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COMPOSITE MATERIAL ANALYSIS

USING

3D PROFILOMETRY

Prepared by

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Introduction

Composite materials are commonly made of woven fibers (carbon or glass) and matrix (epoxy). These materials provide strong material properties of both the fibers and matrix. Carbon fiber and fiberglass composites are commonly used in many industries as a light, strong, and moldable material to provide rigidity to structures and aerodynamic parts.

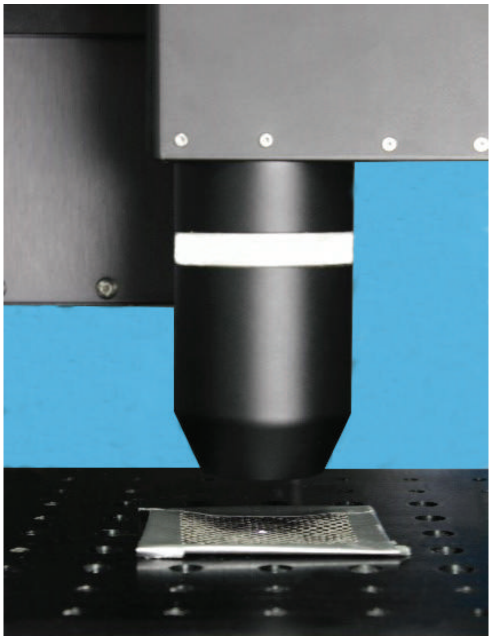
Importance of Non-Contact Profilometry for Composite Materials

It is crucial defects are minimized so composite materials are as strong as possible in reinforcement applications. As an anisotropic material, it is critical weave direction is consistent to maintain high performance predictability. Composite materials have one of the highest strength to weight ratios making it stronger than steel in some cases. It is important to limit exposed surface area in composites to minimize chemical vulnerability and thermal expansion effects. Profilometry surface inspection is critical to quality control production of composites to ensure strong performance over a long service time.

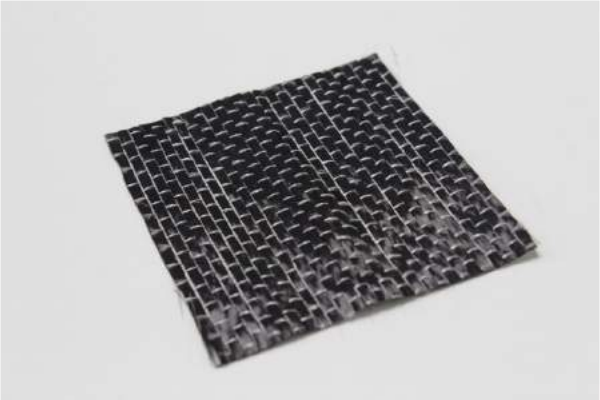
Nanovea's 3D Non-Contact Profilometer is unlike other surface measurement techniques such as touch probes or interferometry. Our profilometers use axial chromatism to measure nearly any surface and open staging allows for samples of any size with no preparation needed. Nano through macro measurements are obtained during surface profile measurement with zero influence from sample reflectivity or absorption. Our profilometers easily measure any material: transparent, opaque, specular, diffusive, polished, and rough with the advanced ability to measure high surface angles with no software manipulation. The Non-Contact Profilometer technique provides the ideal and user-friendly capability to maximize composite material surface studies; along with the benefits of combined 2D & 3D capability.

MEASUREMENT OBJECTIVE

The Nanovea HS2000L Profilometer used in this application measured the surface of two weaves of carbon fiber composites. Surface roughness, weave length, isotropy, fractal analysis, and other surface parameters are used to characterize the composites. The area measured was randomly selected and assumed large enough that property values can be compared using Nanovea's powerful surface analysis software.



Carbon fiber sample being analyzed by the HS2000L profiler.

