TyreSense

Economic Benefits of TyreSense 4

Benefits of augmenting TKPH ratings with the TyreSense 4 Tire Pressure Management System and heat studies in determining optimal tire operating limits in mining operations

Rimex Supply Ltd.

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Introduction

Fuel is a major expense for any mining organization, followed closely by tires and the downtime of vehicles due to tire failure. Commonly, damage severe enough to cause tire failures may occur due to either or both the tire pressure and the temperature exceeding the manufacturer's recommended levels regularly or for long periods of time. Over inflation, under inflation, and vehicle speed are the most common factors that contribute to heat and inflation related damage, along with overloaded vehicles and long haul distances.

To try to achieve optimal tire performance, many mining companies use the tire company's recommended operational Tonne-Kilometres-per- Hour (TKPH)[1] formula and manual temperature, pressure, and tire tread inspections to monitor this performance. This method, however, doesn't take into account the fluctuating real-time operation of tires, which means that the actual safe performance limit of the tires under various operating conditions could differ from the TKPH rating. If the mining company relies only on the TKPH values and manual monitoring, the tires are not likely to achieve the optimal operational temperature and pressure.

This is where a Tire Pressure Monitoring System (TPMS) can be used in conjunction with heat studies to refine the safe performance limits of tires based on actual tire operation data.

In this paper, we'll look at the limits of relying solely on TKPH calculations and manual tire inspections and the benefits of incorporating TPMS technology and heat study results to optimize production, prolong tire life, and avoid unnecessary (and expensive) downtime.

Limits of TKPH and manual tire monitoring

A TKPH rating provides a general guideline for operations, but it has limits. Typically, operating limits are based only on the load put on the tires and the vehicle speed; it doesn't take into account changing real-time operating conditions such as starting, stopping, turning, and inclines, which put additional stress on tires. The TKPH formula also averages the load across all the tires on a vehicle; it doesn't take into account stresses on individual tires caused by uneven loads. It also doesn't apply to vehicles with tires loaded 20% above their rated load capacity or those used for hauls of more than 32 km (20 miles).

Manual tire inspections are also limited in their usefulness. Manual tire monitoring provides pressure information intermittently instead of continuously, which means that dangerous pressure spikes can go undetected. Manual pressure readings taken once a week when the vehicle is parked don't accurately reflect the true average working pressure in the tire. Manual pressure gauges aren't always accurate, and not always used correctly. The reading at the gauge may be lower than the actual tire pressure, which can result in overinflation if a tire fitter relies solely on the manual pressure gauge. Tire additives may further reduce the accuracy of a manual pressure gauge due to blockages. Gauges wear out and fail over time. Valve core leaks can also be caused by manual pressure checks. In addition, manual pressure checks are not always performed as frequently as expected or required, and air is not always added to an underinflated tire during a manual pressure check.

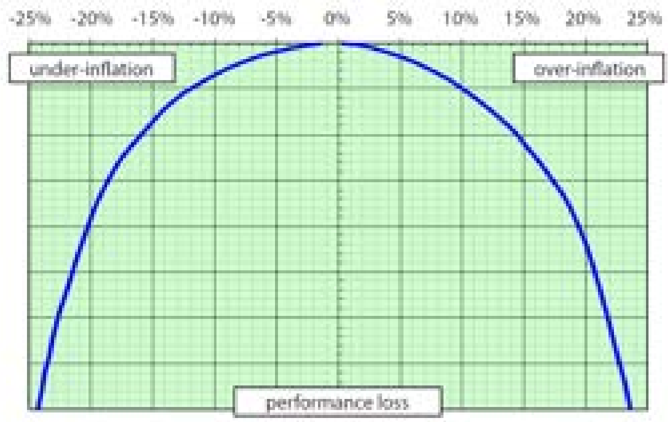
In addition, neither of these methods monitor real-time tire *temperature*, so sites can't tell when the tires are actually reaching critical heat levels.

[1] TKPH is a calculated load rating that a tire manufacturer defines for a tire based on the size, construction, tread pattern, and rubber compound, and the results of testing the tire to a failure point.

