SPRING 2020

Newsletter

SURFACE

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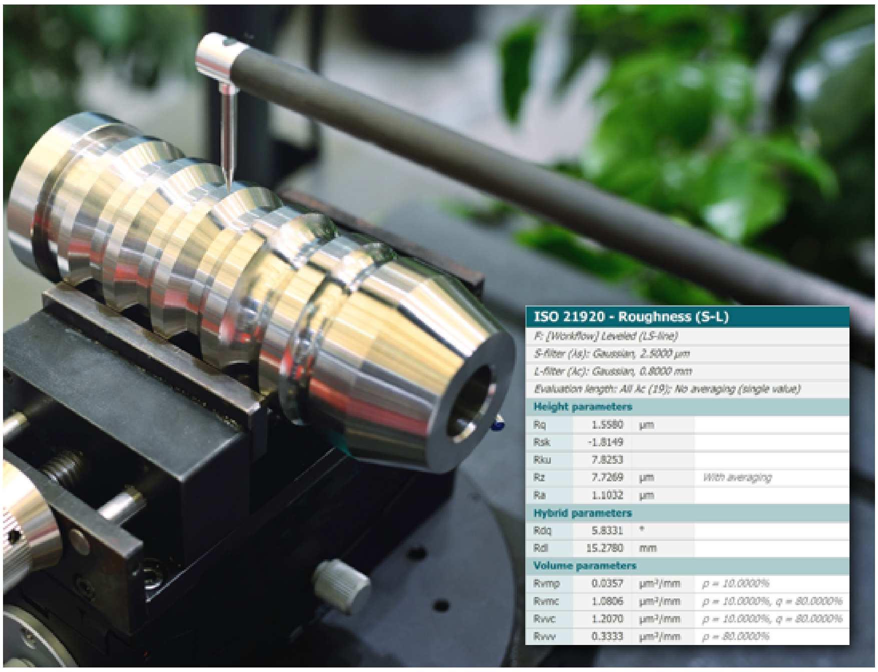
IN THIS ISSUE

LATEST MOUNTAINS® RELEASE

EARLY ACCESS TO UPCOMING ISO PROFILE PARAMETERS



Mountains® 8.1 is on the horizon and due to be released late spring 2020.

The new version will make future ISO 21920 profile parameters available to users, allowing them to prepare for upcoming changes. New features also include extended options for multichannel files, as well as improved tools for colocalization and force curve analysis.

... Turn to page 2 ...

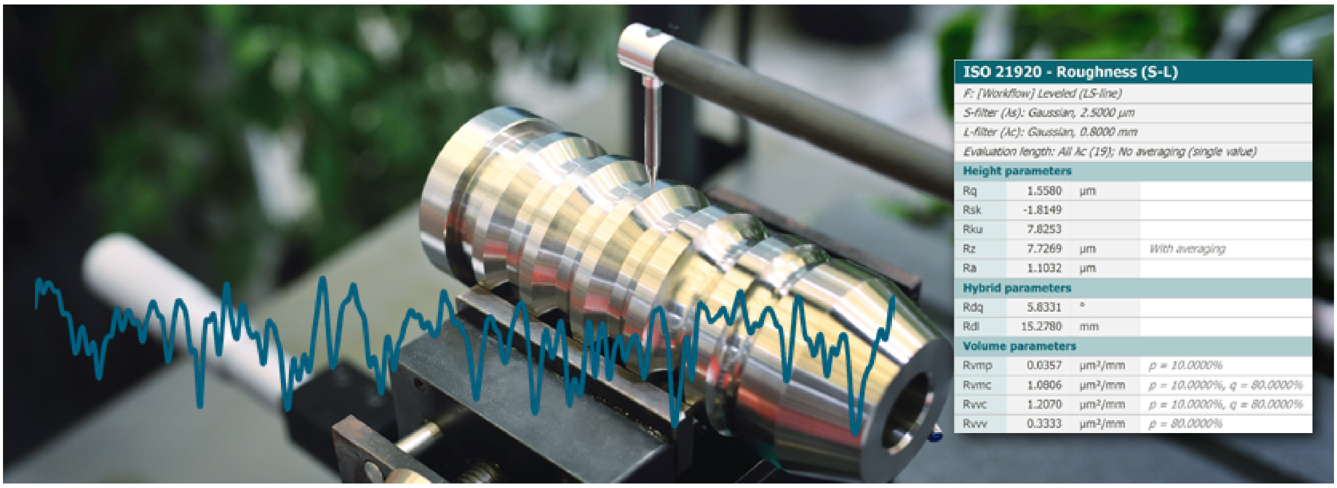
New digital learning resources

With many of us working from home right now, digital resources are becoming more helpful than ever.

Our MountainsSPIP® webinars are online, available for you to watch, as many times as you need and from wherever your workspace is at the moment. bit.ly/2Xqqro3

MOUNTAINS® 8.1 COMING SOON TO AN INSTRUMENT NEAR YOU

Mountains® 8.1 is on the horizon and due to be released late spring 2020. This latest version makes upcoming ISO 21920 profile parameters available, improves display and analysis of multichannel files, in particular those obtained using scanning probe microscopy (SPM), and adds new options to existing force curve analysis tools. Many other improvements await users working with profilometers and microscopes. Let's take a look at a few of the highlights.



Above. *Get ahead of the crowd by accessing and testing new ISO 21920 parameters prior to their publication.*

YET-TO-BE PUBLISHED ISO 21920 PROFILE PARAMETERS

Over the last few years working group (WG) 16 of the ISO technical committee (TC) 213 has been working on the revision of profile standards in order to align them with structure and concepts of ISO 25178 for areal parameters.

