

## Seeing Green by Seeing Red

### On-Line Profile Measurement using Profile360

#### Bytewise Measurement Systems

April 29, 2010

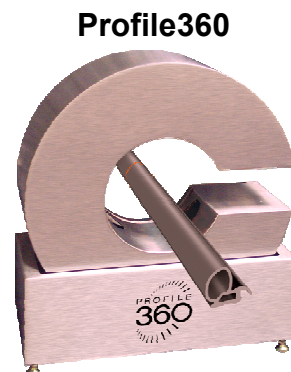
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The automotive profile extrusion industry has always suffered from the high-cost of scrap. The best manufacturers claim scrap rates around 5%, while others have scrap rates closer to 10%. Difficult profiles can often reach 20% scrap rates and higher [1]. A typical automotive extrusion line can run 30 million feet per year. With profiles weighing about .25 pounds per foot, and EPDM compounds running about \$1.35 per pound, a 1% scrap rate will cost \$101,250 in the rubber compound alone, not considering labor, energy, capital equipment, and overhead. A 5% scrap rate produces over a quarter-million dollars per year in materials cost alone. An extruder running at 70 feet per minute can produce scrap at a rate of \$1,400 per hour.

Dimensional defects have numerous root-causes, including visco-elastic properties of the compound, air inflation pressure (for profiles with sealing bulbs), mix dispersion, extruder speed and temperature control, shrinkage, puller speed, and mechanical guiding, among others.

Dimensional measurement methods currently employed by most manufacturers have not changed since the mid-twentieth century, and employ off-line 10X optical comparators to visually check periodic samples cut from the extrusion line. Operators cut slivers by hand, inspect on the 10X comparator, tape the samples to a paper form, and store the physical samples in a filing cabinet. Line operators also use micrometer calipers to check key dimensions while the line is running. Studies have shown that the accuracy and repeatability of these methods is poor due to a high level of operator-to-operator variation, and the temptation for operators to favorably distort the sliver.

Profile360 is an on-line, non-contact profile measurement system produced by Bytewise Measurement Systems. Profile360 employs four laser profile sensors to gather over 4,000 measurement points characterizing the outside profile shape of an extrusion at rates up to five complete profiles per second. There are no moving parts. Profiles are compared to CAD templates, and displayed for the operator as a real-time optical comparator, just like the 10x. Key parameters are measured using “virtual calipers” that emulate micrometer calipers. Measurements are compared to control limits and displayed as real-time results. All measurements are viewable as trend charts that show the measurements along with the control limits. Measurements are displayed with red, yellow, and green backgrounds to indicate whether they are out of specification, in the warning zone, or within specification. Operators are alerted by the red and yellow status indicators to adjust the process to keep dimensions properly centered, thereby assuring compliance with dimensional quality standards.

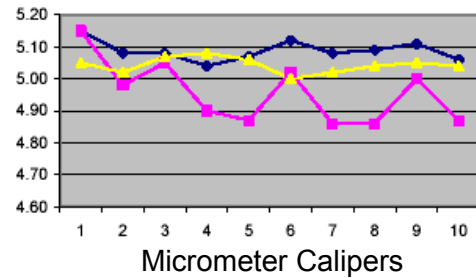
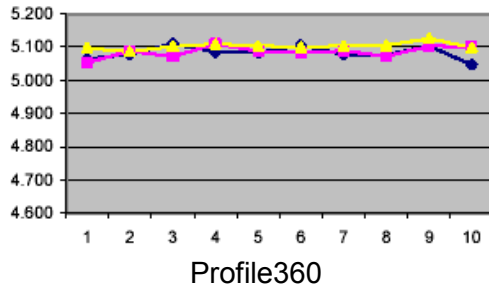


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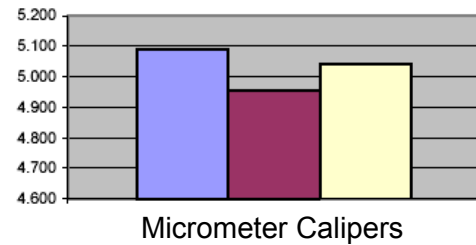
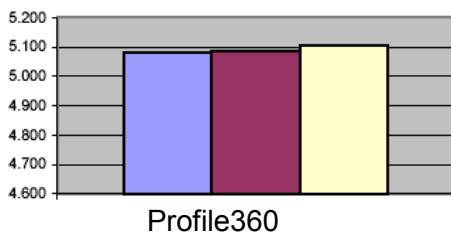
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**Measurement Repeatability**

A repeatability test was conducted comparing Profile360 with micrometer calipers. Three operators made ten measures on each of three samples. An example of the raw data for one sample is shown below, and is typical of the three samples. The second series of graphs compare the averages of the each operator.



