Adaptive Machining for High Precision Fabrication

Radu Pavel, Ph.D.
Chief Technology Officer

Castrol

OPTIS

A JOINT VENTURE WITH TechSolve

Outline

1. About OPTIS
2. How does Adaptive Machining work?
3. The Benefits of Adaptive Machining
4. A Case of Adaptive Machining
5. The Future of Adaptive Machining

Who Are We?

OPTIS is a Joint Venture between **TechSolve** and **Castrol,** combining unique capabilities that deliver transformative **efficiency programs** for manufacturers.

TechSolve + Castrol = OPTIS

TechSolve expertise:

- One of the foremost US authorities to improve machining operations and manufacturing process
- Cincinnati, Ohio based with 40+ Engineers, PhD's, Chemists, Master Black Belts, and Physicists
- For over 30 years, has provided organizations of all sizes with true tangible benefits rather than just advice

Castrol OPTIS A JOINT VENTURE WITH TechSolve

What We Do?

MANUFACTURING PROCESS OPTIMIZATION

Process Improvements – Not just Lean, we apply deep expertise and analytic tools to identify and eliminate manufacturing process wastes.

Machining Efficiency – We 'go inside' the machines (lath, mill, grinding) with profound application knowledge to increase cycle times, reduce scrap rates and lower operating costs.

Machine Monitoring – Our monitoring solution **Opti**Vue™ will visualize and optimize machine performance

SUPPLY CHAIN & PROCUREMENT SOLUTIONS

Supply Chain Development – Optimization across supplier groups to individual supplier performance

Part Cost Reduction – We apply proprietary 'should cost' analytics and provide what is needed to optimize how a part is produced whether it is being made in-house or procured.

Castrol

OPTIS

A JOINT VENTURE WITH TechSolve

Machining Lab Capability

CNC machining centers
- Turning
- Milling
- Grinding
- Gun drilling
- Honing
- Additive Manufacture

Data acquisition systems
- Cutting forces (Kistler)
- Power
- Vibration
- Machine monitoring

Microscopy
- Traditional optics
- Digital microscope

Other equipment
- Hardness testing
- Surface finish measurement
- Fluid testing facility
- Tooling evaluation

Major Equipment List
- Mazak Integrex i200S Mill Turn
- Makino V55 - 3 Axis VMC w/ 20K spindle
- DMG DMU-50 - 3+2 Axis VMC w/ Siemens 840D CNC & through-spindle coolant
- DMG DMU-70 eVo Linear - 5 Axis VMC w/ Siemens 840D & 580 psi through-spindle coolant
- Hardinge Cobra 65 – 2 Axis turning center w/ Fanuc 21T & Bar Feed
- Milltronics HMC35 - 4 Axis HMC w/ Fanuc 0iMC
- Chevalier Smart B1224II CNC Surface Grinder
- Sheffield Cordax D-8 CMM
- Kistler Milling and Drilling Dynamometers /w National Instruments data collection
- Keyence VHX Digital 3D Microscope
- Hybrid machining center, Additive & 3-axis milling

Allows OPTIS to replicate most processes without interrupting your production!

Castrol

OPTIS

A JOINT VENTURE WITH TechSolve

Adaptive Machining

Why, How and Case Study.

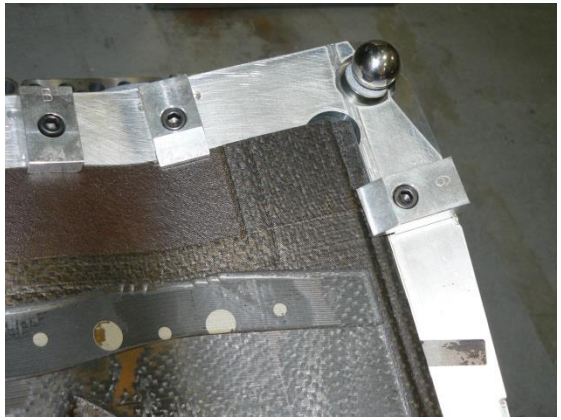
Castrol

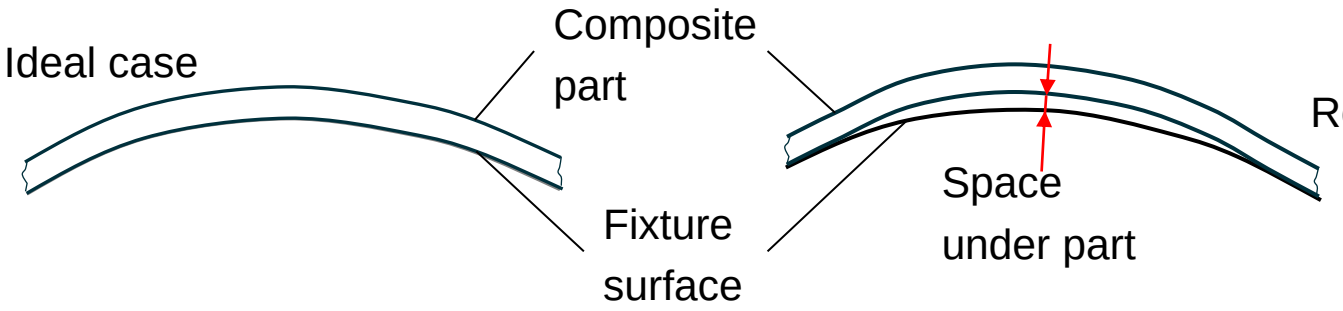
OPTIS

A JOINT VENTURE WITH TechSolve

The Challenge

- Near net shape part variability - increased part-to-part differences vs. traditional parts
- Bulk Residual Stresses can lead to distortions before and after machining
- Thin Walled Parts - Tend to deflect under the clamping forces
- Misalignment plus combinations of distortions on machining fixture are common





Problem Definition

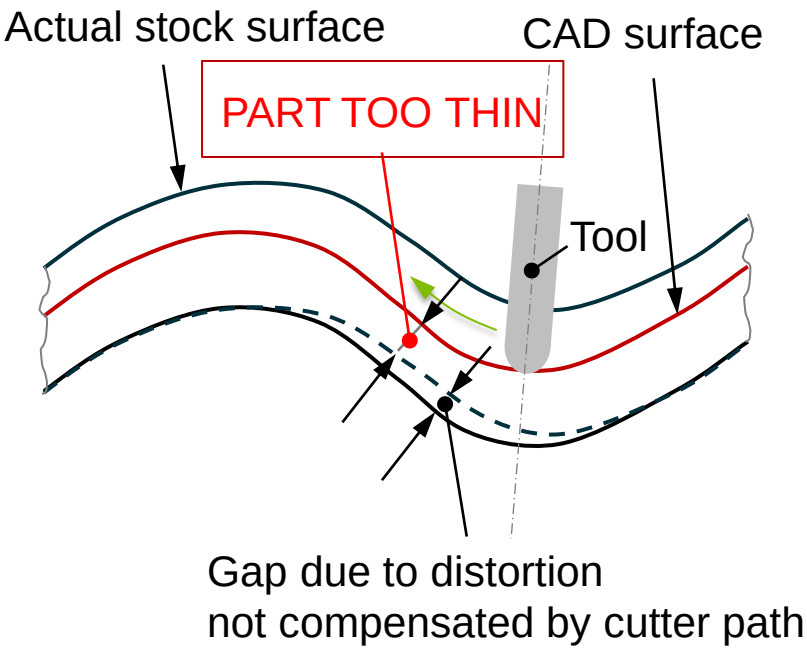
- Due to part and fixturing distortions and deviations, the cutter path generated using a CAD 3D model fails to generate the specified dimensions.

- Parts require post process re-work and added inspection time. This causes:
  - Increased cycle time
  - Lengthy delivery times
  - Lower production rates
  - Higher production costs

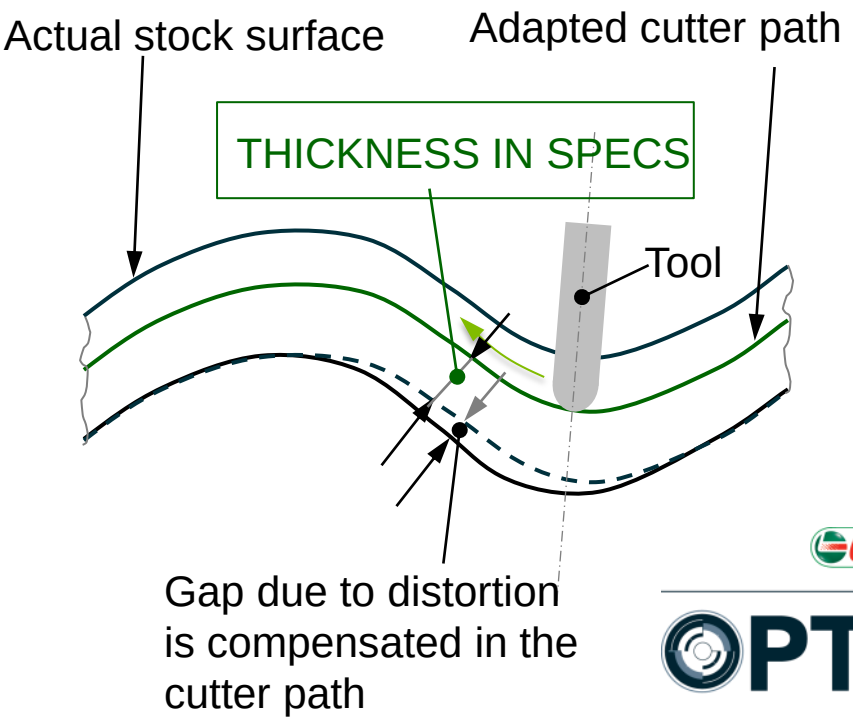
The Adaptive Machining Approach

A concept that represents the adaptation of the cutter path to the actual shape and position of a part in the machining space — working with a part based on how it actually exists in reality not in the virtual CAD space.

