High Precision Industrial 3D Metrology Technology for Aerospace Applications

Steve DeRemer
January 31, 2017
Contents

- Company introduction
- Self introduction
- 3D Measurement technology
- Structured Blue light technology
- 3D metrology applications
- 3D metrology processes
- ATOS – 3D digitizing & RE analysis
- ATOS – Inspection – Surface defect map
- ATOS – Inspection – Reverse projection
- Case study: NASA Resurrecting the F1
- Case study: DSR German Aeronautics and Space Research Center
- Turnkey Non-Contact Measurement and Inspection Integration into Industrial Processes: TRITOP, ATOS ScanBox
- Gom Inspect
Capture 3D, Inc.

- North American Partner of GOM GmbH Optical Metrology Solutions (Braunschweig, Germany)

- Over **10,000** GOM systems installed worldwide

- Capture 3D established in 1997
  - Costa Mesa, California (Headquarters)
  - Connecticut
  - Michigan
  - North Carolina
  - Washington

- Dedicated Automation and Support teams in Michigan facility

- Steadily growing and comprised of 60% engineers
Background: Steve DeRemer

Technical Application Specialist

Started with Capture 3D in 2010

20+ year career in the metrology field utilizing various types of metrology technologies

Tasked with helping companies optimize manufacturing processes with metrology, identify unique applications, and collaborate with companies on process improvement techniques.

MBA - Walsh College of Accountancy and Business
BS Computer Aided Design - Eastern Michigan University
3D Measurement Technology

Contact
- Coordinate Measuring Machine (CMM)
- Measuring Arms

Non-Contact
- CT (X-Ray)
- Ultrasound
- Laser Scanners
  - Laser Scanning Head Add-on

Structured Light
- Blue light 3D scanners
- White light 3D scanners
- Optical metrology/Optical 3D scanners
- 3D digitizers

ATOS Touch Probe Add-on
Tactile vs. Optical Non-Contact Metrology

**Tactile methods**

- **Advantages**
  - Established technique
  - Quick, with small number of inspection features

- **Disadvantages**
  - Slow on free-form surfaces
  - Slow for small number of inspection features

**Optical methods**

- **Advantages**
  - Fast, **full-field** measurement
  - Complete data capture
  - Mobile – moves toward the object
  - Flexible – different object sizes
  - No fixture for stable components needed
  - Variable alignment

- **Disadvantages**
  - Long running times, little data
  - Component holders needed
  - User-dependent alignment
  - Often can’t be moved (non-portable)
Tactile vs. Optical Non-Contact Metrology

- Measurement of inspection features according to drawing
- Evaluation of the 3D point cloud
Industrial 3D Coordinate Measurement with ATOS

**Stereo camera system**

Using the triangulation principle in conjunction with the fringe projection technique, precise 3D coordinates are captured by the stereo camera system.

Triangulation principle + Fringe projection technique = Stereo camera system
Industrial 3D Coordinate Measurement with ATOS

Process reliability in measurement operations

- Online tracking of sensor position
- Unique transformation of single measurements
- Online monitoring of sensor/object movement and ambient light
- Online monitoring of sensor calibration
- Measurement data captured without user intervention
- Prevention of measurement errors
- Verifiable measurement accuracy

Dynamic referencing results in process reliability during measurement operations

= accuracy
GOM reference point system

Strategies for transformation of single measurements

Measurement without reference points

Measurement with reference points
GOM reference point system

**Strategies for transformation of single measurements**
Both variants can be used in the GOM software

- Only possible with sufficient object geometry
  = no process reliability

  Measurement without reference points

  Measurement with reference points

- Also possible on continuous surfaces
  = process-safe measurement strategy
GOM reference frame

Reference frames are designed for collecting reference points easier and faster

- No need to put reference points on parts
- Suitable for small to large parts
- Reduced preparation time
- Quick swapping of parts
- Programmed to acquire reference points only
Innovative Precision Metrology

High Quality Structured Blue Light 3D Scanners

Aerospace certified accuracy

Advanced hardware and high quality optics coupled with intelligent software

*Triple Scan Functionality* – 3 Sensors in 1 – Reduces # of scans, improved data on shiny surfaces, and better measurement in deep pockets.

Rapid high definition data acquisition

Various configuration possibilities from portable to automated

ATOS Triple Scan

ATOS Capsule

ATOS Compact Scan

ATOS Core *Available with Triple Scan functionality

TRITOP
Innovative Precision Metrology

Structured Blue Light 3D Metrology, Inspection, Photogrammetry, and Automation

- Shortened measurement setup and data collection time allows companies to focus on true process optimization.

- A high quality color map inspection data on the part, mold, tool, and/or die allows companies to quickly apply the optimal corrective action and accurately predict trends.

- Speed up time to market, eliminate iterations and save an enormous amount of costs that were once being spent on rework and waste.

