Application Note for Industry

工业应用笔记

Rivet Hole and Rivet Flushness Inspection with NOVACAM™ RIVETINSPECT 3D Metrology System
使用诺飞勘RIVETINSPECT 3D 计量系统进行铆钉孔和铆钉齐平度检查

Keywords:
关键词：
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
3D 铆钉孔检测、内径几何、缺陷、粗糙度、埋头孔、销、螺栓、盲紧固件、锥形铆钉孔内径、分层、非接触、无损检测、无损检测、机器人工具、臂端工具

Introduction：
介绍
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 drilland-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.
飞机装配中的自动化紧固件检查不再只是一种选择——它现在是一种飞机制造商面临着激烈的竞争和对装配过程各个方面的 QA/QC 要求越来越高的必要性。 由于传统的钻孔和填充过程占机身组装成本的一半以上，制造商希望通过将用于大多数铆接的全自动机器人和用于难以触及的空间的灵活半自动工具相结合来改进紧固过程。

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:

RIVETINSPECT ™ 系统为整个铆接过程提供高速微米级精度几何测量和缺陷检测功能。

该系统基于低相干干涉测量法，每秒可采集多达 10 万个 3D 点。 它使用两个基于光

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纤的光学扫描仪探头来扫描铆钉孔、埋头孔和安装后的铆钉头区域。 这两个探针的工作原理如下：

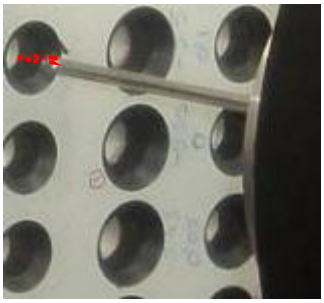

Figure 1*: The small-diameter probe of the rotational scanner reaches inside rivet holes to acquire the complete inside surface geometry*
图 1：旋转扫描仪的小直径探头到达铆钉孔内部以获取完整的内表面几何形状

• The rotational scanner probe reaches inside rivet holes (Figure 1) to measure IDgeometry and detect defects on the rivet hole ID (see Figure 2) and/or countersink
旋转扫描仪探头到达在铆钉孔内（图 1）测量 ID 几何形状并检测铆钉上的缺陷孔 ID（见图 2）和/或埋头孔。
. • The galvo scanner probe, which ismultiplexed to the same detector, scans the countersink and post-installation rivet headarea from above, its beam following an efficient raster pattern (Figures 5-8).
振镜扫描探头与同一探测器复用，从上方扫描埋头孔和安装后的铆钉头部区域，其光束跟随高效的光栅模式（图 5-8）

Both probes are easily integrated as robot endeffectors or in any automated or semi automated system on the plant floor.
两个探头都可以轻松集成为机器人末端执行器或任何自动化或半工厂车间的自动化系统。

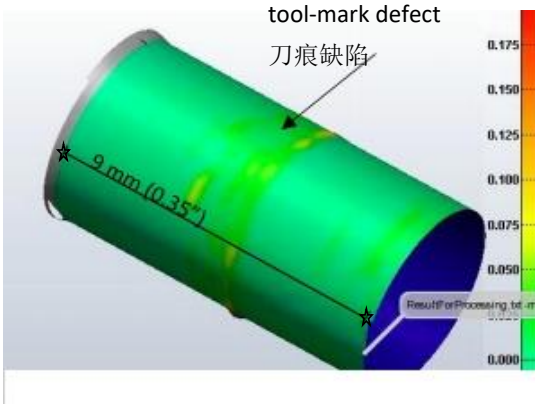

Figure 2: *Rivet hole ID exhibiting a tool-mark defect at the interface of composite and aluminum layers*
图 2：铆钉孔 ID 在复合材料和铝层的界面处表现出工具标记缺陷

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Inside the Rivet Hole

铆钉孔内

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

RIVETINSPECT™ 系统获取的微米级精度 3D 表面数据为制造商提供了前所未有的钻孔过程洞察力。

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.

例如，制造商现在可以轻松访问和可视化缺陷，例如层间或出口毛刺，如图 3 所示。不再需要慢速接触探针和接触粗糙度测量。

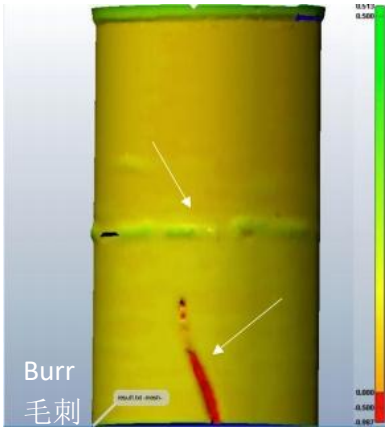

Figure 3: *Inside surface of a rivet hole with a burr defect - an easy defect to instantly detect and identify with the RIVETINSPECT ™system.*

图 3：具有毛刺缺陷的铆钉孔的内表面 - 使用 RIVETINSPECT™系统可以立即检测和识别的简单缺陷。

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.

