PITTING CORROSION MEASUREMENT USING 3D PROFILOMETRY

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INTRO:

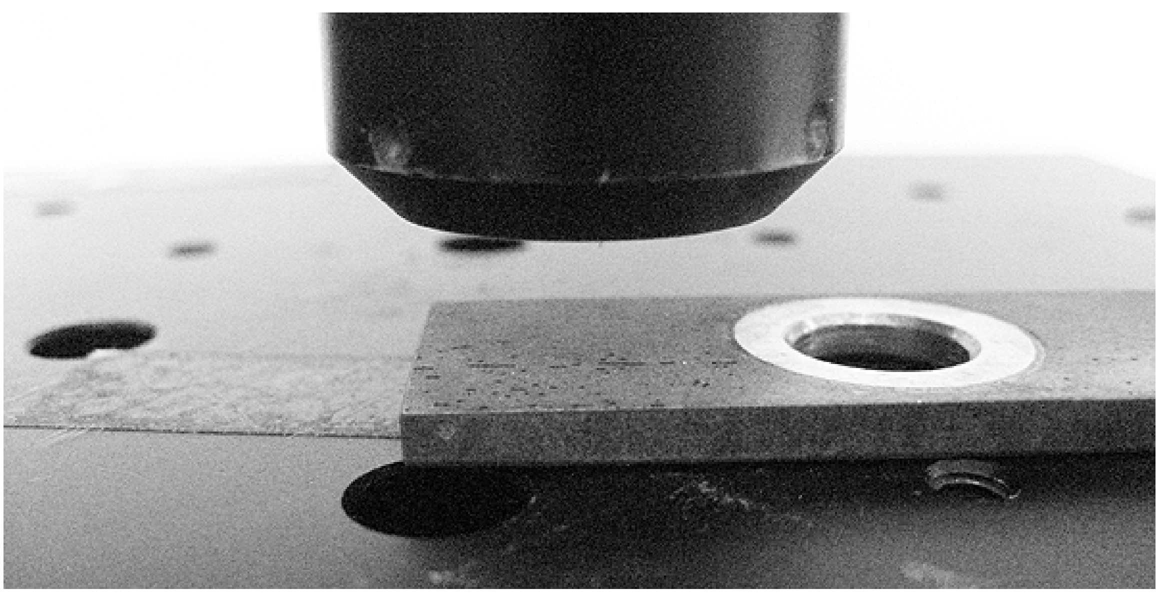
In the form of holes, pitting corrosion is localized and can penetrate into materials very quickly and is one of the most frequent forms of corrosion in stainless steels. The quantification of pitting corrosion has been a main focus of study in recent years. Pitting corrosion is quantified in different ways e.g. average pit depth, maximum pit depth, volume etc.

IMPORTANCE OF 3D NON CONTACT PROFILOMETER FOR PITTING STUDY

Unlike other techniques such as touch probes or interferometry, the 3D Non Contact Profilometer, using axial chromatism, can measure nearly any surface, sample sizes can vary widely due to open staging and there is no sample preparation needed. Nano through macro range is obtained during surface profile measurement with zero influence from sample reflectivity or absorption, has advanced ability to measure high surface angles and there is no software manipulation of results. Easily measure any material: transparent, opaque, specular, diffusive, polished, rough etc. The technique of the Non Contact Profilometer provides an ideal, broad and user friendly capability to maximize surface studies when pitting analysis will be needed; along with the benefits of combined 2D & 3D capability.