Anticipating their publication in 2021, the new ISO 21920 parameters are already available to Mountains® users in the newly released version, allowing them to prepare for upcoming changes.

This new standard brings together parameters from other standards, mainly ISO 4287 (which will eventually be abandoned), and updates certain older parameters. Other parameters have been "imported" from pre-existing standards on surfaces.

These parameters can be calculated on:

- a primary profile
- a waviness profile
- a roughness profile (see image above)
- a band-pass profile

"Sampling length" has been renamed "section length".

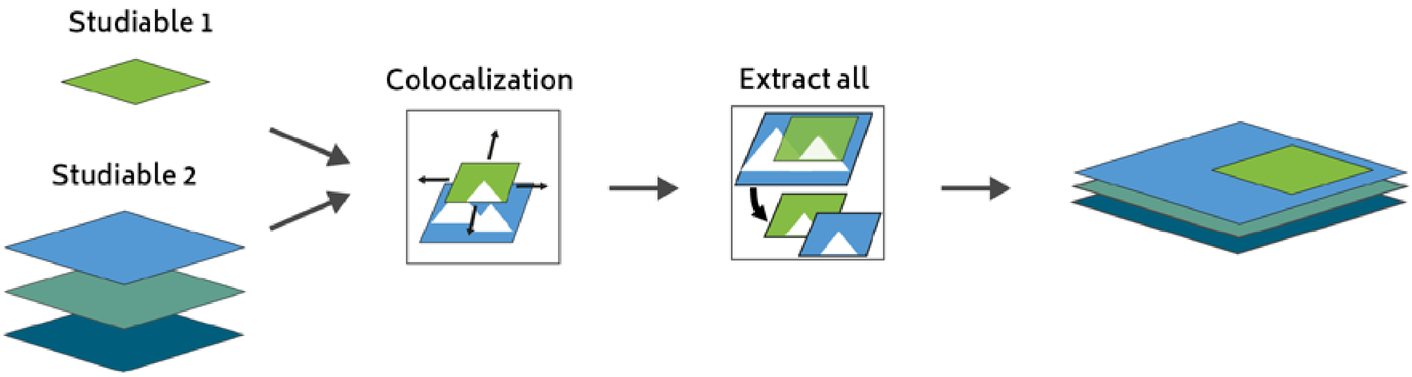
ISO 21920 parameters are calculated on the evaluation length, as a single value, without averaging (with the exception of the Xpt, Xp, Xvt, Xv, Xz-max, Xz parameters which are averaged using the values calculated on the defined section lengths).

NEW PALETTE OPTIONS FOR MULTICHANNEL SPM & HYPERSPECTRAL DATA

Users working with multichannel data, for example from scanning probe microscopes, can now apply different color palettes to each channel, or to all channels. This new option can be used in both 2D or 3D visualization modes.

Axis settings can be set for each channel in the axis settings dialog.

New composite types of rendering are also available, allowing the addition of colors of different layers. Color palettes are shown in a key to the right of the image.



Above. *Different channels can now be manipulated more easily in the colocalization study and multi-channel data can be extracted.*

EXTENDED TOOLS FOR COLOCALIZATION

In version 8.1, it is possible to use Mountains® powerful colocalization tools with multi-channel data.

For example, AFM data containing several signals (height, phase etc.) can now be overlaid with data measured using another instrument (scanning electron microscopy, spectroscopy etc.)

In the case of spectroscopy, this new feature allows users to correlate elemental and chemical information about a sample with topography information obtained from another source.

Different channels can now be manipulated independently of each other much more easily, dynamic images can be generated and it's also possible to extract a multi-channel data set from the results of your colocalization.

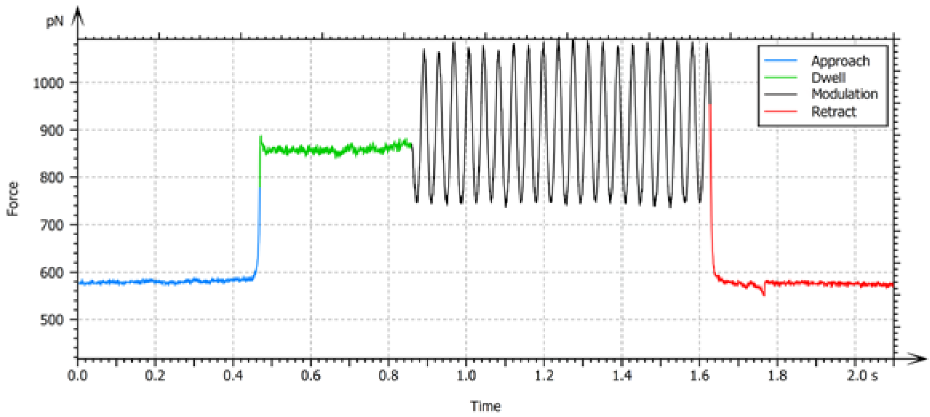
NEW INDENTATION MODEL FOR FORCE CURVES

New signal types, including those with no deflection can now be processed. Users can calculate deflection from force if constants are defined in the input file, or by using the in-built calibration tool. The JKR indentation model can now be used.

New options for choosing which signal to display and applying colors to each type of phase have been made available (see image below).

CALCULATE PARAMETERS ON SHELL (FREEFORM) DATA

The parameters table study is now available for shell data. Users can display number of points and number of facets. This feature forms the basis of a future toolset for freeform surfaces (shells) which will be developed in subsequent versions (for more info, please see page 8).