毛刺缺陷的解决成本高昂。 根据毛刺的严重程度，采取纠正措施可能包括在重新连接表面之前拆卸和去除毛刺或碎屑。 尽管去毛刺工具确实有助于避免拆卸 最好避免去毛刺，特别是对于复合部件，去毛刺可能会在零件之间引入碎屑复合蒙皮和金属子结构。

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 istypically a signal for immediate replacement of a drill

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bit.
紧接着铆钉孔钻孔的高精度自动铆钉孔检测可防止毛刺缺陷传播和不必要的校正返工。 更重要的是，快速的毛刺缺陷诊断导致钻孔过程的快速纠正和恢复。 由于形成的毛刺的严重程度受钻头和钻头的物理和操作参数的影响，毛刺检测通常是立即更换钻头的信号。

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.

RIVETINSPECT™ 系统获取的 3D 数据类似地揭示了复合材料层的分层或由钻孔引起的过度纤维拉扯或撕裂。 再次，及时检测这种缺陷能够对连接的部件或钻具和工艺进行迅速调查。

Replace the Drill Bit on Time – but not Too Soon

按时更换钻头——但不要太快

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 rivethole inner surface geometry is programmatically compared with the design specification shape of the rivet hole (see
Figure 4).
考虑到消耗性钻头的成本和钻头更换过程的成本，只有当钻头的功效显着下降时才更换钻头才有意义。 到确定钻头磨损，以编程方式将获得的 3D 铆钉孔内表面几何形状与铆钉孔的设计规格形状进行比较（参见图 4）。

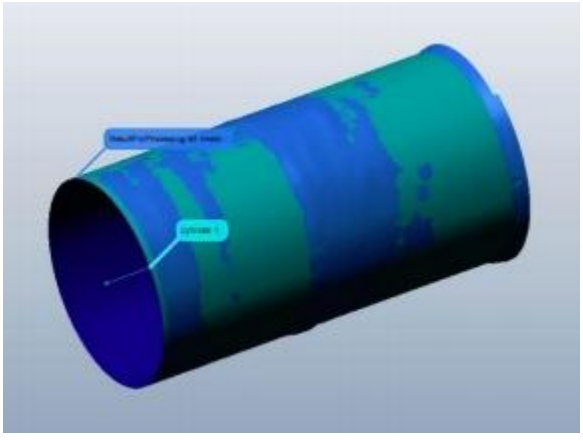

Figure 4: Colour-coded image of dimensionalvariability between the rivet-hole specification (green) and the rivet hole (blue)
图 4：铆钉孔规格（绿色）和铆钉孔（蓝色）之间尺寸变化的颜色编码图像

The scale of dimensional variation suggests the optimal time to replace a drill bit, before

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defects start occurring. With this drill-bit replacement approach, operational savings are achieved.
尺寸变化的规模表明更换钻头的最佳时间，之前缺陷开始发生。 使用这种钻头更换方法，可以节省运营成本达到了。

Taking a Measure of Countersinks

测量埋头孔

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).
由于头部紧固件的齐平安装对于外部空气动力学表面至关重要，因此必须控制每个埋头孔的标称深度和角度以容纳铆钉头。 RIVETINSPECT™振镜扫描仪快速提供的 3D 数据让飞机制造商快速可视化埋头孔表面（图 5），验证是否符合埋头孔角度等规格（图 6）并识别任何表面缺陷（图 7）。

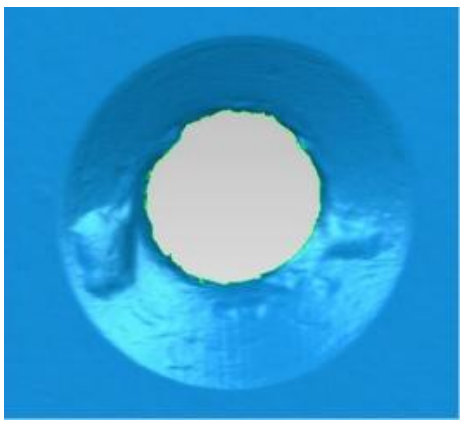

Figure 5: *3D surface of a countersink*
图 5：埋头孔的 3D 表面

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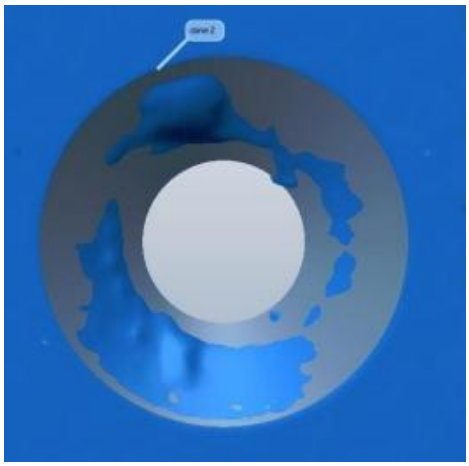

Figure 6: *Variability of the 3D actual countersink (blue) from the spec (gray)*
图 6：3D 实际埋头孔（蓝色）与规格（灰色）的差异