Non - Adaptive



Adaptive



Benefits of Adaptive Machining

Adaptive machining can compensate for part-to-part deviations and inaccurate clamping positions and can also be applied when the exact starting shape is unknown following near net shape manufacturing processes, such as casting and forging, or imprecise repair techniques, such as welding.

Benefits:

- Reduces or eliminates scrap
- Increases part quality
- Reduces cycle time
- Lowers production costs
- Shortens delivery times

Often taken for Adaptive Control

- Adaptive control systems continuously monitor the cutting conditions in real time and provide automatic cutting parameter adjustments to adapt to the dynamic changes that occur during cutting.
- A typical adaptive control system monitors the power or cutting force of a cut in real time and adjusts the feed rate in order to obtain optimized cutting conditions.

Adaptive Machining Project

Objective:

- To identify, integrate, and demonstrate a combination of commercial off the shelf (COTS) technologies that creates an Adaptive Machining capability

Challenge:

- Using new technology for 3D part geometry capture, develop a procedure for adaptive machining of composite parts

Benefits:

- First part, and every part, will meet the dimensional, tolerance, and specifications in a production environment.

Castrol

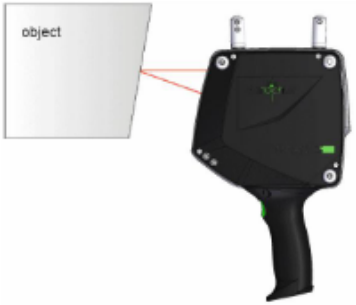
OPTIS

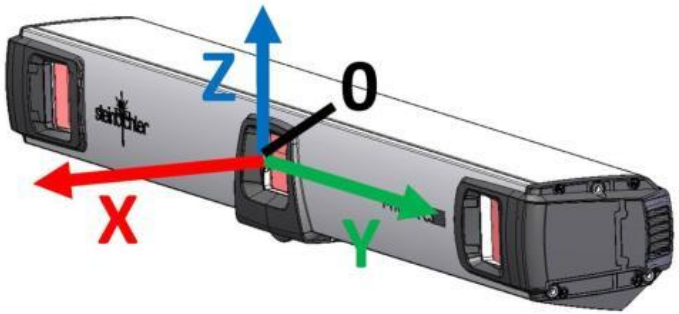
A JOINT VENTURE WITH TechSolve

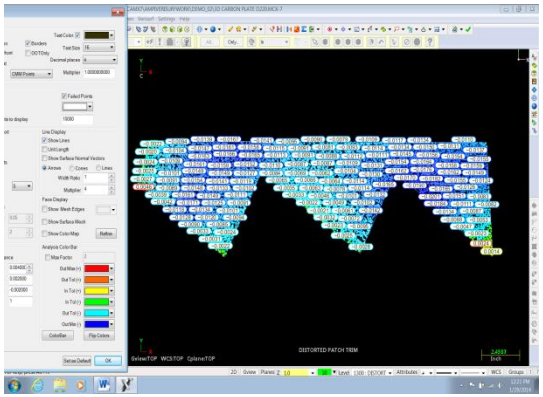
Hardware and Software

Adaptive Machining (AM) approach makes use of:

- a laser and tracker system: Steinbichler's T-Scan
- a point cloud manipulation software: Verisurf
- a procedure developed for identifying the finished workpiece top and bottom surfaces







Approach

Sensor system	Used to measure part thickness and capture the 3D profile of the surfaces
Point cloud	A point cloud is output by the sensor system (Steinbichler T-Scan) and is captured/imported by the metrology software (Verisurf)
3D Imaging & Metrology software	This software package (Verisurf) is used to process the point cloud captured with the sensor system (T-Scan) to extract dimensional and position information
Custom program	This program is calculating the position and shape of the finished surface
CAD/CAM	This software package (MasterCAM or CATIA) is used to generate the adapted NC cutter path.

Castrol

OPTIS

A JOINT VENTURE WITH TechSolve

Scanning and Alignment in Verisurf

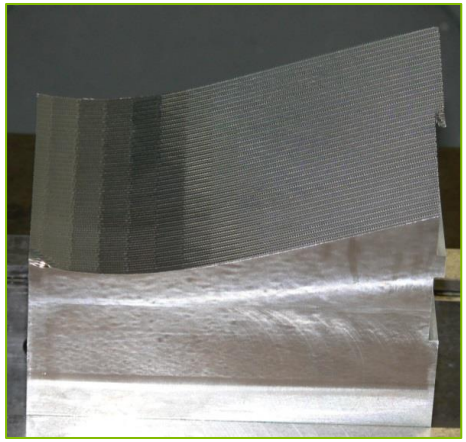
- Scanning
  - Workpiece
  - Fixture
- Alignment procedure includes:
  - Editing of the point cloud to: delete unnecessary data, trim outliers, filter remaining point cloud and select the areas necessary to generate the datum elements
  - Conduct alignment using Verisurf functions
  - Associate each point cloud to its corresponding alignment

Scanned Point Clouds to Mesh

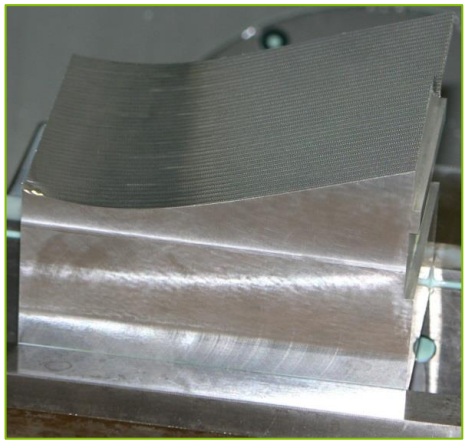
- Create Mesh from Scanned Point Clouds – Create a 3D mesh for each of the exported analysis point clouds
- Smooth and extend mesh if necessary
- For each mesh, surfaces can be created using various functions:
  - Auto-Surface,
  - Surface Patch, and
  - Lofted Surface
- Generate CAD representations of actual surfaces
- Calculate position of finished surface
- Generate adapted cutter path using MasterCam

Procedure Refinement

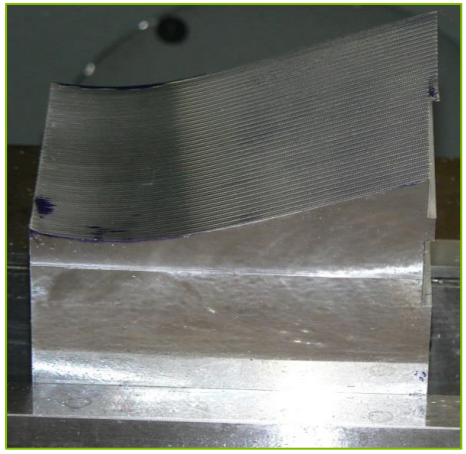
Mesh based CNC cutter path; no special CNC functions used



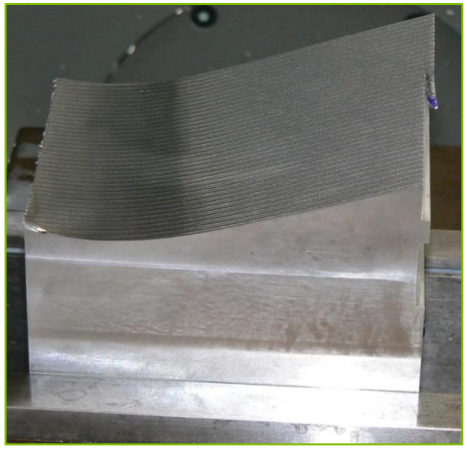
Mesh based CNC cutter path; special CNC smoothing function used



