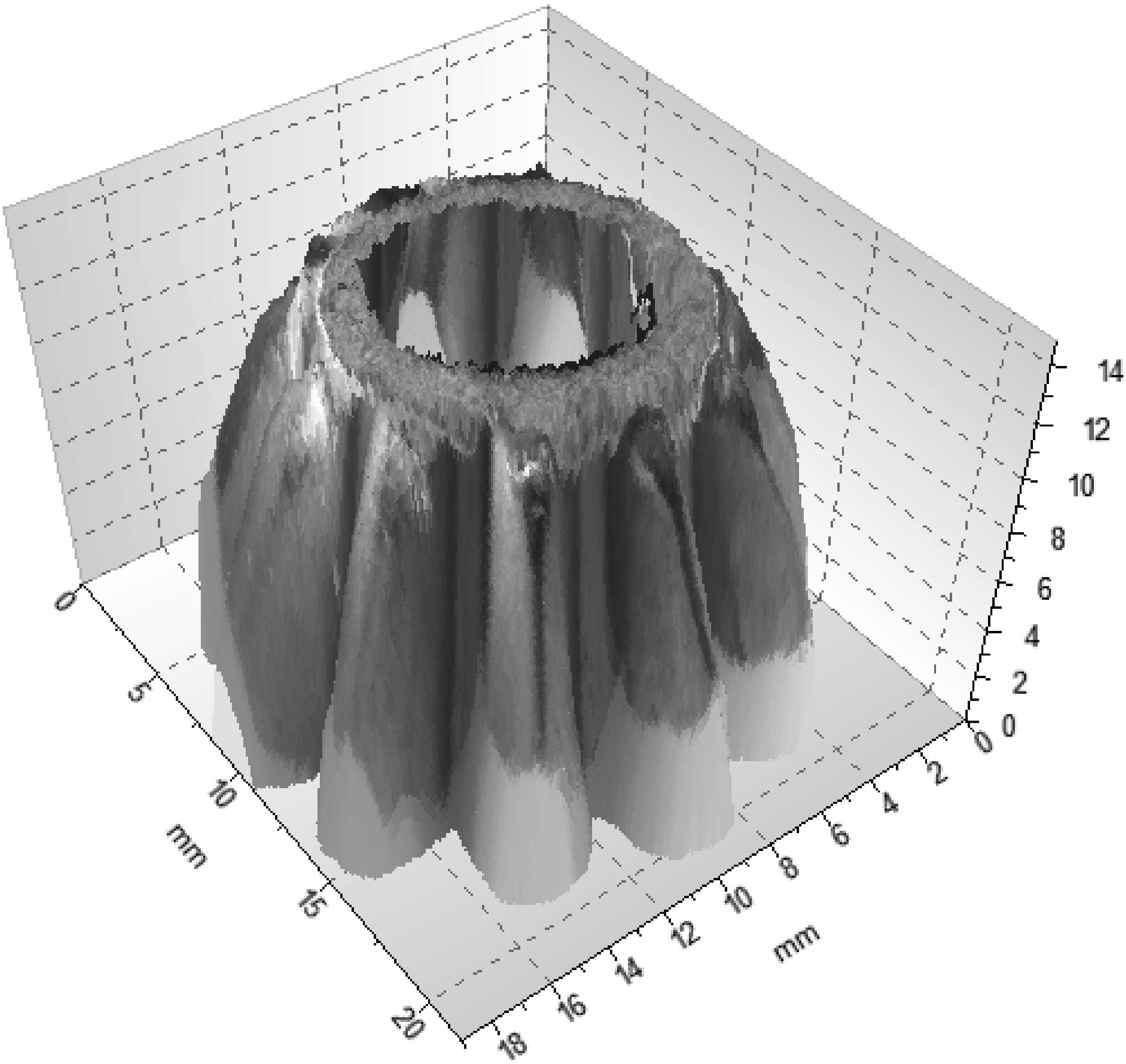
Application Note



Optical Analysis of Shape and Roughness of a Gear Wheel

We make it visible.

Optical Analysis of Shape and Roughness of a Gear Wheel

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Sample: Gear wheel

Instrumentation

Hardware: Axio Zoom.V16
Axio Imager.Z2 with LSM 700

Software: AxioVision and ConfoMap

Tasks: Measure shape and roughness, wear volume and a defect area of a gear wheel.

