Detection of Critical Surface Features in PTLs and GDLs for Improved Device Performance and Manufacturing Reliability

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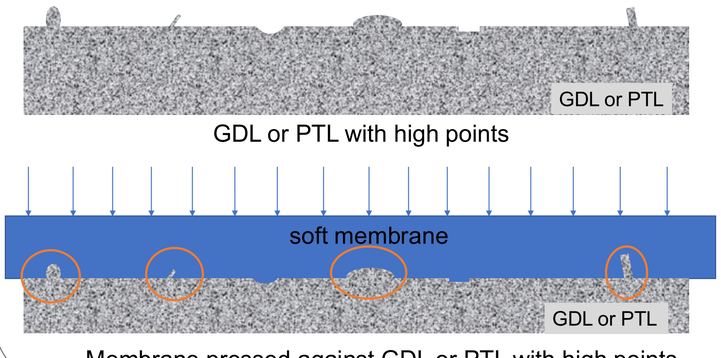
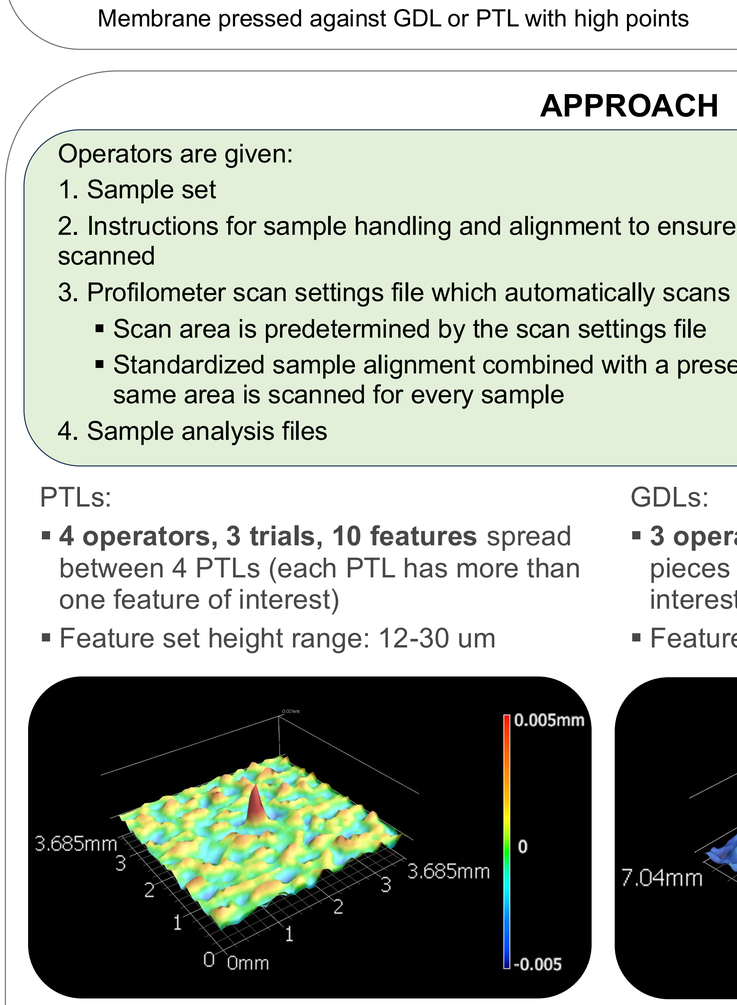
MOTIVATION

- High points on porous transport layers (PTLs) and gas diffusion layers (GDLs) may stress the membrane during lamination and cell operation, and high points on GDLs may affect the reliability of the manufacturing process. Thus, understanding these critical features and developing procedures to scan for them are a key part of developing quality control techniques for PTLs and GDLs.
- **Objective:** Evaluate effectiveness of Keyence VR6200 benchtop-scale structured light optical profilometer for detection of surface protrusions on PTLs and GDLs. Establish standard testing procedure and measure Gage R&R with at least two operators.

