Pressure Mapping: Gaining Competitive Edge in the Automotive Industry

Achieve Design and Process Optimization with Interface Pressure Measurement

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Table of Contents

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Introduction

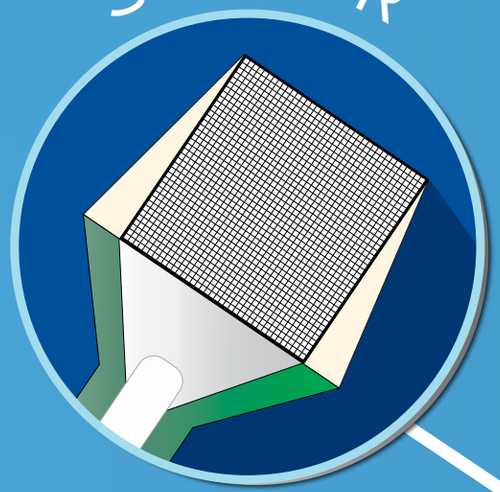
In an increasingly competitive global marketplace, automotive design engineers and researchers must constantly search for ways to improve performance, quality, efficiency, and safety. Gaining a better understanding of contact pressure can be vital to making such improvements. Some key problems that engineers face are:

- Identifying failure mode of a product or a mechanical pressure concentration ("Hot Spot")
  - Verifying proper sealing or snap fit in product design (door / trunk seal, dashboard mounting)
- Understanding force distribution between two load-bearing surfaces
  - Design validation: verify structural integrity of lighter, fuel efficient, cost saving components
- Optimizing the manufacturing process
  - Calibrating / verifying alignment of nip / rollers, presses, or nozzle spray patterns
    - Improving yields and reducing downtime
  - Comparing product from different processes or materials (robotic frame assembly)
- Benchmarking competitive products

Evaluating interface pressure can offer key insights and critical data to address these issues.

COMPONENTS OF A PRESSURE MAPPING SYSTEM

SENSOR

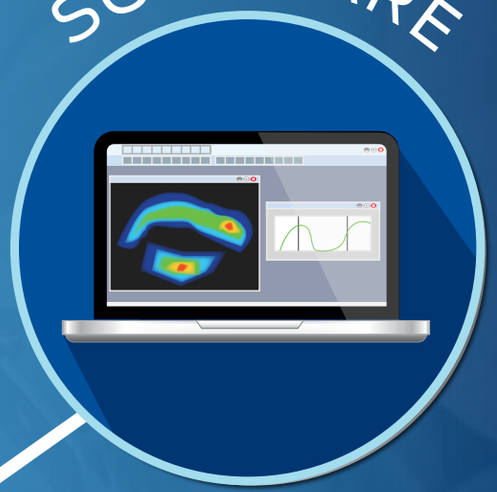


- Minimal invasiveness
- High resolution
- Thin & flexible

ELECTRONICS

- Scan thousands of sensing points within each sensor
- Instant data relay to PC via USB or WiFi

SOFTWARE



- Display pressure distribution data in multiple formats for superior analysis
- Display pressure data graphs in 2D & 3D
- Capture peak pressures and center of force in real time
- Allow for video playback of pressure data

WHAT IS PRESSURE MAPPING?

Even between relatively flat surfaces, one finds the interface pressure distribution is often not uniform with localized areas of peak pressure. Pressure mapping technology helps design engineers obtain insight into areas that may impact design and quality.

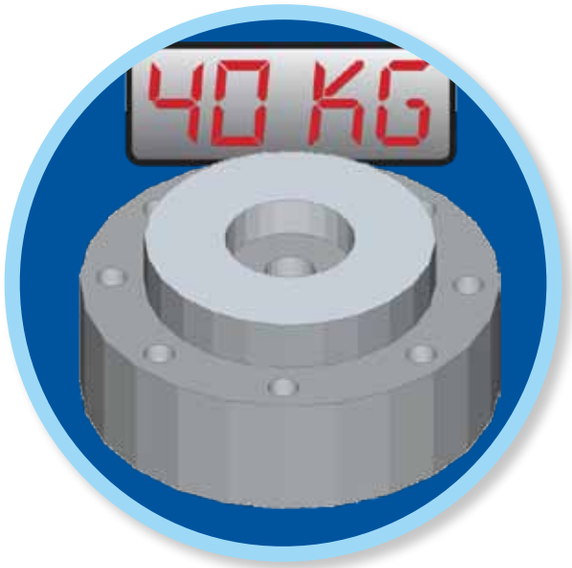
Modern pressure mapping systems require 3 components – **sensors, scanning electronics and software** – to deliver real-time, actionable data, in ways other methods cannot.

- The **sensor** transforms compressive pressure loads to a change in resistance.
- The **scanning electronics** collect analog data from the sensor and convert the data to a digital signal.
- The **software** displays real-time activity of the sensor area, allowing the user to see force, pressure, contact area, and timing data.

Technology Comparison

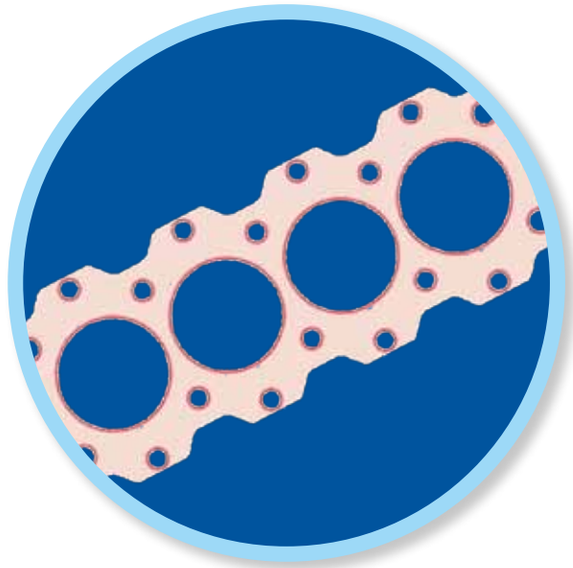
Below are three technologies to consider when trying to measure force or interface pressures. While there is some overlap with the information each sensing technology provides, they each present a unique value in the problem-solving process.