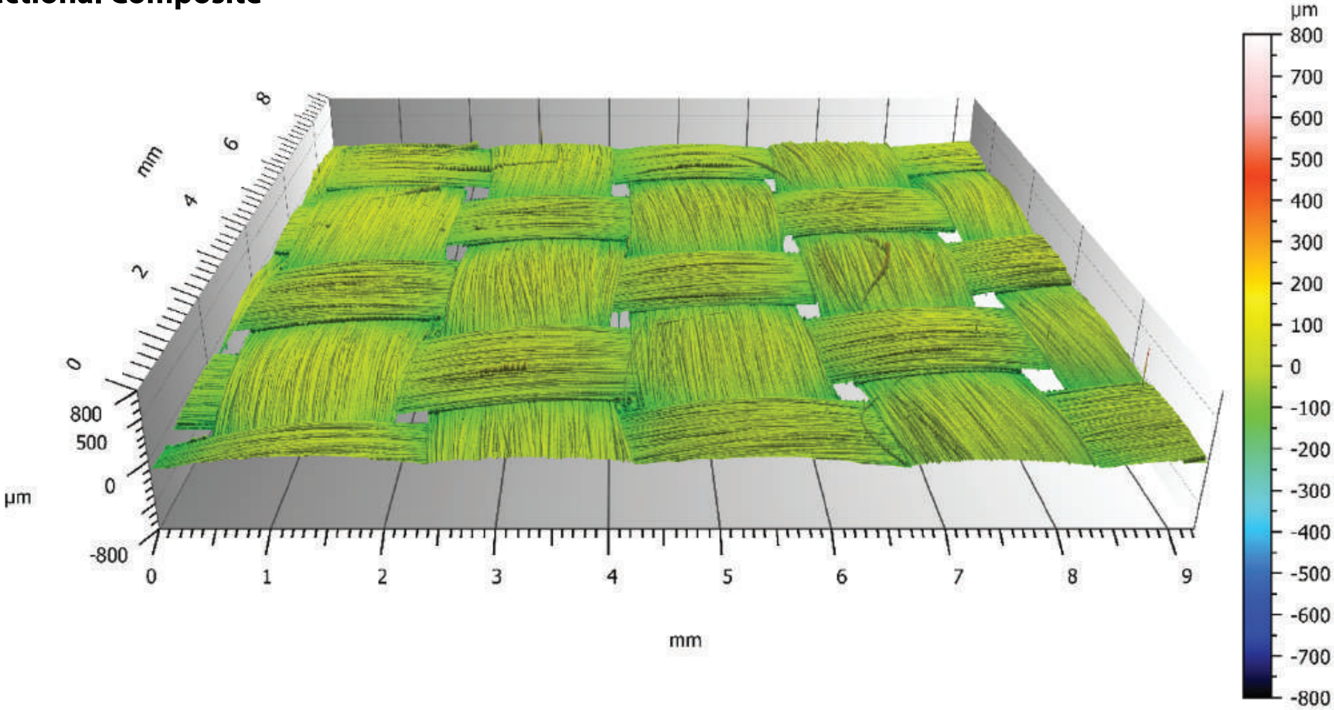


Images of Bidirectional (left) and Unidirectional (right) carbon fiber samples.

