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Real3D™ Measurement Handbook

A guide to advanced
3D measurement
technologies, techniques
and applications for
video borescopes
used in remote visual
inspection applications.



Get the most from your Mentor Visual iQ+.

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Introduction

Advances in image based 3D measurement are making the video borescope an increasingly powerful tool in the inspector's toolbox. While in the past, you could identify indications and capture images; today's advanced video borescopes allow you to map, measure, and analyze indications in 3D.

This guide is designed to help inspectors and asset owners understand measurement technologies available on the Mentor Visual IQ and how they can be properly applied to improve decision making in remote visual inspection applications.

Many video borescope owners underutilize the advanced features of their inspection equipment due to a lack of training. Using this handbook as a guide, you can learn to apply new techniques, and make your expertise a competitive advantage for your organization. [Advanced training is available through the Waygate Inspection Academy.](#)

The Importance of Measurement Precision & Accuracy

Remote Visual Inspection (RVI) is frequently used to determine the serviceability of an asset. That determination is often based on the measurement of an indication or feature inside the asset. Inaccurate measurements can result in unnecessary downtime, scrap, and maintenance costs, as well as safety or reliability risks. It is therefore critical that you understand how to properly apply available measurement capabilities to maximize the quality of decision making.

With traditional measurement technologies, such as stereo, shadow, or comparison, you have little ability to assess either the quality of the data used to compute the measurement result or the correctness of the cursor placement for the desired measurement. This can often lead to inaccurate and inconsistent measurements and potentially costly incorrect decisions.

The latest Real3D measurement technologies provide an interactive, fully-surfaced 3D point cloud that can be used to assess the 3D data quality and verify proper cursor placement on the 3D surface.

Accurate VideoProbe™ measurement requires:

Measurement accuracy and minimum feature size depend on many factors that vary from application to application. Under good conditions, Real3D measurement technologies are often capable of resolving feature depths down to ~0.125mm (0.005") and achieving measurement errors in the +/- 0.05mm (+/- 0.002") range or better.

Performing a Gauge R&R study using representative known samples is recommended to determine if the accuracy/precision requirements of a particular application can be met. Please reach out to your local sales representative for more information to see what Real3D measurement can do for you.

Ideal conditions vary by measurement technology as described below.

Real3D Phase Measurement ideal conditions

- Measurements by a qualified RVI technician
- Clean and calibrated optical tip adapters and camera lens
- Camera positioned very close to the indication, even if slightly out of focus
- Camera positioned in a non-perpendicular incident angle to the surface
- Measurement upon a matte surface finish
- Minimal projected-pattern reflection from nearby shiny surfaces onto the measurement area
- Absence of ambient light
- Systems may be unable to both view and illuminate the bottom of narrow, deep features with either structured light patterns or normal illumination, making them unable to determine accurate 3D data at the bottom of such features.

Real3D Stereo and Stereo Measurement ideal conditions

- Measurements by a qualified RVI technician
- Clean and calibrated tips and camera lens
- Camera positioned very close to the indication and in sharp focus
- Measurement on surfaces that contain differentiated surface textures
- No glare on the indication

Measurement Technologies

(See Mentor Visual iQ VideoProbe™ Operating Manual – Advantages of Measurement Types)

3D Phase Measurement

Using patented structured-light technology, 3D Phase Measurement enables inspectors to locate, measure, and analyze an indication using the same tip optic. The wide field of view and large depth of field allow for measuring with the same tips used for inspecting, thus eliminating the extra steps required to back out, change the tip, and then relocate the indication.

3D Phase Measurement provides accurate measurement “on-demand” while saving time and increasing overall inspection productivity. 3D Phase Measurement employs structured light patterns projected from the tip to create a 3D surface scan of the viewing area and can measure all aspects of surface indications.

Benefits:

- View and manipulate a 3D point cloud for detailed assessment of surface shape and measurement correctness
- Full-screen viewing of measurement image for greater resolution
- Navigate, inspect and measure without changing probes or tip optics
- Available on 6.1 mm diameter probes
- Green side view tip provides ability to measure larger areas and at distances up to 4.7 inches
- Measurements can be refined by moving cursors within the point cloud

3D Stereo Measurement

3D Stereo Measurement utilizes the same optical tips as traditional Stereo Measurement, but employs more advanced calibration and processing algorithms to generate a full 3D point cloud representation of the target surface that can be viewed, manipulated, and analyzed.

Benefits:

- More accurate, precise measurement compared to traditional or manually matched stereo measurement
- Provides better matching capabilities than Stereo Measurement on horizontal and repeating indications
- View the camera image and 3D point cloud side-by-side for highly efficient measurement analysis
- Measure effectively on shiny (or highly-reflective) surfaces which include detail, especially when using Image Brightness and Dark Boost
- Measure on surfaces with some minor movement present
- Available on 4.0, 6.1, 6.2 working channel and 8.4 mm probe diameters

Stereo Measurement

Traditional stereo measurement, which, like 3D Stereo, utilizes a prism to obtain left and right stereo images from slightly different perspectives. The matching of surface points in the left and right images at the cursor locations allows 3D coordinates and measurement results to be computed. This technology, available for more than two decades, is useful on systems with limited computing power, but does not provide a 3D point cloud and therefore limits the inspector's ability to assess measurement quality.

Comparison Measurement

A more traditional 2D measurement technology that uses a physical reference target placed by the manufacturer or inspector at the same tip to target distance as the indication.

Inspection Manager

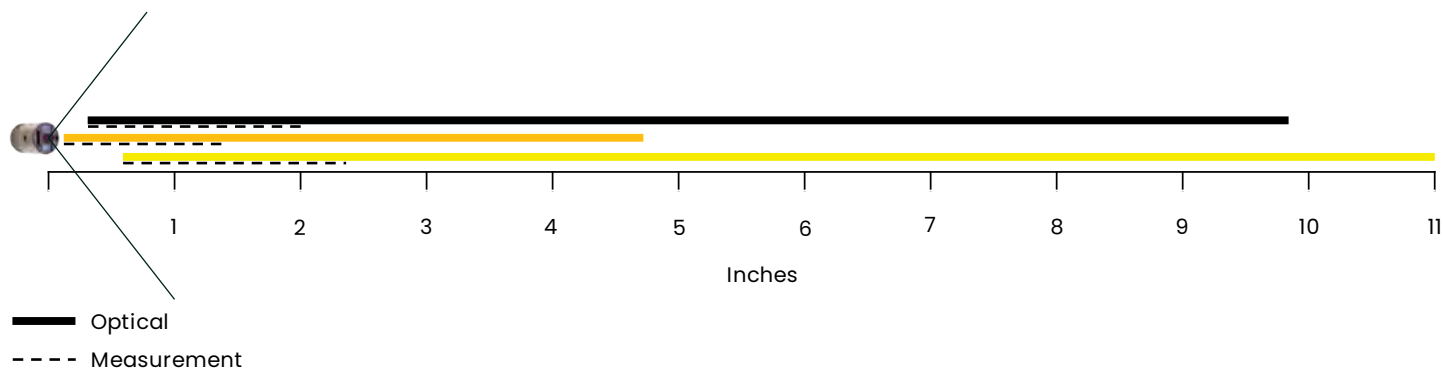
Inspection Manager is a Windows PC-based software tool which allows the re-measurement and analysis of any measurement image captured by a Waygate Technologies VideoProbe. The tool allows you to move measurement cursors, add measurements, or completely clear out previous measurements and begin a new measurement process. If the measurement image was captured with a 3D-Stereo or 3D-Phase process, this tool also allows full point cloud viewing and manipulation.

How to choose the right tip for the job




3DPM Measurement Tips Selection Guide

Two main things to consider when selecting a 3DPM tip are from what direction the defect is viewed and from how far away. To determine whether you need a forward view or side view tip, consider where your insertion point is in relation to the area you're inspecting. Measurement Depth of Field (DOF) values are provided as general guidelines to help select the most appropriate tip for a given application. The actual measurement DOF for a particular application depends on several factors including feature size, required accuracy, measurement types and surface finish.

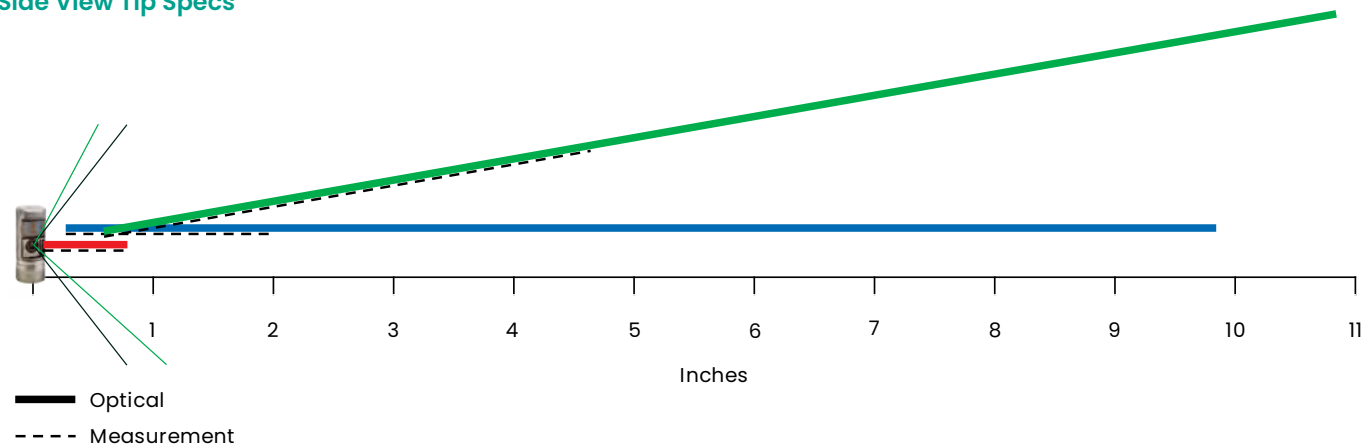
Forward View Tip Specs






Black, Orange, and Yellow forward view tips comparison chart.

Part Number	Color	FOV (deg)	Optical DOF (mm / in)	Measurement DOF (mm / in)	Measurement view size at max distance
XL4TM61105FG 	Black	105	8mm-250mm 0.31"-9.84"	8mm-50mm 0.31"-2"	82mm x 55mm 3.2" x 2.2"
XL4TM61105FF 	Yellow	105	15mm-inf 0.59"-inf	15mm-60mm 0.59"-2.36"	99mm x 66mm 3.9" x 2.6"
XL4TM61105FN 	Orange	105	3mm-120mm 0.12"-4.72"	3mm-35mm 0.12"-1.38"	58mm x 38mm 2.3" x 1.5"

Side View Tip Specs



Blue, Green and Red side view tips comparison chart.
Note: Green tip view is tilted up 10 degrees to improve turbine blade root visibility

Part Number	Color	FOV (deg)	Optical DOF (mm / in)	Measurement DOF (mm / in)	Measurement view size at max distance
XL4TM61I05SG 	Blue	105	7mm-250mm 0.27"-9.84"	7mm-50mm 0.27"-2"	82mm x 55mm 3.2" x 2.2"
XL4TM61I05SF 	Green	105	15mm-inf 0.59"-inf	15mm-120mm 0.59"-4.7"	200mm x 130mm 7.8" x 5.2"
XL4TM61I05SN 	Red	105	2mm-20mm 0.078"-0.78"	2mm-20mm 0.078"-0.78"	33mm x 22mm 1.3" x 0.9"

General Guidelines

- Ensure the inspector is qualified to perform measurement.
- Use in-house procedures and the selector tool on this page to choose the appropriate measurement technology and type for your application.
- Ensure that your measurement tip and probe optics are clean and that the tip is securely attached. If using a stereo tip, be sure to correctly identify the tip serial number when first entering measurement. 3D Phase Measurement tips are automatically recognized by the system.
- For best results when measuring on a narrow surface using 3DPM, orient the tip such that the long dimension of the surface is perpendicular to the projected pattern lines. With forward view black, orange, and yellow and side view green tips, the projected lines are horizontal in the image, so narrow surfaces are best oriented vertically. With side view blue and red tips, the projected lines are vertical in the image, so narrow surfaces are best oriented horizontally.
- With Stereo and Real3D Stereo Measurement, lines or part edges should be oriented vertically rather than horizontally to help the system more precisely identify matching point positions in the horizontal direction.
- Verify that the system measures accurately with the Waygate Technologies NIST traceable verification block before and after performing measurements.
- Position the tip as close as possible to the measurement area (a high Index or low MTD value). Stereo and 3D Stereo require the image to be in focus, but with 3D Phase Measurement, small depth measurements ($< 0.010''$) are generally most accurate when close enough for the image to be somewhat out of focus. Measuring from too far away is the most common cause of inaccurate measurements.
- Pay attention to advisory messages displayed by the system during measurement, which may signal improper setup or inappropriate MTD for the measurement performed.
- Check and adjust the measurement setup and cursor placement with the 3D point cloud view. Many issues are difficult to recognize using the 2D white light image alone but are obvious in the 3D point cloud.
- When performing small depth or depth profile measurements, use the 3D point cloud view with depth map enabled to verify that the indication clearly stands out from the data noise. If not, capture another image from a closer distance or different orientation.
- When measuring the depth of a feature such as a pit or dent, use the point cloud view to verify that you are measuring at its deepest point and that the measurement reference plane is accurately aligned with the reference surface.
- With 3D Phase Measurement, reflections or shadowing can create regions of lower-quality data, which are highlighted in yellow. Avoid measuring in these areas whenever possible, especially for depth, depth profile, or area depth profile measurements. Performing another capture from a different orientation may eliminate the yellow regions.
- When using 3D Phase Measurement, off-perpendicular views yield the best results for depth measurements, especially when measuring objects with shiny surfaces.
- Areas where the system was unable to determine 3D coordinates are highlighted in red. Measurements cannot be taken in these red areas. Measurement data around these unmeasurable areas should be closely evaluated for data validity.
- For best data quality, keep the probe as still as possible during image capture. This is particularly important with 3D Phase Measurement due to the large number of images captured.
- With 3D Stereo, adjust image brightness, dark boost levels and viewing orientation to minimize glare in the area of interest prior to capturing a measurement image.
- Straight lines or edges on viewed objects often appear curved in the 2D image due to the viewing perspective and optical distortion. As all measurements are performed in 3D, the straight 3D measurement lines are drawn on the 2D image as they would be seen by the camera, which is often curved. This helps with alignment to straight edges and more accurately indicates measurement location.
- Use 3X Zoom window for more precise cursor placement.
- Utilize 3D surface mask to optimize cursor placement
- Apply Inverse+, HDR Variable and Dark Boost image transforms to aid in indication analysis



Choose the Right Measurement Type For Your Application

While multiple measurement types may be used for certain applications, this chart is intended to show the expert recommendation.



