NTRC

National Tire Research Center

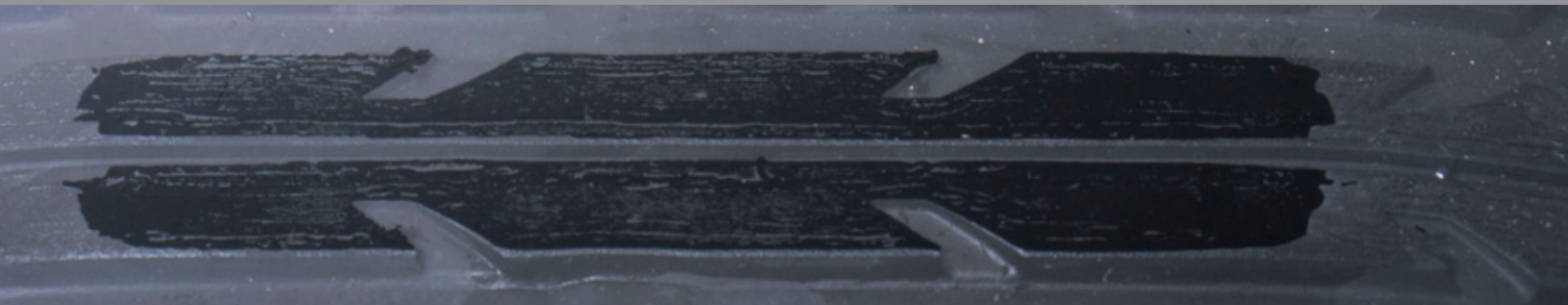
Virginia Tech
Transportation Institute

GCAPS
Global Center for Automotive Performance Simulation
Affiliated company of Virginia Tech

REVOLUTIONIZING *AN* INDUSTRY

When the National Tire Research Center (NTRC) was created in 2010 as an affiliated company of the Virginia Tech Transportation Institute (VTTI) in alliance with Virginia Tech, the Institute for Advanced Learning and Research, General Motors, and the Virginia Tobacco Indemnification Commission, the center was envisioned to house the world's only tire-testing machine capable of generating any force and moment on a tire at top speeds of 200 mph under combined loading conditions.

Today, the center has become synonymous with providing industry-first testing capabilities, including noise, wet, and full dynamic assessments on a flat surface. Customer demand is significant and includes global automobile manufacturers, tire manufacturers, motorsports teams, motorsport tire manufacturers, and aftermarket suppliers. NTRC experts perform critical work that clients need accomplished but cannot perform because they do not have the capability or the work does not meet the clients' core business objectives. The tire center is properly staffed to minimize