Load Cell



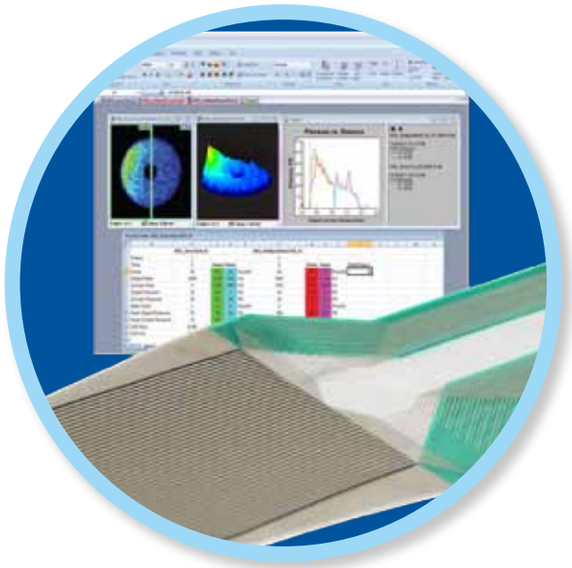
Reliable, but no data on pressure distribution

Pressure Sensitive Film



Flexible, but can only measure peak pressure

Tactile Pressure Sensor

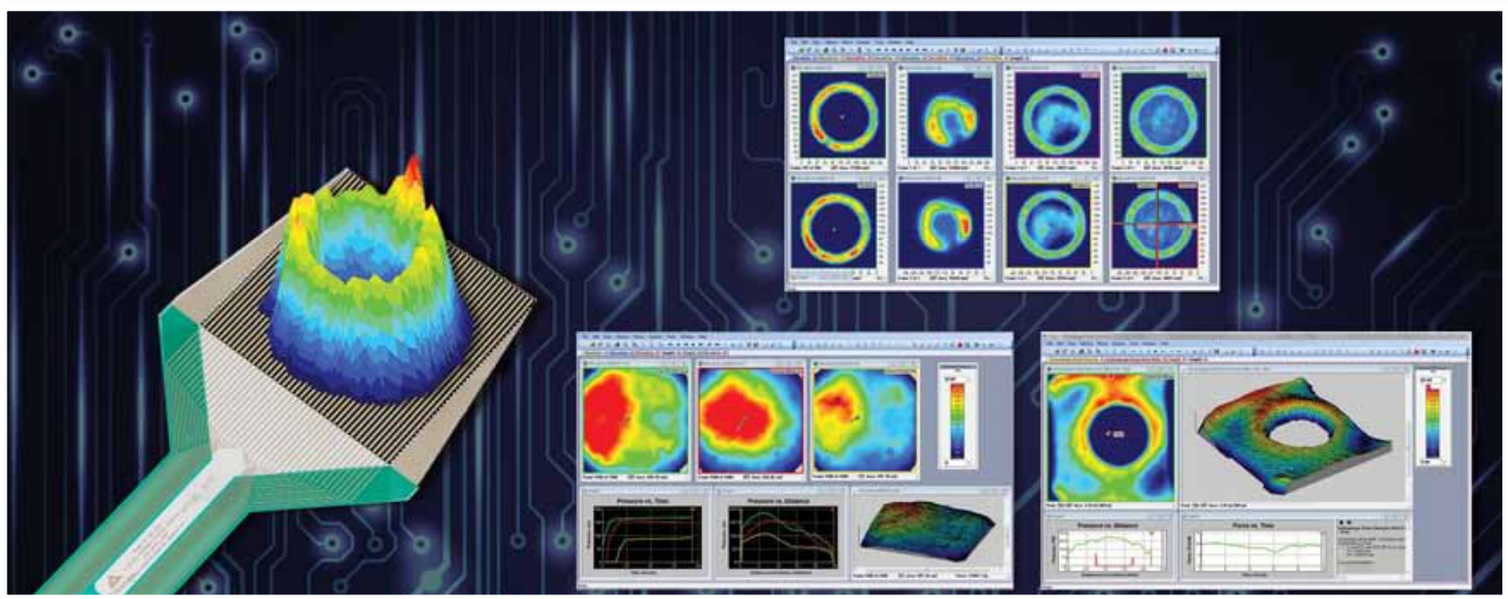


Versatile, with unique pressure distribution data

Download our white paper:
Comparison of Interface Pressure Measurement Options.

What Are the Advantages of Using a Pressure Mapping System?

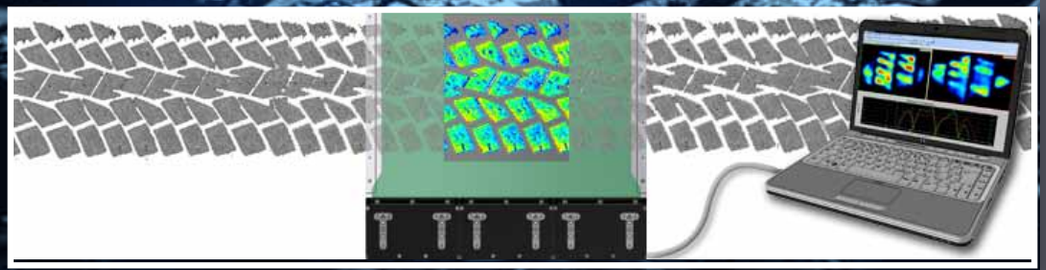
- Clear visual representation of pressure distribution
- Real-time feedback of adjustments made
- Thin sensor provides minimal interference between the objects being measured
- Versatility: single analysis tool for a broad range of applications
- Sensors are customizable to specific form factors, resolutions, and pressure ranges, to meet the needs of unique applications
- Sensors are available for high temperature and humid conditions
- Software can interface with third-party analysis tools
- Offers insights to enhance product design, manufacturing, quality, and research



Automotive Pressure Mapping Applications

This section reviews some common automotive applications, and shows the information that a Tactile Pressure Mapping System can provide.