Length

- Simple measurement of features or components



Point to Line

- Turbine blade edge damage
- Gap width
- Weld width



Depth

- Pits or dents from corrosion, erosion, or FOD impact
- Pipe inside diameter
- Weld height
- Gap width



Area Depth Profile

- Corrosion, erosion and pitting
- Maximum weld height
- Maximum wear groove depth



Angle

- Angle on flat surfaces



Surface Angle

- Blade tip curl
- Angle between two surfaces



Missing Corner

- Missing blade corners



Area

- Coating loss
- Surface area of pitting or corrosion



Multi-Segment

- Total length measurement on curved or irregular surfaces



Depth Profile

- Quick assessment of height or depth



Measurement Plane

- With Area or Missing Corner for blade missing corners
- With Point to Line for blade edge damage
- With Depth for blade tip to shroud gaps
- With Length or Point to Line for small features
- With Area Depth Profile when measuring in a field of pits
- With Radius Gauge to evaluate blended blade radii



Blade Tip Clearance

- Compressor and turbine efficiency checks



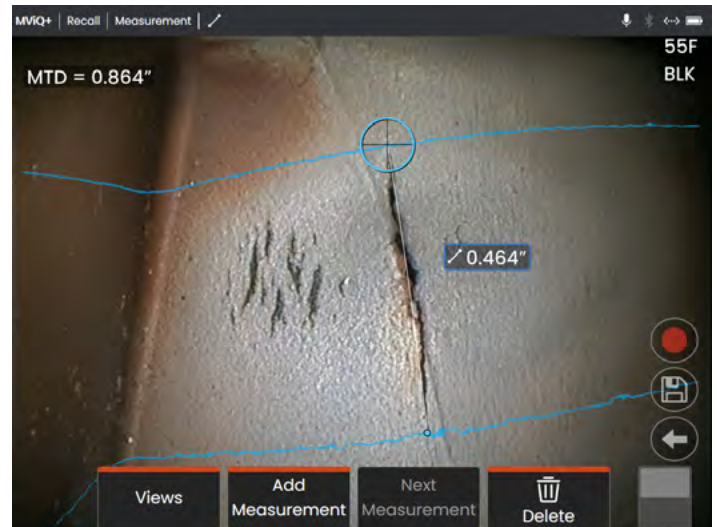
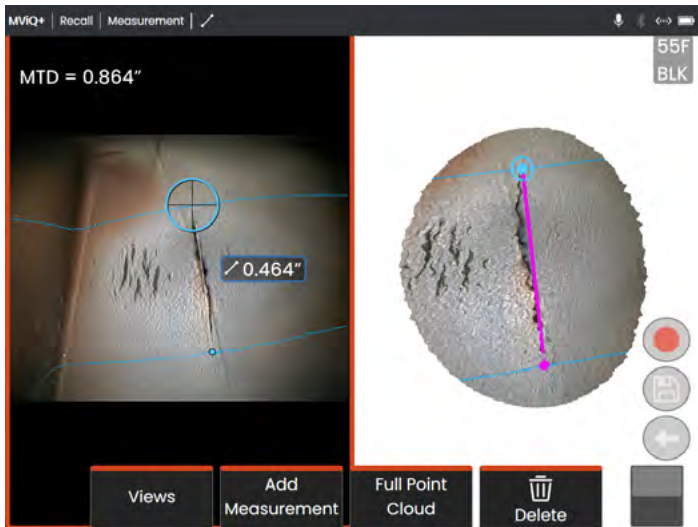
Radius Gauge

- Boroblending radius

Measurement Types

This section will detail each of the measurement types available on the Mentor Visual iQ VideoProbe, suggest applications where each technique can be most effective, and provide tips and suggestions for accurate measurement setup.

Length



Measures the straight-line distance between two selected cursor points.

Example Applications:

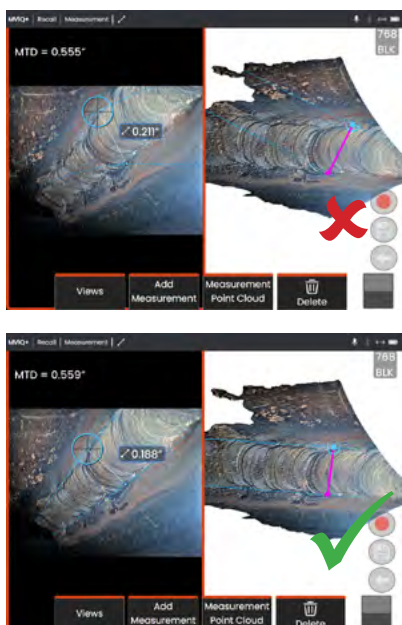
- Simple measurement of features or components
- Indication length measurement (i.e., cracks)
- Measurement of component size migration through expansion or erosion/corrosion/wear
- Determining the remaining size of wear indicators
- Measuring location/zone of indications on a part

3D Surface Mask:

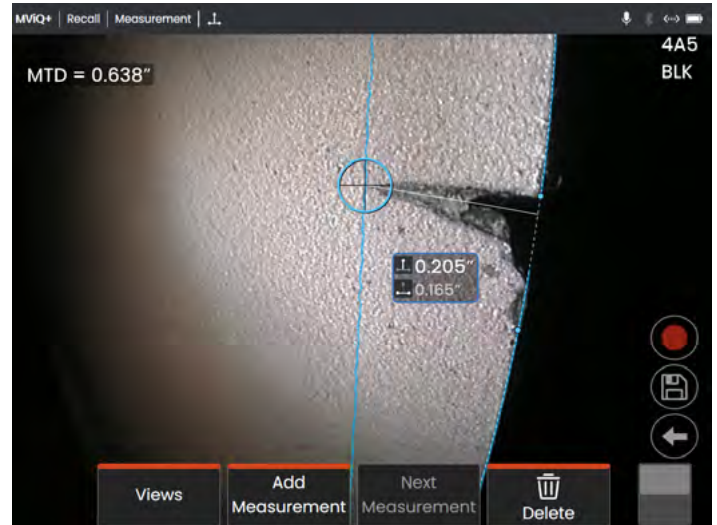
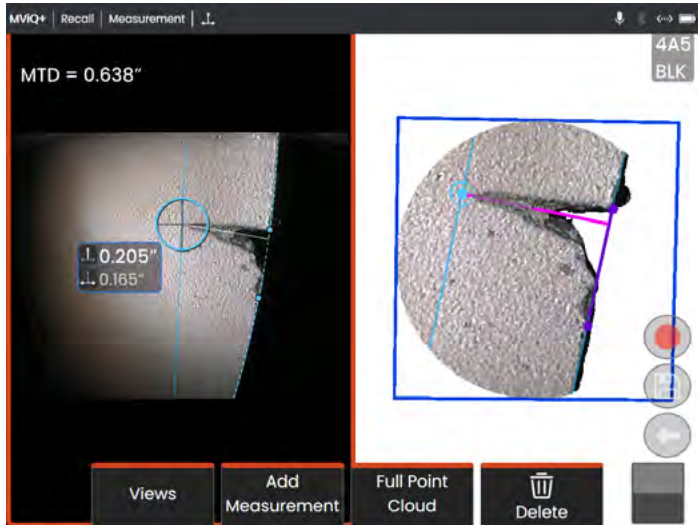
When enabled in Settings, a blue mask will highlight surface points where planes perpendicular to the straight length 3D line between the cursor points intersect the viewed surface.

Best Practices to Improve Measurement Accuracy:

- Length is a straight-line measurement. It is not suitable to measure the distance across a curved surface.
- When measuring a distance from an edge, adjust the cursor positions such that the light blue 3D Surface Mask appears along the edge rather than at an angle to the edge. This will minimize error caused by measuring diagonally. Point to Line may also be a better option in such cases.
- Move the tip closer to make the target area as large in the center of the screen as possible, while keeping the cursor point areas in focus.
- Watch for orange advisory indicators to ensure the measurement distance is within the confidence interval.
- The zoom window can be helpful for accurate placement. It is important to start with a crisp image so that the cursors can be placed accurately on the indication.
- Use a Measurement Plane when red areas prevent proper cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.



Point to Line



Measures the perpendicular distance between a line (defined by two points), and a selected point.

Example Applications:

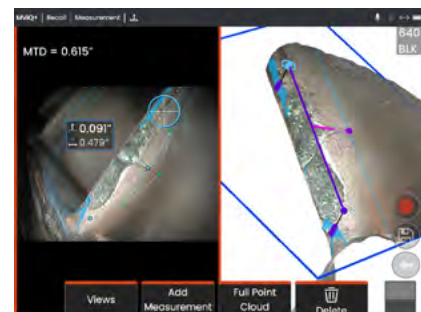
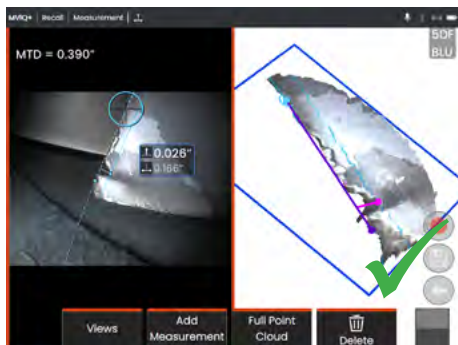
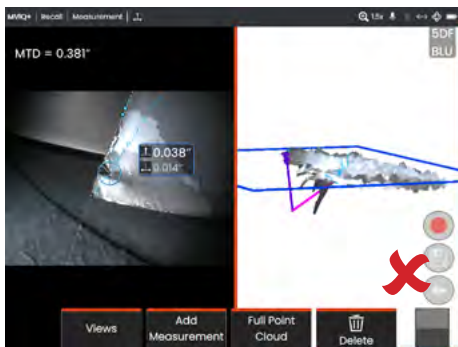
- Turbine blade edge damage
- Estimate missing corner area using multiple point-to-line measurements
- Gap or groove width
- Weld width

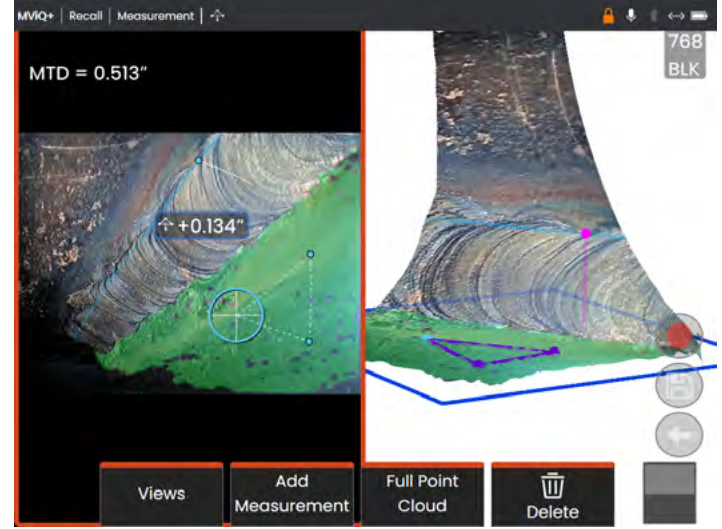
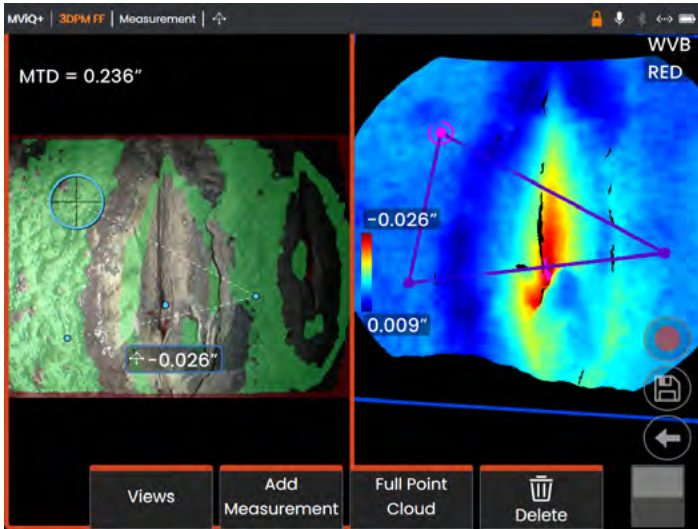
3D Surface Mask:

When enabled in Settings, a blue mask will highlight surface points where planes perpendicular to the straight 3D line between the third cursor point and the reference line intersect the viewed surface.

