

**CONTOUR ANALYSIS OF A WORN GEAR
USING 3D PROFILOMETRY**



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INTRO

A gear is a rotating machine part that transmits torque by meshing with another toothed part. It is a key mechanical component widely used in a variety of industrial applications, such as automobile, machinery and many others. In order to effectively change the speed, torque, and direction of a power source, the gears possess several shapes to achieve different drive mechanisms, including but not limited to spur gears, helical gears, skew gears, bevel gears, hypoid gears, crown gears and worm gears.

IMPORTANCE OF 3D NON-CONTACT PROFILOMETER FOR GEAR INSPECTION

Manufacturing of high precision gears requires stringent quality control, in order to obtain the best operational conditions and energy efficiency. Surface defects on the gears may lead to negative impact on the gear mesh quality. Moreover, during the service time, wear and tear takes places, creating surface defects such as dents and cracks in the gears that may result in decreased power transmission efficiency and potential mechanical failure. An accurate and quantifiable tool for surface inspection is in need. Unlike a touch probe technique, the Nanovea Profilometer performs 3D surface measurement of the sample without touching, making it possible to precisely scan samples with a complex shape, such as gears of different geometry.

MEASUREMENT OBJECTIVE

In this application, the Nanovea ST400 is used to perform a contour analysis on a worn gear. We showcases the capacity of Nanovea non-contact profilometer in providing comprehensive 3D profile analysis of failed mechanical parts.

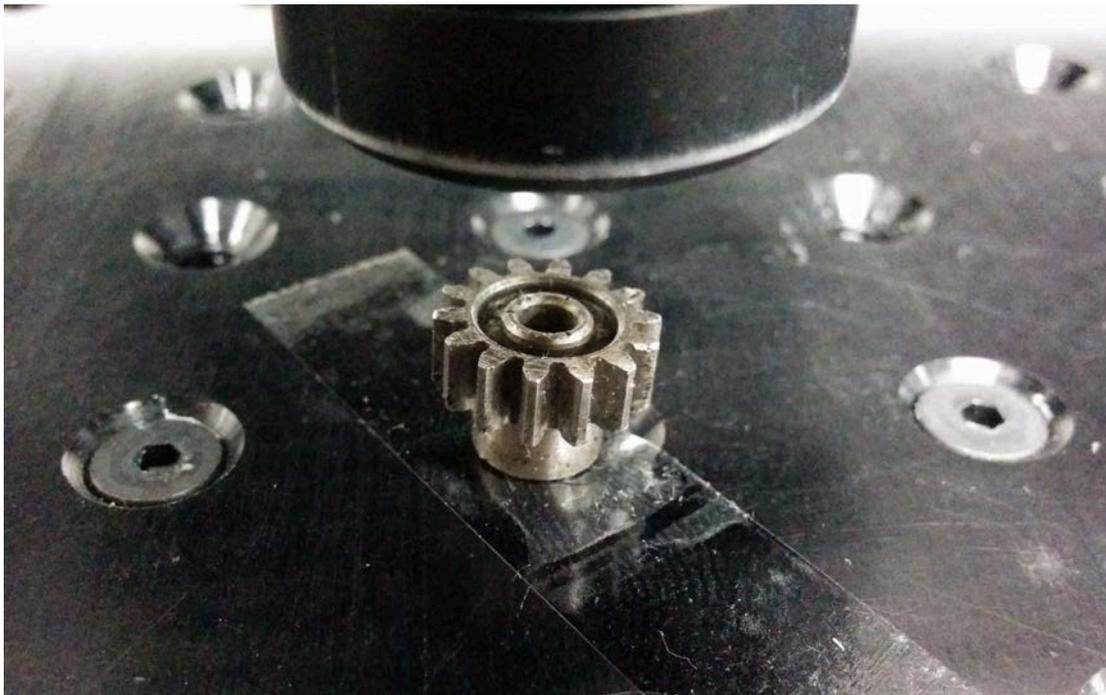


Fig. 1: Optical sensor scanning on the surface of a worn gear sample

RESULTS AND DISCUSSION

The false color view of the gear sample surface is shown in Fig. 2. The height variation and machined patterns on the top surface of the sample can be observed by the change of color. The gear consists of two sections: a center ring and the outer cogs.