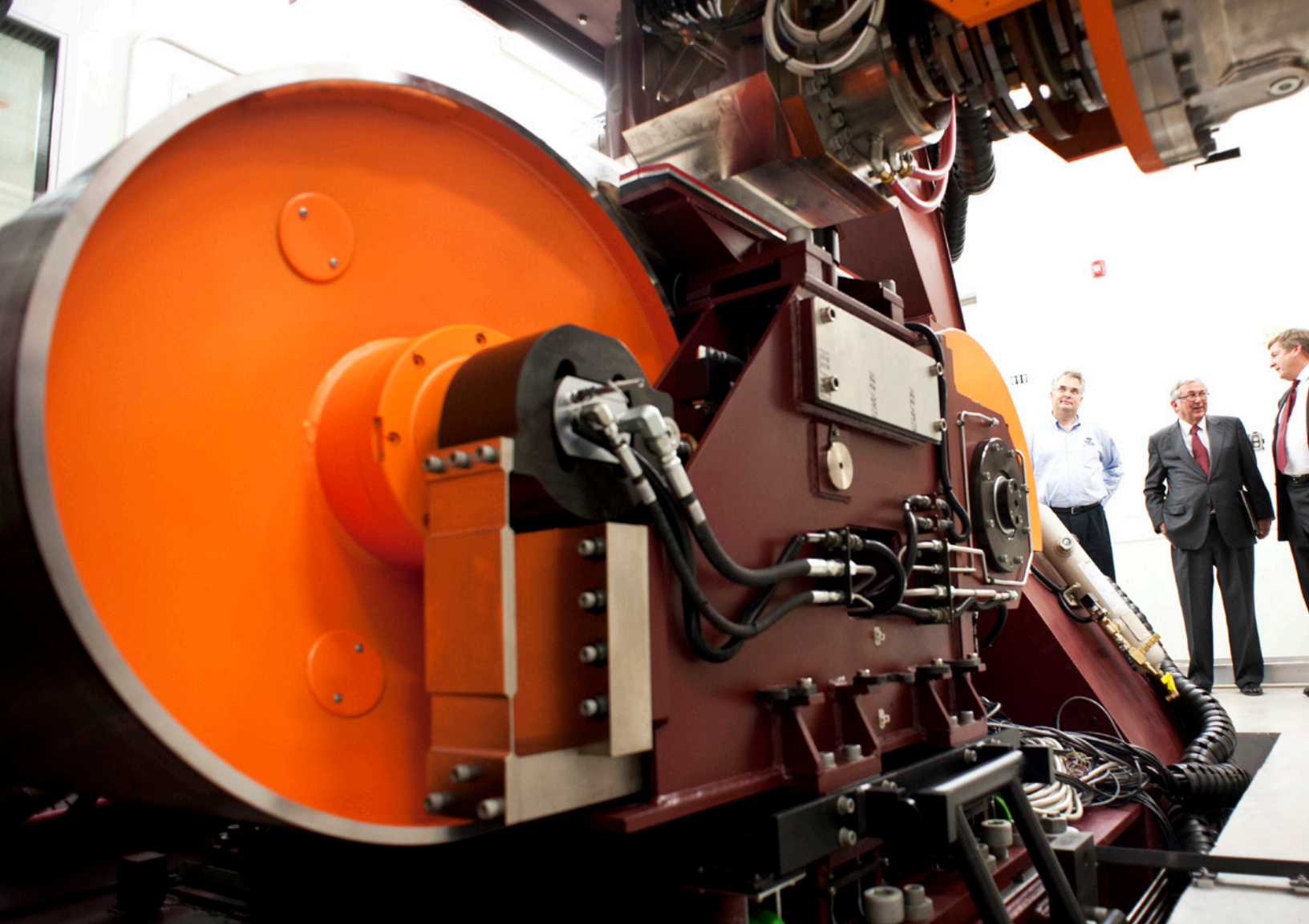
tire, belt, and test changes, resulting in maximum testing efficiency. NTRC personnel perform regular preventative maintenance and calibration checks to enable high uptime and accuracy of equipment.

The NTRC is not affiliated with any vehicle original equipment manufacturer, component original equipment manufacturer, or race organization, thereby producing unbiased test procedures, data, and analyses. Unique funding avenues enable the NTRC to be a low-cost service provider, with expertise and guidance included in the service cost.

The unique resources available at the NTRC have not only transformed the state of the art in testing for the tire industry; they also serve as a catalyst for economic growth within the Southern Virginia region, where the NTRC is headquartered. Academic opportunities also abound, with engineering students from surrounding universities and colleges participating in internships with the NTRC.

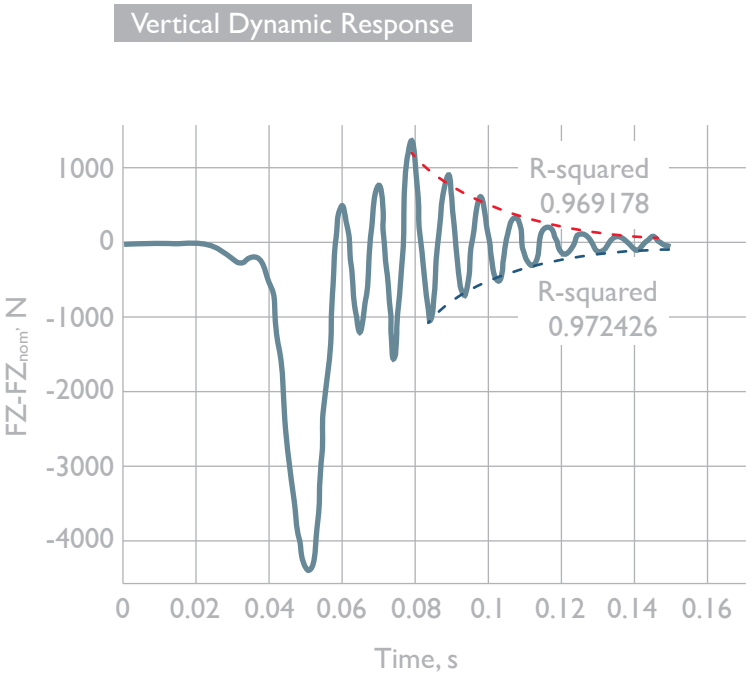
Along with the Southern Virginia Vehicle Motion Labs and the Virtual Design and Integration Laboratory, the NTRC composes the foundation of the Global Center for Automotive Performance Simulation (GCAPS), a world-class facility unveiled during 2014 that provides revolutionary services for not only tire and vehicle testing, but also simulation and modeling. Collectively, these initiatives provide the range of services essential for creating a more dynamic product through both virtual and physical development.

