Tyre Pressure Monitoring For Commercial Vehicles

A review of commercial implications and available technologies
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Executive summary

Poorly maintained tyre pressures are a world-wide problem with significant human, environmental and economic costs. The safety and environmental implications have led to legislation making tyre pressure monitoring systems compulsory on new cars in the USA, EU and elsewhere. The legislation does not currently extend to commercial vehicles in Europe but many of the same issues are involved with big financial implications.

The commercial benefits of effective tyre pressure monitoring systems are compelling and include:

- Fewer breakdowns
- Reduced fuel consumption
- Longer tyre life
- Lower maintenance costs
- Improved safety

Reduced disruption due to breakdowns and savings on fuel and tyres mean that tyre pressure monitoring can provide substantial commercial benefit for operators. Lower maintenance costs are achieved with less time spent on walk-around checks and timely warnings when attention is required. This means that the initial cost of a tyre pressure monitoring system can be recovered very quickly.

Technical innovations for the mass car market have led to reduced costs, and specialised products have been designed for the particular requirements of commercial and freight vehicle operators. These systems continuously monitor tyre pressures and warn drivers of tyre problems such as low pressure and falling pressure due to leakage or punctures. Some systems also measure tyre temperature and give warning of a potential blowout or tyre fire.

TyrePal provide a range of cost-effective systems for both private and commercial vehicles. A display in the cab gives information about all the tyres of the vehicle, and any abnormality sounds and displays an alert. Heavy duty systems for commercial fleets support multiple trailers and there are compact systems for vans and passenger car fleets.

The data from the tyre sensors can also be made available for vehicle builders or for specialised instrumentation, through a serial data node or through a CANbus module.
Tyre inflation, environment and the economy

Research consistently shows a huge economic and environmental cost from wrongly-inflated tyres. A recent UK survey indicated that practically three-quarters of vehicles on British roads had at least one tyre significantly under-inflated.

This is directly costing UK drivers more than £440million, wasting more than 370 million litres of fuel and pumping an additional 1 million tonnes of CO2 into the atmosphere. The level of under-inflation is estimated to result in 700,000 tyres being wasted through unnecessary wear while tyre failure leads to hundreds of fatal or serious accidents every year and tens of thousands of breakdowns.

The impact of correct tyre pressures on safety, the environment and the economy has led to legislation that has spurred innovation in tyre pressure monitoring systems. Much of this innovation has been directed towards car production, but systems are now available that take advantage of the technologies and are optimised for application in commercial vehicle.

Many of the estimates are based on statistics including private cars, but the effect of commercial vehicles can be even more significant. There is little published data about the way tyre pressures are managed in commercial fleets, but The EC has commissioned a study on “Tyre Pressure Monitoring Systems (TPMS) as a means to reduce Light-Commercial Vehicles (LCVs) and Heavy-Duty Vehicles (HDVs) fuel consumption and CO2 emissions”. This will no doubt lead to further regulations in due course.

The process of tyre pressure maintenance is labour-intensive. It can easily take 20 to 30 minutes to check and correct all the tyres on an 18-wheel vehicle, so it is easy and tempting to cut corners on regular checks. Surveys indicate that a significant proportion of commercial vehicles have incorrectly inflated tyres. Even where commercial vehicles are well-maintained, tyre pressure remains extremely important for very significant reasons:

1. Fuel consumption is one of the major costs for commercial vehicles.
2. The increased fuel consumption from under-inflated tyres is almost twice as high for HGVs as it is for cars.
3. Tyre-related costs are the largest single maintenance cost for commercial operators.
4. Tyre failure is the biggest reason for breakdown of commercial vehicles. In addition to the direct cost of a call-out, it leads to disruption of schedules, poor customer service and wasted tyres.
5. Blowouts are very destructive. The tyre is destroyed, the flailing tyre can cause secondary damage, and the blowout can lead to loss of control of the vehicle.