ATOS

Full-field 3D Digitizing

TRITOP

Mobile Optical CMM

Software

Inspection & Reporting

Automation

Automation – ATOS Power

Specifically designed for air and ground power generation companies to rapidly scan and inspect parts for performance and product improvement. Solutions aide manufacturing companies in maximizing time efficiency while reducing costs.
Improving 3D Metrology Applications

- FAI / Quality Control / Root Cause Analysis
- High volume repetitive measurements (trending)
- CFD/FEA /CAE Analysis
- Rapid and Additive Manufacturing
- Adaptive Machining
- Determinant (Digital) Assembly form, fit, and function analysis
- Virtual Assembly Alignment and Predictive / Custom Shimming
- Wing to body / Fuselage mate
- Engine pylon to Wing mate
- Thermal coatings thickness / chemical milling material removal measurements
- Tooling Quantification, Finger Printing and Wear Analysis
- Material characteristic quantification
- e.g. Forming and Stamping – Part Springback
- 1st time digital definition / Reverse Engineering
Improving Engineering Processes

Share knowledge throughout the enterprise reducing duplication of effort and improving collaboration between departments and suppliers.
Design

Reverse Engineering of Single Components
Rapidly scan components and generate an accurate 3D digital definition to support CAD model creation, capture design iterations, and archive “as manufactured” condition.

Reverse Engineering of Complex Shaped Components
Scan complex shaped components quickly and easily without costly fixturing set-ups. ATOS scanner’s high resolution supports the capture of small features such as edges and fillets.

Small Parts Scan
The ATOS 3D scanner’s ability to be configured to various size measuring volumes supports the accurate scan capture of very small features such as edges, fillets, and rounds.

Extra Large Parts Scan
Rapidly measure large turbine buckets to full size aircraft while maintaining a high level of data accuracy. ATOS system flexibility supports extra small to extra large scan projects.
Analysis

3D First Article Inspection
Automatically compare your part’s scan data to the CAD model via an easy to interpret visual 3D color inspection map. Instantly see where the problematic areas exist.

Improve Product Performance
Calculate the nozzle throat total airflow volume by finding the minimum distance between the trailing edge of each vane and the face of the adjacent vane.

Ceramic Cores Analysis
Inspect core dimensions, shrink rates, trip strips, and blisters to tooling to effectively modify molds/tooling for accurate part manufacturing.

Turbolator Measurements
Scan complex and small turbolator features. Measure tight areas between blades.

Digital Assembly
Accurately compare scanned components and assemblies vs. CAD. Interrogate mating components to solve assembly, form, fit and finish issues.

Overall System Performance Improvement
Create an “as manufactured” digital assembly, instead of CAD nominal. This digital definition can be utilized for overall system performance comparison, analysis and optimizations.

Dimensional Analysis (2D)
Compare “as manufactured” part scan data to 2D drawings for inspection analysis.

Tool Path Optimization
Directly mill from ATOS point cloud data to accurately create tool cutter paths. Broken dies can be duplicated quickly without having any surface reconstruction.
Production

Part Verification
Fast measurement of complex parts delivers accurate and robust dimensional inspection reports including complex features, surfaces, holes, and edges.

Coating Thickness Measurements
Quickly measure before and after coating processes to determine coating thickness without sacrificing parts.

Combustor Measurements
Rapidly measure entire component and extract feature information such as hole diameters, vectors, and locations automatically.

Impeller Wheel Balancing
Scan and calculate center of gravity on castings to position part optimally for “best balanced” machining. Minimize the machining away of material which can be used for future refurbishing.

Part and Tool Wear Trends
Identify and document part and tool wear trends. Robust color map deliverable highlights potential problematic areas (part shrinkage, airfoil twist, and tool/mold wear).

Simplified Fixturing
Save time and money by eliminating high precision expensive fixturing. Part position in fixture is not critical providing a simple set-up. Shape and position of part are automatically transformed into a pre-defined coordinate position.

Repeatable Inspections
Measure quantities of parts fast and accurately without operator variability.

Aerospace Certified
Solutions certified within propulsion/aerospace companies per VDI standards.
Measure and Inspect Airfoil Blades and Vanes for Repair
Measure damaged blades to determine extent of damage and optimize repair process. Inspect repaired blade to verify part conformance.
ATOS - 3D Digitizing –
High Quality Mesh processing
ATOS - 3D Digitizing –
Small *As Manufactured* Digital Definition
ATOS
Advanced Technology with High Resolution

Each ATOS system has a various range of volumes which can be interchanged to capture a part’s finest details.