CrossDrive™ System



Tire Tread

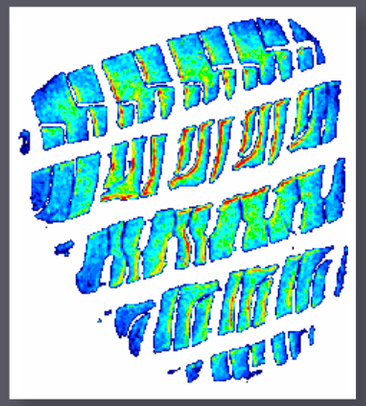
Understanding tire behavior during motion is critical to designing a high-performance tire. To improve handling and response, tire manufacturers need to understand the changes of a tire under various loads and during dynamic events, like cornering and braking. Additionally, knowing the void ratio of the tire is critical for understanding the water displacement potential of the design.

A ruggedized tactile pressure sensor, with electronics in metal enclosures, sits on a steel plate, and can measure the pressure distribution of a tire statically loaded, or rolling across the sensor face. Dynamic measurements can be taken under certain conditions, such as acceleration, deceleration, toe, and camber.

The point-of-contact data is analyzed in software to determine perimeter area, cross-sectional pressure profile, measurement of footprint length and width, and other configurable parameters.

This data can be used to:

- Evaluate and compare tire designs and tread patterns
- Assess different materials and rubber compound formulations
- Conduct quality control measurements
- Perform competitive benchmarking
- Perform road surface predictive wear studies
- Assess camber and impact of suspension
  - Race vehicle "set up"



Tire Footprint from Toe / Acceleration Test

Door Seal

Wind, noise, and water leaks in a new vehicle can be a significant source of customer dissatisfaction, create a perception of poor quality, and cause warranty expenses. Proper adjustment of hinges and door latches while the car is in the factory and the doors are being mounted can eliminate these problems.

Previously, vehicle assembly technicians have had to guess where to position the hinges and latches. To measure the pressure of the door seal, technicians would slide a piece of paper between the body and the weather strip, to feel the amount of pull in different locations. With a pressure mapping system, assembly technicians now have an electronic "feeler" gauge that measures contact pressure, while also acting as a direct feedback mechanism. Technicians can use the gauge to help them optimize seal pressure and deflection around the door frame.

In the study from the previous page, the same total force is applied to two different door seal designs. The 3D pressure display shows a problem in *Figure 1*; the valley in the middle indicates a weak spot in this seal, which represents a leakage path for air or water. *Figure 2* has a lower peak pressure, but a more even pressure distribution, making it the more effective seal design.

Pressure mapping enables a technician to immediately see how the door seal force changes as adjustments are made to the door latches and hinges, and while the door is mounted. The system is an effective quality control tool to ensure a tight door seal, helping to reduce or eliminate water leaks, wind noise, and air leaks in the passenger compartment.

