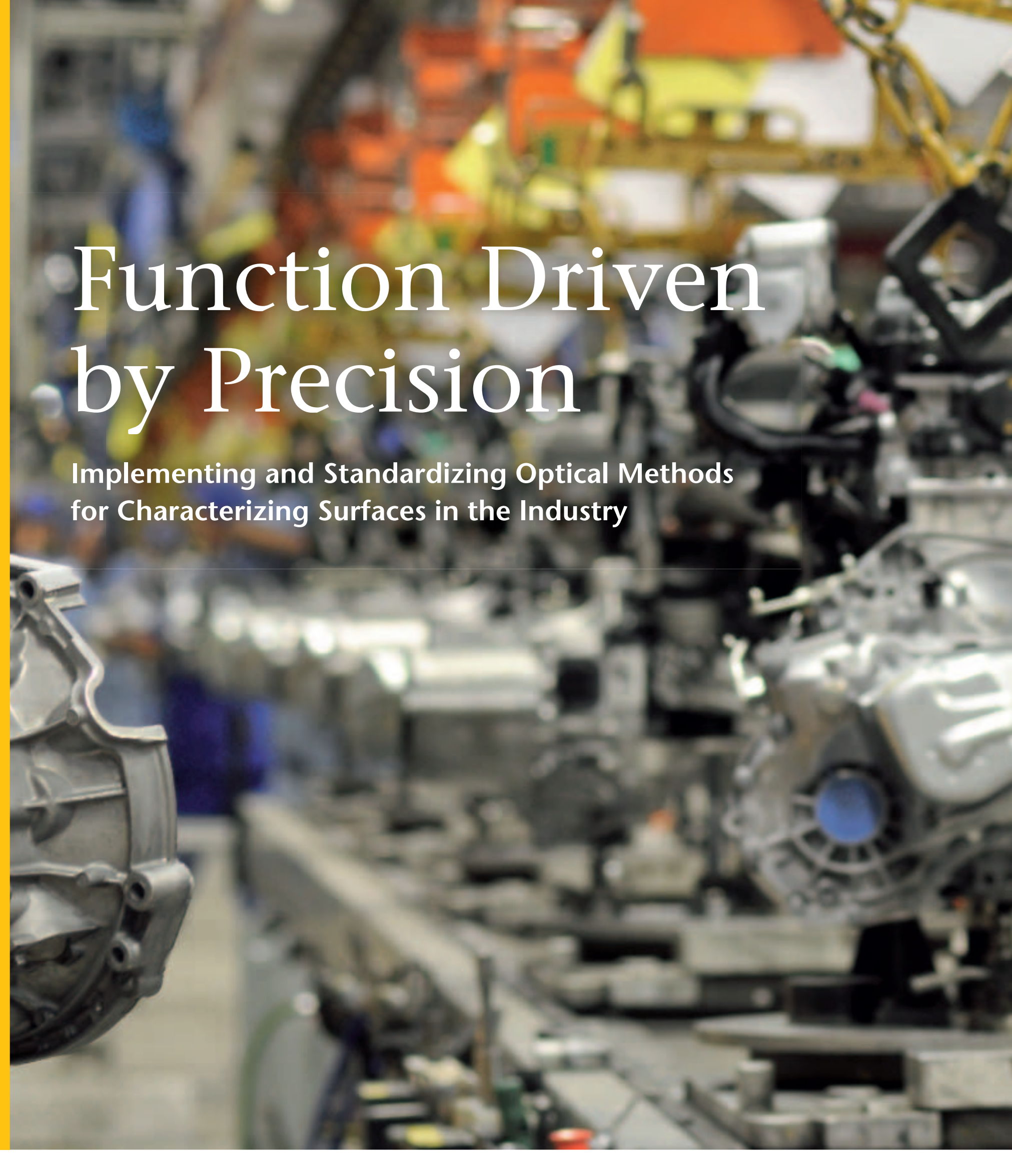

Function Driven by Precision

Implementing and Standardizing Optical Methods for Characterizing Surfaces in the Industry

Automotive engines should offer fuel efficiency and emit hardly any pollutants, while offering ample performance and a high level of driving comfort. Achieving this requires the optimum interaction of all components. In turn, this demands compliance with precision shape tolerances for the individual functional components. For the manufacturer, this means that compliance with these tight tolerances must be guaranteed during quality checks in manufacturing to preclude customer complaints or even recalls.