The cost of routine tyre pressure maintenance and the implications of incorrect inflation mean that the cost of a tyre pressure monitoring system can be recovered very quickly.
Legal position

USA legislation

In 2000, a number of fatal roll-over accidents involving Ford Explorer SUV cars fitted with Firestone tyres led to one of the largest class action law suits in the USA. 6.5 million Firestone tyres were recalled and President Clinton signed the first TREAD act\(^\text{vi}\) that required tyre pressure warning systems to be installed on all year 2004 cars and light trucks up to 10,000lbs. In 2008, this extended to all new cars imported or sold in the US.

European requirements

In March 2009 the European Parliament approved a Directive\(^\text{vii}\) concerning the approval of motor vehicles in Europe and specifically mandated that new cars (class M1) should be fitted with tyre pressure monitoring systems. This European legislation went further than the US requirements in its intention that systems must be sufficiently accurate to optimise fuel consumption as well as providing safety warnings. The regulation as finally implemented lays down minimum performance requirements but does not specify that any particular technology should be used.

The European legislation is being implemented over a two-year phase-in period. From November 2012, tyre pressure monitoring is a requirement for all new vehicle Type Approvals in class M1. This extends to all cars manufactured after November 2014.

The legislation in Europe and the USA does not currently apply to heavier commercial vehicles, but responsibility for safety rests with the operator. For most operators, the most compelling arguments for fitting Tyre Pressure Monitoring Systems remain the commercial and operational benefits.

UK Legal requirements on tyre pressure

It is the driver’s responsibility to ensure that tyres are in proper condition and correctly inflated. The penalties for having illegal tyres are currently up to a £2500 fine and 3 penalty points PER TYRE. Two faulty tyres could cost six penalty points, loss of license and a £5000 fine!

A tyre pressure monitoring system can help the operator and the driver to comply with these legal requirements.

International Standard, ISO21750

ISO 21750:2006\(^\text{viii}\) establishes overall performance guidelines for tyre pressure monitoring systems and their components for passenger cars.

The standard is intended for cars with tyre pressures up to 375kPa (approximately 55psi), so is not directly applicable to commercial vehicles. It also pre-dates the European legislation so although it is a useful reference point that sets some minimum performance requirements, it is not especially demanding by today’s standards.

The standard allows for the user to set the target pressures and requires alerts for

- A low pressure condition
- A leak resulting in rapid pressure loss
- Indication in case of system error
Commercial implications – fuel use

Three factors make up the bulk of fuel usage for an HGV. The following proportions are based on a well-maintained truck traveling at 55-60mph.

Aerodynamic resistance – 50%
This is well documented elsewhere, and the resistance increases exponentially with speed. Most operators are well aware of the improvements to be made from proper aerodynamic design and control of speed.

Mechanical friction - 17%
Mechanical friction is impacted by vehicle loading, maintenance and driving style. Aggressive driving, harsh acceleration and heavy braking are significant factors.

Rolling resistance – 33%
Rolling resistance is often misunderstood and frequently under-estimated. For passenger cars, it accounts for only 5-10% of fuel use, but is much more significant for heavier vehicles. For an HGV, one third of every tank of fuel is used in overcoming rolling resistance.

Essentially, rolling resistance arises from the deformation of the tyres while in motion. The energy loss comes from the deflection of the tyre sidewall and the compression and deformation of the tyre tread at the road surface. These deformations combine into a drag force which can be accurately measured and which is significantly affected by inflation pressure.

For a loaded artic with trailer, half of the rolling resistance is generated by the trailer tyres and the other half by the tractor. Eco tyres can help to reduce this resistance, but maintaining all tyres at optimum pressure is crucially important. It is estimated that where tyres are under-inflated by just 10%, the rolling resistance increases by at least 10%, leading directly to a 3.3% increase in fuel consumption.

Increased tyre pressure generally means less rolling resistance but increasing pressure above manufacturer’s recommended levels is not a practical method for achieving fuel economy as it also impacts on grip and tyre wear. Tread pattern, tyre wall construction and rubber compound all affect rolling resistance, and tyre manufacturers take all of these into account when recommending working pressures. Optimum results are therefore generally obtained by working at pressures recommended by the tyre manufacturers.
Commercial implications - Breakdowns

Tyre problems are the biggest single cause of break-down for commercial vehicles. Overall, tyres are responsible for an estimated 20% of all truck breakdowns.

