On-Line Tire Tread Profile Measurement Technology
Bytewise Measurement Systems
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Introduction

Tire tread extrusion geometry remains one of the largest contributors to non-uniformity in cured tires. Non-symmetry in the cross-section gives rise to lateral force variation, conicity, and couple imbalance. Longitudinal variation gives rise to radial force variation and static imbalance.

Die management across the tire industry is quite good. There are now over 100 Bytewise Profilometers in die shops worldwide. These tire plants achieve the highest precision in die geometry. Nevertheless process and materials changes can result in out-of-specification tread profiles.

Scanning fixed-point laser systems have been adopted in some areas of the tire industry, and abandoned in others. This paper describes a new product introduced by Bytewise in 2004 that uses sheet-of-light laser triangulation sensors to simultaneously measure approximately 4,000 points across the top and bottom sides of the profile at frequencies up to 7.5 Hz.

Problems in Extrusion

Even with the perfect die, tread profile dimensions vary during the extrusion cycle. There are several causes:

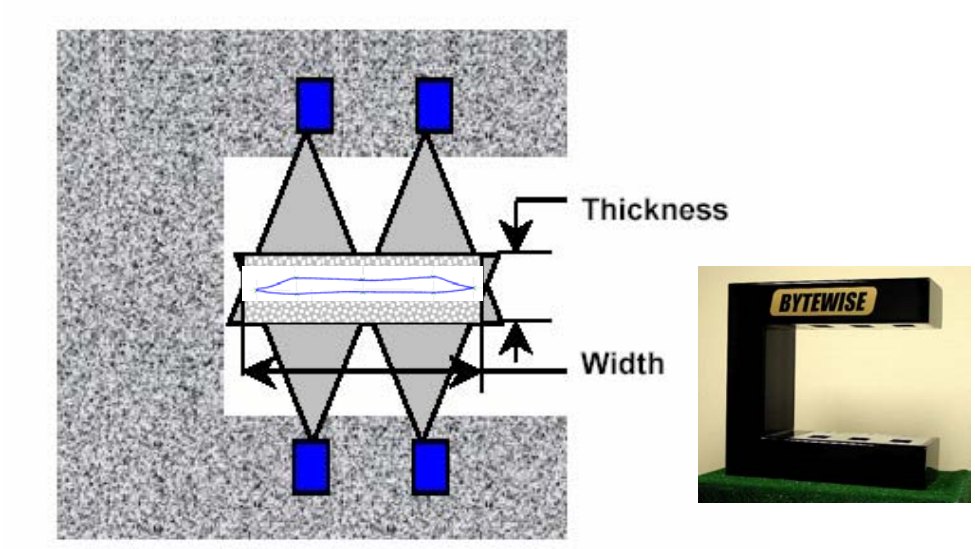
1. Heating variation and heater controller cycling result in flow rate variations
2. Partial die blockage results in uneven symmetry
3. Batch-to-batch variation in Tangent Delta results in varying die-swell
4. Non-Uniformity in mixing affects flow rate and cure rate
5. Down-stream motor drive control and synchronization affects tension and results in draw-down variation
6. Cure properties affect shrinkage
7. Silica-Silane reaction variations result in density variations
8. Feed interruption during batch change causes a drop in head pressure that changes the flow rate

There are two types of resulting dimensional variations:

- Cross Section Variation – Profile is non-symmetrical or simply out of specification.
- Longitudinal Variation – Profile varies along the length of the tread.

Many tire makers desire On-Line measurement so that changes in profile geometry can be recognized and remediated quickly, thereby reducing extruder department scrap and cured tire scrap, and improving overall tire uniformity.

Introducing the Bytewise On-Line Profilometer (OLP)



OLP measures the extruded profile of the tread as it is being conveyed. This actual measurement is compared to a design template - the "desired profile" and its allowable limits. Each Test Plan permits the recognition of various measurement parameters such as overall width, shoulder width, locations from center, and various thicknesses.

