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MINE OF KNOWLEDGE™

Truck performance improvements in surface mines: intervention measurements bring profits

Trucks are subjected to various loads that cannot be anticipated in the design at the OEM level. Apart from many other things, uneven and soft roads as well as uneven loading work as multipliers in terms of load on the tire and suspensions, etc. In other words, for example 20% difference from designed road criteria and 10% uneven loading on the truck plate can increase uneven load on the tire by more than 40% – setting off high tire wear and tear and component failures. This is called multiplier effect.

Let's start with a linear P-F Curve. Let us start with the P-F Curve shown below. In this case, the depth of remaining tread on a tire is used as an indication of tire condition (y-axis) and the time the tire is in use is shown on the x-axis. The manufacturer defines a tread depth range that is still safe, but planning for a tire replacement should also be in the mind. If we can measure the rate at which a tire in any application will wear, we can construct the P-F Curve by plotting the measured tread depth by the distance the tire has been driven. For the sake of this example, let's assume that the number of miles (multiply with 1.6 for km) that it takes to wear away 1/32" of tread is equal to one year. This would now become the amount of time within the yellow area in the P-F Curve below and is commonly called the P-F Interval.

The potential – functionality traditional P-F asset life decision curve, previously on a component case-by-case basis, is reframed here as a P-F performance-functionality relationship that may be considered in the context of individual components through to the entire gross asset to perform under applied operational context.

Loads transmitted from haulers to mine roads via the tires are not as simple as just accounting for the loaded gross vehicle weight (GVW) of any given hauler in a haulage fleet. GVW is gross vehicle weight (misleading as industry quotes in mass units metric or short tons), which varies hugely at

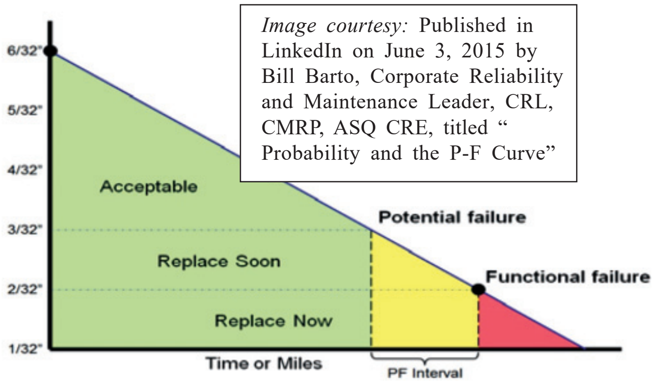
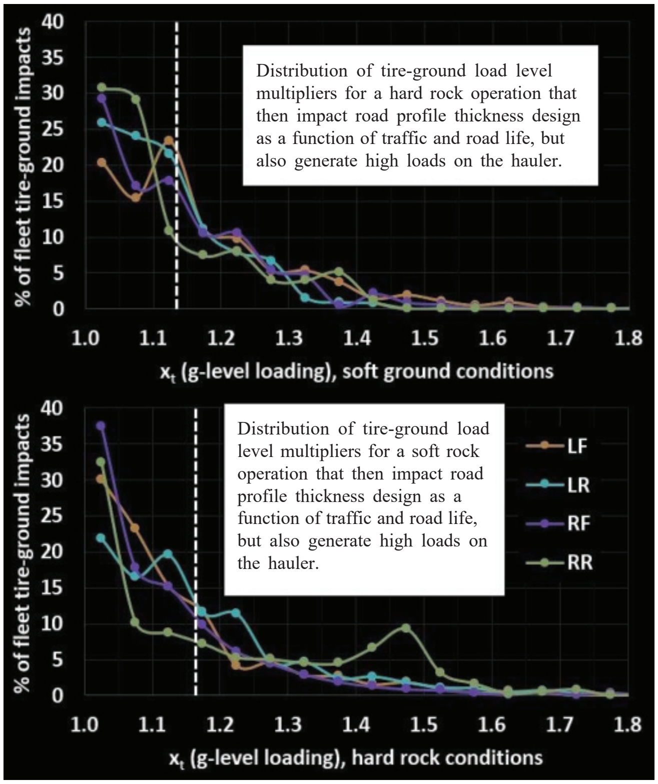


Image courtesy: Published in LinkedIn on June 3, 2015 by Bill Barto, Corporate Reliability and Maintenance Leader, CRL, CMRP, ASQ CRE, titled "Probability and the P-F Curve"

the tire-ground contact when a hauler is in motion. In any bounce, roll (bias), pitch or rack (twist) motion, the loading at any tire-ground interface may be enhanced (">g") or diminished ("<g"), where x_t is an equivalent to an enhancement or diminishing tire loading multiplier; which is really the g-level loading for a vehicle in motion expressed at the tire-ground contacts compared to the static stationary condition at 9.81 m/s^2. The g-level or x_t is then the ratio of the dynamic loading to the static loading or (g+/–"a")/g, where "a" is the incremental +/- acceleration akin to the feeling when an elevator stops (+ve loading acceleration) or drops (–ve loading acceleration).

