3.3 Basics of Automotive Vehicle Braking

It is necessary to have knowledge of the technology correlated with contemporary auto-motive vehicles’ BBW AWB dispulsion to understand the wheel-tyre to on/off-road interface, vehicle dynamics during braking, and the components of a BBW AWB dispulsion mechatronic control system. This section examines these issues to enhance the level of that knowledge.

3.3.1 Wheel-Tyre to On/Off-Road Interface

The longitudinal frictional braking force generated at each wheel of an auto-motive vehicle during a braking manoeuvre is a function of the normal force on the wheel and the coefficient of friction between the wheel-tyre and the on/off-road surface. The relationship between the mass on wheel and the resultant longitudinal frictional braking force is exposed in Eq. (3.1).

$$ F_x = \mu_x \text{sgn}(x) \frac{m_w}{g} $$

where
- $F_x$ - resultant frictional braking force in the $x$-axis longitudinal direction [N];
- $\mu_x$ - wheel-tyre to on/off-road longitudinal coefficient of Coulomb friction in the $x$-axis longitudinal direction;
- $m_w$ - static and dynamic mass on the wheel [kg];
- $g$ - acceleration due to gravity [m/s²];
- $x$ - displacement in the $x$-axis longitudinal direction [m].

![Fig. 3.5 Coulomb friction versus percentage wheel-tyre slip on various on/off-road surfaces](image)

Fig. 3.5 Coulomb friction versus percentage wheel-tyre slip on various on/off-road surfaces [RACELOGIC; THOMAS 1998].

The wheel-tyre to on/off-road longitudinal coefficient of Coulomb friction is not a constant but is a function of factors, well known as being a kind of on/off-road surface and the comparative longitudinal slip between the wheel-tyre and the on/off-road. Particular curves describing wheel-tyre to on/off-road longitudinal coefficient of Coulomb friction as a function of wheel-tyre slip on various on/off-road surfaces are shown in Figure 3.5 [THOMAS, 1998].

From Figure 3.5 and Eq. (3.1), the following statements are induced [THOMAS 1998]:

- The existence of longitudinal frictional braking forces depends on wheel-tyre slip; if the wheel-tyre is rolling at the same tangential velocity as the on/off-road surface then there is no longitudinal frictional braking force; this relationship is essential in appreciative braking and is not easily seen wheel-tyre slip other than near 100% (no wheel angular velocity) is hard to detect without mechatronic devices;

- The peak value of the longitudinal frictional braking force takes place under circumstances of comparatively little slip; this shows that violent use of frictional FMBs, PMBs, EFMBs, EPMBs, or EMBs that initiates a 100% slip usually does not generate the most frictional braking force and a uniformly modulated, controlled brake fluid or air pressure, or brake voltage, respectively, affected by a skilled driver or because the ABS has a tendency to present shorter stops on nearly all on/off-road surfaces;

- The longitudinal frictional braking force created alters significantly with different on/off-road surfaces; the effect of this relationship is apparent to both driver and passengers in terms of stopping distance and deceleration if dry asphalt braking is contrasted with braking on ice;

- Usually, beyond the peak value of friction coefficient achievable on a specified on/off-road surface, the slope of the curve becomes negative; this observable fact (in a basic manner demonstrating that, beyond the slip ensuing in the peak value of frictional braking force, additional brake-pedal force ensues in less braking) explains why a skilled driver can obtain shorter stopping distances than can a less skilled driver and why a mechatronically-controlled ABW BBW dispulsion mechatronic control is as sophisticated as it is; also, the amount of ‘peak value’ in the coefficient of friction curves alters significantly with different on/off-road surfaces; additional gain in longitudinal frictional braking force can be obtained because of slip control on on/off-road surfaces such as ice rather than on dry asphalt, for instance.

An additional feature of an automotive vehicle’s rubber wheel-tyres of great consequence in braking is lateral frictional brake force versus wheel-tyre slip.

Lateral frictional brake force is the force preventing a wheel-tyre from sliding in a direction normal to the direction of the vehicle.