INSIDE



USER EXPERIENCE

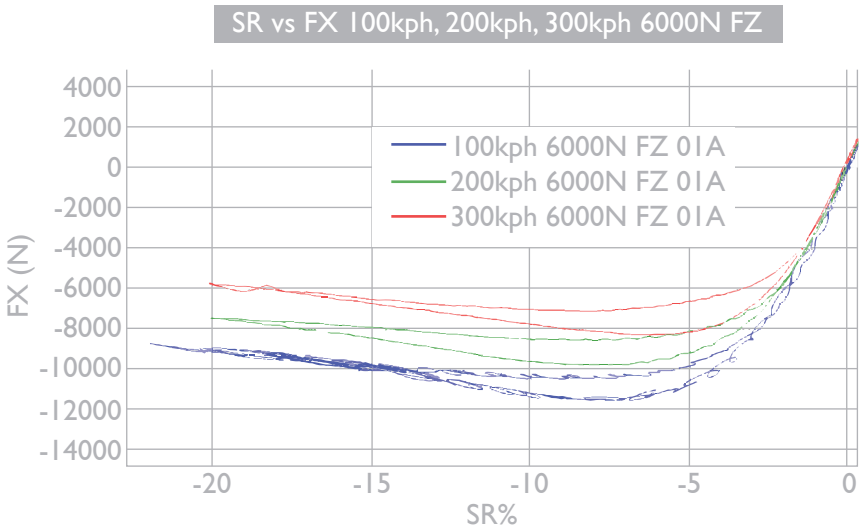
The NTRC understands that moving from one test machine to another is a complicated process that involves more than simply sending tires to a different location to be tested. Center personnel have therefore created a three-tiered approach designed to help clientele seamlessly transition from legacy testing to NTRC testing. During each phase of the transition process, NTRC experts will be intimately involved with the testing, data analyses, and overall experience, thus providing more than just data. Each client receives the full benefits of NTRC's unique expertise and understanding of tires, vehicles, simulation, and integration.



PHASE ONE:

INITIAL CORRELATION TO LEGACY EQUIPMENT

- Test procedures will be developed that produce the same data between legacy equipment and NTRC equipment (approximately 8 hours of test time provided to mimic current test procedures)
- Tests will be performed using the expanded capabilities of the NTRC, determining methods that will increase the understanding and performance of clients' products (approximately 8 hours of test time provided to explore dynamic, cleat, and drive/brake testing)

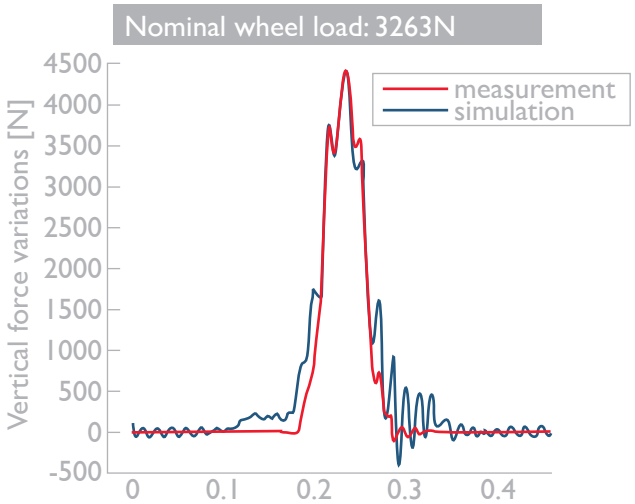


PHASE TWO:

