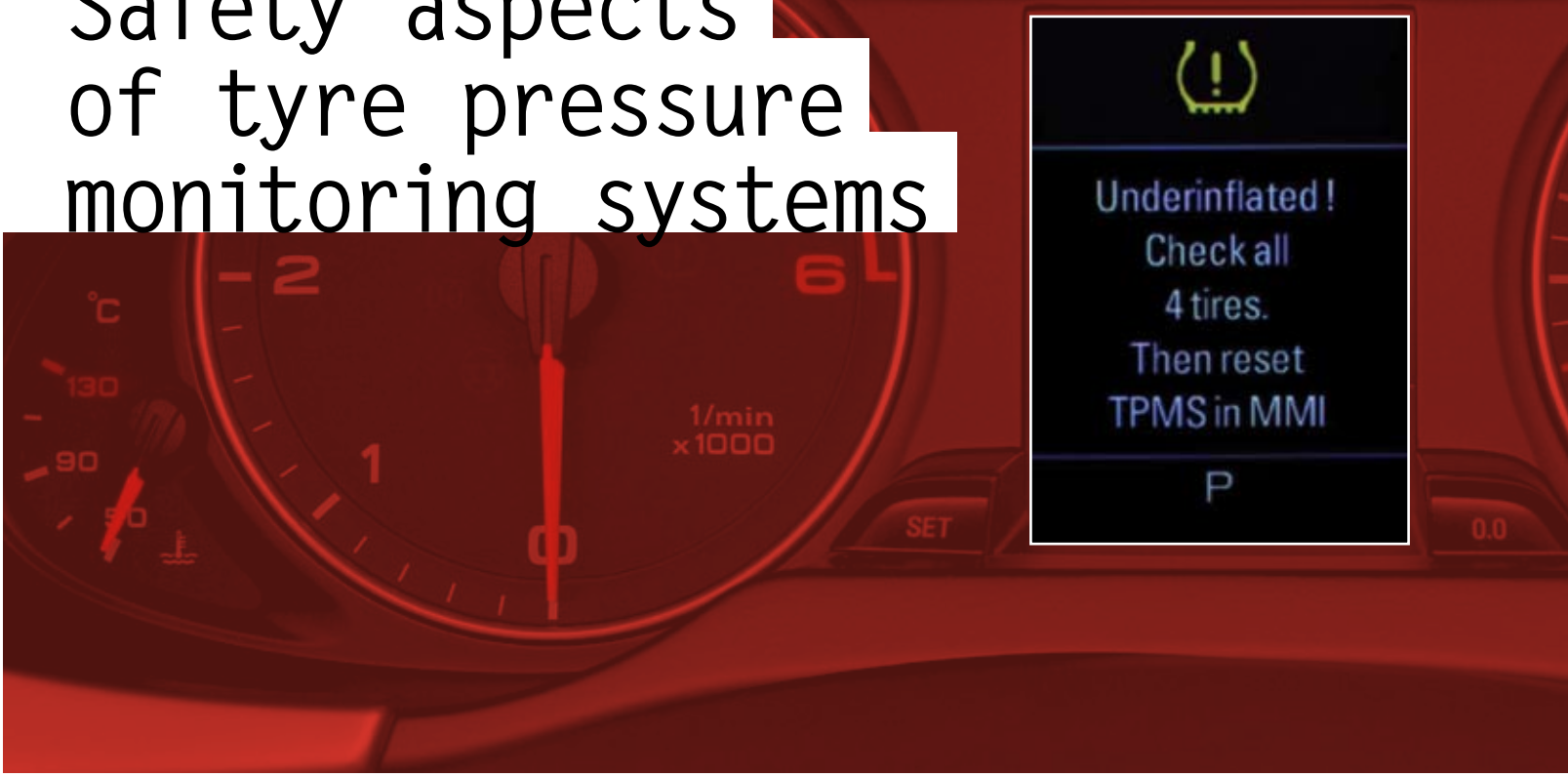
Despite growing awareness about having the right inflation pressures, many people still drive around with dangerously underinflated tyres. But technology is playing a valuable supervisory role

Safety aspects of tyre pressure monitoring systems



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The strong focus on safety aspects in the automotive industry has led to an increased interest in tyre pressure monitoring systems (TPMS) as a means to help drivers maintain correct tyre pressures and reduce the risk of tyre-related accidents.

Despite the fact that most drivers know that having correct pressures is important, different studies have shown that many vehicles still run with underinflated tyres. A study from Sweden, for instance, provides a perfect example, and showed that 20% of the checked vehicles had tyres that were underinflated by 20% or more. The survey results have been mirrored in other countries.

