Application Note
for Industry

Inspecting Hard-to-Reach Surfaces

with NOVACAM™ Non-Contact 3D Metrology Systems

Keywords: 3D measurements, non-contact, automated non-destructive inspection, NDT, dies, bores, tubes, crevices, aerospace, automotive, alternative to silicone replicas.

Introduction

For high-precision measurements in tight spaces, NOVACAM 3D metrology systems based on low-coherence interferometry (LCI) are rapidly gaining in popularity in many sectors. For good reasons. They offer:

- Small-diameter non-contact probes that reach into hard-to-reach spaces
- Micron-precision 3D measurements
- Measurements of high-aspect-ratio features such as threads, undercuts, or grooves
- Support for automation
- Versatility for integration with robots, various stages, or online inspection stations.

No More Need for Replication - Use Small Probes Instead!

Traditionally, many hard-to-reach surfaces have been measured by taking a mold by replication and bringing the replica under a microscope. For example, silicone rubber-based replicas are used to measure defects in inaccessible surfaces in aircraft structures. Although simple to execute, this method is time-consuming, labour intensive, and practical only for inspecting small areas.

Today, such tight spaces can be measured in a direct and automated manner - with NOVACAM 3D metrology systems for tight spaces – the **BOREINSPECT** and **TUBEINSPECT systems**. While both systems use small non-contact fiber-based probes with diameters down to 0.5 mm, their designs make them ideal for different applications:

Bores or crevices in objects that are fixed in place are best measured with NOVACAM **BOREINSPECT™ system**, which scans inside diameters with a rotational side-looking probe. Figures 1 and 2 show an application example.

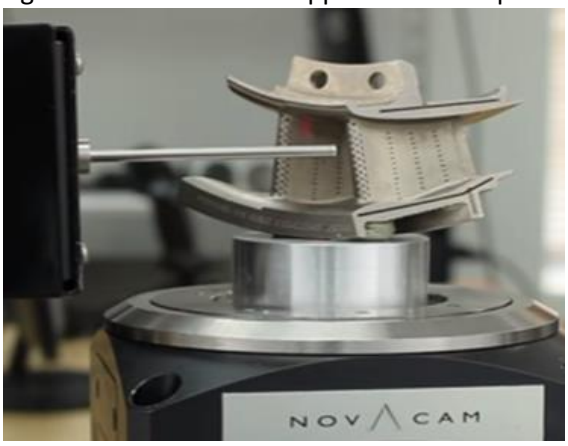


Figure 1: The rotational scanner of Novacam BOREINSPECT 3D metrology system spins and advances a probe as it acquires the throat area of a stator blade.

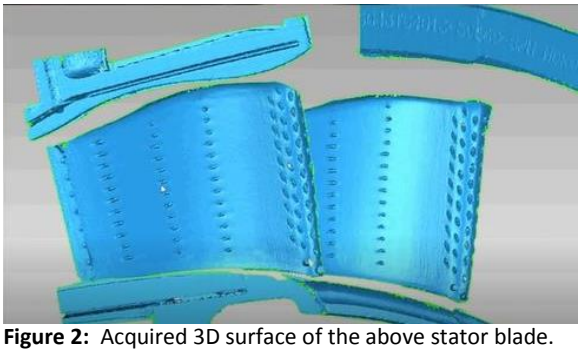


Figure 2: Acquired 3D surface of the above stator blade. Cooling holes and EDM slots inside and outside are characterized down to the micron. Blades can be inspected for wear and defects to ensure required standards are met.

Tubes or cylinders that can be placed on a rotational stage, can be measured both with the above BOREINSPECT system as well as the

TUBEINSPECT™ system, which rotates the measured tube or cylinder while advancing a side-looking probe along the inside and/or outside wall. Figure 3 shows a typical TUBEINSPECT system setup.

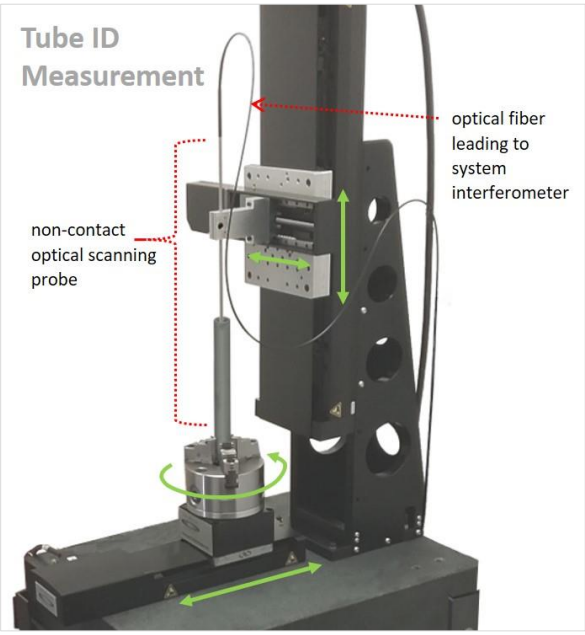


Figure 3: NOVACAM TUBEINSPECT system with a 4-axis inspection station measuring the inside of a barrel.

