Tyre performance limits

In the July article, I considered the forces that are needed for a semi-trailer combination to safely go around a curve. The tyres generate the forces at the road level, so it is important for us to understand what the force limits are for tyres.

Each tyre generates forces and torques at the contact patch, as illustrated below. They are reactions in response to the forces and torques that the vehicle imposes on the tyre. The tyre performance is defined by the maximum forces and torques that it can generate. There are corresponding reaction forces and torques in the roadway. Pavement engineers talk about pressures and micro strains that occur for various tyre sizes and loads and predict the damage levels that will occur.

The braking (or slip) coefficient of a tyre describes the longitudinal (braking and traction performance). If the wheel is braked or driven, it turns at a slightly different speed from the free-running wheel. That is, it 'slips'. A free-running tyre has zero slip and a locked up tyre has a slip of 100 per cent. Figure 2 illustrates typical slip curves for a tyre on a 22.5″ truck rim.

The peak braking forces occur when the wheel slip is about 15 per cent. Above this slip the tyre locks up. If the tyre locks up the braking force is about 60 per cent of the peak, so best performance occurs with the wheel rotating. An Antilock ABS tries to do this. Current generation Electronic Brake Systems (EBS) are smarter again because they attempt to limit the wheel slip to about 10 per cent during braking to prevent getting into the ABS modulation domain (which is about 15 per cent wheel slip).

Notice also that the lateral (steering) force capability reduces as the wheel slip increases. Steering and road handling capability fall off during heavy braking. Not shown in Figure 2, but also true, is that the peak braking forces fall off when the tyre is steering. At a steering angle of 6° the tyre can produce only about ¾ of its straight-line braking (or traction) forces.

The limiting road-handling force limits of a tyre for an 11R22.5 truck tyre are illustrated in Figure 3. Again optimum tyre pressure is assumed. Performance varies with slip angle (which is the angle between the direction between the tyre is direction and the vehicle direction. The slip only goes above 2° during emergency evasive manoeuvres.

The truck operator will be interested in the rolling resistance, which is determined by the longitudinal (drag) force Fx under normal running (without braking). As the tyre rolls through the contact patch it distorts, which causes heating of the rubber. The greater the heat per turn the greater the rolling resistance. Low rolling resistance tyres have construction features and use rubber compounds that reduce the heat generated per turn. There can be a correlation between low rolling resistance and low side-wall strength.

The side force Fy and the aligning torque Tz performance of the tyres need to be accurately known for simulation of the Performance-Based Standards (PBS) transient high-speed off tracking test (which is a lane-change manoeuvre). Experience has shown that A-type PBS combinations (such as tipper and dog or road-train A-doubles) must use tyres with superior lateral force and aligning torque characteristics to meet the PBS standards.

Most truck and trailer tyres used in Australia are now certified to meet the UN ECE Regulation 54. They carry the circle symbol Ex where x identifies the certifying country. This regulation specifies standard sizes, construction features, load ratings and endurance requirements. It does not specify minimal lateral force, aligning moment performance or maximum rolling resistance. Tyres are no longer formally certified in Australia and the old design rule, ADR 24 has been dropped. It is now clear that Australia needs a new 'tyre regulation' for the PBS scheme to allow any tyre model in an accredited group to be used on PBS vehicles.

It is interesting that the Californian government has mandated use of low rolling resistance tyres on long-distance rigs operating in California. In the USA it is the US EPA that certifies rolling resistance performance.

Correct tyre pressure for the load is a crucial factor in achieving the potential maximum tyre performance. Manufacturer's performance curves usually assume that the tyre pressure is optimum. If tyre pressure is set for maximum load that the tyre will be over-inflated for the unloaded vehicle. This can result in a ~ 20 per cent decrease in performance parameters. Tyre-life loss can be even greater.

There is a strong case for using a correctly set Central Tyre Inflation System (CTI) on modern trucks. Finally, there is some interest in the use of wide-based tyres in Australia.

I recently saw a 445 / 50R 22.5 tyre fitted as a drive tyre. This tyre size has a low rolling resistance. It also has lower side-force Fy capability compared with a dual tyre set because it has only two sidewalls and not four. Road agencies do not give wide-based tyres any privileges so the maximum axle weight rating that can be legally used is 7 tonne. There has been controversy about the level of road damage that a wide-based tyre produces compared with a dual-tyre set. The research has shown that the level of road damage from a wide-base tyres is about the same as for a dual wheel set. The real issue is the trade-off between rolling resistance and side-wall stiffness i.e. road handling ability.

For further information see the ARTSA Brake Code at www.artsa.com.au.

