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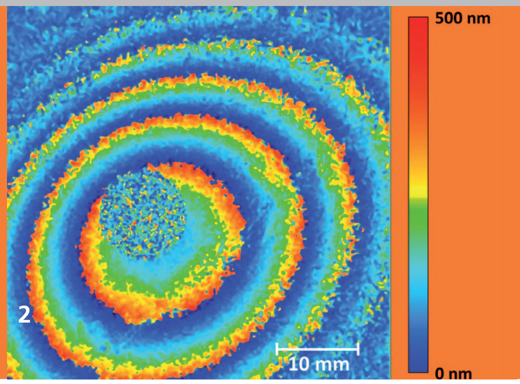
FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES



1 *The ESPI system from Fraunhofer IPM is robust and portable. Here, thermal deformation of a car body is measured.*
2 *Deformation caused by a steel ball on a metal sheet. The contour lines are 500 nm apart.*

SPATIALLY RESOLVED MICRO-DEFORMATION MEASUREMENT

During material processing by welding or cutting, irreversible strains can be introduced into the surrounding material. Such stresses and strains are visible as deformation on gloss-coated surfaces such as automobile body work, even if they are smaller than 1/10 µm. They reduce the value of the component considerably since they lead to expensive reworking.

Less rejects thanks to high precision inline surface measurement

A new micro-deformation measurement system from Fraunhofer IPM detects minimal changes to the component topography very quickly, two-dimensionally and down to the nanometer range – directly in the line. This allows very slight changes or deformation of the component surface – e.g. when subjected to mechanical or thermal loads – to be measured precisely, even at high production speeds. The method is suitable both for process development and for monitoring critical production steps. Thus, for example, it is possible to measure the distortion of the component owing to thermal and mechanical loading during the processing step with accuracies of less than 30 nanometers in welding, soldering or cutting processes. Detecting and understanding the dynamics of distortion with a temporal resolution of several milliseconds makes process control possible, which prevents brief or local over-straining of the component. Process design optimized in this way guarantees constant product quality and minimum rejects.

Two-dimensional shape and expansion measurement instead of simulation

Differential thermal expansion produces mechanical stresses in the component. The resultant changes in shape lead either to irreversible deformation or, if they occur cyclically, to structural failure after a certain time; as a consequence, this leads to cracking or fractures. The challenge in production or process design is not to

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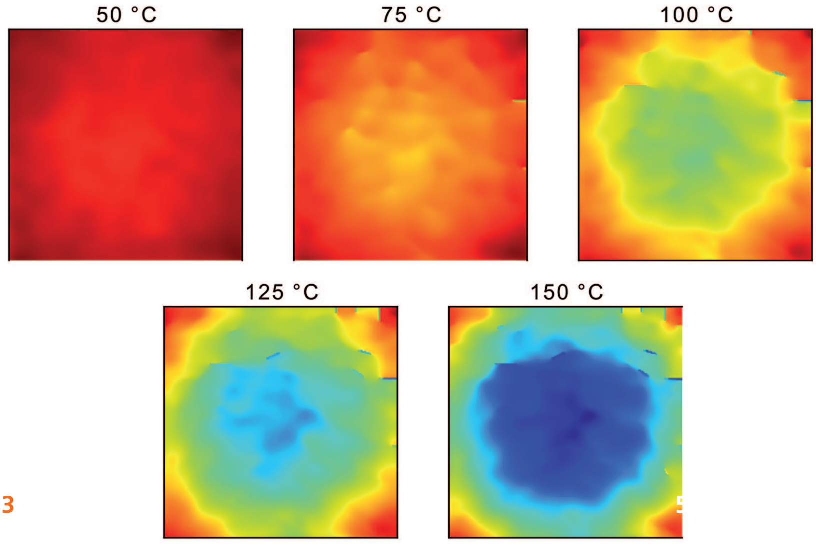

simply map pure process workflow but to also ensure its reliability. In this process, simulation tools help but require precise knowledge of material properties. The thermal coefficient of expansion changes with temperature and may even vary between batches in composite materials. It is not possible to predict the real behavior in the case of inhomogeneous components, even if values are known. Thus, predictions from simulations must be confirmed by measurements. When doing this, it is not always sufficient to measure the resultant steady-state deformation, ignoring transients during that occur as the deformation develops, which may include inhomogenous deformations and larger stresses than the final state. The only way to fully understand and quantify such processes is to use tools for two-dimensional deformation measurement with adequate spatial and temporal resolution.

ESPI: Electronic Speckle Interferometry for measurements accurate to the nanometer

The system for fast measurement of micro-deformation also identifies minute changes to a component's shape. The system operates on the basis of the principle of electronic speckle interferometry (ESPI). This method involves illuminating an object with an expanded laser beam. The resulting camera images contain a speckle pattern. Any deformation of the object by a fraction of the wavelength leads to a detectable change in this speckle pattern. This allows the measurement of minute motions and surface deformations due to internal stress. Special computer algorithms compute these deviations at high speed, providing real-time deformation measurement.

High precision distortion measurement during the welding process in real time

The great advantage of speckle interferometry is its accuracy: the measuring method has thus long been in use for measuring minimal deformation which may be produced as the result of component vibrations, thermal loading or also mechanical tensile and shearing stresses. Classic ESPI methods frequently use temporal phase-shift methods. It is always necessary in this case to take a sequence of camera images to register all required information on the current state of deformation. The position and shape of the object to be measured must be absolutely stable during the recording time since otherwise, measurement is not possible. This means that the measurements can be conducted only in thermally and mechanically stable conditions. The total time required for a series of tests to examine the mechanical deformation as the result of thermal loading would be extremely long because of this. Examining deformation as the result of dynamic, thermal or mechanical processes is virtually impossible.

The system from Fraunhofer IPM conducts measurements 500 times per second – commercial units require a few seconds for a single comparable measurement. The sensor supplies images of the surface deformation with an accuracy of 25 nm in this case. In x/y-direction, each measurement yields one million pixels across the field of view, which can be from a few millimeters to several centimeters. This means that even minute deformation such as that caused by a rolling steel ball on an automobile body component can be measured and displayed on a screen in real time (see Fig. 2).

3 *Deformation measurement on a microchip on PCB substrate during heating at various temperatures. In this case, the microchip bends by maximum 550 nm.*