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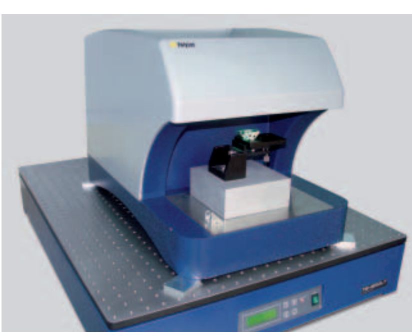


Fig. 1: TopMap Metro.Lab White-Light Interferometer.

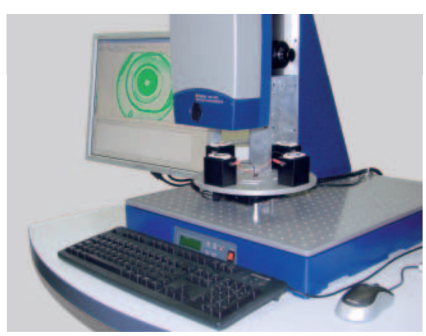


Fig. 2: TopMap In.Line White-Light Interferometer.

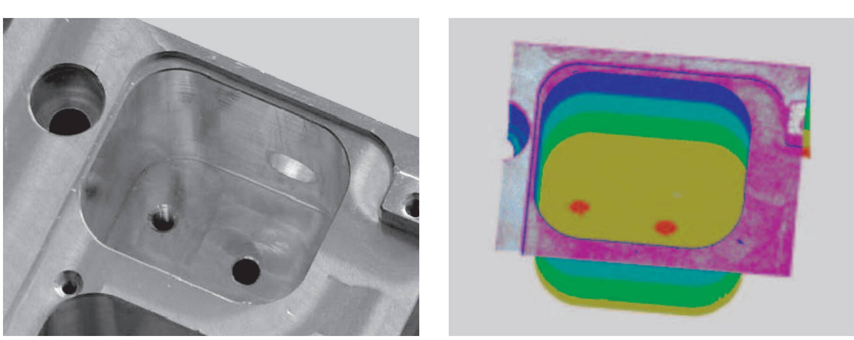
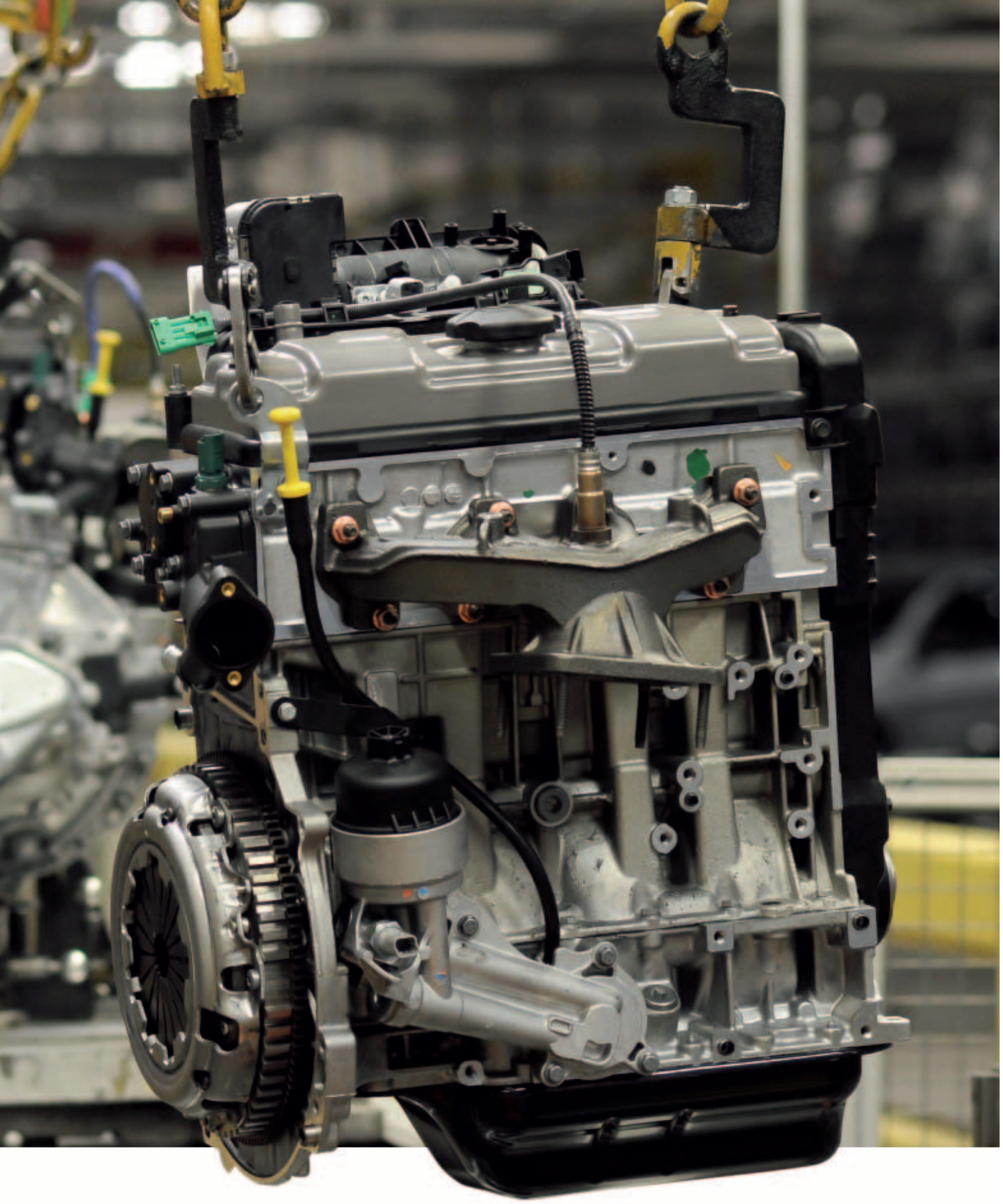


