

## Technical

# Innovations on laser applications in tire making

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Tire and rubber manufacturers are requiring inspection systems to detect small geometric defects wherever they occur on the rubber surface.

These needs apply both to final inspection stations as well as in-process inspection operations.

To increase quality and improve product safety, smaller areas of dimensional variation or defects must be detected with very high reliability.

To meet these expanding requirements, sensor manufacturers have developed new high-speed laser line sensors to acquire high-density data to ensure detection of the smallest defects anywhere on rubber surfaces.

These high-speed laser line sensors generate masses of data, creating a need for a reliable communications network, easily implemented by machine builders, without the cost and risk of developing custom communications links.

Simplicity of implementation benefits

### TECHNICAL NOTEBOOK

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end users with high reliability, low cost and minimum maintenance.

In tire manufacturing, multiple sensors are often implemented in a single station to cover the full surface of the product with high resolution.

This adds further complexity, requiring tight synchronization of data from multiple sensors and encoders, as well as further increasing the amount of data to be communicated at high speed to the host computer.

The issues of multiple sensor synchronization has been resolved by development of a unique synchronization platform, providing microsecond synchronization between sensors, and assembling data from all sensors into a single 3-D profile map, output to the host over a single Gigabit Ethernet cable.

#### Communication issues

A typical inspection application may use multiple laser sensors inspecting different zones of the product, such as calendered rubber, conveyor belts or tread extrusions.

An in-process application such as tread extrusion profiling may use eight or more sensors (half above and half below the conveyor to eliminate errors due to pass-line variations) to provide high data density across the full width of the extrusion (Fig. 1).

For final tire inspection, three or more sensors are typically used, with each sensor measuring 128 or 256 points along the laser line, at frame rates up to 4 kHz, (Fig. 2). Laser sensors with faster frame rates and increased number of points per sensor are in development.

This massive amount of data must be sent to the inspection station's host computer for analysis.

For convenient layout of inspection stations, and to simplify the task of the system integrator, it is desirable for the host computer to be remotely located, often at a significant distance from the sensors.

Analog or serial communication standards, while adequate for earlier inspection systems using single-point sensors, do not provide adequate bandwidth for today's high-speed line sensors.

### Executive summary

High-speed laser line sensors have been developed to acquire high-density data to ensure detection of the smallest defects anywhere on tire and rubber surfaces to meet current inspection requirements. Masses of sensor generated data create a need for a reliable communications network, easily implemented by machine builders, without the cost and risk of developing custom communications links. Simplicity of implementation benefits end users with high reliability, low cost and minimum maintenance.

A review of current communications protocols has led to adoption of Ethernet as the best solution to these needs. Ethernet is a well understood industrial standard, providing high data rates, low-cost implementation, and simple long-length cabling for flexibility in system layout.

Examples of systems integration using multiple high-speed laser line sensors are included for both in-process and final inspection. Implementing these developments in tire inspection systems has simplified integration issues for machine builders and increased reliability while reducing costs for end users.

To determine the optimal communication method for such high-speed vision data, a review of common communication standards was carried out to determine the most effective implementation. A brief review of the advantages and disadvantages of each showed:

- USB 2.0—very popular, fast, economical and simple, but maximum cable length is typically 5 meters.

- FireWire (IEEE 1394)—very fast serial data with simple cabling and hot swapping, but lacks switching fabric and uses undesirable daisy chain topology, limited by maximum cable length of 4.5 meters.

- Profibus—high-speed, with cable lengths from 100 to 1,200 meters but has high cost in cabling, industrial connectors and interface cards.

- Camera Link—designed specifically for high data rate communication of vision information with cable lengths up to 10 meters but requires a camera link board in the PC expansion slot for each camera requires a board, resulting in high cost, and users must be skilled in implementation.

- Ethernet—broadly used and easy to apply and implement, with Gigabit Ethernet (GigE) providing data rates up to 1,000 Mbps, with inexpensive cables running up to 100 meters without repeaters.

**Fig. 1. An in-process application may use eight or more sensors to provide high-data density across the full width of the extrusion.**



**Fig. 2. For tire final inspection, three or more sensors are typically used.**



Offering high speed, longer cable lengths, and economic implementation, GigE has evolved as the communications method of choice for high-speed laser inspection sensors.