TPMS will not prevent 100% of all tyre failures and do not automatically control the tyre pressures to the correct level. However, they can provide early warnings if one or more of the tyres loses air, and also help the driver to maintain the correct tyre pressure level in all tyres. The first point may sound trivial but in practice many drivers do not themselves notice underinflation. Indeed, if you are not an expert, this can be very difficult to determine through visual inspection.

Legislation and technology

The USA is currently the only country with a mandatory TPMS requirement. The link between poor maintenance of tyres and increased safety risks was noted in the so-called TREAD Act (Transportation Recall Enhancement Accountability, and Documentation Act), enacted by the US Congress in 2000. The conjecture was that mandatory fitment of TPMS to all vehicles will have a clear positive impact on vehicle safety. The practical consequence of this was the introduction of the FMVSS 138 rule, in effect since 1 September 2007, which requires that all passenger cars, light trucks and SUVs sold in the USA should be equipped with a TPMS that meets all of the performance standards specified in the rule.

In the European Community, a TPMS rule similar to the US FMVSS 138 rule is currently being discussed. It is expected that mandatory requirements for TPMS will be in effect in three to four years for this region, although as well as safety a main driver in Europe is CO_2 reduction. A Chinese TPMS standard is also being drafted, but it is not currently clear if this will result in mandatory requirements for TPMS.

Two main types of TPMS can be identified – direct TPMS and indirect TPMS. Direct TMPS refers to hardware-based systems relying on direct pressure measurements using pressure sensors mounted inside the

tyres. Indirect TPMS, meanwhile, are software-based systems inferring pressure-related information from measurements of other physical signals, such as the wheel speed signals.

The main advantage of direct TPMS is that they measure the pressures (and temperatures) within the tyres and can therefore issue warnings when the pressure in any of the tyres drops below the desired warning level. High-end direct TPMS can also point out the underinflated tyre(s) and display pressure information on the vehicle dashboard. There are disadvantages of direct TPMS, however, including the complex system design and high costs. Firstly, the complex system design drives considerable production costs, as well as costs for spare parts and logistics. Secondly, service and maintenance costs can be substantial due to the need to replace the wheel-mounted sensor components when batteries wear out. Additionally, given the very harsh environment in which the tyres have to operate – with extreme mechanical stresses of up to several thousand *g* and temperature variations of up to 200°C – their error-proneness can also be problematic.

Indirect TPMS are robust, cost-effective systems that rely on existing sensors from other systems in the vehicle, such as ABS/ESC, and because they are realised in software they require no maintenance and do not generate any service or quality costs for the driver – or for that matter for the vehicle manufacturer throughout the service life of the vehicle. Despite this, a disadvantage is that they cannot display the absolute pressure levels in the tyres – they can only warn if the pressure in one or more tyres is too low.

A common misconception regarding indirect TPMS is that they cannot detect simultaneous pressure drops in more than one tyre. This is true for some basic indirect TPMS, but not for NIRA Dynamics' advanced indirect TPMS, known as TPI.

Indirect TPMS

By applying state-of-the-art signal processing and sensor data fusion techniques to the tyre pressure monitoring problem, Sweden's NIRA Dynamics has developed an advanced indirect TPMS capable of detecting underinflation in one, two, three and four tyres simultaneously, while also meeting the FMVSS 138 requirements applicable for the US market. TPI can also point out the underinflated tyre(s), which simplifies the maintenance tasks, thereby adding value.

TPI was first launched on the Audi TT in 2006 and since 2007 has also been used in the Audi A4/A5 models. The first car equipped with TPI to be launched in the USA will be the 2009 model Audi A6. In the course of the next two to three years, all Audi models and further VW models will adopt this technology, while comprehensive development programs with other OEMs targeting both the European and North American markets are also under way. This marks a breakthrough for TPI and for advanced indirect TPMS in general.

NIRA Dynamics' TPI tyre pressure monitoring system has been used to great effect by Audi

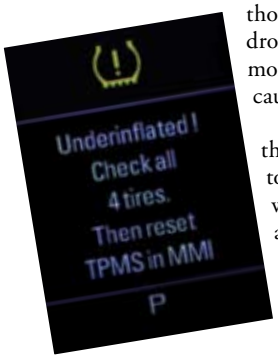
Safety aspects of TPMS

When discussing safety aspects of TPMS, it is important to concentrate on the performance requirements and not mix this up with other requirements stemming from certain features of a specific technology – e.g. direct or indirect. Furthermore, the starting point for discussions regarding performance requirements should be the physics of real-world pressure-drop scenarios, not technology features or unrealistic theoretical scenarios that never occur in practice.