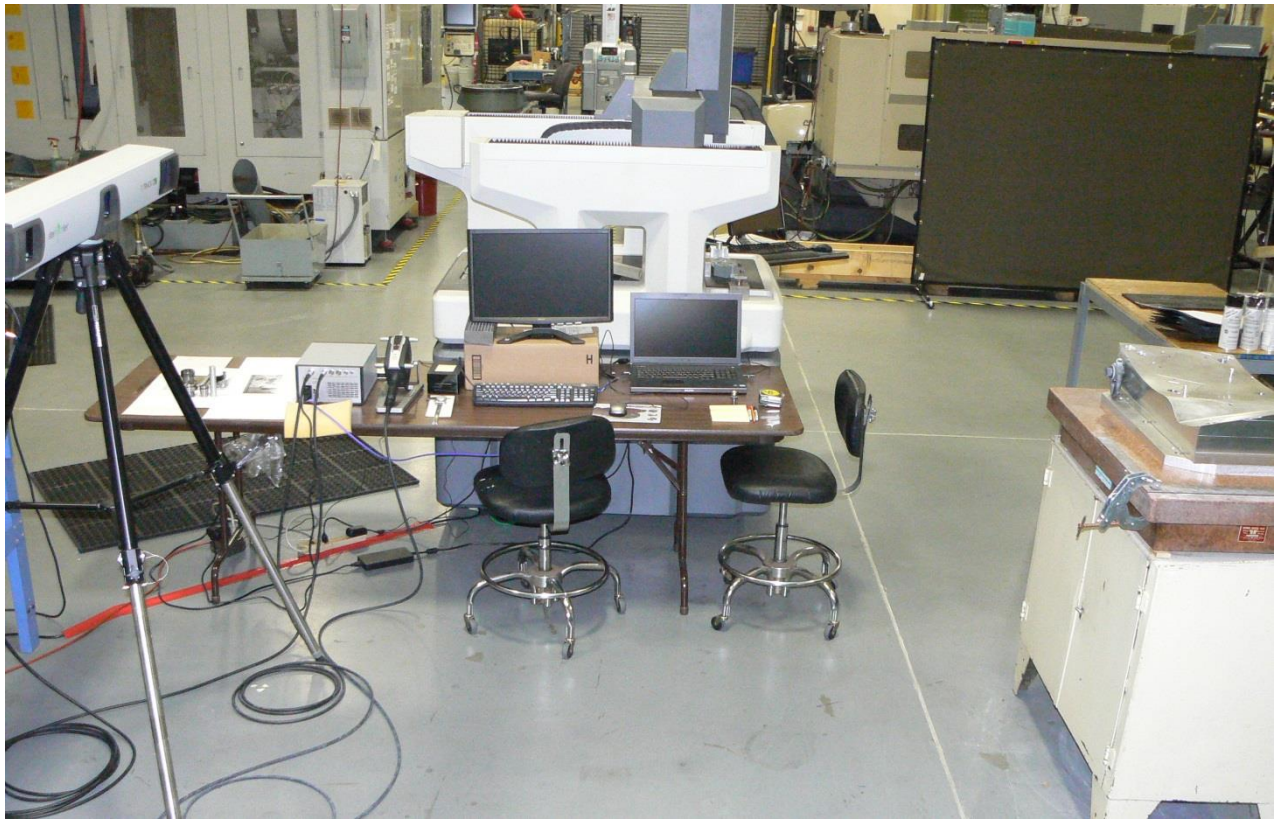
Surface Patch based CNC cutter path; special CNC smoothing function used



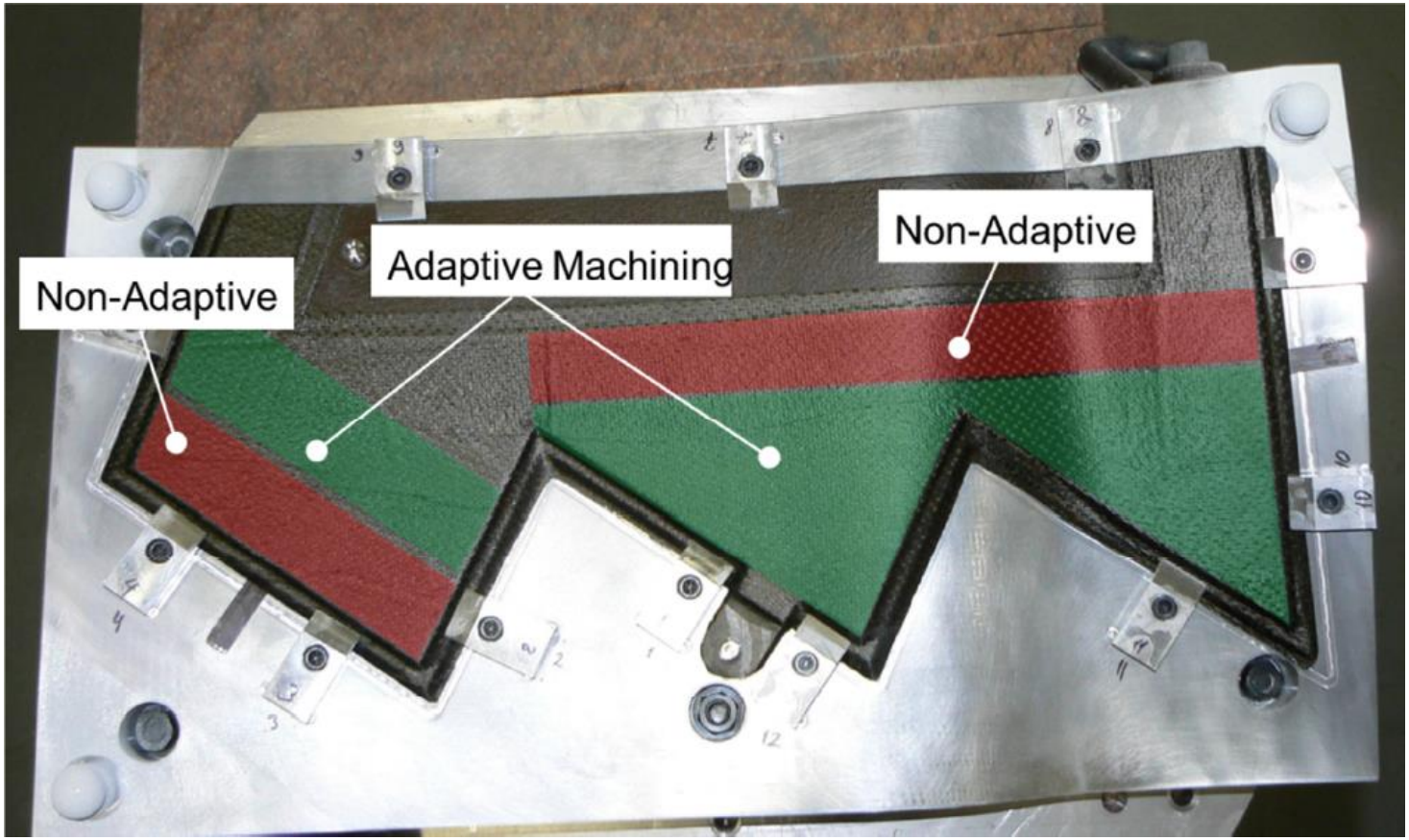
Auto-Surface based CNC cutter path; special CNC smoothing function used