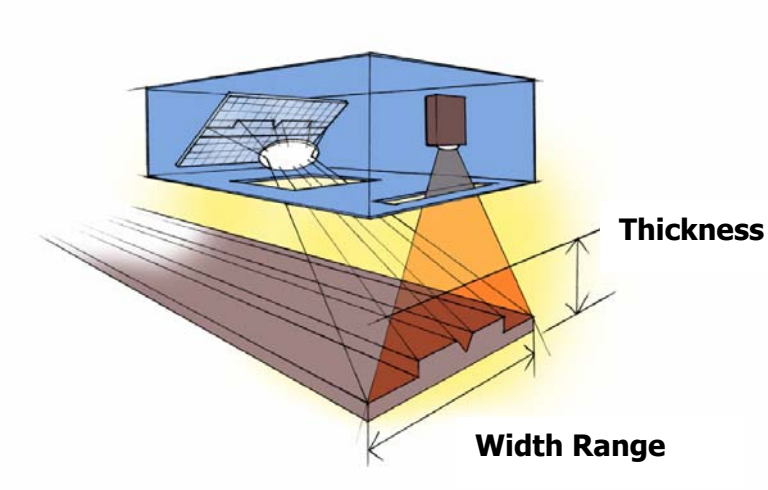
This system makes the profile measurement simultaneously across the profile; it does not scan side-to-side in a Z pattern and there are no moving parts. The simultaneous measurement is more accurate than scanning systems. The measurement frequency is high enough to assure 10 to 20 complete profile measurements for every tire.

OLP is built from standard 150mm sensors mounted in a C-Frame housing. It is available in 3 standard sizes:

- 300mm – Four Sensors
- 450mm – Six Sensors
- 600mm – Eight Sensors

All sizes have a 75mm thickness range.
Accuracy is 0.3mm for the width measurements and 0.15mm for the thickness.

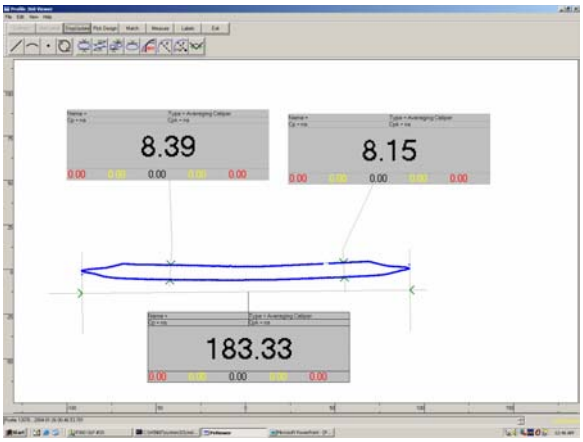
Sheet-of-Light Profile Sensor Technology



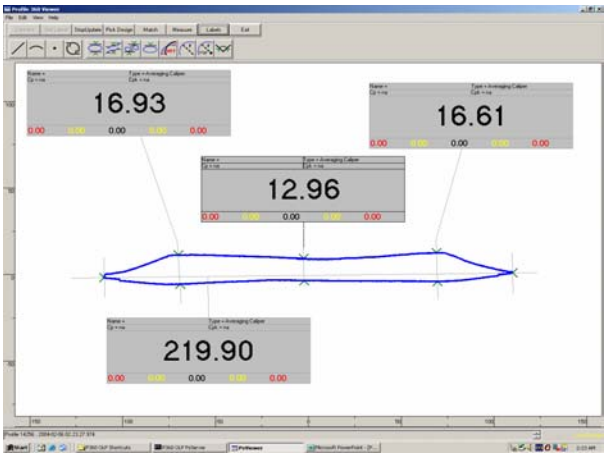
Profile sensors are manufactured by Bytewise. A laser diode shoots a laser light beam through a lens to project a laser line onto the extrusion. The light is reflected off the extrusion, through a lens, and onto a CCD Field Array Detector. The detector recognizes the light energy distributed over 1024 x 1024 pixels. This pixel data is converted into geometric coordinates. The result is a 1,024 number data string that is later analyzed in software to extract various discrete measurements such as widths and thicknesses.

