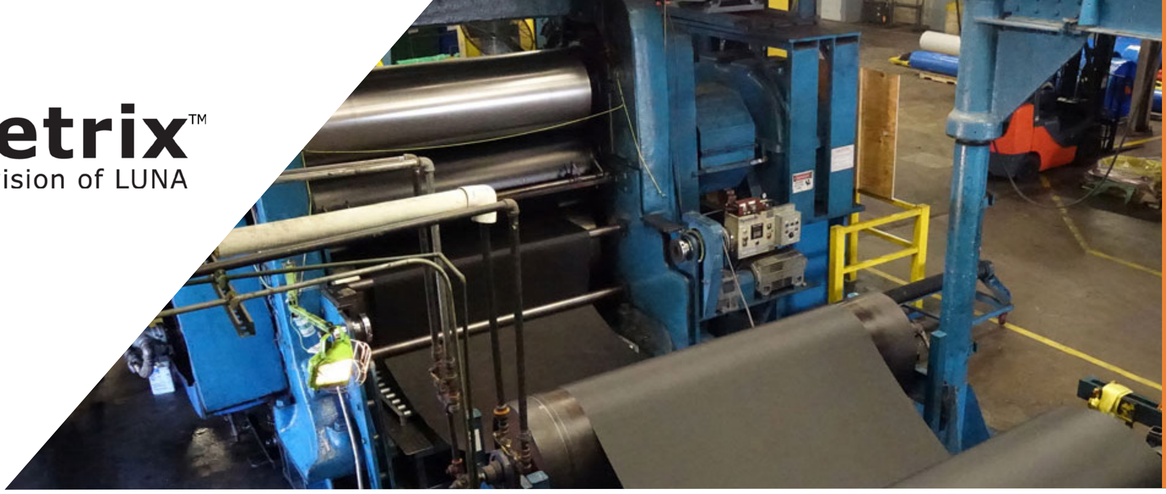
TeraMetrix™
a division of LUNA



Calendering: Tire

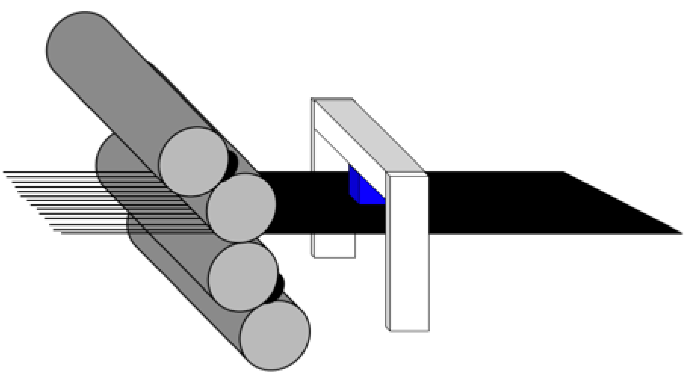
THz Applications

SUMMARY

Manufacturer of safe high performance tires require precise control of the balance and thickness of each body ply, innerliner and tread component. Until now, the solution for measuring these structures for total thickness and top/bottom gum balance required multiple nucleonic &/or X-ray sensors, a two-sided precision O-frame and was only available for wire cord calenders or differentially using multiple scanner/sensor combinations. With the release of the T-Gauge® terahertz sensor, it is now possible to use one single-sided sensor to measure an array textile, wire, and innerliner for total thickness, balance and lamination defects.

BACKGROUND

A typical tire calender consists of a four-roll z-calender that forms the top and bottom gum layers, with a cushion nip to imbed the gum layers to the reinforcing cords (wire or textile). Calender gauging and control systems vary depending upon the target calender roll configuration. Typically, a post-calender scanning sensor is deployed to assure sheet flatness, measure the total thickness, and top/bottom gum balance for feedback control of the cushion nip. Often this same system can be used to control top, bottom or both gum forming nips.