Fig. 3: Measuring a workpiece with surfaces at various depths.

Precision measurement equipment with excellent reproducibility is required to characterize surfaces. Stylus (contact) profiler methods have been used for such tasks for a long time. With these methods, the tolerances are inspected using individual measurement points or through linear scans. Line-only profiles are often inadequate, especially when the entire surface must be analyzed to determine flatness or parallelism. To determine the surface topography using stylus methods, many parallel line profiles are recorded and combined into a single surface. These measurements are very time-consuming and are not acceptable in production quality control situations where throughput is critical. Because fast measurements over large surface areas are easily accomplished using optical measuring methods, these techniques are increasingly in use for production applications.

High Vertical Precision with a Large Lateral Field-of-view

In many cases, flatness measurements are needed that relate several individual sur-



faces, such as comparing the surface at the bottom of a blind hole with the surface at the top of the hole. The vertical measuring inaccuracy of white-light interferometry is independent of the lateral field-of-view. This enables the measurement of large surfaces with high vertical resolution. Polytec developed the TopMap White-Light Interferometers for mastering these measurement tasks. This product line offers an excellent price/performance ratio and can, for example, quickly and reliably measure flatness, parallelism and step height. TopMap MetroLab (Fig. 1) was primarily developed for a metrology lab performing statistical process control measurements. The TopMap In.Line (Fig. 2) was designed to be integrated into the production line when needed.

Measuring Flatness and Parallelism in Quality Control

The two workpiece surfaces displayed in Fig. 3 are to be inspected for flatness and parallelism, where one surface is 50 mm deeper than the other. The TopMap MetroLab White-Light Interferometer, with its vertical scan range of up to 70 mm, is the ideal solution for skillfully performing such measuring tasks. The device features a telecentric optical path. This means that the light beam virtually runs parallel to the object (Fig. 4). Unlike a microscope that has a cone-shaped beam pattern, there are no shadows with the TopMap Metro.Lab. This also allows the light beam to reach deep surfaces.

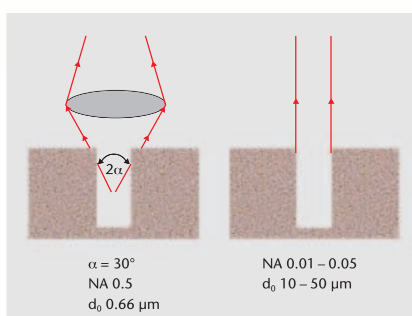


Fig. 4: Typical microscope optics (left) fail to characterize high aspect ratios when compared to Polytec's telecentric optics (right).

The surface of the workpiece to be measured can be smooth or rough, dark or light, with a specular or a light-scattering surface. A special measurement and analysis algorithm (smart surface scanning) ensures excellent results, even if the surface has spatially varying optical properties. The measurement duration depends on the task at hand and usually takes only a few seconds. A special add-in also enables you to easily automate routine measurements and ensures that the necessary data is acquired for an accept/reject analysis or for external quality assurance software. A pallet can also be installed for automatically feeding and measuring the workpieces for serial measurements. If the measurement is to be taken on the production floor, Polytec offers a dust-free and vibration-insulated workstation (Fig. 5). The short measurement times that can be achieved with the white-light interferometer can also be integrated into the production line for 100% inspection. For example, the automotive industry is currently using a TopMap system to measure precision components for drivetrains on the production line.