RESULTS AND DISCUSSION

Surface Analysis

Bidirectional Composite



Unidirectional Composite

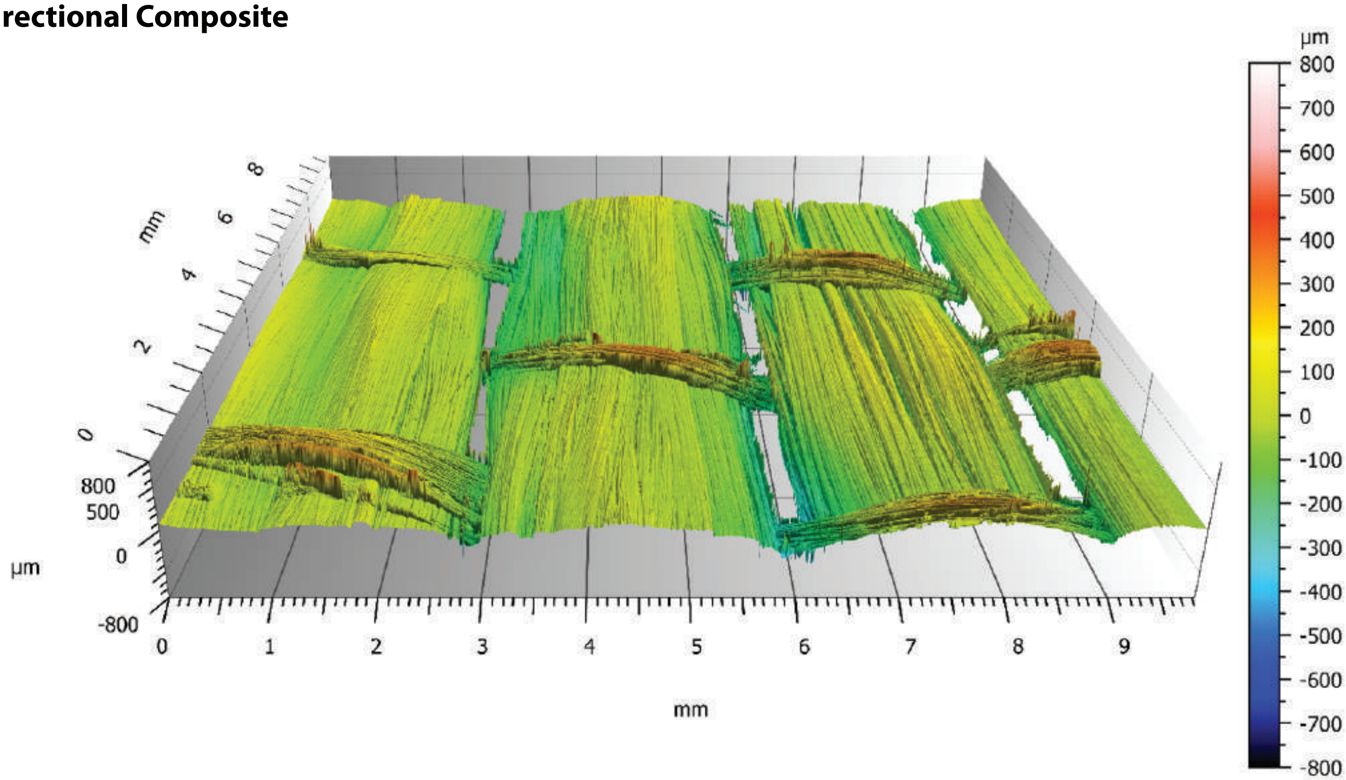
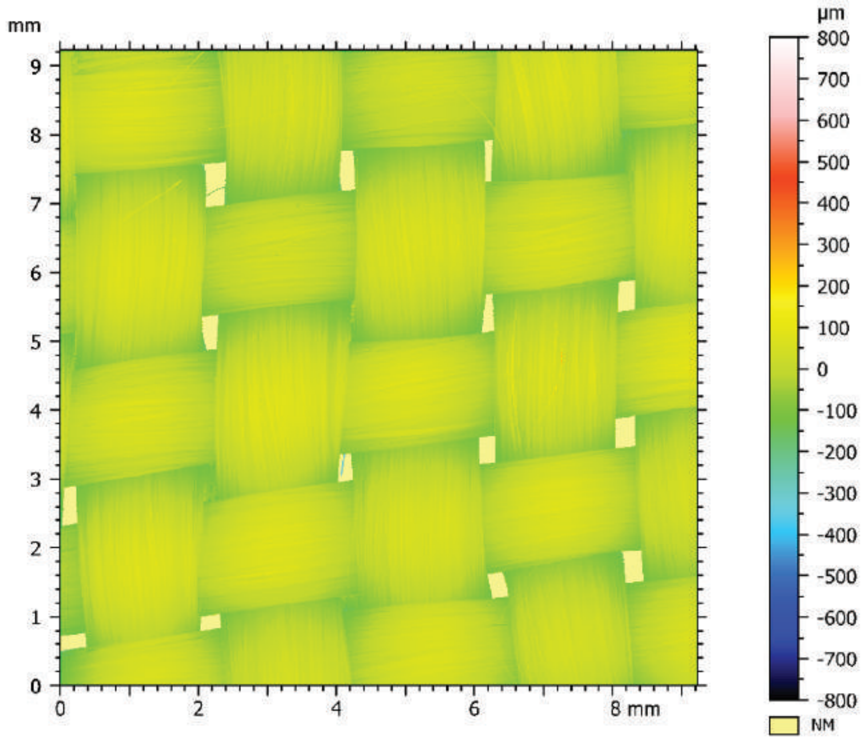