EXTENSIVE CORRELATION TO LEGACY EQUIPMENT AND/OR INTRODUCTION TO NTRC EQUIPMENT

- Proper correlation sometimes requires several test samples and multiple test procedures; a more extensive plan may be accomplished at a reduced rate
- A multi-session correlation plan may be executed for companies with experience using legacy equipment
- Test plans may be developed to introduce NTRC equipment and capabilities to companies that are new to tire testing or those that may have limited experience
- Following each test session, NTRC testing and development experts will review the data with each client to:

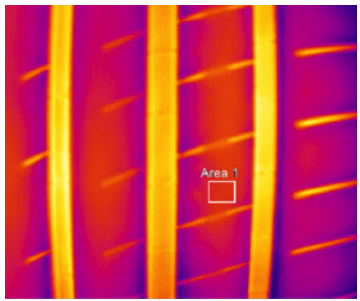
* Understand correlation differences, if any
* Determine the needs/wants of each client and provide suggestions to achieve desired goals
* Determine how the expanded testing capabilities of the NTRC provide an increased understanding of each client's product(s)



PHASE THREE:

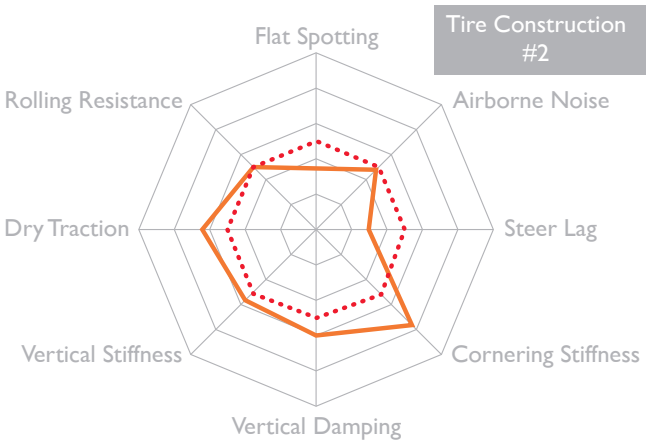
ESTABLISH AND EXECUTE ANNUAL TEST PLAN

- A test plan for future sessions is established after successfully determining that legacy equipment procedures can be replicated at the NTRC with the same or higher-quality data; such test plans may include:



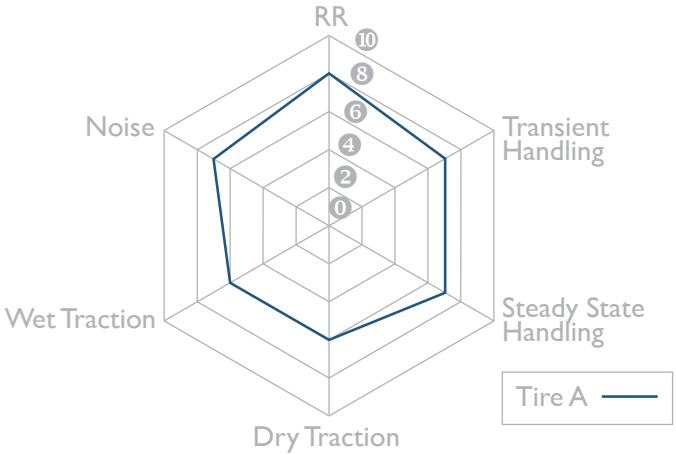
  * Standard test procedures from legacy equipment
  * Research and development sessions that improve testing and products (e.g., wet testing, dynamic testing, noise testing, etc.)