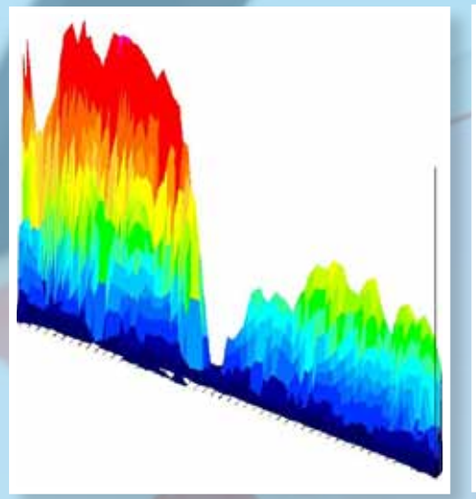


Figure 1: Door Seal Pressure Output Before Adjustments

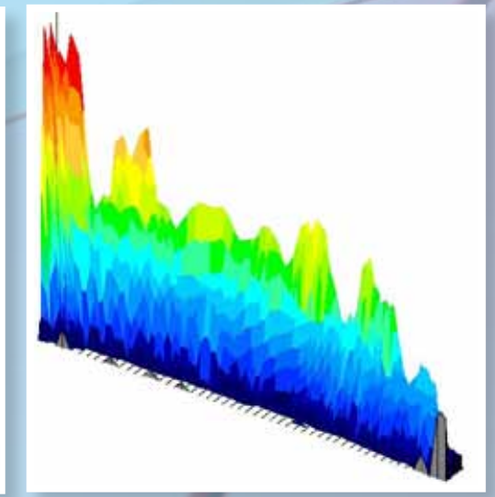
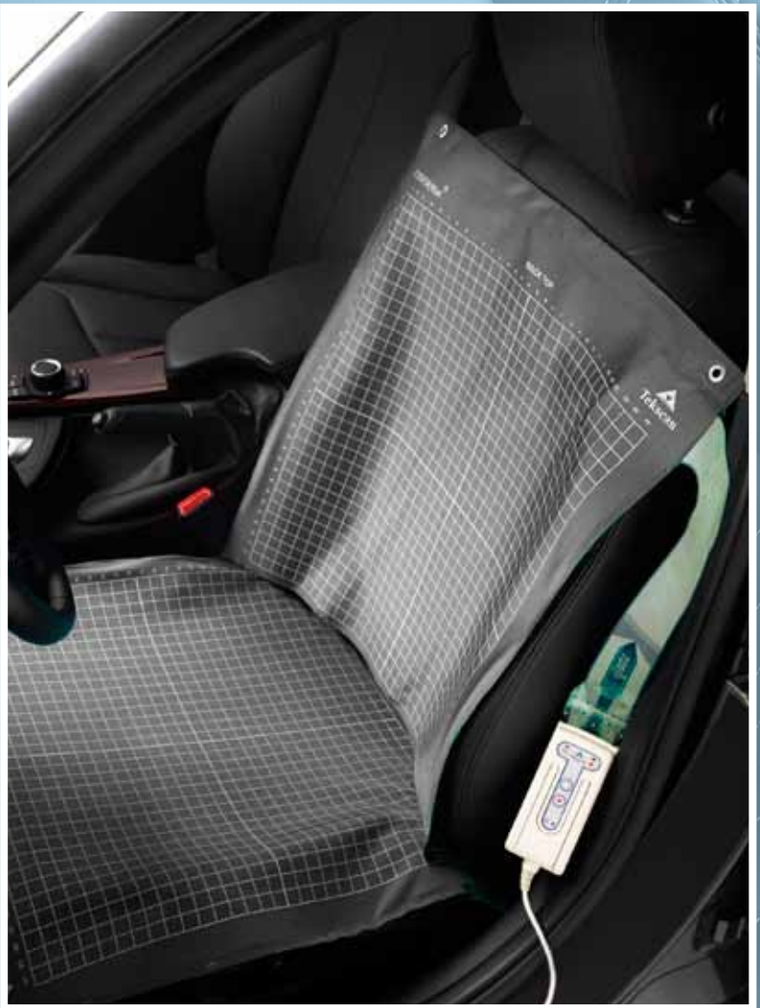


Figure 2: Door Seal Pressure Output After Adjustments

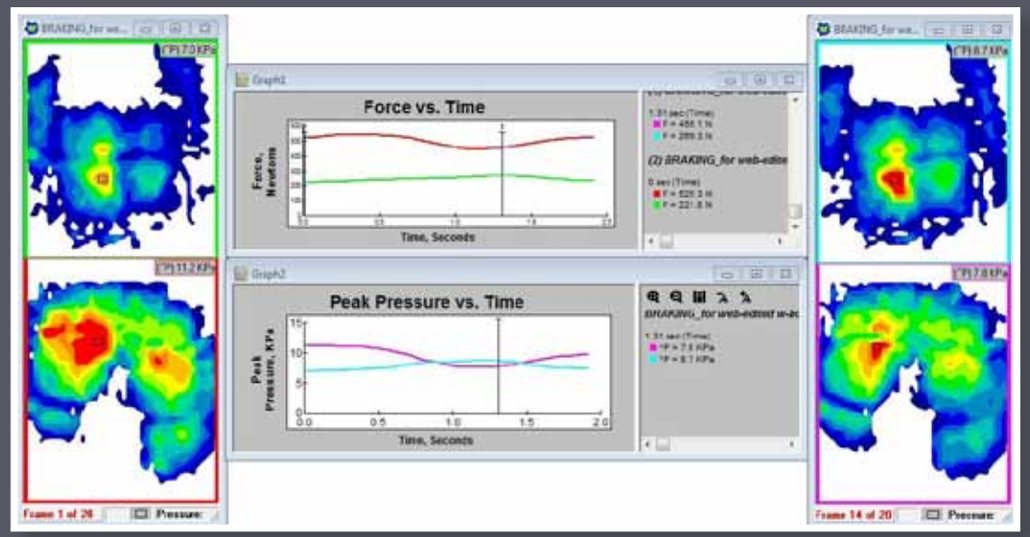
Door Seal Pressure Evaluation

Seating / Comfort

Acquiring and evaluating ergonomic measurements is a difficult challenge. Ergonomic engineers must find a way to maximize efficiency and productivity while reducing operator fatigue and discomfort. A pressure mapping system dynamically measures interface pressure between a human body and a support surface. Automobile seats can be tested to evaluate their comfort, design, material, and durability.



CONFORMat™ System Used in an Automotive Seat Test



Pressure distribution of a driver as he prepares to apply the brakes. The (red) elevated pressure on his right buttock is a result of lifting his right foot. The image on the right shows the change in pressure distribution that occurs while applying the brakes. Note the (red) high pressure region shifted from the buttocks to the lumbar region.

Pressure mapping data can facilitate:

- Optimizing foam stiffness and cover materials
- Selecting the best ergonomic position of the driver
- Studying ease of occupant ingress and egress
- Measuring changes in the driver's position during high activity, and over long periods of time

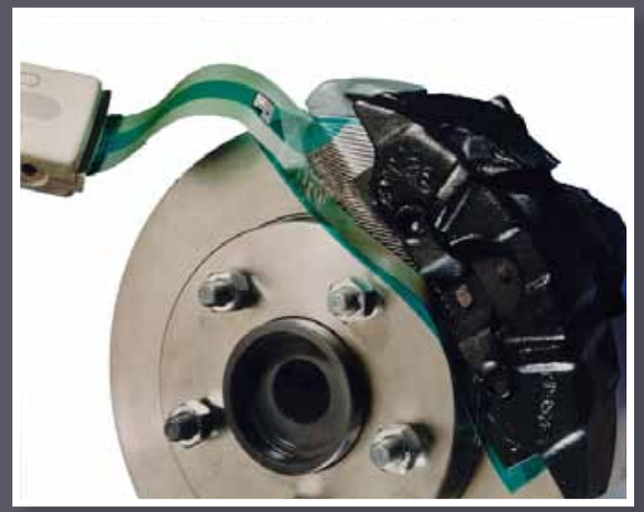
Brake Pad

A pressure mapping system is a versatile research and development tool for brake system and friction plate manufacturers interested in evaluating brake pad pressure distribution. The data provides insight into the dynamic forces and pressures acting between a brake pad and rotor or brake shoe and drum.

