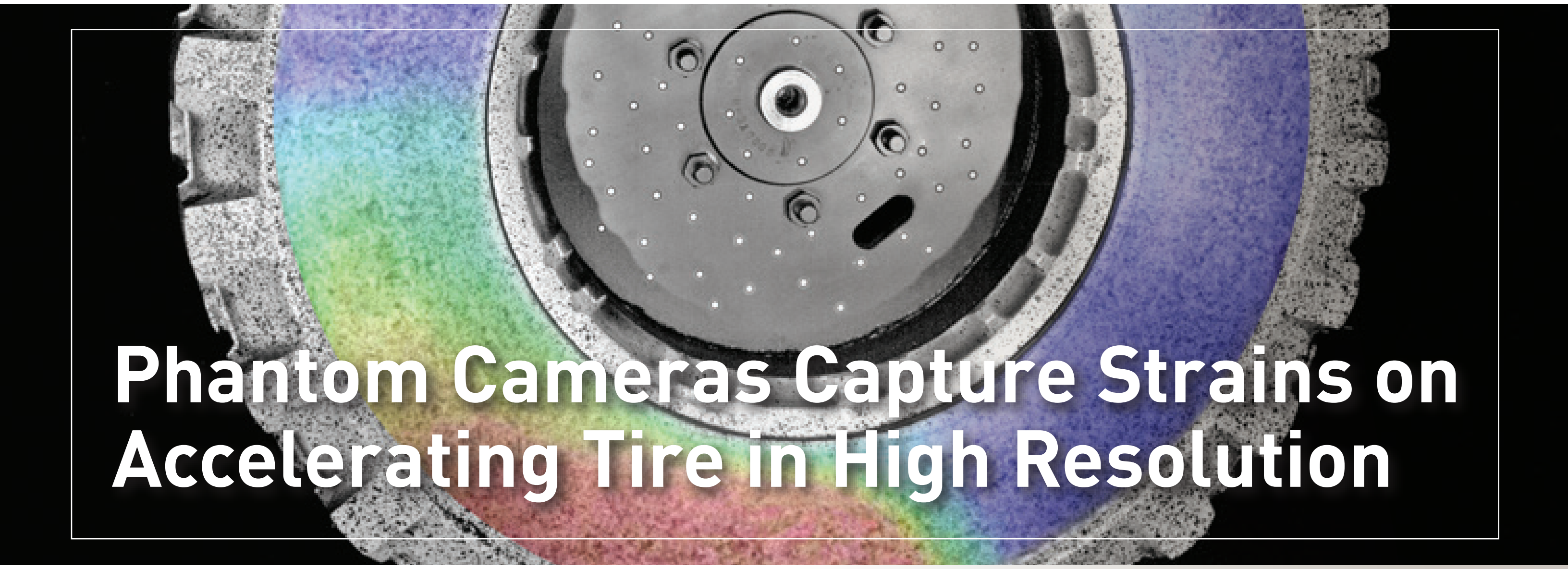
PHANTOM

2019
CASE STUDY



Phantom Cameras Capture Strains on Accelerating Tire in High Resolution

With the help of high-speed cameras, engineers used Digital Image Correlation (DIC) to observe micro-level strain and displacement on the surface of an accelerating Humvee tire.

What happens to a tire when you accelerate? To the eye, it appears as if the tire simply spins—quickly and smoothly. But these observations barely scratch the surface of what's happening.

To investigate how an accelerating tire behaves dynamically, a team of engineers from Vision Research and Trilion Quality Systems turned to an optical measurement technique known as Digital Image Correlation (DIC). As part of a University of Alabama at Birmingham project supported by NATO's Science for Peace and Security program, the engineers used DIC to map the strain and displacement on the surface of a tire accelerating to 65 mph. DIC utilizes two synchronized imaging devices—in this case, two Phantom v2640 high-speed cameras capable of recording 4-megapixel images at 6,600 frames per second. By combining the high-speed footage with 3D motion tracking software, the engineers observed surface deformations down to the micron level.