Right. *Multi-segment force curve data from Bruker showing cell indentation with modulation.*

How to update to Mountains® 8.1
Access to this latest release is included in the Mountains® Software Maintenance Plan (SMP). Please visit www.digitalsurf.com/support/software-updates
To find out more about SMP options, please contact sales@digitalsurf.com

PERFORM 3D FOURIER ANALYSIS USING MOUNTAINS®

The Fast Fourier Transform (FFT) is used in many fields of science and engineering and allows visualization of the frequencies (wavelengths) of a signal. In Mountains®, analysis tools based on FFT can help users determine the periodicity and orientation of certain motifs, in addition to roughness, by showing the frequencies found in the spectrum. Anne Berger, direct sales manager, explains.

For anyone wishing to perform advanced analysis of the topography of a surface, whether their data be obtained using 3D profilometry or atomic force microscopy (or other types of scanning probe microscopy), FFT-based tools can be particularly effective.

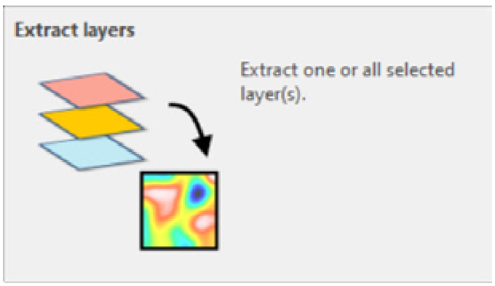
They can be used for instance to make a bandwidth filtering by removing the form, the waviness and the microroughness at the same time in order to keep only the roughness. Filtering using the FFT can also be employed to separate motifs of different directions (e.g. honing grooves on a motor cylinder).

FIRST STEP: MAKE SURE YOU'RE WORKING WITH SURFACE DATA

Mountains® software is designed to be as easy-to-use as possible and so you will need to remember that available tools will only be shown in the contextual ribbon if an appropriate type of data is selected in the document.

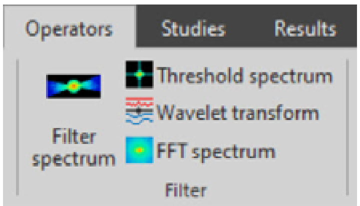
If you are not seeing the tools presented in this article, please first make sure that you have selected a surface (i.e. measurement of heights over a rectangular area).

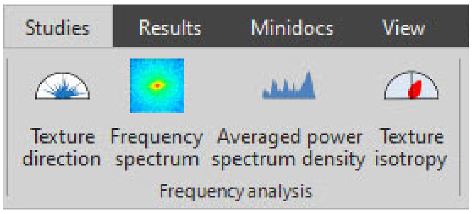
In particular, please note that if you are working with multi-channel data (for example coming from scanning probe microscopy), you will first need to extract the channel (or layer) of data on which you wish to perform FFT analysis. This can be done using the Extract layers operator:



LOCATING FFT TOOLS IN THE INTERFACE

There are several different operators and studies in Mountains® based on Fourier analysis. These can be found in the "Operators" and "Studies" tabs:





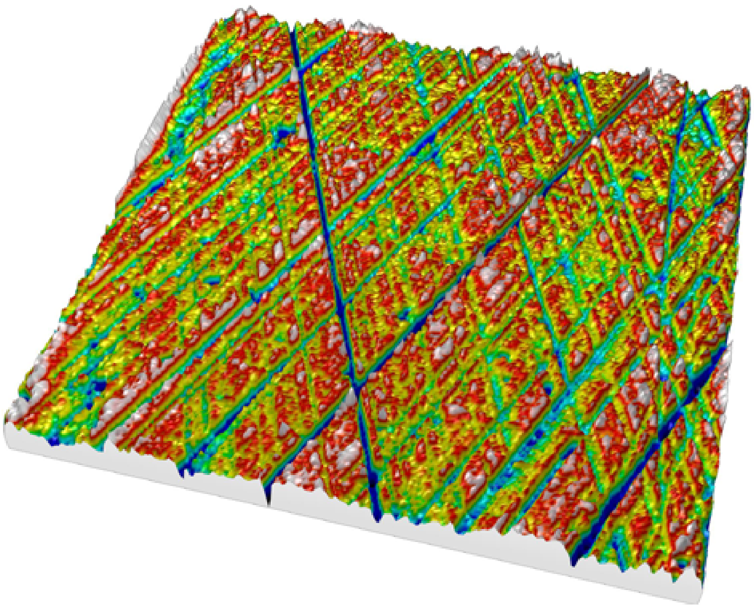
USING THE FREQUENCY SPECTRUM STUDY

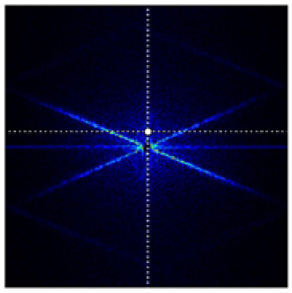
This tool will allow you to generate an interactive representation of the frequency spectrum of your data. It can be useful when analyzing the components of a surface with motifs in order to highlight their periodicity or orientation.

The example at the top of the following page shows a motor cylinder surface with honing marks. The Frequency Spectrum study provides wavelength, angle, phase and magnitude parameters for each point on the surface.

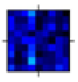
An option for choosing logarithmic or a linear scale is available. Logarithmic scale is useful when your data contains periodic motifs.

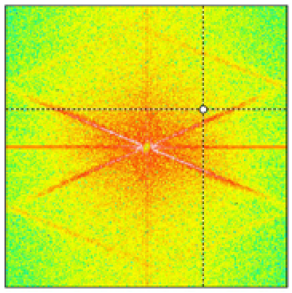
The tool is fully interactive: move the cursor and the parameters table is automatically updated.