In real life, three typical pressure-drop scenarios can be identified,

Indirect TPMS has the added advantage that it is much cheaper to implement and can be introduced more quickly onto new vehicles

"TPI REACTS VERY QUICKLY IN CASE OF TYRE LEAKS AND OTHER RAPID PRESSURE-DROP SCENARIOS"



TPMS can warn drivers that their vehicle has an underinflated tyre (or tyres) despite the appearance suggesting otherwise

including blowouts, leaks and diffusion. Blowouts refer to the rapid (instantaneous) and complete pressure drop due to terminal tyre fault, while leaks cover fast leaks resulting from punctures, non-tight seals between tyre and rim, or leaking valves. Diffusion, though, results from slow pressure drop due to natural diffusion of air molecules through the rubber, or caused by small leaks (e.g. the valve).

TPMS cannot enhance safety in the case of a blowout as they occur too fast to be detected – besides which, you tend to notice a blowout anyway! The relevant scope for TPMS is therefore detection of leaks and diffusion.

For leaks, the main safety requirement on the TPMS is quick detection of the pressure loss. The actual detection level – i.e. the warning threshold – is not critical. The main point is that the system should detect the pressure drop quickly enough to avoid really dangerous situations that can occur with substantially underinflated tyres – loss of braking and handling performance, tyre/rim separations, thread separation, and other terminal structural damages. Secondly, leaks or punctures can appear on one tyre and sometimes on two – for instance, both tyres on one side or on one axle, but only very rarely on three or four tyres simultaneously. Hence, quick and accurate detection of leaks in one or two tyres is a relevant safety requirement on the TPMS, whereas quick leak detection in three and four tyres will not result in increased safety.

In relation to diffusion, the TPMS must be able to detect underinflation in all four tyres. In fact, this is the main requirement for this scenario, given that the diffusion phenomenon occurs in all pneumatic tyres and normally at the same rates in all four tyres. In some rare cases, you can see diffusion in a subset of the tyres – for instance, if the car was parked with some tyres always in the sun and some always in the shade, or if some of the valves are leaking. Another key requirement on the TPMS in case of diffusion is the detection accuracy, as it is well known that driving too long with even a small underinflation can lead to heat build-up, which can result in severe tyre damages (e.g. the background research conducted for the TREAD Act). On the flipside, diffusion is always very slow, by definition, so its quick detection does not provide any safety increase as long as the detection time is short compared to the rate of change of the tyre pressure.

Safety benefits of TPI

TPI is an advanced indirect TPMS capable of detecting underinflation in one, two, three and four tyres. Due to its design, it also reacts very quickly in case of leaks and other rapid pressure-drop scenarios and can simultaneously and accurately track and detect slow pressure drops caused by diffusion.

Resulting from its operating principles (it is a software-based system), TPI will continue to be active and available over the service life of the vehicle. Furthermore, it cannot easily be deactivated or deinstalled from the vehicle, unlike direct TPMS which can be by removing the wheel electronics or by omitting to replace the batteries in them when they wear out. Because of its simple, robust software-based design TPI will also not generate any quality or service costs throughout the service life of the vehicle, while the overall customer acceptance for the system can therefore be expected to be high. Looking over whole fleets of vehicles, TPI will for these reasons provide significant help for reducing the number of tyre-related incidents and accidents when more widely spread in the future, unmatched by any alternative technology available on the market today.

An advanced indirect TPMS, TPI offers clear advantages in terms of lower costs, minimised service needs, and increased safety compared to other existing TPMS technologies. Indeed, TPI is a preferred solution for many customers and the market share for this system and other advanced indirect TPMS is expected to grow rapidly over the coming years. ❮

Author's Q&A

URBAN FORSSELL

Should there be more stringent enforcement of tyre condition?

We welcome safety regulations for TPMS, such as the American FMVSS 138. But we think it is important to view the TPMS as one integrated system or component in the vehicle together with the tyres and other related systems and components, and to apply an holistic and technology-neutral approach when discussing both safety benefits and risks associated with this technology. In the end, it is the vehicle as a whole that needs to be safe.

Do you think the tyre as a causation of accidents is underestimated?

The risk for tyre-related accidents is sometimes overestimated, and there were intense debates before the final FMVSS 138 rule was published. I remember listening to a keynote address by the former NHTSA Administrator, Dr Runge, at the 2004 SAE Government Industry Meeting in Washington where he stated that TPMS have a clear positive effect on safety but that much more significant gains can be made through reduction of the number of people that drive under the influence of alcohol or drugs, that do not use seatbelts, and mandatory requirements for ESC which have proven to give significantly reduced accident rates in many different studies.

Can you imagine what the car will be like in 20 years?

We will see more electrified powertrains, battery- and maybe fuel cell-powered electric and different kinds of hybrid powertrains, but in general the vehicles in 20 years will be similar to today's vehicles. And I'll put my money on the fact we will still have pneumatic tyres in 20 years…