Application Note for
the Industry

3D Metrology for EDM and Laser Machining

with NOVACAM™ Non-Contact 3D Metrology Systems

Keywords: electrical discharge machining (EDM), micro-machining, spark machining, wire EDM, die-sinking EDM, laser drilling, geometric dimensioning and tolerancing (GD&T), micro-milling, micro-drilling, seal slots, cavities, blind holes, stepped holes, high-aspect-ratio, non-contact, automated non-destructive inspection, die metrology, in-process gauging

Introduction

As tolerances for EDM and laser machining grow tighter, so too grows the need to improve our capability to measure the dimensional and finish characteristics of machined workpieces. In many high-precision machine shops, rapid 3D metrology is now essential, and in-process inspection is increasingly the norm.

For such EDM and laser machining applications, NOVACAM optical 3D metrology systems provide just what is needed:

- Non-contact 3D surface measurements with 1 µm (40 µin.) axial resolution
- Very high speed of surface acquisition (up to 100,000 3D measurement points per second)
- Characterization of high-aspect-ratio features, such as deep and narrow EDM slots
- Measurement in hard-to-reach places
- Modularity and ruggedness to enable metrology both in labs and in high-volume automated production settings.

EDM Slots on Turbine Blades

Jet engine turbine blades are good examples of EDM-machined workpieces. The stator blade in Figure 1, for example, features EDM-machined seal slots about 30 mm long, 0.4 mm wide, and 1.8 mm deep. A rapid, low-density scan of each slot was acquired by NOVACAM raster-scanning system (SURFACEINSPECT™ system) in ~1 sec, providing thousands of 3D points for high-speed GD&T. The resulting point cloud, partly shown in Figure 2, can be compared to the original CAD specification file, with results either displayed as a colour-coded deviation map or output as GD&T measurements, tables with dimensions and tolerances, PASS/FAIL values, etc.

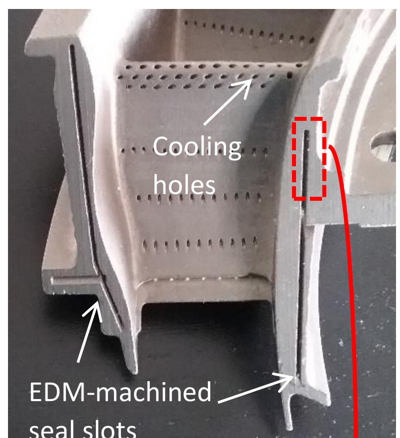

Figure 1: This stator blade features EDM-machined seal slots that are ~30 mm (1.2”) long, 0.4 mm (0.0157”) wide and ~1.8 mm (0.07”) deep.

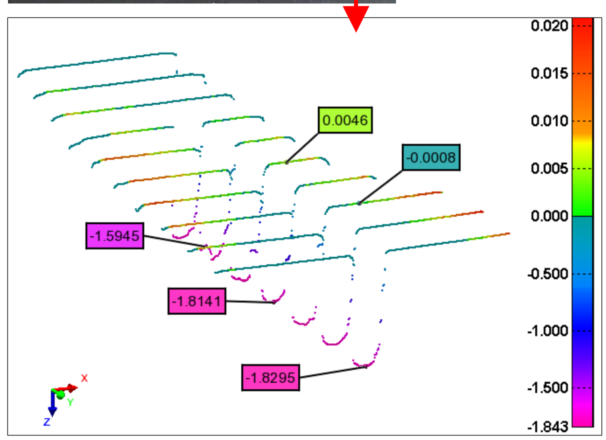

Figure 2: This detail of the EDM slot indicates the data density of the 3D point cloud: a height profile containing 400 3D points was acquired every 1 mm. The height values are relative to the EDM slot upper edge and are noted in mm.

Users may also select higher-density scans of the EDM cavity to allow for even more comprehensive examination. Figure 3 shows three alternate views of the above EDM slot segment that can be generated to support roughness calculations, detailed visual analysis, or automated defect detection.

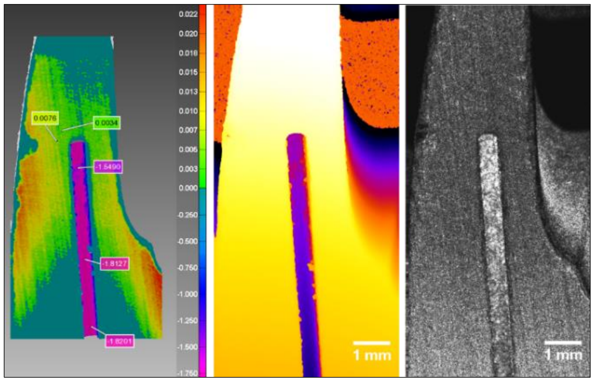

Figure 3: Alternate views of the same EDM slot resulting from higher-density scan. From left to right: top view of the slot and the surrounding surface with colour mapping of the depth; height image; intensity image.

