240206 – Q1
Power electronics and electrical machines application in electrical mobility and industry

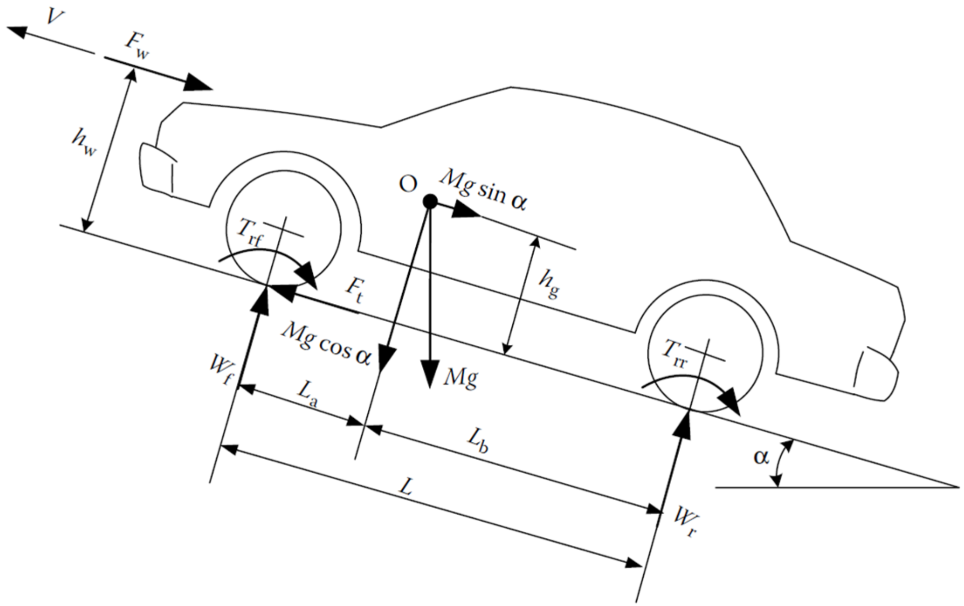
Master's degree in Electric Power Systems and Drives

Daniel Montesinos-Miracle
(daniel.montesinos@upc.edu)
Daniel Heredero-Peris
(daniel.heredero@upc.edu)

Lab 1. Vehicle model

- Objectives
  - Develop a model for the vehicle dynamics
  - Evaluate the vehicle for the required performance
- Main parameters to observe
  - Forces, power and energy for each force
  - Total force, power and energy
  - Evaluate forces, power and energy at performance requirements
  - Differences when recovering or not braking energy in an NEDC cycle

Forces in a vehicle



- F_a: aerodynamic friction losses
- F_r: rolling friction
- F_g: hill climbing force
- F_t: tractive force

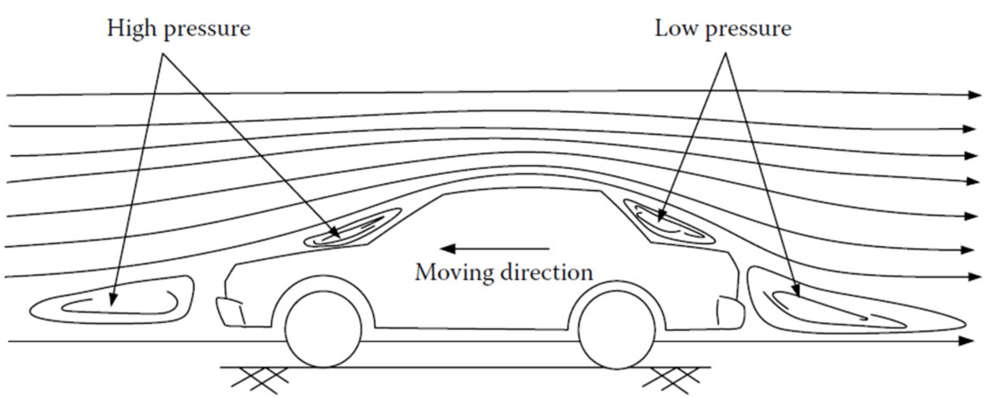
$$Ma = F_t - \left(F_w + F_r + F_g\right)$$

Aerodynamic friction losses

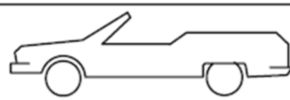
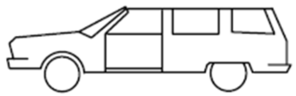
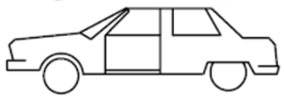
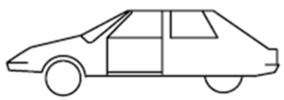
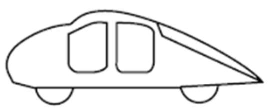
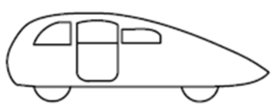
- Two origins
  - Viscous friction of surrounding air
  - Pressure difference in front and rear

$$F_w(v) = \frac{1}{2}\rho A_f c_d \left(V - V_w\right)^2$$

ρ: air density
A_f: frontal area
c_d: aerodynamic drag coefficient
V: vehicle speed
V_w: wind speed