For most mining operations $1.1<x_t<1.4$. As an example, soft rock operations, such as oil sand or laterite mining frequently exhibit x_t~1.2 to 1.3, accounting for road design loads 30% higher than conventionally assumed. The charts below show examples for hard and soft rock mining operations where operations are attentive to operating conditions and have a reduced x_t impact.

Tires are subjected to varying loads both directly proportional to the load balance in the hauler body at the excavator, the ground conditions; and the hauler motions



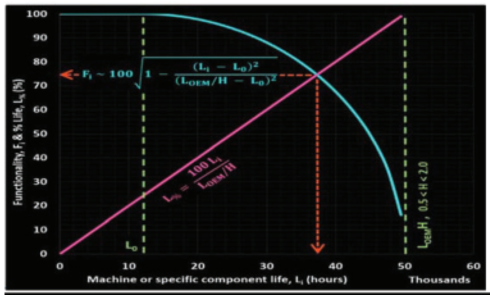
Distribution of tire-ground load level multipliers for a hard rock operation that then impact road profile thickness design as a function of traffic and road life, but also generate high loads on the hauler.

Distribution of tire-ground load level multipliers for a soft rock operation that then impact road profile thickness design as a function of traffic and road life, but also generate high loads on the hauler.

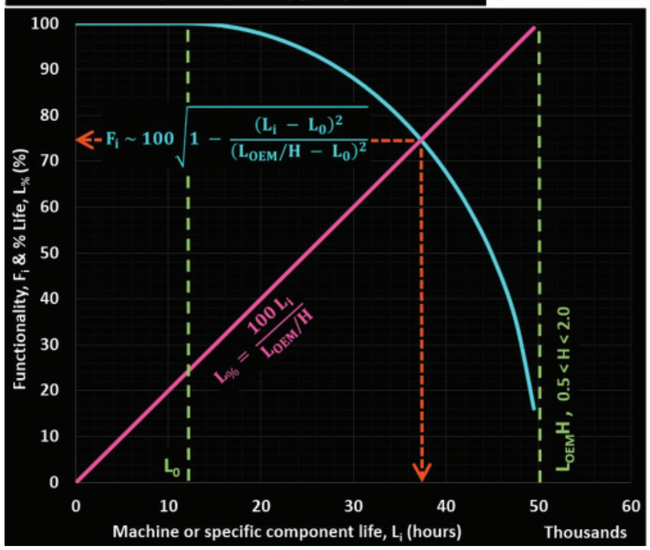
initiated by both. The outcomes are much higher loads between the tire and ground than anticipated through conventional mine road design even to present day; faster road deterioration rates, increasing rolling resistances, lower road and hauler productivity, higher fuel consumption and lower tire life. The connection between off-the-road (OTR) tire performance, roads and hauler and it's components' asset life is evident whether measured from the hauler, the road or the tire itself.

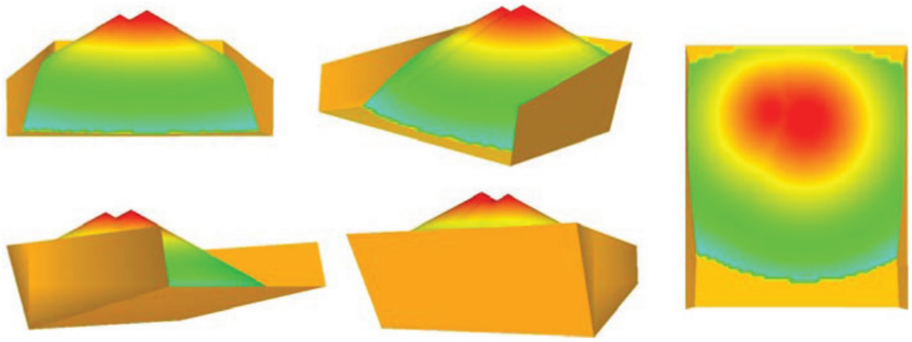
How do you decide when to pull equipment from operations for maintenance, change a component, and repair a crack, or even to lubricate? Losing an asset by leaving those decisions too late; tempting the fate of the P-F curve, conventionally built on operational/maintenance experience (MTTF and MTBF analytics), but very often the loss of asset functionality becomes so rapid that catastrophic failure, with a chain of components 'falling like dominoes', is hard to avoid. This is where we need a decision-making process to decide when to take corrective actions, effectively between the point of significant performance divergence, traditionally termed the "point of potential failure" and the point of "loss of full functionality". Essentially, how long should we continue to operate an asset, putting off maintenance intervention, before the risk of catastrophic failure and loss of the entire asset is a very real prospect.