In *Figure 1*, the software clearly shows where uneven pressure exists between these mating surfaces, predicting wear and stress on the pad.

The center of force trajectory in the software output, *Figure 2*, reveals if the area of average pressure varies throughout a braking cycle.

Pressure mapping data can be used to address the challenges facing brake design engineers, such as predicting wear, and reducing noise, vibration, and harshness.



Brake Pressure Measurement

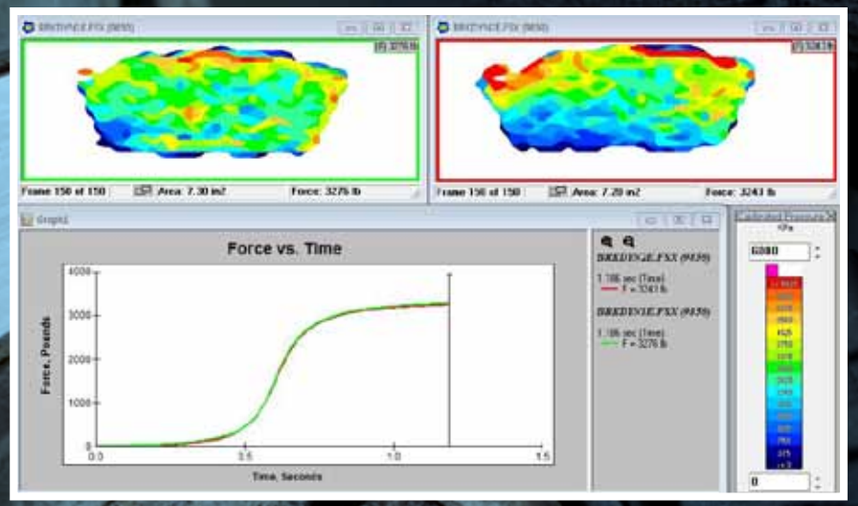


Figure 1: Difference in Pressure Pattern of Inboard (Piston Side) and Outboard (Finger Side) of Brake Pad Showing Flexing of Both Pads

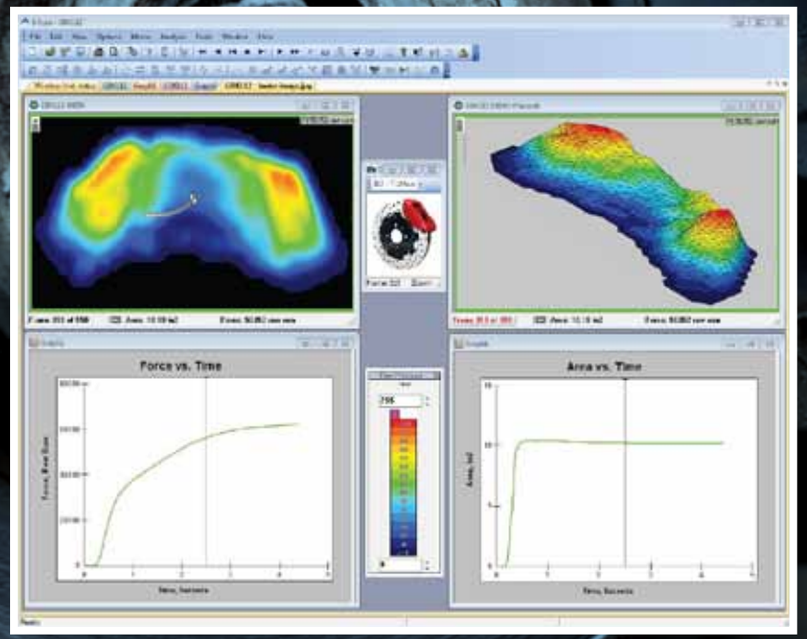
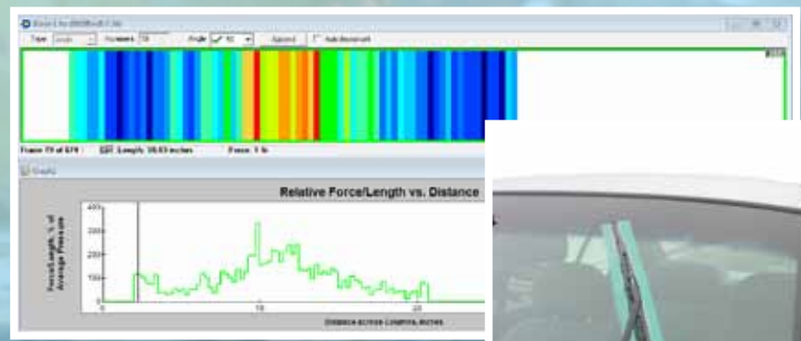
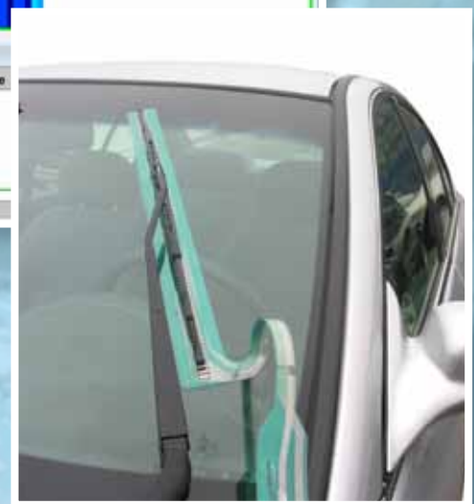


