

The diagram illustrates a tire in contact with a surface. A vertical dashed blue line represents the longitudinal center line of the vehicle. A horizontal dashed blue line represents the moving direction of the contact plane (F_x). The tire's spin velocity is indicated by a curved arrow. At the center of the tire contact, several force vectors originate: F_y (green, lateral force), F_x (red, tractive force), and F_z (black, normal force). The angle between the moving direction of the contact plane and the normal force vector F_z is labeled α . The angle between the longitudinal center line of the vehicle and the tractive force vector F_x is labeled γ .

Legend:

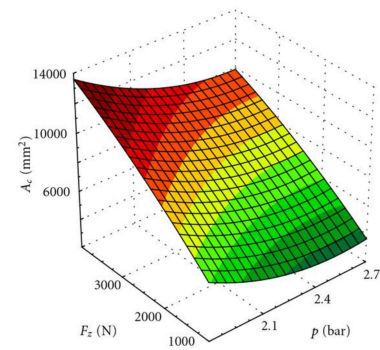
- α - Slip angle
- γ - Steering angle
- F_x - Tractive force
- F_y - Lateral force
- F_z - Normal force



A detailed cross-sectional diagram of a tire, illustrating its internal structure. The diagram is color-coded and labeled with various components. The tread is shown in black with a pattern of grooves. The sidewall is a lighter gray. The inner liner is a pinkish-red layer. The carcass is a yellow layer. The apex is a small red dot. The bead bundle is a red layer. The chaffer is a small red dot. The RFLT is a small red dot. The cap ply is a small red dot. The shoulder is a small red dot. The sidewall is a small red dot. The labels are: TREAD, GROOVE, CAP PLY, SHOULDER, SIDEWALL, INNER LINER, CHAFFER, RFLT, CARCASS, APEX, BEAD BUNDLE.

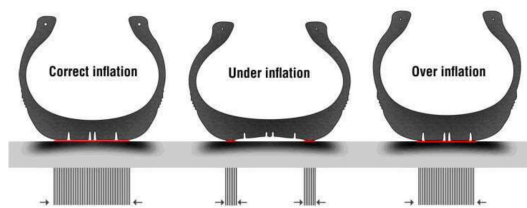


- The area of the tyre in physical contact with the ground
- The contact patch changes shape and size depending on various factors, such as
 - Tyre dimensions
 - Pressure – internal air (gas) pressure.
 - Vertical loading
 - Tractive effort
 - Lateral loading
 - Wheel attitude



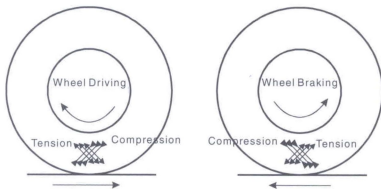
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CONTACT PATCH

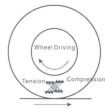


BASIC TYRE FORCES - TRACTION

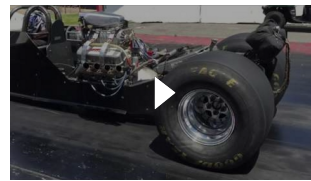
- Sidewalls in shear due to traction / drive forces



BASIC TYRE FORCES - TRACTION

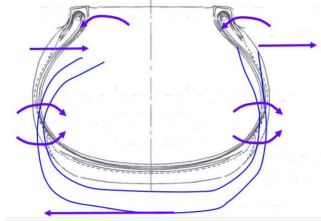


[Dragster slow motion tire wrinkle](#)

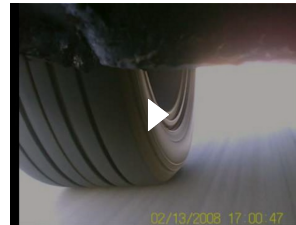


BASIC TYRE FORCES - CORNERING

- Sidewalls in bending due to lateral forces
- Beads react moments as well as forces



[tyre deflection wmv](#)



CARCASS DISTORTION

- The tyre does distort and deform when reacting the forces we demand of it.
- In a performance event the continual stretching and relaxing of the rubber can lead to heat build up. In extreme causing a blow out.
- However there is an 'optimal' temp for the tyre to work at.
 - Summer tyres/winter tyres
 - Race tyre warm up and monitoring



