

## Measuring Tube ID and OD with Novacam TubelInspect System

**Keywords:** tube inside dimensions, inside diameter (ID), outside diameter (OD), geometrical dimensioning and tolerancing (GD&T), surface topography, non-destructive testing (NDT), non-contact measurement, 3D mapping of tubes, shafts, internal features, groove depth and width, thread inspection, cylindricity, ID surface and dimensional defects, roughness, porosity, film thickness, dimensional deviations, chatter, lobing.

### Introduction

Inner surface topography of manufactured tubes can greatly affect their intended functional performance. This is why manufacturers in many high-precision industries – automotive, aerospace, energy, and medical device manufacturing among others – need to inspect tube IDs (and sometimes also ODs) down to the micron to ensure adherence to strict specifications. These specifications typically include:

- Dimensional parameters (GD&T): diameter, straightness, cylindricity, true position, etc.
- Geometries of inner features such as steps, splines, threads, O-ring grooves, chambers, cavities, cross-holes
- Roughness characteristics
- Distortion, chatter or lobing, and runout
- Defect characterization.

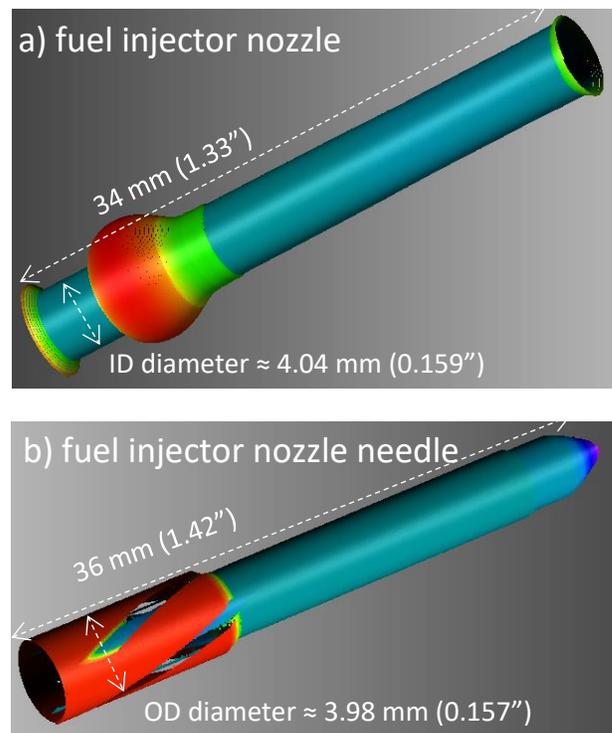
### Can the tube be rotated?

**Is the answer NO?** For tubes that cannot be rotated, Novacam has developed an ID metrology system called **BoreInspect**, subject of another application note.

**Is the answer YES?** For tubes that can be rotated – for example on a spinning chuck, Novacam’s **TubelInspect** 3D metrology system provides the capabilities needed to measure both the ID and OD of the tube in a non-contact manner. This highly versatile system is being used both in manual and automated inspection setups to measure tubes of various dimensions.

### Examples of Measured Tubes

TubelInspect non-contact probes, which come in diameters as small as 0.5 mm (0.02”), measure small-aperture tubes such as fuel injector nozzle parts (Figure1) down to the micron.



**Figure 1: Acquired fuel injector components**  
a) ID of a diesel fuel-injector nozzle  
b) OD of the matching fuel-injector nozzle needle

The following 6 images of an 18", .22 caliber rifle barrel (46 cm long, 5.6 mm diameter) obtained with TubeInspect illustrate several options available for interactive visual inspection as well as automated reporting.

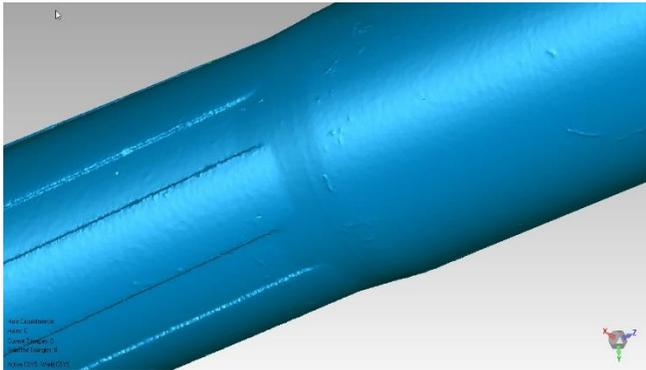


Figure 2: Close-up view of the inside surface of the barrel.



