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Lateral slip and side force

Vehicle dynamics

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Lateral slip

Slip is the relative motion between a tire and the road surface it is moving on. This slip can be generated either by the tire's rotational speed being greater or less than the free-rolling speed, or by the tire's plane of rotation being at an angle to its direction of motion.

The lateral slip of a tire is defined by the sideslip angle, which is the angle between the direction it is moving and the direction it is pointing. This can occur, for instance, in cornering, and is enabled by deformation in the tire carcass and tread. Despite the name, no actual sliding is necessary for small slip angles. Sliding may occur, starting at the rear of the contact patch, as slip angle increases.

Sideslip angle can be defined as:

$$\alpha = \tan^{-1}\left(\frac{v_y}{|v_x|}\right)$$

When a vehicle takes a curve, the front part of the tire resists the effect of the curve and practically maintains the direction of rotation. However, the rear part, which supports less pressure, yields to the lateral force and deforms with this sideslip angle by sliding slightly on the asphalt.

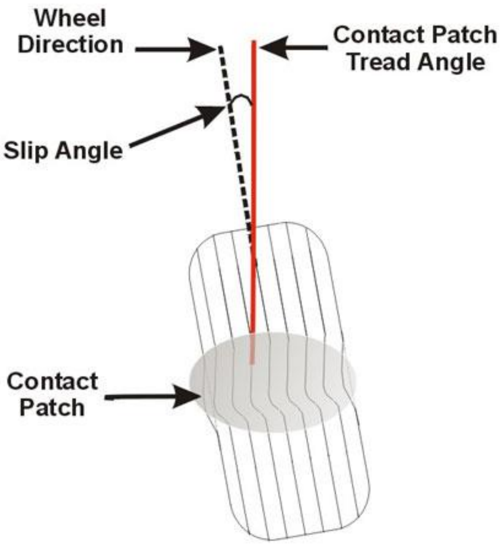

Figure 1: Sideslip angle in a tire

The sideslip angle can be different in the rear tires than in the front when taking a curve, which has certain effects on the direction of the vehicle. The ratios between the slip angles of the front and rear axles (a function of the slip angles of the front and rear tires respectively) will determine the vehicle's behaviour in a given turn. If the ratio of front to rear slip angles is greater than 1:1, the vehicle will tend to understeer, while a ratio of less than 1:1 will produce oversteer.

Relationship between sideslip angle and side force

Tire forces are generated inside the contact patch of the tire and the ground. They are a combination of two factors: friction in the contact patch and elastic deformations of the tire.

The deformation of the rolling surface generates a reaction force in the tire that is precisely the lateral force. By integrating the force generated by each of the treads along the total contact surface, the total lateral force is obtained. In fact, this deformation does not occur exclusively on the tread, but is a combination of the deviation of the tire flank and the tread rubber itself in contact with the asphalt. The exact relationship between the deformation of the flank and the band depends on the construction of the tire and its inflation pressure.

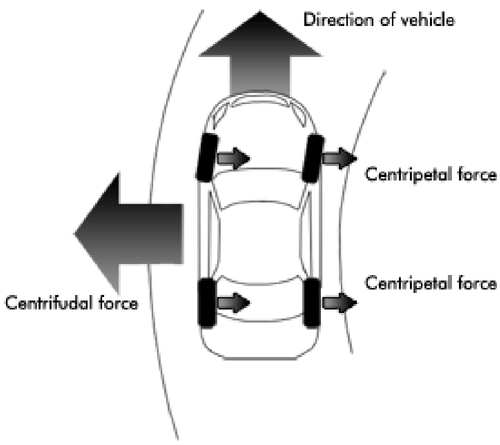

Figure 2: Necessary forces on tires to take a curve

The side force, or cornering force, is a force parallel to the road surface generated by the tires of a vehicle when taking a curve. It is the force generated by the tires to oppose the inertia of the vehicle that when taking a curve would take the vehicle out of its path (Figure 2). It is generated by the static friction of the tires, by means of which they adhere to the road surface to oppose the centrifugal force. The friction depends on the friction with the surface, the load of the tire and its composition. The side force is in the plane of the contact patch and perpendicular to the intersection of the contact patch and the midplane of the wheel. This cornering force increases approximately linearly for the first few degrees of slip angle, then increases non-linearly to a maximum before beginning to decrease.

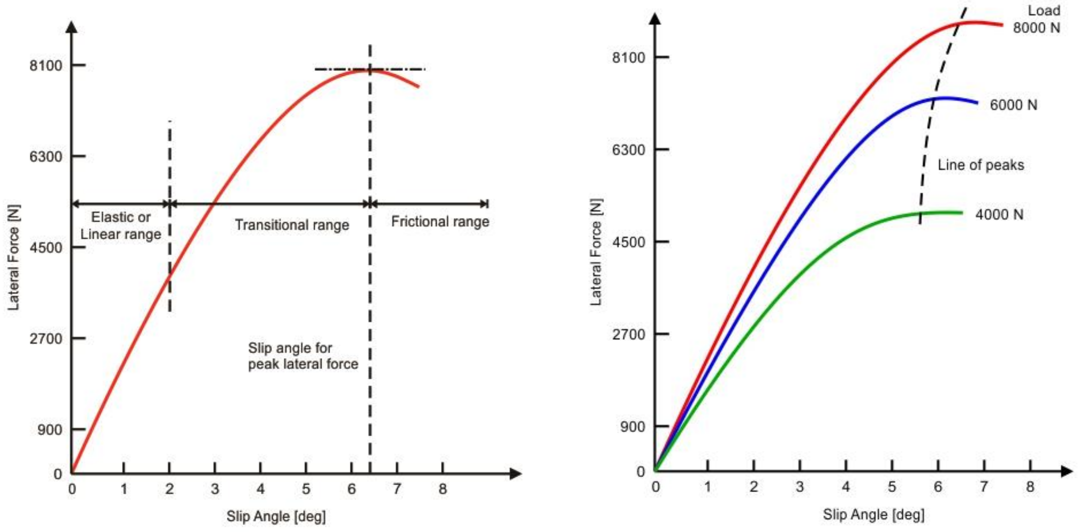

Figure 3: Relationship between sideslip angle and side force (Curve zones and curves according to vertical load)

In Figure 3 we can see the relationship between sideslip angle and the lateral force suffered by the tire. The elastic deformation that the tire undergoes is increased with a constant rhythm along the elastic zone of the curve of Figure 3. However, as we get closer to the maximum of the curve, the tire begins to reach the limit of its elastic capacity, since it cannot be deformed indefinitely. When this starts to happen, the tire will start to slide.

At some point or time when the tire or part of it has begun to slide and where the maximum possible slippage is reached, the lateral force is maximized. When the tire reaches the value of the drift angle that corresponds to the maximum value of Fy, the lateral force, most of the tread in contact with the asphalt is sliding, and therefore, the lateral force exhibiting it is the result of the combination of both elastic friction and sliding.

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