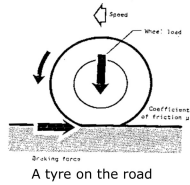
[Overlay of Tire Temperature and Wheel Loads at VIR – Ize-Racing](#)



FRICTIONAL FORCES

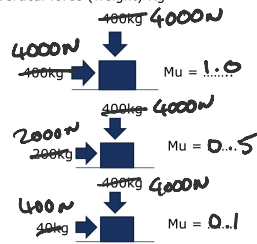
Coefficient of friction - μ

$$\mu = \frac{\text{Horizontal force (push) Kg}}{\text{Vertical force (weight) Kg}}$$



A tyre on the road

*Tyres can achieve $\mu > 1.0$!
Racing tyre $\mu \approx 1.4 - 1.6$.*



$$F = \mu R.$$

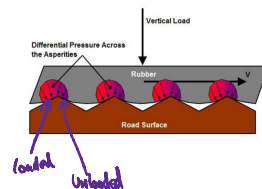
FRICTIONAL FORCES

- Several mechanisms for generating 'frictional' forces
 - hysteresis
 - adhesion
 - tearing



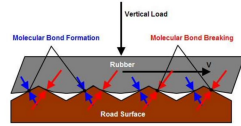
FRICTIONAL FORCES

- Hysteresis
 - dominates "real world" tyre grip on uneven (textured) surfaces
 - generates pressure differential between loading and unloading faces of rubber
 - also known as "mechanical keying"
 - high level of damping (hysteresis) in compound promotes grip on textured surfaces
 - sensitive to sliding velocity and road texture
 - insensitive to lubrication (liquid, powder)



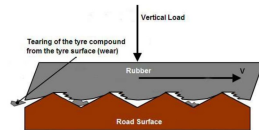
FRICTIONAL FORCES

- Adhesion
 - “momentary molecular bonding” between tyre and road
 - uses “residual electrostatic forces”
 - primary mechanism for “rubber on glass” friction
 - “tops up” grip for dry, unlubricated surfaces
 - highest at very low sliding velocities



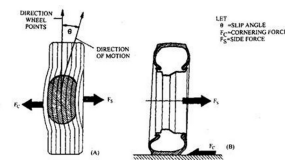
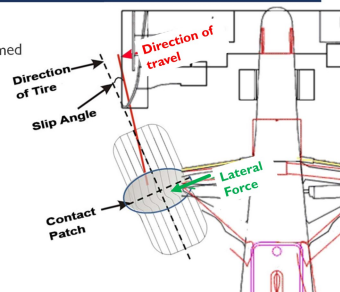
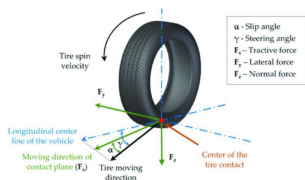
FRICTIONAL FORCES

- tearing
 - physical limit of rubber cohesion
 - surface of rubber dragged away from body
 - deposits on road ("skid marks"), rubber dust on bodywork, tyre graining
 - responsible for tread wear, always occurring to some extent



SLIP ANGLE - CORNERING

- Slip Angle
 - When cornering the rubber tyre is deformed



From https://www.google.com/search?q=tyre+contact+patch+vertical+loading&source=lnms&tbm=isch&sa=X&ved=2ahUKEw8qKcIqXnAhUjB5hUBHUXnDMoQ_AUJoAXoECAwQAw&biw=1730&bih=871

[Slip Angles - Tire Traction - Explained](#)
Engineering Explained

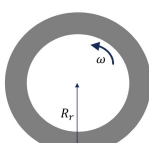


Explained: Tire Slip Angle



SLIP RATIO – LONGITUDINAL

- Slip Ratio Definition

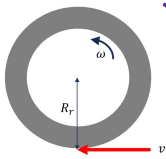


$$v = \omega r$$



SLIP RATIO – LONGITUDINAL

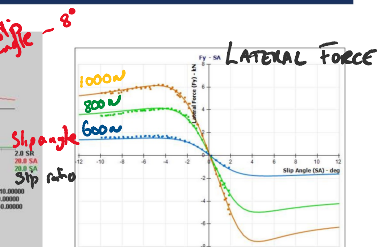
- Slip Ratio Definition



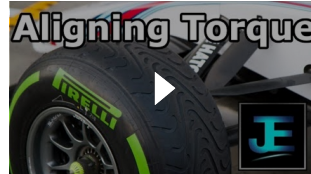
$$\text{Slip Ratio} (\%) = \left(\frac{\omega \times R_r}{v} - 1 \right) \times 100$$