Because this technology is common in LAN applications, it is well known and easily supported by machine builders and systems integrators.

Ethernet also features Power over Ethernet (PoE), with up to 48 VDC transmitted over the same cable as data transmission.

This results in only one cable from the host to the sensors, simplifying layout and wiring for the machine builder and providing the end user with high reliability and lowest maintenance issues.

Gigabit Ethernet meets the requirements for fast communication of large amounts of data and vision information.

#### Integrating multi-sensor data

In many rubber and tire inspection applications, multiple laser line sensors are implemented to cover the full surface of the object.

This creates challenges of synchronizing data from all sensors, and stitching multi-sensor data streams into a single file, without requiring the integrator to carry out complex operations in the host computer.

In the example of Fig. 1, where eight or more sensors are used to provide high-density detailed data from an extrusion, it is highly desirable to ensure that data from each sensor is obtained

at essentially the same point in time.

Otherwise, each sensor's data will come from a different position along the length of the extrusion.

External hard-wired triggers to each sensor could achieve this goal, but is complex and reduces reliability.

Ethernet communications is not deterministic, and does not provide real time control of synchronization between devices.

Stitching involves integration or combining the synchronized profiles from each sensor into a single 3-D surface map, transmitted as a single data file to the host.

Individual 3-D maps from each sensor could be transmitted to the host, but the integrator would then be required to carry out the complex stitching operation in the host.

To simplify the tasks of synchronization and stitching for the system integrator, LMI has developed a synchronization platform.

This platform is designed to accept and integrate data from multiple vision sensors, as well as other local inputs such as encoders monitoring movement of the material and other types of sensors such as photocells.

When implemented with an encoder, the platform simultaneously sends an internal micro-second based time tag together with an encoder pulse count to every sensor in the system.

Encoder information is attached to the 3-D profile data that is sent back to the host computer.

In contrast to a hard-wired trigger, a time tag and an encoder pulse count provides more flexibility for synchronization methods across numerous devices.

This approach simplifies data analysis in the host computer because profiles output by all sensors are tightly synchronized within the sensor system itself.

All profiles are taken at essentially the same instant of time.

Each "slice" of data from all sensors is combined into a single complete 3-D data file sent from the platform over a single GigE output cable to the host computer.

This total integration architecture simplifies installation.

**Fig. 3. A typical in-line automatic tire final inspection system.**



## Technical

The platform also provides tools for multi-sensor position calibration using an appropriate artifact of known dimensions which is placed in the system measuring area.

This process locates each sensor's position with respect to a global coordinate system defined relative to the target. Transformation parameters for each sensor in the system are acquired during the system calibration process and are used to transform profile data from the multiple sensors into a single coordinate system.

### Simplified with smart sensors

Smart sensor technology provides factory calibrated laser sensors, which simplify the task of system integration and increases system reliability by reducing the number of components required and minimizing potential failure points.

Today's laser sensor systems have all optical calculations carried out in a processor inside the system.

These calculations include applying the triangulation equations, applying factory developed linearization factors, applying automatic gain control to ensure accurate readings independent of the rubber surface texture and color,

and conversion of the measured values to engineering units.

The integrator does not need to apply any processing or other computing capability for sensor operation. The only task is to connect the sensor output to the system processor.

The internal processor inside the sensor has extra capacity for specialized applications and can host added software processing provided by the sensor manufacturer, the integrator or the end user.

Some examples of unique application software for tire manufacturing include calculating radial run-out and applying texture adjustment.

The system integrator's proprietary analysis software running in the sensor system reduces the need for external computers.

### Tire final inspection

A typical in-line automatic tire final inspection system is shown in Fig. 3.

These tire final inspection systems typically use three high-speed laser line sensors, one inspecting each sidewall and the third inspecting the tread.

Sidewall inspection for bulge and depression detection requires very high density data to properly detect small

bulges and dents which may occur anywhere on the sidewall.

The application is complicated further by the need for analysis software to remove or filter out all points which relate to raised lettering, bar codes and other acceptable variations in the surface.

These sensors also employ "dual triangulation" with two cameras viewing the laser line, one on either side of the laser projector.

This design eliminated data dropouts caused by shadowing of the laser beam at the edges of raised material on the sidewall surface.