Importance of correct tire pressure

Both overinflation and underinflation reduce tire life. An underinflated tire generates more heat, while an overinflated tire loses the ability to dissipate heat. Excessive heat can result in extended downtime when a vehicle must park and wait for a tire to cool down or when it's out of commission due to tire failure. To optimize tire life and performance, it's vital to maintain correct tire pressure.

Figure 1: Effect of inflation pressure on tire performance



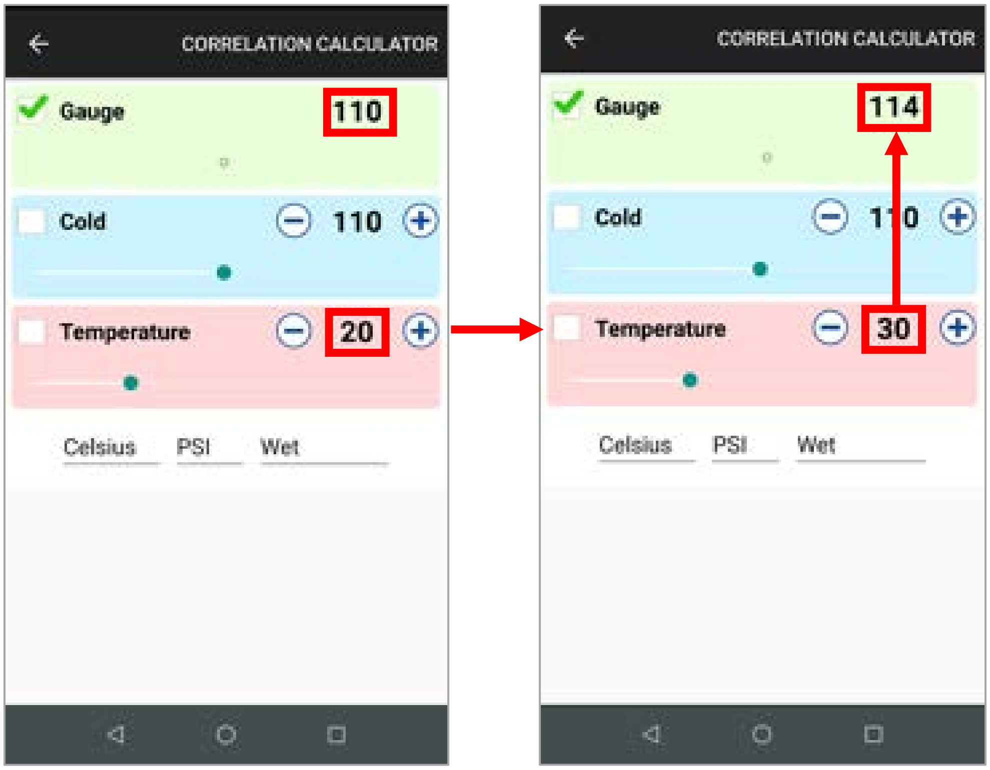
Tire inflation values are typically based on a manufacturer's cold inflation pressure value at 20°C (68°F)[2]. Average ambient temperatures on site vary widely, however, and this requires adjustment in the tire pressure inflation values. For example, a tire manufacturer might recommend a cold inflation pressure value of 758.4 kPa (110 PSI) at 20°C (68°F), but the mine site ambient temperature averages 30°C (86°F), so the internal tire temperature will likely seldom drop below this value. If the goal is to maintain the tire manufacturer's recommended average operating pressure, the tire fitter can use the **TyreSense Correlation Calculator** (*Figure 2)* to determine that the gauge pressure at 30°C (86°F) should be 786 kPa (114 PSI). This only works if the actual tire chamber temperature is 30°C (86°F), however, if the actual temperature inside the tire is different, it would be easy to miscalculate and over or under inflate the tire.