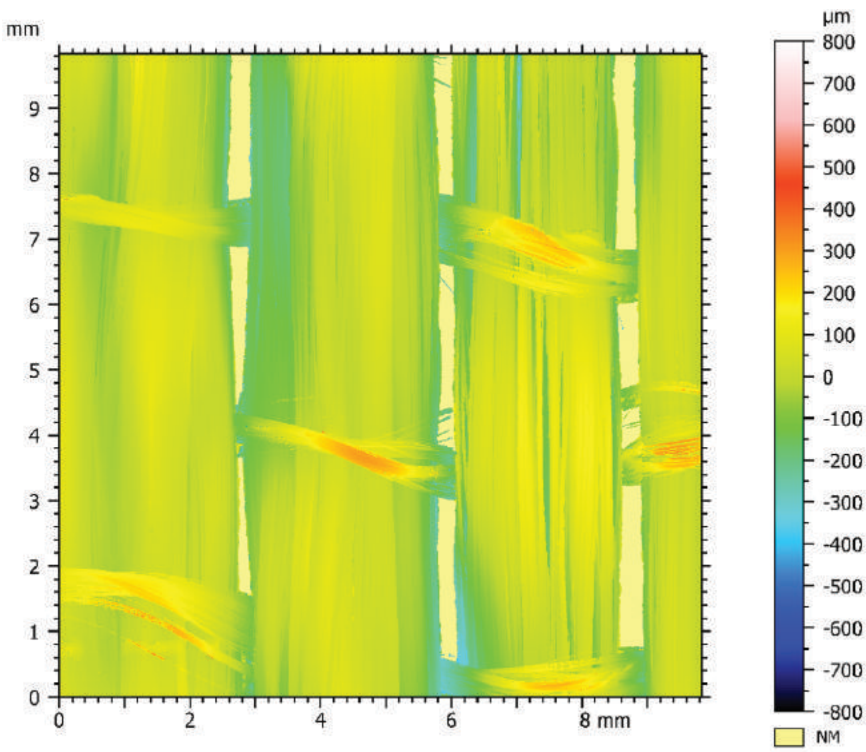
Figure 1: 3D views of the carbon fiber samples.

Bidirectional Composite



ISO 25178		
Height Parameters		
Sa	34.37	µm
Sq	42.07	µm
Sp	545.6	µm
Sv	421.7	µm
Sz	967.3	µm
Ssk	-0.4699	
Sku	3.229	
Other 3D Parameters		
Miscellaneous		
Spar	85.19	mm²

Unidirectional Composite



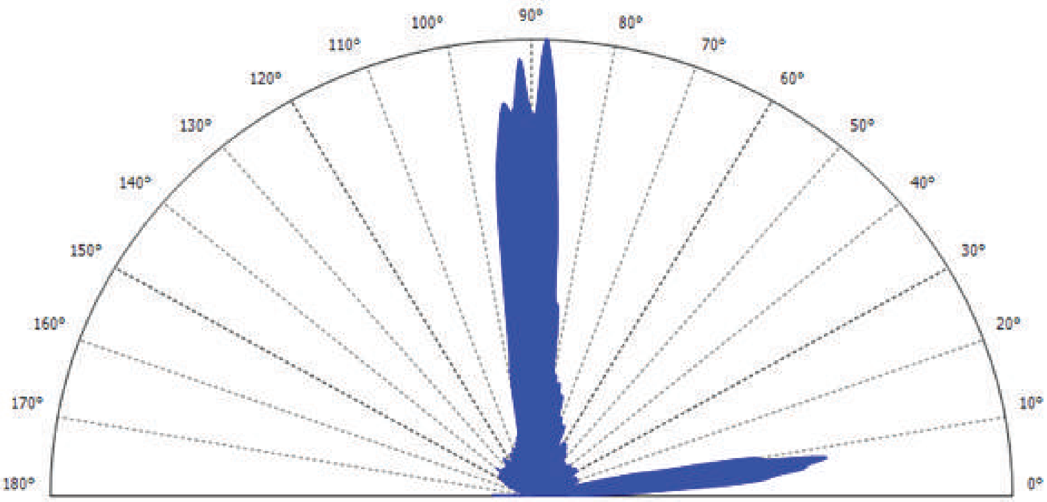
ISO 25178		
Height Parameters		
Sa	59.43	µm
Sq	80.62	µm
Sp	636.8	µm
Sv	719.0	µm
Sz	1356	µm
Ssk	-0.36	
Sku	4.377	
Other 3D Parameters		
Miscellaneous		
Spar	96.63	mm²

Figure 2: 2D view of the carbon fiber samples with height parameters.

