Application Note for the
Aerospace Industry

Rivet Hole and Rivet Flushness Inspection

with NOVACAM™ RIVETINSPECT™ 3D Metrology System

Keywords: 3D rivet hole inspection, ID geometry, defects, roughness, countersinks, pins, bolts, blind fasteners, tapered rivet hole id, delamination, non-contact, non-destructive inspection, NDT, robot tools, end-of-arm tooling

Introduction

Automating fastener inspection in aircraft assembly is no longer just an option – it is now a necessity for aircraft makers who are facing stiff competition and increasingly higher precision QA/QC requirements for each aspect of the assembly process. Since the traditional drill-and-fill process accounts for over half of airframe assembly costs, manufacturers are looking to improve the fastening process through a combination of fully automated robots for the majority of riveting, and flexible semi-automated tools for hard-to-reach spaces.

The RIVETINSPECT system provides **high-speed micron-precision geometry measurements and defect detection** capabilities for the entire riveting process. Based on low-coherence interferometry, the system acquires up to 100k 3D points/second. It uses two fiber-based optical scanner probes to scan the rivet hole, the countersink, and the rivet head area post-installation. The two probes work as follows:

- The **rotational scanner probe** reaches inside rivet holes (Figure 1) to measure ID geometry and detect defects on the rivet hole ID (see Figure 2) and/or countersink.
- The **galvo scanner probe**, which is multiplexed to the same detector, scans the countersink and post-installation rivet head area from above, its beam following an efficient raster pattern (Figures 5-8).

Both probes are easily integrated as robot end-effectors or in any automated or semi-automated system on the plant floor.

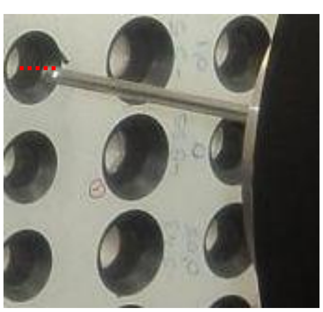

Figure 1: The small-diameter probe of the rotational scanner reaches inside rivet holes to acquire the complete inside surface geometry

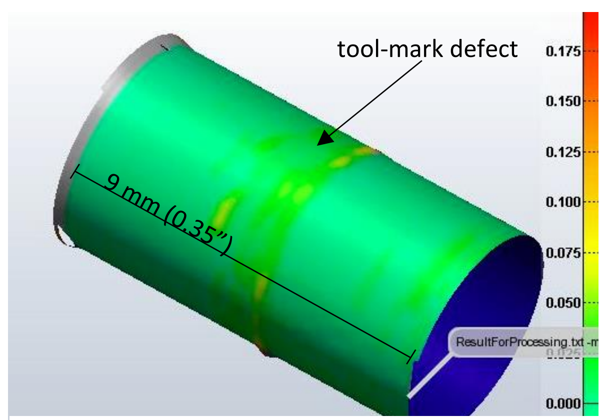

Figure 2: Rivet hole ID exhibiting a tool-mark defect at the interface of composite and aluminum layers

Inside the Rivet Hole

The micron-precision 3D surface data acquired by the RIVETINSPECT system provides manufacturers with an unprecedented level of insight into the drilling process.

For example, manufacturers can now easily access and visualize defects such as **inter-laminar or exit burring**, such as shown in Figure 3. No more need for slow contact probes and contact roughness measurements.

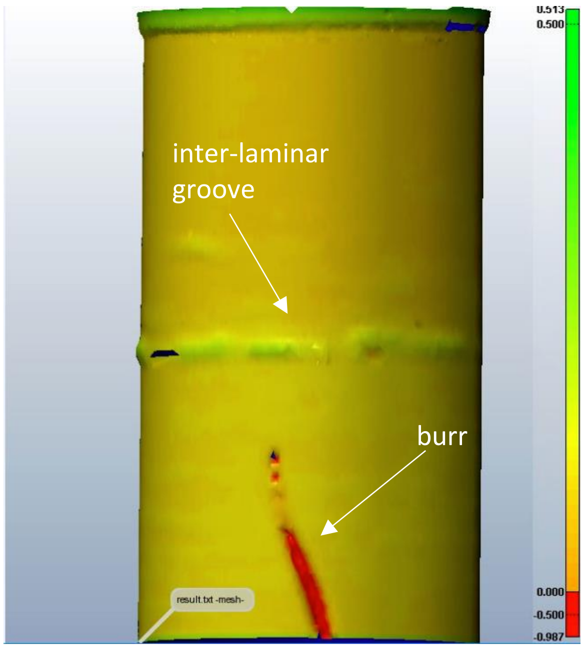

Figure 3: Inside surface of a rivet hole with a burr defect - an easy defect to instantly detect and identify with the RIVETINSPECT system.