Prior to T-Gauge® most wire calender systems deployed a combination of backscatter x-ray, transmission x-ray, and Sr^{90} nucleonic sensors. The backscatter x-ray sensors are used to estimate the top and bottom layer thicknesses (to provide balance), while the transmission x-ray and the Sr90 beta sensor are used to provide a steel cord compensated estimate of total thickness. As a result, the scanning sensor package is complicated, requires an O-frame scanner and because these devices are mass sensors they require extensive calibration to provide a thickness value for calender control.

X-ray backscatter sensors cannot detect the presence of textile cord, so they are unable to provide textile ply balance. With high performance and low resistance tires increasingly using textile components, the need for tight manufacturing control of fabric cord products has become more critical.

A NEW ALTERNATIVE

The world leader in terahertz systems, TeraMetrix, has now released a terahertz sensor capable of measuring both total thickness and balance of a textile ply using a single sided scanner, and a reflection sensor that emits harmless far infrared energy (THz).

The terahertz (THz) sensor operates by emitting a short pulse of energy that reflects from the various surfaces of the product. When the time between these reflections is measured, the thickness and the balance can be directly determined, much as it is with ultrasound, but there is no need for contact or a coupling medium.

The entire sensor is 5 x 7 x 2.5 inches and can be scanned 3 or 6 inches above the sheet. The sensor is connected to a control unit with a high flex umbilical.

T-Gauge® Terahertz Sensor Mounted On A Scanning Frame Measuring A Multilayer Web

In sample testing of textile cord, the gum above the textile cord, the gum below the textile cord, and the total thickness can be measured. For wire cord plies the gum above the cords and the total thickness can be measured, so a balance could be reported if a diameter is assumed for the wire cord. For wire cord, a sensor above and below the web can measure the gum above and below the cords without any assumptions.

Testing of Textile Cord Samples

Textile cord samples were sectioned and examined under a microscope to examine the structure and measure balance. Figure 1 shows the cross section and the measurements that were made on one of the samples.

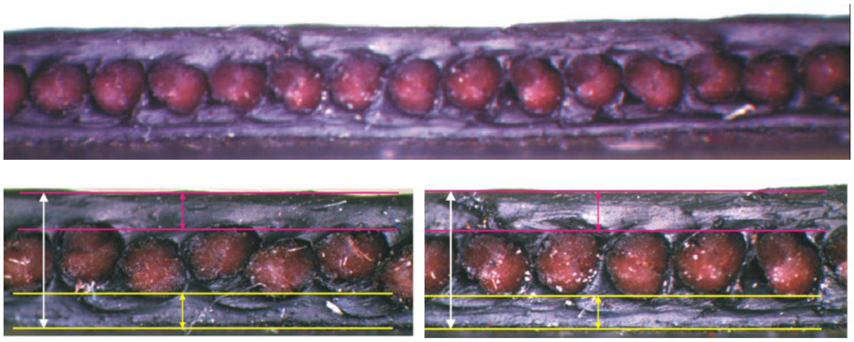


Figure 1: Microscopic analysis of a sample shows the makeup of the sample Sample marked with a total thickness of 70 mils to 69 mils and even balance with 31.75 mils cord gauge.

Assuming the 70.0 mils total thickness

Top Left = **18.9 mils** Top Right = **20.1 mils** Top Avg = **19.5 mils**
Btm Left = **17.9 mils** Btm Right = **16.7 mils** Btm Avg = **17.3 mils**

If we include the cord gauge of 31.75 mils, we get an average:
Top layer = **31.75 mils/2 + 19.5 mils = 35.375 mils**
Bottom layer of = **31.75 mils/2 + 17.3 mils = 33.175 mils**

Using the provided sample values to set the initial measurement, cross direction scans were made to show product profile. Stable measurements were obtained across the product.