Best Practices to Improve Measurement Accuracy:

- Review the 3D point cloud to ensure your cursors are located correctly.
- Space the first two cursors far apart along the reference edge. If possible, place them on opposite sides of the indication being measured. Placing them close together can cause error by tilting the reference line in 3D space.
- Check the point cloud to verify that the reference line is not tilted with respect to the reference edge on the part. This is especially important when both reference line cursors are on the same side of and away from the third cursor.
- Also check the point cloud to be sure the measured distance is not at a diagonal, which can give a higher-than-actual result.
- Use a Measurement Plane when red areas prevent proper cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.
- Use a Measurement Plane when measuring distance from a rounded edge to determine the perpendicular distance from the edge. Position the reference cursors such that the light blue 3D Surface Mask appears along the outer face of the rounded edge.

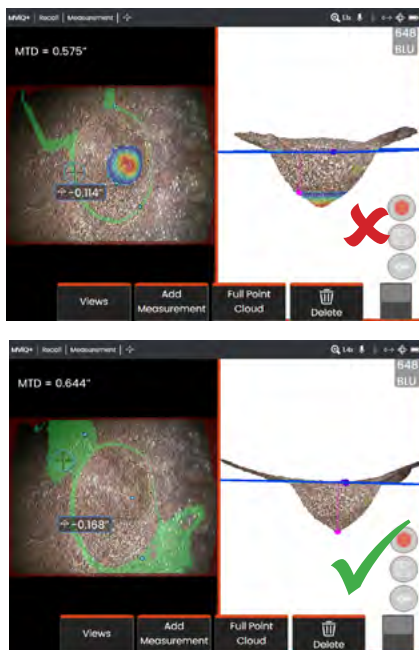




Measures the distance from a reference plane (defined by three selected points) to a fourth selected point above or below the plane.

Example Applications:

- Blade tip to shroud gaps
- Pits or dents from corrosion, erosion, or FOD impact
- Pipe inside diameter
- Weld height
- Stator vane rock
- Gap width



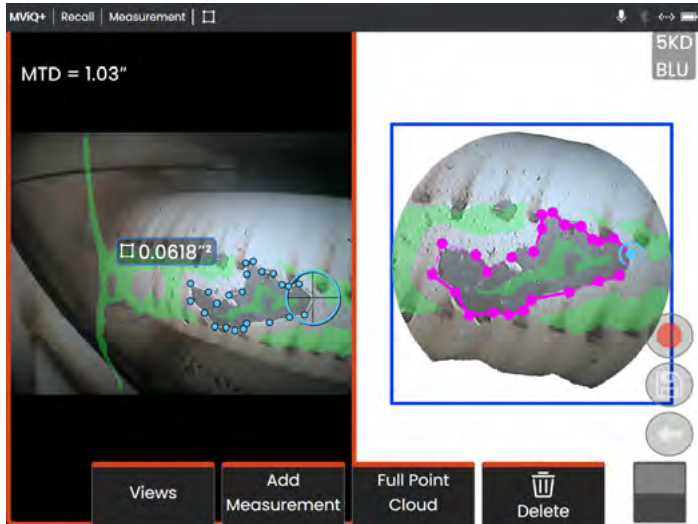
3D Surface Mask:

When enabled in Settings, surface points very close to the reference plane are shown in green. Surface points the same distance from the reference plane as the measurement result are shown in light blue. If the result is negative, a color gradient also highlights regions deeper than the measurement point with red indicating the deepest points.

Best Practices to Improve Measurement Accuracy:

- The measurement tip should be as close as possible to the indication to increase the accuracy of measurement.
- Position the three reference-plane cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure that the measurement is taken at the deepest point. If measuring height or depth to a flat surface, try to maximize the amount of light blue shown on that surface.
- Check the 3D point cloud view to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- The green Surface Mask, visible when a reference plane cursor is active, indicates points very close to the reference plane. Adjust the cursor positions to maximize the amount of green on the reference surface. The 3D point cloud view can also be used to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- After the third cursor is placed, the Depth Assist feature will often automatically place the fourth cursor at the deepest point, highest point, or on a blade edge nearby. Check the position of the auto-placed cursor and adjust if necessary.
- Enable depth map mode in the point cloud view to better see surface contours and ensure that you are measuring the desired point—often the highest or lowest on an indication—and that the indication clearly stands out from the 3D data noise.
- The line projected from the depth measurement point should end near or within the triangle formed by the reference-plane cursors to minimize inaccuracy due to plane tilt.
- If you must measure at a point far outside the reference triangle, increase the size of your reference triangle to compensate (this only applies to flat surfaces, not curved surfaces).
- Use a Measurement Plane when measuring blade tip to shroud clearance and red areas along the blade edge prevent proper fourth cursor placement or 3D noise may be affecting the result. See the Measurement Plane section for details.

Area



Measures a planar area on a surface by outlining an indication with multiple cursor points.

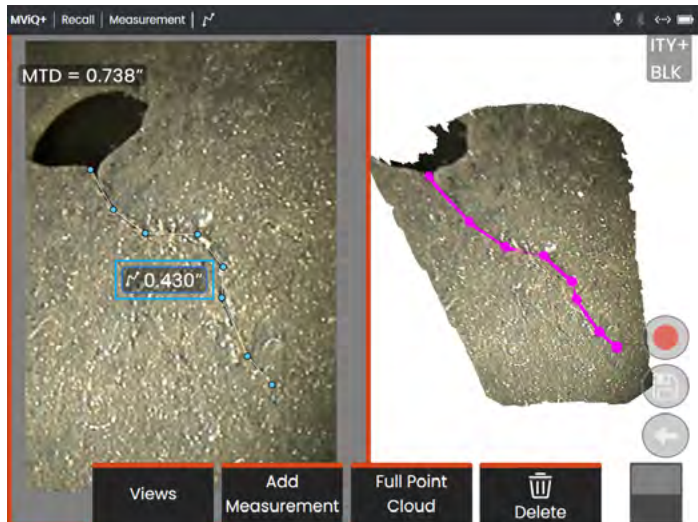
Example Applications:

- Missing blade corners using a Measurement Plane
- Coating loss
- Surface area of pitting or corrosion
- FOD impact damage

Best Practices to Improve Measurement Accuracy:

- Check the point cloud to ensure accurate cursor placement.
- When measuring a curved surface, reduce error by measuring multiple smaller areas and combining the results.
- Use with a Measurement Plane to measure area and lengths of blade missing corners. See Measurement Plane section for details.

Multi-segment



Measures the total length along a curved or jagged path using multiple cursors placed along the path of the indication.

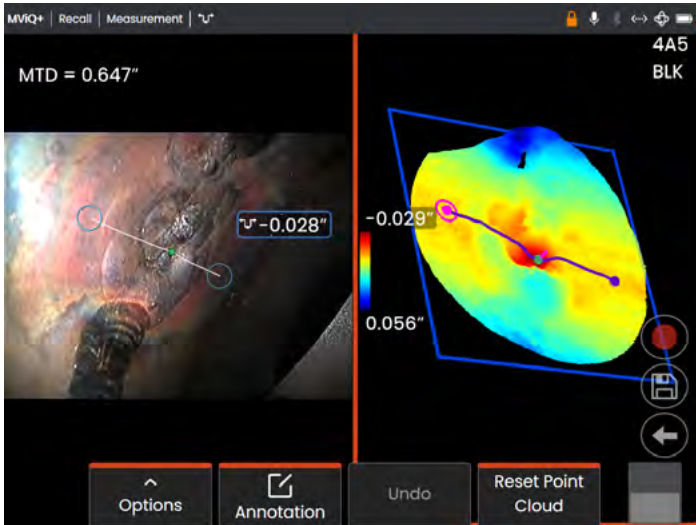
Example Applications:

- Total travel path of a complex crack
- Total length along a curved surface

Best Practices to Improve Measurement Accuracy:

- Check the point cloud to ensure accurate cursor placement.
- Space your cursors as far apart as possible while following the path of the indication to minimize the effect of 3D data noise on the result.

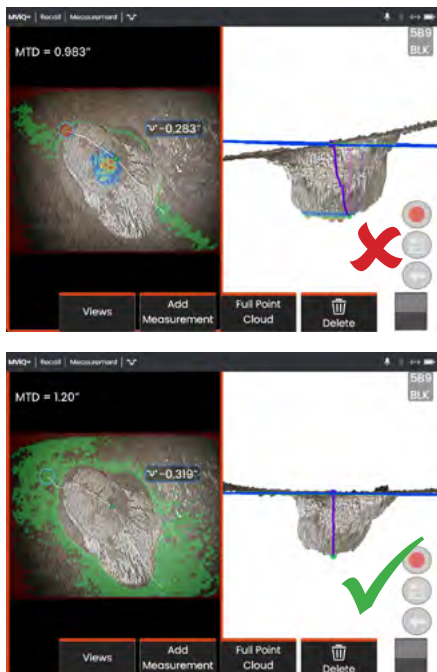
Depth Profile



From any viewing angle, maps the perpendicular distance from a reference plane along a line between two selected points and automatically identifies the deepest or highest point.

Example Applications:

- Depth of isolated corrosion or erosion pits
- Depth of FOD impact damage
- Weld height or wear groove depth
- Quick assessment of surface contours



3D Surface Mask:

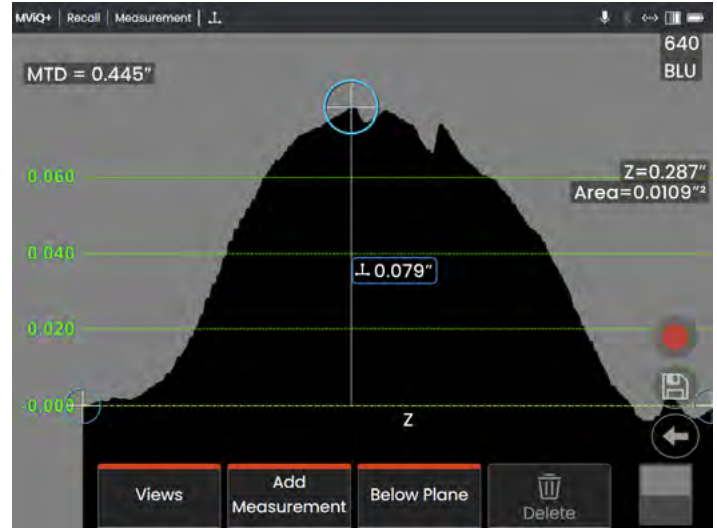
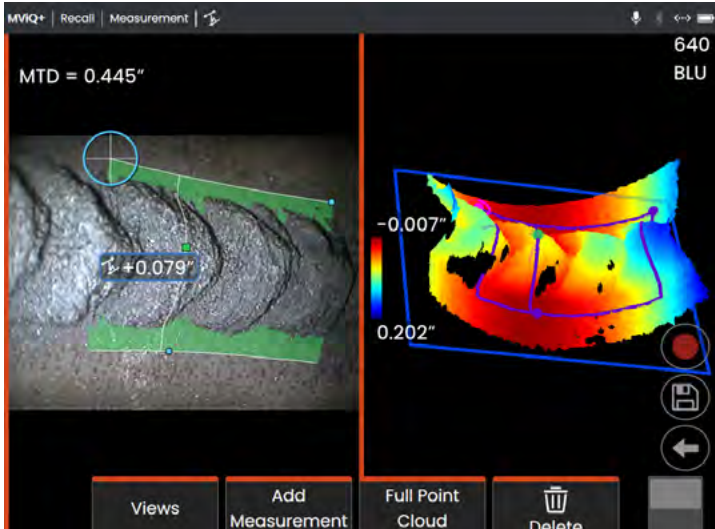
When enabled in Settings, surface points very close to the reference plane are shown in green. Surface points the same distance from the reference plane as the measurement result are shown in light blue. If the result is negative, a color gradient also highlights regions deeper than the measurement point with red indicating the deepest points.

Best Practices to Improve Measurement Accuracy:

- Position the measurement tip as close as possible to the indication to increase measurement accuracy.
- Position the cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface. If measuring a recessed point, use the color gradient to ensure that the measurement is taken at the deepest point. If measuring height or depth to a flat surface, try to maximize the amount of light blue shown on that surface.
- Enable depth map mode in the point cloud view to better see surface contours and ensure that you are measuring the desired point—often the highest or lowest on an indication—and that the indication clearly stands out from the 3D data noise.
- The green Surface Mask visible when a cursor is moved indicates points very close to the reference plane. Adjust the cursor positions to maximize the amount of green on the reference surface. The 3D point cloud view can also be used to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- If the cursor turns red, this indicates improper placement.
- As the reference plane is determined by fitting to all the surface data within both cursor perimeters, ensure that the two cursors are fully positioned on the same plane of interest—not overlapping an edge, or on offset or curved surfaces that could cause measurement error.
- If measuring on a curved surface, such as inside a small pipe, space the cursors apart in a direction parallel to the curvature to keep them on the same plane. In the point cloud view, the blue reference-plane square should appear tangent to the reference surface.
- The Depth Profile view may be used to help visualize the surface contours along the profile slice.
- In applications seeking the deepest or highest point, Area Depth Profile or Depth may be preferred over Depth Profile as they automatically identify the deepest or highest point in an area.