Height parameters determine how rough composite parts will be with a low fiber to matrix ratio. Our results compare different weave types and fabric to determine surface finish post processing. Surface finish becomes critical in applications where aerodynamics may become involved.

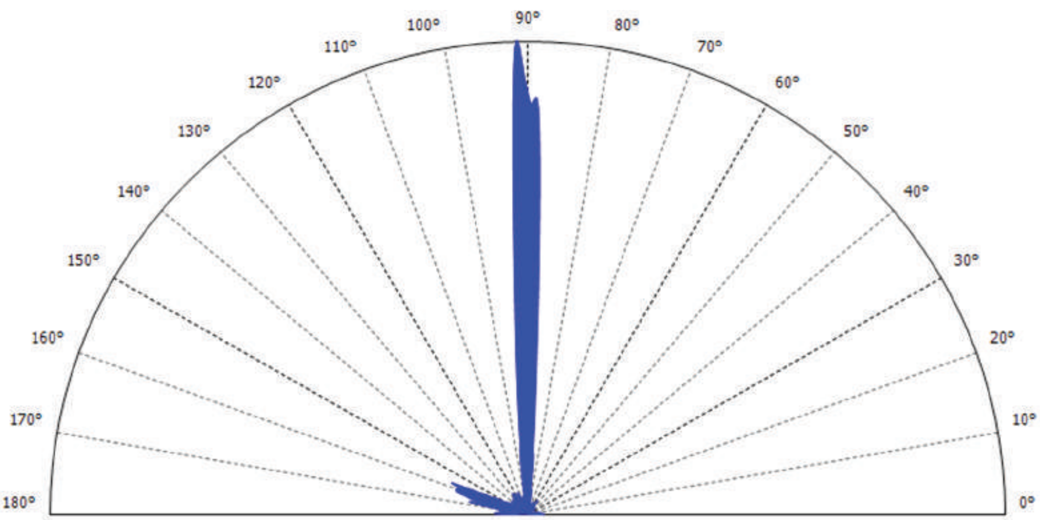
Isotropy

Bidirectional Composite



Parameters	Value
Isotropy	59.96%
First Direction	88.24°
Second Direction	93.75°

Unidirectional Composite



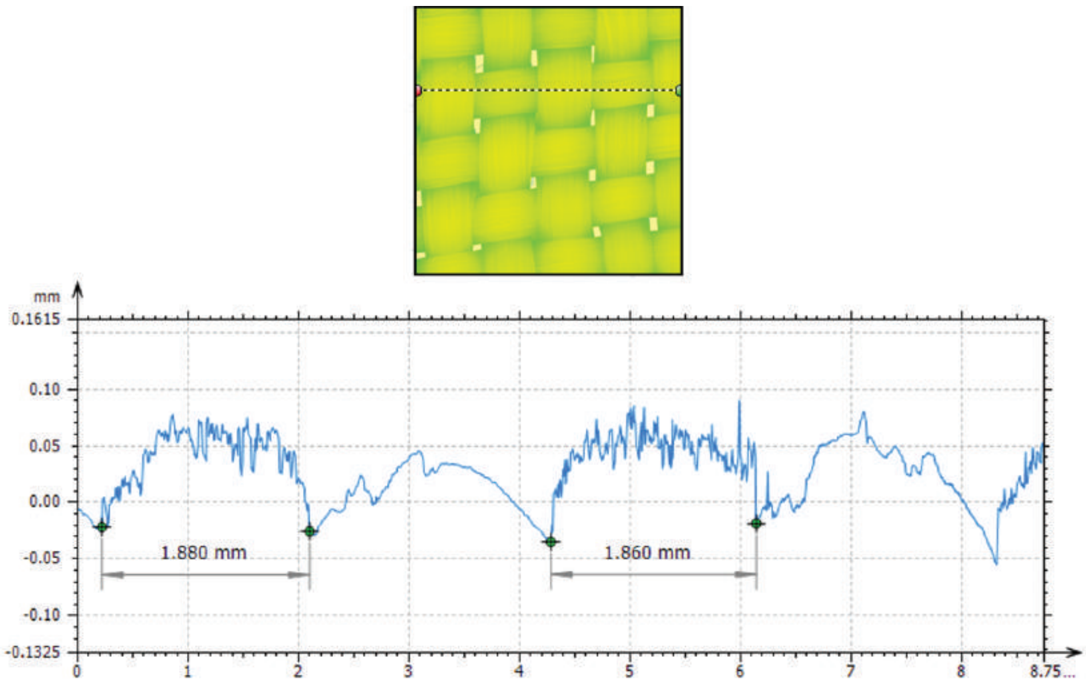
Parameters	12.83%
Isotropy	91.24°
First Direction	157.3°
Second Direction	