Introducing

Quality control in industrial production of gear wheels requires quick measurements of shape and roughness, and wear volume. The optical inspection of the gear wheel is difficult, because of the steep walls and because of the absolute height of the wheel.

Quick Inspection

For the first inspection Axio Zoom.V16 is preferred, since this zoom microscope offers the best ratio of working distance to magnification among all zoom microscopes on the market. Consequently it can do an All-In-Focus image (fig. 1) and a height map (fig. 2a) of the 20 mm high gear wheel. All-In-Focus image and height map are calculated from an automatically recorded z-stack of images. If only the All-In-Focus image is required it is often sufficient to close the aperture stop and snap simply one image. A 3D realistic view of the gear wheel is obtained by projection of the All-In-Focus image onto the topography (fig. 2b).

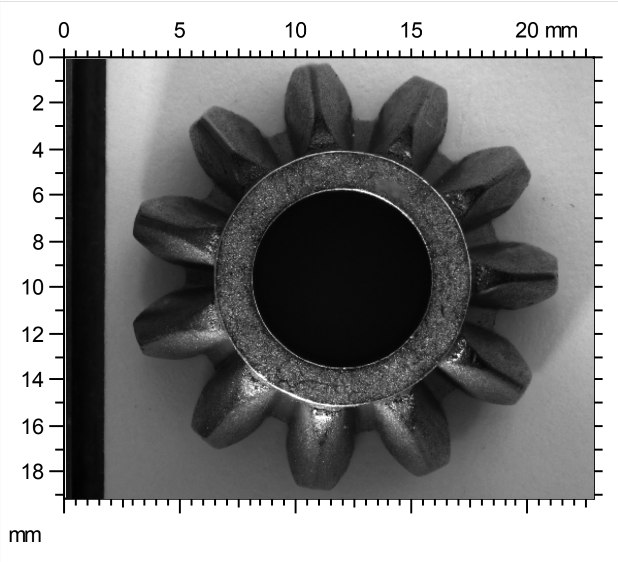

Figure 1 *All-In-Focus image (texture), top view*

Contour

The software module Contour Analysis in ConfoMap segments the horizontal contour of the gear wheel in the height map (fig. 2a). Geometrical parameters, such as the angle between adjacent teeth of the gear wheel, are measured in the horizontal contour map (fig. 3).

With the same contour module you can also segment a vertical contour along a line in the height map. For example the inclination angles are measured in fig. 4b. It is remarkable, that the angle can be measured up to 89° inclination enabled by light scattered from the rough surface.

Defect analysis:
Wear volume and other defect parameters

In the center of the All-In-Focus image (fig. 4a) you observe a defect on the tooth. A height map is recorded with better xyz-resolution as in the previous examples by means of a confocal z-stack record with the laser scanning microscope LSM 700 on Axio Imager.Z2. The defect is hardly visible in the original height map, but it is made visible as a valley by removal of the underlying ideal form (fig. 5c). The frequently used parameters, area, depth, volume, of the defect are obtained with the tool “measurement of a wrinkle” in ConfoMap. To this end the defect is enclosed by the dashed line. Alternatively the map of the defect can be inverted and the defect can be segmented with the tool “volume of island” (fig. 5b) from the module “Grains & Particles” of ConfoMap. The latter tool gives about the same resulting height and volume as the “measurement of a wrinkle”, but it comprises many more geometrical parameters.