Burr defects are costly to address. Depending on the severity of burring, corrective measures may include disassembly and removal of burrs or chips prior to re-joining the surfaces. While deburring tools do help circumvent disassembly deburring is best avoided, particularly when it comes to composite components, where deburring may introduce debris between the composite skin and the metal substructure.

High-precision automated rivet-hole inspection that directly follows the rivet hole drilling prevents burr defect propagation and unnecessary corrective rework. What is more, rapid burr defect diagnosis leads to rapid rectification and resumption of the drilling process. Since the severity of burrs formed is impacted by the physical and operational parameters of the drill and bit, burr detection is typically a signal for immediate replacement of a drill bit.

Delamination of composite material layers or excessive fiber pulling or tearing caused by drilling are similarly revealed with the 3D data acquired by RIVETINSPECT system. Again, timely detection of such a defect enables prompt investigation of the joined components or of the drill tools and process.

Replace the Drill Bit on Time – but not Too Soon

Given the cost of consumable drill bits and the cost of the drill-bit replacement process, it makes sense to replace drill bits only once their efficacy has measurably deteriorated. To establish drill bit wear, the acquired 3D rivet-hole inner surface geometry is programmatically compared with the design specification shape of the rivet hole (see Figure 4).

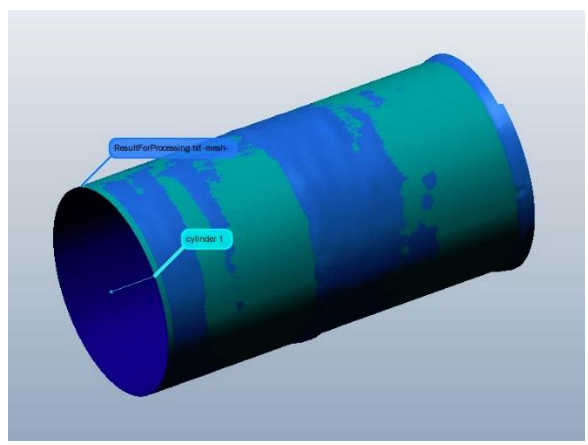

Figure 4: Colour-coded image of dimensional variability between the rivet-hole specification (green) and the rivet hole (blue)

The scale of dimensional variation suggests the optimal time to replace a drill bit, before defects start occurring. With this drill-bit replacement approach, operational savings are achieved.

Taking a Measure of Countersinks

Since flush installation of head fasteners is crucial for exterior aerodynamic surfaces, the nominal depth and angle of each countersink must be controlled to accommodate rivet heads. The 3D data rapidly delivered by the RIVETINSPECT galvo scanner lets aircraft manufacturers quickly visualize the countersink surface (Figure 5), verify conformity to specifications such as countersink angle (Figure 6) and identify any surface defects (Figure 7).

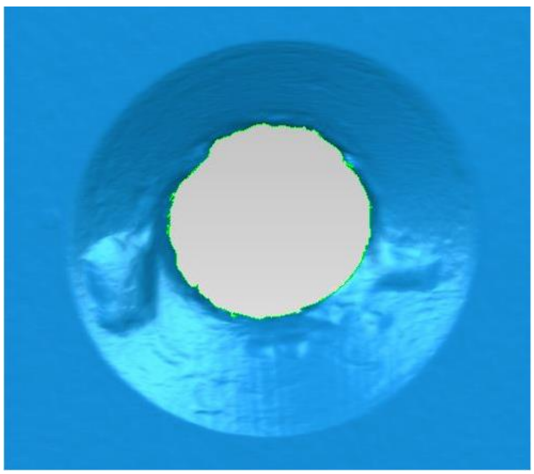

Figure 5: 3D surface of a countersink

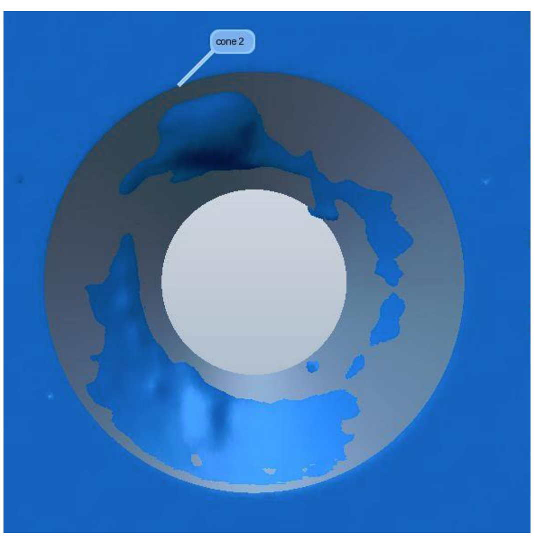

Figure 6: Variability of the 3D actual countersink (blue) from the spec (gray)