- NTRC experts will be available to help determine test plans that will improve product performance
- Test time needs will be determined that yield efficiency gains from proper staffing and optimized test procedures
- NTRC experts will review the expected test volume and approximate a schedule for proper pricing and data delivery dates



SCENARIO A

Tire A				
	Target	Simulation Result	Max Error	Possible Min Value
Vehicle Test A	10	11	10%	9.9
Vehicle Test B	10	11	10%	9.9
Vehicle Test C	10	11	10%	9.9



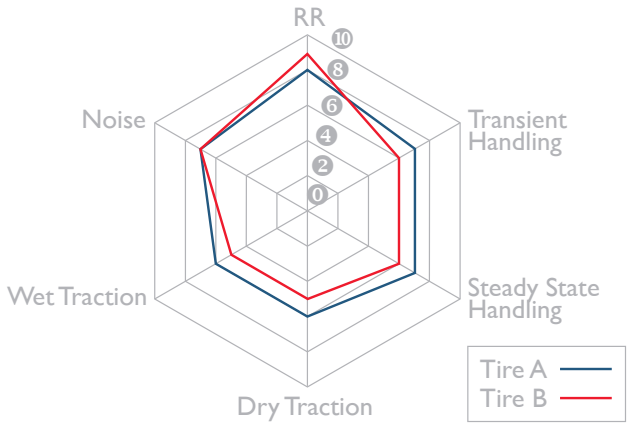
IMPORTANCE OF TIRE CHARACTERIZATION

A higher fidelity tire characterization reduces vehicle simulation error, allowing the tire to be rebalanced for improved rolling resistance while achieving vehicle performance targets.

To illustrate the importance of tire characterization performed by the NTRC, two scenarios are presented that simulate Federal Motor Vehicle Safety Standards (FMVSS) No. 126, the Consumer Reports Avoidance Maneuver, or other maneuvers that involve drive or brake torque at vehicle speeds greater than 35 mph. In Scenario A, a tire is tested for force and moment with traction at 35 mph, while Scenario B represents a tire tested for force and moment with traction at actual maneuver speeds.

By properly characterizing the tire using real-world conditions in Scenario B, the extrapolation error is greatly reduced. This increases the fidelity of the tire model and, thus, the vehicle simulation.

The reduction of error in the vehicle simulation increases confidence that the vehicle will meet its performance targets. This allows for the tire to be rebalanced (Tire B) to increase vehicle fuel economy while achieving all other performance targets.



SCENARIO B

Tire A				
	Target	Simulation Result	Max Error	Possible Min Value
Vehicle Test A	10	11	5%	10.45
Vehicle Test B	10	11	5%	10.45
Vehicle Test C	10	11	5%	10.45

Tire B - Rebalanced for improved RR				
	Target	Simulation Result	Max Error	Possible Min Value
Vehicle Test A	10	10.6	5%	10.07
Vehicle Test B	10	10.6	5%	10.07
Vehicle Test C	10	10.6	5%	10.07

TIRE CHARACTERIZATION SERVICES

The NTRC offers myriad tire characterization services that are designed to enhance the quality of clients' products. The following services may be integrated into the testing and development process.

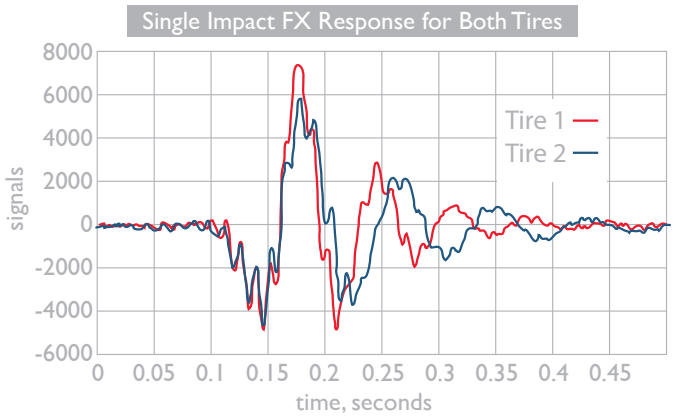
FORCE AND MOMENT

- Transformational LTRe force-and-moment tire test laboratory
- High-speed capability up to ±200 mph (320 kph)
- Highest wheel torque capability available
  - * ±7,375 lb. ft. (10,000 Nm) is four to five times larger than existing Flat-Trac systems

    * Operable across full-speed range
    * Uses high response electric motor for accurate slip ratio control
- High simultaneous tire positioning rates for transient event simulation
- Path following that mimics exact tire conditions from multiple maneuvers and tracks
- Improved control that results in a system with hardware-in-the-loop (HIL) capabilities
- Wet-test capable