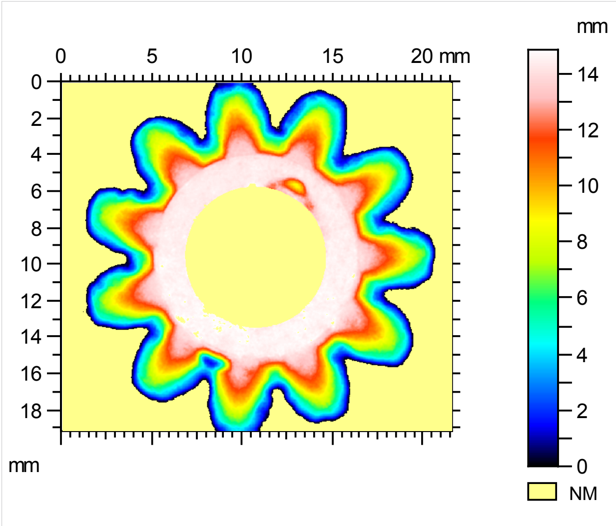

Figure 2a *Height map*

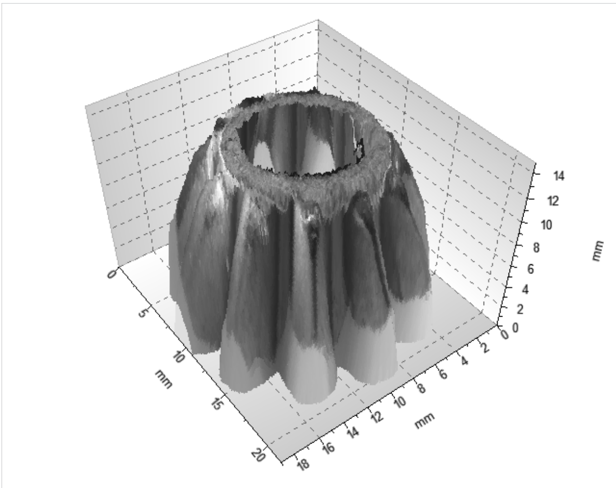

Figure 2b *Texture projected on the 3D topography*

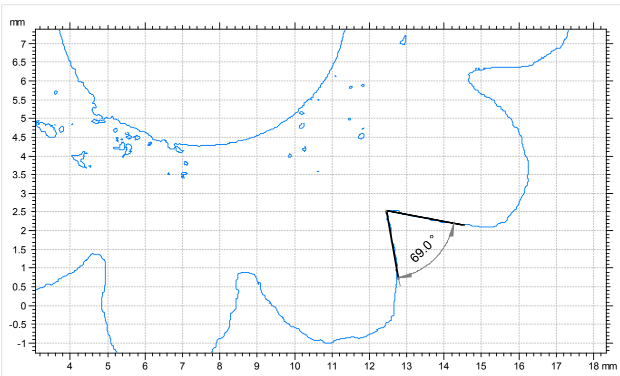

Figure 3 *The angle between adjacent teeth of the gear wheel is measured in the horizontal contour.*

Figure 4 *Zoom into one tooth of the gear wheel for vertical contour inspection*

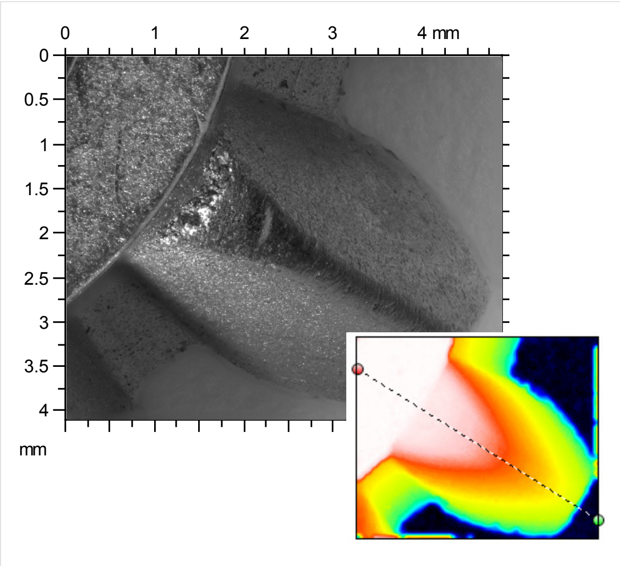

Figure 4a *All-In-Focus image (texture) of one tooth*

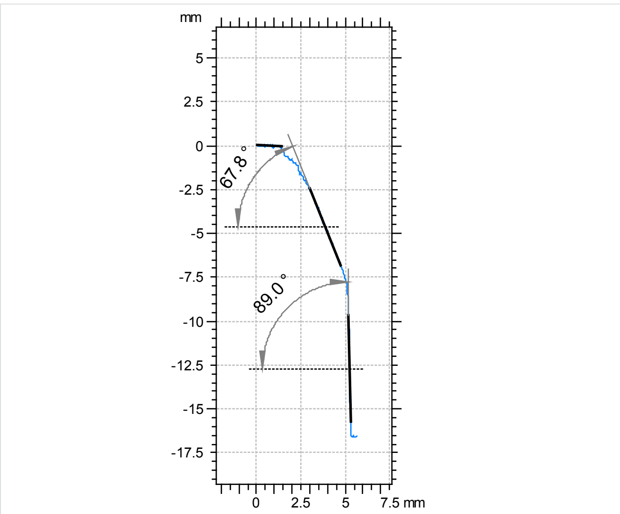

Figure 4b *Cross-section (vertical contour) along the dashed line, inclination angles measured*

