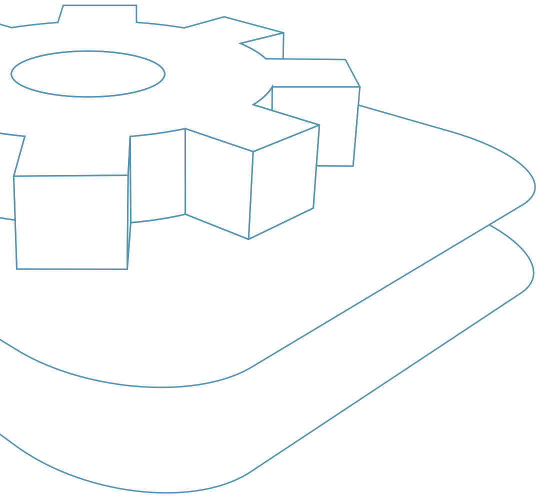


Roughness measurements with Digital Holographic Microscopy

The 3D optical topography provided by the DHM™ R1000 allows complete surface analysis of, amongst others :

- **Roughness measurements**
- **Waviness measurements**
- **Shape determination**

The versatility of DHM™ R1000 in this field is illustrated by the roughness determination of micro-balls. Repeatability and reliability measurements are performed and results compared to those obtained with a profilometer.

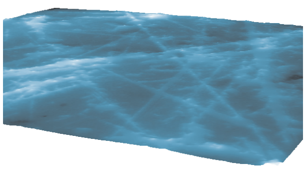
Surface roughness parameters are usually measured using scanned contact stylus probe based instruments. International standards and norms are based on those instruments. For small scale roughness, smaller than a few tenths of micrometers, such measurement becomes difficult: ambient vibration amplitudes can be of the same order of magnitude as the roughness itself and contact with the sample may damage it. For these applications, Digital Holographic Microscopes provides an ideal alternative as they provide interferometric resolutions with extremely short acquisition time.

The strength of DHM™ system lies in particular on the use of the so-called off-axis configuration, which enables to capture the whole information by a single image acquisition within a few microseconds. DHM™ images provide measurements of the surface topography which can be used for surface analysis and roughness measurements amongst others.

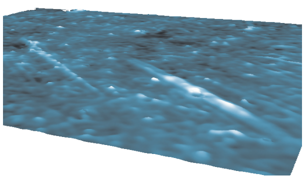
These possibilities make the DHM™ R1000 a unique tool for surface roughness parameter measurements:

- The extremely short acquisition time makes DHM™ systems insensitive to vibrations. They can operate without vibration insulation, making them a cost effective R&D solution and enable their implementation on production lines.
- 3D and real-time measurements enable control of entire samples.
- Lateral resolution is better than that of most conventional styli. By proper convolution of the measurements with the stylus shape, any geometrical shape of stylus probe can be simulated.
- The measurements are possible on a large variety of surface shapes.

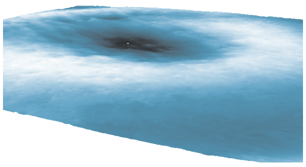
International standards are often not applicable for small samples, in particular those of sizes under the standard profile measurement length. The 2D sampled area gives a large number of points for perfect 2D statistics. The roughness module of the Koala Software allows the adaptation of the measurement parameters such as cut off frequencies to establish correct roughness measurements.



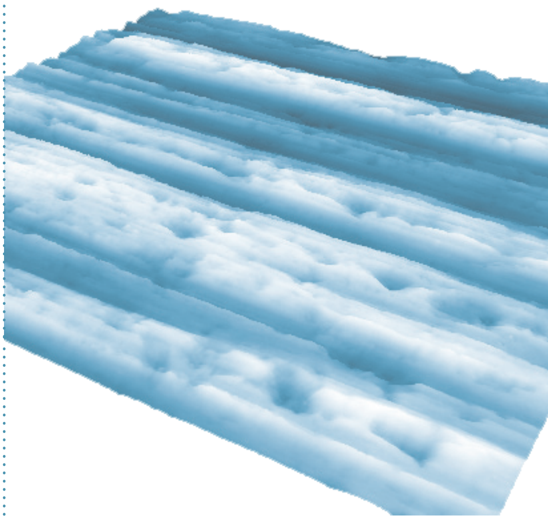
Hip protheses
R_a: 25.7nm, R_t: 264nm



Micro-ball
R_a: 14.2nm, R_t: 270nm



Electrical contact
R_a: 52.7nm, R_t: 916nm



Surface with roughness parameters
R_a=248nm and R_t = 1.55µm

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Measurement principles

The samples characterized were metallic micro-balls with diameters of 0.5, 0.7, 0.8, 0.99, 1.0 and 1.2mm. A hologram is recorded from the ball surface and the complex wave front is then reconstructed. The instrument used is a DHM™ R1000 with a 50x (NA=0.8) objective. A least square fit is then performed to determine the radius and the center of the sphere. Finally the flattened surface (residue) is obtained by the difference of the two surfaces (Fig. 1a).