Up to 5, 8, or 12 Million Points Within a Volume or Single Scan

1.5 in x 1.1 in x 1 in
Flexible fields of view

Swapping out lenses
Measurement Area Size and Resulting Scan Data Density

Larger Field of View

Smaller Field of View
ATOS - 3D Digitizing – Full size and scale models
TRITOP Digital Photogrammetry

- Non-contact wireless digital photogrammetry system
- Can be used in conjunction with ATOS, or as a stand-alone coordinate measuring system
- High accuracy especially for larger objects
- Independent of environment conditions
TRITOP – Photo Collection
Images are then ‘bundled’ into a triangulated 3D constellation
TRITOP (Photogrammetry) Output
ATOS XL (ATOS + TRITOP)
Scanning with fringe projection
ATOS
Automatic referencing of individual scans
ATOS + TRITOP
Automatic referencing of individual scans
ATOS + TRITOP
Automatic referencing of individual scans
ATOS – NRC C130 RE Analysis
New software functionalities:

- Surface Defect Map
- Reverse Projection
Detection of surface defects based on meshes
ATOS – Inspection - Surface defect map

Aircraft panel - Surface comparison with 0.4 mm tolerance

Aircraft panel - Surface defect map with 0.4 mm tolerance
“Reverse Projection”

Using the ATOS sensor as both a data collection tool as well as a method to convey the results of analysis.
ATOS – Inspection – Reverse projection

ATOS Triple Scan sensor is used to collect the **3D scan data** describing the part geometry.

The collected scan data is then **overlaid with a nominal CAD file** (in this case, a best-fit plane).

A **comparison** is performed between the nominal geometry and the 3D scan data, identifying an area which is outside the designated tolerance value (dark blue).
ATOS – Inspection – Reverse projection

A curve is created by picking points along the boundary of the area that is shown to be out of speculation.

The created curve is then ‘reverse projected’ back onto the physical part using the DLP Projection within the ATOS sensor.
NASA brought the F1 “moon rocket” engine back to life

NASA and Shape Fidelity worked together to construct a complete and accurate digital assembly of the legendary engine from the Saturn V.

A high-resolution **ATOS 3D scanning with TRITOP photogrammetry** was used to,

- Create a **digital assembly** of the entire engine
- **Scan** and model all of the parts
• The complete assembly was scanned and the positions of small optical targets placed on each part were captured with a photogrammetry system, TRITOP, creating a constellation of points representing the precise, as-assembled positions of each part.

• Each part was then removed and scanned individually
Resurrecting the F1 - Scanning

- The same photogrammetry targets were integrated with each scan.

- These targets enabled each individual part to then be re-assembled to its proper position in the digital assembly.
Resurrecting the F1 - Results

- The final composite model, accurate inside and out, made up of all the rocket’s thousands of pieces carefully fitted together.
DLR study – Laminar Flow Structure Feasibility

- DLR (German: Deutsches Zentrum für Luft- und Raumfahrt e.V.,) is the national aeronautics and space research center of the Federal Republic of Germany.

- R&D in aeronautics, space, energy, transport and security for national and international cooperative ventures

- Studied the effects of surface geometry on flow resistance
  - Using Advanced Technology Research Aircraft (ATRA)’s Airbus A320 tailplane
  - Improving *laminar vs turbulent airflow*
  - To improve fuel efficiency
  - To find eco-friendly production method
Used GOM’s optical 3D measuring systems, **ATOS and TRITOP**, for measurement and testing.

Goal was to improve the aerodynamics of the aircrafts and optimize the geometry by producing as little flow resistance as possible.

- The first measurement data provided a precise representation of the wing geometry
- The wing was further adjusted in an iterative process in order to represent the displacement of the transition point.
- During the actual flight testing, thermographic measurements were carried out. Five flight tests have shown a positive effect on the geometry change
- As turbulent areas cool down faster, significant thermal differences become visible on the infrared image and were visualized with 3D scanner
- 1.5m x 3m area was scanned in under 15 minutes
- The measurement data was then compared to the component’s initial state and perform a full inspection of it with the ATOS inspection software.
Findings suggest that it is possible to,

✓ Improve the **performance** of aircraft

✓ Allow for more **energy-efficient** production

✓ **Reduce** environmentally harmful **carbon dioxide emissions**

This qualitative knowledge will be applied to the wing and fuselage production in the future.
ATOS ScanBox Automation

ATOS automation systems offer:

- High measuring speed and throughput
- Repeatability
- Suitable for any production environment

ScanPort
ScanBox 4105
ScanBox 5108
ScanBox 5130
ScanBox 6130
ScanBox Series 7 & 8
ATOS ScanBox Automation

**ATOS automation systems offer:**

- High measuring speed and throughput
- Repeatability
- Suitable for any production environment
Automated Measurement Solution: Double robot cell
Automated Measurement Solution: Double robot cell
Free GOM Inspection Software

Free inspection software allows you to:

✓ Perform versatile inspection analyses
✓ Process mesh from scan data
✓ Create and export reports
✓ Improve communication between those who measure, inspect, draw and produce
✓ Not only analyze the ATOS data, but also 3D point clouds of whitelight, laser and CT scanners
✓ Import, process and analyze everything in one, free software package

Visit [www.capture3d.com](http://www.capture3d.com) for download and more information
Capture 3D – Customer focused. Precision driven.

Thank you for your attention.

info@capture3d.com
www.capture3d.com