Both systems acquire measurements along a linear, circular, or spiral path, in a point-by-point manner, at up to 100 000 3D points (measurements) per second.

What's the Technology?

NOVACAM 3D metrology systems are fiber-based, modular, and based on low-coherence interferometry (LCI). The central component of each system is NOVACAM MICROCAM™-3D/4D interferometer. The interferometer produces and sends (via an optical fiber) a light signal to an optical probe, which directs the light at the inspected surface and sends the reflected optical signal back to the interferometer for processing. The PC is used for automatic analysis, logging, reporting and user display.

Scanning is collinear, which means that high-aspect-ratio features on the IDs, such as O-ring grooves, can be reliably characterized.

Types of Measurements Obtained

From the acquired 3D point cloud, GD&T software can extract measurements of:

- **3D geometry parameters** (straightness, cylindricity, conicity, ovality, taper, distortion, runout, lobing, angles, etc.),
- **chatter,**
- **roughness,**
- **defects**, and
- **thickness.**

Each area scan also concurrently gives a **height image** and an **intensity image** (shown in Figure 4), both of which facilitate automated defect identification and measurement.

Since light can penetrate semi-transparent materials, coating or film **thickness measurements** may also be derived from the same scan.

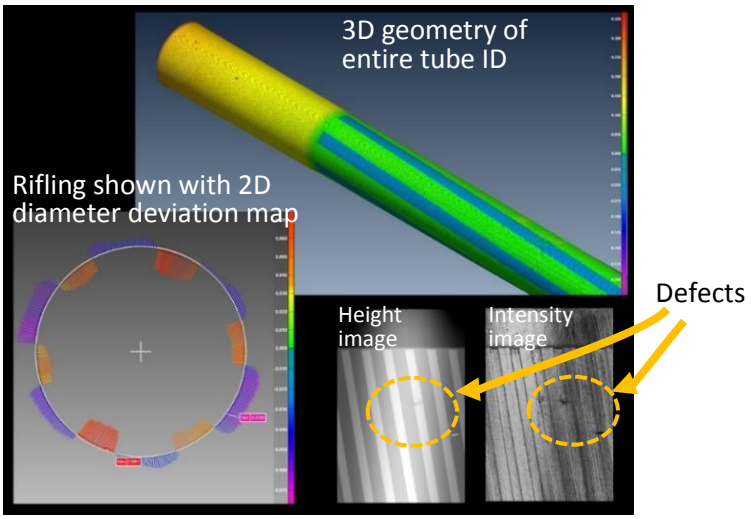
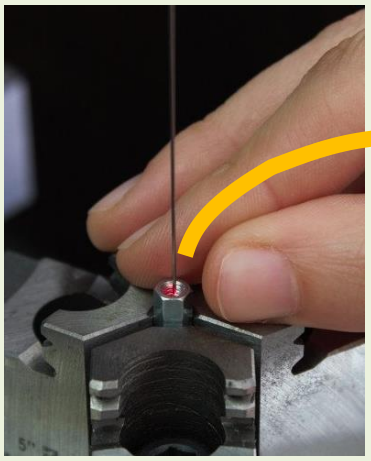


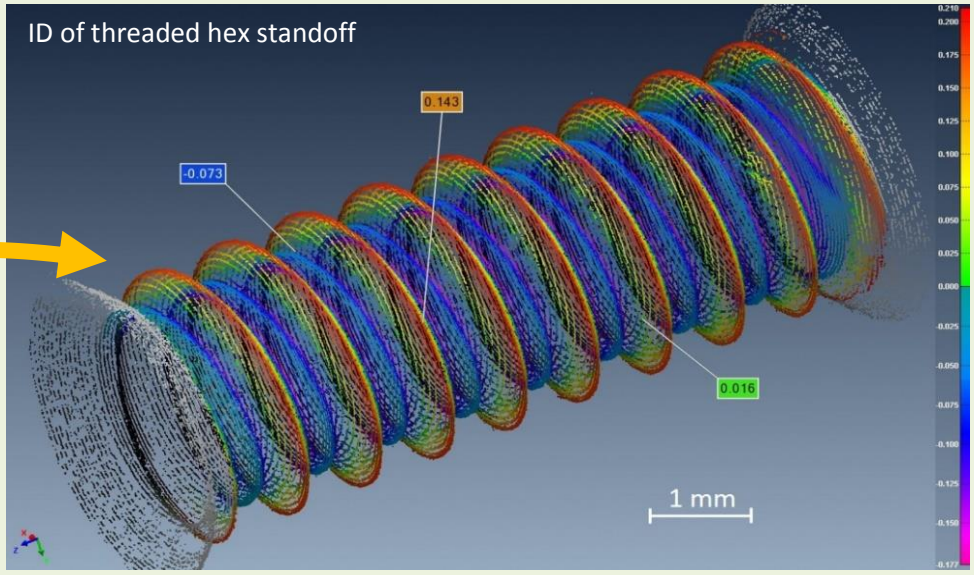
Figure 4: Rifle barrel (length ≈ 460 mm (19"), ID ≈ 5.6 mm (0.22") acquired with TUEINSPECT system. Unwrapped height and light intensity images of the barrel ID show defects.