This study is one of the first investigations of how tires perform at high speeds and during accelerations with this level of accuracy. Made possible only through the power of high-speed imaging, it provides an experimental look into something that until now was only theoretical.

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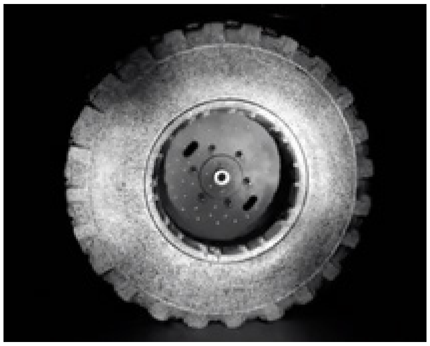
DIC VERSUS TRADITIONAL MEASUREMENT TECHNIQUES

DIC enables full-field analysis of deforming shapes in three dimensions—in contrast to the point measurements delivered by traditional sensors like strain gauges. The technique utilizes two synchronized high-speed cameras, which record an object from different angles. Then, DIC software correlates the images together into a 3D mesh. "Just like how you use two eyes to see the world in three dimensions, you need two cameras looking at the same object to generate a three-dimensional model," explains Jonathan Pickworth, Sales Director at Trilion.

Unlike traditional sensors, DIC is non-contact and offers several advantages. For one, it avoids having to use and apply mechanical sensors, including strain gauges, extensometers, vibrometers and accelerometers, to the surface of the object. "These sensors can perturb the system and lead to inaccurate measurements—especially if they aren't distributed evenly along the surface," explains Kyle Gilroy, Applications Engineer at Vision Research. Unobtrusive and less time consuming to set up, DIC instead utilizes a speckle pattern that is painted onto the object's surface to provide focus points for the cameras during high-speed filming.

In this way, DIC provides measurements from many more data points over an area without disturbing the system. Using specialized software, engineers can then analyze how the object moved, vibrated or changed shape freely.



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DIC AND VIBRATION ANALYSIS

In addition to evaluating strain and displacement, engineers can utilize DIC to perform vibration and modal analysis. For this reason, DIC plays an important role in vibration testing, which evaluates components' vibration or oscillation behavior prior to being released for production. Unlike other techniques used for vibration analysis, DIC avoids having to use physical sensors and is not limited to a handful of data points.

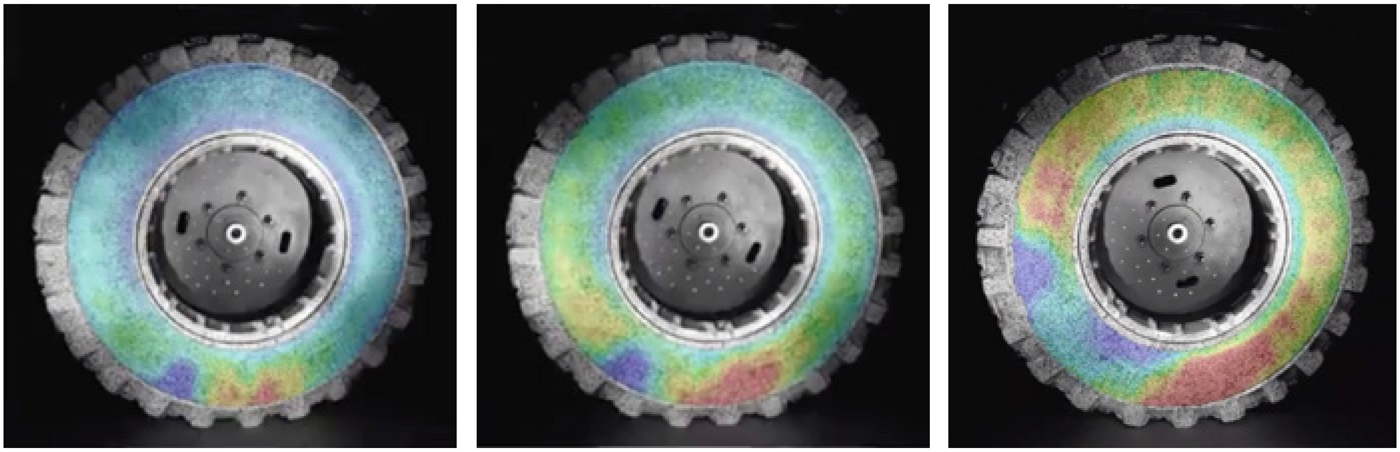
While the engineers didn't include vibration analysis as part of the tire experiment, Vision Research's high-speed cameras and Trilion's measurement systems—ARAMIS and GOM Correlate, in particular—do support this capability with respect to DIC. To measure frequency with cameras, engineers need to record at least twice as fast as the highest frequency of interest. With high-end cameras like the Phantom v2640, fast vibration and shock phenomena can now easily be measured with great accuracy. "Due to its unique ability to deliver high resolution at fast frame rates, this camera would also let you see lower amplitudes at higher frequencies," Winterhoff says.