Figure 3: Isotropy charts of carbon fiber scans showing directionality of fibers.

Isotropy shows directionality of the weave to determine expected property values. Our study shows how the bidirectional composite is ~60% isotropic as expected. Meanwhile, the unidirectional composite is ~13% isotropic due to the strong single fiber path direction fiber.

Weave Analysis

Bidirectional Composite



Unidirectional Composite

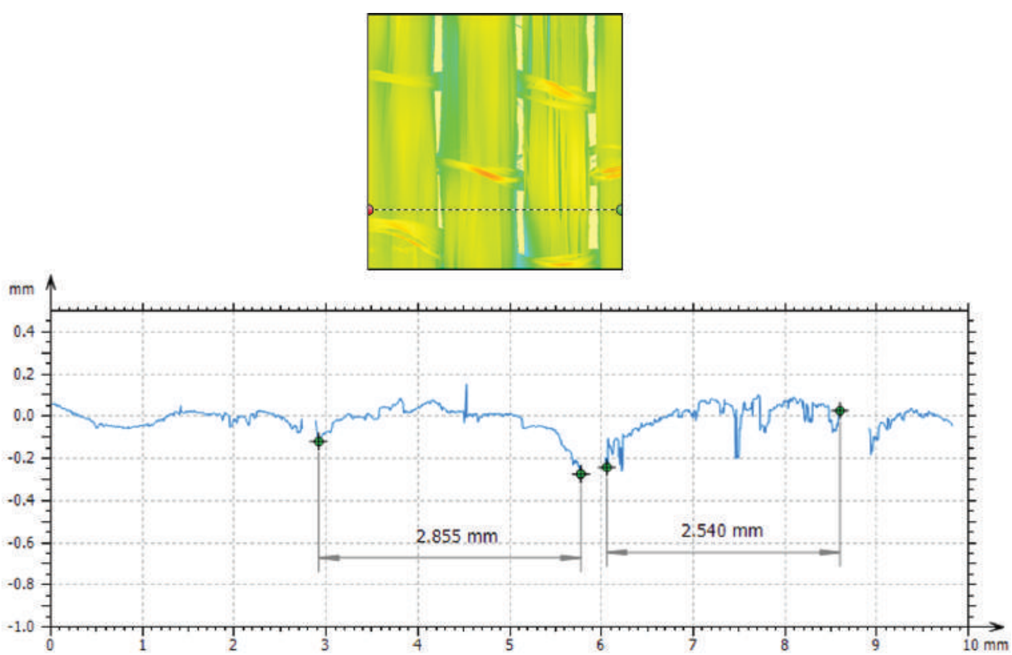
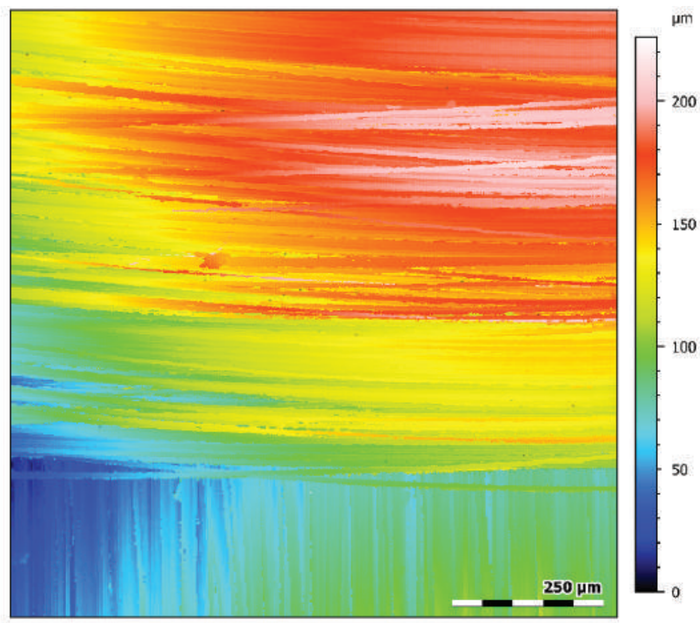


