NOVACAM TECHNOLOGIES INC.

Application Note
for Industry

Measuring Bores

with Novacam BoreInspect System

Keywords: 3D non-contact optical inspection, NDT, 3D mapping of bore holes, shafts, cylinders, chambers, valve bores, inner cavities, GD&T, ID characterization, surface topography, cylindricity, porosity, splines, surface and dimensional defects, roughness, film thickness, geometric tolerances of internal features, dimensional deviations, lobing, scrolling, CMM, CNC, internal diameter (ID)

Introduction

Measuring bore inner diameters (IDs) is a challenging task in many high-precision manufacturing industries. Engineers in the automotive, aerospace, and other precision sectors must ensure that IDs of bore holes in their domains adhere to strict specifications. Such specifications typically relate to:

- dimensions (GD&T)
- straightness, cylindricity, conicity, ovality, taper, distortion, and runout
- inner features such as steps, threads, cavities, chambers, and cross-holes
- roughness characteristics
- defect characterization.

Even today, some manufacturers resort to cutting open selected machined parts in a lab to inspect bore IDs under large microscope-like systems or making high-precision replica casts of bore interiors to inspect them indirectly. For many, this may no longer be optimal.

Novacam BoreInspect greatly facilitates and speeds up the task of high-precision bore inspection. This modular non-contact inspection system features a rotational scanner (Figure 1) that easily enters bores to acquire their inner 3D topography directly and down to the micron. The surface acquisition and subsequent 3D characterization, defect detection, or roughness analysis are easily automated and carried out right on the plant floor, bringing high-precision component manufacturers significant savings.

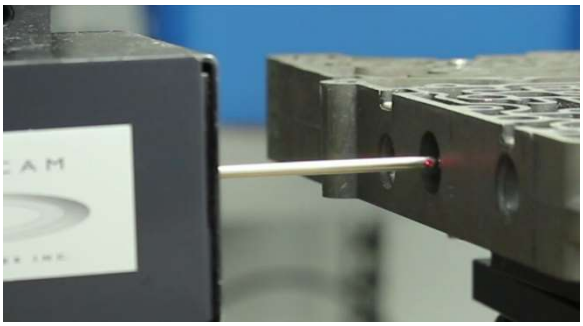


Figure 1: The optical probe of the BoreInspect scans a valve-body bore ID as it is rotated and moved into the bore

Micron-Precision 3D ID Data

Based on low-coherence interferometry, the BoreInspect acquires bore ID surfaces by having its rotational non-contact probe direct a beam of light onto the surface and collect the reflected signal. The system thereby obtains high-precision 3D topography of the surface (Figure 2) in a point-by-point manner, at a rate of up to 100,000 points (measurements) per second.

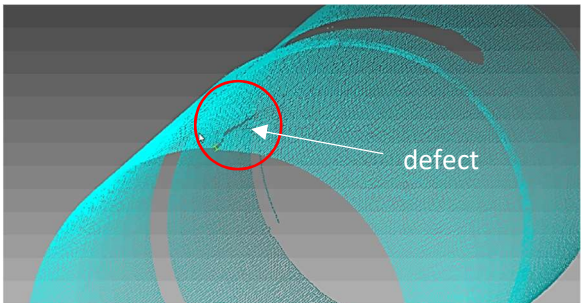


Figure 2: The acquired 3D map of a bore ID in the above valve body reveals a defect next to the bore opening.

Automated bore inspection is supported by system capabilities such as datum alignment, automated pass/fail reporting, and exportable reports. The ID data may be evaluated with respect to user-defined criteria (GD&T, inner feature specifications, defects, or roughness), or compared to a reference CAD model. For manual 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 (Figure 2). Views such as deviation maps (Figure 3) often provide key insight into bore machining processes.

