

Next Generation Portable “Electronic Feeler Gage” For Maintaining Coater Gap Uniformity in Production

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Extended Abstract

Evaluation of advantages of various technologies used in measuring thin gaps in shop-floor coating operations with a focus on slot die and roll coating. Introduction of a new portable non-contact thin gap sensor system with extended measurement ranges up to 500 microns (0.020 in) with improved ease-of-use for auditing gap uniformity. The instrument offers excellent stability even in production facilities with variable environmental conditions. Operators will still be able to achieve repeatable gap uniformity better than 0.5 microns (20 microinches). Simplicity of the new system results in lower costs allowing firms to dedicate multiple systems for larger range assessment in all their manufacturing sites. We will show specific application examples currently in use in the production of labels, special films, wall panels, batteries and foam-based products. The full system includes sensor/wands, special wand holders and portable signal conditioning electronics with simple-to-use interface software and built-in data logger. The presentation is of interest to personnel charged with the job of maintaining repeatable gaps to control product uniformity and quality.

1. Industry Requirements

Capacitec has been working closely over the past 10 years with the leading global manufacturers of tapes, films and other materials for various commercial and industrial uses. The common thread between users is the utilization of extruder dies and rollers to apply very thin coatings to a variety of media or in the production of thin films, tapes or other materials. Examples:

- Adhesive coatings onto labels
- Photographic coatings onto films
- Electrolytic materials
- Chemical coatings onto films and tapes
- Manufacture of plastic tapes
- Production of composite materials

Whether measuring the gap in a slot die or the gap between rollers, users are looking to set a uniform gap along the full length of the die or roller set. For years they have been looking for new methods to improve upon the traditional contact measurement methods, which gave them no better than a few microns accuracy. Ideally they were looking to achieve submicron levels of gap accuracy along the full length of the gap. In the late 1990s Capacitec was able to exceed users accuracy requirements by developing a lab

based slot die coater system (reference *System 1*) that assured accuracies down to 0.25 microns (10 microinches). The next challenge was to develop a system that was more flexible, portable and cost effective for use on the shop floor. This new instrument (reference *System 2*) will be described in this presentation (see Table 1 below for a quick overview)

2. Traditional Gap Measurement Methods in Production

Currently, many manufacturers have to adapt to the situation of having gap variations of more than 1.25 microns over the length of the coater dies. Some use a variety of time consuming “home grown” methods using traditional metrology tools. Others rely on feeler gauges. These procedures often suffer from poor repeatability and a high level of subjective variation between users. These methods also do poorly in Gage R&Rs, a requirement seen more and more often as quality methods such as six sigma are put in place. In addition the feeler gauge users must put up with following problems:

- Once the gap is set it is very difficult to recheck the actual dimension
- Feeler gauges cannot accurately measure "inboard" gaps
- Could damage highly polished surfaces such as the mouth of a coater or roller surfaces

3. Meeting New Industry Driven Measurement Benchmarks for the Shop Floor

Several of Capacitec’s customers who were using the traditional slot die coater in the lab (ref. *System 1*), and consistently attaining the benchmark level of less than 0.25 micron gap uniformity of slot die gaps, requested that Capacitec develop a modified system for use on their shop floor. They wanted the new system (ref. *System 2*) to use the same base technology but to focus on the added requirements of lower cost, portability and the ability to survive the production environment. These new requirements were met and the portable instrument was introduced in 2006. The table below lays out the differences between the traditional lab based system and the new simplified portable “electronic feeler gage” system.

<i>Feature</i>	<i>Lab based system (System 1)</i>	<i>Shop floor system (System 2)</i>	<i>Benefits of shop floor system</i>
Calibration/ # of channels	Full set of calibrations for up to 8 channels	<i>1 or 2 calibrations</i>	<i>Simplified for shop floor use</i>
Calibrated range and accuracy	Typical range from starting thickness is 250 microns = 10VDC Resolution: ± 0.025 microns Accuracy: ± 0.5 microns Repeatability: ± 0.25 microns	<i>Typical range from starting thickness is 500 microns = 10VDC Resolution: ± 0.05 microns Accuracy: ± 1.0 microns Repeatability: ± 0.5 microns</i>	<i>Can measure more gaps with fewer sensor wands at lower sensitivity</i>
Power	120/240 VAC	<i>±15 VDC supplied by rechargeable portable battery pack</i>	<i>Portability, ability to reach limited access locations</i>
Connection to data acquisition and host computer	Analog input to PC laptop based Capacitec Bargraf software	<i>• Built-in data logger • RS232 to host</i>	<i>Portability, convenience on shop floor</i>

Additional benefits of the Shop floor system include; same high accuracy, 2 calibrations, readout is in engineering units and a simple to use set-to-standard feature.

