Technical

Halobutyl inner liner is key to tire reliability

By Jeffrey Valentage
ExxonMobil Chemical Co.

Butyl rubber is a copolymer of isobutylene and about 2 percent isoprene, and it has a significantly lower vapor transmission to small molecule diffusants than other elastomers.

Butyl rubber was first used to produce tire tubes because of its excellent flexibility, fatigue resistance and improved air retention in comparison to natural rubber.

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Halogenation by either bromine or chlorine greatly extended the usefulness of butyl rubbers by significantly increasing curing rates. This enabled co-vulcanization with other general purpose rubbers used in the tire carcass without affecting the desirable impermeability and fatigue properties, a significant contribution to the development of a reliable tubeless tire.

Inner liner—The tire foundation

Today's tires are not just a simple commodity but a highly complex laminate construction of multiple components and chemically different materials that allow manufacturers to address the balance between performance, durability and efficiency for each specific tire model and application.

Regardless of the specific tire model, it is the job of the inner liner to contain the air once the tire has been mounted properly and inflated on the wheel. If the tire is unable to maintain optimal air inflation pressure reliably between service intervals, benefits from any performance improvements made can be reduced significantly and serviceability suffers.

Testing air retention

To test how well a tire holds air, the ASTM F1112 IPLR or inflation pressure loss rate test method is utilized, which measures the percentage of air loss per month.

This static test is conducted at 21°C (70°F) in a temperature-controlled room, with the tire inflated to 2.4 Bar or 35 psi, and can be completed in as few as 42 days. Great care has to be taken when mounting the tire and installing the valve stem to ensure a good seal to the rim, eliminating any possibility of air leaks.

ExxonMobil Chemical is a global butyl industry leader in testing IPLR and other tire related analytical capabilities. Even though the industry has an established and recognized testing standard for IPLR, only General Motors[1] and more recently Fiat Chrysler Automobiles have adopted and implemented a specification of 2.5 percent or less for all tires purchased.

Not all tires hold air the same—Importance of understanding the variation in air retention

Contrary to popular belief that "all tires hold air the same," there is a wide variation in air retention performance in tires.

Based on more than 300 commercially available passenger car radials (PCR) tested and analyzed by ExxonMobil since 1985, the amount of air loss per month varied from as low as 0.9 percent to more than 4 percent **(Fig. 3)**.

In-service pressure loss can be two to three times higher than static, while tires tested at typical operating temperatures of 60°C (140°F) can have air pressure loss seven to nine times higher.

Executive summary

When it comes to tires, consumers want longer tread life, a smooth and quiet ride, fuel economy and consistent performance. All of these traits are hallmarks of a tire that maintains optimal air pressure, or simply stated—keeps the air in the tires.

Today's tires are a complex piece of construction, and regardless of the tire model, it's the job of the inner liner to contain the air in the tire. There is a wide variation in air retention performance among tires, but in all types of tires, it is concluded that the key parameters driving air retention properties in the inner liner are halobutyl content, gauge and tire operating temperature.

As regulations continue to change and progress, the goal of any new standard or regulation should be to drive consistent and reliable performance and efficiency improvements over the life of a tire. However, without including an inflation pressure loss rate specification maximum, the performance characteristics shown on any label or minimal standard guideline is unlikely to reflect a consumer's real world results.

A simple and effective solution to maintaining consistent tire performance efficiency is by improving air retention of the tire, and there is proven and readily available technology with which to accomplish this critical trait of a tire. By increasing halobutyl content and optimizing the inner liner gauge, air retention can be improved significantly without sacrificing any other tire performance attribute.

ExxonMobil also has extended its global tire studies to include truck and bus radials (TBR) 11R22.5 **(Fig 4)**. Based on 22 commercially available TBR tires, values ranged from 0.6 percent to 1.9 percent inflation pressure loss rate.

Regardless of the tire type, by analyzing the construction and composition along with testing inflation pressure loss rate, we can conclude that key parameters are driving air retention properties in the inner liner: halobutyl content, gauge and tire operating temperature.

The passenger car radial examples in **Fig. 5** show that composition is the main driver, as halobutyl content is increased, air loss per month is significantly reduced. Gauge or inner liner thickness also can affect air retention but to a lesser extent.

The combination provides manufacturers the tools to balance air retention, weight and total cost of the inner liner.