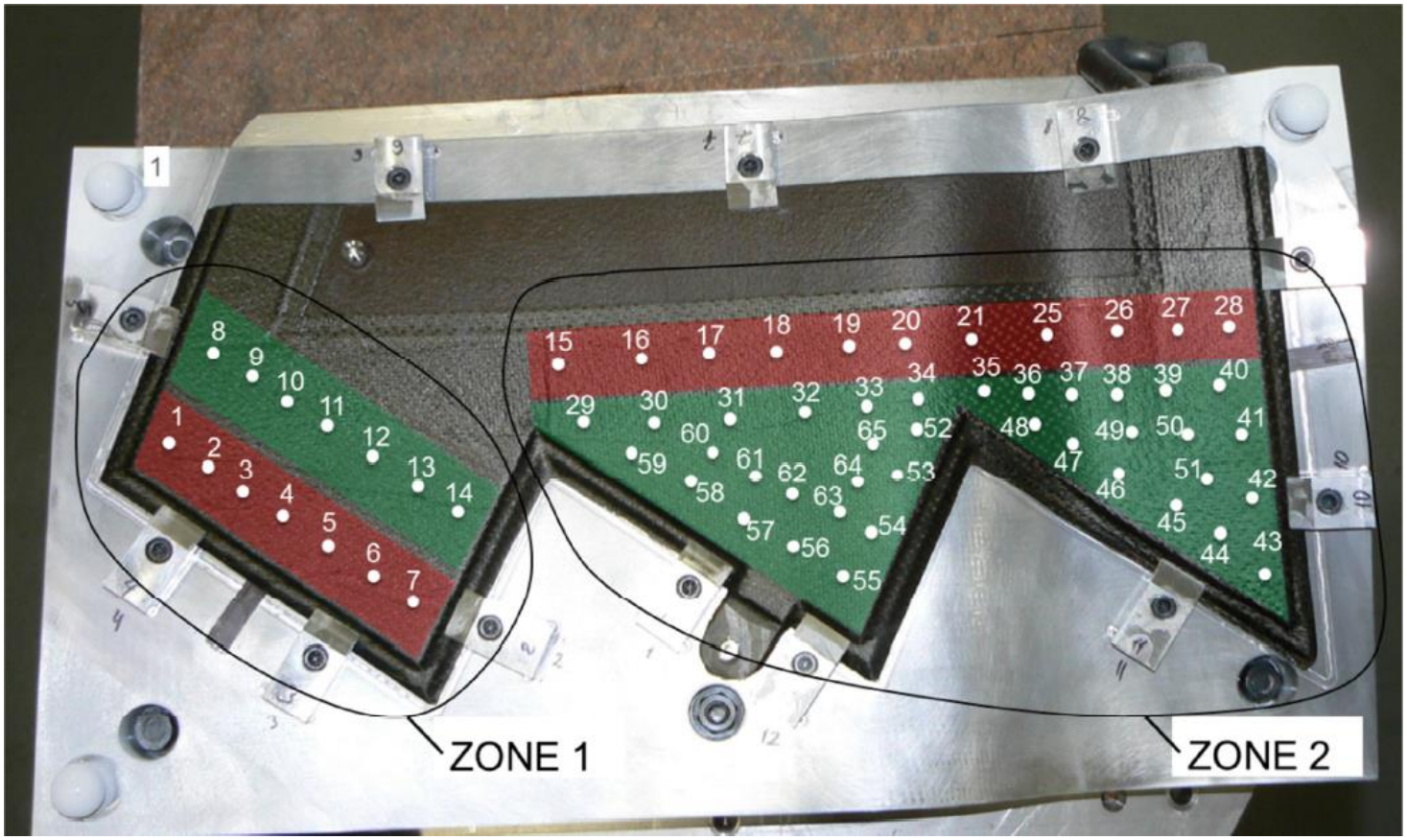
Work Area



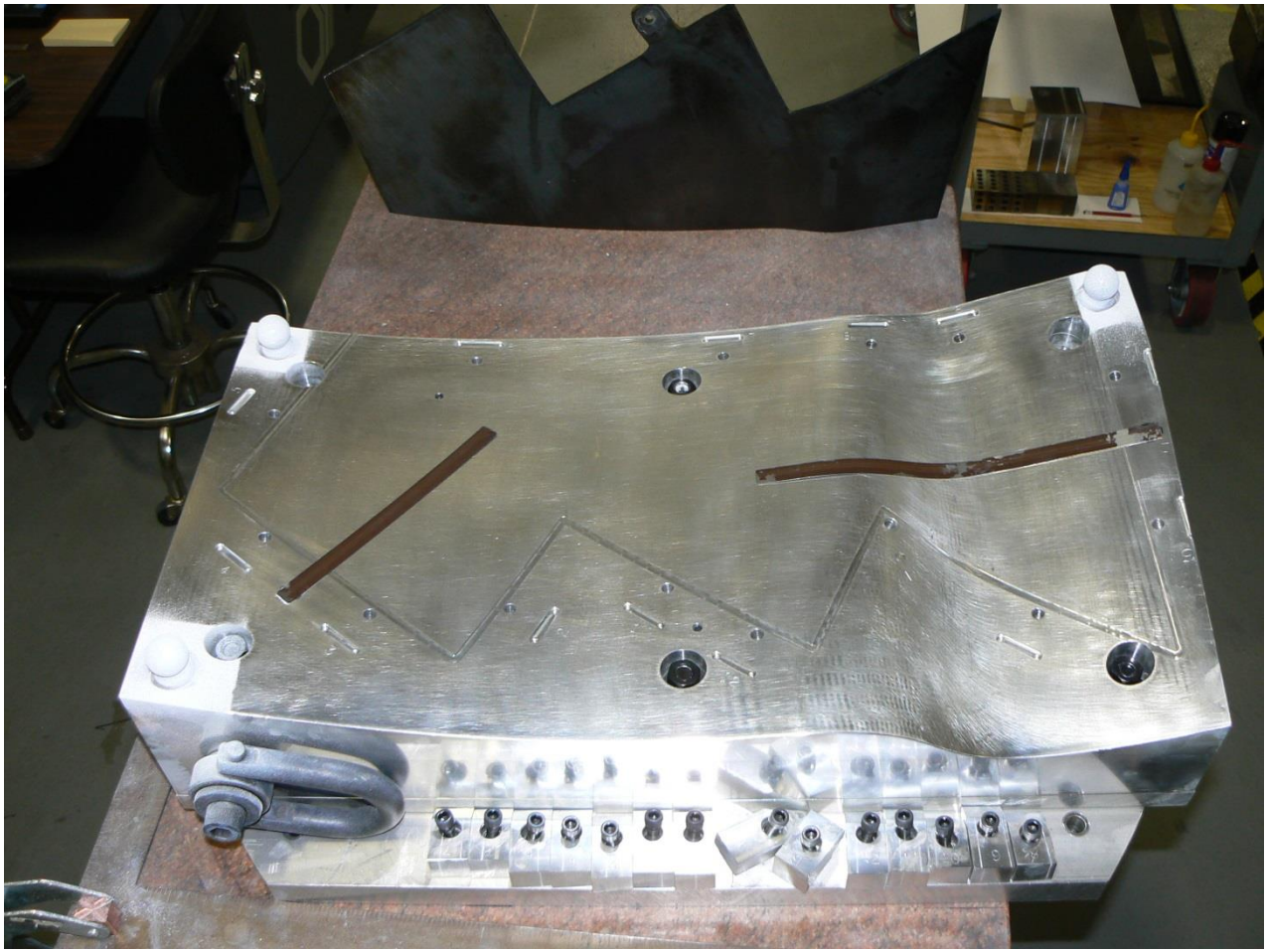
Demo Part - Areas Investigated



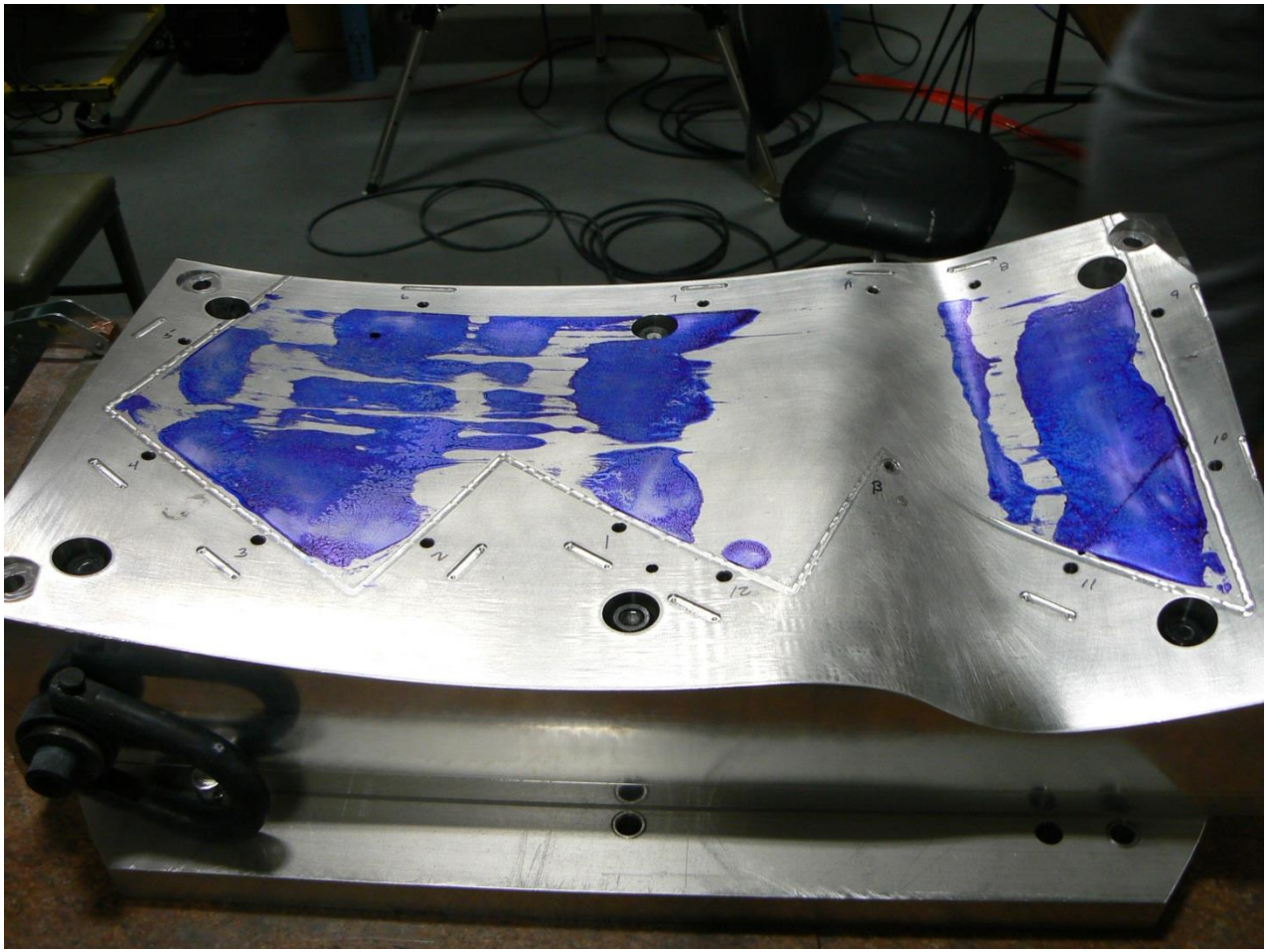
Demo Part – Verification Points



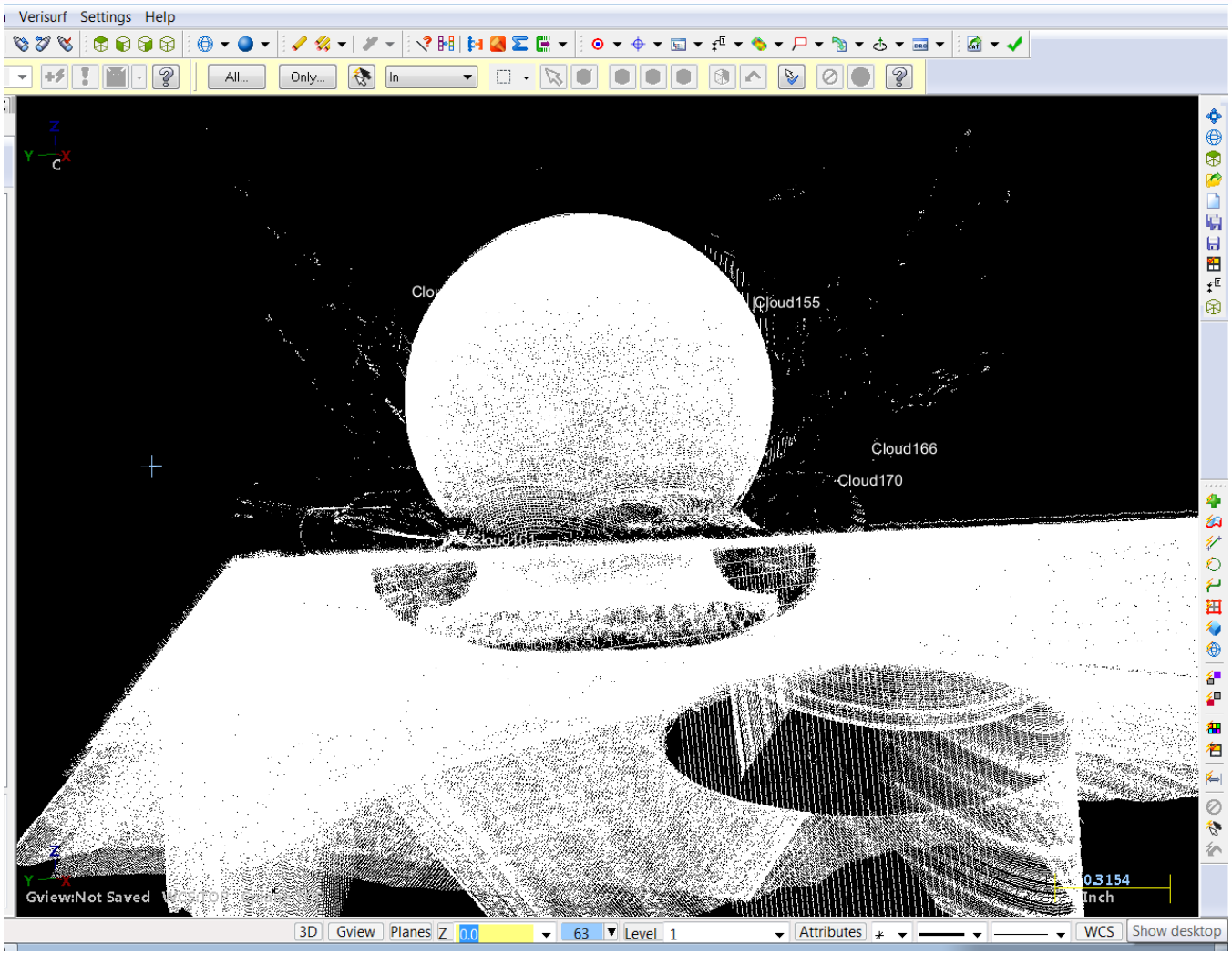
Fixture with Shims



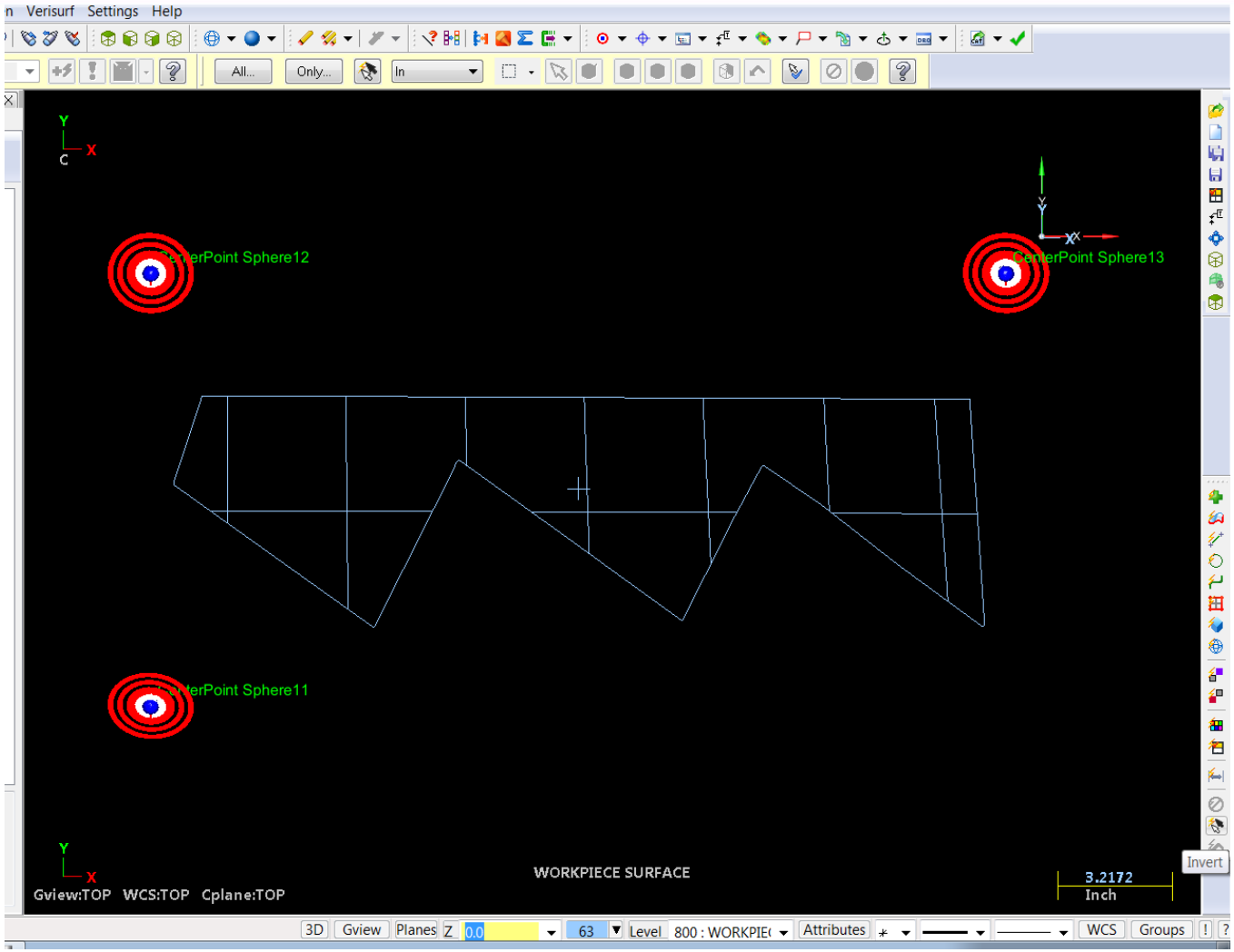
Blue Ink Test



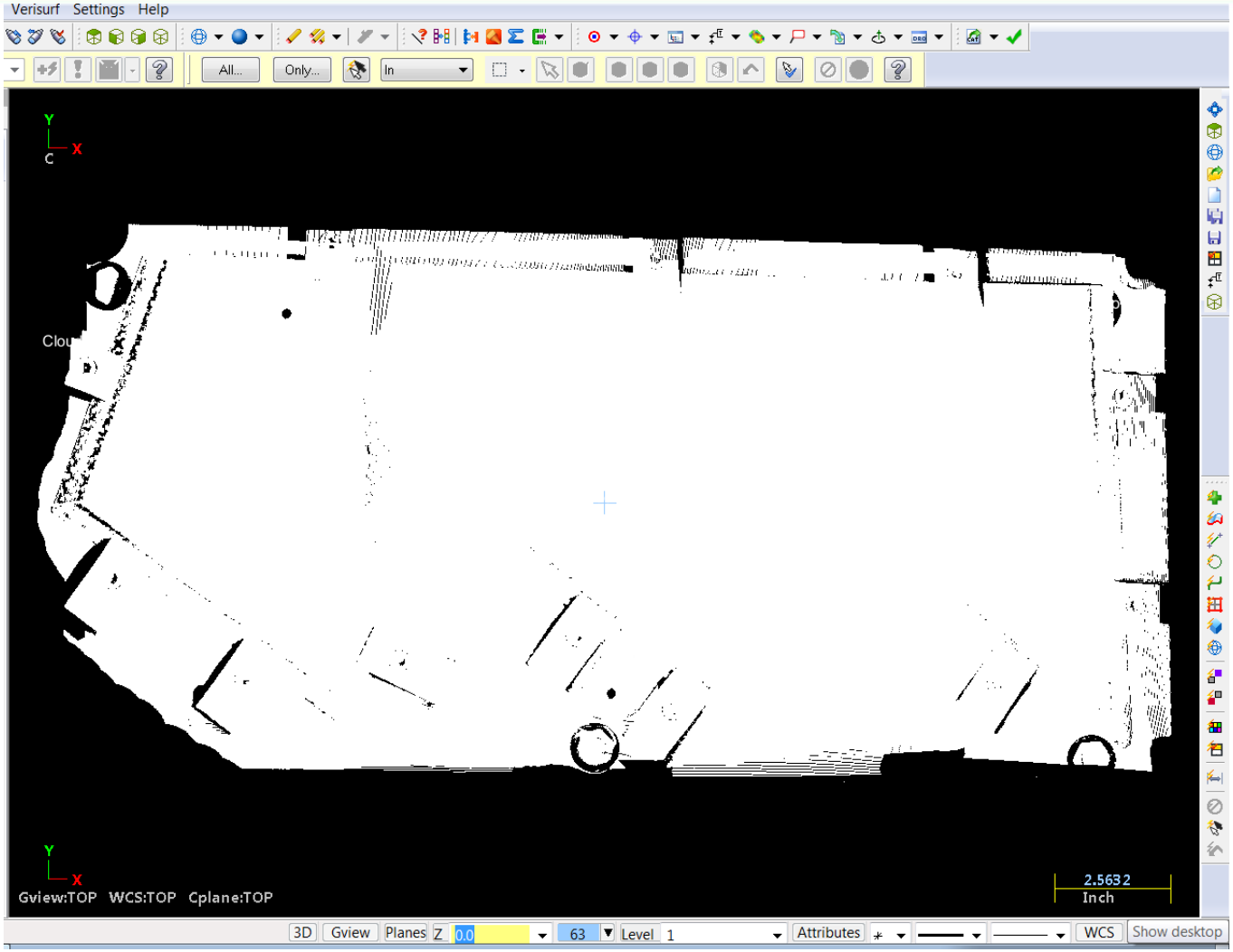
Spheres Scanning and Editing