### Conclusion

Today's high-speed laser line sensors provide high-density data to detect and quantify defects and dimensional variations in both in-process and final inspection applications in high-volume tire manufacturing.

Synchronization and communications issues are simplified by the synchronization platform, with communications to the host computer on a single Gigabit Ethernet cable.

The platform is designed to simplify the tasks of system integration, and maximizes reliability for the end user.

### The authors

Walter Pastorius is technical marketing adviser for LMI Technologies Inc. He received his doctorate in mechanical engineering from the University of Windsor.

He has more than 30 years of experience in both marketing and research and development in the machine vision industry. Pastorius has authored more than 100 articles and technical presentations in the field of new applications for vision sensors in manufacturing in automotive, aerospace, lumber, road inspection, foundry and other industries and is co-holder of several patents.

Martin Sanden is market manager, rubber and tire, for LMI Technologies B.V.

Sanden received his master's degree in mechanical engineering from Chalmers University of Technology in Gothenburg, Sweden. He has more than 20 years of sales, marketing and technical experience in laser measurement technology and applications.

# N.C. issues first multi-award retread contract

By Miles Moore  
Rubber & Plastics News Staff

RALEIGH, N.C.—The state of North Carolina has issued its first multi-award contract for retread tires, after nearly three decades of a single-award contract to the consistent lowest bidder.

Issued Jan. 9, the multi-award contract runs until Nov. 30 of this year and is worth an estimated \$4 million altogether.

It resulted from a bill passed recently by the North Carolina legislature that encourages multi-award retread contracts for the state, although the state's procurement contracts traditionally are single-award.

The new contract's supporters say it will bring fairness to North Carolina's retread procurement procedures. But Bobby White—vice president of White's Tire Service Inc. of Wilson, N.C., the state's sole contractor for retreads from 1981 until now—said he was the victim of political meddling, and that he has always provided the state with superb bead-to-bead retreads for the least possible price.

Controversy over retread procurement in North Carolina began in 2007, when a state audit suggested White's Tire had overcharged the state more than \$361,000 for spot repairs. White replied that the audit was inaccurate, and that his company generally performed many more spot repairs than the three per tire the state allowed him to charge for.

Nevertheless, a 2008 study from Smithers Scientific Services Inc. recommended that the state consider multi-award contracts for retreads. The bead-to-bead retreads from White's Tire performed excellently in use, Smithers said, but so did pre-cure retreads both from White's and from White's competitors.

The legislature then acted to write and pass a bill that called on the North Carolina Department of Administration to consider multi-award contracts for retreads, as well as other changes to retread contracting, such as an end to charging for spot repairs.

Department of Administration officials devised the new contract in a closed-door meeting. In that contract, White's Tire—the state's only manufacturer of bead-to-bead retreads—remained the sole purveyor of that product.

However, the contract for the first time also allows for procurement of pre-cure retreads of several different types and sizes. In those areas, White's shares the contract with two other North Carolina retreaders: Snider Tire Inc. of Greensboro and Maness Tire and Recapping Inc. of Rockingham.

The new contract does not allow charges for spot repairs—only section repairs and nail holes. In bidding the new contract, White's Tire—unlike Snider Tire and Maness Tire—took the path of not charging for repairs at all. White's Tire was the low bidder in all pre-cure

areas except nondirectional tires, size 1400R24, in which Maness Tire edged it slightly, \$315.69 per tire vs. \$331.52. Snider's Tire bid \$446 for the same tire but also offered an expected mileage of 36,000 vs. 26,000 for White's Tire and 25,000 for Maness Tire.

Russ Hunt Sr., president of Snider Tire, welcomed the new contract. "This is a step in the right direction," he said. "Being able to get through the door, when we couldn't before, is a great thing for us."

White, however, said that by changing the retread contract the state fixed what

wasn't broken.

"For 30 years White's Tire has gone to the bid table and had the lowest bid," he said. "We proved we have a very good retread and fantastic service. With the new contract, I delivered the knockout blow at the bid table when we went to no charge for repairs."

White said the retread contract's administrator told him the legislature had mandated multiple awards for retreads. But James Staton, the state of North Carolina's chief purchasing official, said there was no mandate—merely a desire to fulfill the legislature's express wishes.

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