NON-CONTACT DIMENSIONAL MEASUREMENTS OF BIPOLAR FUEL CELL PLATES

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INTRODUCTION

In-process non-contact dimensional measurement is critical to the eventual rapid manufacture of fuel cell plates. This need has been identified by the Department of Energy's Hydrogen Program, and by numerous manufacturers' of fuel cell plates. To facilitate this effort, NIST has explored the use of non-contact systems for performing dimensional measurements so that manufacturers may perform 100 % part inspection during the manufacturing process.

This paper describes a dedicated system developed at NIST for performing non-contact dimensional measurements of fuel cell plates using laser spot triangulation probes. This system utilizes two probes tilted in opposing directions so that each probe can detect one side wall of the channel and some portion of the channel bottom. Procedures have been developed to calibrate the system parameters (tilt angles of the probe, offsets between probes, etc.) so that the data from the two probes can be tied to a single coordinate system. A brief description of the system and preliminary measurement results are presented in this paper.

DUAL-PROBE SYSTEM

The configuration of the system is shown in Fig. 1. The device consists of two laser spot probes and a precision translation stage with a high accuracy encoder, whose axis of motion is along the *X* direction. The data acquired from each probe is triggered based on stage position, and as mentioned earlier, the six system parameters (shown in Figs. 2 and 3), are used to tie the two data sets into a common frame.

The procedure to calibrate these parameters and their uncertainty are described in [1]. One approach to estimating the tilt angles (angle θ in Fig. 2) in the probes is by measuring calibrated step heights. However, this method can produce large uncertainties in the tilt angles and does not separate the effect of the misalignments (tilt in the *YZ* plane, see Fig. 3) in the probe. Therefore, the tilt angles are calibrated by measuring profiles on vertically oriented gage blocks (gaging surface is parallel to the *YZ* plane) [1].

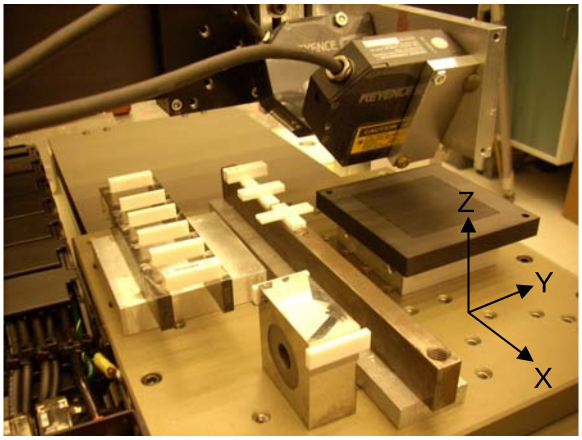

FIGURE 1. The dual-probe system.

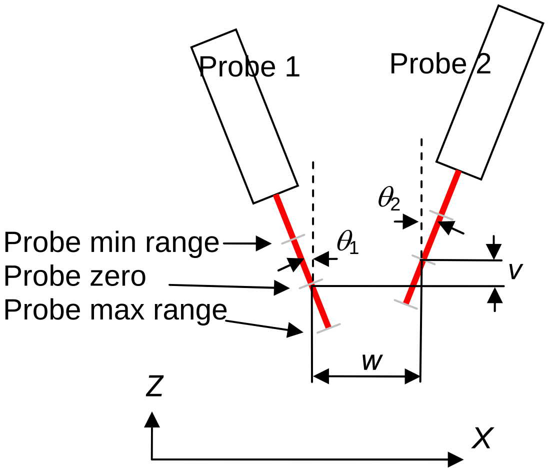

FIGURE 2. Four system parameters – tilt angles θ_1 and θ_2, and offsets v and w. The travel axis is along the X direction.

The horizontal offset between the probes can be calibrated by measuring gage blocks of known width. But it should be pointed out that laser triangulation probes are extremely sensitive to material properties [2] and therefore the offset calibrated using ceramic gage blocks may not be valid for other materials. When measuring fuel cell plates, a master plate of identical material as the part is used to determine this offset.