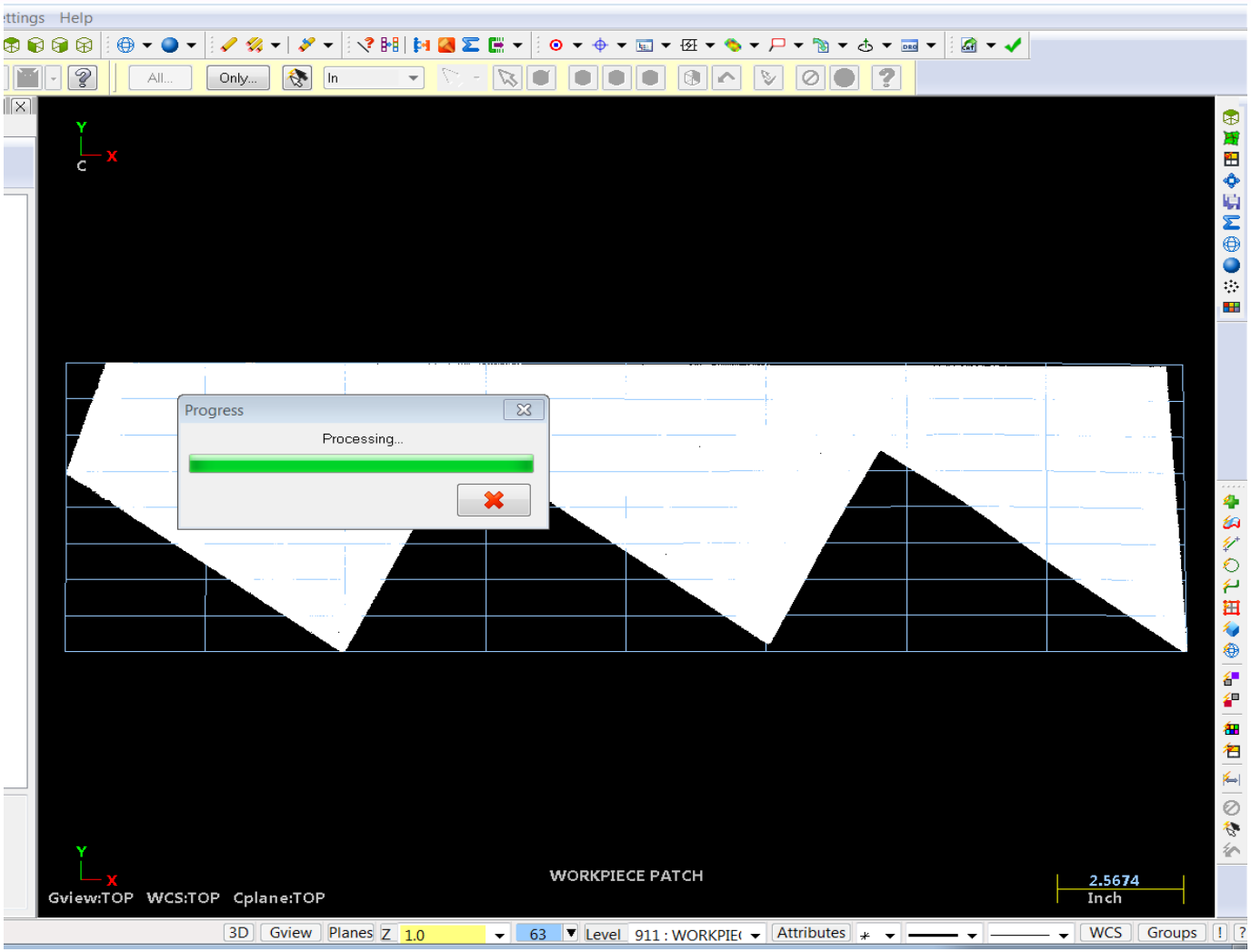
Alignment Using Tooling Balls



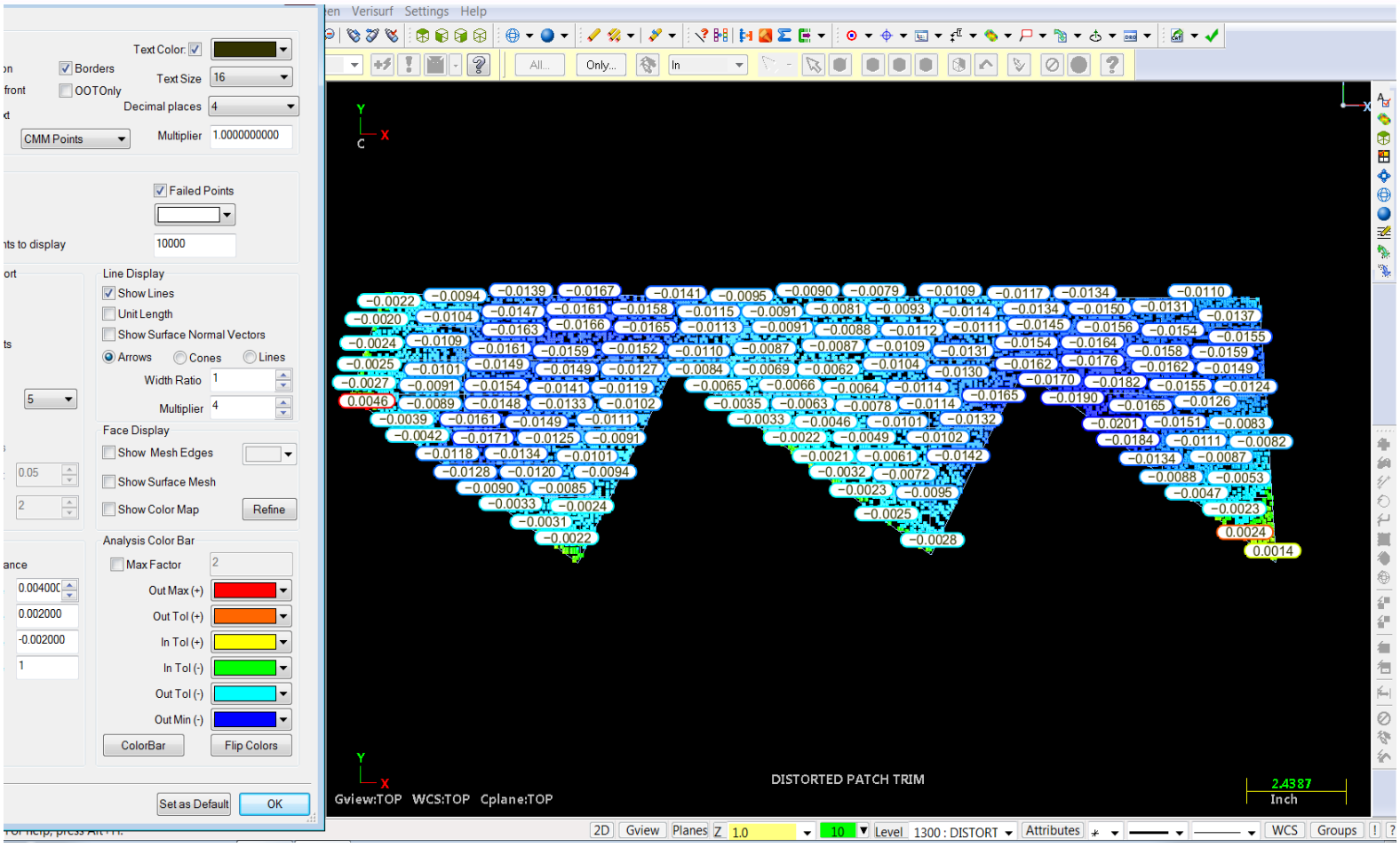
Surface Point-clouds Editing



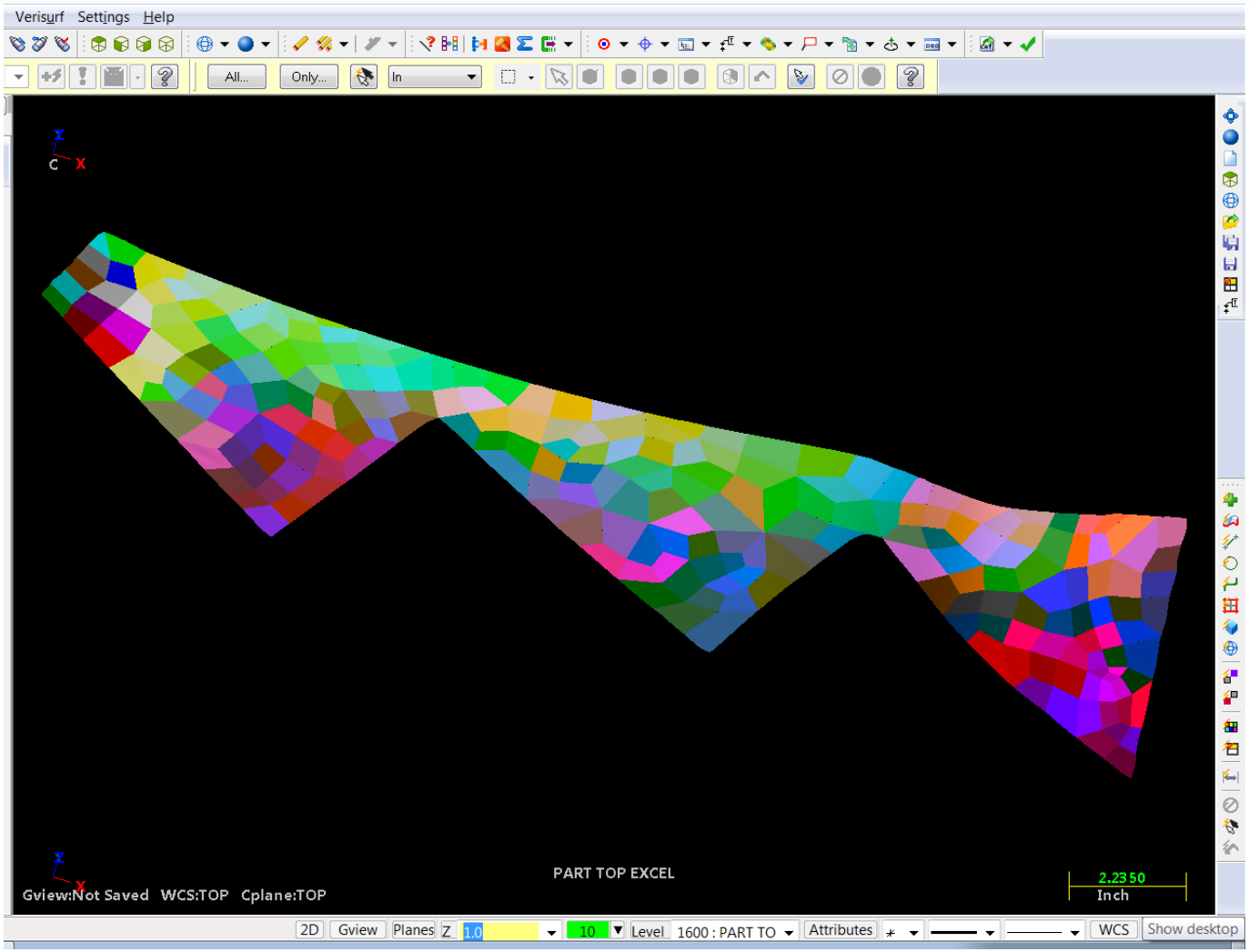
Generation of CAD Surfaces



Workpiece Points Analysis



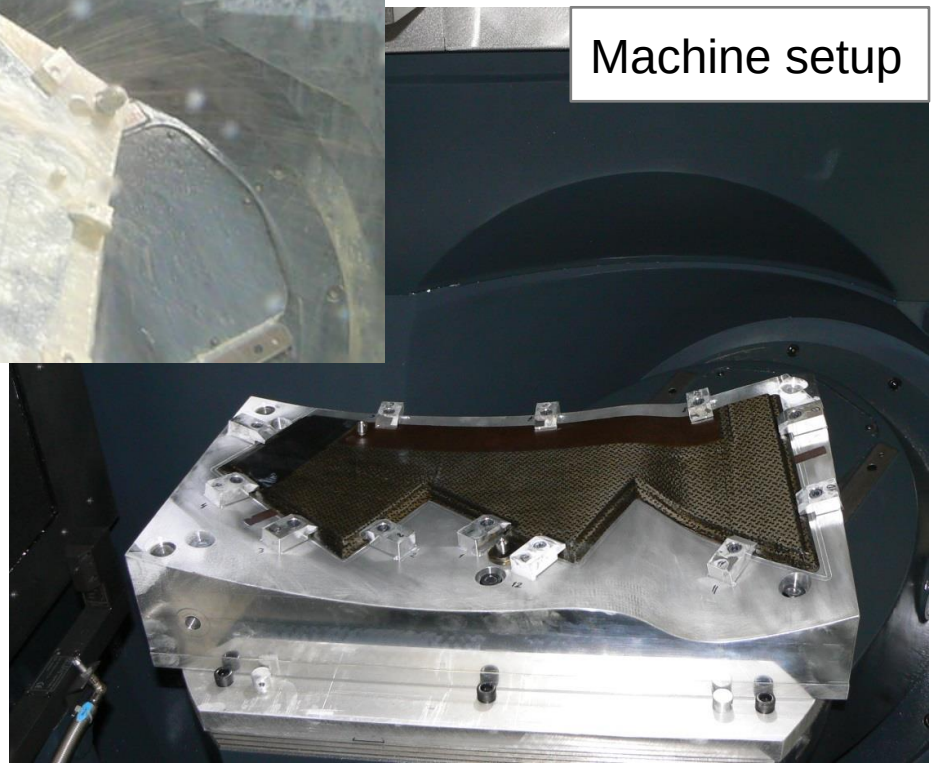
Finished Part Surface



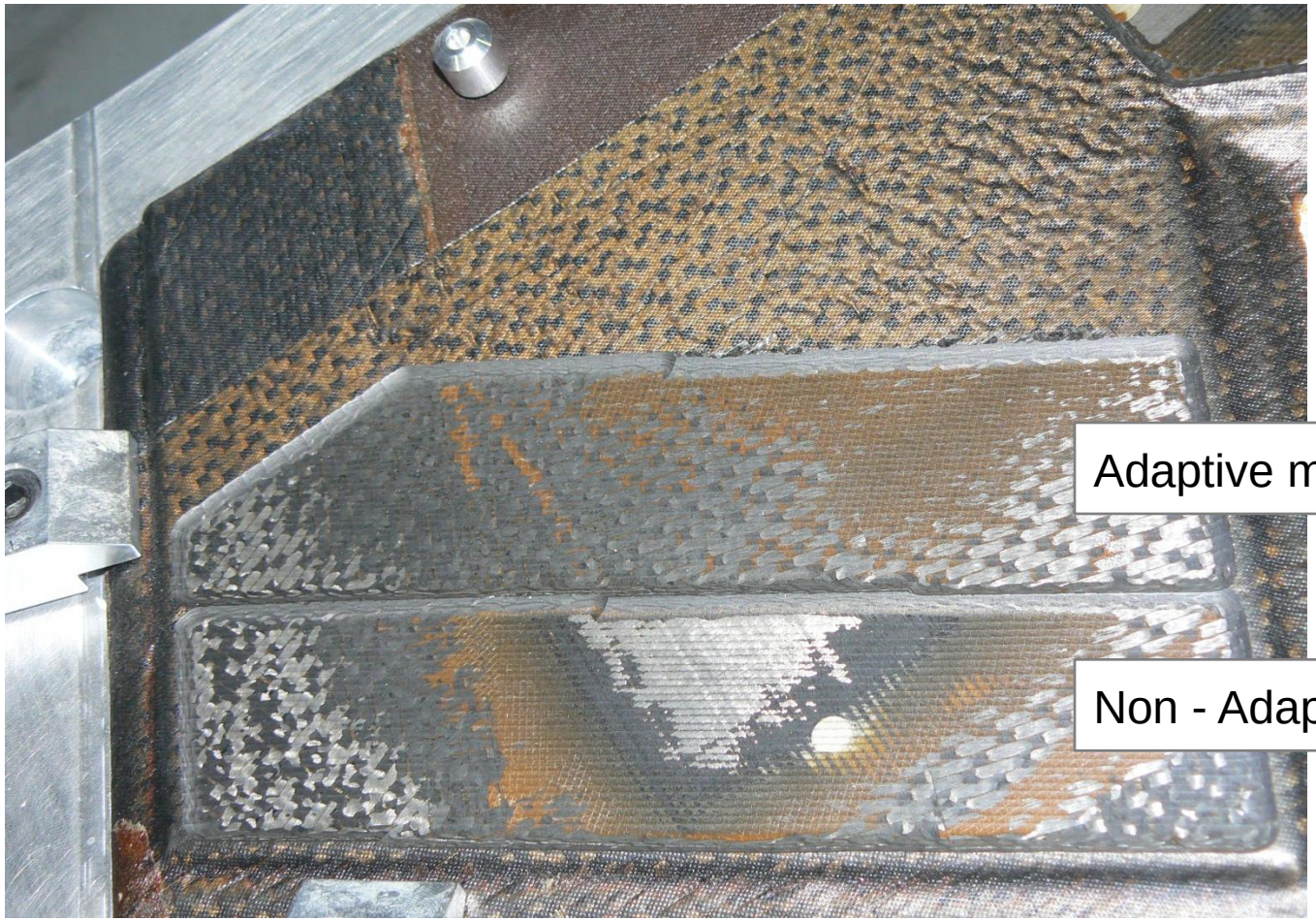
Machining

In-process