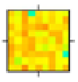


Parameters	Value	Unit
X	2560	µm
Y	183	µm
Wavelength	182	µm
Angle	85.9	°
Magnitude	1.02	nm
Phase	-76.6	°





Parameters	Value	Unit
X	50.2	µm
Y	75.3	µm
Wavelength	41.8	µm
Angle	33.7	°
Magnitude	-18.9	dBc
Phase	111	°



Above. *A motor cylinder surface with honing marks (left). The Frequency Spectrum study (right) provides an interactive plot with a logarithmic or linear scale. It calculates parameters for each point on the surface.*

POWER SPECTRUM DENSITY: SEE WAVELENGTH INTENSITY

The Averaged Power Spectrum Density (PSD) tool helps you gain a more detailed understanding of your data. It is widely used in optics, often to characterize polished surfaces and super-finishing with very little roughness. You can display an interactive plot with wavelength on the X-axis and intensity (square of the amplitude) on the y axis.

The images below show AFM topography of a glass surface before and after an acid attack and their corresponding PSD plots.

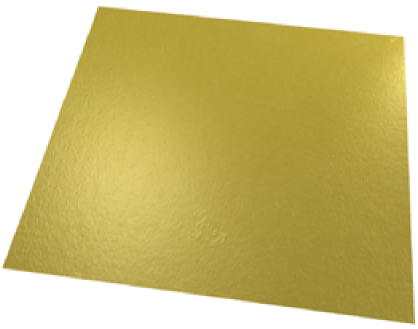
ISOTROPY, DIRECTIONALITY, PERIODICITY AND MORE

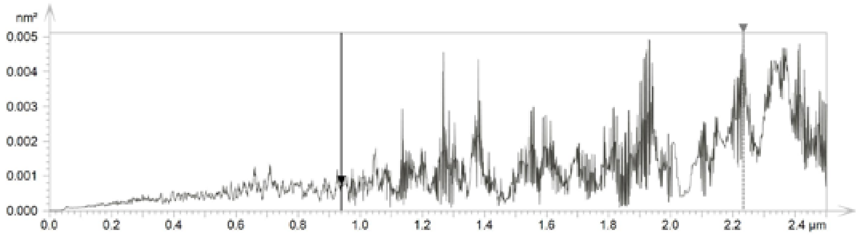
Many other FFT-based tools relevant to a wide variety of applications are available in Mountains®.

Dominant surface directions can be displayed, texture isotropy can be calculated and auto-correlation tools help distinguish between isotropic surfaces (with a circular central node) and anisotropic surfaces (with a central node extended along one direction).

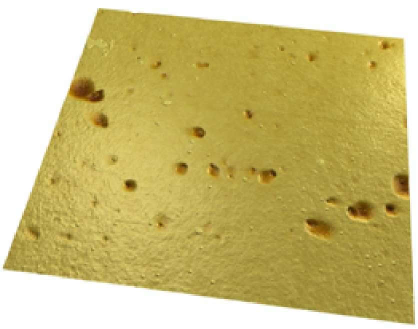
READ MORE

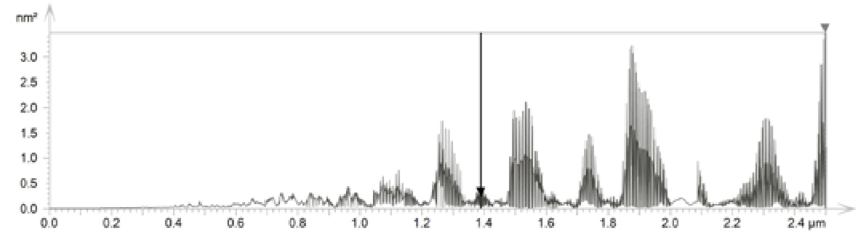
▸ *in the Reference Guide (Help files): press F1 in Mountains®*





Parameters	Value	Unit
Wavelength	0.940	µm
Amplitude	0.0272	nm





Parameters	Value	Unit
Wavelength	1.39	µm
Amplitude	0.497	nm

Left & above. *AFM topographies and corresponding Power Spectrum Density plots.*

ASSESSING THE TRIBOLOGICAL INTERFACE OF MECHANICAL PARTS

Researchers at the **Luleå University of Technology and Scania in Sweden,** recently investigated how surface topography influences oil film formation in tribological interfaces pertinent to gears. The study was oriented towards the improvement of fuel economy and sustainability. Jonny Hansen (pictured left), a member of the research team, explains how Mountains® software was used to help achieve results.

At the design stage, it is often more economically beneficial to develop a rough surface rather than a smooth one. In practice, however, a rougher surface may lead to an increase in surface distress and in expense. Hence, the challenge for gear manufacturers is to maintain adequate lubrication quality for relatively rough surfaces.

In this study, MountainsMap® software was used to prove surfaces can be kept rough as long as the most prominent peaks are removed. The results highlight the importance of controlling the structure of a tribological interface for minimized friction and wear.

TRIBOLOGICAL TEST SEQUENCE

A friction test, with a ball-on-disc setup, of a rough surface (0.3µm) and an opposing smooth one with nanometer roughness, was employed for tribological testing. The test conditions were set up to mimic those found in gears, i.e. lubricated steel surfaces subjected to GPa pressure and a high degree of sliding with rolling. The operating conditions were kept constant throughout the test, and were specifically selected to generate a nominal oil film thickness of 0.05µm between the point of contact of the ball and the disc.

