Application Example: 3D Motion Analysis

Optical deformation measurement for the analysis of rolling machines

Measuring System: PONTOS
Keywords: Analysis of solid forming processes, Optimization of manufacturing processes, Analysis of guides, Drives, Stiffness, Dynamic behavior of machine tools, Extension of tool service life

When forming with machine tools, dynamic processes have a great effect on the quality of the finished parts. Machine stiffness, deviation of guides and drives, as well as centering and angular positions plays a decisive 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 for tools and maintenance can be reduced.
3D motion analysis / component development
(machine tools, process optimization)

Optical deformation measurement for the analysis of rolling machines

Measuring System: PONTOS
Keywords: Analysis of solid forming processes, Optimization of manufacturing processes, Analysis of guides, Drives, Stiffness, Dynamic behavior of machine tools, Extension of tool service life

Many forming manufacturing processes require further analysis in addition to existing knowledge. Optical 3D deformation measurement enables the inspection of shape and dimensions of forming tools. But also dynamic processes have a great effect on the quality of the finished parts when forming with machine tools. These can be effectively analyzed as well using non-contact 3D deformation measurement.

The PONTOS stereo camera system for optical dynamic 3D analysis can show a possible deflection of guides and drives as well as centering, angular positions and machine stiffness. By subsequent optimization tool service life can be increased and the costs of manufacturing processes reduced.
Dynamic deformation measuring system
The transportable PONTOS optical measuring system measures the spatial coordinates and displacement of individual points. The system typically consists of a stereo camera sensor, tripod and computer (Fig. 1). The points or areas to be measured on the object 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)](image)

![Fig. 2: PONTOS consumables, self-adhesive markers](image)

The PONTOS measuring head is freely positioned on the tripod in front of the measuring object. The self-monitoring system records flexibly triggered images for one or more load conditions. Any number of markers in space can be determined simultaneously with high precision and accuracy based on stereo camera technology (Fig. 3, 4).

![Fig. 3: PONTOS measuring principle, spatial 3D online measurement of positions and displacements of markers, 3D displacement vectors.](image)

![Fig. 4: Online deformation measurement of a wind power plant. The PONTOS system enables analysis of vibrations, frequencies, torsion, bending, speed and acceleration as well as of trajectories.](image)
With the use of high-speed cameras, the system is also suitable for measuring fast processes and motion sequences, e.g. for component testing in wind-tunnels and 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 which cannot be measured directly (e.g. concealed blanks or tool tips, etc.), 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 the movement of a tool tip using an adapter (calibrated group of points), visualization via primitives.

As measurements are made online, the recorded high-speed images can also be automatically evaluated in the form of a real-time deformation analysis with the PONTOS software. Various report options are available for evaluating the positions and displacements of the measuring points. Deformations such as torsion, bending, deflection etc. can be observed in real time. Structural vibrations, speeds and accelerations can be investigated using 3D displacement vectors and diagrams. Measurement results and analysis can be exported as PDF-reports or as videos 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. Real-time analyses can also be produced in the form of diagrams and videos.

The variable PONTOS system can be quickly and flexibly adapted to suit different sizes of measuring field from the standard 0.5 x 0.4 m² to 5 x 4 m². To setup the system and to prepare a medium sized measuring object (2 x 2 m) requires typically less than half an hour for one person. The optical PONTOS system for dynamic 3D analysis therefore replaces conventional displacement measurement systems and acceleration sensors.

**Dynamic analysis of a rolling machine for thread production**

Thread rolling has not only become established in the mass production of standard screws, but also plays a supporting role in the "individual production" of heavy-duty and precision fixing and motion threads. Thread rolling produces very accurate geometries with high surface quality. This is because cold forming enables the thread to withstand higher loads than with metal-cutting processes.

However, when a new product is manufactured, the expensive forming tools (lead screws) sometimes have an untypically short service life. As a result, the manufactured parts are too frequently of inferior quality and costs are rising due to more frequent tool exchange.

Often the only way to quickly find the cause of such problems is to analyze the dynamic forming process of the rolling machine while in operation.

However, it is difficult to analyze the usually rapid and complex movements with the required precision using conventional measuring systems. New optical measuring systems clearly have an advantage here. The PONTOS system can take detailed measurements of not only complex but also rapid sequences, as they typically occur in forming processes.
In order to find the root cause and to optimize this process, it was also necessary to measure the machine stiffness, i.e. the position of the roll axes relative to one another and relative to the machine bed. The roll feed and the absolute angular speed were also required. The position and orientation of the workpiece blank and its rotational speed and acceleration during the forming process also had to be determined.

**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 rolling machine (Fig. 8). The self-monitoring system produces reliable and precise data even under critical working conditions, such as production environment.

![Fig. 8: PONTOS measuring set-up in the production environment](image)

Self-adhesive markers were applied to the rolls, the roll guide and the machine bed. The position of the workpiece blank and its spatial position were recorded with the help of an adapter, which was applied to the workpiece blank. This adapter was calibrated in advance, i.e. its position relative to the axis of the component was measured by means of several short recordings.

The rolling machine was then moved to a starting position and a measurement was made which represented the reference state for the subsequent displacement measurements. The motion measurement was then carried out for typical manufacturing cycles.

**Measuring results**
The time required for one person to prepare and carry out the measurement was less than one hour. The evaluation and analysis can be carried out immediately on site based on the images obtained, and also subsequently varied at will at any time. Extracts from the process analysis are shown graphically below.
Figure 9 describes the 3D displacement of the roll guide. As well as the feed in the X-direction, a vertical deflection due to the forces acting can also be clearly seen here. The vectors in the image reflect the displacement of the roll guide in the Y-axis and the Z-axis. The actual position of the workpiece during the process is shown in Figure 10. As well as the initial centering of the workpiece blank, the feed in the axial direction can also be seen here. The angular position of the workpiece blank relative to the coordinate system can be seen in Figure 11.

Summary

The tool service life was significantly increased as a result of the data obtained here, which likewise took place under further defined process parameters. Determining the machine stiffness also enables future processes to be assessed with regard to the component quality which can be achieved with the given machine parameters. Scrap was reduced and manufacturing quality increased as a result of the process optimization carried out by means of the investigation. Not least, this means a significant reduction in manufacturing costs.