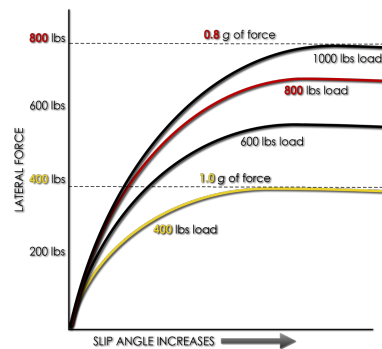
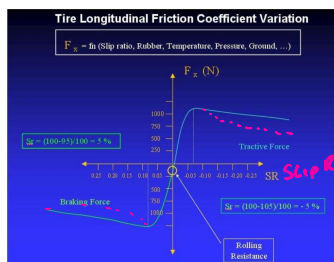
TYRE CHARACTERISTICS



Explained: Aligning Torque

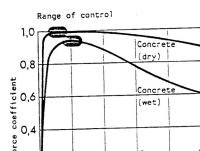


TYRE CHARACTERISTICS

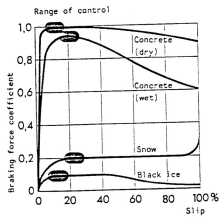


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FRICTION

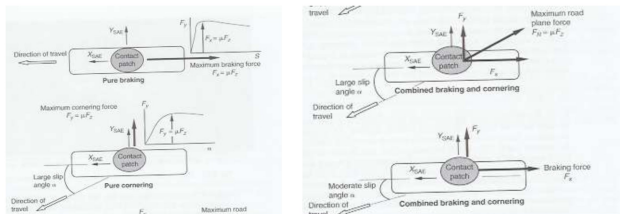


FRICTION

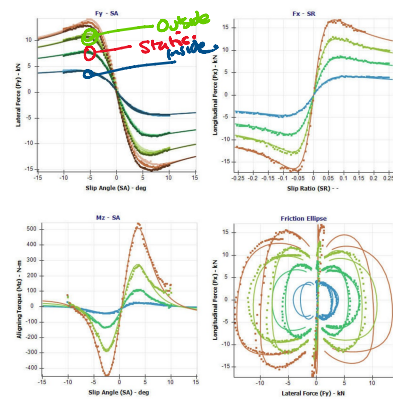
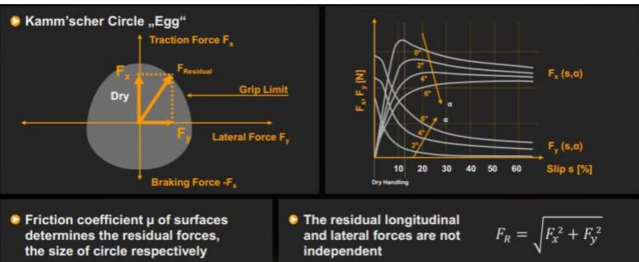


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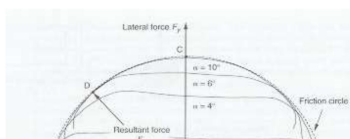
COMBINED FORCES



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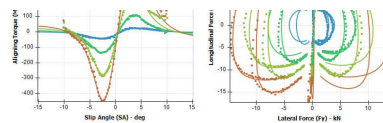
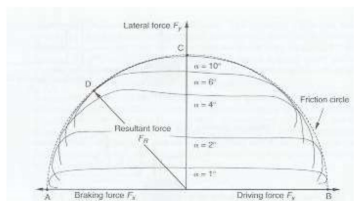

$$\frac{Mah}{t} = \text{HAND TRANSFER.}$$

COMBINED FORCES



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COMBINED FORCES



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