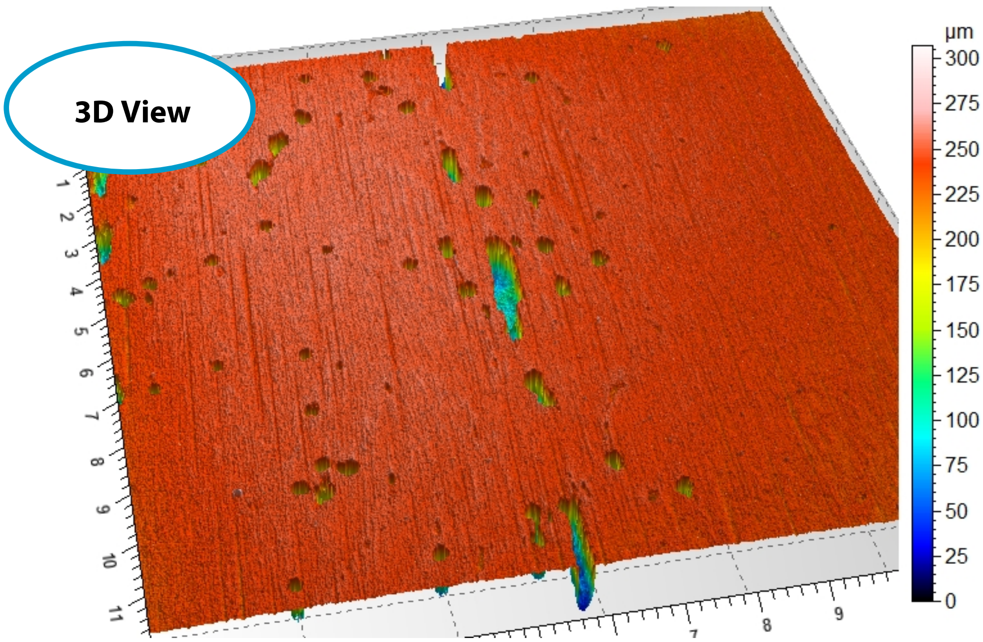
MEASUREMENT OBJECTIVE

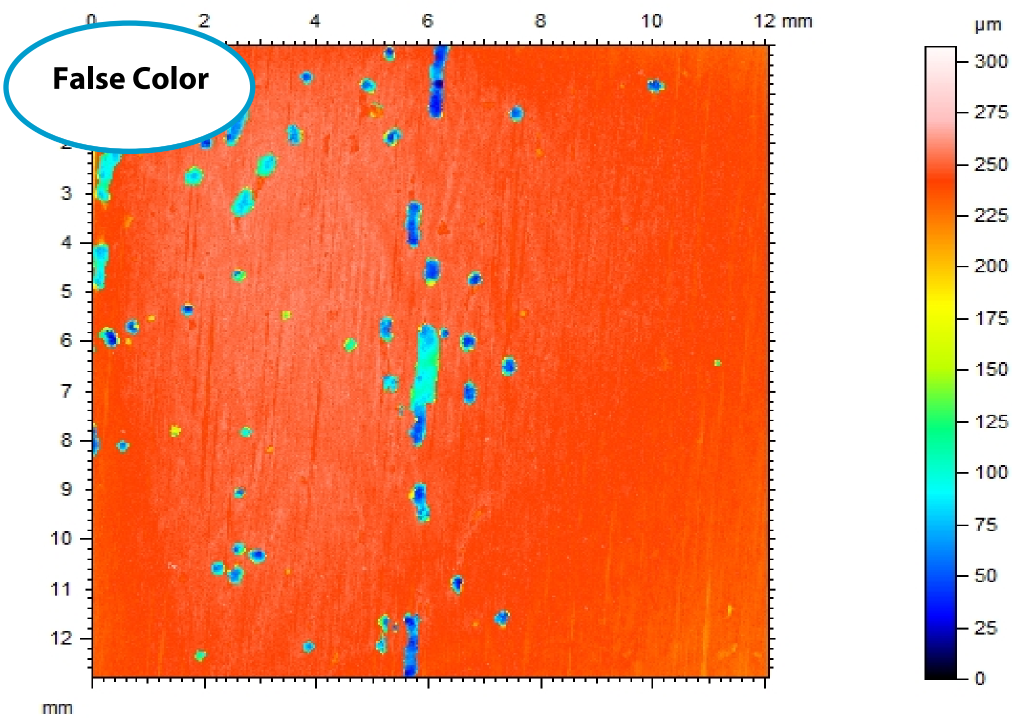
In this application the Nanovea ST400 Profilometer is used to measure the surface of a corrosion pitted stainless steel coupon. The area measured was selected at random, and assumed large enough in that it could be extrapolated to make assumptions about a much larger surface. Density, area, volume, size and shape will be used here to quantify the level of corrosion.



