Haul-truck tyre-life improvement using water-cooling system

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The life of haul-truck tyres in surface mines depends on the regularity of usage, tyre pressure, weather conditions, and friction between tyre and road surfaces.

The hauling operation in mine sites generates heat on the surface of the truck's tyres. This heat increases the wear and tear of the tyres and, as a result, the tyre life will be decreased. The heat generated in tyres is due to the friction when the rubber structure is under deformation. The generated heat in haul-truck tyres plays a critical role in the operation and maintenance of many mine sites. The lack of control over this unwanted heat generation leads to early tyre failure. The control of tyre temperature has usually occurred through the management of truck tonnes per kilometre per hour (TKPH, which is the industry standard for tyres). Implementing an efficient cooling method and technique will result in reducing the thermal stresses on the tyre and extending tyre life. The cooling method has been significant due to the increasing efficiency of new mining operations, with reducing downtimes in operation sections and decreasing related maintenance costs.

Trucks' tyre-heat management is an important problem for tyre manufacturers and mining companies. Tyre operating limits are the main limiting factor in mine production, forcing trucks to move constrained mine material and travel at lower-than-required speeds. Therefore, there is a certain requirement for an effective method of heat dissipation in haul-truck tyres in open pit and open-cut mines.

Figure 1 illustrates some of the major haul-truck tyre sections and components.

The properties of the rubber change with the increase in tyre temperature. Therefore, the tyre becomes susceptible to mechanical failures, such as tread separation, tread cut, side cut, cut-through and carcass break-up.

