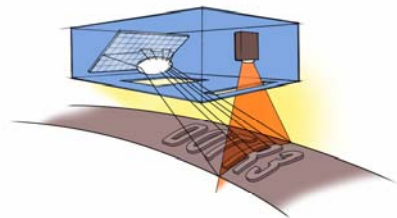




***Automatic Tire Identification and DOT
Code Recognition
Using
Very-High-Speed
Laser Profile Sensors***

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Automatic Tire Identification and DOT Code Recognition Using Very-High-Speed Laser Profile Sensors

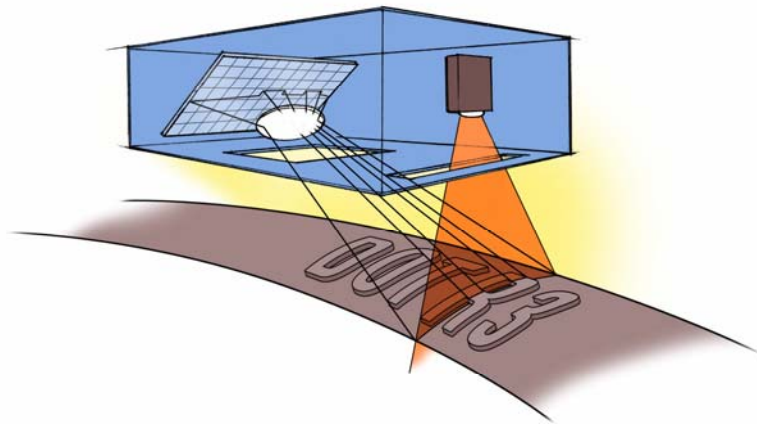
Introduction

ByteWise Measurement Systems has introduced a new product family that uses **Very-High-Speed Sheet-of-Light Laser Triangulation Profile Sensor (VHSL) Technology** to acquire dimensional data that characterizes the sidewall topographical geometry. When applied to the bead area the sensor digitizes the circumferential band that contains the DOT Code, Mold Code, E-Mark Code, or other molded-in features. This has applications in several areas:

1. Tire Identification for Sorting in Final Finish
2. Phase Angle Recognition
3. DOT Code Recognition for Vehicle Identification Number Matching

Profile Sensor Technology Overview

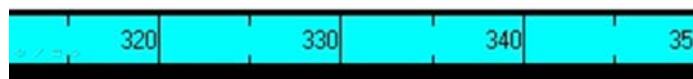
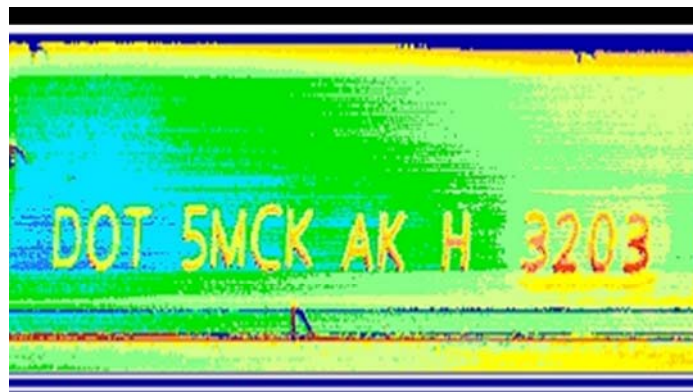
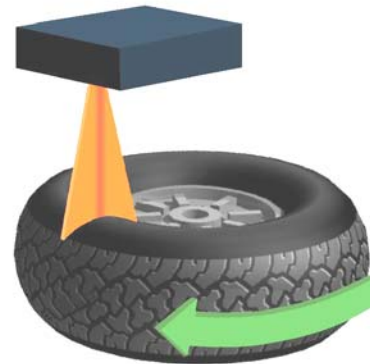
The Profile Sensor utilizes a laser light source to project a laser light line across the surface of the tire profile in the radial direction, from the bead toward the tread. The laser light line reflects from the surface, through a lens, and onto a high-speed, high-resolution 2-dimensional digital detector. These detectors and light sources are assembled into unitized sensor assemblies. The sensor outputs a formatted video signal to a PC over a high-speed bus. The PC transforms the video signal into a calibration-compensated xy number string. Sequential number strings are synchronized to an encoder and combined into a file suitable for post-processing.



