



# Advanced Optical Surface Metrology

## 3D Measurements of Surfaces with Steep Flanks

Surfaces with steep flanks and varying reflective properties are usually not measurable with conventional surface measurement techniques, even though there is an ongoing miniaturization of components and rising demand for automation in industry. A solution can be provided by "Focus Variation", a new optical measurement technique that allows the robust measurement of complex surfaces with vertical resolutions up to 10 nm. In addition to topographic data, true colour information that is perfectly registered to the height data is obtained. The optical 3D measurement device "InfiniteFocus" is based on this new technology and provides a significant improvement in quality assurance. Allowing surface measurements in the micro and nano range as well as relatively large components, the Instrument can be used in the lab and as a measurement tool during production.

Optical surface measurement techniques are well established in industry, but they still hardly provide robust measurement of surfaces that meets the demands for speed, accuracy, repeatability and Inline-capability. However, "Focus-Variation" allows advanced optical 3D surface metrology enabling the robust and repeatable measurement of components with steep flanks and varying reflective properties with a vertical resolution up to 10 nm. This new optical technology is the core of the optical measurement system InfiniteFocus and delivers dense measurements over large areas with a density of 2 million to 16 million measurement points. Regardless whether it is used in the lab or during production, this technique works faster and more accurate than conventional methods. Measurements over a high

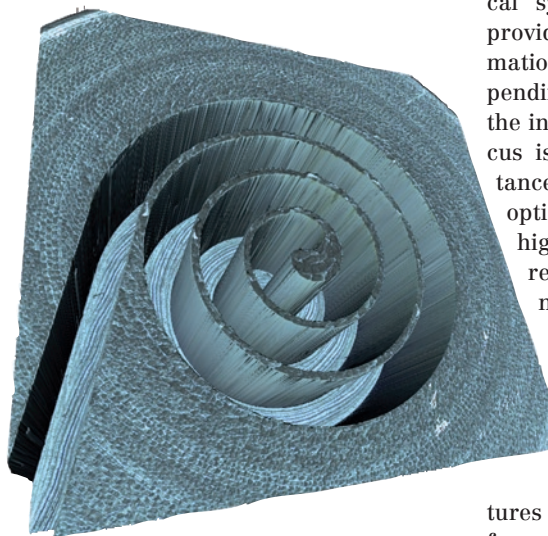


Fig. 1: For all kinds of milling and drilling applications, robust surface measurement of machined tools is essential. Focus-Variation, a new optical measurement technique, allows robust measurement of steep flanks such as circular milling structures or tool edges.

vertical scan range are provided with a high vertical resolution, also enabling the robust measurement of relatively large components.

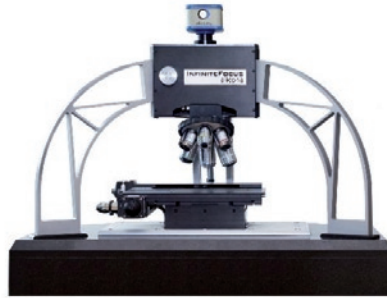
### Robust Optical Surface Measurement

The operating principle of Focus-Variation, developed by Alicona Imaging, combines the small depth of field of an optical system with vertical scanning to provide topographical and colour information from the variation of focus. Depending on the topography of a surface, the information from the variation of focus is analyzed in relation to the distance to the optics. Using conventional optical measurement techniques a high vertical resolution can only be reached with a small vertical scanning range, whereas the use of InfiniteFocus yields a high vertical resolution over the entire scanning range, allowing a dynamic of 1:200000.

Unlike other techniques, Focus-Variation simultaneously captures the entire surface topographic information, in combination with its true colour information. Both, the topographic and colour information are perfectly registered to each other. Additionally, a quality measure is determined for each measurement point.

The advanced technology is the core of the optical 3D measurement device "InfiniteFocus". The main component of this optical metrology instrument is a precision optic consisting of various lens systems. It can be equipped with different objectives allowing measurement with different resolutions. With a beam splitting mirror, light emerging from a white light source is inserted into the optical path of the system and focused onto the specimen via the objective. Depending on the topography of the specimen, the light is reflected into several directions as soon as it hits the specimen. If the topography includes diffuse reflective properties, the light is reflected equally strong into each direction. In case of specular reflections, the light is reflected mainly into one direction. All rays emerging from the specimen and hitting the objective are bundled in the optics and gathered by a light sensitive sensor behind the beam splitting mirror. Due to the small depth of field of the optics, only small regions of the object are sharply imaged. To allow a complete detection of the surface with full depth of field, the precision optic is moved vertically along the optical axis. This means that each region of the object is sharply focused. A sensor captures a series of 2D

datasets during this scanning process. Thereby, all sensor parameters are optimized at each vertical position according to the reflective properties of the surface. After the scanning process, the 2D datasets are evaluated to generate 3D information as well as an image with full depth of field. This is achieved by analyzing the variation of focus along the vertical axis.