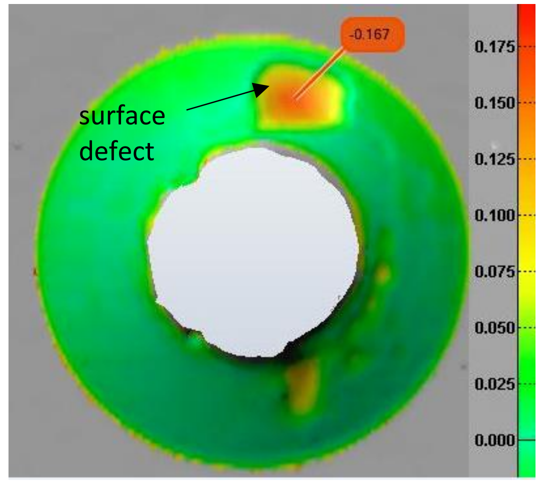

Figure 7: Surface defect identified on the countersink

Checking Rivet Flushness

For aerodynamics reasons, the flushness of rivets must be within 0.002” (50.8 microns). 3D surface topography data (Figure 8) helps verify conformity to these specifications.

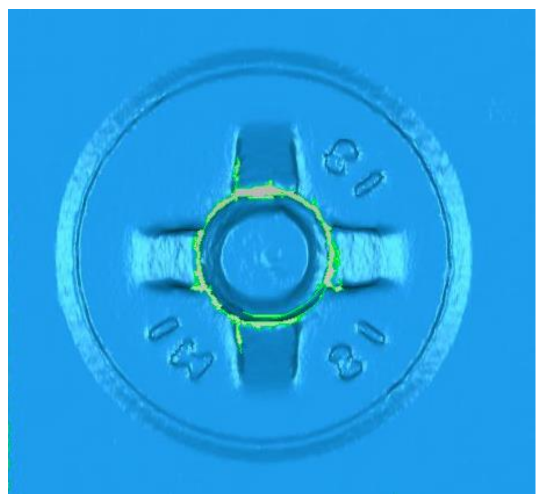

Figure 8: 3D surface of an installed rivet head

Additionally, surface defects around the rivet head, such as skin distortion, rivet removal damage, scratches, or other types of deformation, can be detected. The field of view of the standard RIVETINSPECT galvo scanner covers up to 30 mm^2. Larger FOVs are also available.

Automating Riveting Measurements Right in Process, on the Plant Floor

Deployed as measurement end-effectors on aircraft assembly robots, RIVETINSPECT scanner probes assist in a range of aircraft assembly tasks including drilling, fastener installation, sealing, and machining operations such as deburring. Being fiber-based, the probes can be deployed up to 10 m away from the detector (interferometer) enclosure.

Notably, RIVETINSPECT system measurements are immune to air perturbation, ambient lighting, and to cutting of the beam. The probes enable 3D metrology anywhere, even in harsh (radioactive, very hot or cryogenic) environments

The RIVETINSPECT system software also provides full automation support.

Hard to Reach Corners

For inspection needs of riveting or bolting applications in hard-to-reach spaces, RIVETINSPECT system scanners are integrated into custom hand-held inspection tools appropriate to the particular environment.

Conclusion

The RIVETINSPECT 3D metrology system brings important inspection capabilities to the aircraft riveting process: micron precision, high-speed acquisition and versatility of deployment configuration.

Novacam encourages technicians and engineers in charge of aircraft assembly applications, including fastener installation, to contact us to discuss your applications and particular challenges.

RIVETINSPECT™ 3D metrology system components

<table>
<tr><th>Component</th><th>Physical aspect</th><th colspan="2">Deployment area</th></tr>
<tr><td>MICROCAM™-3D or 4D interferometer*</td><td>19” rack-mountable instrument</td><td colspan="2">plant floor / control room</td></tr>
<tr><td>workstation computer</td><td>mini desktop-size PC or laptop</td><td colspan="2">plant floor / control room</td></tr>
<tr><td>rotational scanner (RS) probe</td><td>Rotational scanner featuring a small-diameter** side-looking probe</td><td>rivet hole inspection</td><td rowspan="2">on the plant floor as:
- robot end-effectors
- 3D inspection instruments in automated assembly lines
- 3D-vision components in hand-held inspection tools</td></tr>
<tr><td>galvo scanner (GS) probe</td><td>surface scanning galvanometer probe</td><td>countersink and rivet flushness inspection</td></tr>
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* NOVACAM rotational probes come in diameters as small as 0.5 mm (0.02”)
** Detailed technical specifications are available upon request.

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