Measuring EDM Graphite Electrodes

Measuring graphite electrodes used in the process of die-sinking EDM represents an alternative approach to measuring the quality of the EDM process. The wear or damage of these electrodes can be quickly and precisely characterized with the same instrument as the one used for EDM slot measurements.

Benefits of the Underlying Technology

The narrowness of the openings of many EDM slots and holes makes measuring their bottoms difficult or impossible with touch probes or with optical systems that rely on triangulation. The unique ability of NOVACAM 3D metrology systems to measure such high-aspect-ratio features stems from the underlying technology, low-coherence interferometry. The non-contact optical probes acquire surfaces by directing a beam of low-coherence light at the surface and capturing the light signal reflected back. Since the scanning is collinear – i.e., the emitted and reflected light travels along the same path – obtaining profiles of high-aspect-ratio cavities is not a problem.

The scanning speed of these systems is another crucial benefit where takt time is of concern. The optical measurements are acquired at up to 100,000 3D points second, enabling efficient in-process GD&T. Depending on the point density selected by the user, various workpiece surface characteristics (2D or 3D profiles, dimensions, flatness, roughness, etc.) can be determined and defects identified. When needed, even the thickness of semi-transparent materials such as coatings on EDM-machined components can be measured with the same instrument.

Choice of Probes and Scanners

Along with the interferometer, which is the core of its 3D metrology systems, Novacam has developed several models of non-contact probes and scanners to suit the varying needs of the metrology of micro-machining applications.

Galvo (raster) scanners (Figure 4) provide the most efficient line-by-line scanning of micro-machined surfaces. With these scanners, dimensional profiles of EDM- or laser-machined slots or holes on open surfaces are acquired in seconds. The cooling holes micro-drilled on the

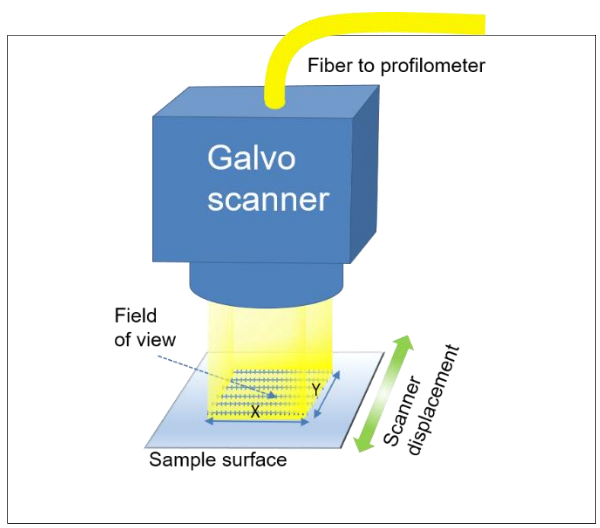

Figure 4: NOVACAM optical galvo scanner (GS) probes come in several sizes of field-of-view.

stator blade in Figure 1 were scanned by the same galvo scanner as the EDM seal slot. The point cloud obtained reveals the dimensionality of the cooling holes and crucial details of the micro-drilling process (Figures 5 and 6).

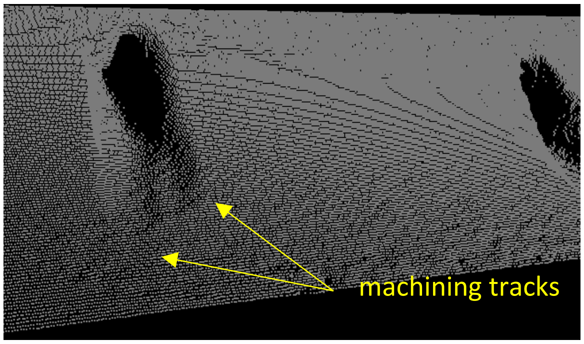

Figure 5: This high-density point cloud of the cooling hole opening (with a diameter ~.64 mm or 0.25") provides a clear view of the dual-channel diffuser formed by laser-drilling.

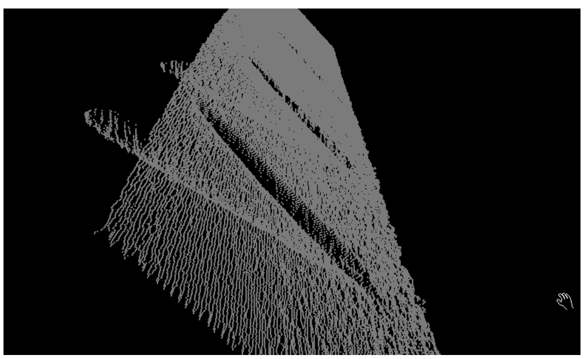

Figure 6: Partial view of the cooling-hole through-hole. The through-hole is shown as protruding below the turbine blade surface. The diameter and angle of central axis can be calculated. Profiles taken from multiple angles may be combined into a more complete image of the through-hole for CAD drawing comparison.