RESULTS: 3D Surface

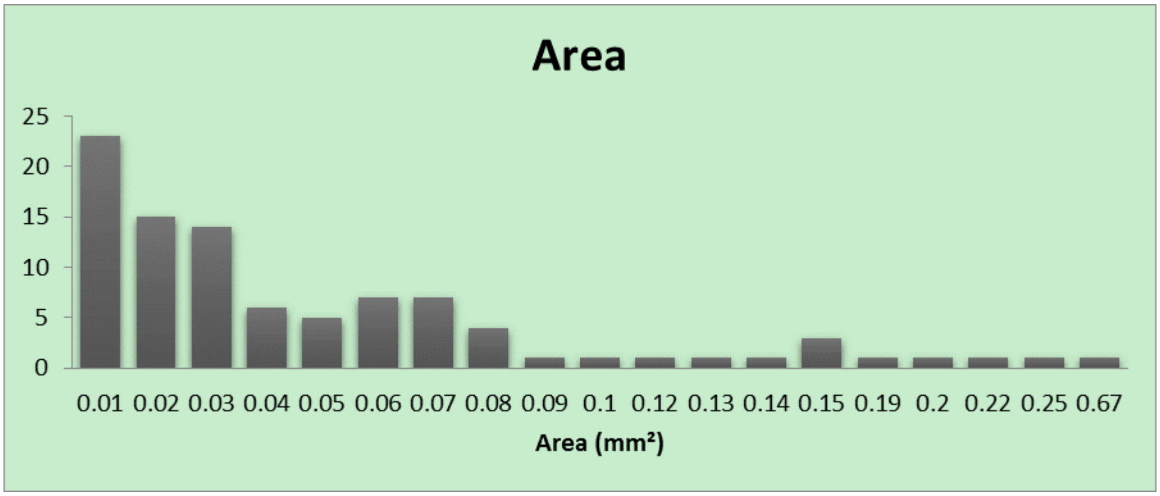
The 3D View and False Color View of a randomly selected area on the sample surface after pitting corrosion show pits of various shape and depth. It provides users a straightforward tool to directly observe the distribution and morphology of the pits from different angles. Several pits exhibit an elongated shape parallel to the direction of the machine marks, indicating the importance of surface finishing to the corrosion resistance of metals.