Figure 2: Analyze Peak Pressures and Center of Force Trajectory



Force Output Measured: Wiper Blade at 50° Angle on Windshield Output Displayed Graphically: Force vs. Distance Across Sensor Rows



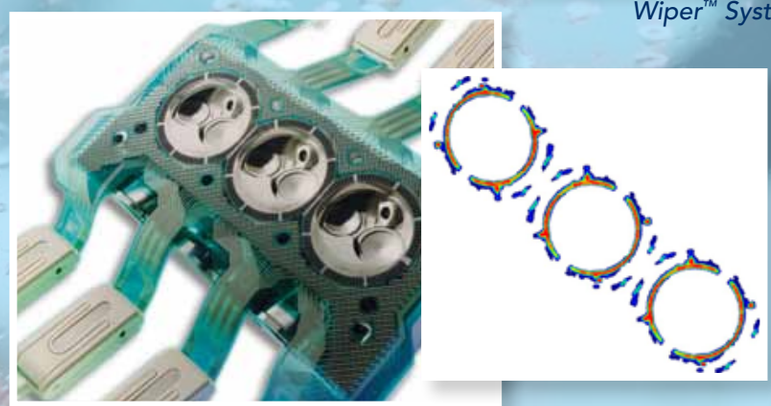
Wiper™ System

Windshield Wiper

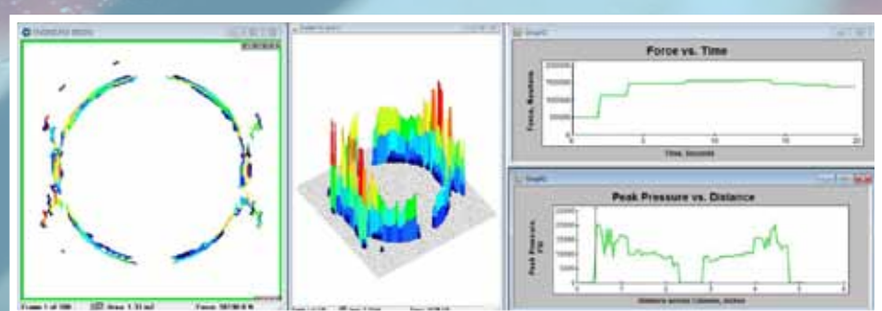
Designing a windshield wiper system that effectively cleans a windshield is not an easy task, given the constraints. The combination of different blade lengths, durometers, low and uneven pressures, and varying windshield contours combine to make this a complicated material and dynamics problem.

A pressure mapping system can measure the force distribution along the entire length of a wiper blade at different positions on the windshield. The system collects and consolidates static measurements at the different angles to capture the full wiper cycle. Dynamic measurements can be taken in wind tunnel studies to evaluate the impact of "lift-off" on the blade pressure distribution.

Measuring blade-to-windshield interface force profiles under various testing conditions provides key insight to improve blade design and wiper system performance.



Engine Gasket Pressure Measurement



2D and 3D Pressure Output of Single Gasket Head Shown Graphically as Functions of Force vs. Time and Pressure vs. Distance. Extremely High and Low Pressures Exist, which may Yield an Uneven Seal.

Engine Gasket

An important factor in maximizing the efficiency of an engine is making sure the combustion opening is properly sealed through the entire combustion cycle. Decisions need to be made about the block and head structure, fasteners, lubricants, torque, torque sequence, and gasket design. Pressure mapping sensors can be inserted into and around the various engine gaskets, seals, and fasteners, to measure the dynamic pressure distribution at these locations.

A pressure mapping system provides valuable data to assist designers and FEA modelers who make decisions about these components. It can be used for tests such as validating engine assembly techniques and "motoring" the engine, to characterize the seal pressure changes that occur due to vibration, cylinder pressurization, and torque. Since the system can record over time, the data reflected shows the pressure distribution of components in their relaxed state, not just the peak pressure reached during assembly tightening.

Fuel Cell Stack Assembly

In a fuel cell, numerous thin plates are stacked in close proximity to separate the flows of hydrogen or hydrocarbons and oxygen. Maintaining and improving contact pressure uniformity over the large area between these plates is an important factor in the design and performance of fuel cells. Eliminating parasitic leakage paths is essential to obtaining efficient operation.

In addition to proper stacking pressure, applied clamping torque may also affect contact pressure distribution within a fuel cell. Engineers can use a pressure measurement system to optimize the clamping design of fuel cells. Dynamic measurement allows researchers to obtain real-time feedback while adjusting clamps, which greatly simplifies optimization of parameters.

The *Figure 1* shows a drop off in pressure towards the middle of the plate, with standard clamping. Although more costly to implement, the reinforced clamp, *Figure 2*, is a better solution, with an improved distribution of pressure across the plate face.

Tactile pressure measurement offers fuel cell manufacturers tremendous insight into the behavior of components and assembly alternatives.

The data allows for direct comparison of the pressure patterns from different designs, thus saving time in design verification and re-engineering costs.