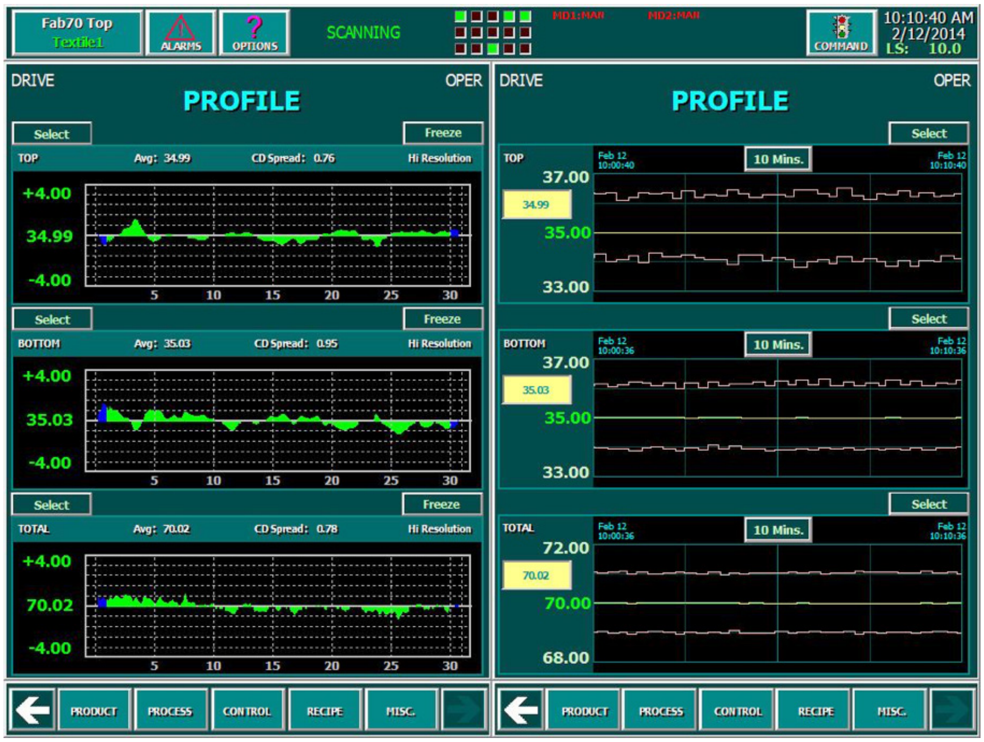


Figure 2: Profiles of the top, bottom and total thickness for calendered rubber with textile cord.

Testing of Wire Cord Samples

See Figure 3.

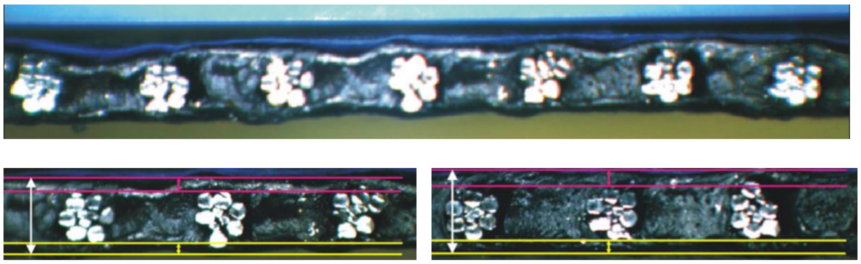


Figure 3: Microscopic analysis of a sample shows the makeup of the sample

Assuming 64.9 mils total thickness

Top Left = **11.5 mils** Top Right = **12.5 mils** Top Avg = **12.0 mils**
Btm Left = **9.4 mils** Btm Right = **10.0 mils** Btm Avg = **9.7 mils**

Taking into account the wire sensor listed as 44.2 mils we get
Top Avg = **34.1 mils** Btm Avg = **31.8 mils**

Stable profiles were generated for both the top and bottom.