Figure 3: Users can zoom in further to examine barrel ID surface details.

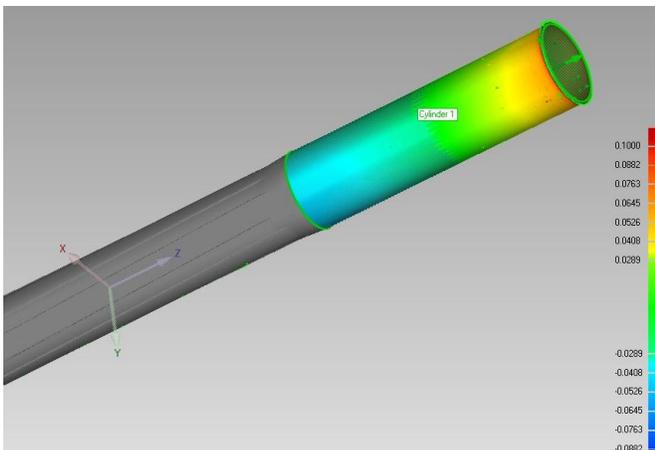


Figure 4: 3D deviation map of the barrel ID. Colours represent deviation (in mm) from a perfect best-fit cylinder.

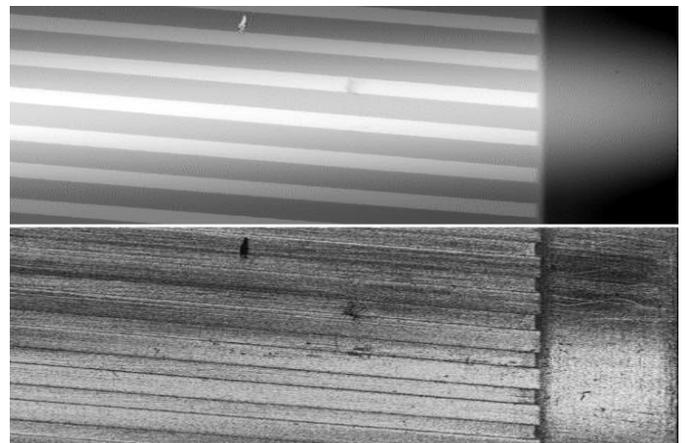
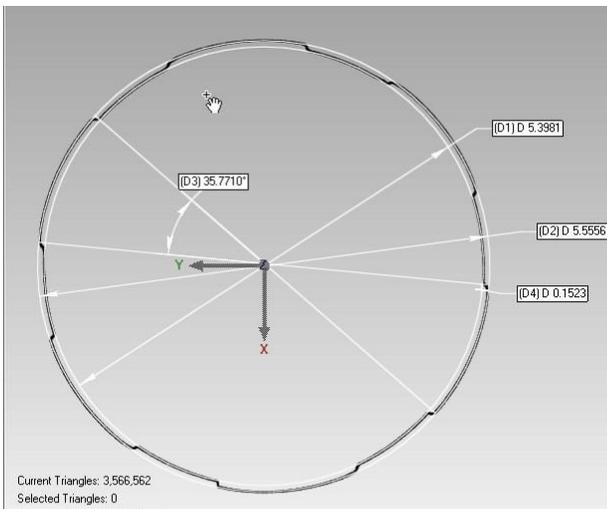


Figure 5: Views of the "unfolded" tube ID surface as a height image (top) and a light intensity image (bottom) support fast defect detection. Here, dimensional proportions were adjusted for easier viewing.