Based on our global tire studies, best-in-class passenger car radials have an inflation pressure loss rate of less than 1.5 percent per month, with an inner liner composition of 100 phr halobutyl content and a gauge of ~ 1mm.

Comparing the regional average inflation pressure loss rates for passenger car radials, the Americas had the lowest at 2.2 percent, Europe at 2.4 percent, Asia-Pacific region as a whole at 2.6 percent, and China had the highest average at 2.8 percent.

For truck and bus radials, best-in-class tires tested had an inflation pressure loss rate of less than 0.7 percent per month, with an inner liner composition of 100 phr halobutyl content and a

The author

Jeffrey Valentage has been involved in the automotive industry for more than 25 years.

He began his career as a process/project engineer and manufacturing manager at a major plastics molder that supplies a wide variety of interior and exterior automotive components.

Valentage joined ExxonMobil Chemical in 1997 and has served as an applications engineer, OEM account manager, global automotive business development manager and global automotive market planner, covering the broad spectrum of polymers ExxonMobil Chemical supplies to the automotive industry.

Valentage

In his current role as global tire market development manager, butyl, Valentage focuses on advancing halobutyl inner liner developments to improve tire air retention.

Maintaining proper inflation pressure helps retain consistent and reliable performance and efficiency over the life of the tire, he said, improves tire durability and reduces maintenance requirements.

Valentage holds a bachelor's degree from the University of Phoenix. He has presented several times at the Society of Plastics Engineers; Society of Automotive Engineers; and other technical conferences on a variety of topics. He also has served as an SPE chairman.

Fig. 1. Example cutaway showing the multiple components of a typical tire.

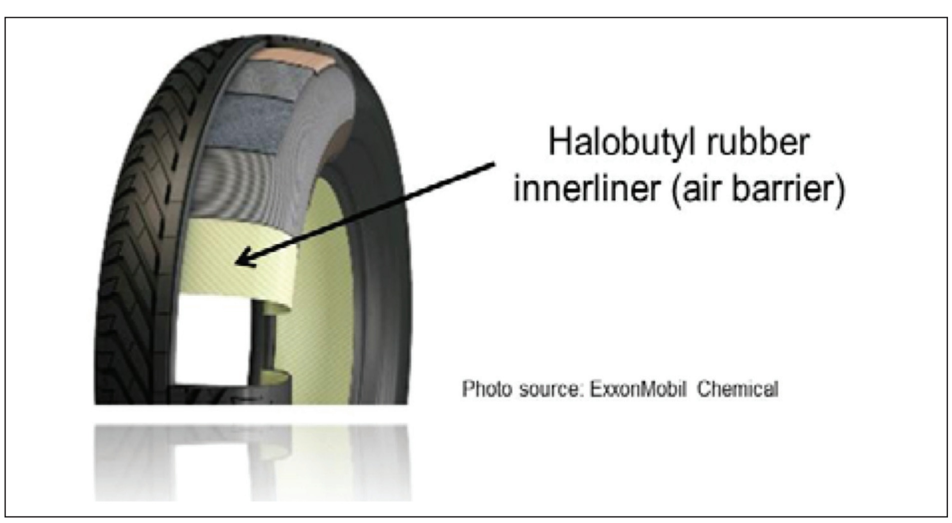


Fig. 2. Tire being tested at ExxonMobil's facility in Baytown, Texas.