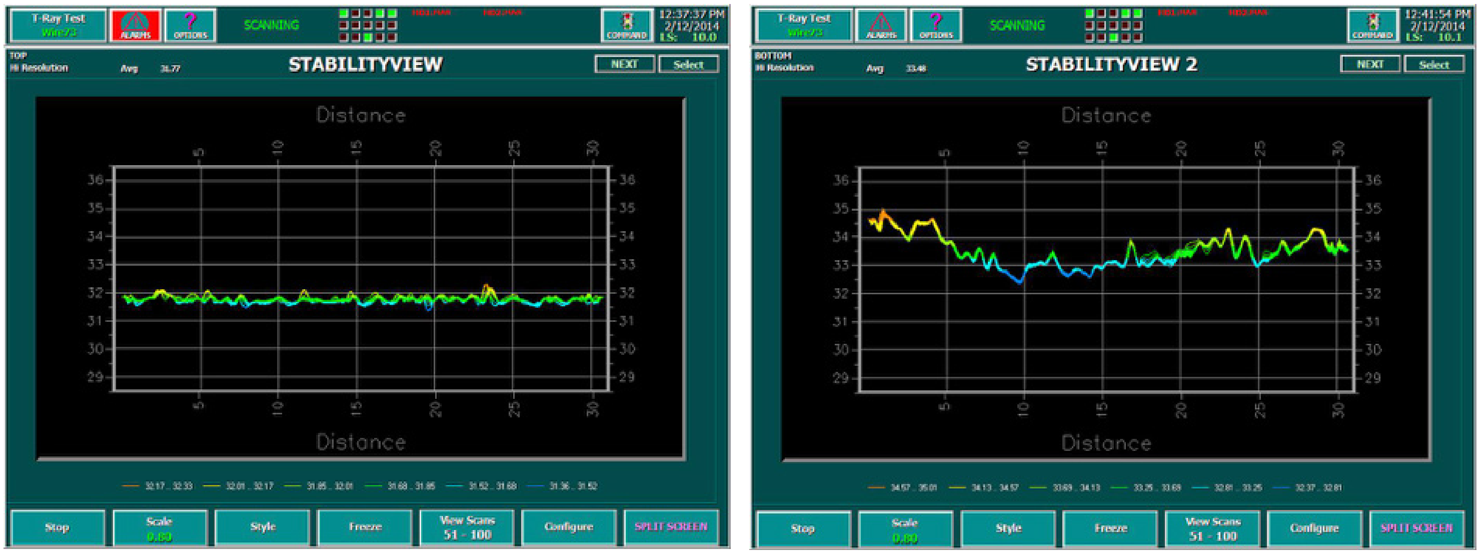
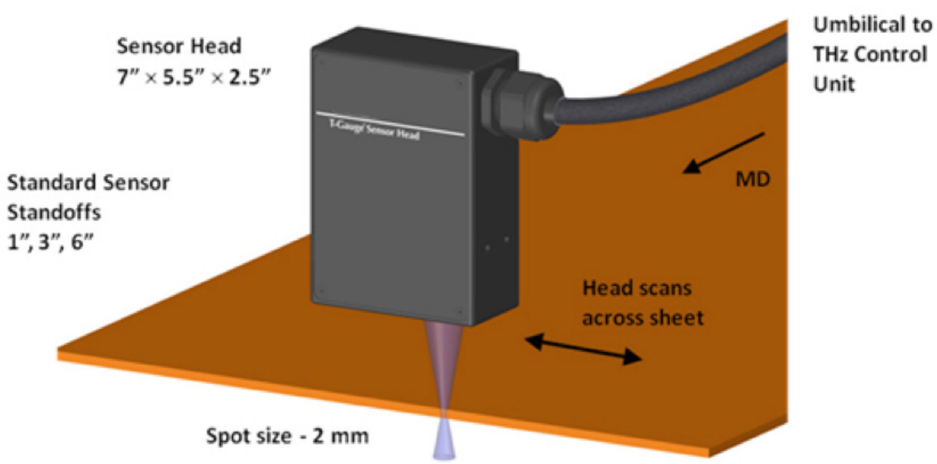


Figure 4: The calibrations used in these measurements were approximate, but still resulted in measurements very close to the expected values.

ON-LINE APPLICATION

In operation, the THz pulse is focused onto the sheet and the reflections off the sheet and its interior interfaces are detected by the sensor. For this application, the 3-inch standoff distance between sensor and web is recommended. The measurement is immune Z-axis flutter, dirt or gum build up on the lens and works well in dusty or fume generating environments.