Every operation is different, imposing varying levels of 'harshness', 0.5<H<2.0, relative to the expected original equipment manufacturer (OEM) component or entire asset life, assured by the OEM, (L OEM), such that H>1 expresses a level of harsh operation/environment over that anticipated by the OEM. H may be expressed relative to the time of initial loss of asset/component functionality, Lo, or relative to the observed operating conditions. You can generate your own site specific P-F curves for any asset from the L OEM, H, and Lo. The P-F example shows a L OEM~60,000 hr asset, operating in a H~1.2 environment (reducing the maximum asset life to 50,000 hours). Lo~12,000 hours. The P-F indicates changing the component at Li~37,300 hours when



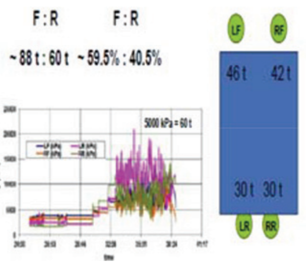
The range limits of the performance – functionality P-F curve are expressed as initial functionality at commissioning to complete loss of functionality as a function of the harshness of the operating environment.

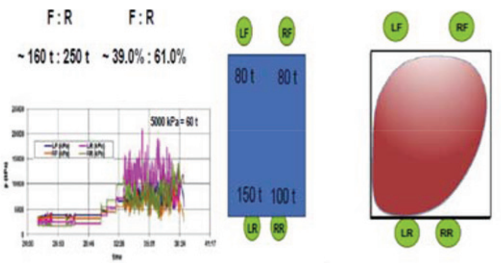




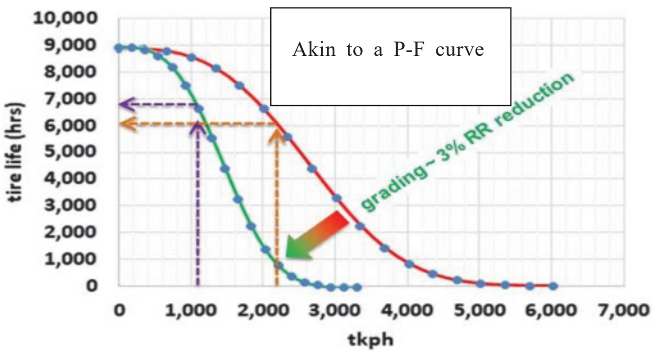
Example above is a 4 pass load from an excavator into the body of a hauler that appears centred, but in fact overloads the front tire – ground contacts.

functionality is reduced by 25.4%, Fi~74.6%.



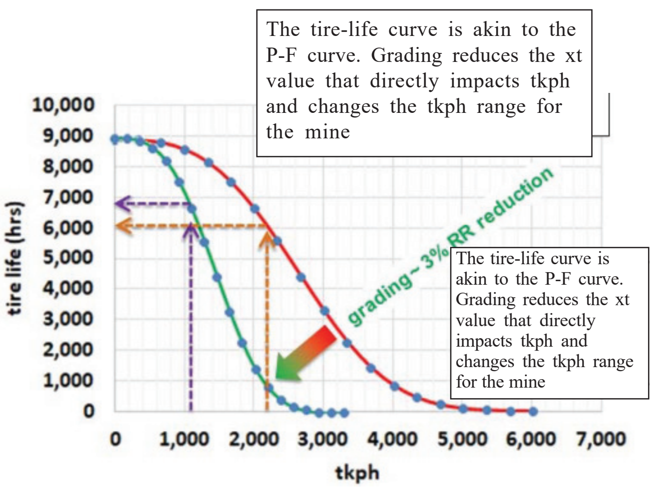


The tire life – tkph curve is a variation of the P-F curve, where the impact of loading condition on the tires is captured as a 'real-time' tonne-kilometre-per-hour (tkph) monitoring relative to the load on the tire (enhanced by x_t). Functionality may be measured as tire wear rates, ability to maintain performance for a given air and belting temperature and/or in relative comparison to previous site specific functionality.



Reducing the impact on tires may be directly correlated to the degree of grading power used to maintain haul roads. But … What is the actual benefit of grading roads to operational tire life?

1. Housekeeping grading will always reduce tire fabric (crown and sidewall) cut damage situations. But...
2. Consistent grading will always reduce rolling resistance, reduce tkph and increase tire life. Hauler motions affecting maintenance and Running surface deterioration are all related to body load balance, load angle of repose and loose density, and the bearing capability of the road which changes with increasing loading hauler round trip cycles. It is the classic chicken - egg scenario. Adverse hauler motions from imbalanced loads cause faster road deterioration while poor road quality causes hauler adverse motions. The result equals lower tire life and lower hauler availability, higher fuel use and emissions and greater maintenance costs. In oil sands operations, as an example, grading reducing rolling resistance by 3% can correspond to a 50% decrease in mine tkph as a performance metric and increase tire life by ~750 hours.



Another discussion I think – a little more complex as need to account for unsuspended load which has an odd distribution.

Payloads with different angles of repose and of different broken rock density create front to rear axle payload distributions with a wide range; that more than anything impact the loading and life of tires. It cannot be assumed that a rock density of 2.0 t/m^3 and pile slope of 2:1. What if both varied by 40% which is within the range of operating conditions. In its simplest terms, the primary goal when designing a truck body for a mine site is that the target payload is achieved with optimum axle splits. Provided the body is loaded correctly, the density and slope of the material will not influence axle splits. The only concern with varying densities on site is the potential for overloading the truck itself, which must be managed by having strict loading behaviors.