Fig. 3. Commercially available PCR tires tested for IPLR

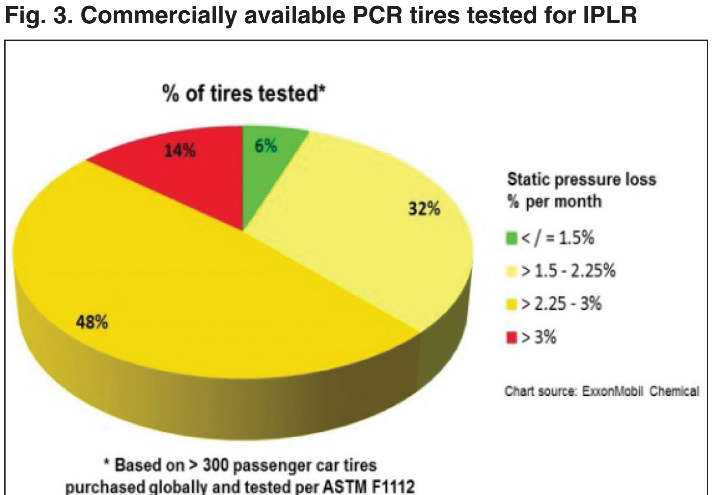
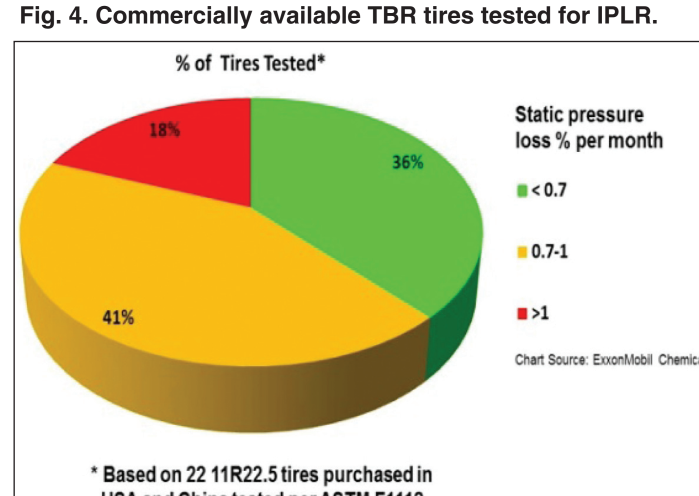


Fig. 4. Commercially available TBR tires tested for IPLR.



gauge of ~ 2mm.

Comparing truck and bus radials purchased in the U.S. and China, all tires manufactured in the Americas and Thailand had </= 0.9 percent inflation pressure loss rates, while tires manufactured in China had the widest range and inflation pressure loss, rates as high as 1.9 percent.

If we take into account the significant amount of tires that have higher inflation pressure loss rates than best-in-class tires tested **(Figs. 3 and 4)**, the industry as a whole has significant room for improving air pressure retention.

Importance of improved air retention—efficiency

Original equipment manufacturers globally are demanding lower rolling resistance tires to help meet ever more stringent fuel economy requirements and environmental concerns. Lower rolling resistant tires have become a popular OE choice since they potentially can provide a 1-2 percent improvement in vehicle fuel efficiency.

The optimal or ideal conditions are used, though, when testing and certifying new vehicles for fuel efficiency, including tire inflation pressure. The ideal testing environment, however, doesn't necessarily reflect real world conditions and results for consumers.

Recent studies conducted by Rubber Manufacturers Association and European Tyre and Rubber Manufacturers Association found that ~ 69 percent of U.S. and ~ 80 percent of EU passenger vehicles were running on underinflated tires (www.RMA.org and www.ETRMA.gov), negating any efficiency improvement that may have been gained.

These and other studies highlight an important issue. In general, tires are not being maintained properly even with continued attempts to promote awareness and educate consumers on the importance of proper tire maintenance.

How does air loss affect efficiency? As air is lost over time, the footprint or contact patch of the tire increases from its optimal design. Larger footprint equals more surface area in contact with the road, increasing rolling resistance **(Fig. 6)**.

By improving air retention of the inner liner, the optimal contact patch can be maintained consistently between vehicle service intervals, maintaining tire rolling resistance and efficiency. A 10 percent increase in rolling resistance can decrease fuel efficiency by 1-2 percent (www.epa.org).

Labeling

Many countries now require a label to provide consumers an easy way to compare key performance parameters such as wet grip, fuel efficiency, wear and noise. All of the testing for the labeling, though, is done at optimal tire inflation pressure, and consumers are unlikely aware that performance can decline significantly as air pressure is lost.

Without including an inflation pressure loss rate specification maximum on the label, the performance characteristics shown may not reflect a consumer's real world results.

Air retention and tire durability

Inner liners that contain the air more effectively not only improve efficiency but also contribute to improved tire durability. As air permeates through the inner liner and into the tire carcass, oxygen can start to degrade the rubber around the steel belts and pressure can build up over time, both of which contribute to belt separation **(Fig 8)**.

Premature tire failure can be accelerated further by additional heat generated because of non-optimal inflation pressures and extended periods of running under-inflated **(Fig 9)**.

In the examples shown, durability decreased more than 45 percent and belt area cracking increased ~ 40 times from a best-in-class to an industry average inflation pressure loss rate. Reducing the permeability of the inner liner by increasing the halobutyl content is the most effective way to minimize oxygen migration and pressure build-up in the tire carcass.