Hence, the test began under substantial contact interference. As the test continued, surfaces were altered due to wear, and successive improvement of the lubrication quality followed – a process known as running-in. At the end of the test, the oil film had fully formed and no metallic contact persisted.

SURFACE RE-LOCATION ANALYSIS IN MOUNTAINSMAP®

3D surface roughness data was acquired from the rough surface of the ball using an optical profilometer. Typically, when assessing the same area before and after a test, surface misalignment issues can be found. The following post-processing routine was therefore employed in MountainsMap®:

1. The two studiables were loaded and the "Remove form" function was used.
2. A Robust Gaussian filter was employed, in order to separate the roughness profile from the primary profile.
3. The "Shift surface" operator was used on the series of studiables, to correct lateral and rotational misalignments (see details opposite).
4. The "Extract area" operator was used to assess only the area subjected to wear.

FEATURED RESULTS

Figure 1 displays the results of the surface re-location analysis that was carried out in MountainsMap®. We can see that the most prominent peaks have been removed, but the structure of the surface topography still remains. Both of these changes contribute to improvement in lubrication quality, which ultimately allows for full film separation at the end of the test.

With these results, we were able to compute the statistical data of the surface roughness. An example of the most common parameters that emerge on technical drawings are listed in figure 2.

The results indicate that surface roughness peaks are especially susceptible to oil film breakdown and thus to wear and plastic deformation. When comparing the computed oil film thickness (0.05µm) to the Sq parameter obtained after the test - in accordance with standard practice - it became clear that the oil film can be over 5 times thinner than surface RMS height. This statement may seem contradictory, but it stems from the fact that rough surfaces are elastically deformed inside the area of contact. This is further discussed in our published article.

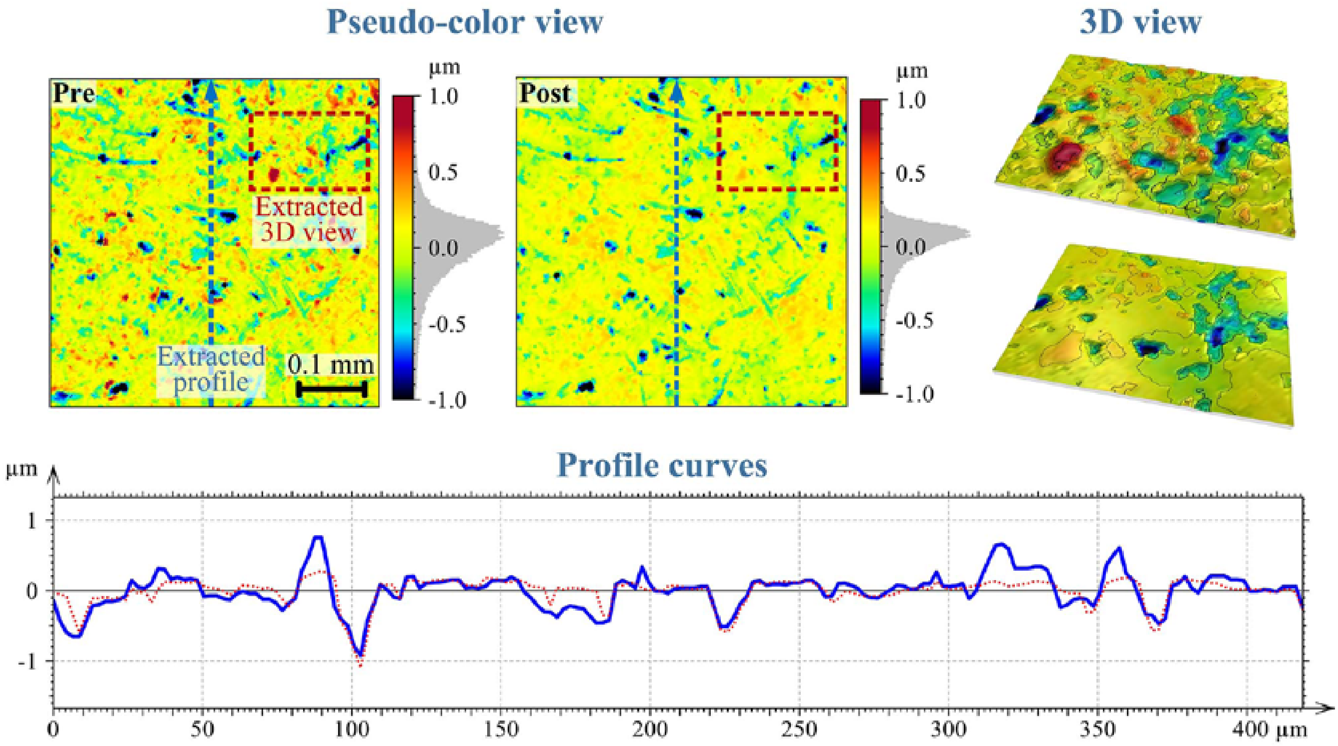


Figure 1. *Surface examined before and after a running-in test. The most prominent peaks have been removed due to wear and plastic deformations.*

CONCLUSIONS

By using MountainsMap® software, it was possible to study how surface roughness had to change in order for a fully separable oil film to form. It was found that the most prominent peaks were removed, while the main structure of the surface remained.

These findings may aid engineers in their efforts to design durable and energy efficient tribological interfaces for rotating machinery.