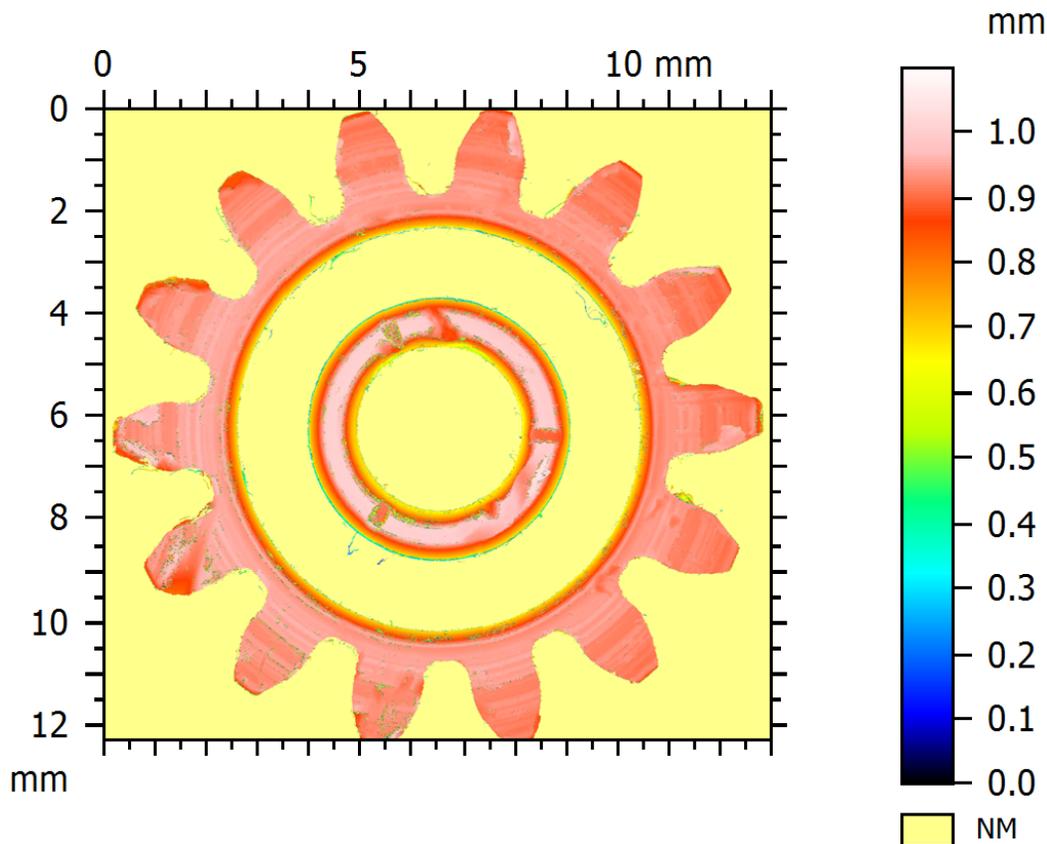


Fig. 2: False color view of the gear sample.

The contour analysis of the worn gear is presented in Fig. 3. It shows that the inner ring possesses a radius of 2.56 mm. The outer cogs have been deformed and worn after long term wear and tear during the service period. The tip (top land) of the teeth have a distance of 6.35 mm to the center of the gear. The shape of a tooth on the right of Fig. 3 were altered – the angle between two shoulder face is changed from above 50° to 43.4° . By setting up a tolerance limit value, the analysis software can automatically determine which and how many cogs have been worn out, allowing users to make a quick and accurate decision whether to replace the gear.