Automatic Tire Identification and DOT Code Recognition Using Very-High-Speed Laser Profile Sensors

Laser triangulation provides for true geometrical measurement of the tire surface. This has several advantages over traditional machine vision technology:

- By combining sequential profiles, the Profile Sensor generates a data set of three-dimensional (xyz) geometrical coordinates (numbers) whereas machine vision works from a data set of two-dimensional gray-scale images.
- The Profile Sensor is calibrated via a method traceable to NIST Standards.
- The laser triangulation method can compensate for varying angles between the face of the sensor and the slope of the tire in the measurement area.
- Laser triangulation is not influenced by variations in surface color, texture, and background lighting.
- The quality metric for the profile sensor is gauge R&R using a certified gauge block. This is quite different from traditional machine vision systems that employ identification schemes such as Data Matrix, where the quality metrics include parameters such as contrast, growth, and axial nonuniformity.



DOT Code Scan in Color Topographical Visualization



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Sensor Performance

Sensors vary according to field-of-view, and are specified by width range (letter height), and depth-of-field. Sensors have been produced with width ranges from 25mm to 300mm. The 25mm sensor has an average error magnitude of approximately 3 microns while the maximum error is on the order of 10 microns.

Development History

The DOT Code System utilizes the sensor and software platform first developed for TGIS (the Tire Geometry Inspection System), which was introduced in 2002. TGIS scans the sidewall of an inflated tire in a Tire Uniformity Machine and inspects it for runout, bulges, and depressions. In addition, the system can be employed to determine the rotational angle of the tire in the test machine. This can be used to associate the bulge and depression angles to the true mold geometry.

As tire makers adopted TGIS technology, many asked if this technology could be employed to identify tires according to Mold Code and DOT Code, and to determine the phase angle of the tire for marking. These applications are described in the sections that follow.

Mold Code Recognition

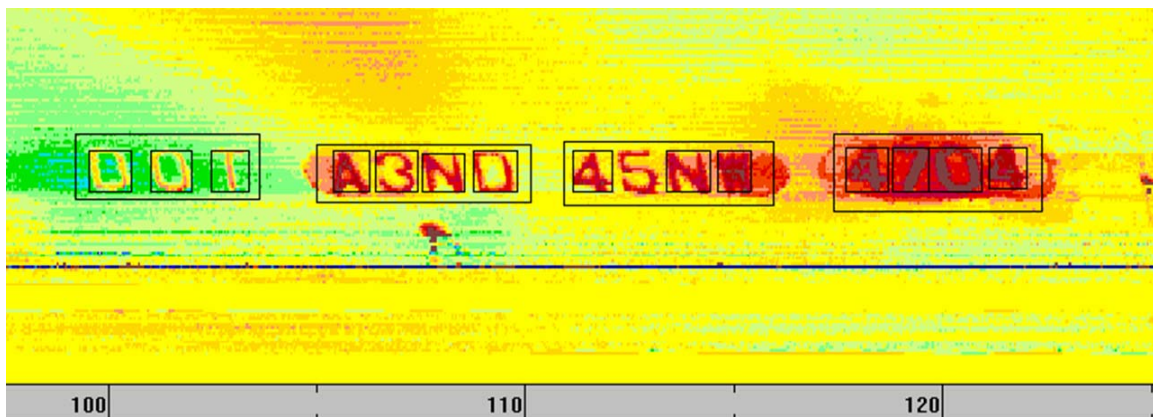
A system was produced to read Mold Code characters with a 4mm height and 3mm width. A special VHSL sensor configuration was developed to achieve the range and resolution required for letters of this size. This system permits the user to identify tires after curing in order to sort them to the proper final finish operations. When combined with a tire tracking systems, the data measured in force variation and balance testing can be associated to the mold via the Mold ID Code, thus providing traceability of tire testing data to the mold of origin.

