Application Note
for Industry

Measuring Tube ID and OD

with NOVACAM™ TUBEINSPECT™ 3D Metrology 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 offers an ID metrology system called the **BOREINSPECT™ system**, subject of another application note.

Is the answer YES? For tubes that can be rotated on a rotational stage, NOVACAM™ **TUBEINSPECT**™ 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

The TUBEINSPECT system non-contact probes, with diameters as small as 0.5 mm (0.02”), measure small-aperture tubes such as fuel injector nozzle parts (Figure1) down to the µm.

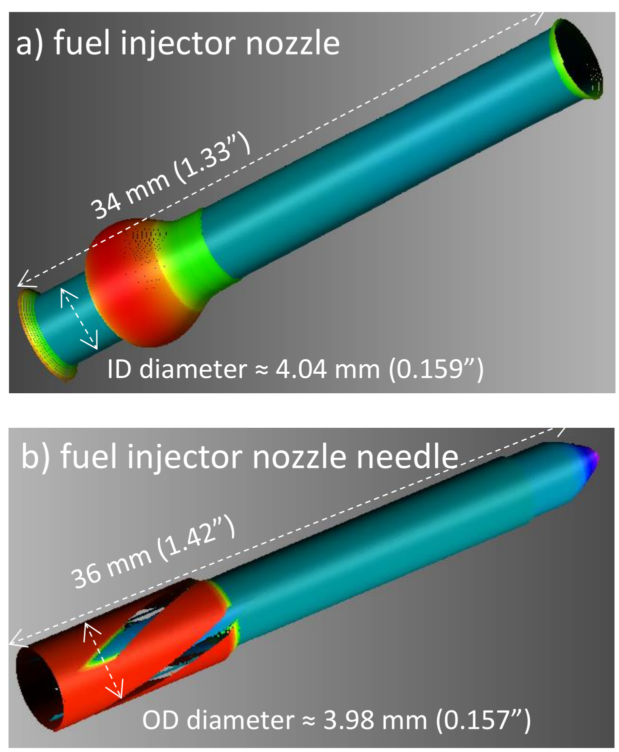


Figure 1: Acquired fuel injector components
a) ID **o**f a diesel fuel-injector nozzle
b) OD of the matching fuel-injector nozzle needle

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

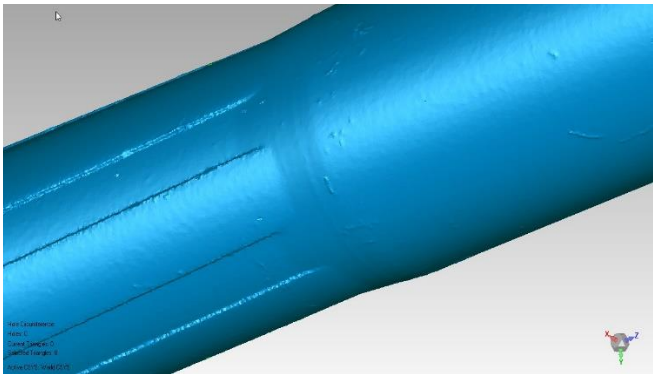


Figure 2: Close-up view of the inside surface of the barrel.

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

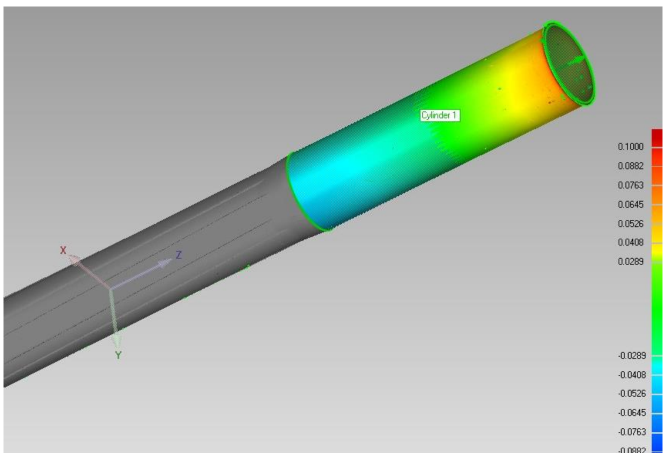


Figure 4: 3D deviation map of the barrel ID. Colours represent deviation (in mm) from a perfect best-fit cylinder.

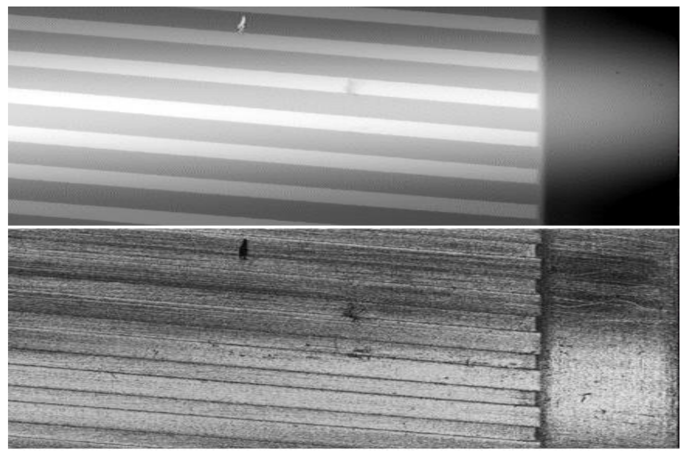
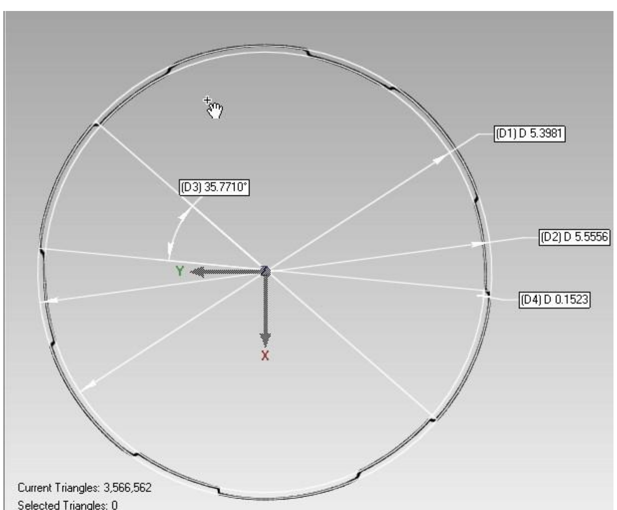