The TyreSense TPMS measures and records the real-time operating pressure and temperature of the tires. This data, plus the TyreSense Correlation Calculator tool, allows a tire fitter on site to calculate the appropriate gauge inflation pressure for any tire at any time. Available within the TyreSense mobile app for Android and iOS devices, the Correlation Calculator calculates tire inflation pressure using cold inflation pressure, gauge pressure, and chamber temperature values. As the tire is not required to cool down before the required gauge inflation pressure value is calculated, quick inflation and deflation turnaround times can reduce overall vehicle downtime. Tire fitters can monitor the change in real-time tire pressure in the client application during inflation/deflation to ensure the target tire pressure value is achieved.

Maintaining the correct tire pressure and temperature during operation can help prevent damage and unnecessary downtime. With the TyreSense TPMS, site personnel can use real-time tire pressure and temperature data to determine when to take corrective action.

[2] This can vary by manufacturer.

Figure 2: Correlation Calculator on Android



The Gauge value changes as the Temperature value increases.

To use the Correlation Calculator to make accurate tire pressure adjustments, a tire fitter needs to know two of the three values shown in the calculator. Typically, these will be the cold inflation pressure value and the tire chamber temperature value as detected by the TyreSense wheel sensor installed inside the tire. The value with the check mark, Gauge, represents the *calculated* value based on the two other values. Only one variable can be selected at a time to be calculated. You can also change the units and the type of tire in use (wet or dry/nitrogen).

The example shown in *Figure 2* assumes that the manufacturer's recommended cold inflation pressure value at 20°C (68°F) is 758.4 kPa (110 PSI). To start, the tire fitter would select **Gauge** as the variable to be calculated, then set the **Cold** value to 110 and the **Temperature** value to 20[3]. The Gauge value will read 110.

If the tire chamber temperature, as detected by the wheel sensor, is 30°C (86°F), the tire fitter would change the **Temperature** value to 30. The calculated **Gauge** value, which changes as the tire fitter adjusts the temperature, represents the target tire inflation pressure value. In this case, the tire fitter would inflate or deflate the tire to achieve 786 kPa (114 PSI) gauge inflation pressure.

With a wheel sensor installed, the tire fitter can also monitor the tire pressure during inflation or deflation, which can provide more accurate readings than the pressure taken by a manual pressure gauge. The Correlation Calculator also helps sites manage tire pressures in areas where there are significant seasonal ambient temperature variations.

[3] The Correlation Calculator assumes the default cold inflation pressure value is calibrated for 20°C (68°F).

Use of heat study data

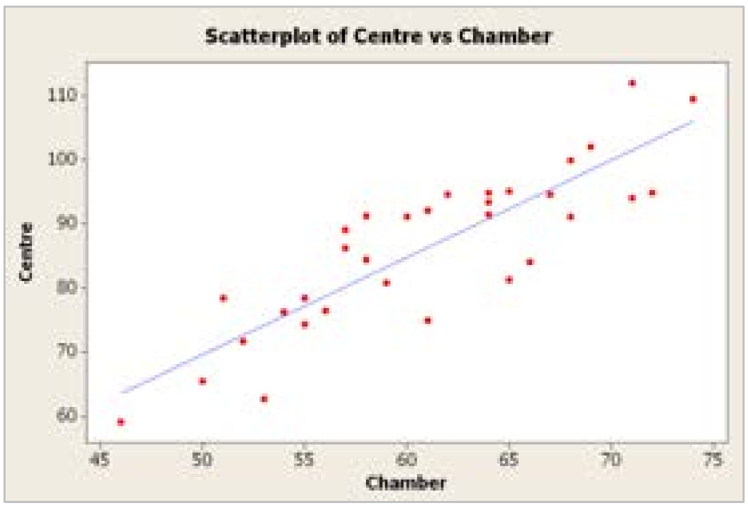
A heat study was conducted at a TyreSense client site in northern Australia to look for correlations between tire belt temperatures and chamber temperatures. This involved drilling through the tread of a tire down to the belt package at 6 to 10 points across the tire and inserting a temperature probe at regular intervals during a work shift. Tire chamber temperatures were monitored and recorded by the TyreSense system. The formula used for this study was the following:

$$T_{Centre\ Belt} = 1.52T_{Chamber} - 6.28$$

with R^2 (adjusted) of 73.3% with the data available.