Current Triangles: 3,566,562  
Selected Triangles: 0

Section C-C

	Name	Measured	Nominal	Deviation	Status	Upper Tol.	Lower Tol.
1	D1	5.3981	5.3900	0.0081	PASS	1.0000	-1.0000
2	D2	5.5556	5.5500	0.0056	PASS	1.0000	-1.0000
3	D3	35.7710	35.7000	0.0710	PASS	1.0000	-1.0000
4	D4	0.1523	0.1500	0.0023	PASS	1.0000	-1.0000

Figure 5: Go-no-go reporting of various ID features can be automated.

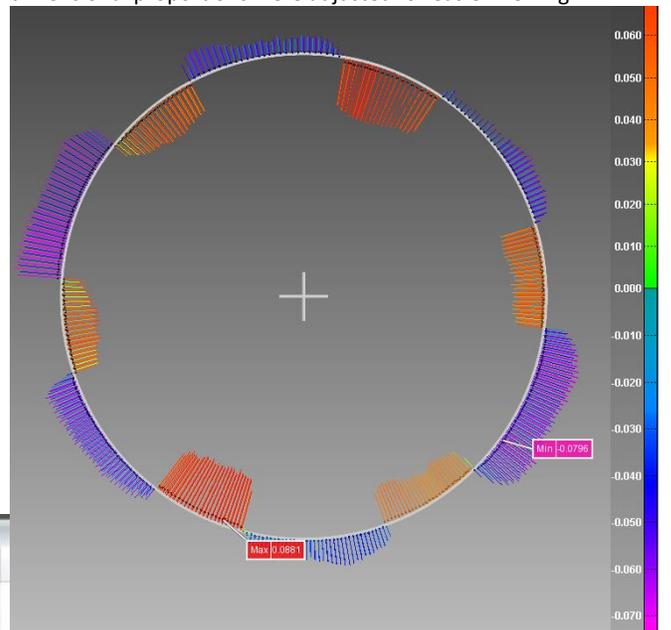


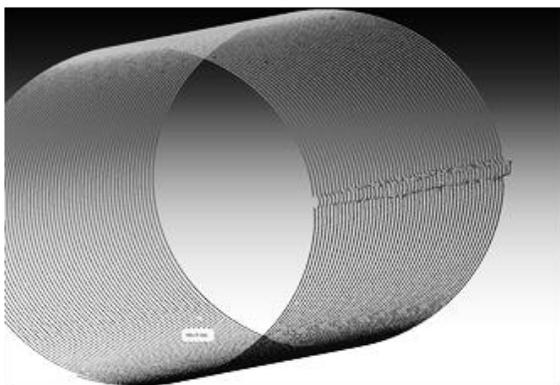
Figure 6: Diameter deviation map for a selected location in the barrel.

## How Measurements Are Obtained

Based on low-coherence interferometry, the TubeInspect acquires surfaces by having its non-contact optical probe direct a beam of light on the surface and collect the reflected signal. The signal travels through an optical fiber to a low-coherence interferometer for processing.

The tube is rotated while the probe is being advanced into it, and the system thereby obtains high-precision 3D topography of the entire ID surface in a spiral pattern and in a point-by-point manner, at a rate of up to 100,000 measurements per second. An example of the resulting point cloud is shown in Figure 8.

When applicable, coating or film thickness data may also be extracted from the same scan.