Measure Tubes and Bores of All Sizes

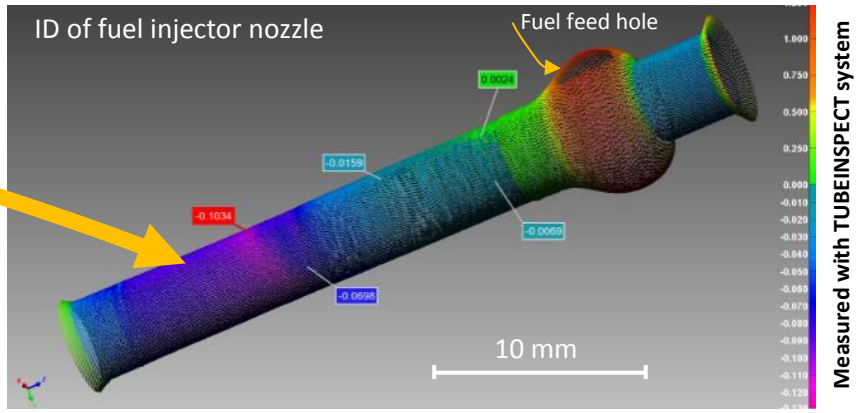
High-precision 3D measurements of tubes, bores, barrels, shafts, valves, nozzles, and other cylindrical or conical shapes provide manufacturers with unprecedented amount of data and process insight. The next page shows several application examples.

Threaded hex standoff #4-40
length = 6.35 mm (0.250”)
minor diameter ID ≈ 2.1 mm (0.08“)

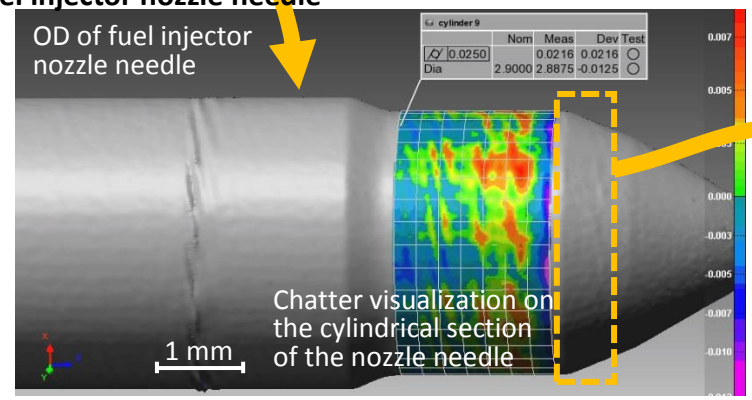


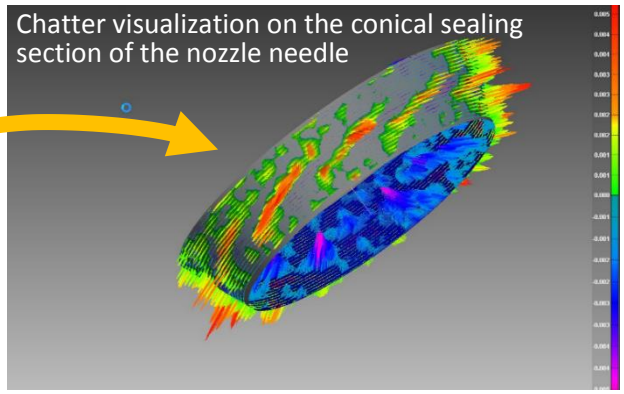


Fuel injector nozzle
length = 36 mm (1.41”)
entrance diameter ≈ 4.04 mm (0.159”)