THE ACCELERATING HUMVEE TIRE

In an experiment conducted at the National Tire Research Center (NTRC) in Alton, VA, engineers used DIC to study the strain and displacement that occurs on the surface of an accelerating tire. They combined GOM Correlate—Trilion's DIC and 3D motion tracking software—with two Phantom v2640 high-speed cameras.

To simulate a Humvee, the team loaded the tire and filled it up to its full pressure. Then, after applying the speckle pattern to the surface of the tire, the engineers triggered the cameras to record the acceleration process at 4,800 frames per second (fps) at 2,048 x 1,952 resolution. To evaluate surface displacement and strain, they then ran the high-speed footage through GOM Correlate, which expressed micro-level surface deformations as colored deviations, much like a computer simulation.

"The v2640 cameras are unique in that we were able to capture excellent strain gradients in ultra-high resolution," says DJ Winterhoff, Applications Engineer at Trilion. "One of the things we noticed was torsional strain occurring at the instant the test started. This torsional signature might equate to some energy loss. Designing Humvee tires to be more rigid might result in better traction, which would get the tire up to speed faster."



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NEED FOR SPEED: CHOOSING THE RIGHT CAMERA

Performing effective DIC analysis requires the right high-speed camera. "You want to see how deformations like strain evolve over time," Gilroy says. "If you use a slower camera, too much data is lost between frames. The result is you only get short, discontinuous snapshots of what's happening." That being said, the necessary frame rate depends on the application. For example, measuring a bullet as it passes through glass requires 1 million fps. A tire spinning at 60 mph, on the other hand, requires only 4,000–6,000 fps.

For maximum success, the cameras should deliver the most resolution possible at the required frame rate to best capture the fine, visual texture of the speckle paint pattern. What makes the Phantom v2640 unique is its ability to achieve exceptionally high frame rates and resolution at the same time. For one, the camera can shoot at 6,600 fps at full 2048 x 1920 resolution—and over 190,000 fps at reduced resolutions. Unlike most high-speed cameras, which utilize 1-megapixel sensors for DIC, the v2640 features a custom, CMOS 4-megapixel sensor—making it the fastest and most sensitive camera in its class.

"The camera's ability to achieve ultra-high resolution at very high frame rates gave us additional spatial resolution—leading to more detailed strain measurements of the tire," Gilroy says. "As a result, we learned a great deal about how tires perform at high speeds and accelerations and now have the experiments to back up existing theories."

Phantom v2640

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Trilion is a Pennsylvania-based scientific equipment supplier that develops 3D optical measurement and inspection testing devices that can be used to measure material properties, structural response and product quality.

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