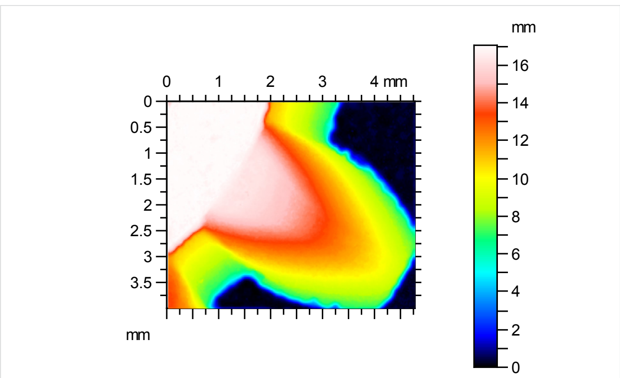

Figure 4c *Height map*

Figure 5 *Alternative measurements of volume and depth of a defect*

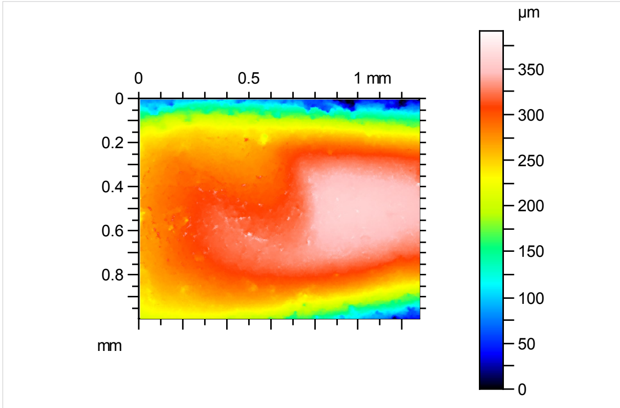

Figure 5a *Original height map*

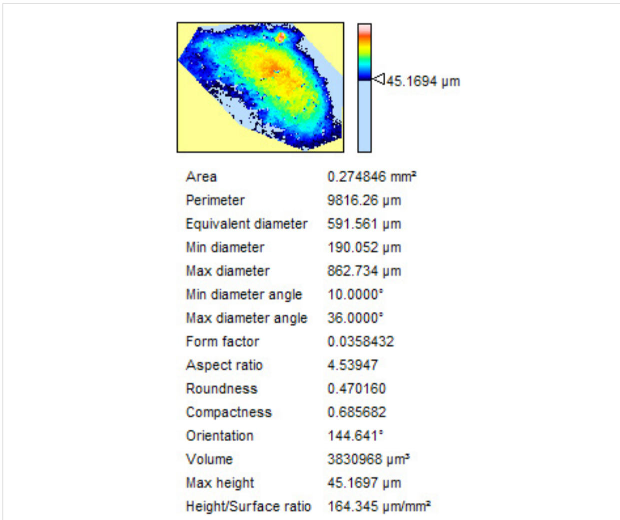

Figure 5b *Measurement of wear volume and other geometrical parameters of the defect by the tool "volume of island"*

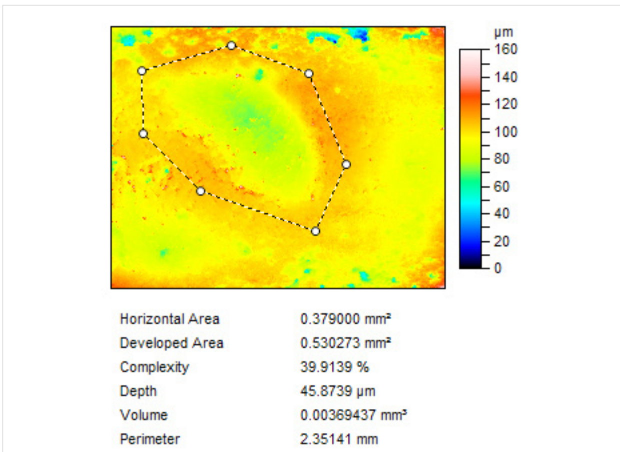

Figure 5c *Height map after form removal by a polynom of order 4, parameters are obtained with the tool "measurement of a wrinkle"*