DYNAMIC CHARACTERIZATION

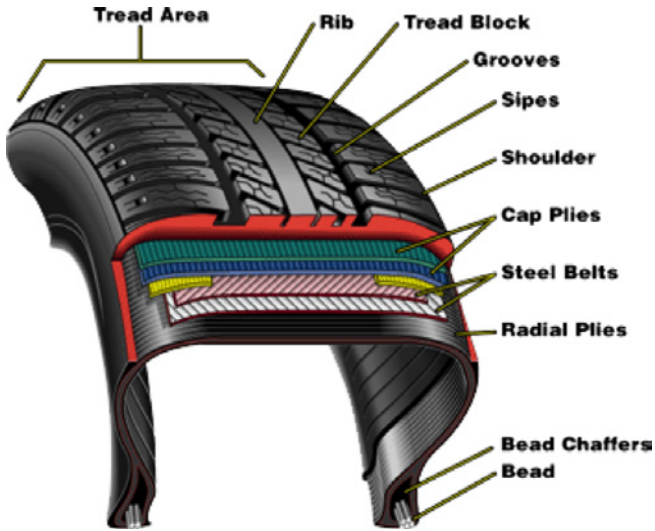
- Perform Drive File Replay of tire for model correlation and durability (track and highway)
- Enables direct component comparison to tire models
    * Lap durability
    * Direct comparison of tire response from vehicle input for metric development and subjective correlation
- Impact testing for ride and load model parametrization



TIRE CHARACTERIZATION SERVICES *ctd.*

MATERIAL INTEGRATION

- Integration and manufacture of material supplier technology into tires
- Complete extensive performance testing to be used for marketing of technology with comparison to current technology
- Material characterization equipment and rubber mixing equipment available
  - * Coordination of current testing standards (e.g., rolling resistance, treadwear, etc.)
  - * Creation of new tire testing procedures (e.g., noise, flat spotting, indoor treadwear, etc.)
  - * Project summaries and reports with an end-vehicle application focus
  - * Currently aligned with one tire manufacturer; in discussions with others to produce control and new technology tires