Analysis and Viewing Software

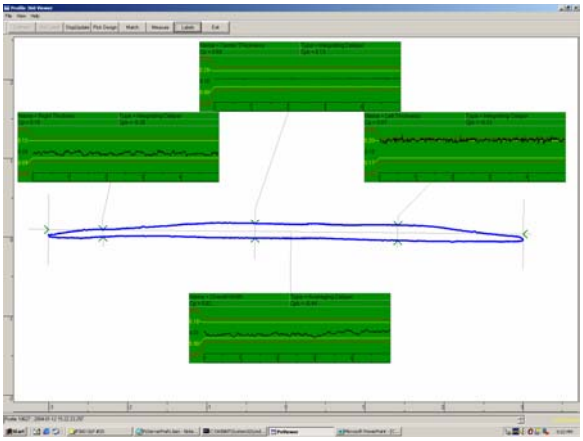
The software has two components, the Measurement Server Software and the Analysis and Viewing Software, which can run on the same PC or on any other PC with TCP/IP connectivity to the Measurement Server PC. The software provides a complete suite of utilities to support Test Plan Creation and Management, Reports, Real-Time Measurement Viewing, Trend Viewing, Data Archiving, and Real-Time Data Output.



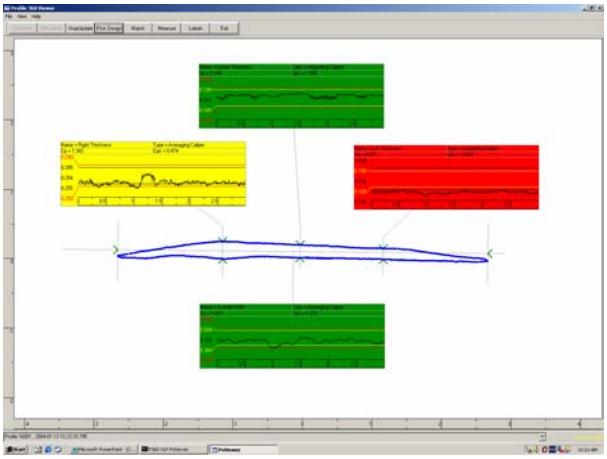
This is an example of a simple passenger tire tread extrusion measurement showing one overall width and two channels of thickness. Note that the right thickness is 0.24mm less that the left thickness.



This is an example of a simple truck tire tread extrusion measurement showing one overall width and three channels of thickness. Note that the right thickness is 0.32mm less that the left thickness.



This is an example of the trend display for a sidewall extrusion measurement with one overall width and three channels of thickness. Each trend chart includes the upper and lower control limits.



This is an example of the trend display for a sidewall extrusion with one overall width and three channels of thickness. Each trend chart includes the upper and lower control limits. The red, yellow, and green backgrounds indicate whether the real-time measurement in out-of-control limits, within specification, or in a warning range.

Measurement Capability

A Repeatability Test was conducted on a tread rubber profile, which demonstrated a 1-Sigma value of 0.005mm.

The trial was conducted by taking 10 samples each of 5 width or thickness measurements with the profile stationary in the instrument. The profile was removed and replaced in the instrument and the test was repeated. A total of 3 Trials were done.

The smallest standard deviation was 0.002mm, the largest standard deviation was .006, and the average of all standard deviations was 0.005.

Summary

On-Line Tread Profile Measurement satisfies two requirements for assuring the extrusion process remains in control. First, the Real-Time View quantifies how well the tread profile conforms to specification in terms of widths, thicknesses, and feature locations. Second, the Trend View quantifies how these values change over time. This permits the operator to quickly respond to step changes and trend changes caused by the many extrusion variables.