For well-managed fleets where other issues like battery failure and mechanical breakdown are reduced, the proportion is much higher, especially for those operating in environments where there may be a higher risk of punctures, such as, waste management, construction sites, docks etc.

A puncture or blow-out can happen at any time, and can be caused by conditions unrelated to the quality of maintenance and beyond the control of the driver. The cost of a breakdown is not only the direct cost of the call-out but also

- Loss of time
- Disrupted schedule
- Customer impact
- Repair cost

Blow-outs

A blow-out is a destructive event, at best leading to the tyre being written off and potentially leading to loss of control of the vehicle. Further damage can occur when the steel-reinforced casing of the blown-out tyre acts like a massive strimmer, and adding to the cost and complexity of the call-out.

Blow-out prediction

Blow-outs are widely considered to be unpredictable, but they don’t just happen. They are invariably caused by a tyre being over-stressed. Heat builds up, the side-wall begins to de-laminate and eventually, the tyre bursts. In some cases, the tyre can even catch fire. The original cause might have been damage to the side-wall, a slow puncture or an overloaded tyre making the tyre flex excessively.

Regular checking of tyre pressures can reduce the probability of a blowout, but conditions outside the control of the operator can lead to a puncture at any time. Tyre pressure monitoring systems can check tyre pressures every few seconds while the vehicle is in motion and give a warning if a tyre is under-inflated or losing air.

Systems are available that also monitor tyre temperatures and this does not need to be particularly accurate to give an alert if the tyre temperature exceeds a safe level. These are the most effective systems in providing advance warning before a blow-out or tyre fire occurs.

Tanker fire on M6 motorway was said to be started in a tyre.
Commercial implications - Tyre wear

Incorrect inflation has a significant and well-documented effect on tyre wear. It reduces the footprint of the tyre in contact with the road, so wear is concentrated only in certain areas.

**Over-inflation**

Over-inflation typically causes wear in the centre of the tread, but this may be irregular, especially on drive axles.

**Under-inflation**

The effect of under-inflation is a little more complex, as in addition to the wear on the outer edges of the tyre, the lower pressure results in more deflection of the tyre side wall that can itself be damaging. This is a similar effect to running tyres overloaded.

Significant under-inflation can lead to rapid damage to the side wall and complete destruction of the tyre in the form of delamination and blow-out.

Figures published by Michelin in 2006 state that 20% under-inflation leads to 19% reduction in tyre life, while 20% over-inflation causes a 20% reduction in life. Higher figures are often quoted elsewhere, and it is known that super-singles are particularly prone to accelerated wear if under-inflated.

**Dual wheels**

Mismatched tyre pressures are a real problem for dual wheels. The mismatch results in a change in diameter that makes the larger wheel drag the smaller one and the smaller wheel hold the larger one back.

A difference of just 10 psi can change the diameter by 16mm, resulting in the smaller tyre being dragged more than 1Km for every 100Km travelled. This leads to rapid and irregular wear for both tyres of the pair, as well as increased fuel consumption in overcoming the resistance.
Commercial implications - Safety

The UK Department for Transport statistics show that defective or under inflated tyres are a factor in hundreds of road accidents each year. The latest statistics (Road Casualties Great Britain: 20011 (Annual Report)) records 709 accidents where tyre condition was a factor, making this the most common contributory vehicle defect.

For commercial vehicles the position is rather different, with overloading or poor loading the primary contributory factor in accidents involving a vehicle defect, followed by brake defects and then tyre defects.

Value of effective management

Overloading and brake defects can clearly be addressed by effective management and proper maintenance, but tyre problems can continue to arise from causes outside the control of the operator or driver.