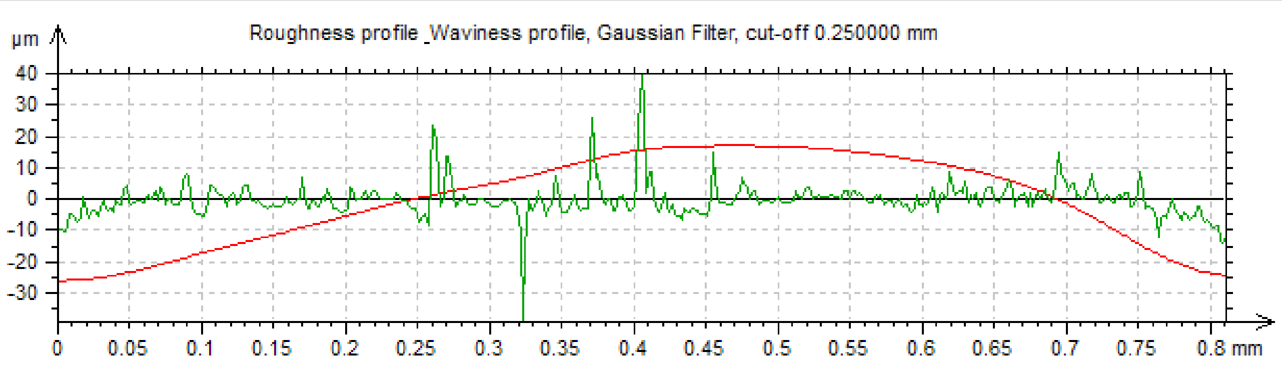

Figure 6

Roughness

An ISO-conform roughness measurement is a statistics of a set ("profile") of height measurements with a typical lateral sampling resolution 0.5 µm/ pixel at about 1 µm Ra roughness. The z-stacks of non-confocal microscopes are converted into height maps by means of the criterion of local sharpness contrast around each pixel.
However sharpness is not measurable on plane sections in the surface (like on a mirror). Consequently the height cannot be guaranteed measured with the ISO-required lateral sampling resolution, and out of z-stacks of non-confocal microscopes, wrong roughness parameters are often calculated. Confocal recorded z-stacks are free of this problem. They are converted into height maps, which are suitable for ISO-conform roughness evaluation. As an example the roughness is measured in the defect area of the previous section along a line (fig. 6.a). In order to obtain the roughness profile, the low-pass filtered profile is subtracted from the primary profile (fig. 6c). A list of standard roughness parameters along this line is given in fig. 6b.

Conclusion

It has been demonstrated, that the Axio Zoom.V16 is excellent to observe and measure features in the vertical and horizontal contour easily. The confocal laser scanning microscope LSM 700 extends the optical metrology onto measurements of wear volume and roughness.

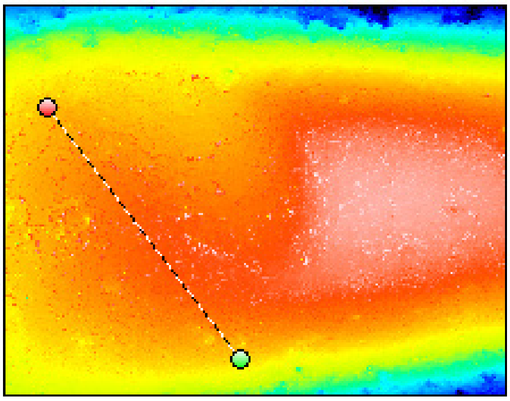

Figure 6a *Original height map*

ISO 4287 Amplitude parameters – Roughness profile

Ra	3.00	µm	Gaussian filter, 0.25 mm, End-effects managed
Rq	4.77	µm	Gaussian filter, 0.25 mm, End-effects managed
Rp	21.20	µm	Gaussian filter, 0.25 mm, End-effects managed
Rv	17.70	µm	Gaussian filter, 0.25 mm, End-effects managed
Rz	38.9	µm	Gaussian filter, 0.25 mm, End-effects managed
Rc	11.50	µm	Gaussian filter, 0.25 mm, End-effects managed
Rt	79.30	µm	Gaussian filter, 0.25 mm, End-effects managed
Rsk	0.983		Gaussian filter, 0.25 mm, End-effects managed
Rku	8.04		Gaussian filter, 0.25 mm, End-effects managed

Figure 6b *Measured roughness along the trace in image a.*

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