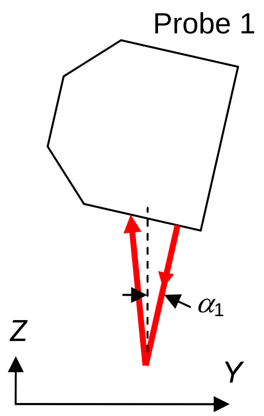

FIGURE 3. Fifth system parameter – misalignment angle α_1. The sixth system parameter is the misalignment angle for the second probe which is not shown here.

The system was validated by measuring the height and width of numerous gage blocks. The errors in width and height measurements using the non-contact system are less than ±1 µm (note that the nominal values of the gage blocks are considered the true values and the error is defined as the difference between the measured value and the true value); this suggests that channel widths and heights can in fact be measured with an uncertainty that is potentially comparable to that obtainable on a coordinate measuring machine (CMM), which is on the order of a micrometer.

PROFILES FROM FUEL CELL PLATES

Profiles from numerous fuel cell plates were acquired and the channel width and height values were compared against measurements made on a CMM with a contact probe. Some of those results are presented here.

The initial investigation was concentrated on graphite plates with vertical side walls. Fig. 4 shows a profile across a channel on such a plate. The measurements were made at 30 mm/s with a sampling interval of 3 µm. For this study, pairs of plates made of identical material were considered. The plates contained 45 rows (three parallel channels that fold over 15 times), each of which was measured on a contact CMM. One plate was used as the master (to calibrate probe offset) and the other as the test artifact. The errors in width and height on the test artifact were within ±2 µm of the calibrated values, indicating that the non-contact system can indeed perform high accuracy measurements, but at a much faster rate. The manufacturers of bipolar plates desire a tolerance of less than 10 µm on these features, but they have so far been unable to realize such low uncertainties with commercially available non-contact systems.

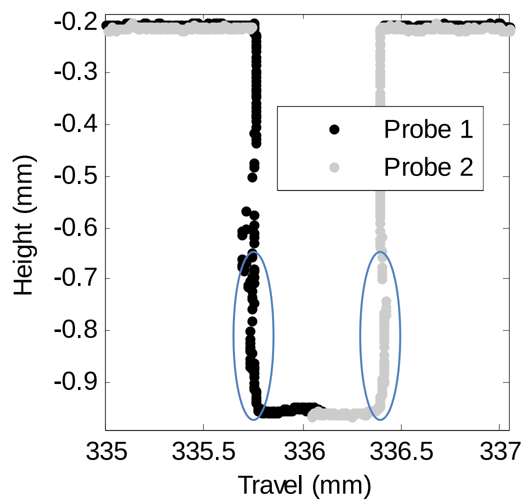

FIGURE 4. Profile across a channel of a graphite fuel cell plate with vertical walls.

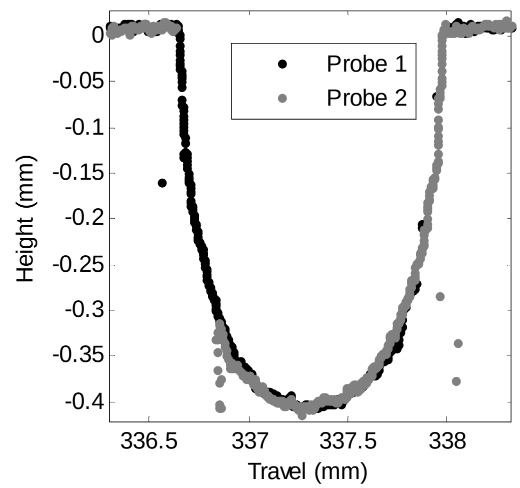

FIGURE 5. Profile across a channel of a chemically etched fuel cell plate.

Notice in Fig. 4 that the sidewall profiles near the intersection of the bottom surface are not vertical. This is really not a surface feature, but is due to multiple reflections that are possible near the intersection of surfaces. This is a known problem with laser triangulation probes [2].

Plates made of Aluminum that were chemically etched were also measured. The profiles on one channel for two different plates are shown in Figs. 5 and 6. Notice that in one case (Fig. 6), there appears to be a dimple in the side wall, which presumably is the result of changes in the manufacturing process parameters. This is an example where rapid metrology feedback is critical in ensuring process stability.