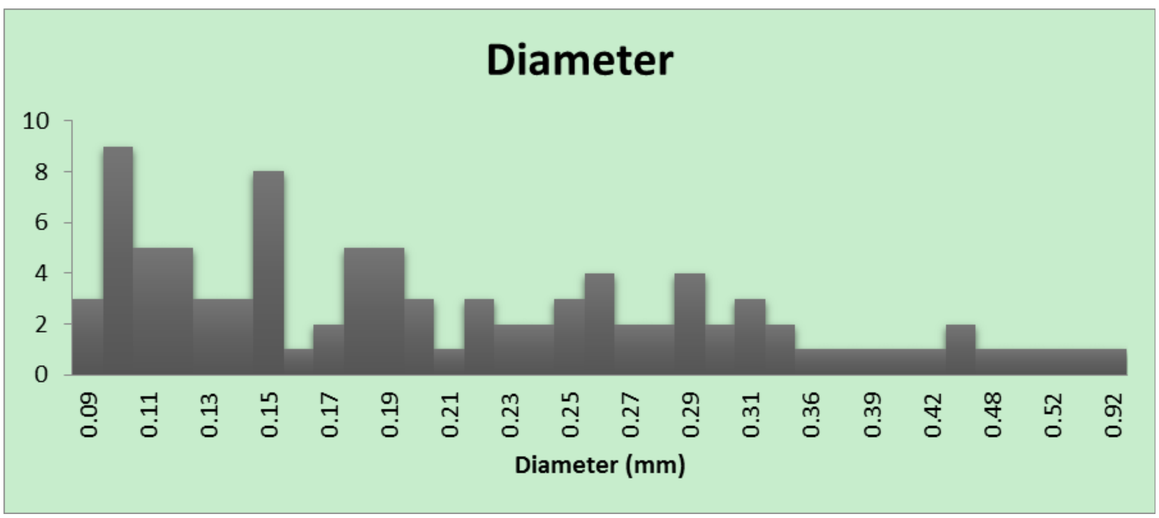


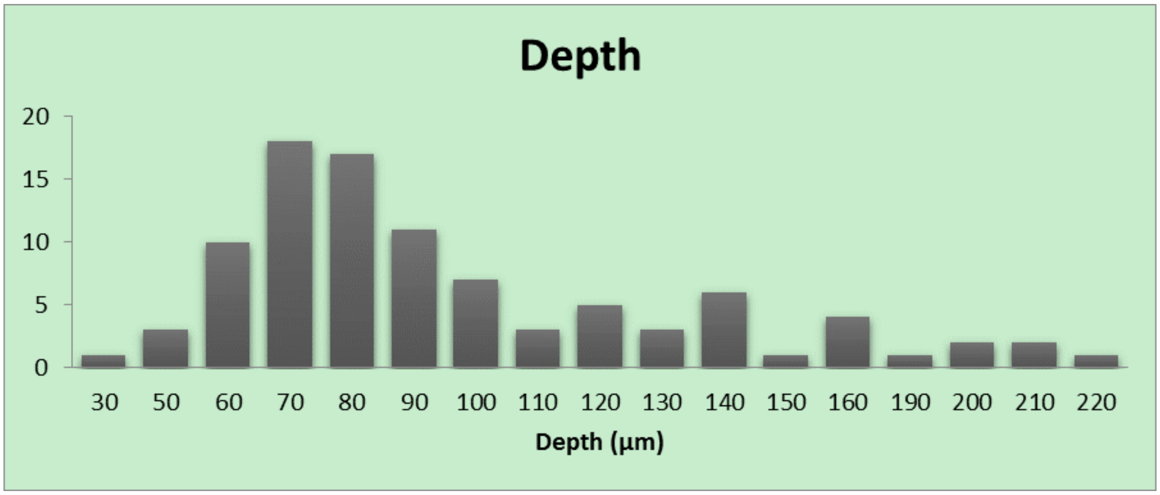


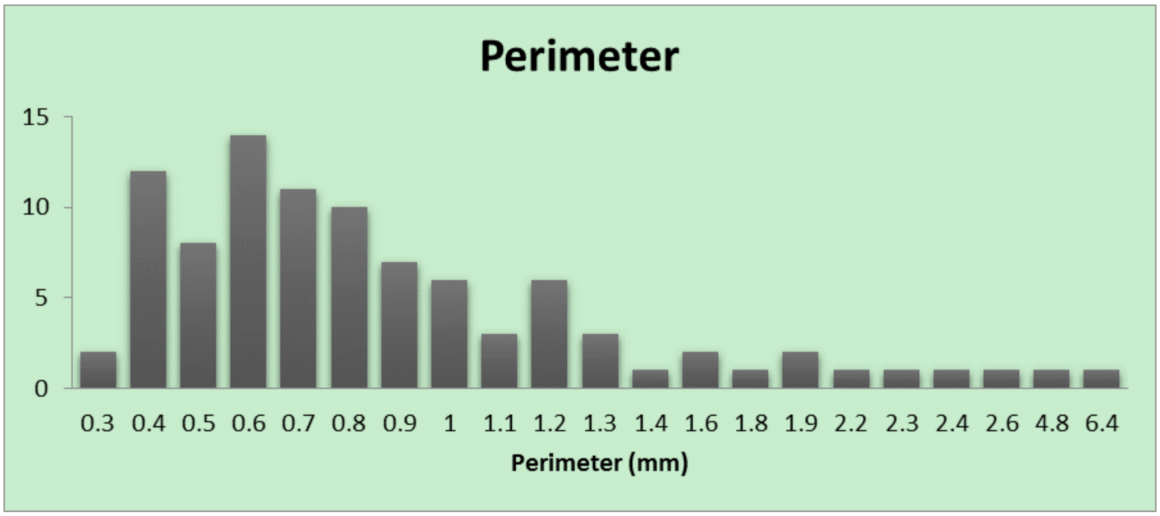
2D Surface Analysis

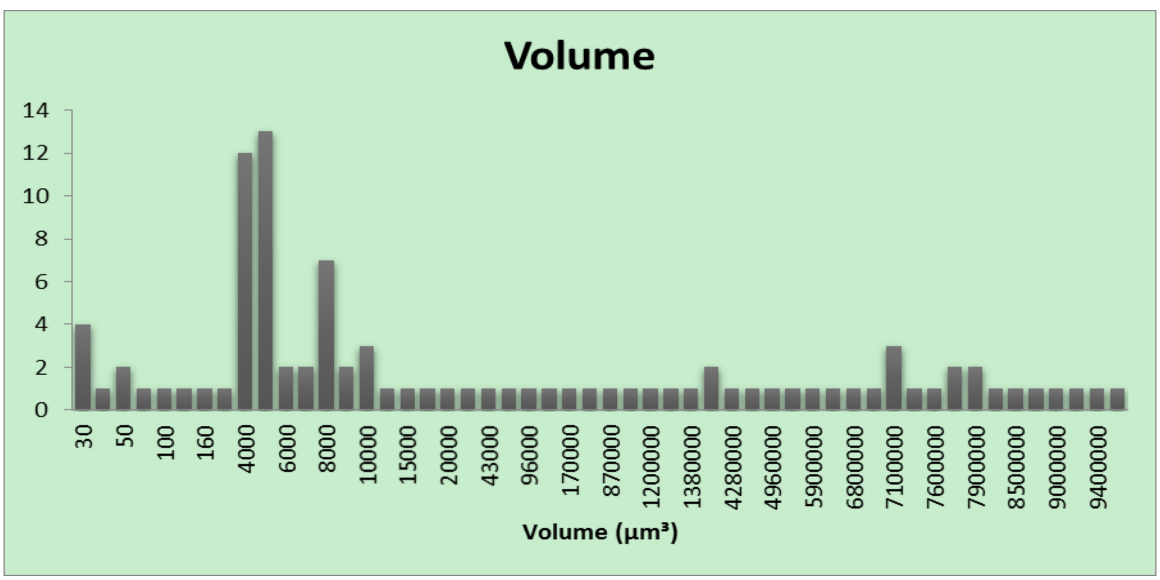
The pits can be quantified in numerous ways using built-in software tools as shown in the following figures as examples. It can be observed that ~55% of the pits have an open area size below 0.03 mm^2 and pit depth ranging from 60 to 90 µm. One quarter of the pits possess a volume of 4000-5000 µm^2. Such statistical information allows us to compare the pitting resistance of different materials and provide more insight in the mechanism of pit formation and development.






Depth
20
15
10
5
0
30
50
60
70
80
90
100
110
120
130
140
150
160
190
200
210
220
Depth (µm)


Perimeter
15
10
5
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.6
1.8
1.9
2.2
2.3
2.4
2.6
4.8
6.4
Perimeter (mm)


Volume
14
12
10
8
6
4
2
0
30
50
100
160
4000
6000
8000
10000
15000
20000
43000
96000
170000
870000
1200000
1380000
4280000
4960000
5900000
6800000
7100000
7600000
7900000
8500000
9000000
9400000
Volume (µm³)