Air retention and wear

As previously discussed, if optimal air pressure is not maintained consistently, the designed footprint of the tire cannot be maintained.

In an over-inflated condition, there is greater pressure on the treads in the center (or crown) of the tire, and in an under-inflated condition, there is more pressure on the shoulders **(Fig. 10).**

In either condition the treads will wear unevenly, significantly reducing the useful life of the tire. The reduction in tire life because of uneven treadwear can be from 10-50 percent[2] depending on the inflation pressure conditions over the life of the tire.

TPMS and extended vehicle service intervals

With the addition of TPMS, or tire pressure monitoring systems, and extended service intervals, maintaining optimal air inflation pressure has become even more critical. TPMS, which in the U.S. has been mandated by law (TREAD Act of 2000), provides the vehicle driver with a warning when air inflation pressure reaches a critical minimum (25 percent under-inflation).

Consumers are relying on the warning light to give them an indication to check their tires along with a "quick visual" and the more common "kicking the tire" inspection method, instead of checking the actual pressure.

The photos **(Fig. 11)** show that it is very difficult to tell visually whether a tire is under-inflated, and with today's stiffer sidewalls, kicking the tire is simply not very affective.

With OEMs continuing to extend time between vehicle service intervals to improve customer experience and satisfaction, tires will need to maintain optimal air inflation pressure for longer periods of time.

Fig. 5. IPLR as a function of bromobutyl content and gauge.

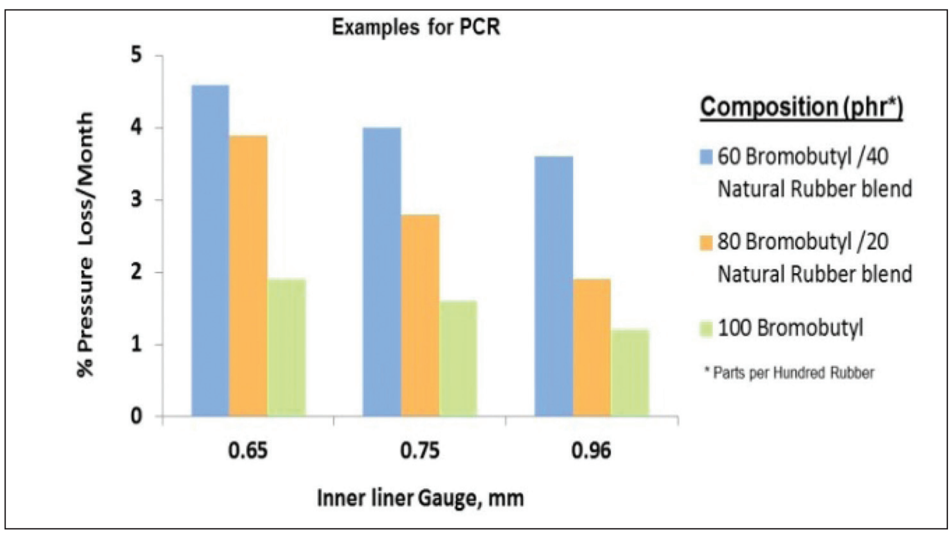
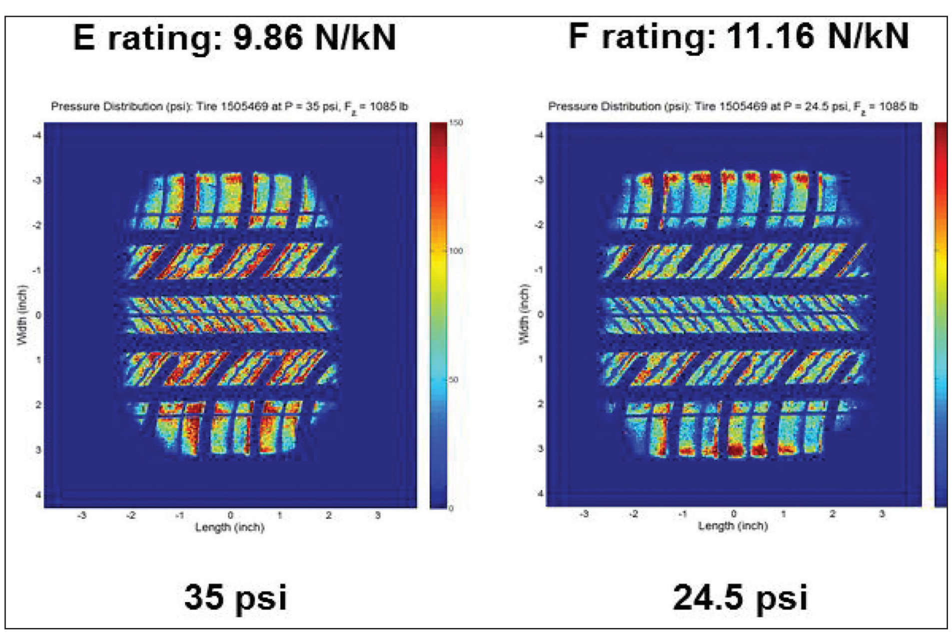


