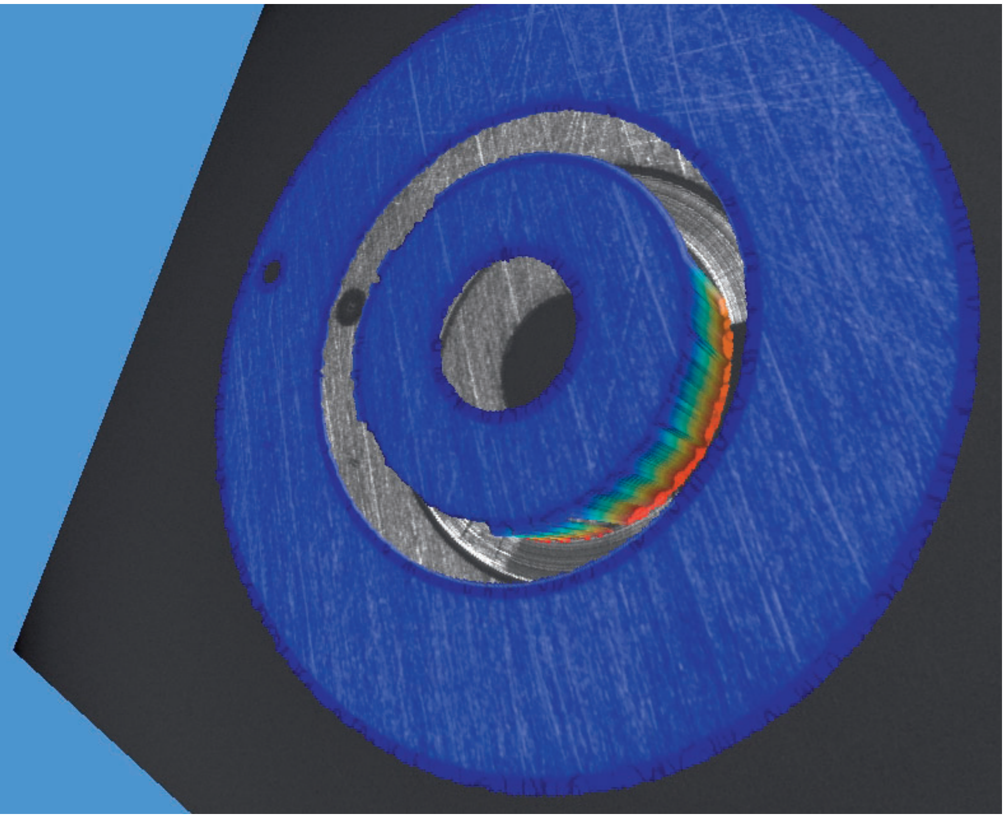
Where Quality Counts

Optical Surface Metrology in Manufacturing Using White-light Interferometry



The use of optical measuring techniques in quality assurance is becoming more and more popular, especially where fast and accurate results are required. 3-D topography of the entire surface is obtained resulting in considerably more information and indeed more meaningful information than from the linear profiles obtained using mechanical sampling methods.

Use of the latter tactile technique is very time consuming if an entire surface topography is to be determined, as surfaces must be assembled from individual lines of data. A clear example is the measurement of tool marks. Because they are spatially aligned, very different results are obtained depending on the direction of the line profiles. For example when determining smoothness, the measurement direction could be parallel or perpendicular to the machining direction. Mechanical sampling methods reach their limits, especially when short cycle times are required. These are the most important reasons why optical topography measuring methods are used ever more frequently in quality assurance.

Optical Measuring: Contact-free and Whole-surface

White-light interferometry (also called coherence scanning interferometry) is ideal for these tasks because it enables the measurement of large fields of view with interferometric accuracy in the vertical direction. With white-light interferometry, measurement accuracy is independent of the field of view and a parallel optical path can be used to avoid shadowing. This means that even low lying surfaces inside deep holes can be reached and characterized almost up to the edge. Large working distances can also be implemented and hence a large measuring volume achieved. As an example, Polytec's TMS-100 TopMap Metro.Lab has a vertical scan range of 70 mm for a field of view of 38 mm x 28 mm. This permits measurement of step heights of up to 70 mm with a measurement uncertainty of a few micrometers.

Example: Measuring Components for Piezo Injectors

Piezo injectors are critical components in automotive engines. In this example two separate surfaces of the component are to be recorded as a 3-D profile with a cycle time of approximately 5 s and evaluated for smoothness, parallelism and separation. Here, reproducibility of approximately 100 nm is required. The result can be seen in fig. 1. The two surfaces are acquired in a precisely separated manner to determine the parameters mentioned.

Example: Smoothness Measurements on Sealing Surfaces

For the smoothness measurement on a work piece with faces that seal (fig. 2) it turned out that values from the side walls (large image) were also recorded. They are removed using a suitable mask because they should not be included in the evaluation. A smoothness of 2.5 µm (fig. 3) was determined for both surfaces together, while the line profiles each gave smaller smoothness values (1.2 µm or 1.6 µm) because the highest and/or lowest point of the surfaces was not on the line profile (fig. 4). This indicates the necessity of considering the entire surface in the case of precision work pieces so that reject parts are reliably detected.