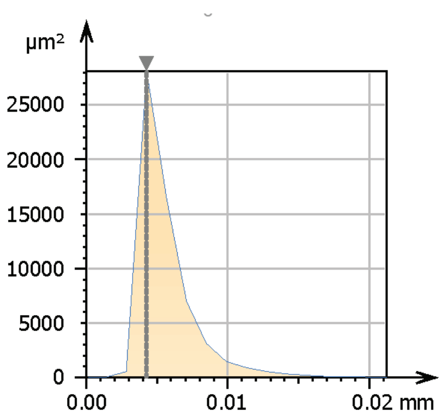
Figure 4: Distance measurement comparison of the samples.

Weave size determines the consistency of packing and width of fibers used in the composite. Our study shows how easily we can measure weave size down to micron accuracy to ensure quality parts.

Texture Analysis

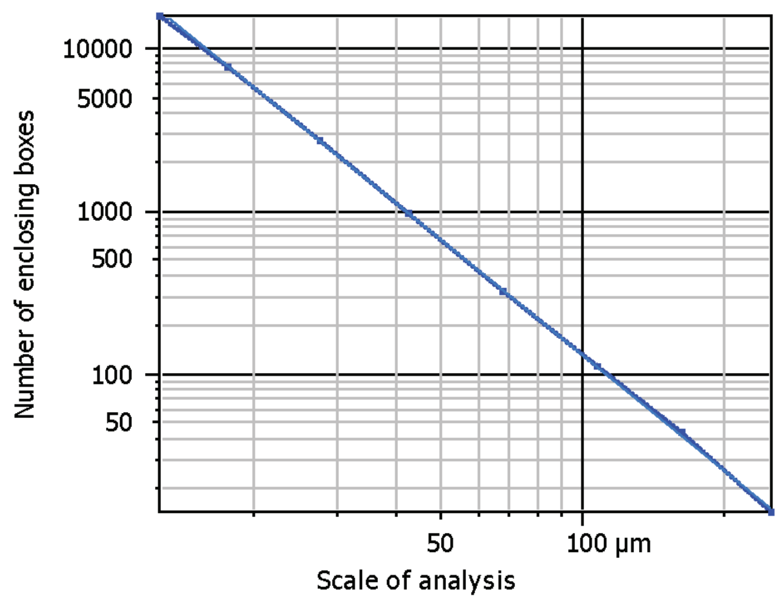
Bidirectional Composite





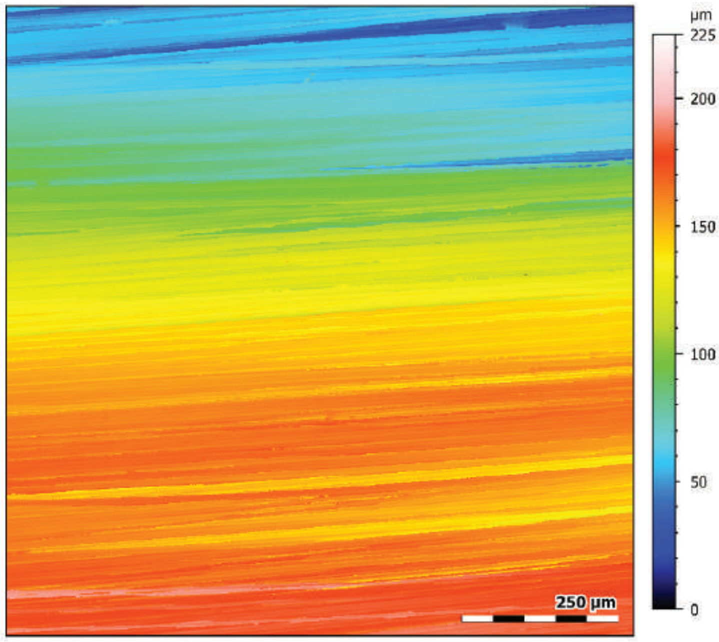
Information	
Zoom factor	x64
Smoothing	None

