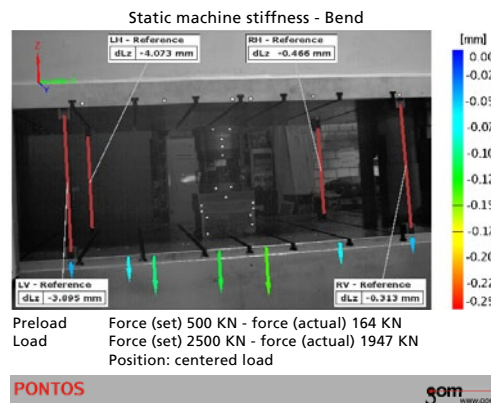


Fig. 11: Static deformation analysis, bending of press bed with centered load.

The PONTOS system makes it possible to measure deformations optically and simultaneously record analog measurement signals. Static load analyses therefore involved feeding in external force signals, which were evaluated here in conjunction with the bending and tilt data. Therefore, machine deformations do not refer to theoretical feed forces but to the actual impact forces, which were measured in analog mode.

Measuring results of dynamic machine stiffness

Both the real-time motion measurement of individual components and the displacement speed of rams, drawing punches and blankholders were measured during dynamic machine stiffness analysis (Fig. 12). The diagram shows the influence of blankholder clamping and, at the center (red line), the tool's cutting impact. Clearly negative vibrations caused by the ram return stroke are visible here, which commonly result in inferior component quality and premature tool wear.

Dynamic deformation analysis

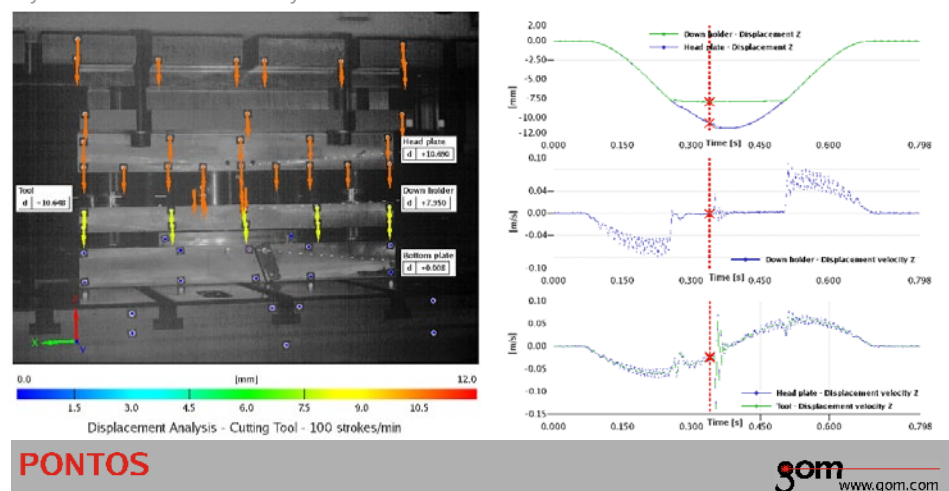


Fig. 12: Dynamic deformation analysis, real-time motion measurement of die and punch (left). Displacement measurements for blankholder and head plate (top right). Displacement speed of blankholder (center right). Displacement speed of head plate and cutting tool (below right). Clearly negative vibrations can be seen immediately after the cutting impact; these are responsible for inferior component quality and premature tool wear.

In addition, dynamic bending of the head plate, blankholder and base plate were analyzed in real time (Fig. 13). The greatest impact can be seen when the blankholder is halted. The cutting impact only causes slight bending in the blankholder.

Dynamic deformation analysis

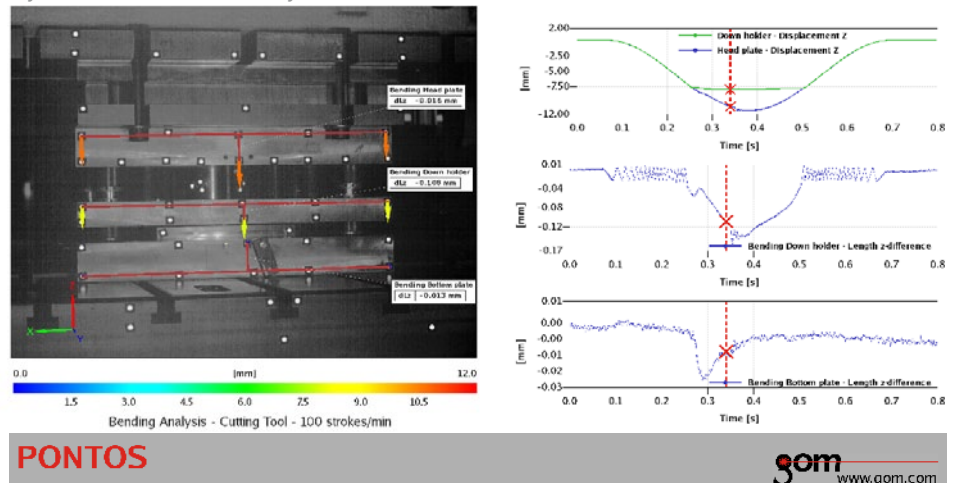


Fig. 13: Dynamic deformation analysis, real-time bending analysis of head plate, blankholder and base plate (left). Displacement measurements for blankholder and head plate (top right). Bending of blankholder (center right). Bending of base plate (below right).

Conclusion

The data obtained here, which was also carried out under additional defined process parameters, can be used to analyze the speed, bend and tilt factors for blankholders, rams, die cushions and drawing punches while the press is in operation. It enables vibrations and oscillation to be analyzed and statements to be made on machine stiffness under real impact forces. The machine capability study is crucial for estimating future processes and assessing whether sufficient component quality can be achieved. The outcome settings can be used in turn as input parameters to optimize future forming simulation processes. In this way, it is possible to find an optimal combination of speed, contact pressure and punching force. Since the process parameters and the static and dynamic interactions between press and tools are the determining factors in tool wear, optical 3D analysis helps to significantly extend tool service life.

We would like to thank IFUM Hanover for the chance to execute this project.