Based on tire chamber and belt temperatures recorded at this site, it's clear there is a relationship between chamber temperature and belt temperature.

Figure 3: Tire belt and chamber temperatures



The site followed a TKPH protection scheme that limited vehicle travel to 35 km/h (22 mph). Setting the critical belt temperature (the temperature at which the rubber starts to revert) to 110°C (230°F), this yields a chamber temperature of 76.5°C (170°F). Based on feedback from the site, speed limiting at 80°C (176°F) did not control the temperature sufficiently, so an alert threshold temperature of 70°C (158°F) was proposed.

Although there isn't a completely predictable correlation between tire belt temperature and chamber temperature, the information from heat studies does help determine more accurate temperature alert threshold values. In this case, the critical alert value would be set at 70°C (158°F) within the TyreSense monitoring system to adjust for the difference between the tire chamber temperature and the belt temperature.

Value of the TyreSense 4 TPMS

Real-time pressure and temperature data

The primary advantage of a TPMS system over TKPH lies in the real-time data monitoring. The TyreSense TPMS monitors real-time tire temperature and pressure so site personnel can see potential problems before they can cause tire damage or failure. Wheel sensors transmit tire chamber pressure and temperature data at one second intervals to a receiver unit mounted on the vehicle, which monitors the data and stores it in logs. The receiver then transmits sensor data for all tires to a TyreSense server, which makes the information available in a browser-based client application. The system displays alerts and sends notifications immediately if sensor data exceeds thresholds configured in the system. This allows site personnel to respond far more quickly to changing tire conditions than relying solely on a TKPH protection scheme.

Timely tire pressure management

Since the wheel sensors supply continuous real-time pressure and temperature data, sites don't have to rely only on manual pressure checks[4], which provide a pressure reading at only one point in time, when the vehicle is stopped. Wheel sensor readings occur continuously regardless of whether the vehicle is stopped or in motion, which provides a more accurate picture of the tire's operating conditions at any time. It also helps eliminate inaccurate readings from manual gauges that have failed or are not used correctly. Site personnel can use this information to ensure tires remain inflated to the correct pressure values.

Tire agnostic

The TyreSense TPMS works with any brand of tire. You can also use the system to compare performance among different brands and types of tires.

Online access

The TyreSense TS4 browser-based client application allows sites to manage the system and view site, vehicle, and tire data securely from any device that has an internet connection.

Configurable alerts and notifications

Site personnel can configure system pressure and temperature alert threshold values down to the level of an individual tire. Level 1 (warning) and 2 (critical) alerts appear on the browser-based client application and in the mobile app. Alert notifications can be sent by email, text message, or through the mobile app, or broadcast to all three. Timely alerts allow sites to respond immediately to changing tire conditions.