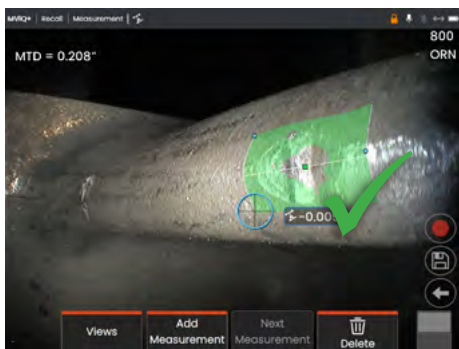
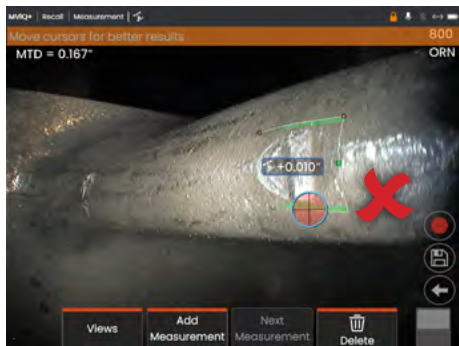
Area Depth Profile



Sweeps a series of depth profile slices over an area defined by three cursors and identifies the profile slice having the highest or lowest point.

Example Applications:

- Corrosion, erosion and pitting
- FOD impact damage
- Maximum weld height including orbital welds
- Maximum wear groove depth



3D Surface Mask:

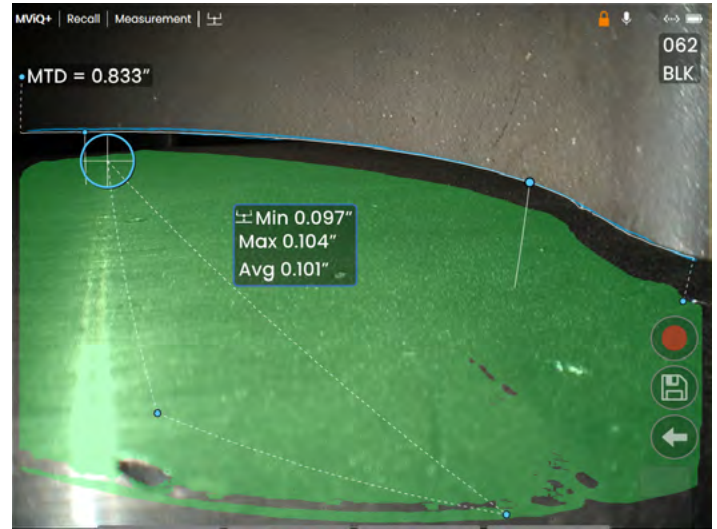
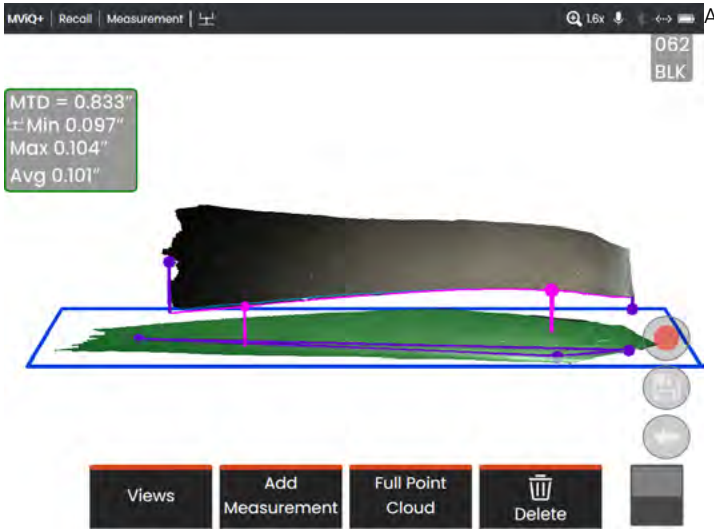
Each depth profile slice in the series uses a reference plane determined from the surface orientation at the slice endpoints. This allows curved surfaces, such as pipe walls to be followed. When enabled in Settings, the 3D Surface Mask shows surface points near the individual slice reference planes in green.

Best Practices to Improve Measurement Accuracy:

- Position the measurement tip as close as possible to the indication.
- Use with reference surfaces that are flat or have curvature in only one direction, such as a straight section of a pipe. Do not use on surfaces with complex curvatures such as a pipe elbow or turbine blade root at the leading or trailing edge.
- When measuring on a curved surface, position the cursors such that the reference profile lines are curved. If unsure of proper orientation, practice on a test piece of the same shape. When cursors are properly placed, you should get a result close to zero, and most of the area should be shown in green. See images.
- If only a small line of 3D Surface Mask green is shown near the two reference profile lines, the cursors are likely positioned incorrectly on a curved surface.
- The green Surface Mask visible when moving the cursors indicates points very close to the reference planes of the depth profile slices. If you only have a small line of green near the two reference profile lines, you are likely positioning the lines incorrectly on a curved surface. See images.
- The reference profile lines follow the surface curvature and are used to determine the reference planes for the profile slices. Position the cursors such that the reference profile lines are fully on the reference surface.
- Use the 3D point cloud to verify that the reference plane for the result slice, indicated by a blue square, is accurately aligned with the reference surface at the location of the result slice.
- The first two cursors define the first reference profile line. The third cursor sets the distance between the second reference profile line and the first. The system determines the endpoints of the second reference profile line to match the curvature of the surface along the first. If you have difficulty getting the second reference profile line where you want it, you are likely not setting up the measurement correctly with respect to surface curvature.
- The Depth Profile view may be used to help visualize the surface contours along the identified profile slice.



Blade Tip Clearance



Automatically identifies the blade and liner, maps the edge of the blade, and determines the minimum, maximum, and average clearance within the mapped blade edge region.

Example Applications:

- Compressor and turbine efficiency checks

3D Surface Mask:

When enabled in Settings, the 3D Surface Mask shows liner points near the reference plane in green and points offset from the reference plane by either the Min or Max result distance in light blue.

Best Practices to Improve Measurement Accuracy:

Technology Choice

- Both 3DPM and 3D Stereo can be used.
- The 105° FOV of 3DPM tips allows a wider blade tip to be viewed and measured from a given distance than 3D Stereo.
- 3D Stereo may provide better results than 3DPM in compressors having shiny blades and liners.
- With 3DPM, a non-perpendicular view of the blade can improve data quality by directing mirror reflections from the blade and liner away from the camera.
- The 3DPM XL4TM61105SF green tip may be unable to generate 3D data on the liner when inserted

Setup

- Position the probe tip as close as possible to the blade while keeping the blade tip region of interest in the view.
- Position the probe tip with the optics close to the liner to give a clear view of the blade tip and gap.
- Adjust the view to avoid seeing other edges in the image near the blade tip as they may affect the system's ability to accurately map the blade edge.
- If possible, adjust the tip orientation to create a visible dark shadow on the liner side of the blade edge, which helps with blade edge mapping. Rotating the tip such that the viewing

optics are between the illumination exit point and the liner can create this shadowing.

- With shiny compressor blades, use Dark Boost and/or Brightness to optimize visibility of the blade tip with minimal glare near the edge.

Checking the Reference Plane

- The 3D Surface Mask should show green over most of the liner in the vicinity of the blade tip.
- The blue rectangle should line up with the liner in the point cloud view.
- Check the 3D liner data in the point cloud view. If large anomalies are present, adjust the tip position for a view less perpendicular to the blade. Otherwise, manually adjust the 3 liner cursor positions to maximize green mask coverage and improve blue rectangle alignment.

Checking the Blade Edge Mapping

- Verify that the blade edge line closely follows the blade edge in the 2D image.
- Activate the Min and Max cursors and verify in the zoom window that they are accurately positioned on the blade edge.
- Check the point cloud for data quality on the blade near the tip. If significant anomalies exist, adjust the setup and capture a new image.
- Verify that the blade curvature is followed by the blade edge line in the point cloud view.
- Exclude areas near the ends of the mapped edge that are affected by 3D noise, missing corners, etc., from the analysis by moving either bounding cursor away from the edges.
- The algorithm applies fitting and filtering to reduce the impact of small gaps or noise in the blade 3D data. This may result in the blade edge line being slightly offset from the blade edge data in the point cloud view where the gaps or noise exist.



Blade Tip Clearance Advisory Messages

Functionality Notes

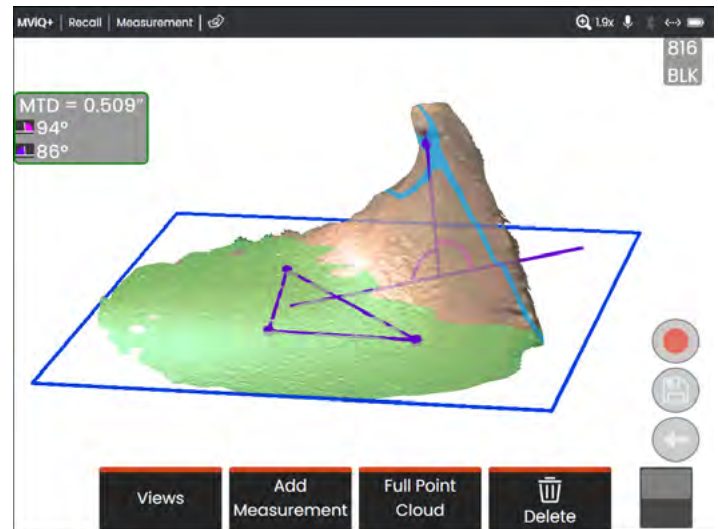
- The blade and shroud can have any orientation in the image.
- Not intended for use with honeycomb liners, turbine blades having outer shrouds, or blades that have irregular tip geometries by design or due to rubs.
- The clearance is measured from a reference plane determined from the 3 reference plane cursor locations. These cursors can be manually re-positioned.
- The algorithm maps the blade edge using the "Normal" 2D image (HDR images are not used). 3DPM pattern images may also be utilized where edge contrast is low in the normal 2D image.
- The pixels near the blade edge must be brighter than those just off the blade edge for successful mapping.
- The Max measurement point is visually differentiated from the Min measurement point by having a larger inactive cursor size.
- The Min and Max cursors cannot be manually re-positioned.
- The two bounding cursors, one at each end of the mapped blade edge, can be moved to exclude end portions from the min/max/average analysis.
- Long touch any shroud cursor to return all 3 shroud cursors to their automatically-chosen positions.
- Long touch either bounding cursor to return it to its automatically-chosen position.
- Use Auto Repeat to improve efficiency when making repetitive Blade Tip Clearance measurements.

Advisory System Checks:

The system looks for several common issues that may degrade accuracy.

- **Shroud 3D data quality may be reducing accuracy:**
The reference plane may not be accurately aligned to the liner in the vicinity of the blade tip due to excessive 3D noise, large gaps in 3D data, or insufficient liner visibility in the view.
- **Blade 3D data quality may be reducing accuracy:**
Excessive 3D noise or large gaps in 3D data exist near the blade edge
- **Move closer to target or move cursors for better results:**
The system may not be capable of accurately measuring a gap of the indicated size from the current tip-to-target distance.
- **To improve accuracy, capture image with tip optics closer to the shroud:**
The viewing perspective may not allow the true blade edge to be accurately mapped and measured.

Surface Angle



Measures the angle between a reference plane, defined by three points, and an angle plane determined by fitting the surface within the fourth plane cursor.

Example Applications:

- Turbine blade tip curl
- Weld toe angle
- Angle between two surfaces.

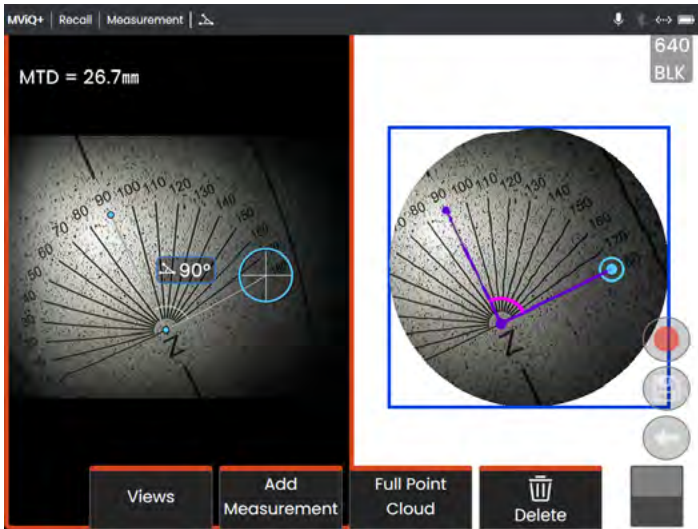
3D Surface Mask:

When enabled in Settings, surface points very close to the reference plane are shown in green, and surface points very close to the angle plane are shown in light blue.

Best Practices to Improve Measurement Accuracy:

- Position the measurement tip as close as possible while keeping enough reference surface in the view for establishing the reference plane.
- Position the three reference-plane cursors to maximize the coverage of 3D Surface Mask green pixels on the reference surface.
- Check the 3D point cloud view to verify that the reference plane, indicated by a blue square, is accurately aligned with the reference surface.
- In the 3D point cloud view, verify that the angle plane, indicated by the light blue 3D Surface Mask and the angle line, is tangent to the surface at the desired measurement point.
- The fourth cursor is relatively small to allow it to be placed near the tip of curled turbine blade corners. This small fitting area does make Surface Angle somewhat sensitive to 3D noise on the angle-plane surface. In applications where both surfaces are large relative to the size of the fourth cursor, accuracy can be improved by placing the Measurement Plane on the angle-plane surface, in which case the Surface Angle result is the angle between the reference plane and the Measurement Plane.