Fig.6. Change in tire footprint as air pressure is lost and increased rolling resistance.



Higher pressure tires and secondary maintenance systems

Another growing trend is to utilize tall/narrow ultra-low rolling resistance tires. These tires typically need to operate at increased tire pressures though, greater than 45 versus 35 psi.

The higher pressure requirements of these types of tires also will require an improved inner liner to maintain the advertised efficiency improvements. In the early stages of introduction on limited vehicles, it is too early to tell whether this unique style of tire/wheel combination will gain wider industry and consumer acceptance.

Automatic inflation systems have been introduced as a potential solution to the tire maintenance issue. However, these systems would add additional weight, cost and complexity in an industry that continuously looks for ways to minimize weight, reduce component count and reduce costs.

The simple solution is to build a better inner liner into the tire, eliminating the need to add additional systems to the vehicle and reducing maintenance frequency for owners.

New regulations

The recently passed FAST or Fix Americas Surface Transportation ACT of 2015 includes a mandate to set minimal tire performance standards for efficiency (rolling resistance) and wet traction. China continues to progress tire label regulations with compulsory compliance targeted for some time in 2019.

These new and current regulations are intended to simplify the purchasing

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Fig. 7. Example of EU tire label.

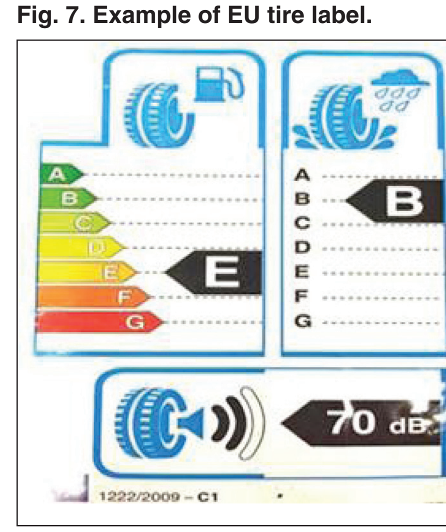

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Fig. 8: Endurance testing of PCR tire with increasing inflation pressure loss rates.

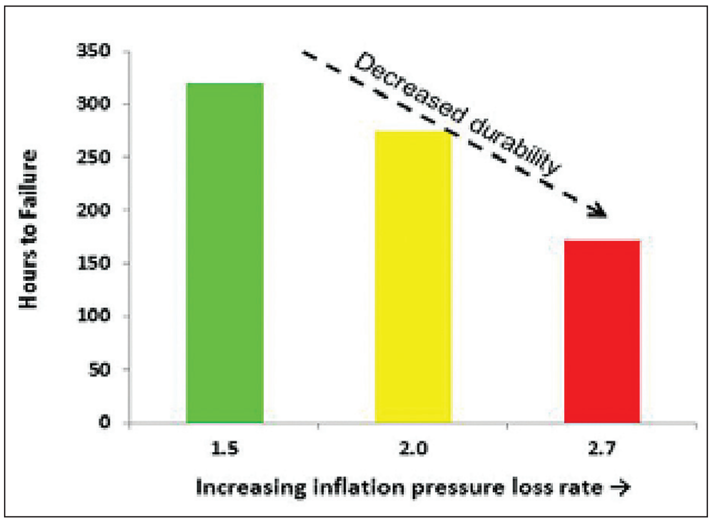
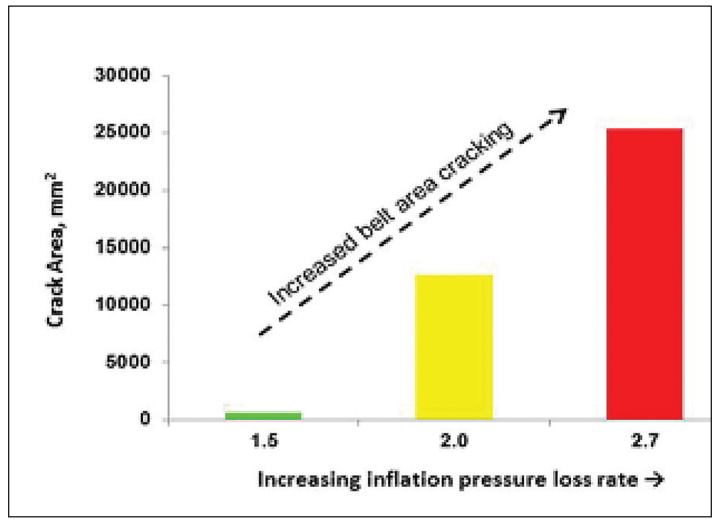