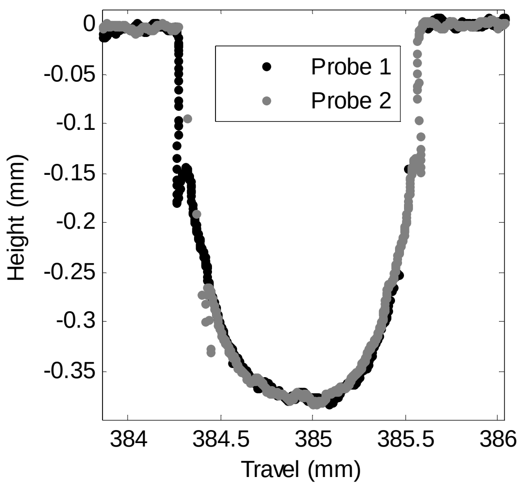

FIGURE 6. Profile across a channel of a chemically etched fuel cell plate.

Detailed uncertainty budgets for channel height and width for the case of the graphite fuel cell plates with vertical channel sidewalls have been developed. The calculations, described in [1], show that the expanded uncertainty in width is 6 µm (k = 2) while that of height is 3.8 µm (k = 2).

SPEED TESTS

In-process measurement that supports rapid manufacturing requires that measurements be made not only in-situ, but also in a timely manner. The system described here relies on acquiring profiles on plates by scanning the probes across the part. The initial experiments were performed at 30 mm/s, where a single profile across a 100 mm long plate would take a little more than 3 s. Acquiring six parallel profiles spread out on the plate would therefore take about 20 s.

Measurements of a single fuel cell plate at different speeds, from 30 mm/s up to 500 mm/s, were performed to evaluate if there is any noticeable degradation in accuracy at higher speeds. The channel heights and widths at different speeds for each of the different rows are shown in Figs. 6 and 7 respectively. Notice that the channel heights and widths at 300 mm/s agree with those at 30 mm/s rather closely. Some discrepancy is observable at higher speeds, but for the most part, the agreements in width and height between 500 mm/s and 30 mm/s are quite consistent.

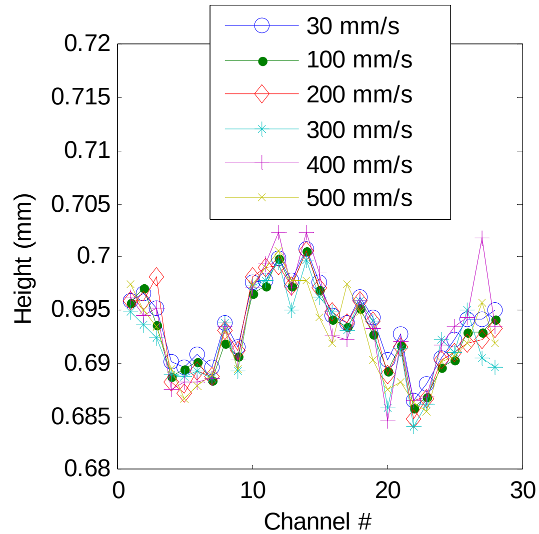

FIGURE 6. Channel heights as a function of channel number at different speeds.

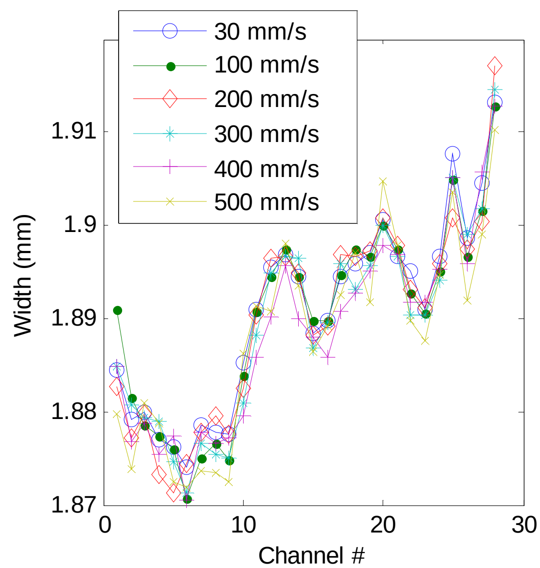

FIGURE 7. Channel widths as a function of channel number at different speeds.