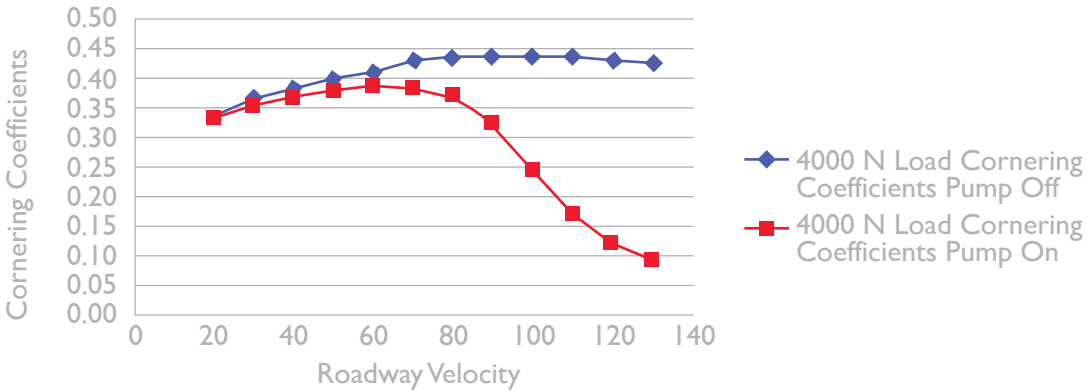


TIRE CHARACTERIZATION SERVICES *ctd.*

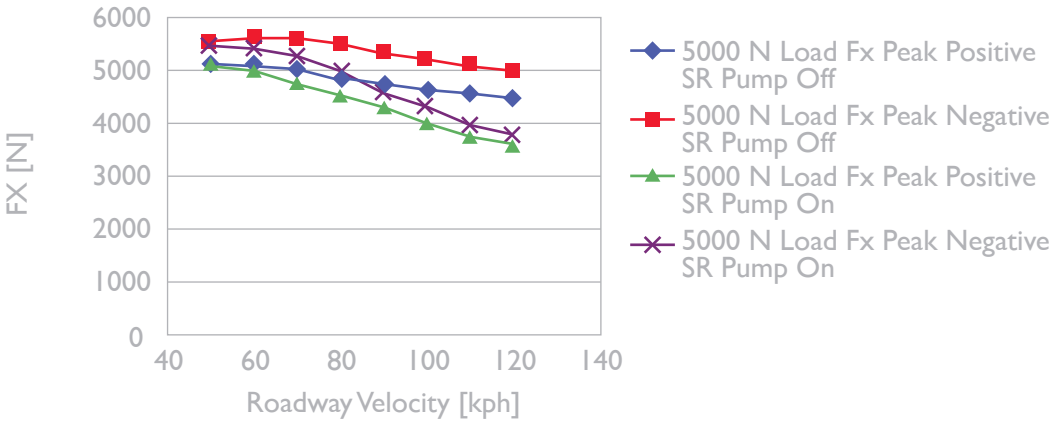
WET TESTING

- Laboratory indoor wet testing
- Can control and apply varying levels of water onto the flat surface of the force-and-moment machine
- Ability to research methods for determining the hydroplaning characteristics of a tire
    * Speed at which a tire first has a reduction in lateral force
    * The coefficient of friction
- Development of a procedure for lateral characterization in wet conditions
- Developing procedures to determine the traction characteristics of tires under several wet conditions
- Comparisons to outdoor testing completed, analyzed, and understood to successfully transfer the indoor wet characteristics for use in tire and vehicle development

4000 N Cornering Coefficients



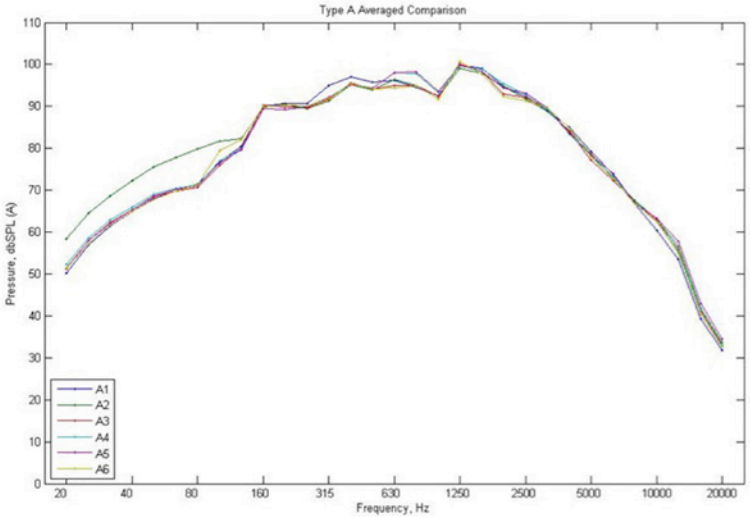
5000 N Peak FX

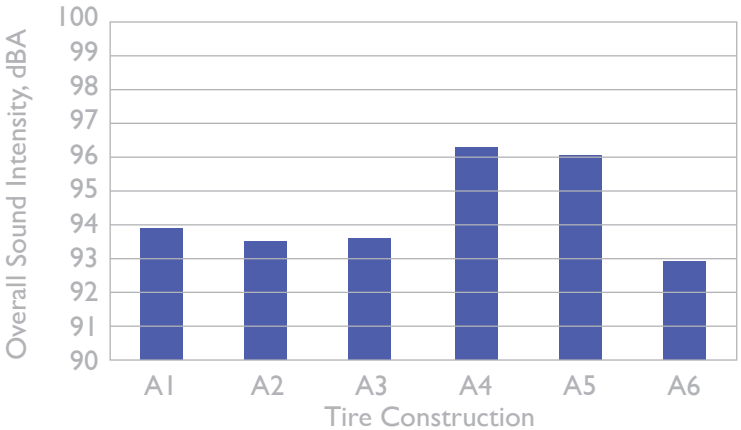


TIRE CHARACTERIZATION SERVICES *ctd.*

NOISE TESTING

- Brings tire airborne and structure-borne noise testing into the laboratory on a flat-surface test machine, an industry first
- Includes mounting a microphone array to the machine, performing the tire test, collecting data, and processing data
- Multiple surfaces can be mounted on LTRe belt
  * Smooth for airborne
  * Non-uniform for structure-borne
  * Replication of reference surfaces possible
- Six different constructions show noise differences in various ranges of frequency bandwidth