DOT Code Character Recognition

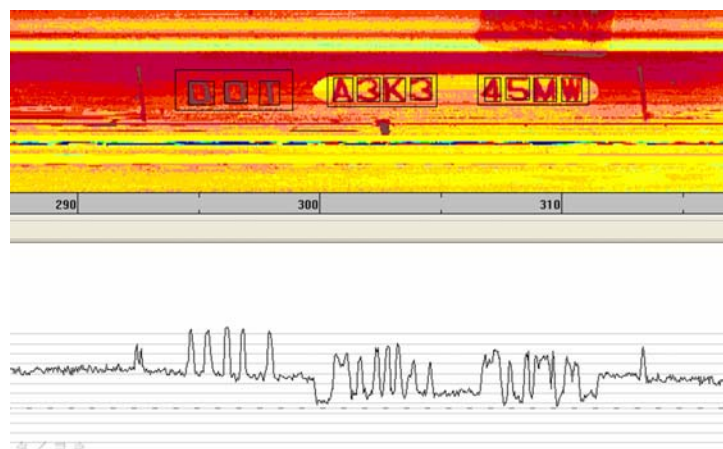
The VHSL sensor is quite resolute for measuring molded characters. A 100mm range sensor operating at 2,000 Hz on a 1,000mm circumference tire turning at 15 RPM digitizes the surface on 0.067mm spacing in the radial axis (letter height), and 0.125mm spacing in the circumferential axis (letter width), therefore a character that is 8mmx4mm in size is expressed by a 120x32 point grid. This 3,820 number set is conditioned and transformed into text characters by a proprietary algorithm. Typical DOT characters are about 1mm in depth. The sensor resolution in the depth axis is 1 micron. This makes it very easy to discern the difference between the letter surface and the tire background.

Automatic Tire Identification and DOT Code Recognition Using Very-High-Speed Laser Profile Sensors

A pattern matching method is employed to find the DOT Code, Mold Code, or E-Mark Code wherever it occurs on the sidewall. A character extraction method finds all characters within the data string and extracts them individually for translation. The translated text string is output to the host system via Ethernet messaging.



Pattern Matching Routine applied to find DOT Code Characters



DOT Code with Waveform



Automatic Tire Identification and DOT Code Recognition Using Very-High-Speed Laser Profile Sensors

Traditional vision technology discerns character shape by contrast between light and dark areas. This translation is done by numerically comparing the unknown character pixel values to those of the “taught-in” character sets. When applied to molded letters with black characters on a black background there are problems with both the character image acquisition, and the taught-in images. The edge delineation between a letter and the tire surface can only be discerned by a light vs. dark differentiation. Light areas are created by the illumination while dark areas are created by the shadows. The sizes and shapes of shadows vary considerably with the distance between the tire and the light source, and/or detector. This variability affects both the unknown character and the taught-in characters. This is because the 2D camera technology does not recognize the third dimension - the depth of the letter topography. For a system reading the depth of the letter via laser triangulation, lighting, camera angle, and camera distance cannot change the surface topography. In addition, the laser light source and detector are fixed together and calibrated so there can be no variation in lighting. The detector is looking only for a red laser light of the prescribed wavelength and does not otherwise recognize light versus shadow. This makes laser triangulation an ideal technology for reading molded-in characters on tire sidewalls.

Implications for DOT Code Recognition in Auto Assembly Plants

Car makers typically have tire suppliers that use a variety of different DOT Code Formats. A DOT Code Format is defined as ***“a combination of character height, width, depth, spacing, font, number of characters, type of characters (letter or number), and the size and shape of the clear area around the characters”***. If all tire suppliers deliver the same DOT Code format, the system performance can be maximized. If suppliers utilize different formats, each format will need to be scanned and taught-in. In that case it is necessary for the system to determine the type of format present before making the translation. Laser Triangulation can successfully differentiate between different DOT Code formats, however, it is more complex than recognizing a single format.

Conclusions

1. Laser Triangulation Profile Measurement is a very reliable and robust method of recognizing molded characters on tires.
2. A carefully designed motion control system is required to assure that the molded characters are properly scanned by the sensor.
3. The system can be configured to discern between different DOT Code formats, but will naturally perform better if all tires use the same format.
4. The system can be tuned to identify tires according to other molded-in features, such as Mold Code, E-Mark Code, and molded-in (non-paper) Bar Codes.