Parameters table

ISO 25178	Pre		
Height Parameters			
Sq	0.308	µm	*Root-mean-square height*
Ssk	-0.829		*Skewness*
Sku	7.20		*Kurtosis*
Sp	2.41	µm	*Maximum peak height*
Sv	2.47	µm	*Maximum pit height*
Sz	4.88	µm	*Maximum height*
Sa	0.221	µm	*Arithmetic mean height*

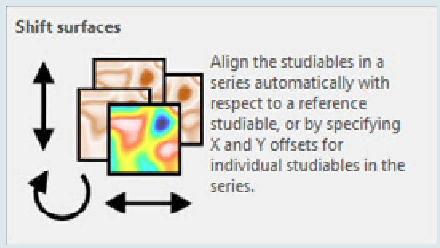
ISO 25178	Post		
Height Parameters			
Sq	0.268	µm	*Root-mean-square height*
Ssk	-1.46		*Skewness*
Sku	9.65		*Kurtosis*
Sp	1.88	µm	*Maximum peak height*
Sv	2.60	µm	*Maximum pit height*
Sz	4.48	µm	*Maximum height*
Sa	0.185	µm	*Arithmetic mean height*

Figure 2. *Typical 3D roughness parameters. The peak parameter shows significant reduction whereas the valley parameter shows a minor increase – both contribute to improved lubrication quality.*

SHIFT SURFACES OPERATOR

When studying surface change, it is often difficult to measure exactly the same location on a sample. The **Shift Surfaces operator** makes it possible to reposition one surface in relation to another. Readjustments can be done either by points of interest or automatically. Surface subtraction is then applied to quantify differences which can be visualized in cinema mode (4D view).

This **operator** can also be used in a template in order to stay positioned in the same coordinates frame. This is a way of carrying out profile extractions from the same place or analyzing contours.



The Shift Surfaces operator can been used to reposition the sample area

READ MORE

Topography transformations due to running-in of rolling-sliding non-conformal contacts. *Hansen, J., Björling, M., & Larsson, R. In: Tribology International, 144(106126).* *doi.org/10.1016/j.triboint.2019.106126*

CONTACT

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FREEFORM SURFACES: CAN I CALCULATE SURFACE TEXTURE?

Until the beginning of the 1980s, surface texture characterization was based exclusively on 2D profilometry. Then came the dawn of surface measuring instruments such as 3D profilometers. **François Blateyron**, Digital Surf's senior expert on surface metrology, examines the next big change in surface analysis - freeform surfaces - and discusses current and upcoming tools available for studying them with Mountains®.

Most engineers and designers of mechanical components know roughness specifications through profile parameters, such as Ra. Many metrologists in the industry control surface texture specifications using a stylus profilometer that measures heights along a profile. This is fine as long as the texture is simple enough and homogeneous enough. But more and more, engineered surfaces have patterns, structures or specific texture printed, added or implanted on them, in order to better control surface function (adhesion, lubrication, hydrophobicity etc.) Specifications on such surfaces are more reliable and representative if they use areal parameters calculated on surfaces. The introduction of areal surface metrology was an important turning point in the 1990s.

However, the true complexity of a real surface may not even always be fully captured with a standard surface, coded on a matrix of heights. When the surface has complex form and superimposed small texture, or when the manufacturing process creates spatter particles or cavities, or when you are interested in characterizing roughness on the vertical wall of a rectangular trench, an acquisition along the Z-axis will result in lost information. So, what's the solution? Freeform surfaces are the next paradigm shift.

DEFINITION OF A FREEFORM SURFACE (SHELL)

In order to keep surface information intact during acquisition and analysis, it is necessary to move the data structure from a function z=f(x,y), where one height value is coded for every x,y position on a regular grid, to a curvilinear form, (x,y,z)=f(u,v), where points in space are connected to their neighbors as triangles.

A freeform surface, called a "shell" in Mountains® (for reasons of brevity and because it corresponds to the outer envelope of a 3D object), is a point cloud (x,y,z) associated with connectivity information so that all points are connected in a triangle mesh in space. That way, the complete surface around an object can be coded. This also allows coding of undercut structures or internal cavities (see example image on following page).

Triangle meshes are commonly used in dimensional metrology to represent, for example, a mechanical workpiece measured by a coordinate measuring machine (CMM). The difference here is that resolution has to be fine enough to allow surface texture analysis at the micrometer scale.