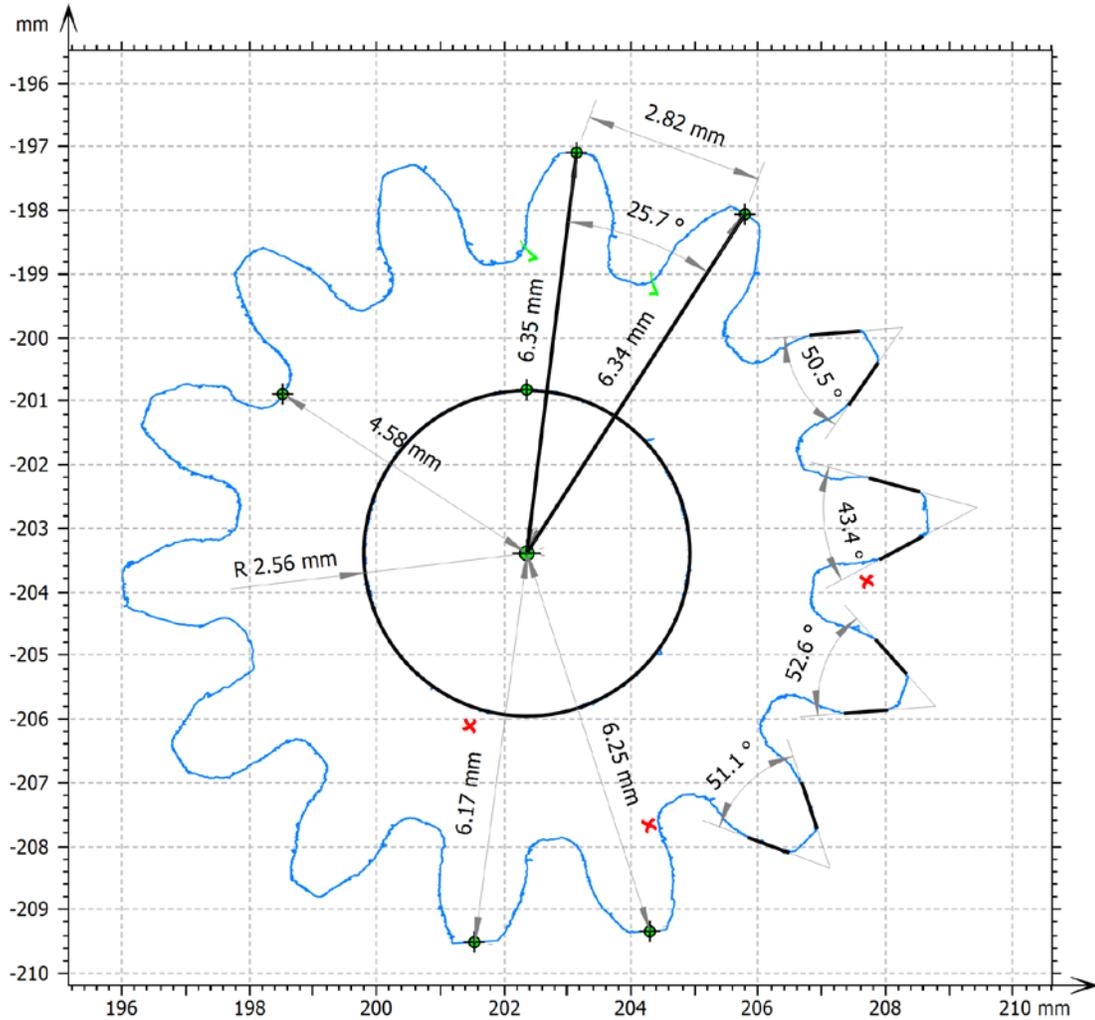


Fig. 3: Contour analysis of the worn gear sample.

The roughness and uniformity of the gear surface play an important role in ensuring its quality and functionality. The 3D non-contact surface scan determines the surface finish quality with high precision. Fig. 4 presents the surface morphology of the gear sample at a high magnification. The surface roughness values are calculated and summarized in Table 1.

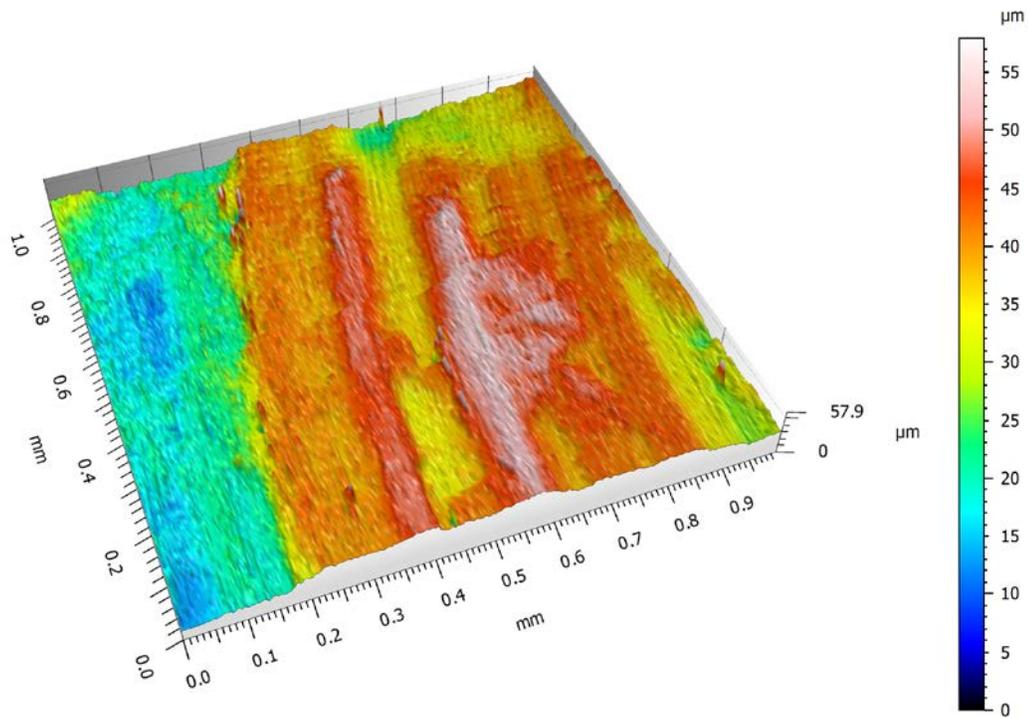


Fig. 4: Surface finish of the gear sample at a higher magnification.