**Raw Data - Three Operators, Ten Measures**



**Average Data - Three Operators, Ten Measures**

The average standard deviation for all tests and all operators was 60% smaller for Profile360: 0.018mm (0.36%) vs. 0.044mm (0.88%) for the micrometer calipers. This is expected because of the subjectivity in the amount of closure with micrometer calipers, and the known operator-to-operator variation.

According to David Wade, Ford Motor Company, "The Byte-wise in-line laser measurement system improves gage repeatability and reproducibility, compared to 10X measurement systems, enabling a statistically significant reduction in geometry variation resulting in increased dimensional control of extruded weather-strips."[3]

**Case Study [4]**

Meteor Sealing Systems, an automotive sealing systems producer in Dover, Ohio, has focused on productivity improvement by implementing continuous on-line monitoring for profile geometry, and partnered with Byte-wise Measurement Systems for the measurement technology. Meteor supplies extruded seal assemblies to car makers and

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Tier 1 convertible roof makers. Although Meteor supplies all types of door and window seals, they have developed special expertise in sunroof and convertible top seals.

Chris Dennis, Process Engineer for Meteor explains how Meteor employs Profile360 to improve productivity. When an extrusion run is started the equipment is set up according to standards for that profile. It takes some time for the line to come up to speed and achieve equilibrium. Once stabilized the process must be tweaked to compensate for the inherent variations in the compound's visco-elastic and cure properties, and the normal fluctuations in the temperature and speed of the extruder and down-stream equipment. Like many other auto seal makers, Meteor uses a 10x optical comparator to verify all dimensions, inside and outside, for their quality management program, however, during startup of the line Meteor gets a much faster size check using the on-line technology. The real-time display allows them to quickly see the results of all equipment adjustments. Profile360 enables the operator to start up a run and tune it into specification much faster, resulting in less scrap and higher production yield. Once the line is stable the display will toggle to red if a dimension goes out of specification, alerting the operator to adjust the line.

Many of Meteor's extrusions are dual-durometer, using two extruders to process different compounds through a single die. This requires very precise set-up and control to assure the flow of rubber is balanced. A typical seal may require a dense compound for the base and a sponge compound for the bulb. When there is a batch change from one pallet of rubber to the next small variations in visco-elasticity can change the flow properties and die-swell behavior of the profile. Meteor sets up the Profile360 to independently monitor the base and bulb dimensions, and alarm when there is a change.

Profiles that feature bulbs for sealing are usually inflated with high-pressure air to maintain the bulb diameter during vulcanization. Deviations in air pressure control can lead to over- or under-sized bulbs. Profile360 is set up to measure bulb diameter and alarm when the size changes.

Another common problem in bulb-profiles is "bulb lean", a condition where the bulb is not properly aligned with the base. A bulb that leans too far may leak, or cause fitment problems at assembly. In this case Profile360 is set up to monitor the position of the bulb with respect to the base and alarm when the process changes. Bulb lean is affected by compound properties, die swell, die flow, mechanical guides, and profile orientation in vulcanizing.