As an alternative to galvo scanners, Novacam also manufactures **optical probes** (diameters currently as small as 0.5 mm) and **rotational scanners** (spinning a probe at up to 1,800 RPM or 30 rotations per second) to measure EDM- or laser-machined features in hard-to-reach spaces. These spindle-like optical probes are narrow enough to reach inside bores, injection molds, or spaces such as the inner surfaces of jet engine stator blades (Figure 7). Dimensions, roughness, or defects of machined features on interior surfaces can therefore also be completely characterized (Figure 8).

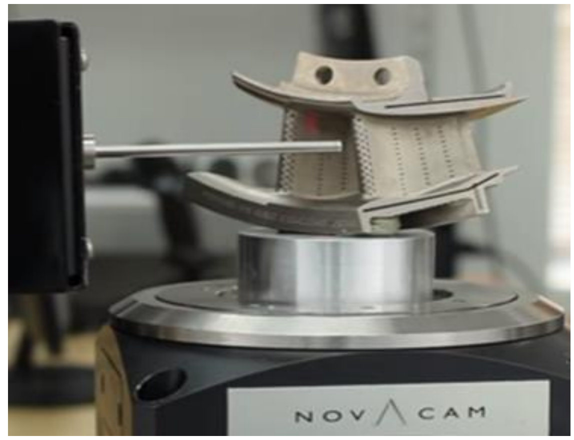

Figure 7: Novacam rotational scanner spins a small-diameter probe as it acquires the inside surface of a stator blade. The ID, including its cooling holes, is acquired as a dense spiral of 3D points.

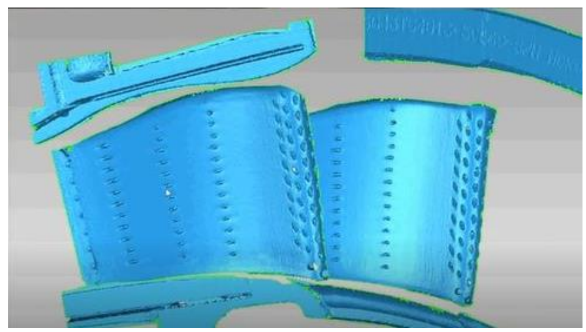

Figure 8: Complete 3D surface of the stator blade. Cooling holes and EDM slots on the inside and outside of the blade were characterized down to the micron.

Flexible Deployment & Support for Automation

NOVACAM 3D metrology systems are modular, meaning that the optical probe or scanner measuring the workpiece surface is a separate piece of hardware from the signal-processing interferometer. Connected with a fiber-optic cable, the components can operate several meters apart. As such, each probe or scanner is easily integrated as an end-effector with various displacement mechanisms (stages, robot arms, gantries) and can be deployed right on the shop or plant floor, integrated within CMM and CNC machines, and even in harsh environments.

Beyond Traditional CMM Metrology

Traditionally, measurements of EDM- and laser-machined workpieces have been obtained by contact CMMs or various manual gauges (pin gauges, etc.) upon completion of the machining or assembly process. Today, many facilities need to cut down their inspection cycle time below what contact CMMs permit. Some facilities also aim to improve their final workpiece quality by incorporating inspection right in the machining process, where adjustments to the machining are still possible and desirable to make. The aim is to lower the scrap rate, and improve quality and yields.

Addressing these needs, NOVACAM non-contact 3D metrology systems bring time and cost savings to many manufacturers. Given the systems' sampling speed that is thousands of times higher than that of contact CMMs, the GD&T inspection cycle is typically 2 to 4 times shorter, while the acquired 3D point cloud density is much higher. High-speed GD&T metrology can be incorporated right into the manufacturing process. The high speeds also improve the rate of carrying out higher-density scans required to obtain linear or area roughness measurements or to support automated defect detection.

Additional Return on Investment

With NOVACAM systems, multiple probes can be connected to the same profilometer and can work in parallel, giving clients additional ROI.

Conclusion

For high-precision inspection of EDM or laser-machined features, NOVACAM 3D metrology systems brings speed, micron resolution, and versatility of installation.

Novacam encourages managers and engineers in charge of EDM/laser machining and related metrology to contact us to discuss your applications and any particular challenges.

NOVACAM™ 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">Shop or plant floor / control room</td></tr>
<tr><td>Workstation computer</td><td>mini desktop-size PC or laptop</td><td colspan="2">Shop or plant floor / control room</td></tr>
<tr><td rowspan="4">Choice or combination of</td><td>front-looking probe(s)</td><td rowspan="4">- Automated metrology
- Near-line metrology
- Closed-loop manufacturing</td><td rowspan="4">On the plant floor as:
- robot end-effectors
- 3D inspection instruments in automated machining
- 3D-vision components in hand-held inspection tools</td></tr>
<tr><td>side-looking probe(s)</td></tr>
<tr><td>rotational scanner probe(s)</td></tr>
<tr><td>galvo scanner probe(s)</td></tr>
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*Technical specifications are available upon request.

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