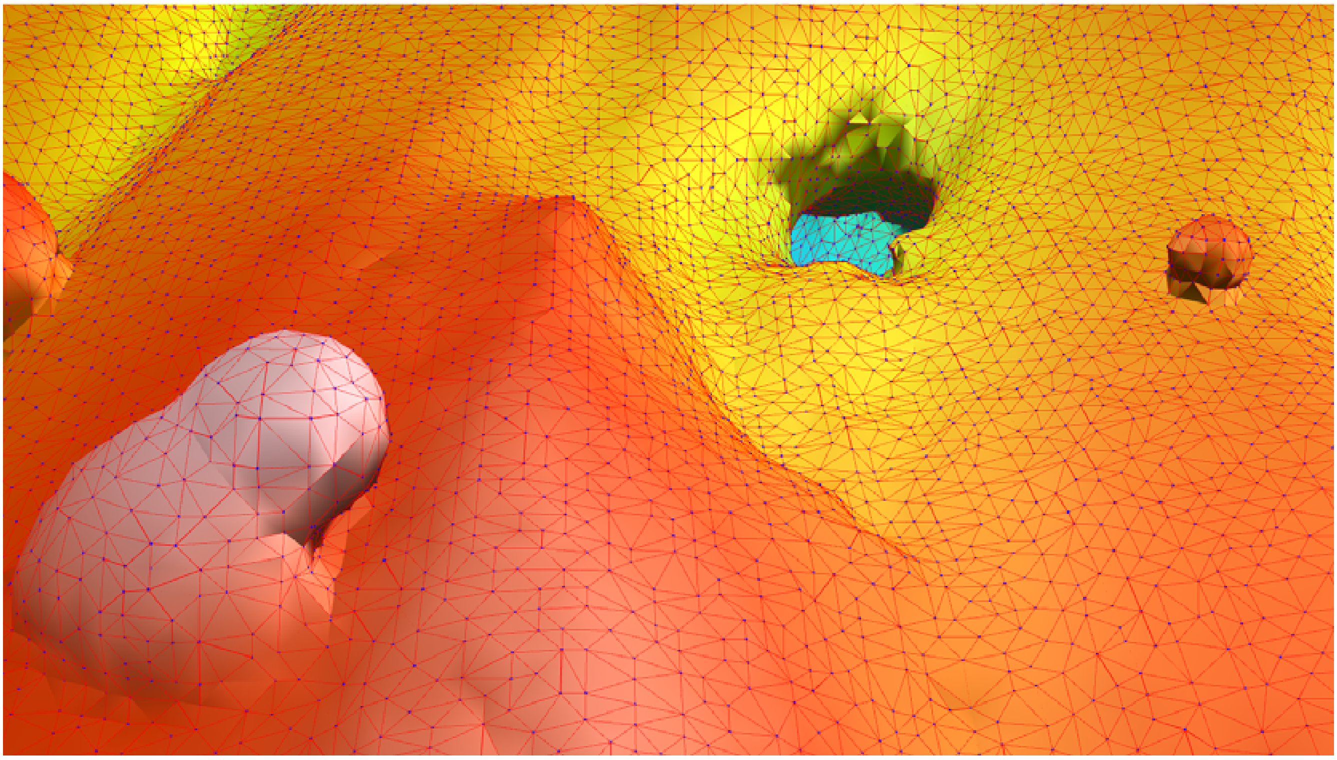
Mountains® 8 is compatible with freeform data structures and version 8.1 contains some new features. These form the basis of a future ecosystem around freeform surfaces (shells) which will be further developed and improved in subsequent versions.

ACQUISITION & PROCESSING OF FREEFORM SURFACES

Freeform surfaces can be produced using several instrument techniques:

- **Optical profilometry (confocal, interferometer, focus variation etc.)**: multiple acquisitions are performed at different angles, then partial height maps (standard surfaces) are stitched together into a single mesh in space.
- **Scanning electron microscopy (SEM):** images are processed by pairs; reconstructed height maps are stitched together.
- **X-ray computer tomography (XCT):** an interfacial surface is extracted from a voxel cube.
- **µCMM or 3D scanner:** a point cloud of sufficient density is meshed into a freeform surface under certain convexity conditions.

Mountains® 8 can load freeform surfaces from various file formats (STL, 3MF, OBJ, PLY). They are loaded as "shell" studiables and can be displayed



Above. *3D view in Mountains® of a shell (or freeform surface) of metallic powder melted by a laser in additive manufacturing. Non-melted powder particles are visible above the surface, as well as a cavity below the surface. The triangle mesh and points have been overlaid on a colored surface.*

in an interactive 3D view and further analyzed with Operators and Studies.

Besides coordinates and connectivity information, a shell studiable may also contain additional information, called attributes, created during acquisition or extraction, or generated by a specific Operator in Mountains®. These attributes may be color or intensity values, normal vectors, distance values from the reference surface, or any application-oriented attribute that needs to be linked to the shell studiable. An attribute can be associated with points or triangles, or even edges.

BRIDGE WITH XCT DATA

A bridge between the DigiXCT® software from Digisens[1] and Mountains® is currently under development. This will enable extraction of accurate freeform surfaces from the density information contained in volume datasets and importation into Mountains® for surface texture analysis. The link to the original volume dataset will be maintained over time.

CURRENT MOUNTAINS® TOOLS

Mountains® 8.0 already included two Operators for processing freeform surfaces:

- The first one intersects the freeform surface with an oriented plane in order to create a contour profile that can be analyzed. This can be useful, for example, for checking angles and dimensions or even comparing the profile with a DXF model.
- The second one allows the user to orient the freeform surface and position a rectangle to define the portion of the freeform surface to extract and convert to a standard surface. Useful, for example, when analyzing roughness on an internal surface (e.g. the internal surface of the chamber of a pump produced by additive manufacturing that cannot be accessed by regular profiler unless the workpiece is cut).

NEW PLUG-INS FOR SURFACE TEXTURE PARAMETERS ON A FREEFORM SURFACE

Digital Surf has been partnering with the Center of Precision Technologies (CPT) at the University of Huddersfield (UK) to develop a set of surface texture parameters calculated on freeform surfaces.

A team of talented researchers and PhD students at Huddersfield have developed the background mathematics and adapted the definitions of areal surface texture parameters to apply them to freeform surfaces.

[1] Digisens specializes in the management and analysis of XCT datasets for inspection and metrology. www.digisens3d.com

A symmetrical expression can be found for most parameters on freeform surfaces compared to standard surfaces:

$Sa = \frac{1}{A}\iint_A \lvert z(x,y)\rvert dxdy$ *Sa* parameter on a standard surface	$Sa = \frac{1}{A}\iint_{\Sigma_{form}} \lvert r(u,v)\rvert d\sigma_{form}$ *Sa* parameter on a freeform surface
$Sq = \sqrt{\frac{1}{A}\iint_A z^2(x,y)\,dxdy}$ *Sq* parameter on a standard surface	$Sq = \sqrt{\frac{1}{A}\iint_{\Sigma_{form}} r^2(u,v)\,d\sigma_{form}}$ *Sq* parameter on a freeform surface

where Σ_{form} represents the form surface which acts as a reference surface from which the deviations r(u,v) are measured between each point of the freeform surface and the form surface that is associated with it.