This next section lays out further details of the features of the new portable solution:

3.1 Capacitive Technology

The first step in the design of the portable solution is the continuation of the use of capacitive technology as the basis for sensor design. The choice of capacitive was based on several of its inherent advantages including:

- Non-contact measurement method using ultra thin sensors
- Instrument linear output with excellent repeatability and higher probe temperature capability (up to 200°C)

3.2 Sensor Wand Selection

The capacitive sensors are attached back-to-back on a sensor wand. The configuration, thickness and material of the sensor wand depend on the application at hand. Sensor wands come in two groups (Kapton® or Composite) depending on thickness. When very thin gaps are measured (from 0.125 mm to 1.0 mm) the sensor wands are typically made of Kapton® with a standard wand length 150mm. When the measurement is between roller gaps a “T” design sensor is often recommended to help capture the absolute minimum gaps. (See Figure 3 for an example of a “T” sensor wand in a wand holder.)

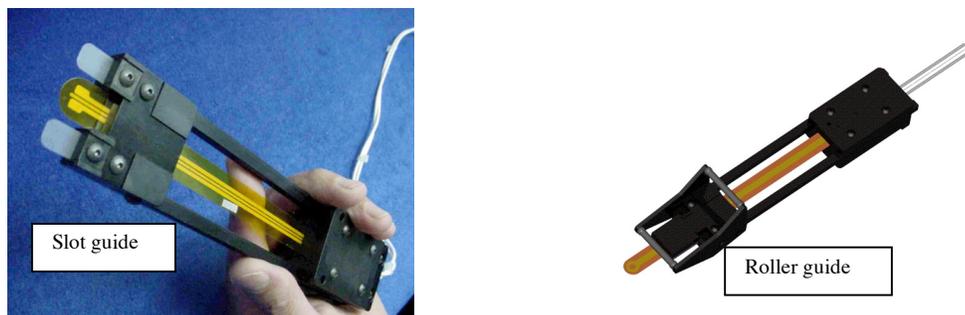


Figure 2: Custom wand holders with adjustable insertion length and slot guides (left) or roller guide (right)

3.3 Maximizing Range

In the science of capacitive measurement technology there is a relationship between sensor size and accuracy. Also by decreasing the sensitivity, users can attain larger linear ranges. The selection of the sensor wand thickness is still made in relationship with the gap size. In the portable solution, wand thickness is selected to create an overall range of up to 500 microns. This produces an accuracy of $\pm 0.2\%FS$, or 0.5 microns.

3.4 Fixture Options

An additional discovery uncovered during the design process of the lab system was the importance of wand positioning when taking gap measurements. The best measurements were attained when the sensor wand was held stable in a parallel position relative to the two halves of the coater die or the roller pair. When the wand was allowed to twist or rock out of this position, accuracy and repeatability would deteriorate. In order to assure best-case parallelism between the sensor wand and the die slot or rollers, special custom fixtures were designed. (See Figure 2 on previous page for slot die and roller pair versions).

3.5 Instrumentation

The dual-sensor probes are combined with a matching Gapmaster3 portable electronics package that consists of two condensed versions of the 4100-SL amplifiers, built-in clock card with 2Hz frequency response, AC adapter or rechargeable $\pm 15VDC$ power supply and LCD screen. The LCD display on the instrument can be configured to display user selectable readout text such as top, bottom and sum. (See Figure 3)

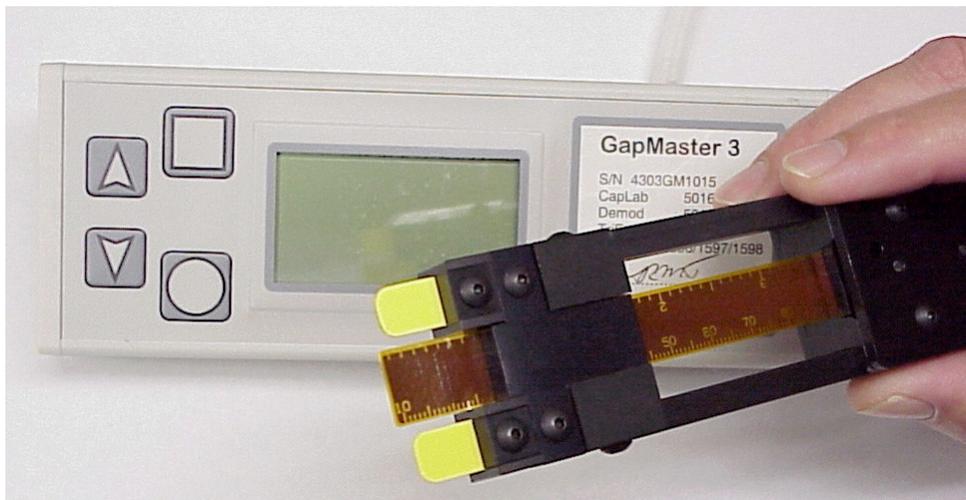


Figure 3: Complete Gapmaster 3 Portable Shop Floor System