**Fig. 2: Optical 3D measurement device "InfiniteFocus" for surface measurement in the micro and nano range. Topographical and colour information is provided from the variation of focus.**

Due to the large amount of data, mechanical restrictions can be eliminated allowing measurement results with a high resolution. Once all height measurements are determined, an image with full depth of field is computed.

The technique of Focus-Variation has been accepted as a unique technique in ISO 25178, a recently developed standard for the classification of topographical measurement techniques to be published this Year.

### **Focus-Variation**

Based on Focus-Variation, optical 3D measurement can be performed in the lab as well as during production. Depending on the desired measurement task and application, several sensors are offered in order to provide Inline quality assurance. Both alternatives provide robust and dense measurements even at complex geometries such as steep flanks and strong reflections. The robust and compact design of the sensors also allows the operation in rough environments.

### **Evaluation of Tolerances and Wear Analysis**

Mechanical components are manufactured based on CAD models. In order to evaluate their manufacturing quality it has to be determined whether the measured values are within pre-defined tolerances. The measurement of variation can

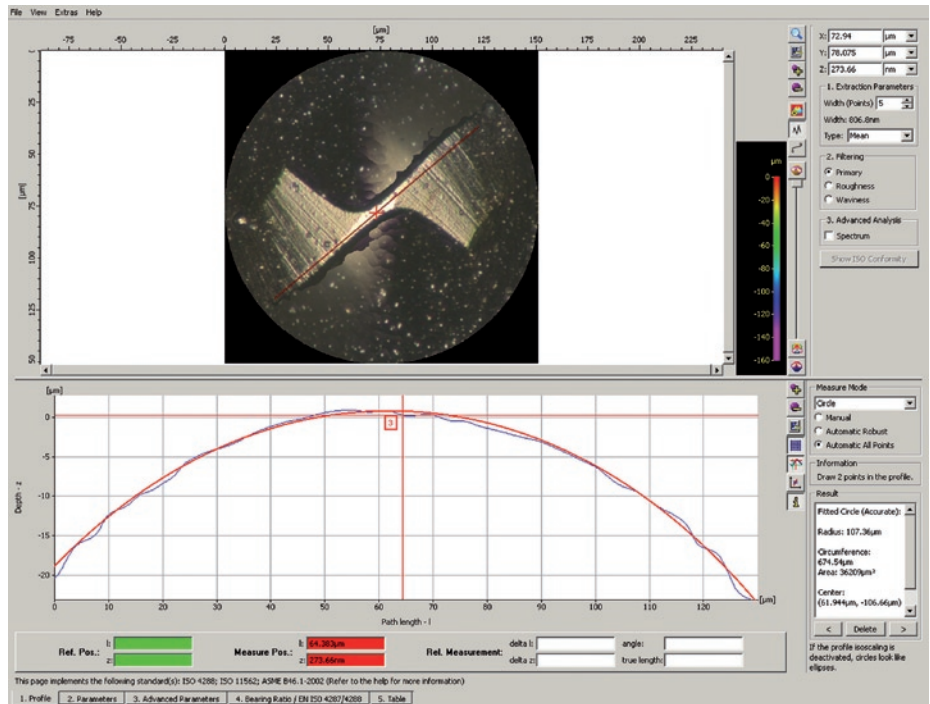


Fig. 3: Optical radius measurement of a drill dip with the 3D surface measurement device "InfiniteFocus". Based on the technique of "Focus-Variation", robust measurement of steep flanks and topographies with varying reflective properties are achievable.

be achieved due to the capability of "InfiniteFocus" to register different 3D models. Another application in this field is wear analysis, often used in quality assurance of cutting tools and analysis of wear surfaces. This technique allows the display and measurement of worn material.

### Applications for Precision Machining, Milling and Drilling, Mould and Tool Making

The optical measurement technique is often used in precision machining applications for the measurement of surfaces both in the micro and nano range as well as for relatively large components. Particularly in the field of mould and tool making and all kinds of milling and drilling applications, surface measurement of the machining tool as well as the machined tool is essential. Even at surfaces with a large lateral and vertical range, such as circular milling structures or tool edges, robust measurements are achievable.

### Accurate 3D Measurement of Micro Gear Wheels

Due to the miniaturization of components, there is an increasing need for advanced surface measurement capabilities to provide robust measurements, even on complex geometries such as steep flanks, e.g. at the single cogs of gear wheels. This is a typical industrial application that can be easily achieved due to the distinctive

measurement capabilities reached with Focus-Variation. Geometries with steep flanks of more than 80° can be measured accurately in seconds. Additionally, parameters such as the inner and outer diameter, flank angles and angles of angular geared components can be computed.

### Summary

Focus-Variation is an optical measurement technique for surface analysis in the micro- and nano range. The 3D surface measurement device "InfiniteFocus" from Alicona Imaging is based on this technique and achieves measurement results better 10 nm. Measurement can also be performed on steep flanks and regions with strongly varying reflective properties. The operating principle combines the small depth of field of an optical system with vertical scanning to provide topographical and colour information from the variation of focus. More over high resolution measurements are provided at a long vertical scan range, enabling the robust measurement of relatively large components. The system can be used in the lab as well as for Inline quality assurance.

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