Figure 5: Views of the "unfolded" tube ID surface as a height image (top) and a light intensity image (bottom) support fast defect detection. Here, dimensional proportions were adjusted for easier viewing.



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.

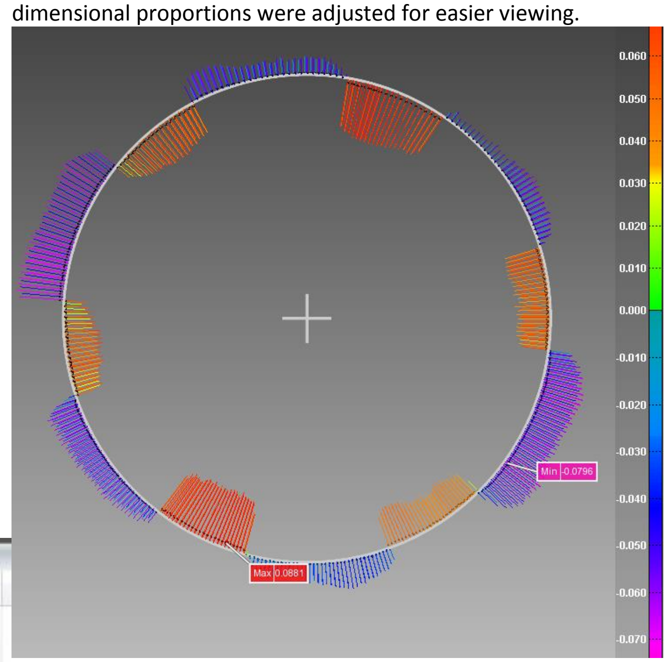


Figure 6: Diameter deviation map for a selected location in the barrel.

How Measurements Are Obtained

The TUBEINSPECT system is based on low-coherence interferometry technology. Its non-contact scanning optical probe directs a beam of light at the measured surface, collects the reflected signals, and sends them via an optical fiber to the system interferometer for processing.

As the probe advances inside the rotating tube, it acquires the surface in a point-by-point manner at a rate of up to 100,000 3D measurements per second. ID profiles can be linear, circular or spiral. Figure 8 shows an example of a 3D point cloud acquired with a high-density spiral profile of an ID.

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.

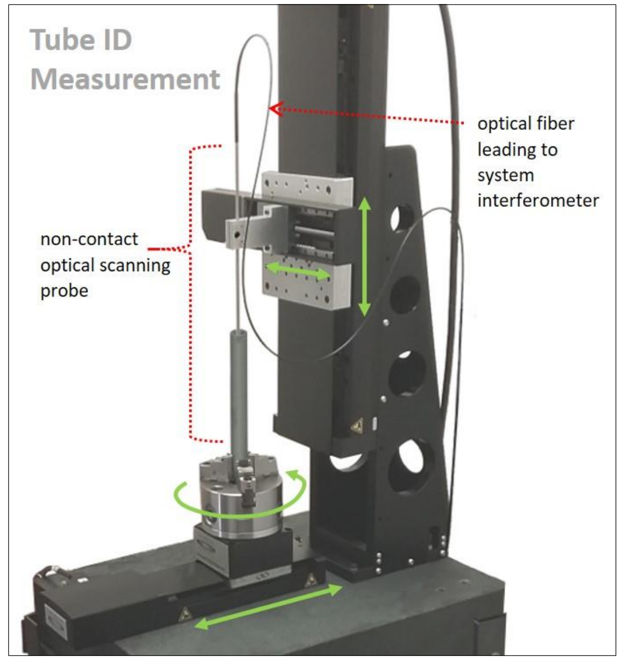


Figure 9: NOVACAM TUBEINSPECT system with a 4-axis inspection station

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 system data acquisition software. Each scanning sequence may be saved for later recall and execution.

Support for Automated and 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 system is fiber-based and modular (the fiber connecting the probe to the interferometer can be several meters long), it allows for a variety of inspection setups to accommodate automation in most plant-floor environments. The TUBEINSPECT system can:

- Be configured to prevent unintended operator contact with the probe on a shop floor: the stages and probe may be enclosed below the inspection table, with the probe entering the rotating 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 system configurations cover tubes up to 1,000 mm (≈40”) 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 system components are selected in consultation with our application specialists.

Conclusion

With the TUBEINSPECT system, measurements are fast, precise, and easy to automate. Parts as diverse as couplings, oil and gas safety valves, medical implants, and barrels 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
Workstation computer	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 MICROCAM interferometer are available upon request
- To see the TUBEINSPECT system 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 rotated, ask about NOVACAM BOREINSPECT™ system.

Novacam Technologies Inc.
1755 St. Regis, Suite #130
Dollard-Des-Ormeaux, QC, H9B 2M9, Canada

For more information,
visit www.novacam.com,
email info@novacam.com, or
call 514-694-4002 / toll-free 1-866-694-4002

Document: AN-TUBE-INSPECT-1.3 (2021-05-24)