Detailed data logs

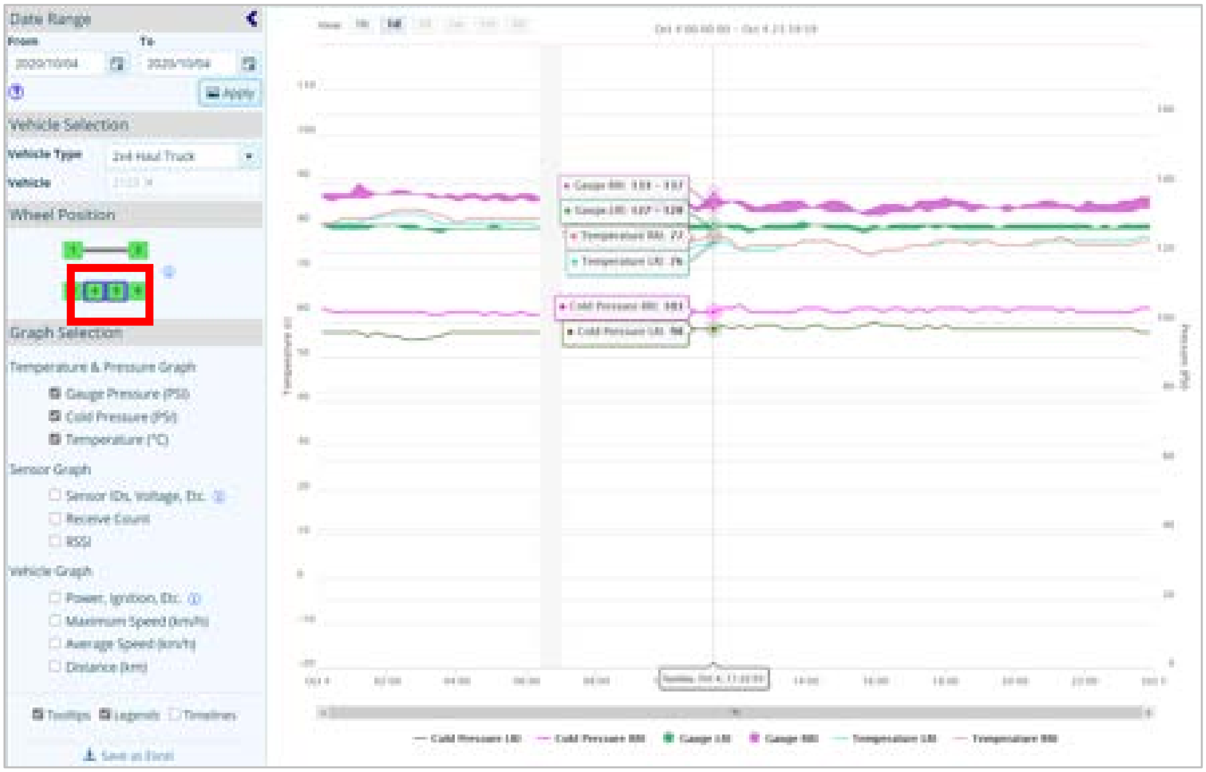
TyreSense data logs show trends in tire conditions that site personnel can use to see and correct issues before they become problems. For example, a steady decrease in cold inflation pressure values for a tire could indicate a leak. Higher pressure and temperature readings for one tire on a vehicle could indicate an alignment or other vehicle configuration issue or an overinflated or underinflated tire. A spike in cold inflation pressure and gauge pressure could indicate an impact event.

Real-time data from one customer's data logs showed that when a tire pressure reached a critical alert level and the site personnel took corrective action (slowed vehicle speed) this brought the tire pressure and temperature values down. When data logs for a vehicle indicated that one tire was running hotter than others, pressure values for all tires on that vehicle were compared. After tire pressures were checked and adjusted to the correct levels, the data logs showed the tires operating within their optimal range of temperature and pressure.

Site personnel can view data logs for one tire or compare data for multiple tires on a vehicle. Sites can also track the pressure and temperature history of any tire in the system, then compare those records to maintenance procedures and schedules to monitor compliance with company and site maintenance programs.

[4] While the elimination of manual pressure inspections is not recommended, a TPMS allows a reduction in the frequency of these inspections without jeopardizing tire safety or performance. Use of a TPMS system augments, but doesn't replace, a regular maintenance routine that includes manual pressure checks and visual inspections for cuts and any other visible signs of damage or excessive wear.

Figure 4: Data log comparing data from two wheel sensors



Powerful reports

TyreSense reports provide valuable metrics that can inform site maintenance programs and operational decisions. Reports available in TyreSense 4 provide information about system performance, personnel response to alerts, tire temperature and pressure data, and vehicle activity. For example, site personnel could look at the Vehicle Performance report and cross-reference vehicle speed with tire data such as that found in the Daily Average/Maximums report. In one case, an employee monitoring the system noticed that one vehicle showed consistently higher tire pressure and temperature values. The Vehicle Performance report showed that vehicle traveled at higher average speeds than other vehicles on the site. The vehicle operator was instructed to slow vehicle speed, and the tire temperate and pressure values dropped down to the expected values. Reports can be generated on demand or scheduled for distribution to specific teams or individuals so the right people get the information they need to maximize productivity.