**Figure 8:** Point cloud of the inner surface of a hydraulic system component (diameter 15 mm) featuring a groove

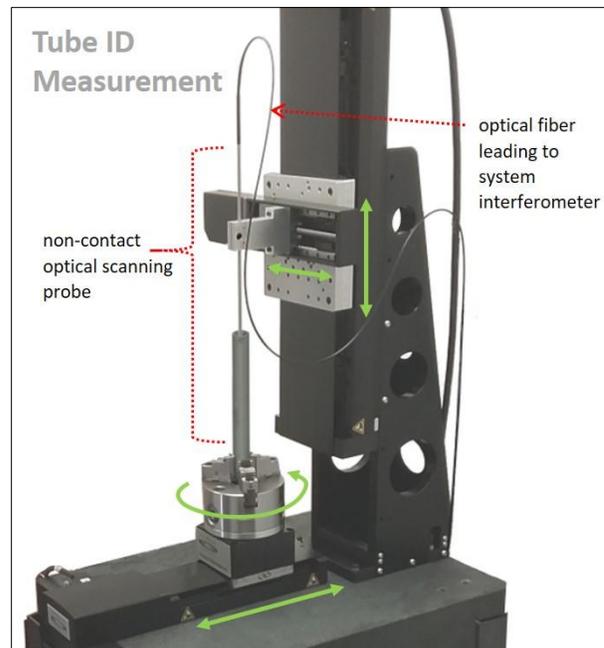
## Tube Interior Features Revealed

Tube ID features such as undercuts, threads, grooves, O-rings, cavities, chambers, and EDM cross-holes can all be measured and assessed, to the micron, for geometric tolerances.

Figure 2 shows scan results for a rifle barrel featuring rifling grooves.

## System Setup

A common setup for measuring small-diameter tubes in a lab or shop environment is shown in Figure 9. This same setup can be used to acquire the OD of the tube.



**Figure 9:** Novacam TubeInspect with a 4-axis inspection station

## Automation of Tube Scanning Sequences

Defining scanning sequences is quick and easy with the use of a joystick and with optional setting of parameters in the TubeInspect data acquisition software. Each scanning sequence may be saved for later recall and execution.

## Support for Automated & Visual Tube Inspection

Automated tube inspection is supported by system capabilities such as datum alignment, automated pass/fail reporting, and exportable reports. Measurements may be evaluated with respect to user-defined criteria (GD&T), inner feature specifications, defects and roughness, or compared to a reference CAD model.

For visual inspection, accompanying metrology software on a PC (e.g., PolyWorks Inspector™) enables full viewing and analysis of the acquired point cloud as a 3D interactive map. Views such as deviation maps (e.g., Figure 4) often provide key insight into tube machining processes.

## Modular & Shop-Floor Ready

Since the TubeInspect is fiber-based and modular (the fiber connecting the probe to the interferometer can be up to a mile long), the TubeInspect allows a variety of inspection setups to accommodate automation and almost any shop or plant-floor environment. The TubeInspect can:

- Be configured to prevent unintended operator contact with the probe in shop environment: the stages and probe may be enclosed below the inspection table, with the probe entering the spinning tube from below instead of from above
- Be interfaced with data loggers, enabling trend analysis with SPC software
- Function in harsh environments – e.g. radioactive, very hot, or cryogenic.

## Tube Parameters

Standard TubeInspect configurations cover tubes up to 600 mm ( $\approx 24''$ ) long, with diameters from 1 to 175 mm (0.04" to 5"). For non-standard tube specifications, custom smaller-diameter or longer probes are built upon request. For optimal performance, TubeInspect components are selected in consultation with our application specialists.

## Conclusion

With TubeInspect, measurements are fast, precise, automatable, and easy to interpret. Components as diverse as couplings, oil and gas safety valves, and medical implants are inspected for adherence to strict specifications. Novacam encourages technicians and engineers in charge of tube inspection to contact us to discuss your applications and your particular metrology challenges.

### TubeInspect system components

Component	Physical aspect	Deployment area
Microcam-3D or -4D interferometer	19" rack-mountable instrument	lab / shop / plant floor / control room
computer workstation	mini desktop-size PC or laptop	lab / shop / plant floor / control room
probe	non-contact side-looking probe selected to match the application	inspection station in lab / shop or on the plant floor as 3D-inspection instrument in automated production lines
rotational stage	application-specific rotational stage/fixture to spin the measured tube. Standard setup includes a 5" chuck on a rotational stage.	inspection station in lab / shop or on the plant floor as part of inspection setups in automated production lines. Loading and unloading can be automated using robots.

- Detailed technical specifications for the Microcam interferometer are available upon request
- To see TubeInspect in action, watch the "3D tube ID measurement" video here: <https://www.novacam.com/resources/novacam-metrology-videos/3d-tube-id-measurement-video/>
- For ID measurements of tubes that cannot be spun on a rotational fixture, ask us about the BoreInspect system.



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