Angle



Measures the 3D angle between two lines defined by three points.

Example Applications:

- Angle on flat surfaces
- With Measurement Plane to measure dilution chute erosion angle

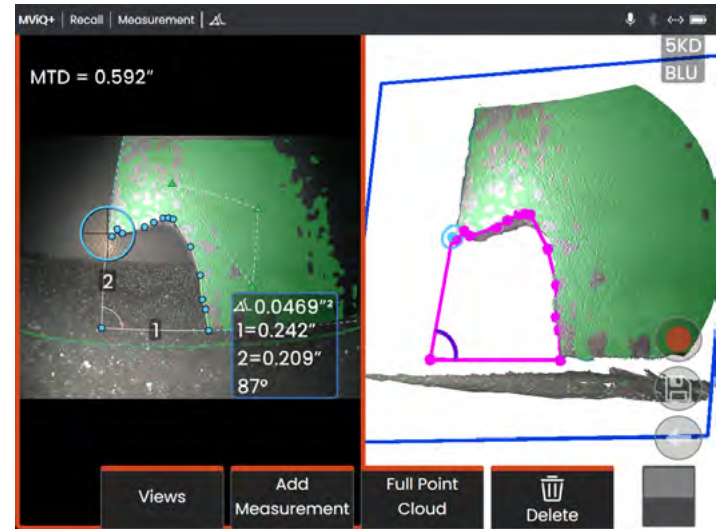
3D Surface Mask:

There is no 3D Surface Mask with Angle.

Best Practices to Improve Measurement Accuracy:

- Avoid placing cursors very close together to reduce the impact of noise in the 3D data on the result.
- Check the 3D point cloud view to verify that the plane containing the measurement points, indicated by a blue square, is accurately aligned with the desired surface.

Missing Corner



Measures the area and edge lengths of a missing blade corner with one point designating the position of the tip of the missing corner and up to 23 additional points placed along the broken edge. Requires a Measurement Plane placed on the surface of the blade near the missing corner.

Example Applications:

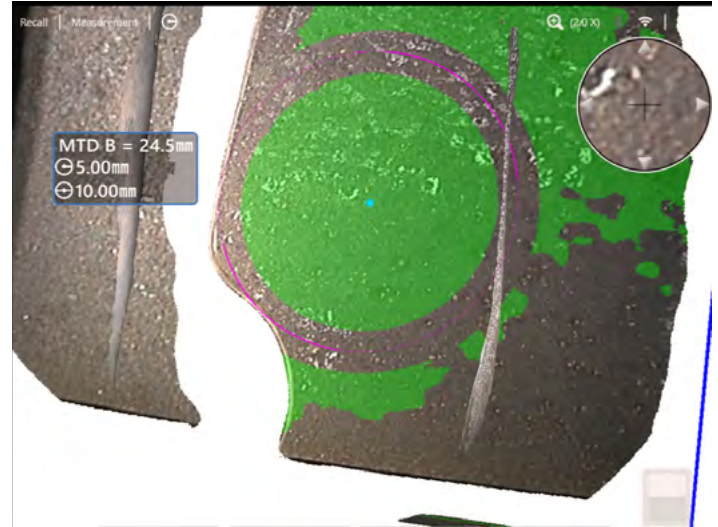
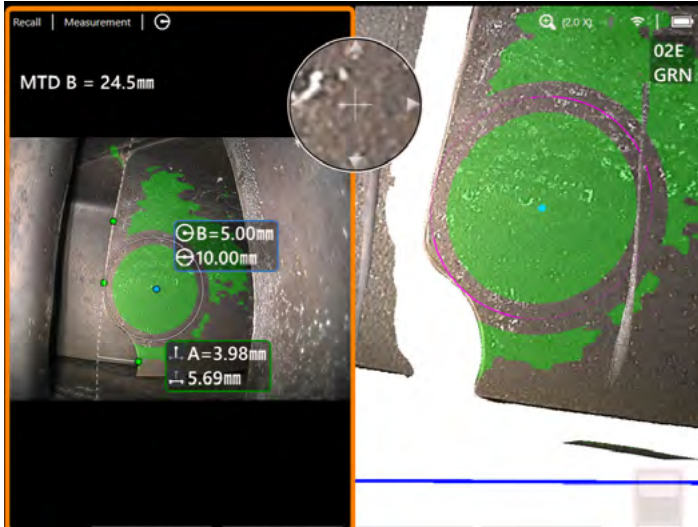
- Turbine blade missing corners

3D Surface Mask:

When enabled in Settings, surface points very close to the Measurement Plane are shown in green. Surface points near the projected missing edge lines are shown in light blue.

Best Practices to Improve Measurement Accuracy:

- Adjust the Measurement Plane cursor positions to maximize coverage of the green 3D Surface Mask on the blade near the missing corner.
- Adjust the Missing Corner cursors to align the dashed extension lines with the blade edges in the 2D image.



Creates a 3D circle of a user-designated size to enable a visual comparison against the shape of a surface to be evaluated in accordance with a known radii (or diameter).

Example Applications:

- Gas Turbine boroblend: scallop or tip blend.

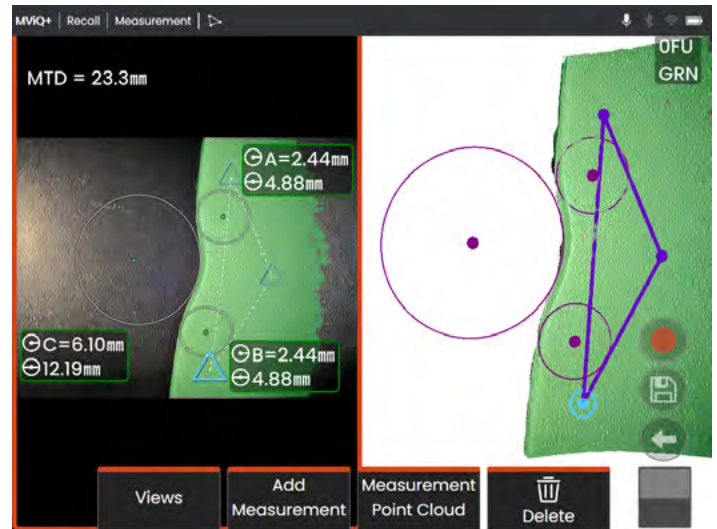
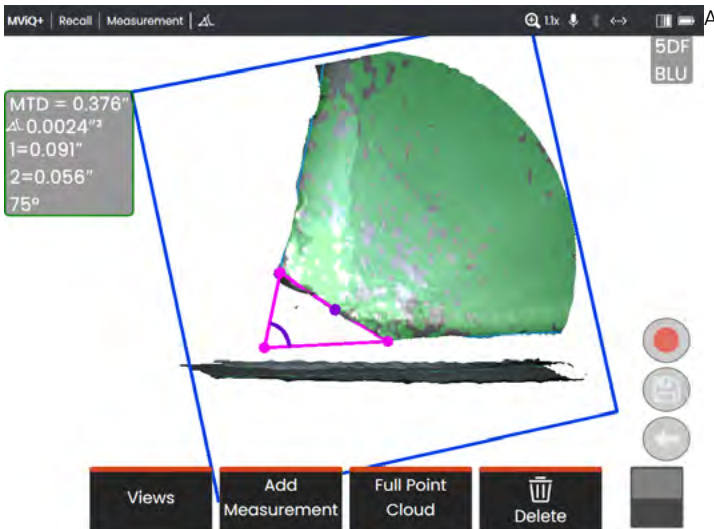
3D Surface Mask:

When used without a Measurement Plane, a best-fit plane is determined using points inside the circle on the same surface as the center cursor. When enabled in Settings, points near the best-fit plane are shown in green with the exception of points in the vicinity of the circle, which are not masked in order to increase the visibility and position of the circle.

Best Practices to Improve Measurement Accuracy:

- Best suited in conjunction with long range Yellow (forward facing) or Green (side facing) 3D Phase Measurement tips.
- Can be used with Measurement Plane in order to enable radii check on edges of components such compressor blade aerofoils or indeed when the surface is curved and a 'best fit' plane is considered appropriate.
- Note that the circle line visibility in the point cloud view varies as it crosses between the near and far sides of the surface.

Measurement Plane



Measurement aid used in conjunction with other measurement types to allow the placement of cursors in red areas where no 3D data is present or where noise in the 3D data may be reducing measurement accuracy. This is accomplished by mathematically extending the measurement plane into 3D space.

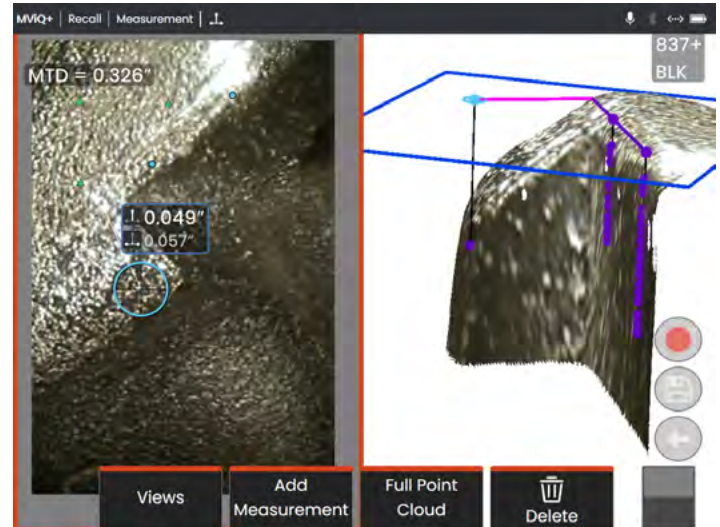
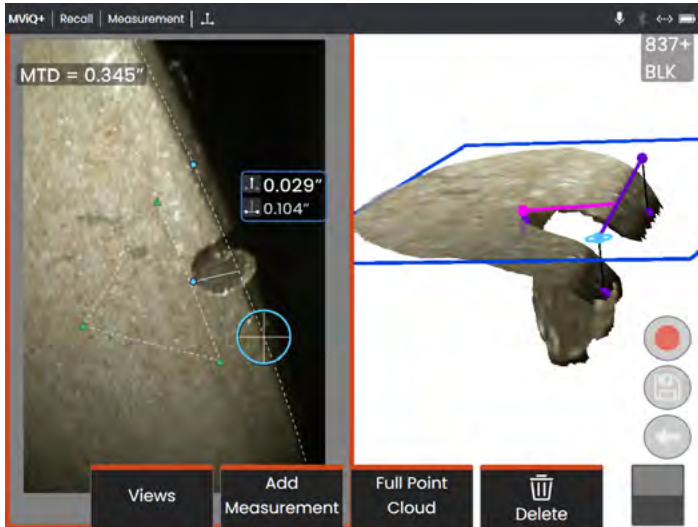
Example Applications:

- With Area or Missing Corner to measure blade missing corners
- With Point to Line for blade edge damage
- With Depth for blade tip to shroud gaps
- With Length or Point to Line for small features when unable to get closer
- With Area Depth Profile when measuring a field of pits on a flat surface
- With Depth Profile when you cannot fit the cursors fully on a flat reference surface
- With Radius Gauge to assess boroblend edge radii

Effect of a Measurement Plane on other measurement types:

- **Length, Point to Line, Multi-Segment, and Area:** All cursors are projected onto the Measurement Plane, and the result is computed using the projected positions on the plane.
- **Depth:** The first three cursors select individual surface points as with a normal Depth measurement. Only the fourth is projected onto the Measurement Plane.
- **Depth Profile:** The Measurement Plane is used as the reference plane, so the Depth Profile cursors may overlap edges or be in red areas. The result is the height or depth from the Measurement Plane. Use only with flat reference surfaces.
- **Area Depth Profile:** Both reference lines are positioned on the Measurement Plane allowing them to pass through red areas or surface pits without affecting the profiles taken between the reference lines. The result is the height or depth from the Measurement Plane. Use only with flat reference surfaces.
- **Angle:** All three cursors are projected onto the Measurement Plane.
- **Surface Angle:** Only the fourth cursor is projected onto the Measurement Plane. The first three cursors still separately define the reference plane.
- **Missing Corner:** Requires prior placement of the Measurement Plane, and all cursors are projected onto the Measurement Plane.
- **Radius Gauge:** The Radius Gauge circle is placed on the Measurement Plane.
- Only one Measurement Plane can be used on an image.
- If a Measurement Plane is present, all other measurements use it regardless of the order in which they were placed.

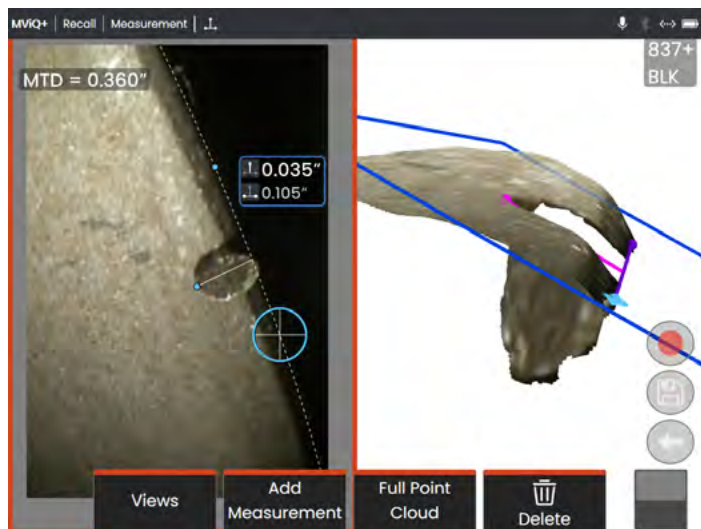
Measurement Plane Guide Lines



Guide Lines are shown in the point cloud views when using a Measurement Plane with Length, Point to Line, Multi Segment, or Area. They are shown as black lines that are perpendicular to the Measurement Plane and extend from the cursor locations on the Measurement Plane to surface points straight above or below the cursor locations. Spheres are shown where Guide Lines intersect the surface.