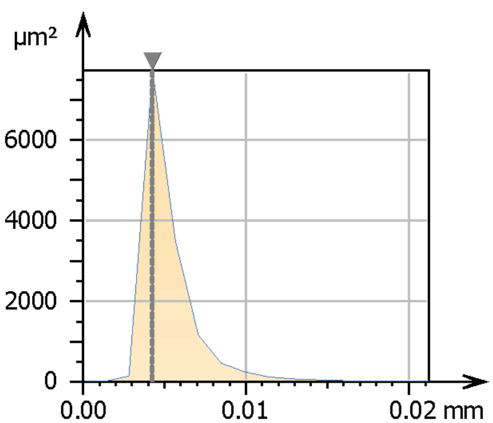
Parameters		
Wave	0.004247	mm
Amplitude	167.6	µm
Dominant wavelength	0.004247	mm
Maximum amplitude	167.6	µm



Parameters	Value
Fractal dimension	2.519

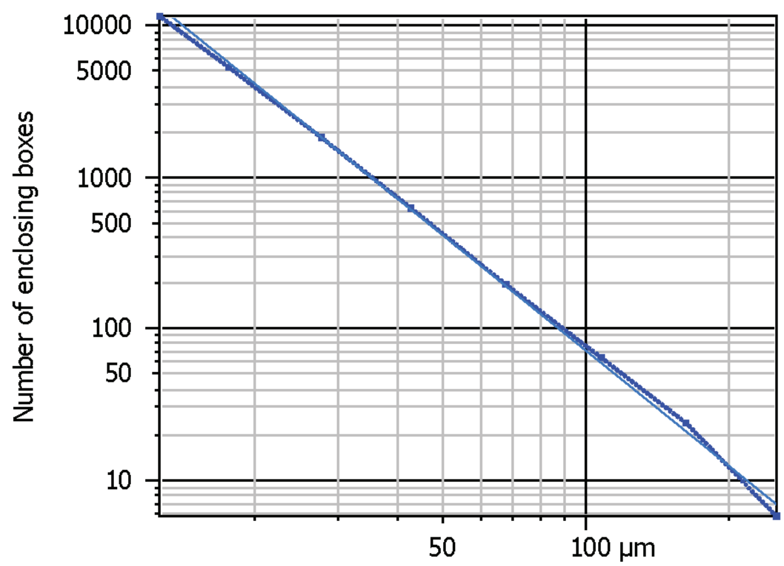
Unidirectional Composite





Information	
Zoom factor	x64
Smoothing	None

Parameters		
Wave	0.004247	mm
Amplitude	87.90	µm
Dominant wavelength	0.004247	mm
Maximum amplitude	87.90	µm



Parameters	Value
Fractal dimension	2.519

Figure 5: Fractal Analysis of the weave types.

Texture analysis of the dominant wavelength suggests strand size for both composites are 4.27 microns thick. Fractal dimension analysis of the fiber surface determines smoothness to find how easily fibers will set in a matrix. The fractal dimension of the unidirectional fiber is higher than the bidirectional fiber which may affect the processing of composites.

Conclusion

In this application, we have shown the Nanovea HS2000L Non-Contact Profilometer precisely characterizes the fibrous surface of composite materials. We distinguished differences between weave types of carbon fiber with height parameters, isotropy, texture analysis, and distance measurements along with much more.

Our profilometer surface measurements precisely and quickly mitigate composite damage which decreases defects in parts, maximizing composite material capability. Nanovea's 3D profilometer speed ranges from <1mm/s to 500mm/s for suitability in research applications to the needs of high-speed inspection. The Nanovea profilometer is the solution to any composite measurement need.

Learn more about the Nanovea Profilometer or Laboratory Services.