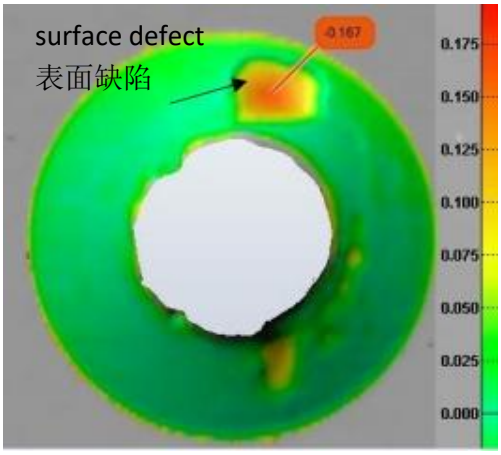

Figure 7: *Surface defect identified on the Countersink*
图 7：识别出的表面缺陷埋头孔

Checking Rivet Flushness
检查铆钉平整度

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.

出于空气动力学原因，铆钉的齐平度必须在 0.002 英寸（50.8 微米）以内。 3D 表面形貌数据（图 8）有助于验证是否符合这些规范。

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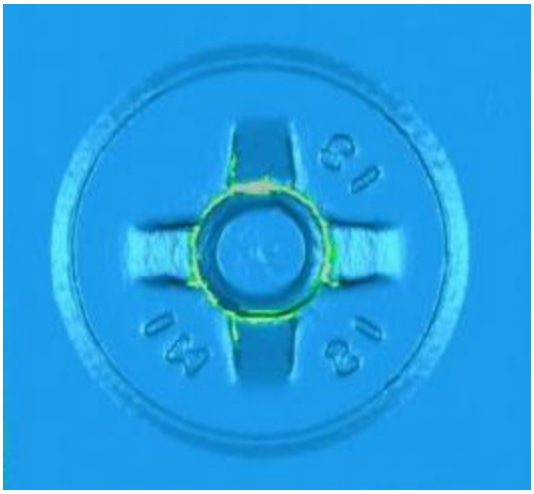

Figure 8: *3D surface of an installed rivet head*
图 8：已安装铆钉头的 3D 表面

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.
此外，铆钉头周围的表面缺陷，如表皮变形、铆钉脱落可以检测到损坏、划痕或其他类型的变形。 视野范围标准 RIVETINSPECT 振镜扫描仪的最大覆盖面积为 30 mm2。 更大的 FOV 也可用的。

Automating Riveting Measurements Right in Process, on the Plant Floor
在工厂车间自动进行铆接测量

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.
部署为飞机装配机器人的测量末端执行器、RIVETINSPECT 扫描仪探针协助一系列飞机组装任务，包括钻孔、紧固件安装、密封和机加工操作，例如去毛刺。 基于光纤，探头可以是部署在距离探测器（干涉仪）外壳最远 10 m 处。

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

值得注意的是，RIVETINSPECT™ 系统测量不受空气扰动、环境照明，以及光束的切割。探头可在任何地方进行 3D 计量，即使在恶劣（放射性、极热或低温）环境中也是如此

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The RIVETINSPECT ™system software also provides full automation support.

RIVETINSPECT ™系统软件还提供全自动化支持。

Hard to Reach Corners
难以到达的角落

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.

RIVETINSPECT ™ 系统扫描仪集成到定制的手持式检测工具中，以满足铆接或螺栓连接应用在难以到达的空间中的检测需求适合特定的环境。

Conclusion
总结

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

RIVETINSPECT ™3D 计量系统为飞机铆接过程带来了重要的检测能力：微米精度、高速采集和部署配置的多功能性。

RIVETINSPECT™ 3D metrology system components
RIVETINSPECT™ 3D 计量系统组件

Component **组件**	**Physical aspect** **具体方面**	**Deployment area** **部署区域**
MICROCAM -3D or 4D interferometer* 微型摄像机-3D 或 4D	19” rack-mountable Instrument 19” 机架式仪器	plant floor / control room 厂房/控制室
workstation Computer 工作站 计算机	mini desktop-size PC or laptop 迷你台式电脑或笔记本电脑	plant floor / control room 厂房/控制室

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rotational scanner (RS) probe 旋转扫描仪 (RS) 探头	Rotational scanner featuring a small-diameter**side-looking Probe 旋转扫描仪具有小直径**侧视探测	rivet hole Inspection 铆钉孔检查	on the plant floor as: - robot end-effectors - 3D inspection instruments in 在工厂车间，如： - 机器人末端执行器 - 3D检测仪器
galvo scanner (GS) Probe 振镜扫描仪 (GS) 探测	surface scanning galvanometer probe 表面扫描检流计探头	countersink and rivet flushness Inspection 埋头孔和铆钉齐平检查	

* NOVACAM™ rotational probes come in diameters as small as 0.5 mm (0.02”)

NOVACAM™ 旋转探头的直径小至 0.5 mm（0.02 英寸）

** Detailed technical specifications are available upon request.

可根据要求提供详细的技术规格。

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