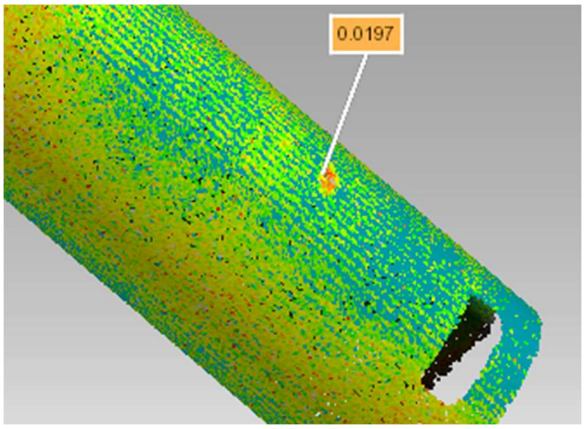


Figure 3: Deviation map (viewed with PolyWorks Inspector ™) highlights a bore ID surface defect – a 19.7 µm deep pit.

The ID surface can additionally be captured as a height or intensity image (Figure 4) or saved in other common CAD formats. When applicable, coating or film thickness data may also be extracted from the same scan.

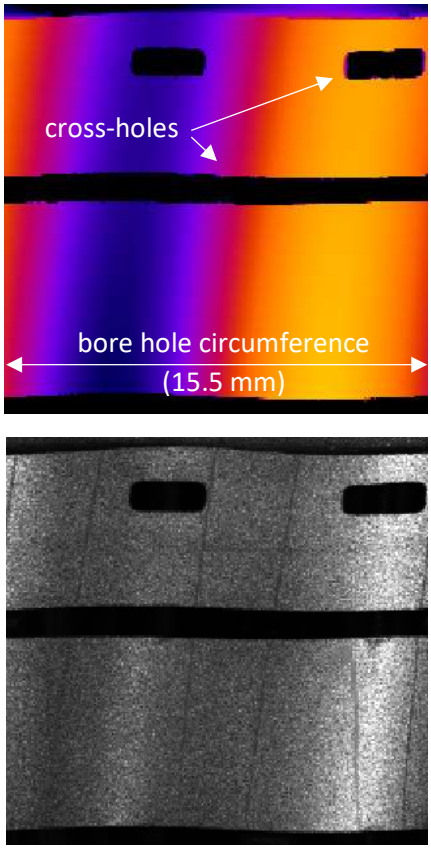


Figure 4 Height image (top) and intensity image (bottom) of the unfolded bore interior.

Easy Automation of Bore Scanning Sequences

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

For additional value, a scanning sequence can comprise multiple bores (Figure 5).

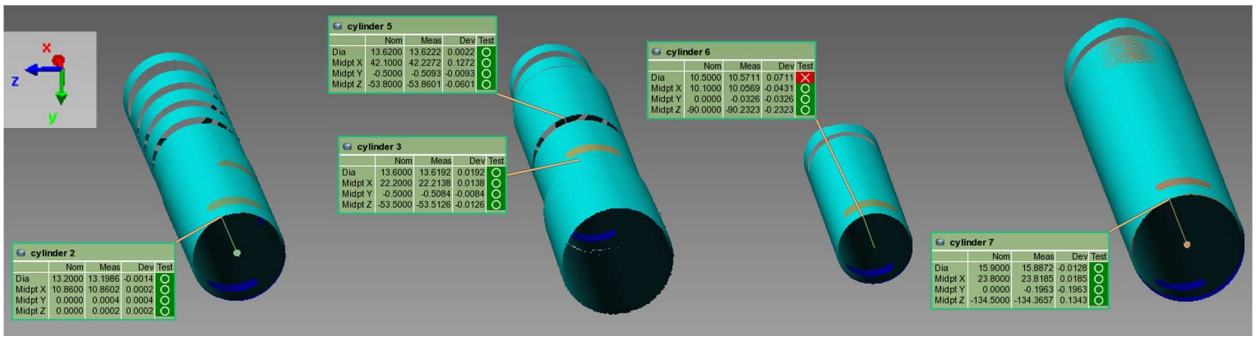
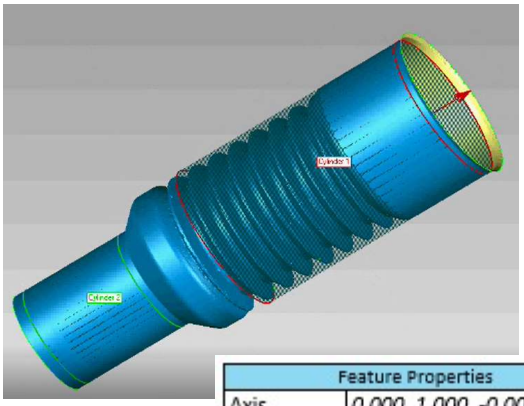


Figure 5: Four bores in a valve body were scanned and analyzed in one inspection sequence. The results include dimensional measurements and pass/fail reporting for each bore, as well as the bore pitch (bore spacing), and exact positioning of each bore on the valve body.