Keyence VR6200 profilometer



GDL or PTL with high points



Membrane pressed against GDL or PTL with high points

This work advances the Roll-to-Roll Consortium by developing techniques that are necessary to understand and detect material abnormalities as outlined in the goal:

2.) Understand material and process behavior to advance methods to increase energy efficiency, reduce material usage, reduce hazardous waste, and reduce equipment cost in manufacturing processes

APPROACH

Operators are given:

1. Sample set
2. Instructions for sample handling and alignment to ensure the same area of the sample is scanned
3. Profilometer scan settings file which automatically scans the part with preset settings
   - Scan area is predetermined by the scan settings file
   - Standardized sample alignment combined with a preset scan settings file ensures that the same area is scanned for every sample
4. Sample analysis files

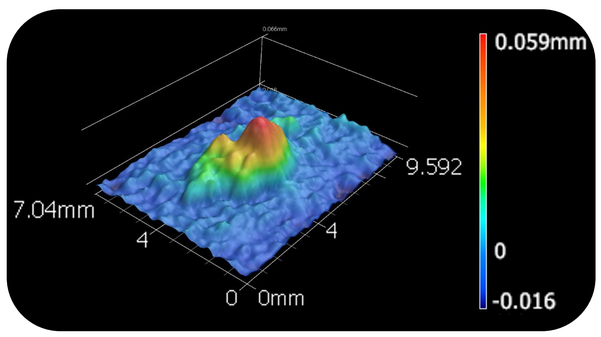
PTLs:

- **4 operators, 3 trials, 10 features** spread between 4 PTLs (each PTL has more than one feature of interest)
- Feature set height range: 12-30 um

GDLs:

- **3 operators, 3 trials, 8 features** on 8 GDL pieces (each GDL has one feature of interest)
- Feature set height range: 25-167 um

Example high point on a PTL



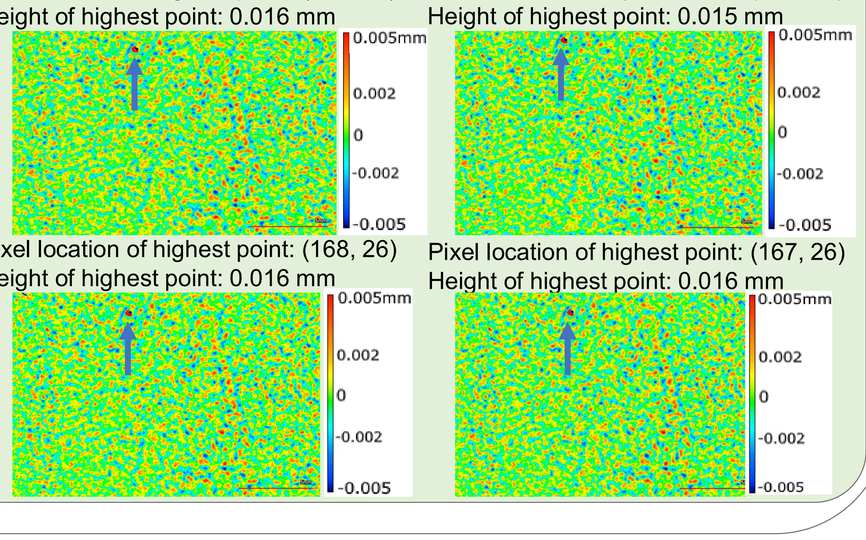
Example high point on a GDL

Operators follow the procedure to scan each sample and record the following:

- Height threshold applied to filter out low height areas and show only highest areas
- Height of highest 2 points in the region measured
- Pixel locations of highest 2 points in the region measured

Example data and height maps for Sample A Feature B

	Trial 1	Trial 2
Operator 1	Pixel location of highest point: (166, 25) Height of highest point: 0.016 mm	Pixel location of highest point: (157, 10) Height of highest point: 0.015 mm
Operator 2	Pixel location of highest point: (168, 26) Height of highest point: 0.016 mm	Pixel location of highest point: (167, 26) Height of highest point: 0.016 mm