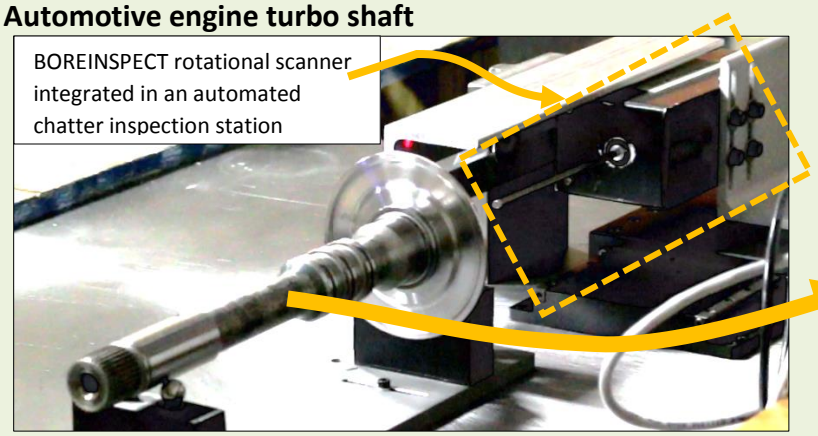


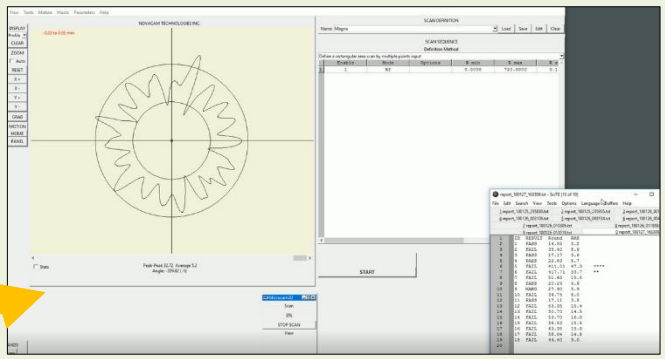
Fuel injector nozzle needle





Automotive engine turbo shaft





Turbo shaft ID chatter visualization and automated “Pass/Fail” analysis

Measured with BOREINSPECT system

Versatility & Support for Automation

Automated measurements right on the manufacture floor help manufacturers reduce scrap and production line down-time, improve quality and yield, and bring significant overall savings.

NOVACAM 3D metrology systems support shop-floor measurement automation; they are modular and their fiber-based probes are easily integrated with precision stages, robot arms, and gantries, as well as within CMM and CNC machines. Automation is also supported through capabilities such as datum alignment, automated pass/fail reporting, and exportable reports. Measurements may be automatically evaluated with respect to user-defined criteria (GD&T, feature specifications, roughness, and defect inspection) or compared to reference CAD models. An API for the systems is available.

System Characteristics and Capabilities

Light bandwidth: Broadband light
Wavelength: 1,310 nm
Acquisition rate: Up to 100,000 3D points per second
Axial resolution: < 1 µm
Lateral resolution: 4-75 µm (depending on the probe used)
Depth range scanned: < 7 mm
Standoff distance: From 0.5 mm to 1 meter
Distance of probe from interferometer enclosure: Up to 10m

Additional Benefits

- **Multiple probes can be multiplexed to the same interferometer** (See Figure 5), giving clients additional return on investment
- NOVACAM systems also **measure tool wear or damage** (e.g., on EDM electrodes or on drill bits) to help optimize timing of tool replacement or reconditioning
- Measurements are **not affected by ambient lighting, air perturbation, or cutting of the beam**
- The systems also excel at **measuring in harsh environments**, including very hot, cryogenic or radioactive.

Conclusion

Novacam encourages managers and engineers in charge of metrology to contact us to discuss your metrology applications and any particular challenges related to hard-to-reach spaces.

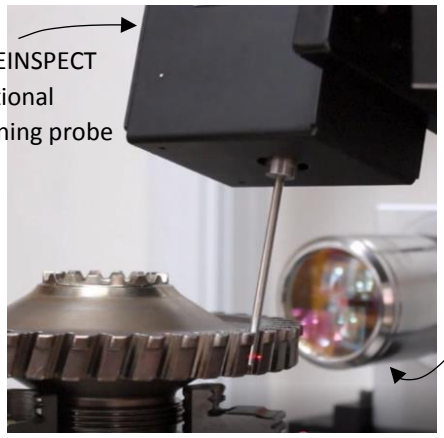


Figure 5: NOVACAM BOREINSPECT system measures fir tree slots on a jet engine turbine. NOVACAM SURFACEINSPECT system measures the turbine outside edge.

To learn more:

- Watch videos of the systems in action: https://www.novacam.com/resources/novacam-metrology-videos/
- Explore NOVACAM 3D metrology systems here: https://www.novacam.com/products/

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