Bore Interior Features Revealed

Bore 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 6 shows BoreInspect scan results for a bore featuring inner threads.



Feature Properties	
Axis	0.000, 1.000, -0.001
Diameter	13.459 mm
Center	-0.108, -12.831, 0.050 mm
Base Points	-0.113, 23.520, 0.061 mm
Top Point	-0.103, -2.142, 0.039 mm
Height	21.379 mm
Fitting Statistics	
Number of points	307 896
Maximum negative	-0.412 mm
Maximum positive	0.021 mm
Standard deviation	0.005 mm

Figure 6: 3D map and thread measurements for the inner thread of a turbocharger impeller. The high-precision measurements were calculated from 307,000 3D points acquired in ~4 seconds.

Bore Metrology on the Plant Floor

Thanks to its fiber-based and modular design, the BoreInspect performs in a range of settings, including in high-throughput industrial metrology applications. The scanner is mounted on a stage suitable for the application, such as a robot arm, gantry, or motor-controlled stages. It is connected to the system's interferometer with an optical fiber that can be hundreds of meters long.

The scanner can be configured to function even in harsh environments (radioactive, very hot, and cryogenic).

Planes, Trains and Automobiles … and Precision Machining

Thanks to its high scanning rate, micron vertical resolution, and excellent measurement repeatability, the BoreInspect supports lab, shop, and integrated inline metrology applications across many industries (see table below).

The system performs in automated production lines at several Tier 1 and Tier 2 automotive and aerospace manufacturers.

Aerospace

- GD&T inspection of valves, cylinders, manifolds, and other engine components featuring bores or pipes
- Dimensional and defect inspection of drilled rivet holes at aircraft fuselage assembly

Automotive

GD&T inspection of gas, diesel, and propane engine components: valve bodies, valve seats, cylinder heads, camshafts, crankshafts, combustion chambers, and more

High-precision machining

GD&T inspection of parts machined for:

- Defence
- Industrial
- Medical equipment
- Nuclear
- Oil and gas
- Power generation
- Transportation (aerospace, automotive, train, marine)

Bore Parameters

The range of available standard BoreInspect configurations covers:

- bores as deep as 1 m (3.3')
- bore diameters between 1 and 75 mm (0.04" and 3").

For other bore specifications, custom smaller- or larger-diameter or longer probes are constructed upon request. For optimal performance, BoreInspect components are selected in consultation with our application specialists.

Conclusion

With the BoreInspect, bore metrology is fast, precise, automatable, flexible, and easy to interpret. Components as diverse as turbines, actuator housing cylinders, safety valves, and deep bores (from deep hole drilling, gun drilling, or vibration assisted drilling) may be inspected for adherence to strict bore ID specifications.

Novacam encourages technicians and engineers in charge of bore inspection to contact us to discuss your applications and any particular metrology challenges.

BoreInspect 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
rotational scanner (RS1, RS2, or RS4)	- probe-rotating and advancing unit and - a non-contact side-looking probe selected to match the application	inspection station in lab / shop or on the plant floor as: - end-effector in robot inspection systems - 3D inspection instrument on automated production lines

- Rotation speed is up to 30 rotations per second. With 100,000 measurements taken every second, you will obtain up to 3,300 3D measurements per rotation
- Detailed technical specifications for the Microcam interferometer are available upon request
- If you need ID and OD inspection of tubes that can be spun on a chuck or other fixtures, ask us about the TubeInspect system

An Invitation – Watch BoreInspect in Action

To see the BoreInspect at work, please watch the "Valve body bore measurement" video at https://www.novacam.com/resources/novacam-metrology-videos/valve-body-bore-id-measurement-video/

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