Fuel Cell Stack

Difference in Pressure Pattern of Inboard (Piston Side) and Outboard (Finger Side) of Brake Pad Showing Flexing of Both Pads

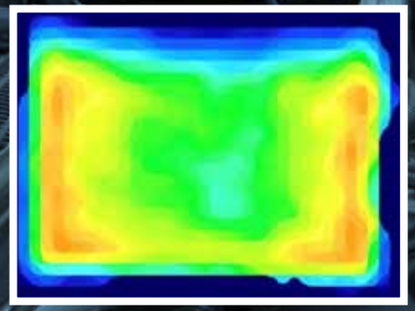


Figure 1: Standard Clamp

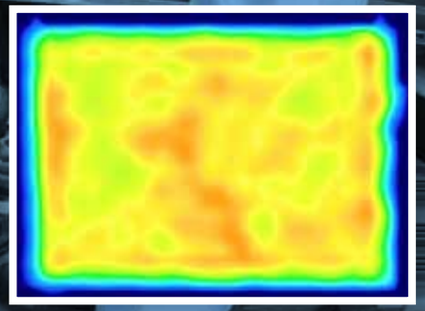
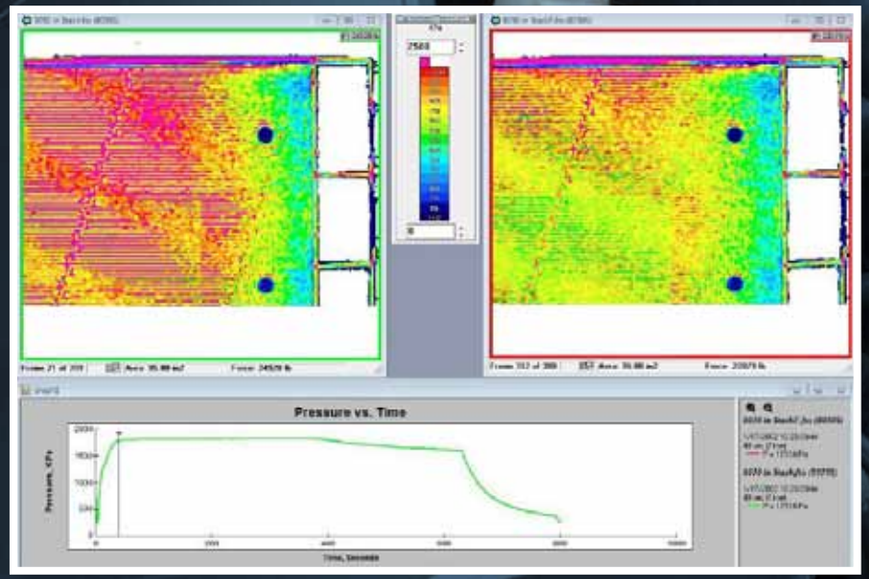
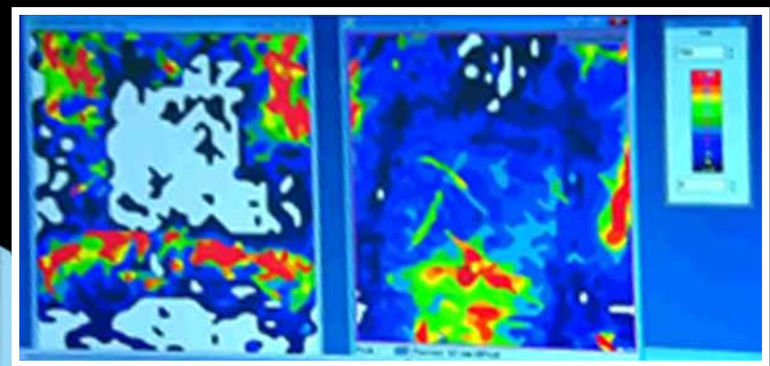
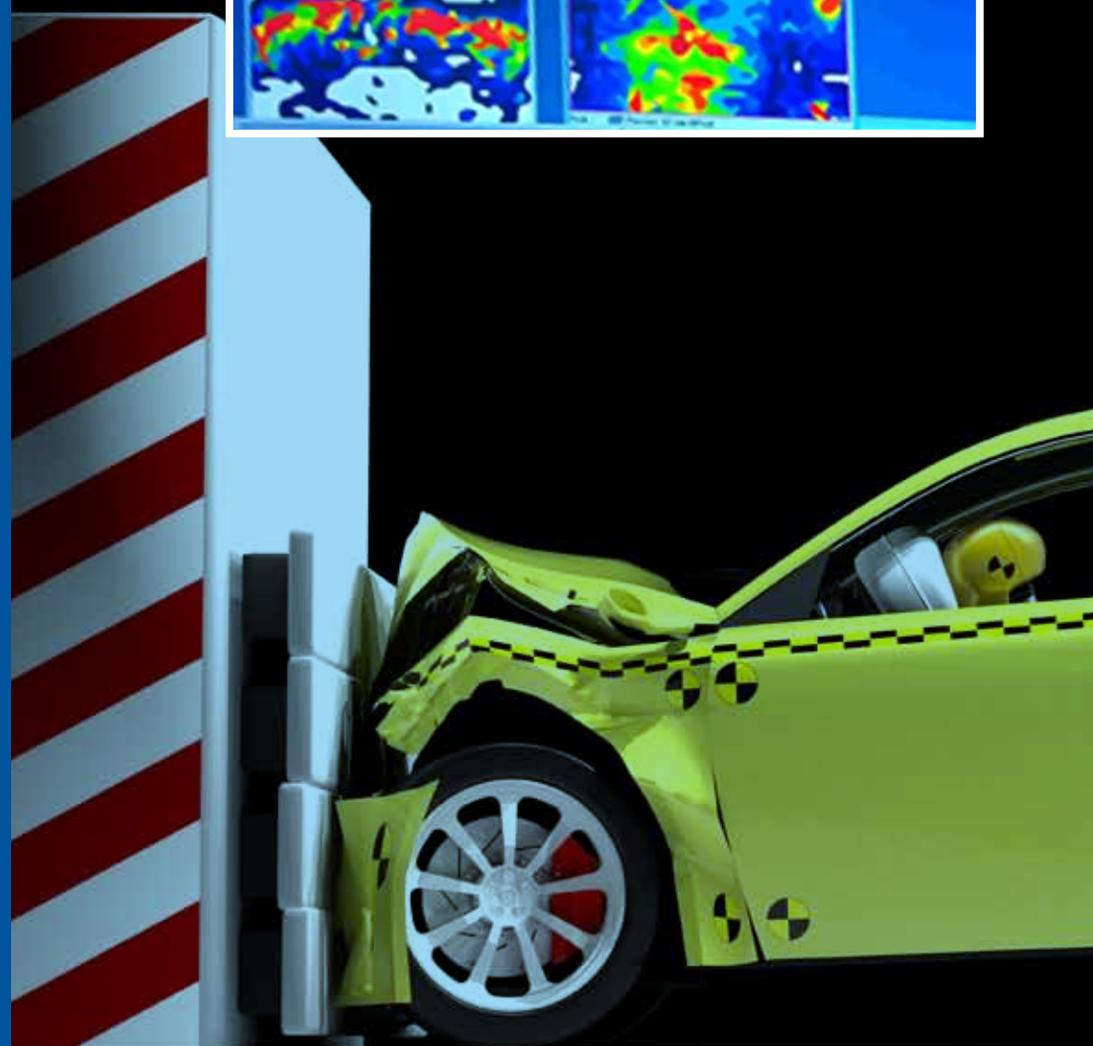