Type A Averaged Comparison
Pressure, dbSPL (A)
Frequency, Hz
A1
A2
A3
A4
A5
A6


Overall Sound Intensity, dBA
Tire Construction
A1
A2
A3
A4
A5
A6

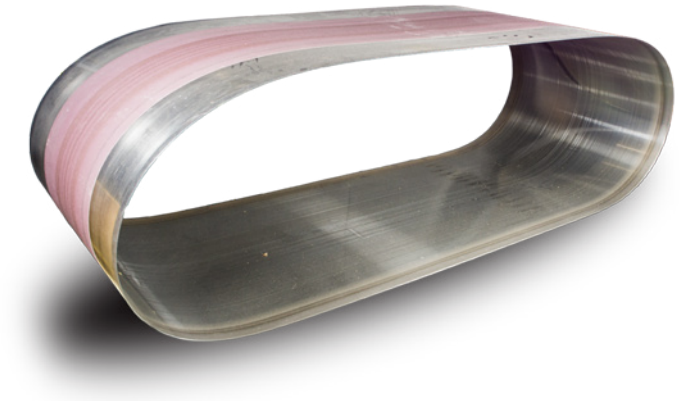
TIRE CHARACTERIZATION SERVICES *ctd.*

TRACTION

- Globe's most capable laboratory tire traction testing
- Increased wheel torque capability
    * ±7,375 lb. ft. (10,000 Nm) is four to five times larger than existing Flat-Trac systems
    * Operable across full-speed range
    * Uses high response electric motor
- Replication of traction-trailer for longitudinal tire response characterization in a more repeatable manner

SURFACE BENCHMARKING

- In collaboration with VTTI, the NTRC offers the experience and tools necessary to help clients characterize U.S., Mexican, and Canadian road surfaces
- Can apply non-uniform surfaces to flat-track belt for tire and road noise evaluations



TIRE MODELING

The NTRC houses the world's premier force-and-moment tire testing machine. This machine enables capabilities non-existent at any other location. The NTRC is a one-stop shop for both tire characterization that facilitates proper parametrization and the generation of tire models from test data.

Test parametrizations include:

- Steady-state force and moment
- Traction
- Combined slip
- Rolling radius
- Lateral and longitudinal transients
- Multiple stiffnesses
- Cleat envelopment and impacts of various sizes and orientations

The math and simulation group within the Virtual Design and Integration Laboratory has the following capabilities in tire modeling:

- Parametrization in MF-Tyre™, MF-Swift™, and FTire™ formats
- Ideal correlation of measured and modeled data within modeling programs
- Standard tire model formats supported by multiple vehicle modeling programs
- Creation of a tire model that encompasses the full dynamic capability of the LTRe

TIRE CHARACTERIZATION SERVICES *ctd.*

ENDURANCE

- The most representative lab testing in existence via use of actual road conditions and a flat surface
- Uses track replay of the tire enabled by torque and dynamic positioning rates of the LTRe
- Can be taken to failure of the tire or to set conditions with the force generation monitored
- Can be performed on passenger-car, light-truck, or motorsport tires

THERMAL CAPABILITIES

- Important to forces, moments, and tire positions, producing more robust data required for tire modeling and data analyses
- Uses infrared sensors on the tire surface (tread and/or sidewall) and the belt material
- Thermal camera is available to enhance data, with analog outputs synced into the data acquisition system and two visual formats (video and multiple pictures)

FLAT SPOTTING

- Industry first for in-lab flat surface measurement
- Fixture and procedure developed to mimic on-road conditions that create quality issues related to tire flat spotting

CONTACT US

To learn more about how GCAPS and the NTRC can help your company excel in the industry, visit www.sovamotion.com or call 434.766.6644.

If you are interested in becoming a part of the GCAPS team, contact Human Resources at hr@sovamotion.com.

GCAPS

Global Center for Automotive Performance Simulation

Affiliated company of Virginia Tech

VirginiaTech

Transportation Institute