Fig. 8 shows a profile across a few channels acquired at a speed of 30 mm/s. Fig. 9 shows a profile across the same channels at 500 mm/s. The lower data density at 500 mm/s (sampling interval of 25 µm as opposed to 3 µm at 30 mm/s) was necessitated by the hardware used. In addition, it can be seen that there are numerous outliers in the profile which have to be carefully processed prior to any numerical computations, such as height and width of channels. However, as Figs. 6 and 7 show, careful processing of the data acquired at 500 mm/s can provide excellent agreement with that acquired at 30 mm/s.

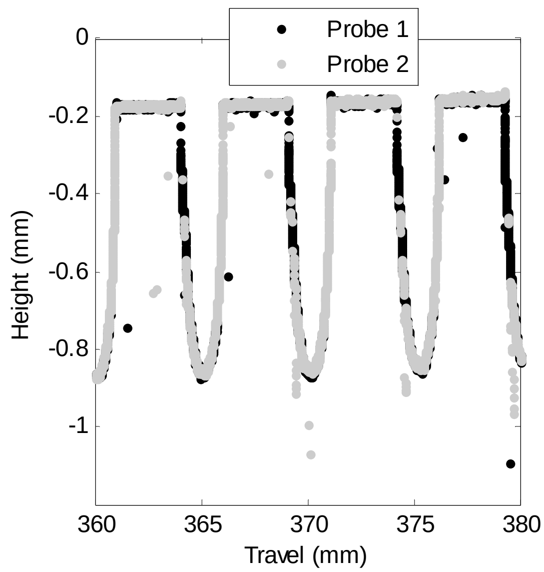

FIGURE 8. Profile across a few channels at 30 mm/s.

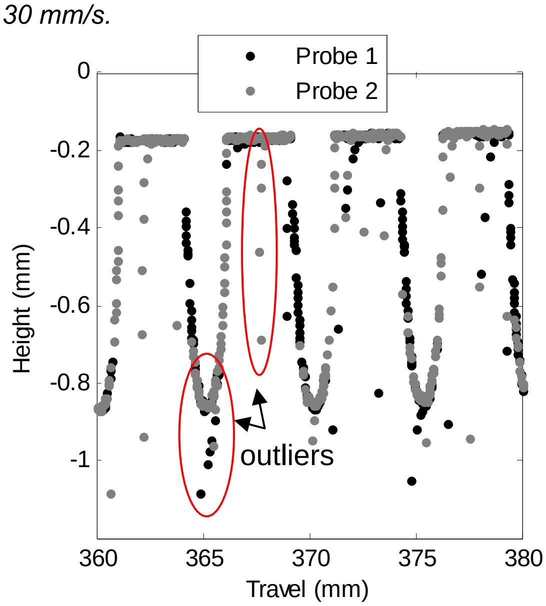

FIGURE 9. Profiles across a few channels at 500 mm/s.

CONCLUSIONS AND FUTURE WORK

This paper describes a dedicated non-contact fuel cell measurement system. A unique aspect of this design is the use of two tilted probes so that information from the side walls of channels can be captured, in addition to the top surface of the plate and the bottom of the channel.

Preliminary measurement results obtained from the non-contact system are described in this paper along with a brief summary of some of the challenges in using laser triangulation probes. One of the primary barriers to the adoption of such non-contact systems towards in-process measurement is the measurement speed. Experimental evidence has been presented here that demonstrates the non-contact system can measure channel height and width even at speeds of 500 mm/s with little degradation in accuracy.

Some anticipated future work is to modify the setup towards measurement of plate thickness by placing one probe above the plate and the other below. Thickness and parallelism measurements are critical towards the concept of “smart assembly” [3], which is to tag each plate with its own thickness and parallelism information so that during assembly, appropriate plates can be chosen to improve the overall stack’s parallelism.

ACKNOWLEDGEMENTS

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