Fig. 9: Sheargraphy of PCR tires with increasing inflation pressure loss rates.



Liner

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process for consumers, reduce vehicle fuel consumption and ultimately drive improved tire performance and quality. However, without including an inflation pressure loss rate specification maximum, the performance characteristics shown on any label or minimal standard guideline is unlikely to reflect a consumer's real world results.

The goal of any new standard or regulation should be to drive consistent and reliable performance-efficiency improvements over the life of a tire. Utilizing currently available technology and materials, the tire industry has the potential to achieve global specifications for inflation pressure loss rates of less than 2 percent for all passenger car and 0.7 percent for truck and bus radials.

This would be a significant step forward in reliably maintaining current and future radial tire performance efficiency improvements, while also improving end user satisfaction. By improving the air retention of the global tire fleet vehicle fuel consumption could be reduced by up to 1B gallons and CO_2 emissions reduced by greater than 600 million tons annually (ExxonMobil Chemical estimate).

Summary

We drive our tires, not our vehicle. The vehicle's ability to perform as designed is greatly influenced by how well the tires manage and transfer the energy to the road surface. A simple and effective solution to maintaining consistent vehicle and tire performance-efficiency is by improving air retention of the tire, a proven and readily available technology today.

By increasing halobutyl content to 100 phr and optimizing the inner liner gauge, air retention can be significantly and cost effectively improved. Better air retention doesn't require the sacrifice of other tire performance attributes, a common tradeoff when reducing rolling resistance.

No additional or special equipment is needed in the vehicle. Maintaining proper inflation pressure helps retain consistent and reliable performance and efficiency over the life of the tire, improves tire durability and reduces maintenance requirements.

ExxonMobil Chemical butyl business—Pioneering technology

ExxonMobil Chemical invented and patented butyl rubber in 1937. The motivation to develop a better, less costly synthetic rubber came from a surge in automotive production in the 1920s and 1930s, which generated high demand for tires and inner tubes.

Compared to natural rubber, the material used at the time, butyl rubber improved the ability to hold air, flex and dampen vibration. As a result, it soon became the leading material for inner tubes and—some 20 years later in the 1950s—halogenated butyl helped enable the development of reliable tubeless tires.

Over the last 75 years, ExxonMobil has pioneered air barrier technology, helped drive tire industry growth through butyl product and process innovations, increased supply security through continued capacity investments to meet growing industry demand and providing our customers industry leading expertise and market analysis.

ExxonMobil Chemical is continuing to provide long-term butyl industry leadership by leading through commitment.