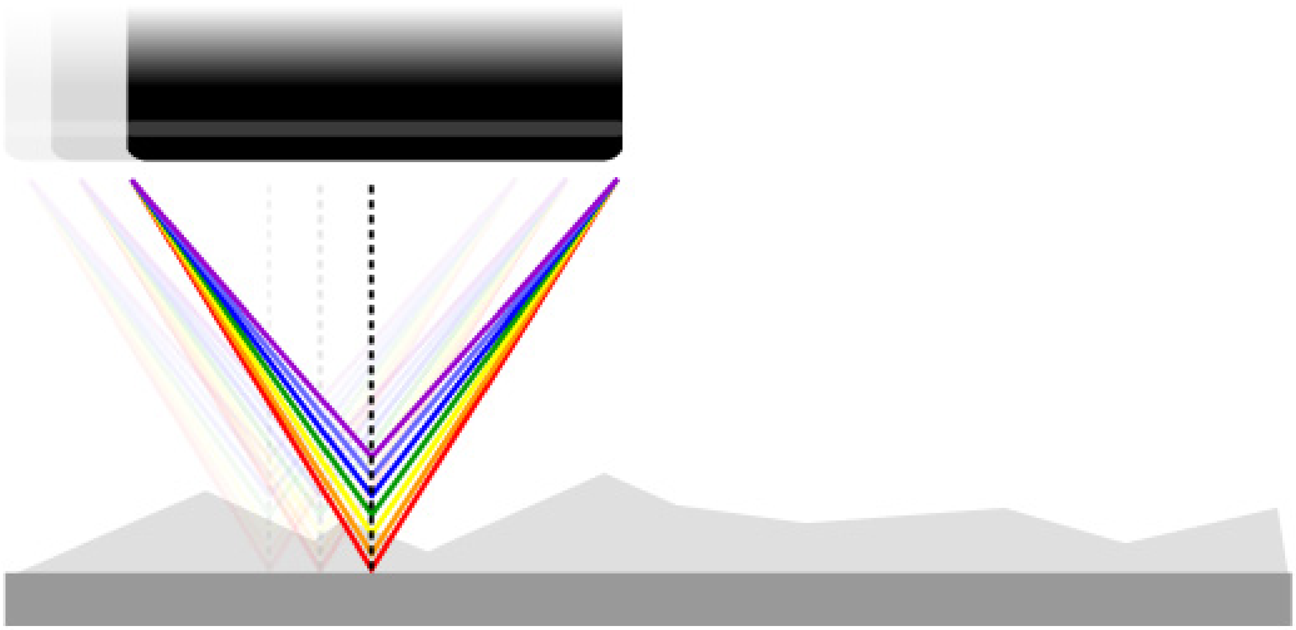
CONCLUSION:

In this application, we have shown how the Nanovea 3D Non Contact Profilometer can precisely characterize the corrosion pitted surface of stainless steel. The data shows a measurement of 95 pits found in the area measured with a density of 0.3110 pits/mm^2. The pit density, together with the statistical information such as the volume loss and pit size distribution generated by the software, could be used to compare the pitting resistance against other test coupons developed under different conditions. The data shown here represents only a portion of the calculations available in the analysis software, however this statistical data can be calculated over the entire surface measure, or each pit could be analyzed individually by selecting one pit.

Learn more about the Nanovea Profilometer or Lab Services

MEASUREMENT PRINCIPLE:

The Chromatic Confocal technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



Unlike the errors caused by probe contact or the manipulative Interferometry technique, Chromatic Confocal technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing.

Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent or opaque, specular or diffusive, polished or rough. Measurement includes: Profile Dimension, Roughness Finish Texture, Shape Form Topography, Flatness Warpage Planarity, Volume Area, Step-Height Depth Thickness and many others.

DEFINITION OF HEIGHT PARAMETERS

	Height Parameter	Definition
Sa	Arithmetical Mean Height	Mean surface roughness. $$Sa = \frac{1}{A} \iint_A \lvert z(x,y) \rvert dxdy$$
Sq	Root Mean Square Height	Standard deviation of the height distribution, or RMS surface roughness. $$Sq = \sqrt{\frac{1}{A} \iint_A z^2(x,y) dxdy}$$ Computes the standard deviation for the amplitudes of the surface (RMS).
Sp	Maximum Peak Height	Height between the highest peak and the mean plane.
Sv	Maximum Pit Height	Depth between the mean plane and the deepest valley.
Sz	Maximum Height	Height between the highest peak and the deepest valley.
Ssk	Skewness	Skewness of the height distribution. $$Ssk = \frac{1}{Sq^3} \left[\frac{1}{A} \iint_A z^3(x,y) dxdy \right]$$ Skewness qualifies the symmetry of the height distribution. A negative Ssk indicates that the surface is composed of mainly one plateau and deep and fine valleys. In this case, the distribution is sloping to the top. A positive Ssk indicates a surface with a lot of peaks on a plane. Therefore, the distribution is sloping to the bottom. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Sku	Kurtosis	Kurtosis of the height distribution. $$Sku = \frac{1}{Sq^4} \left[\frac{1}{A} \iint_A z^4(x,y) dxdy \right]$$ Kurtosis qualifies the flatness of the height distribution. Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.
Spar	Projected Area	Projected surface area.
Sdar	Developed Area	Developed surface area.