For well-managed vehicles, the provision of an effective tyre pressure monitoring system can significantly reduce the danger of breakdown or accident.
TPMS Technologies

Pressure for innovation

Tyre pressure monitoring systems have been a legal requirement on all new cars sold in the USA since 2008 and on new models sold in the EU from 2012. There are arguments that the US legislation, implemented in 2004, was over-hasty because of the lack of standardised technology. Research and development was already under way in various places but the commercial potential stimulated a scramble of innovation. The technology is still in a state of flux, but after some false starts, a number of reliable and cost-effective solutions have been developed.

Indirect Tyre Pressure Monitoring Systems

Some of the first systems worked indirectly by comparing the speed of rotation of the wheels. An under-inflated tyre has a slightly smaller circumference than one at the correct pressure, so a sustained difference in speed is interpreted as an under-inflated tyre. The system has to distinguish this tiny effect from differences caused by cornering and other aspects of normal driving, and some systems require 20 minutes driving or more to establish a pattern.

The main advantage of indirect technology is that it can be based on data from the antilock brake (ABS) system and is therefore cheap to implement. After some pressure from German members of the EC standards committee, the European regulations were finally agreed to require a puncture (falling pressure) warning within 10 minutes and a low pressure (diffusion test) warning within 60 minutes of cumulative driving, enabling it to accommodate indirect measurement. The result of this is that indirect systems can be used in cars, despite their technical limitations.

The main limitations of indirect systems are that they remain rather inaccurate and slow to respond. They do not monitor tyre temperature, which is important in predicting a blow-out, and they are not readily able to detect a condition where the pressure of all tyres changes simultaneously – a common situation as tyres gradually lose air through diffusion or when tyre pressure changes due to seasonal temperature variation.

Direct Tyre Pressure Monitoring Systems

Direct systems use individual pressure sensors for each tyre and transmit data to a central receiver that provides information for the driver. These systems overcome most of the problems associated with indirect systems. They can detect small changes in pressure, including those that occur in all tyres simultaneously. Response can be rapid, with real-time updates even when the vehicle is stationary. Direct systems also lend themselves to tyre temperature measurement.

Sensors with a battery-powered transmitter are either located inside the tyre (internal sensor), or in a special valve cap (external sensor). Typically, the sensors also provide temperature data.

Internal sensors generally have batteries encapsulated with the sensor, so after a life of about five years, the tyres have to be removed and the sensors replaced. This type of sensor can be a good solution where operators have their own tyre fitting facility, but experience in the US suggests that it creates problems where independent tyre fitters are used.

External sensors consist of sensor caps that screw onto the tyre valves and usually have some kind of anti-pilfer device. They can be installed by the user in a few minutes and can readily be rotated with the tyres. Batteries can be replaceable, so the service life of the sensor is not dependent on the battery.
Future trends

Much recent development in sensor technology has been aiming to reduce sensor power requirements, with products targeted towards car manufacturers who install internal systems in new vehicles as part of the production process. Innovative approaches include research into replacing batteries entirely with micro-energy harvesting devices that will eventually use movement of the tyre to power the sensors. These systems are yet to be produced commercially or proven in actual use on tyre pressure monitoring applications.

Vehicles are now built with instrumentation and engine management through a CANbus system that is effectively a data network on the vehicle. Most commercial vehicle manufacturers do not currently incorporate tyre pressure data into their CANbus instrumentation, and they discourage any addition to the CANbus, even a read-only approach, in case it interferes with the operation of the vehicle. Some vehicle builders add a second CANbus for their own instrumentation, and for these manufacturers, the addition of a tyre pressure monitoring system is a relatively straightforward matter.

Fleet management is making increasing use of telematics systems to provide remote monitoring of vehicles. These systems began purely with location reporting, but have quickly moved on to reporting additional data from the vehicle instrumentation. For commercial fleet vehicles, this provides opportunities for remote access to the data for central monitoring and performance diagnosis. Some telematics systems have a facility for additional serial data input, and this provides a further possible route for accessing TPMS data.

TPMS requirements for commercial vehicles

TPMS for commercial vehicles can draw on the mass market technology developed for passenger cars, but they do have somewhat different requirements because they are operated in different ways. The following are especially significant:

1. Transmission distance from sensor to display is much greater.
2. Multiple trailers are often used in HGV fleets.
3. Tyres may be purchased in bulk with different types used on the same vehicle
4. Tyres may not remain on the same vehicle for the entire life of the tyre
5. Worn tyres are reprocessed (re-tread or recut) for further use
6. Tyre management is frequently outsourced.