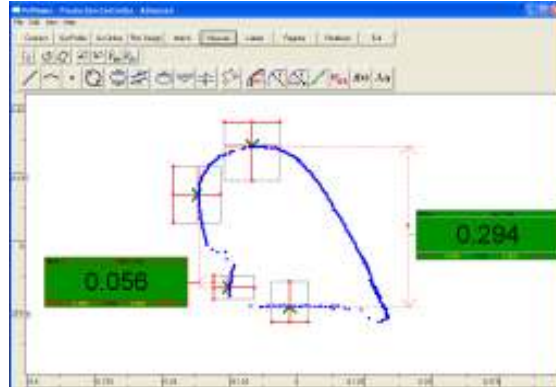


**Chris Dennis, Process Engineer at Meteor Sealing Systems, demonstrates Profile360 on a dual-durometer seal**

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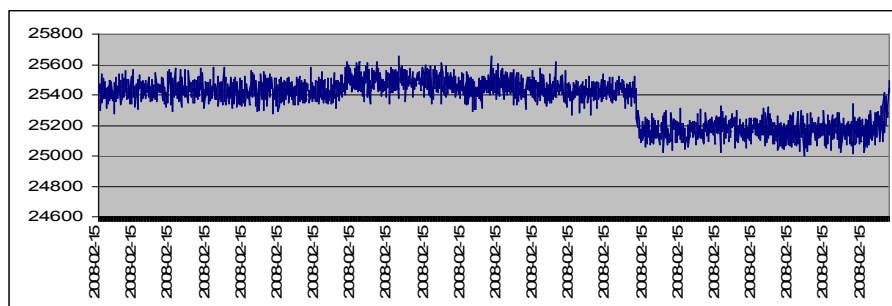
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**Meteor monitors a dual-durometer seal using software calipers set to measure bulb height and lateral distance between the bulb and the base.**



### **The Rheology of Die-Swell**

Uncured rubber compounds are characterized according to three main physical properties. The Elastic Modulus ( $S'$ ) describes the elasticity of the compound – its tendency to spring back when compressed. The Viscous Modulus ( $S''$ ) describes the viscosity of the compound – its resistance to flow. Tangent Delta is expressed as the ratio,  $S''/S'$ . Correlation studies done at high strain rates typical of extruder die shear rates indicate a strong relationship between tan delta and die swell; with lower tan delta predicting higher die swell.



**Two lots of the same compound often exhibit different visco-elastic properties that cause changes in die-swell, as shown in the trend chart**

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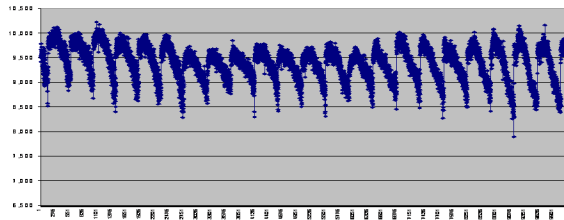
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#### Diagnostic Use

While on-line measurement is critical to keeping the process centered, it can also be used to speed up the launch of new products and troubleshoot extruder line problems. New product launches consume a lot of time and materials when they involve new compounds, dies, and processes. The on-line optical comparator feature helps startup engineers see where a profile deviates from the specification and how the profile responds to process, material, and die changes. This can shave days off of a startup.

One company was surprised to uncover a serious problem in the puller motor controller that caused cyclical stretching of the profile. This behavior was clearly visible in the trend chart, which recorded a 7-minute period in all dimensions, but had not been picked up by conventional off-line checks [5].



**Bad puller control results in cyclical changes to key profile dimensions**

#### Conclusion

Suppliers of automotive body sealing systems face a challenging set of technical requirements as cars become more aerodynamic, the space available for seals decreases, profiles become more complex, and new materials and coatings come into production. Business conditions make this even more difficult as the car companies seek lower prices and the sealing companies try to reduce fixed-costs. In this tough environment, investments in quality improvements such as on-line profile measurement support the business objectives of improved technology, improved quality, and reduced cost. Although an extruder running at 60 feet per minute can produce scrap at a rate of \$1400 per hour, a Profile360 investment can deliver a 1-year payback by reducing scrap by only 40 minutes per week. Profile360 users have verified that the system has the accuracy and repeatability needed to make meaningful measurements on-line. More importantly, they have demonstrated the ability of shop-floor operators to transfer the real-time measurements into timely process adjustments that deliver scrap reductions, quality improvement, and faster product launches.

#### Sources

- [1] In-plant interviews by Bytewise, 2009
- [2] In-plant survey by Bytewise, 2002
- [3] With permission of David Wade, January 2010
- [4] With permission of Meteor Sealing Systems, January 2010
- [5] Company name withheld by request