- Mathematical details can be found in the paper: *Pagani L, Qi Q, Jiang XQ, Scott PJ, **Towards a new definition of areal surface texture parameters on freeform surface**, Measurement 2017.*

Mountains® 8.1 will introduce a plugin that calculates a subset of ISO 25178-2 parameters directly on a loaded freeform surface, without the need to convert it to a standard surface.

Parameters are calculated from the form deviation values associated with each point of the freeform surface. This means that a form surface has to be associated with a freeform surface. This is done through a dedicated plugin operator that fits a least-square form to the point cloud. The form can be a plane, polynomial, cylinder or sphere. This is a preliminary stage before parameters can be calculated.

Further developments on the subject will be made in subsequent versions and some will be made available as optional modules.

ADVANCED ANALYSIS: CAD COMPARE, FILTERS AND MORE

In the case of an additive manufactured component, it is usually necessary to fit a CAD model or the designed mesh to the freeform surface under test. Such fitting is complex and computer-intensive. When no model is available, the reference surface may be approximated using a low-pass filter (S-Filter), the same way a waviness surface is used as the reference surface to calculate roughness heights. Smoothing filters as well as some morphological or envelope filters and retouch tools can also be useful. These functions will be available in future versions.

As a leading product for surface texture analysis, Mountains® embraces the next revolution in metrology and is committed to providing the tools necessary to users in industry and research. Initial feedback on these applications provided by users will help validate tools and prepare the forthcoming standardization. You could say Digital Surf is preparing the future with key partners and that some of this future is already available in Mountains® 8.1.

MountainsMap® Premium, MountainsSEM® Premium and MountainsLab® Premium all include the Shell Extension module that adds features for freeform surfaces. The module is also available as an option with other products.

REFERENCES

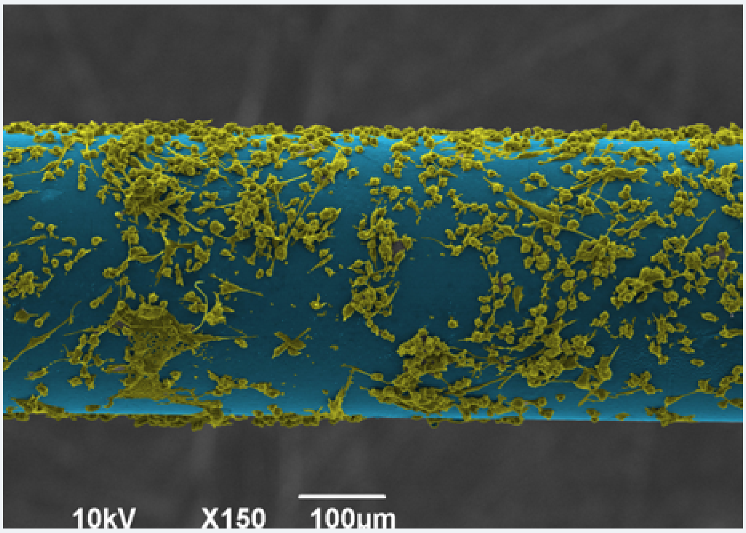
- *Introduction to shell data:* www.digitalsurf.com/blog/what-is-a-shell-or-freeform-surface
- *Shell Extension module:* www.digitalsurf.com/optional-modules/shell-extension
- *CPT at Huddersfield University:* research.hud.ac.uk/institutes-centres/cpt
- *Read more on freeform surfaces:* www.elsevier.com/books/advanced-metrology/jiang/978-0-12-821815-0

EVENTS NEWS

MRS 2019

Digital Surf was thrilled to participate at the 2019 Materials Research Society Fall Meeting & Exhibit from December 1 to 6 in Boston, MA, USA. The world's foremost international scientific gathering for materials scientists registered over 6,600 attendees from 59 countries for this new edition. Arnaud, Isabelle and Nicolas were pleased to meet visitors from around the world and provide a live demo of new MountainsSPIP® 8 software. Watch video: bit.ly/2RlGoIl

WHAT'S HOT ONLINE



SEEN ON FACEBOOK

April 8, 2020: JEOL USA's "Image of the day" was a SEM micrograph entitled "Surrounded" submitted by Simone Lauciello of the Fondazione Istituto Italiano di Tecnologia.

The image shows tumor cells on a myelin covered wire. It was imaged with a JEOL JSM-6490LA scanning electron microscope and colorized using MountainsSEM® software. Nice work!

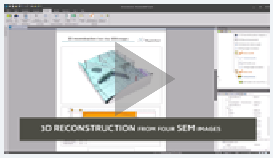
bit.ly/2UYvday

POPULAR ON LINKEDIN

April 1, 2020: although the Digital Surf team continues to work remotely, team members extended a warm welcome to new employees in their first day in their new job by making videos & PPT presentations.

bit.ly/39QaXw8

Have you visited our YouTube channel recently?



Watch our new Mountains® 8 video tutorials to help you use version 8 features.

Check them out:

www.youtube.com/playlist?list=PLK5Jlf_LO8rjhB8ILDbKNmbSAA6xfMYcm

Surface Newsletter

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MEET DIGITAL SURF
- **Control** - May 5-8, 2020 - Stuttgart, Germany
  Unfortunately, due to the current coronavirus situation, Control 2020 has been canceled. We will be presenting Mountains® 8.1 features that were scheduled to be showcased during this trade show online. Please visit www.digitalsurf.com/agenda/control-international-trade-fair-2020

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