Summary of Benefits

The TyreSense TPMS provides accurate real-time readings of tire pressure and temperature and alerts site personnel if those readings exceed configured thresholds. If vehicle operators take appropriate action when advised in response to major pressure and temperature fluctuations, premature tire failures can be prevented. Early intervention can reduce capital tire replacement costs as well as operating costs associated with vehicle downtime from either tire failure, tire cool down periods, or overly cautious cool down periods because of lack of actual tire data.

The TyreSense system, when used correctly, could maximize available operating time for all of an organization's working sites and pay for itself within months.

Appendix A: Operating TKPH

The following image is an excerpt from the Bridgestone[5] Data Book 2020 Off-the-Road Tyres, which can be found at https://tire-import.com/data/documents/Bridgestone_OTR_Databook_2020.pdf.

This excerpt is used only to help illustrate how TKPH can be calculated.

5. Ton-Kilometer-Per-Hour (TKPH)

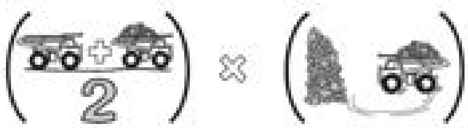
5.1 Operating TKPH

Earth-moving, mining and logging tires have become increasingly important with the development of large construction vehicles. The primary task of these heavy-duty tires is to haul heavy loads faster, over longer distances. This heavy hauling inevitably causes heat built-up in the tires. As tires have limited resistance to heat, deterioration of the tire may occur at an early stage of operation if used beyond the rated TKPH.

Accordingly, it is necessary when selecting tires, to determine the amount of work which will keep the tire within a safe range to avoid over-heating when the vehicle is operated under given conditions. The amount of work done under the given conditions and within a safe range is shown as "Operating Ton-Kilometer-Per-Hour (Operating TKPH)" which can be determined by the following formula:

Formula for Calculation of Operating TKPH

Operating TKPH =



Mean Tire-Load (MTL) × Average Work Shift Speed (AWSS)

$$\text{MTL [metric tons]} = \frac{\text{Tire Load (Empty)} + \text{Tire Load (Loaded)}}{2}$$

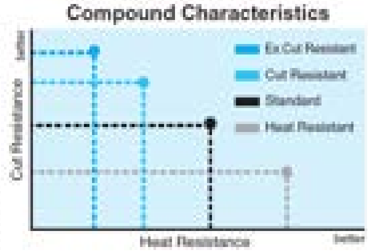
$$\text{AWSS [km/hour]} = \frac{\text{Round Trip Distance[km]} \times \text{Number of Cycles per Shift}}{\text{Total Hours of Operation per Shift}}$$

*Calculation formula of "Operating TKPH" may be different between tire manufacturers.

5.2 Tire TKPH

Tire TKPH varies depending on the tire's design (size, tread pattern and the type of compound). A High TKPH tire generates less heat than that of lower TKPH tire. However, the lower TKPH tire will have greater cut and wear resistance than the higher TKPH one.

Compound Characteristics



The TKPH method is applicable in the following situations.

(1) One way distance: within 16 km (10 miles)

a. When haul length exceeds 16 km one way, consult a Bridgestone Representative.

b. If the round-trip distance is less than 5km (3miles), Tire TKPH figures can be increased by 12%.

(2) Ambient temperature: 38˚C (100˚F)

For ambient temperatures other than 38˚C (100˚F), the Tire TKPH rating should be revised based on the following formula.

a. Radial Tire

Revised TKPH rating = [1 + α × (38˚C–Max. Ambient Temperature ˚C)]* × Tire TKPH

Below 27.00 (33.5) inches in Section Width: α =0.010
Above 30.00 (37.25) inches in Section Width: α =0.009

b. Bias Tire

Revised TKPH rating = [1 + α × (38˚C–Max. Ambient Temperature ˚C)]* × Tire TKPH

Below 27.00 (33.5) inches in Section Width: α =0.006
Above 30.00 (37.25) inches in Section Width: α =0.005

*Revising coefficient: The value is shown in the following table.

[5] This is not an endorsement and is used as an example only.