Example Applications:

- Edge damage on rounded turbine blade or vane edges
- Turbine vane platform to shroud gaps
- Edge radius estimates
- Gap width
- Any in-plane dimensions between points not on the same plane



Conventional Measurement on a Diagonal

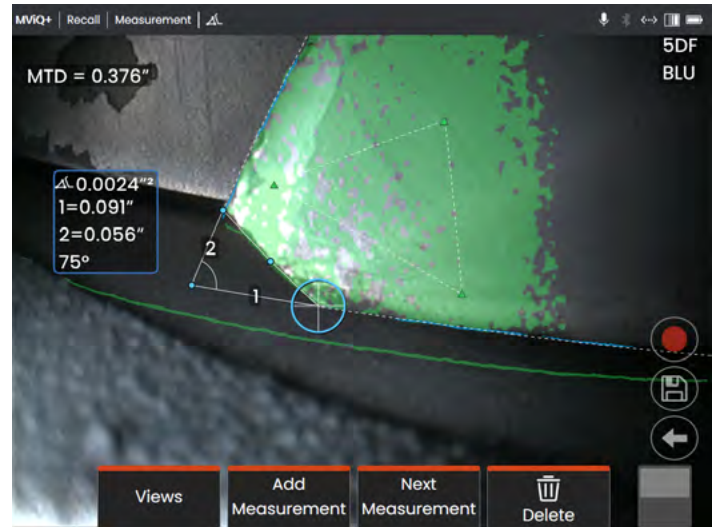
Best Practices to Improve Measurement Accuracy:

- Adjust the cursor positions until the Guide Lines and surface spheres appear in the point cloud view at the desired locations.
- Use when measuring on rounded edges and an in-plane measurement like that obtained using an optical comparator is desired. The conventional Point to Line measurement of a rounded leading edge indication in the lower left image is on a diagonal and therefore gives a larger result than would be obtained using an optical comparator. The same indication is measured in the top left image using a Measurement Plane with Guide Lines to remove the angle.
- Ensure that the rounded edge is angled toward the probe tip and fully visible rather than angled away from the tip.
- Cannot be used when the 3D data does not extend all the way to the edge of the surface.
- Should be used to guide cursor positioning on rounded edges oriented toward the probe tip, especially when the EVA exceeds about 15°. The rounded edge is off the measurement plane, so unless the EVA is low, the cursors cannot be placed properly using only the 2D image.

Measurement Plane Examples

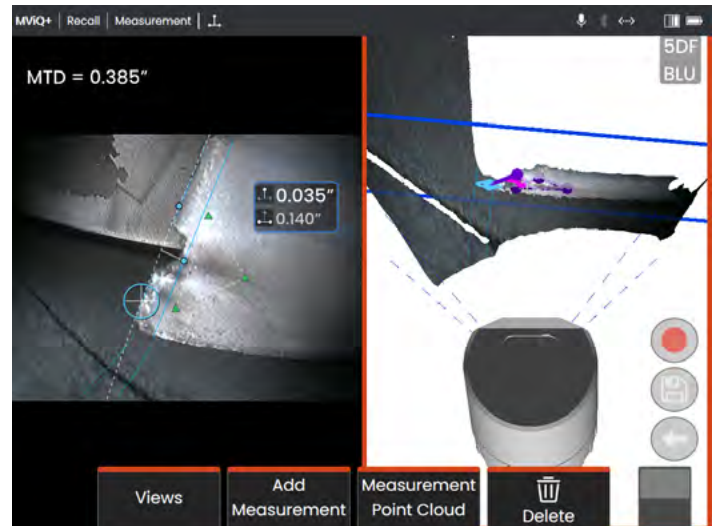
Turbine blade missing corner dimensions:

- Use a Measurement Plane with Missing Corner or Area.
- Position the probe tip according to recommendations in the Measurement Plane EVA Advisory section.
- Place the Measurement Plane on the face of the blade near the missing corner. Maximize the green surface mask near the area of missing material.
- Place a Missing Corner or Area measurement with one cursor on each remaining corner, one cursor out in space where the corner used to be, and as many as are needed to follow the broken edge.
- After pressing "Done", adjust the cursors so that the extended lines line up with the blade edges near the missing corner region.
- The missing area, missing edge dimensions, and the corner angle are all provided eliminating the need for additional measurements. This measurement data field can be moved into position as desired.



Turbine blade edge indication:

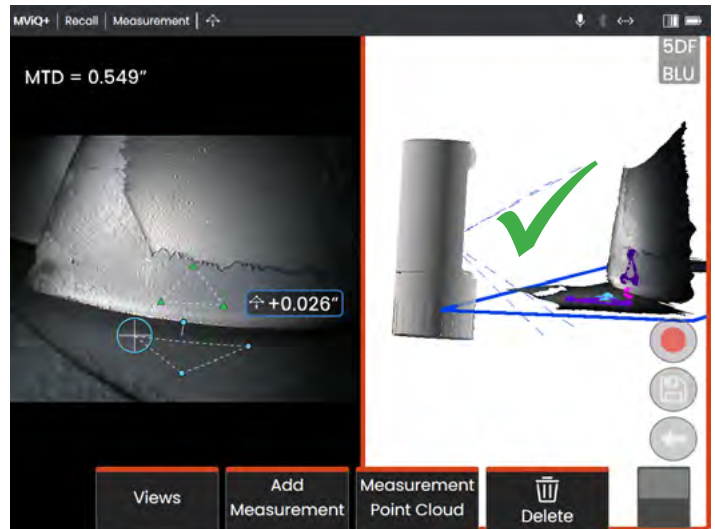
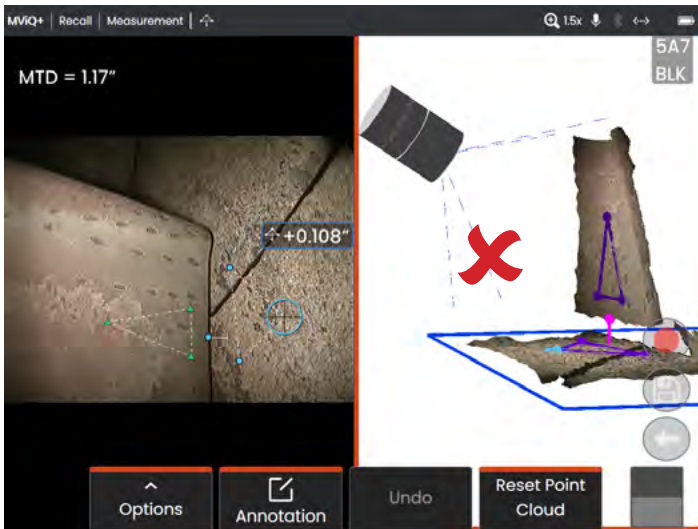
- Use a Measurement Plane with Point to Line when 3D data along the blade edge is missing or noisy.
- Place the Measurement Plane on the face of the blade near the indication and maximize the green surface mask near the indication and surface edge.
- Add a Point to Line measurement with the first two cursors placed on the edge of the blade and the third at the inner edge of the indication.



Measurement Plane Examples

Turbine blade tip to shroud clearance:

- Use a Measurement Plane with Depth when 3D data at the edge of the blade is missing, noisy, or drawn down and back toward the shroud as shown in the lower right image.
- Position the probe tip low to the shroud so that you can see back under the blade. The left image below is captured from too far above the shroud.
- Place the Measurement Plane on the face of the blade near the desired measurement point. Too much spacing between the cursors near the blade edge can increase error due to blade curvature. Look at the green surface mask for cues of this curvature near the area to be measured.
- Place the first three Depth cursors on the shroud.
- Position the fourth Depth cursor at the edge of the blade in the 2D image. This cursor is projected onto the Measurement Plane, so it may appear slightly off the edge in the point cloud due to missing or noisy 3D data at the edge.



3D Stitching (3DS)



Composite image examples captured using 3D Phase Measurement

Inspect, interrogate (measure) and report more of the scene. Ability to combine up to ten images (3D Phase or 3D Stereo) to create a composite image is now possible on the device. Reduce measurement uncertainty by capturing higher quality images and performing measurements on the overall composite image.

3DS can be undertaken during a given inspection or from recalled images captured earlier. Images must however be captured from the same probe and tip in order to successfully stitch.

Example Applications:

- Large defect measurement assessment
- Establishing defect location relative to fixed positions on the component
- Creation of stitched image for reporting purposes

Disclaimer:

The quality of the 3DS process is dependent on a number of factors. You, the User, are responsible for checking the quality of both individual and composite images to ensure the best possible outcome. Please refer to the General Guidelines section in this document to learn more.

The factors that have the greatest effect on 3DS are:

- Distance from target
- Visual features contained within the scene
- Image overlap
- Target material composition

Best Practices to Improve 3DS Accuracy:

Technology Choice

- Both 3DPM and 3D Stereo can be used.
- The 105° FOV of 3DPM tips allow a wider scene to be viewed and measured from a given distance than 3D Stereo (50 or 60° FOV dependent on tip used).
- 3D Stereo may provide better results than 3DPM in compressors having shiny blades and liner.

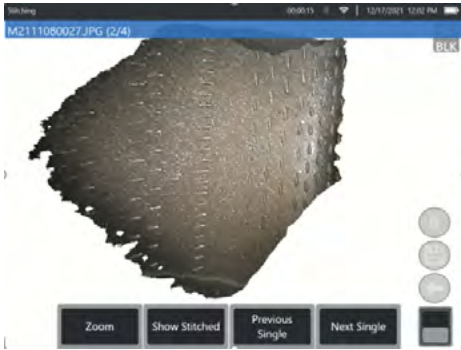
Setup

- Position the probe tip as close as possible to the target surface.
- Images must have at least 50% overlap. Too little overlap often results in failed or inaccurate stitching.
- Surface must have unique details that look similar from one image to the next.
- Surfaces that have a shiny or reflective appearance that changes as the probe tip moves position can be problematic. Increasing overlap can help.
- Avoid excessive (c.20°) rotation steps between image captures.
- Avoid excessive (c.30%) magnification steps between image captures.
- Clean data helps – minimize MTD. Use Green or Yellow 3DPM tip where possible.
- Always check registration or stitching quality before proceeding and measuring.

Checking Registration Accuracy

- During the capture and subsequent stitching of images, it is possible to intermittently check the registration or quality of stitch before proceeding and capturing more images or subsequent measurement assessment.
- This is an important process to ensure accuracy of measurements on stitched images.
- Watch surface details while using 'Next/Previous Image'
- If well registered, surface details will move very little between images
- If poorly registered, details will shift.

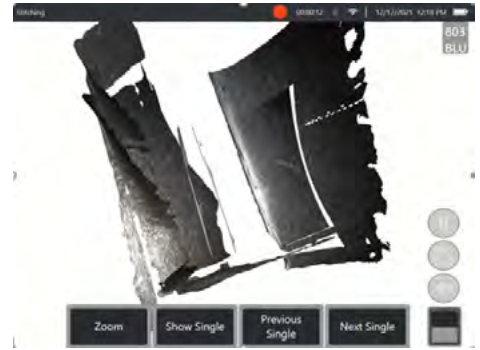
3D Stitching (3DS)



Checking registration of individual images



This example shows good registration.



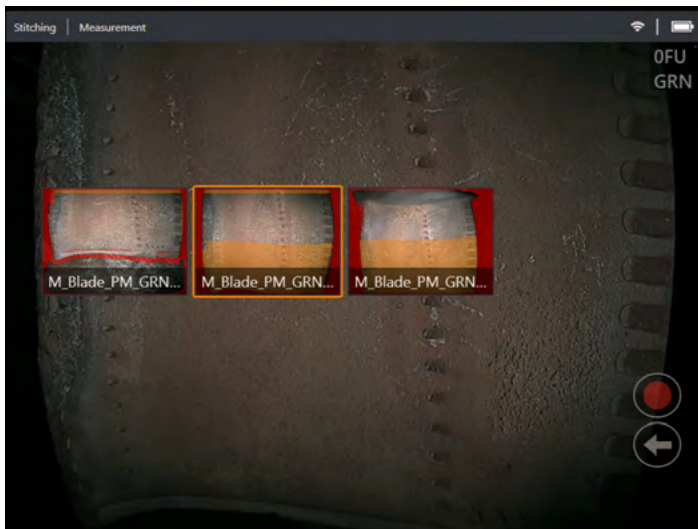
The example shows poor image registration of a compressor blade

Signs or indicators of poor image registration are:

- Clear gaps between images
- Surfaces offset from one another
- Surface features are not in the same location when switching between images.

3D Stitching – Orange Mask

Orange mask is shown when the device is presenting individual 2D images. The mask represents the areas of the image that do not contribute to overall composite point cloud and are not used for measurement.



All three images are used to generate the composite stitched image but some areas (shaded orange) are discarded and not used. The primary image contains the least orange masked area.