Any system for commercial vehicles must therefore meet the following requirements:

1. Be capable of transmission from sensor to cab while providing adequate sensor battery life.
2. It should be easy to switch monitoring between multiple trailers in a fleet
3. Sensors should be readily replaceable and easy to transfer from one tyre to another.
4. Systems should be capable of integrating with CANbus or other instrumentation systems
TyrePal TPMS solutions

Tyre Pal supply retro-fit tyre pressure monitoring systems for all kinds of vehicles, from passenger cars to buses, HGVs and specialist vehicles. The appropriate system for most commercial applications is the TC215 system which is available with a standard in-cab monitor and a variety of external or internal tyre sensors. CANbus and RS232 modules are also available to integrate tyre data with the vehicle data bus or other instrumentation systems.

TyrePal TC215 heavy duty TPMS

This system monitors the pressure and temperature of up to 22 tyres, including 10 on the tractor and 12 on a trailer.

Tyre data is measured every six seconds by smart sensors that can be mounted inside or outside the tyres. The sensors send the data to a monitor in the cab that displays the tyre pressures in turn and gives an alert for any problem. The standard in-cab monitor gives clear and distinct alerts for:

- air loss (puncture)
- low pressure
- high pressure
- high temperature (potential blowout or tyre fire)

Warnings are also given if a sensor signal is lost, if a sensor battery is low, or when the monitor battery needs recharging.

The monitor is powered by an internal lithium battery, recharged from the vehicle supply and has a robust articulated mount that can be attached to the screen with a strong suction pad or permanently attached with a screw fitting. A push button on the monitor enables or disables trailer monitoring, and is used when trailers are swapped. Each trailer has a unique ID, so it's ideal for large trailer fleets.

When the vehicle is parked, the monitor enters a sleep mode to conserve battery power, but the system continues to check pressures once every hour so that warning of any problem such as a slow puncture overnight can be given immediately on starting up.

TC215 sensor options

Sensors are fitted to each tyre and transmit tyre temperature and pressure data at 433MHz. Each sensor has a unique ID and can be coded to any wheel position. Internal, external or air flow-through sensors are available and different types can be used on the same monitor.

The external and flow-through sensors have replaceable batteries with a service life of up to 2 years. They incorporate an anti-pilfer locking system. Internal sensors fit inside the tyre and have a sealed construction with non-replaceable battery and a service life of about 5 years.
TCTH Hand Held Reader-Programmer

Systems can be set up directly from the monitor but for fleet applications where a number of vehicles are involved, is generally quicker to use the hand-held reader-programmer.

This is used to register sensors to specific wheel positions, set vehicle and trailer IDs and to set alert levels. The hand-held reader is also used when setting up CANbus systems.

TCRT Smart Relay

Where the distance from the tyres to the monitor exceeds about 7 metres, a Smart Relay can be used to boost the signal. It operates from the 12 to 24V vehicle power supply and in this application it acts as a simple booster that requires no programming.

Where multiple trailers are in use and are regularly exchanged, the Smart Relay is used to simplify the process. One is fitted to each trailer, where it stores the trailer’s ID and tyre alert settings. When a trailer is connected, pushing a button on the relay sets up a data connection with the monitor in the cab.

CANbus and Serial data

Tyre pressure and temperature data can be accessed for custom instrumentation by using a CANbus Module (J1939) or a Serial Data Node. This technology is ideal for specialist vehicle builders or for providers of custom instrumentation. The data from the system can be used can be used for in-cab display, for remote monitoring, or for control applications such as central tyre inflation (CTI).

In these applications, the system uses standard tyre sensors from the TyrePal TC series together with the CANbus module or the Serial Data Node. The receiver module stores the vehicle or trailer ID, together with sensor IDs and alert levels for each wheel position being monitored. The hand-held programmer can be used for setting up the system.
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