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Figure 1

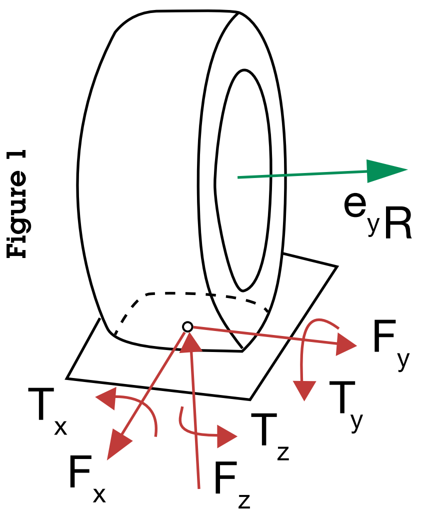


Figure 1: Tyre forces and torques

F_x	**Longitudinal Force**	- Braking/ traction
F_y	**Lateral Force**	- Steering/ handling
F_z	**Vertical Force or Wheel Load**	- Weight
T_x	**Tipping Torque**	- Rollover
T_y	**Rolling Resistance Torque**	- Rolling losses
T_z	**Self-aligning and Bore Torque**	- Handling

Figure 2: Typical tyre slip curve for a truck on a 22.5" rim

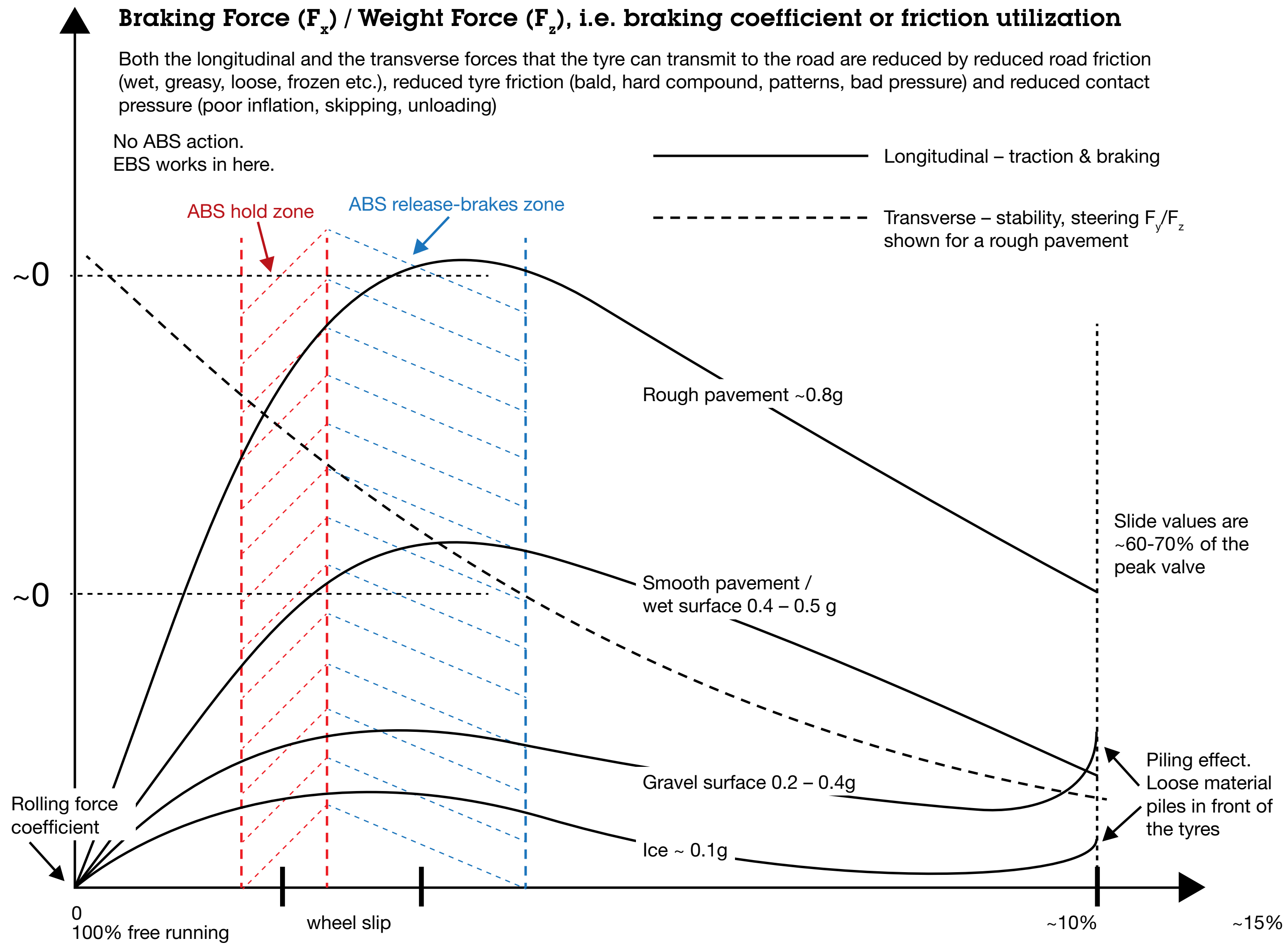
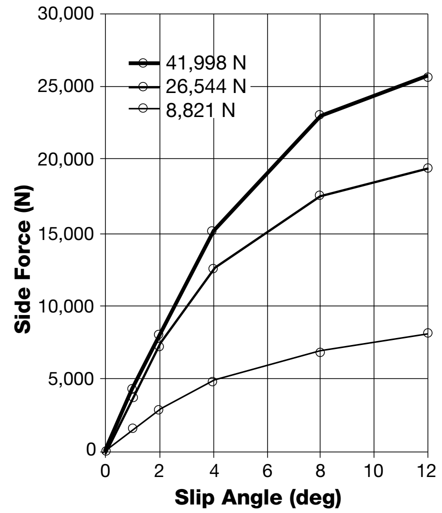


Figure 3



Side force F_y versus heading (slip) angle for three loads.