ISO 25178			
Height Parameters			
Sq	10.5	μm	<i>Root-mean-square height</i>
Ssk	-0.576		<i>Skewness</i>
Sku	2.41		<i>Kurtosis</i>
Sp	22.5	μm	<i>Maximum peak height</i>
Sv	35.4	μm	<i>Maximum pit height</i>
Sz	57.9	μm	<i>Maximum height</i>
Sa	8.73	μm	<i>Arithmetic mean height</i>

Table 1: Summary of the roughness values.

CONCLUSION

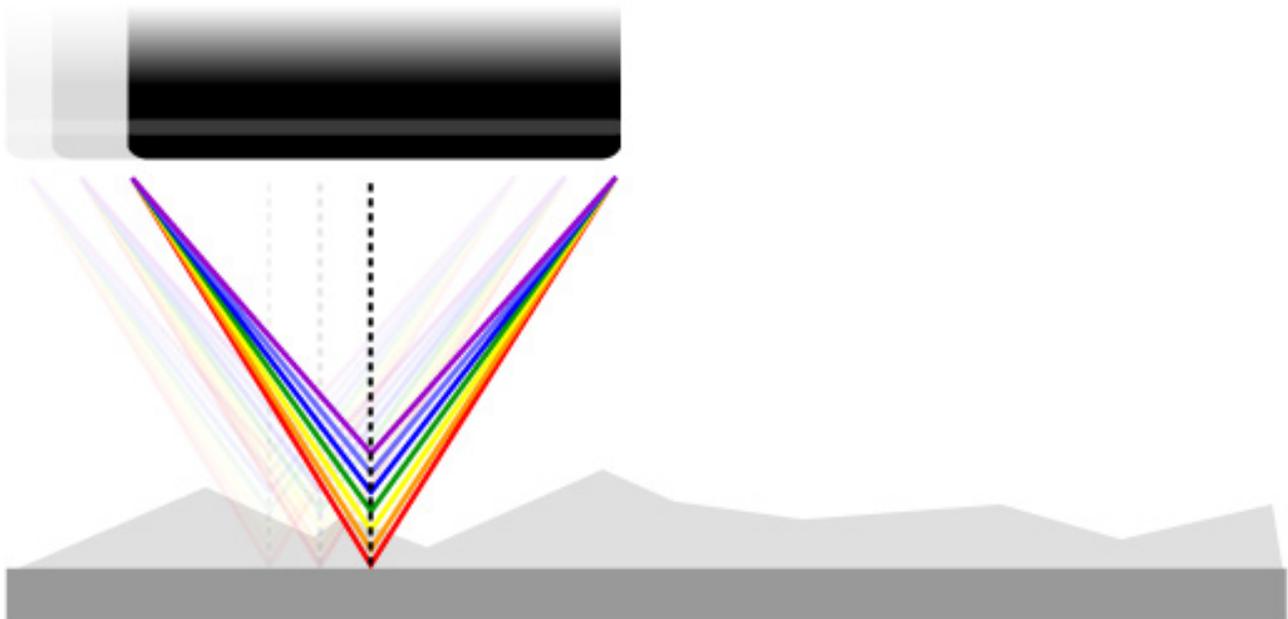
In this application, we have showcased that the Nanovea ST400 3D Non-Contact Profilometer performs surface contour analysis on a worn gear sample. The capacity of high resolution scan enables users to measure the detailed morphology and tiny surface features. Moreover, it can pick up any undesired defects including chipping or cracks on the gear surface. The detailed contour analysis provides a useful tool to determine whether the new mechanical parts fall in line with manufacture specifications, and to evaluate the failure mechanism of the worn components.

The data shown here represents only a portion of the calculations available in the analysis software. Nanovea Profilometers measure virtually any surface in fields including Semiconductor, Microelectronics, Solar, Fiber Optics, Automotive, Aerospace, Metallurgy, Machining, Coatings, Pharmaceutical, Biomedical, Environmental and many others.

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. $Sa = \frac{1}{A} \iint_A z(x, y) dx dy$
Sq	Root Mean Square Height	Standard deviation of the height distribution, or RMS surface roughness. $Sq = \sqrt{\frac{1}{A} \iint_A z^2(x, y) dx dy}$ <p>Computes the standard deviation for the amplitudes of the surface (RMS).</p>
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. $Ssk = \frac{1}{Sq^3} \left[\frac{1}{A} \iint_A z^3(x, y) dx dy \right]$ <p>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.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>
Sku	Kurtosis	Kurtosis of the height distribution. $Sku = \frac{1}{Sq^4} \left[\frac{1}{A} \iint_A z^4(x, y) dx dy \right]$ <p>Kurtosis qualifies the flatness of the height distribution.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>
Spar	Projected Area	Projected surface area.
Sdar	Developed Area	Developed surface area.