Fig. 5: Workstation for TopMap White-Light Interferometer.

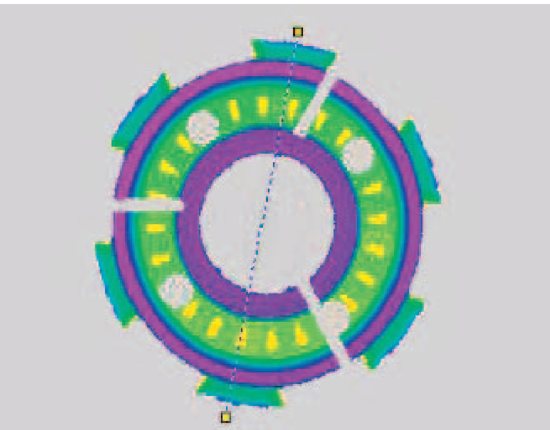


Fig. 6: Shock absorber component with several annular surfaces.

Typical flatness measurements [1]				
Sampling increment	Nominal sampling increment		Fast sampling	
Evaluation procedure	Smooth surfaces [2]	Rough surfaces [3]	Smooth surfaces [2]	Rough surfaces [3]
Flatness deviation	10 nm	65 nm	12.5 nm	75 nm
Repeatability of flatness measurement	0.75 nm	3.5 nm	1.25 nm	5.5 nm
Average flatness deviation	10 nm	65 nm	12.5 nm	75 nm

[1] Rounded values from the empirically measured data and a statistical analysis determine the deviation of the measured flatness for various TMS-300 devices with various sampling increments for both evaluation procedures. (Measuring on a flat mirror (95% of the maximum measuring field, interference contrast ≈ 1)

[2] Evaluation of the correlogram phase

[3] Evaluation of the correlogram envelope

Table 1: Specification for flatness measurements with TopMap In.Line.

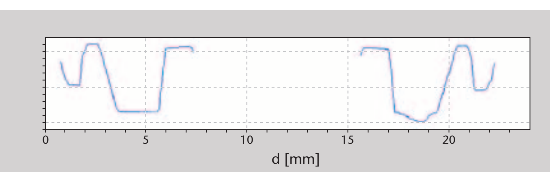


Fig. 7: Step height profile of component along the dotted line in Fig. 6.

Traceability, Repeatability and Reproducibility

International standardization for optical measuring methods is still behind the well-established, traditional scanning stylus measurement procedures. Although the ISO 25178-604 draft covers the general aspects of the white-light interferometer, it does not address the important issues regarding telecentric systems. The VDI/VDE directive 2655 sheet 1.3 deals with this topic in greater detail.
In collaboration with the German PTB (National Metrology Institute) and other institutes, Polytec has contributed an abundance of preliminary work in this area. Calibration methods and measurement uncertainties were presented and discussed at the SPIE Photonics Europe conference in the spring of 2010 [1].
It is difficult to verify the measurement uncertainties in the nanometer range over the entire vertical scanning range. However, experts have approved the factory calibration developed by Polytec. This permits Polytec to prescribe specification values that are considerably more detailed than is common in the market today (Table 1). Additional values for the TopMap In.Line (specifications for the vertical resolution, accuracies for measuring step heights on a standardized workpiece and the values achieved for repeatability and reproducibility measurements) can be found in the TopMap In.Line datasheet at www.topmap.info. Although the TopMap's capability must ultimately be verified on the specific workpiece, these figures provide strong evidence of the instrument's performance on individual measurement tasks.

Example

In particular, the strengths of white-light interferometry lie in measuring workpieces that are difficult to characterize using contact measuring systems. A specific example makes this clear. The component (shock absorber) shown in Fig. 6 has several annular surfaces, one of which is sloped. Contact measuring systems did not provide the accurate and reproducible results necessary for ensuring that manufacturing was meeting the part tolerances. However, measuring the entire surface using white-light interferometry enables an automated evaluation, which automatically detects the surfaces and evaluates them in a reproducible fashion. As a result, a very high level of reproducibility was achieved. This reproducibility also applied to measuring step heights between the individual surfaces that were inspected on this workpiece (Fig. 7).

Literature

S. Boedecker[a], W. Bauer[a], R. Krüger-Sehm[b], P.H. Lehmann[c], C. Rembe[a]: Comparability and uncertainty of shape measurements with white-light interferometers. SPIE Conference Photonics Europe, 12. – 16. April 2010, Brussels

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