FRACTOGRAPHY ANALYSIS
USING 3D PROFILOMETRY

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INTRO:

Fractography is the study of features examined on fracture surfaces and has historically been investigated via Microscope or SEM. Microscope being used for macro scale analysis and SEM particularly when it is the nano or microstructure that is vital to the analysis. Both ultimately allowing for the identification of the fracture mechanism type. Although effective, the Microscope clearly has its limitations and the SEM in most cases, other than atomic level analysis, is unpractical for fracture surface measurement and lacks broad use. With advances in optical measurement technology, the 3D Non Contact Profilometer is now the instrument of choice, providing nano through macro scale 2d & 3D surface measurement.

IMPORTANCE OF 3D NON CONTACT PROFILOMETER FOR FRACTURE INSPECTION

Unlike an SEM, the 3D Non Contact Profilometer can measure nearly any surface, sample sizes can vary widely due to open staging, there is no sample preparation needed and horizontal and vertical dimensions are far superior to that of an SEM. Nano through macro range is obtained during measurement (Profile Dimension, Roughness Finish Texture, Shape Form Topography, Flatness Warpage, Volume Area, Step-Height Depth Thickness and others) and measurement has zero influence from sample reflectivity and has advanced ability to measure high surface angles. Easily measure any material: transparent, opaque, specular, diffusive, polished, rough etc. The 3D Non Contact Profilometer provides broad and user friendly capability to maximize surface fracture studies at a fraction of the cost of an SEM.

MEASUREMENT OBJECTIVE

In this application, the Nanovea ST400 is used to measure the surface fracture section of a steel sample. There is an endless list surface parameters that can be automatically calculated after the profile scan. Here we will show a 3D Profile, a 2D extraction and a surface directional map.
RESULTS:
TOP SURFACE

3D Profile of Top Surface.

2D Surface Extraction

3D Surface Direction Mapping

• Isotropy: 51.26% • First Direction: 123.2°
• Second Direction: 116.3° • Third Direction: 0.1725°

2D Surface Extraction Results

From this extraction Surface Area, Volume, Roughness and many others can be automatically calculated.
SIDE SURFACE

2D Surface Extraction Results

From this extraction Surface Area, Volume, Roughness and many others can be automatically calculated.
CONCLUSION:

In this application, we have shown how the Nanovea ST400 3D Non Contact Profilometer can precisely characterize both the topography and the nanometer details of a fracture surface. From the 3D profile the surface can be clearly identified and areas of interest can then be quickly analyzed with an endless list of surface calculations. To further view in detail a 2D cross section can quickly be chosen to analyze, at nanometer range. With this information surface fracture areas can be broadly investigated with a complete set of surface measurement resources. Special areas of interest could have been further analyzed with integrated AFM module. Additionally, Nanovea has included a portable version to their Profilometer line-up, especially critical for field studies where a fracture surface is immovable. With this broad list of surface measurement capability, fracture surface analysis has never been easier, friendlier or as thorough with a single instrument.
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

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<th>Height Parameter</th>
<th>Definition</th>
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| Sa | Arithmetical Mean Height | Mean surface roughness.  
\[
Sa = \frac{1}{A} \iint_A |z(x, y)| \, dx \, dy 
\] |
| Sq | Root Mean Square Height | Standard deviation of the height distribution, or RMS surface roughness.  
\[
Sq = \frac{1}{\sqrt{A}} \iint_A z^2(x, y) \, dx \, dy 
\]  
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.  
\[
Ssk = \frac{1}{Sq^3} \left[ \frac{1}{A} \iint_A z^3(x, y) \, dx \, dy \right] 
\]  
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.  
\[
Sku = \frac{1}{Sq^4} \left[ \frac{1}{A} \iint_A z^4(x, y) \, dx \, dy \right] 
\]  
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. |

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