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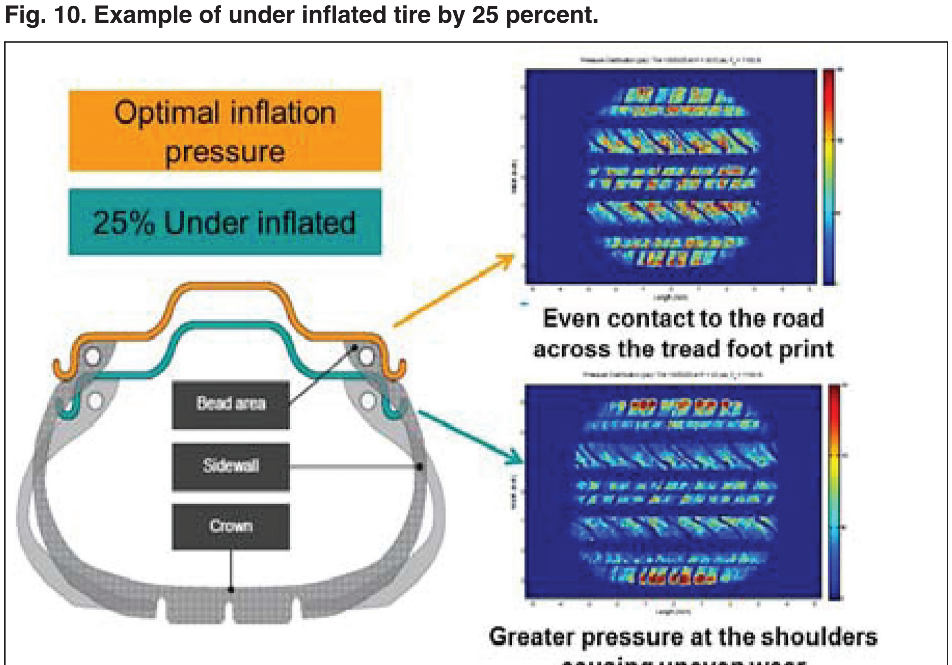
—"Global Automotive and tire industry trends, product solutions," Jeff Valentage, International Rubber Conference, RubberCon, Chennai, India, Dec. 3, 2015.

1. TPC (Tire Performance Criteria) SPEC 1156 M+S (all season tires) and TPC SPEC 1156 (non all season tires), IPLR < 2.5 percent by ASTM F1112.
2. Data sources for percent under-inflation: www.Safecar.gov, www.discounttire.com, www.michelin.com, www.coopertires.com, www.cars.com, 2014 ETRMA Tire Report.

Fig 11. Example of a tire at 100 percent and 75 percent optimal inflation pressure.

Fig. 10. Example of under inflated tire by 25 percent.



Products

Nerpco USA L.L.C. has unveiled its NM-38 (1 pound, 0.62 liter) batch mixer, which follows the same design as the NM-100 (3-pound batch) and the NM-270 (7-pound batch) mixers.

All of Nerpco's mixers utilize hydraulic drives, the company said, which result in variable bi-directional rotor speeds from zero to their maximum. Nerpo said the NM-38 has a chrome-plated drilled body with a hinged discharge side, chrome-plated Viscoseals (dust stops), stainless steel hopper, a lubrication system with pressurized oil, temperature control, 25 micron filtration to the anti-friction spherical roller bearings and connecting gears.

Nerpco claims it reduces the cost of operating a laboratory by thousands of dollars. The Nerpco Mixer line covers a range of 1 to 285 pound batches.

For more information, visit www.nerpcousa.com.

WSF Industries' SmartClave control system mounted on a horizontal autoclave.

WSF Industries Inc. has introduced its SmartClave technology for the company's autoclave control systems. WSF said the system eliminates the need for separate digital process controllers and integrates a programmable logic controller and touch-screen display with an messaging system to assist operators in all phases of autoclave operation.

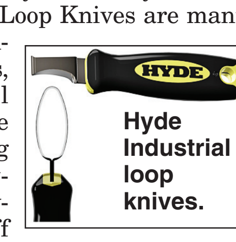
The SmartClave is scalable to meet any autoclave application, WSF claimed, as it can provide fully automated process control and material handling or be programmed to control simple autoclave door closure. SmartClave is supplied standard on all new WSF autoclaves and can be retrofitted to existing WSF autoclaves in the field, the company said

According to WSF, SmartClave offers messaging throughout the autoclave closure and process operation as well as system integration with operator assist, diagnostic, maintenance and alarm features. The technology provides enhanced autoclave door closure and process safety interlocking by monitoring all sensors, operating switches and output devices, the company said.

For more information, visit www.wsf-inc.com.

Hyde Industrial Blade Solutions has unveiled loop knives designed to remove flash waste and excess material from molded or extruded rubber and plastic parts quickly and safely.

The Hyde IBS Loop Knives are manufactured with high-carbon steel blades, Hyde Industrial said, for longer edge sharpness and long life when removing flash from anything coming off production lines.



Hyde Industrial loop knives.

Each Hyde Loop Hoof Knife is 6.5 inches and features a pick for hard-to-remove imperfections, the company said. In addition, the blades have a 0.515 inch diameter and 1.3 inch long cutting edge, Hyde Industrial said, and are mounted to a molded handle made of a polypropylene core and thermoplastic elastomer soft grip covering to absorb shock.

For more information, visit www.hydeblades.com.