Selection of an individual 2D image and subsequent measurement may result in displaying an orange measurement cursor. This cursor highlights it being derived from a different image within that stitched image set. Note: normal measurement cursors are coloured green (when inactive). See above.

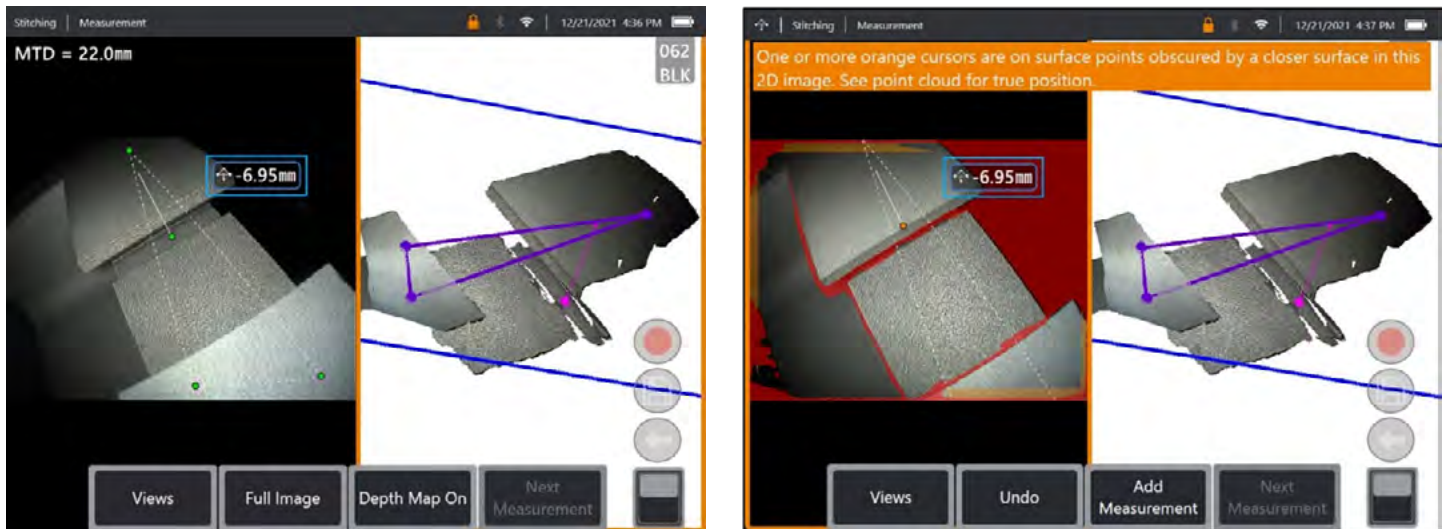
3D Stitching (3DS)

3D Stitching – Occluded Cursors

On surfaces with significant steps, some parts of the surface may be visible in one image but hidden by a closer surface in a different image.

When a cursor is placed on a surface point that is occluded by a closer surface in the current 2D image, the cursor is shown in orange and a message is displayed.

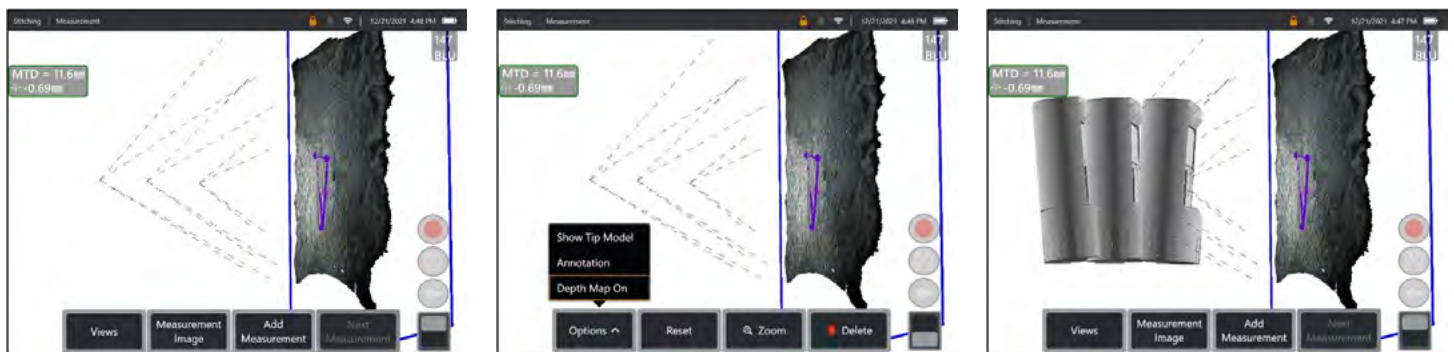
Saving of full screen 2D images is disabled when stitching to reduce risk of misinterpretation of the position of occluded cursors on the 3D surface. See images below.



Perspective Lines and Tip Model (not exclusive to 3D Stitching)

These are only shown when a measurement is present and 'full image' enabled in order to reduce visual intrusiveness. They can be activated/deactivated within Settings > Measurement Annotation.

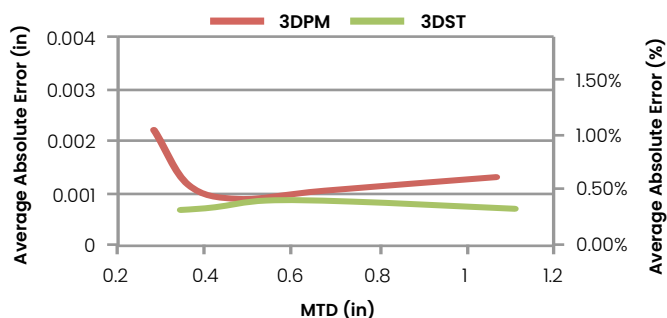
With 3D Phase images, a tip model can be enabled via 'Options' 2nd level soft key. This provides visual reference of the probe tip in relation to the target surface.



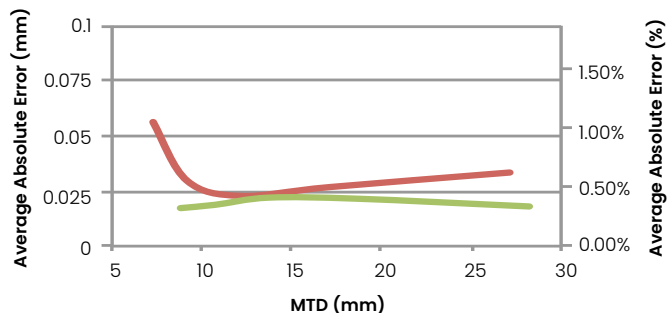
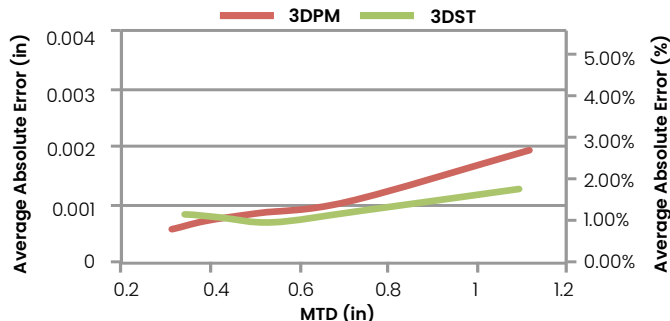
Measurement Accuracy Data

The measurement accuracy curves on pages 19–20 were created from trained third party test results using 6.1 mm diameter 3DPM and 3D Stereo (3DST) on a Mentor Visual iQ under controlled conditions with a matte finish test block. They should be interpreted as system capability under ideal conditions. Actual results vary with application, surface conditions, equipment condition, and user expertise.

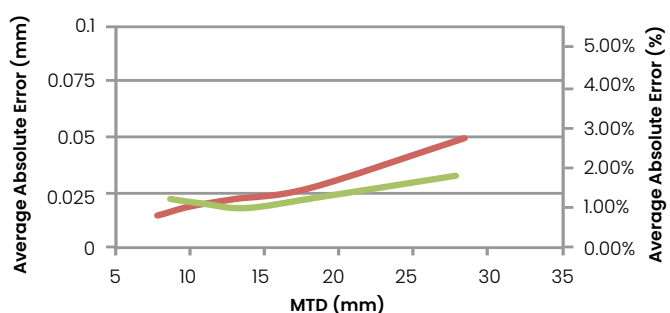
Length Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.21" (5.33 mm) Long Feature



Pt-Line Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.071" (1.803 mm) Edge Ding Feature

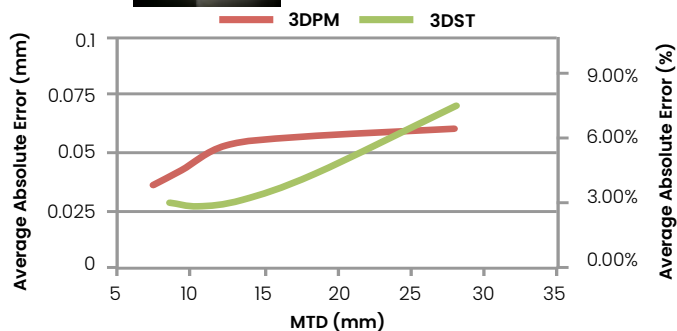
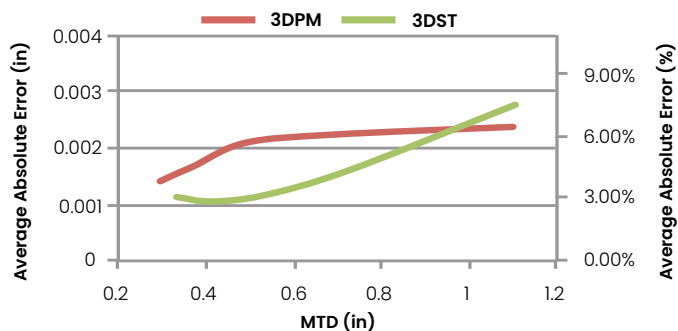


Accuracy curve for length measurement of a crack.



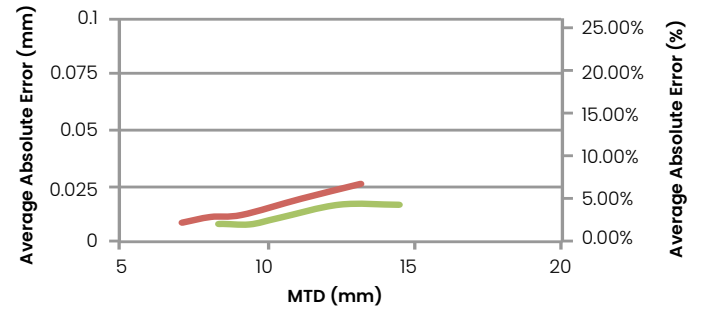
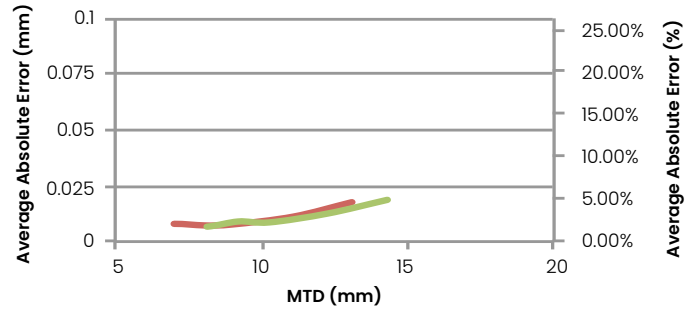
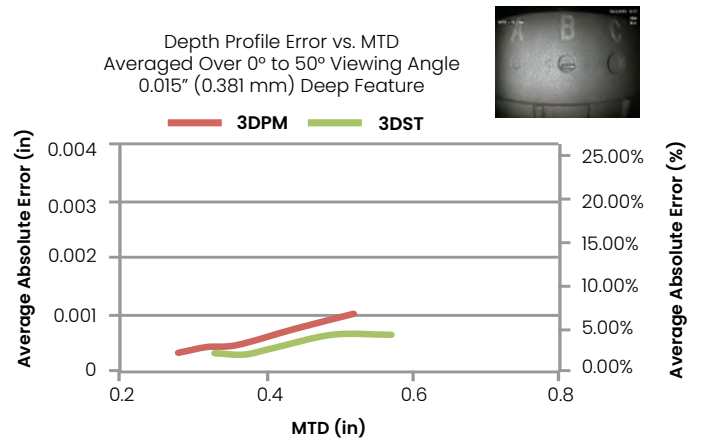
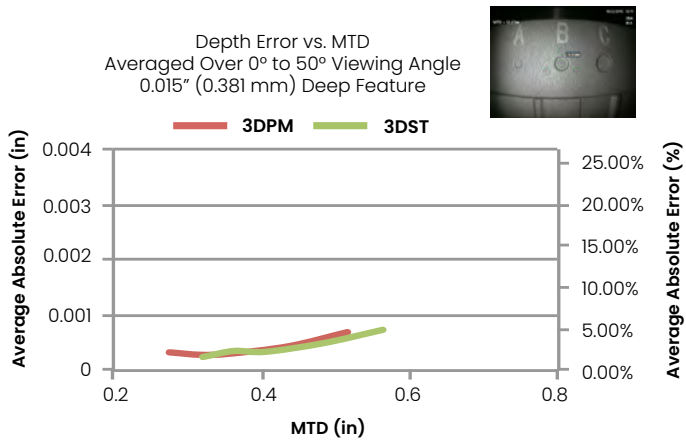
Accuracy curve for point to line measurement of an edge ding.