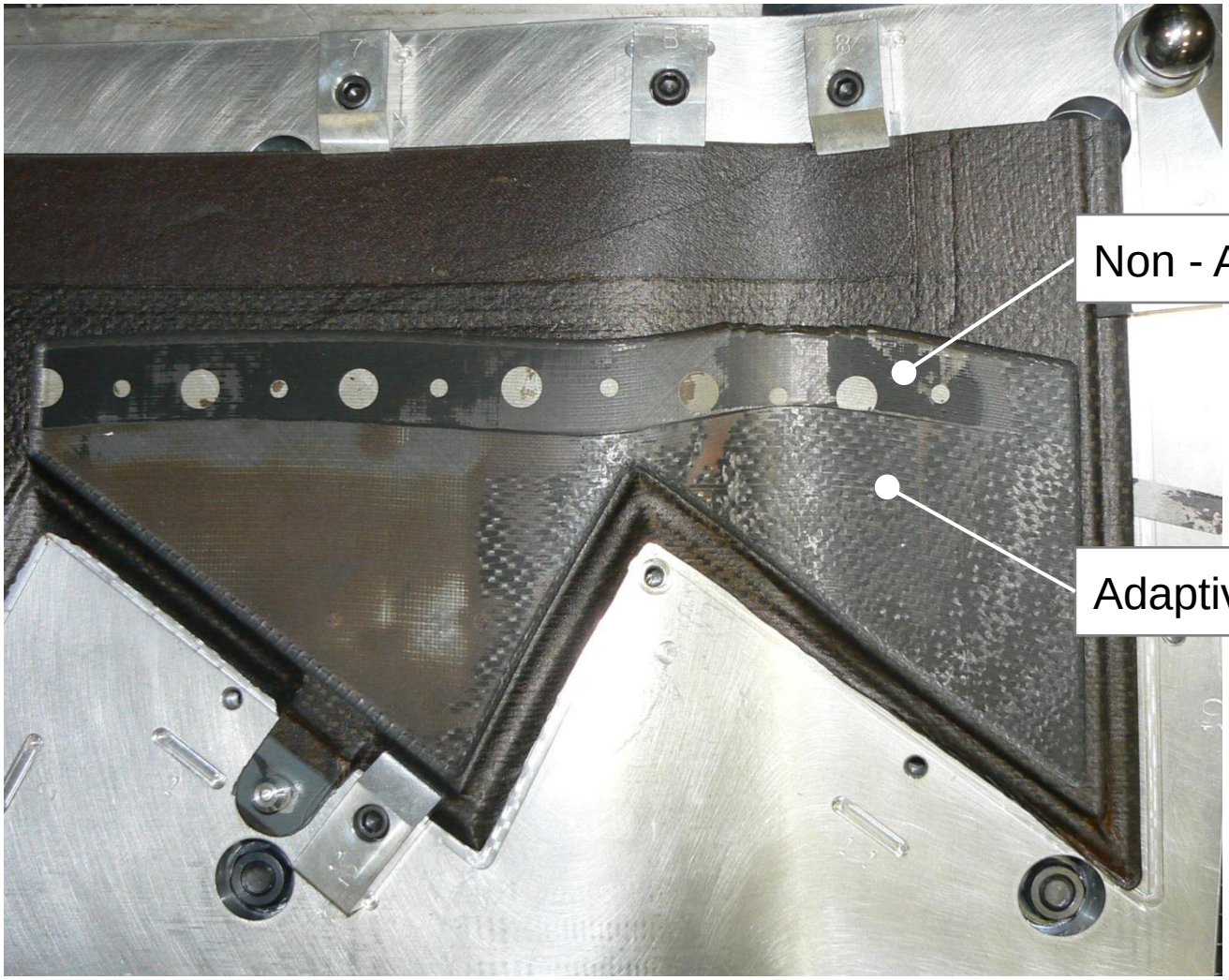
Machine setup



Witness Surface 1



Witness Surface 2

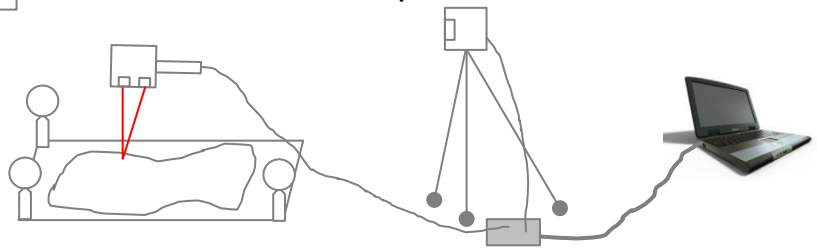


Challenges

- Precision of the T-Scan system
- Operator’s experience
- Limitations of metrology software
- Files size
- Procedure development dependent on software capabilities

Current Methodology

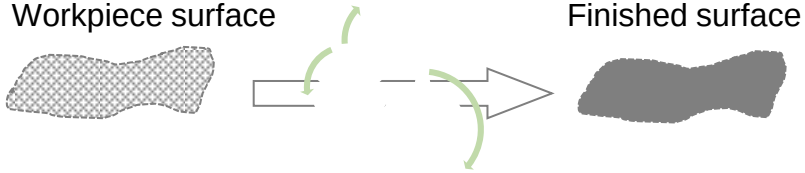