RESULTS/DISCUSSION

With feature location data:
- If trial correctly reported the location of the highest point → Pass
- If trial did not correctly report the location of the highest point → Fail

$$\text{Effectiveness} = \frac{\text{\# Passes}}{\text{Total \# trials}}$$

With feature height data: → Compute traditional Gage R&R metrics on the height measurement data

PTLs

System effectiveness in identifying correct location of the highest point:

	Operator 1	Operator 2	Operator 3	Operator 4
Number of passing trials:	30/30	30/30	30/30	30/30
Percent effectiveness:	100%	100%	100%	100%
False alarm rate:	0%	0%	0%	0%

- All operators correctly identified the locations of the highest points within a tolerance for all trials and all features.
- Overall effectiveness was 100% across all operators for detecting correct location of the highest point on PTLs

Gage R&R analysis on height measurements:

Source	Variance	% Contribution	Standard Deviation
Total Gage R&R	0.00000073	2.24	0.000854
Equipment Variation (Repeatability)	0.000000606	1.86	0.000778
Operator Variation (Reproducibility)	0.000000124	0.38	0.000352
Operator	0.000000000673	0.00207	0.0000259
OperatorxPart Interaction	0.000000123	0.378	0.000351
Part to Part	0.0000318	97.8	0.00564
Total Variation	0.0000325	100.0	0.00571

Largest source of variation in measurements comes from variation in the heights of the features themselves.

Equipment variation contributes more than operator variation.

The system can measure within 1um in the height range of 12-30 um.

Total Gage R&R %Contribution:
1-9% indicates acceptable measurement system depending on the application and other factors

GDLs

System effectiveness in identifying correct location of the highest point:

	Operator 1	Operator 2	Operator 3
Number of passing trials:	24/24	24/24	23/24
Percent effectiveness:	100%	100%	95.8%
False alarm rate:	0%	0%	4.2%

- 1 failing trial out of 72
  - The highest points were detected 100% of the time, including in the failing trial where the highest point was identified as the 2nd highest point, i.e. the features of interest were present in the resulting scan data 100% of the time, even if the feature of interest was not flagged as the point with the highest height.
- Overall effectiveness is 98.6% across all operators for identifying the correct location of the highest point on GDLs

Gage R&R analysis on height measurements:

Source	Variance	% Contribution	Standard Deviation
Total Gage R&R	0.0000593	3.58	0.0077
Equipment Variation (Repeatability)	0.00000618	0.373	0.00249
Operator Variation (Reproducibility)	0.0000532	3.21	0.00729
Operator	0	0	0
OperatorxPart Interaction	0.0000532	3.21	0.00729
Part to Part	0.0016	96.4	0.04
Total Variation	0.00166	100.0	0.0407

Largest source of variation in measurements comes from variation in the heights of the features themselves.

Operator variation contributes more than equipment variation.

Operator variation almost exclusively comes from operator x part interaction.

The system can measure within 8 um in the height range 25-167 um.

Total Gage R&R %Contribution:
1-9% indicates acceptable measurement system depending on the application and other factors

CONCLUSIONS/COLLABORATIONS

- Created standard testing procedures for using the Keyence VR6200 profilometer to scan PTLs and GDLs for high points. These procedures can be used for future scanning of PTLs and GDLs.
- Concluded that the system is effective for detection of high points on PTLs and GDLs for the height ranges tested.
- Concluded that the amount of equipment and operator variation contributing to height measurements is less than 4% of the total variation in measurements and thus is acceptable for both PTL and GDL applications.
- The system can measure heights within 1 um in the height range 12-30 um on PTLs and within 8 um in the height range 25-167 um on GDLs.
- We collaborated with industry partners who provided commercial specimens and helped us define specific quality control needs and barriers.

POTENTIAL FUTURE WORK

- Repeat experiment for other commercial GDLs and PTLs and compare the surface quality of the available products.
- Determine repeatability for in-line, high speed, laser triangulation system on web-line to detect high points.
  - Compare to the repeatability of the benchtop profilometer.

ROLL TO ROLL CONSORTIUM
U.S. DEPARTMENT OF ENERGY
Hydrogen and Fuel Cell Technologies Office

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