Pt-Line Error vs. MTD
Averaged Over 0° to 50° Viewing Angle
0.037" (0.94 mm) Missing Corner Feature



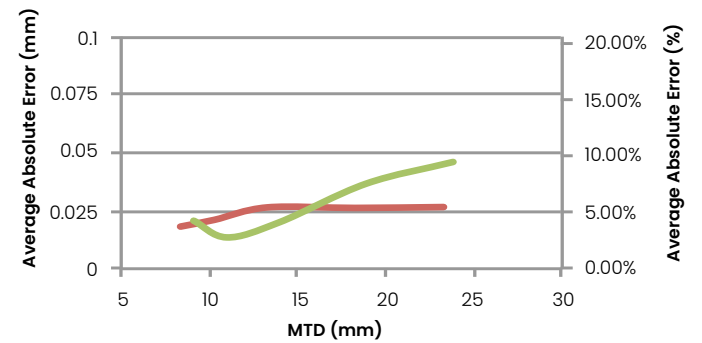
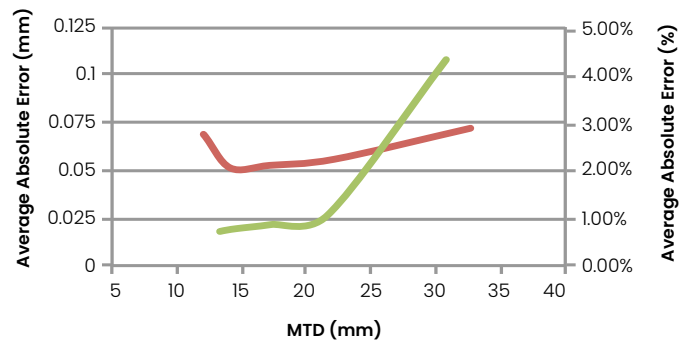
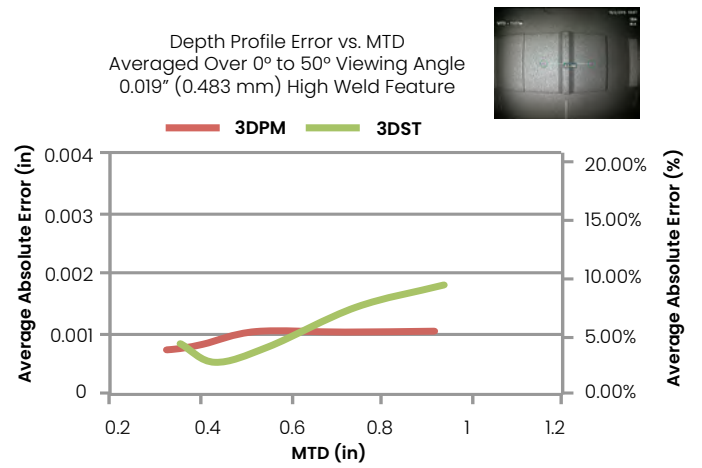
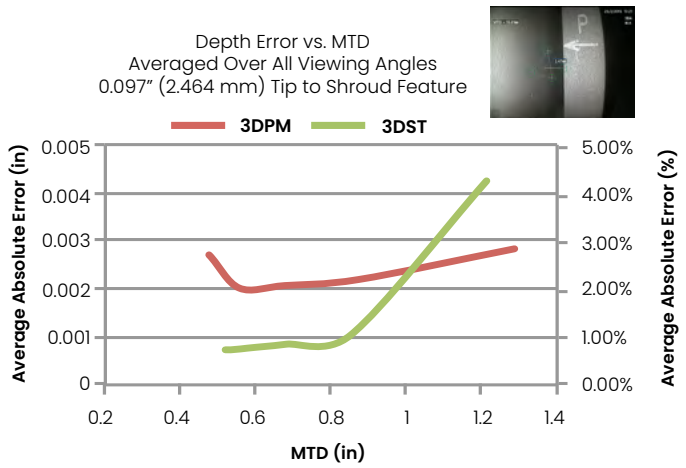
Accuracy curve for point to line measurement of a missing corner.

Note: Measurement Planes were not used in this testing but would likely improve the results on some features.



Accuracy curve for depth measurement of a pit or dent.

Accuracy curve for depth profile measurement of a pit or dent.



Accuracy curve for depth measurement of a tip to shroud distance.

Accuracy curve for depth profile measurement of weld height.

Specifications

Measurement Tip Optic Specs and Part Numbers for Mentor Visual iQ

Mentor Visual iQ 4.0 mm Tips

3D Stereo Measurement and Stereo Measurement Tips

Part No.	Color	FOV (deg)	DOF mm	(in)
TM405555FG	Black	55/55-FWD	5-inf	(.20-inf)
TM405555SG	Blue	55/55-SIDE	4-inf	(.16-inf)

Mentor Visual iQ 6.1mm Tips

3D Phase Measurement Tips

XL4TM61105FG	Black	105-FWD	8-250	(.31-9.84)
XL4TM61105SG	Blue	105-SIDE	7-250	(.27-9.84)
XL4TM61105FF	Yellow	105-FWD	15-inf	(0.59-inf)
XL4TM61105SN	Red	105-SIDE	2-20	(.08-.79)
XL4TM61105FN	Orange	105-FWD	3-120	(.12-4.72)
XL4TM61105SF	Green	105-SIDE	15-inf	(.59-inf)

3D Stereo Measurement and Stereo Measurement Tips

XLG3TM616060FG	Black	60/60-FWD	4-80	(.16-3.15)
XLG3TM615050SG	Blue	50/50-SIDE	2-50	(0.8-1.97)

Mentor Visual iQ 6.2mm Tips

3D Stereo Measurement and Stereo Measurement Tips

TM626060FN	Black	60/60	4-80	(0.16-3.15)
TM626060SN	Blue	60/60	4-80	(0.16-3.15)

Mentor Visual iQ 8.4mm tips

3D Stereo Measurement and Stereo Measurement Tips

XLG3TM846060FG	Black	60/60-FWD	4-50	(.16-1.97)
XLG3TM846060SG	Blue	60/60-SIDE	4-50	(.16-1.97)

Stereo and 3D Stereo use the same Optical Tip Adapters

Glossary

3D Data Mask – Shows red and yellow pixel masks. See "Red Mask on Image" and "Yellow Mask on Image" for details.

3D Perspective Lines – Dotted blue lines showing the four corners of the tip field of view in the full image point cloud to help the user understand and improve tip orientation relative to a surface. May be shown or hidden via the settings menu.

3D Phase Measurement – A measurement technology that projects line patterns on an object via a series of LEDs. Measurements are calculated using the concept of phase shift analysis combined with proprietary processing technology.

3D Point Cloud – A 3D graphical representation of the surface being inspected on which lines and spheres are added to show measurements made on that surface. The 3D point cloud can be rotated and viewed from multiple angles and perspectives. It allows an inspector to check measurement setup and initiate and edit cursor placement points.

3D Stereo Measurement – Uses the same optical principles and tip optics as Stereo Measurement and combines these with the ability to create, manipulate and analyze a 3D Point Cloud representation of measurement data.

3D Surface Mask – Colored semi-transparent masking of surface points in the 2D image and point cloud views during 3DPM or 3D Stereo measurement that helps guide proper cursor placement.

Active Cursor – The cursor currently being manipulated, indicated by a blue circle.

Advisory Message – "For best results the reference cursors should be on the same plane" – In depth profile measurement, indicates the reference cursors are not on the same plane.

Advisory Message – "Move closer to target or move cursors for better results" – Indicates that the measurement is too small to be reliable at the current tip to target distance. Can be remedied by moving tip closer to the indication or selecting larger measurement area.

Auto-Repeat – Setting Auto Repeat in the measurement menu to "On" remembers all measurements performed on the current image along with the current measurement view. Upon subsequently pressing the 3DPM Capture (from live) or Stereo (from Freeze Frame) soft keys, these measurements will be automatically performed on the newly captured image. This feature improves efficiency when making repetitive measurements.

CSV – Comma separated value, used for point cloud file data export. Can be opened in a CAD package.

Dark Boost – Dark Boost is a live video processing function which digitally brightens darker areas in scenes with bright foreground surfaces, or glare, without over-exposing or degrading the contrast of more uniform scenes.

Depth Assist – Feature wherein the system searches the surface data in the vicinity of the first three cursors of a Depth measurement and automatically places the fourth cursor at the deepest point, highest point, or a point on a blade tip saving the user the time of locating those points manually.

Depth Map – 3D point cloud viewing mode in which either the tip to target distance (full image) or the perpendicular distance from the measurement reference plane (measurement image) is color coded to provide better understanding of 3D data noise levels and surface contours.

Depth Profile View – Alternative 2D view of depth profile along a selected depth profile line.

FOD – Foreign Object Damage.

Full Point Cloud – Shows all measurements and surface data. The depth map indicates the distance from the measurement tip to the surface.

Guide Lines – Lines shown in the point cloud views when using a Measurement Plane with Length, Point to Line, Multi Segment, or Area to help the user position cursors to align with out-of-plane surface points.

Image Brightness – As it relates to a video borescope is a combination of several components, not just available light

- For live video, the image brightness control adjusts the brightness set point for the camera's auto gain and exposure control processing
- For still images, the image brightness control digitally adds or subtracts an offset from the image's RGB values

InspectionWorks Connect – Remote collaboration tool allowing live remote viewing of inspection video, two-way chat and annotation. Can be activated directly on the Mentor IQ handset.

Inactive Cursor – Cursors not currently selected, indicated by a green circle. Insight for where data can be pushed and remeasured by SMEs.

Inspection Manager – PC-based re-measurement tool for visual inspection images.

Measurement Point Cloud – Shows only the active measurement and surface data in its vicinity. The depth map indicates the perpendicular distance of the surface points from the measurement's reference plane.

Missing Corner – The corner of a turbine blade that has been broken off usually by an object passing through the turbine.

MTD – Maximum target distance. Identifies the distance of the furthest cursor point in a given measurement from the tip of the probe.

Noise in the Point Cloud – Artifacts in the 3D data not representative of true surface geometry. Noise is generally reduced by moving the tip closer to the target surface or changing angle of approach to reduce reflections.

Orange Outline Around Measurement Results and MTD

Value – Indicates that the measurement is too small to be reliable for the current tip to target distance. Can be remedied by moving tip closer to measurement or selecting larger measurement area.

Probability of Detection (POD) – *“POD is the probability that a flaw of a specific type will be detected by a given technique given the flaw exists in the material.” Bill Prosser, NASA*

You may ask, “What is Waygate Technologies’ POD on the Mentor Visual iQ (MViQ) VideoProbe™? And, how will it help me during inspections and indication analysis?”

In essence, POD is a combination of technologies which allow for the transformation of a white light image into one which will facilitate assessing the health of the visual surface, provide additional information about a surface’s condition, and if & when an indication, or “flaw”, is detected these tools are available to provide greater precision and accuracy when deploying Real3D™ Phase and Real3D Stereo Measurement – both of which provide an XYZ pivotable point cloud for analysis.

Profile Slices – Paths along the surface between the reference profile lines in an Area Depth Profile Measurement that map the perpendicular distance between the surface points and the reference surface.

Projected Plane Measurement – The use of a Measurement Plane in combination with another measurement type to mathematically project the plane of a surface over the entire image and measure on that plane.

Red Filled Cursors on Depth Profile – Indicates cursor is not on a flat surface or not on the same plane. Cursor must be repositioned for accurate measurement.

Red Mask on Image – Indicates surface data in this area is not available for measurement. Moving closer or adjusting viewing orientation may reduce red mask area.

Reference Line – In a point to line measurement, the first two cursors, placed on unaltered surface points, define a straight reference line in 3D space from which the distance to the third cursor point is measured.

Reference Plane – The plane, defined by three or more points on a reference surface, from which the perpendicular distance to other surface points is computed. A blue square indicates the reference plane position in the measurement image 3D point cloud view.

Note: A reference plane is calculated as flat, even if the surface the plane rests on is not flat. This is a potential source of error.

Reference Profile Line – Area Depth Profile lines set by the measurement cursors which follow the surface contours and are used to determine the area and reference planes for the profile slices.

Reference Surface – Unaltered part surface to be used as a reference for various measurements.

Result Slice – The Area Depth Profile profile slice that includes the highest or lowest point and is shown on the image and in the point cloud.

Signal Strength Range Guide – Visual aid displayed when viewing live video with a 3DPM tip attached to indicate the system’s ability to achieve sufficient brightness with the tip LEDs for a high-quality scan. Increasing the number of bars by moving closer to the target will increase 3D data quality and measurement accuracy.

Surface Mask – One of several masks coloring pixels on a surface with various color gradients to indicate various surface contours or distances between cursors.

Yellow Mask on Image – With 3D Phase Measurement, indicates surface data may be of low quality for measurement. The potential for reduced accuracy may exist, especially for depth or small measurements. Yellow mask areas are often caused by surface to surface reflections. Changing the probe orientation to make such reflections bounce away from the probe tip may improve data quality and reduce or eliminate yellow mask areas.

3DPM Save Format –

- **PMap** – Original projected pattern images are embedded in the saved image file and fully re-processed to generate new 3D data when re-measurement is performed on the recalled image. Generally used for development and troubleshooting purposes.
- **ZMap** – Computed 3D surface data is embedded in the saved image file and used when re-measurement is performed on the recalled image. Gives smaller files than PMap and is recommended for most users.

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