Two contributions remain in the residual surface: the waviness and the roughness. Both are differentiated in the frequency domain. A cut-off frequency has been taken to suppress forms with sizes of about 1/5th of the field of view (Fig. 1b).

The roughness parameters can then be determined on the surface allowing a better statistical sampling (about 500'000 points) than on a single profile. The parameters of interest here are the mean roughness (R_a) and the maximum roughness (R_t). R_a is defined as the average of the absolute values and R_t as the highest peak to peak value. Other standard values are also obtained.

Measurements

The measures presented here are the 1mm diameter balls. Figure 2 shows the 3D representation of a roughness surface. The field of view is 100x100µm². The R_a determined on this surface is 14.2nm and the R_t is 270nm.

15 identical micro-balls with a diameter of 1mm have been measured by DHM™ R1000 and compared to measurements done with a TalySurf profilometer from Taylor-Hobson. The average R_a of these balls is 19.9nm and the standard deviation is 3.36nm.

The repeatability and reproducibility have also been tested. The repeatability has been verified by performing 25 times the same measurement on the same surface. The standard deviation of R_a was found to be 0.11nm and that of R_t 17.7nm.

The reproducibility has been tested to know if the roughness was uniform on one ball. 25 measurements have been performed on different areas of the ball surface. The standard deviation of R_a was found to be 1.26nm and the one of R_t 34.4nm.

The results show that the measurement uncertainty is far below the variations of the roughness to be measured, establishing the pertinence of the measurement technique.

The roughness values for the balls of other diameters were measured by DHM™ R1000 and profilometer. Measurements on the 0.5mm ball were not possible with the profilometer. Both measurement techniques show an increase of the roughness with the diameter of the ball.

The profilometer results are dependent on the tip radius (2µm). DHM™ results can simulate the tip to provide the same information as profilometers. For very low roughness, DHM™ R1000 provides lower roughness values than those provided by the profilometer, due to its insensiviy to external vibrations. DHM™ is thus a perfect system for fast measurements on production lines.

Conclusion

The DHM™ R1000 allows precise and robust roughness measurements. A standard deviation of 0.11nm was obtained over 25 identical measurements. The measurements were performed on balls of 6 different diameters. The results are reliable for all the tested diameters and correspond to values obtained by a profilometer. DHM™ R1000 thus allows a complete surface texture analysis in terms of form, waviness and roughness quantification.

References

F. Montfort et al., "Surface roughness parameters measurements by Digital Holographic Microscopy (DHM)", ISPMM 2006, Urumqui, China

http://www.lynceetec.com/downloads/

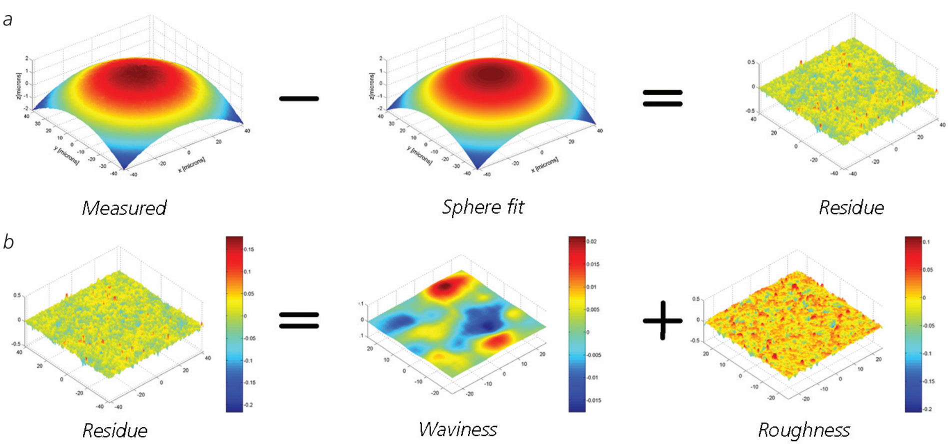

Figure 1: *(a) Form factor removal principle: a spherical fit is subtracted to the measured surface to obtain the residual surface.*
(b) Roughness surface determination: the residual surface is decomposed in two parts by frequency: the waviness is composed of the low frequencies and the roughness of the high ones.

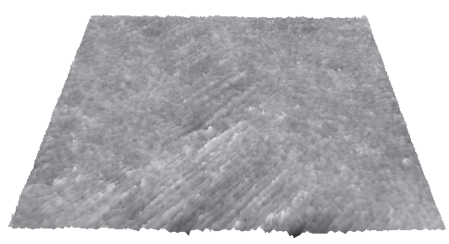

Figure 2: *3D representation of the roughness surface of a 1mm diameter micro-ball. The field of view is 100x100µm². Measured values: R_a= 14.2nm, R_t= 270nm.*