1 Scan fixture and workpiece



2

Clean & filter point clouds;
align, mesh, and fit surfaces

3



Run algorithms to determine finished surface

4

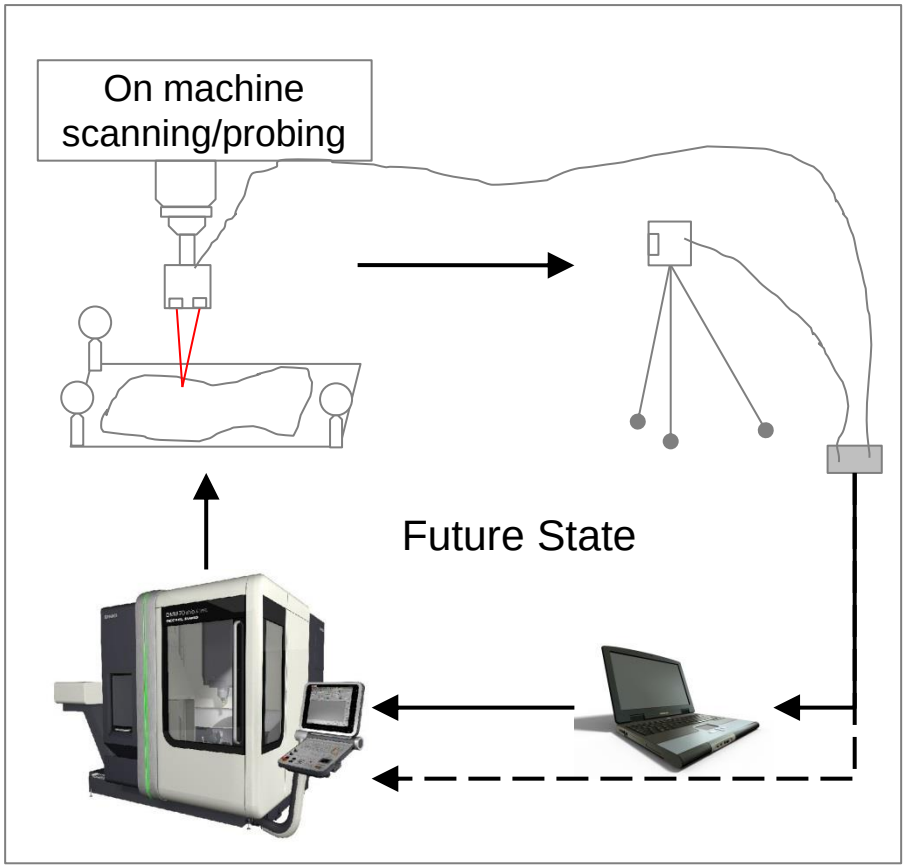
Export surface to CAM program and post adapted cutter path to the machine tool

Castrol

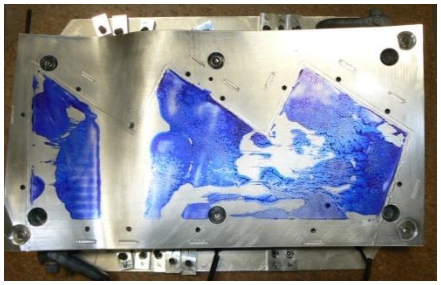
OPTIS

A JOINT VENTURE WITH TechSolve

Automation



The Future of Adaptive Machining



Deformation due to cutting forces

Geometric correction

Actual stock surface

Adapted cutter path

THICKNESS IN SPECS

Tool

Thin wall will be pushed ‘down’, along the normal force, towards the fixture

Gap due to distortion is compensated along the cutter path

THANK YOU!

visit us:
Castrol's Booth N-6176
www.optis-solutions.com

Castrol

OPTIS

A JOINT VENTURE WITH TechSolve