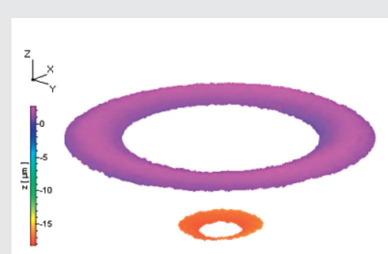


Fig. 1: The smoothness and parallelism of two annular surfaces of a component part in a piezo injector. The height is represented by colors.

Use in Quality Assurance – Practical Aspects

In practice, suitable programming of a test process sequence is easy and safe. For example, the surfaces of interest are automatically selected and evaluated with software. An appropriate user interface means that even inexperienced users can carry out a good/bad analysis and export the relevant data to the quality assurance software, for example to create quality assurance cards. For this purpose Polytec makes an extensive library of subroutines available for C# programs, however most users leave it to the measurement instrument manufacturer to develop such add-ins. This also ensures that the evaluation algorithm for the work pieces is stable and comparable in terms of accuracy and repeatability, and that no additional errors occur.

Intensive cooperation between supplier and user is of course also necessary if a measurement instrument is to be integrated into a production line. Here, interfaces must be precisely defined, as well as environmental influences on the measurements in the production shop. For example fig. 5 shows the vibrations that occur when the measuring station is loaded. Although they attenuate after less than one second, vibrations must be considered during the measurement sequence.

Cycle Time Precise to the Second

There are different time sequences depending on the work piece and measurement task. For piezo injectors it was possible to verify the following testing times:

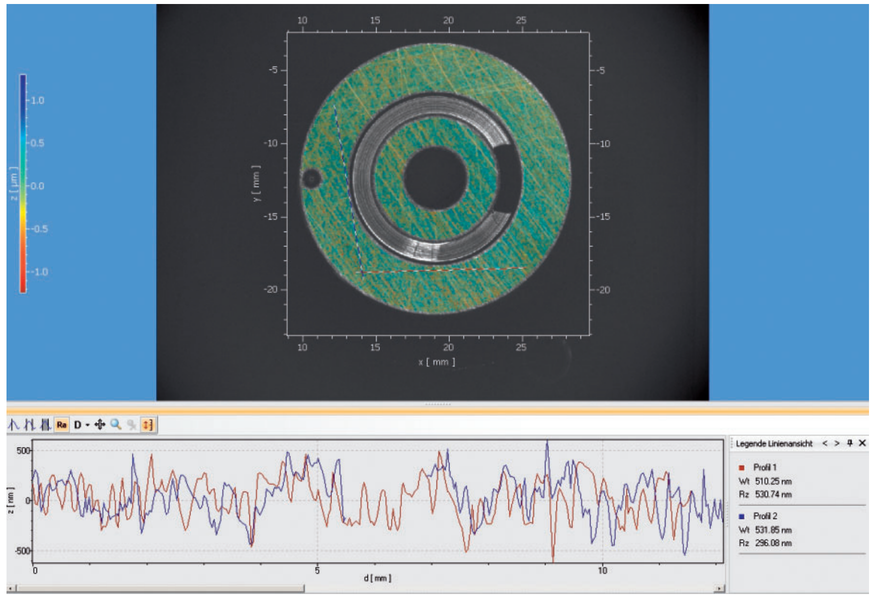


Fig. 4: Line profiles along two sections over the work piece.

- 1–2 s Loading and vibration attenuation
- 1–2 s Quick measurement to find the height of the surfaces
- 2–3 s Precise measurement of surfaces of interest
- 2–3 s Calculation and unloading

When the height differences are greater, the times may well be longer. Often the cycle times are not critical down to the second because only occasional samples are measured. If the test pieces cannot be brought into a different measurement area, then a protected measurement station can also be deployed in the vicinity of the production process. With this approach work pieces can be sequentially characterized on pallets.

Summary

These examples show that optical surface metrology used in quality control provides a high measurement accuracy while simultaneously measurement times can be significantly decreased in comparison to traditional methods.

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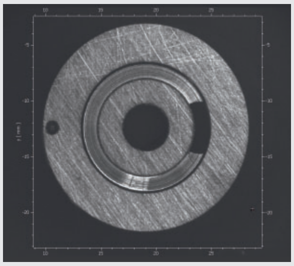

Fig. 2: Photograph of a work piece with sealing surfaces.

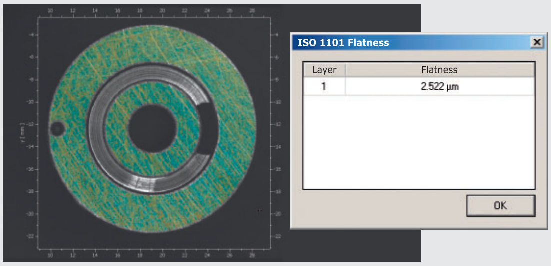

Fig. 3: Smoothness measurement on the work piece (ISO 1101).

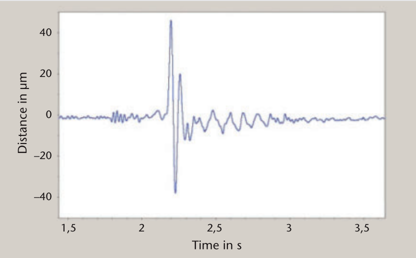

Fig. 5: Vibration attenuation behavior after loading with a work piece.