To predict the heat-generation rate

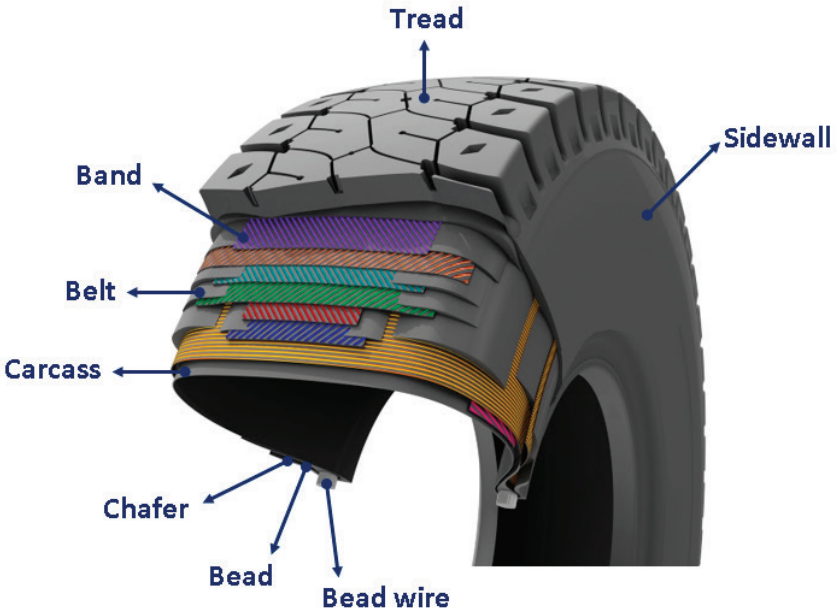

Figure 1. Structural components in haul-truck tyres

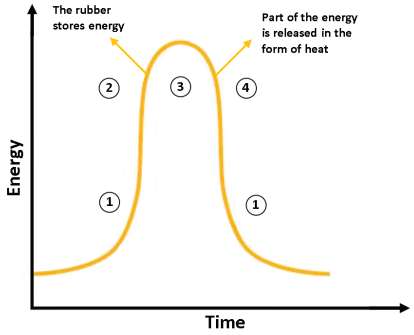

Figure 2. Energy distribution in haul-truck tyres

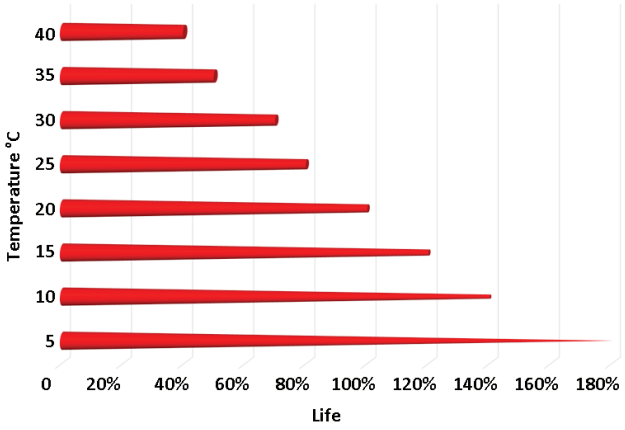

Figure 3. Effects of temperature on tyre life (Source: *Haul Truck Tyre HandBook*, Bridgestone 2015)

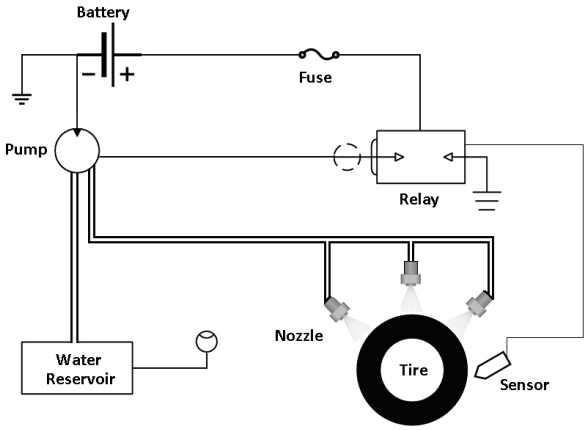

Figure 4. Circuit diagram

in truck tyres, it is essential to fully understand the structure, and rolling and flexing mechanisms of tyres. The fundamental phenomenon of the heat generation in tyres is the friction between molecules when the rubber in the structure of the tyre is under a kinematic deformation by a continuous compression-tension or torsion (see Figure 2).

This kinematic deformation is known as the hysteresis effect. In fact, as the tyre rolls and flexes, a portion of the motive power transmitted to the tyre is absorbed due to the tyre hysteresis and thus converted into heat; consequently, the tyre temperature increases. This effect is intensified by increased load and truck speed, as well as tyre under-inflation, road undulations, and excessive cornering.

Heat is also generated within the tyre carcass due to the friction at the tyre-road interface. The friction force depends on the nature of the surface roughness and the sliding velocity.

Although the tyre carcass can withstand high loads and has sensible wear properties, it has low thermal conductivity and therefore cannot effectually dissipate the heat to the surrounding atmosphere.

As a result of the poor thermal conductivity of rubber, the temperature rise is primarily dependent on the thickness of tread. If the heat generation is faster than it can be transferred to the ambient air, it gradually builds up in the tyre and reaches its maximum at the outermost ply or belt. As the operating temperature of the tyre increases, the rubber considerably loses its strength. Tyre operating temperature has an important impact on tyre life (see Figure 3).