Figure 2: Reinforced Clamp



Pressure Around Ports and in Flow-Field Before and After Pressurization



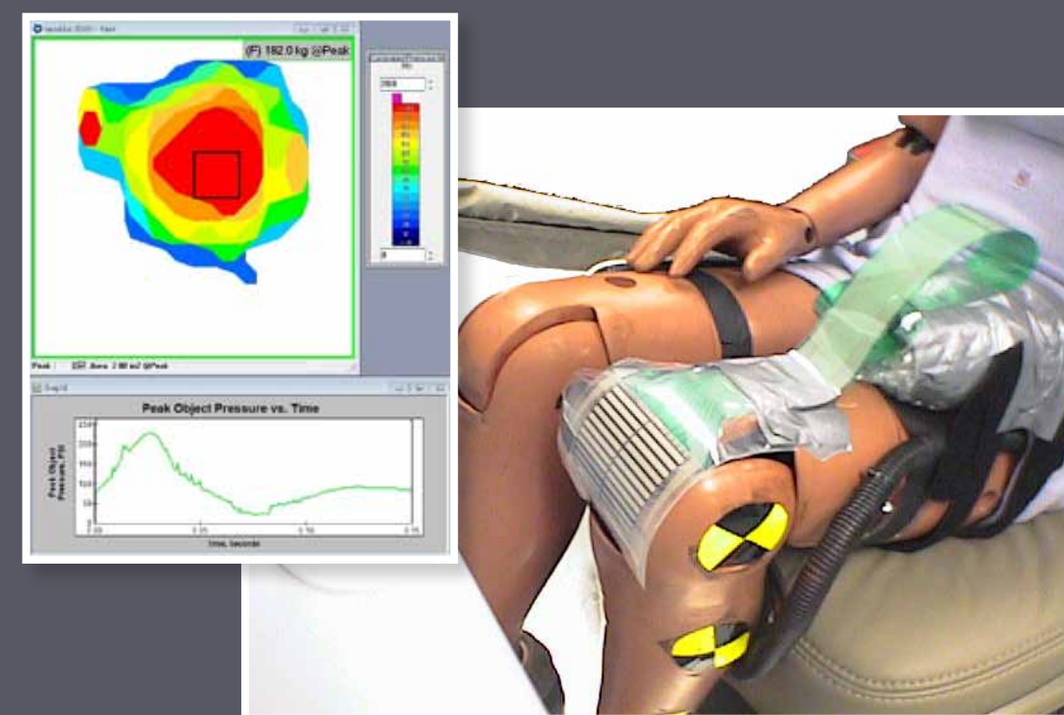


Crash / Impact Evaluation

Crash Test Dummy / High Speed Impact

Safety is certainly a major area of focus for auto manufacturers, suppliers, and research institutions alike. Among other concerns, issues with vehicle safety can also damage a manufacturer's reputation, significantly affecting business. A pressure mapping system can be used in crash test dummy studies to capture the dynamic pressure and force exerted during an impact.

The system can be used in other impact tests to identify the temporal, local, peak, and spatial pressure of two objects colliding. With scanning speeds of up to 20 kHz, even extremely rapid strikes can be recorded. The pressure distribution data can help optimize the design of various safety components, such as airbags, seatbelts, bumpers, and dashboards. Proper functionality in these areas is critical for designing safer cars and minimizing injury.



Output of Peak Pressure Exerted Upon a Crash Test Dummy's Knee During High-Speed Impact / Collision Testing

Other Application Examples

Seat Belt Design

Steering Wheel Ergonomics

Trunk & Door Slam / Seal Performance

Hose Crimp / Clamp Testing

Coil / Leaf Spring Design

Tire Bead Seat / Seal Evaluation

Conclusion

In a highly competitive automotive industry, design engineers and researchers need the right analysis tools to produce a more efficient and higher quality product.

Interface pressure measurement provides a better understanding of the relationship between two objects in contact, which can be critical to gaining a competitive edge.

Pressure mapping provides unique data and insight into a system or product's performance, helping automotive professionals validate their technology, improve processes, reduce costs, and enhance design and quality, for optimal results.

Visit ***www.tekscan.com/pm*** for more information on pressure mapping technology and products.

A Tekscan Pressure Mapping System is a versatile research toolkit for automotive professionals. With industry-specific sensors and software analysis tools, and high-speed, high-temperature, and wireless capabilities, it provides data you can't get anywhere else.

It's no coincidence automotive manufacturers, tier 1 suppliers, and research institutes worldwide use Tekscan Pressure Mapping Systems in various applications to improve their performance.

Tekscan™