The total sheet thickness measurement is always available for textile grades (and wire/steel grades so long as there is some space between the cord bundles). The rubber layer thickness above the cord is also directly measured. The simultaneous availability of all such information allows for many detailed sample parameters to be calculated (e.g. total thickness, balance, density and lamination voids).

Because the measurement relies on Time-of-Flight values for reflections from interfaces, this method is sensitive to changes in the sample's layer structure. In particular, delaminations between the layers are very easy to identify while remaining insensitive to Z-axis flutter, dirt, fumes etc.

FOUR ROLL Z-CALENDER DEPLOYMENT OPTIONS

Typically QCS systems are deployed post-calender on tire body ply calenders to feedback control total thickness of the composite sheet, thickness of top and bottom gum ply and assure proper balance orientation of the fabric/steel structural elements.

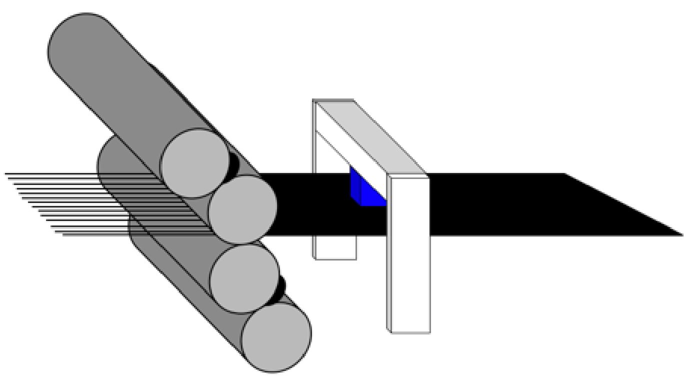
Currently deployed solutions rely on combinations of X-ray, SR-90 isotopic sensors, eddy current and/or mechanical air caliper devices. One essential difference between terahertz and current solutions is that terahertz is a time-of-flight, radar-like direct thickness measurement. Unlike most current solutions that depend upon a Beers Law conversion of mass absorption to thickness THz provides a true linear thickness calibration without mass conversion. Since all calenders are designed for thickness control a THz solution enables a more efficient operational envelop based on thickness rather than basis weight conversion for future QCS deployments.

In addition to post-calender scanning it should be noted that THz sensors can be deployed as non-contacting single-point thickness sensors directly on the calender roll face for high speed three-zone servo gap and pre-set control. The importance of this collateral capability is that while the post-calender scanning sensor(s) can measure total sheet flatness parameters, balance and structural integrity; any post-calender scanning solution will remain incapable of controlling short-term calender roll run out.

T-GAUGE® TIRE CALENDER CONFIGURATIONS

In addition to tire body ply calender applications, T-Gauge® can be easily be deployed on innerliner gum lines for measurement for both total and layer thickness. On-process testing has previously confirmed that even when both gum layers are of identical composition THz waveforms will respond to the gum layer interface sufficiently to ascertain top/bottom layer thicknesses. Moreover, since many roller-die innerliner and tread lines require measurement on a supporting belt structure, T-gauge can be deployed directly without accommodation of addition rolls and/or open space view ports.

TeraMetrix offers a full suite of laboratory terahertz instrumentation that includes: SPG single-point units for Tire lab & ad hoc on-line engineering validation. T-Ray® 5000 and T-Gauge® platforms provide mission critical tools for complex product development and QC operational management in diverse markets including: aerospace, military, building products, plastics, paper and pharmaceuticals, spectroscopy and THz imaging.



T-Gauge® Post Calendar:
Total Thickness & Balance
Top/Bottom Layer Thickness
(for final sheet flatness via
calendar cushion roll control)

Industry Leading Regulatory Compliance
The T-Ray® 5000 intelligent TCU has been certified by Underwriters Laboratories has received the CE mark, is fully compliant with FDA CDRH laser safety regulations, and has been tested to meet FCC part 18 regulations.

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