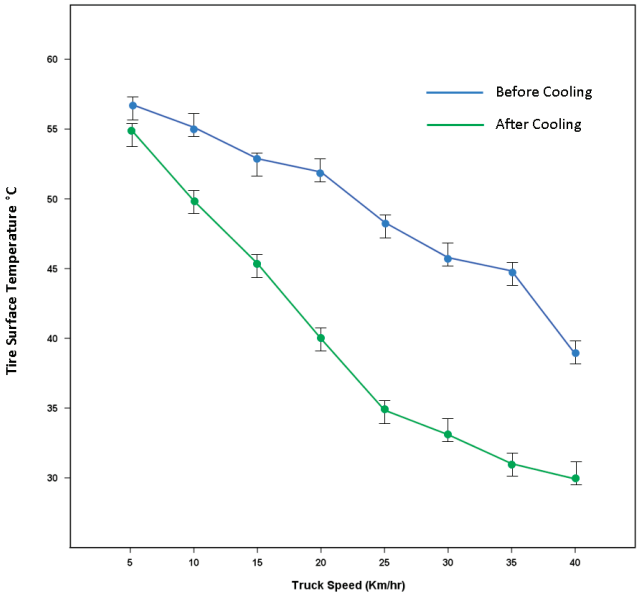

Figure 5. Temperature results at different truck speeds

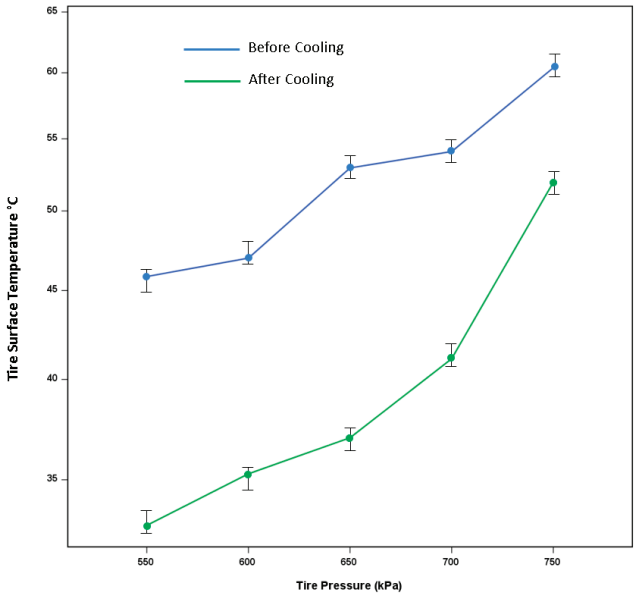

Figure 6. Temperature results at different tyre pressures

Generated heat can affect haul-truck tyres in many ways, and there has yet to be any successful method of actively preventing haulage truck tyres from overheating while in use. Currently, mine sites are limited to passive techniques in managing their haul-truck fleet, either through monitoring live TKPH levels in each truck tyre or through periodic temperature and pressure measurements. These methods often have poor correlation with the actual state of the tyres, and can be extremely conservative – thus leading to unnecessary losses in production and energy efficiency. If an effective cooling technique is applied on mine sites, truck and tyre operation would be improved in many ways, eventually leading to increased site production, optimised energy efficiency and reduced maintenance costs, as well. Even a drop of 1°C could reduce rubber wear rates in tyres, expand the operation of haul trucks, and improve tyre resistance to damage.

Some cooling techniques have been identified through this study. These techniques can be classified into five groups: 1). Conduction, 2). Forced Convection, 3). Refrigerant, 4). Tyre Carcass Modifications, and 5). Heat Pipe/Working Fluid. In what follows, a new tested method to decrease the haul-truck tyre temperature in surface mines will be explained.

In this study, a tyre cooling system using water spray is designed to be used to reduce tyre surface temperatures to extend the operating life of the tyre. The water jet nozzles are mounted facing the tyre surface under the chassis facing the tyre surface. These nozzles are installed at a certain angle to the tyre. The system can be operated either manually or automatically based on the temperature rise of the tyre.

Figure 4 shows the circuit diagram of the system. The heat generated at the surface of the tyre will give a temperature rise. Once the temperature sensor detects the rise, the relay will close the electrical circuit of battery and pump. The water will be pumped through the nozzles to the tyre surface. The water is continuously sprayed on the moving tyre until the tyre temperature drops to a certain acceptable degree.

The presented tyre cooling system has been installed to test on a haul truck (Caterpillar 793D) in a surface copper mine in the north of Arizona, United States (2016), to test the method. Figure 5 illustrates the effect of using this system on reducing truck tyre temperature for different truck speed. This figure also shows that reducing tyre surface temperature by more than 10°C is possible when the truck moves mine material with speed – around 30 kilometres per hour. Figure 5 has been completed based on the thousand rows of data collected from the monitored truck in three months.

Figure 6 also shows the relationship between tyre air pressure and tyre surface temperature in two different conditions: before and after using the water spray cooling system. The results obviously show that there is a great opportunity to reduce tyre temperature by using the proposed method in this study.

Although there are a lot of benefits to using the developed method to reduce the haul-truck tyre temperature to increase productivity, increase energy efficiency, and reduce maintenance and overall costs in mine sites, there is some limitation for using the method in some mines. For example, in coal mines, the rolling resistance (friction between the tyre and haul road) will be increased when the water is sprayed on the tyre surface; however, based on the current technologies, there is not an alternative option for mining companies to reduce the haul-truck tyre temperature.