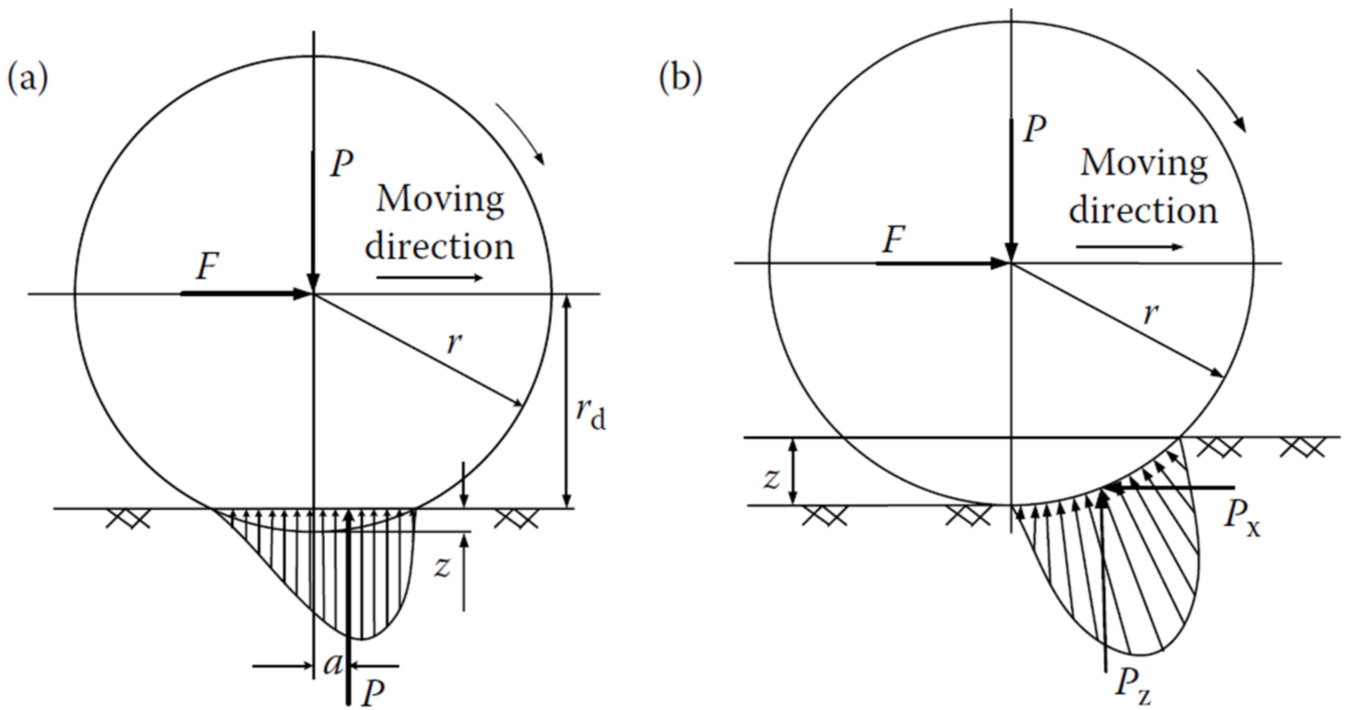


Aerodynamic drag coeficient

Vehicle type		Coefficient of aerodynamic resistance
	Open convertible	0.5…0.7
	Van body	0.5…0.7
	Ponton body	0.4…0.55
	Wedged-shaped body; headlamps and bumpers are integrated into the body, covered underbody, optimized cooling air flow	0.3…0.4
	Headlamp and all wheels in body, covered underbody	0.2…0.25
	*K*-shaped (small breakaway section)	0.23
	Optimum streamlined design	0.15…0.20
Trucks, road trains		0.8…1.5
Buses		0.6…0.7
Streamlined buses		0.3…0.4
Motorcycles		0.6…0.7

Rolling friction

- Due to hysteresis of tire material



On hard road surface

On soft road surface

Rolling friction

- Depends on many factors: vehicle speed, tyre pressure, road surface conditions

$$F_r = f_r M g \cos(\alpha), \quad V > 0$$

f_r: rolling friction coefficient

M: vehicle mass

g: gravity constant

α: road slope

Rolling Resistance Coefficients

Conditions	Rolling Resistance Coefficient
Car tires on a concrete or asphalt road	0.013
Car tires on a rolled gravel road	0.02
Tar macadam road	0.025
Unpaved road	0.05
Field	0.1–0.35
Truck tire on a concrete or asphalt road	0.006–0.01
Wheel on iron rail	0.001–0.002

- Accepted speed dependence for most situations

$$f_r = 0.01\left(1 + \frac{V}{160}\right), \quad V < 128 \text{ km/h}$$

Hill climbing force

- Conservative
- Great influence on vehicle dynamics

$$F_g = Mg\sin(\alpha)$$

M: vehicle mass

g: gravity constant

α: road slope

Performance required

Performance target/unit	Target value
0 to 100 km/h	5,9 s
Maximum speed	120 km/h, at 0% grade
Grade at 80 km/h	7,2 %
Maximum grade	33 %, at 5 km/h
NEDC cycle	-

Vehicle parameters

Parameter	Mid-size car
Vehicle mass (m_v)	1000 kg
Tyre effective rolling radius (r_w)	0,26 m
Reduction gear (k_{gear})	5
Drag coeficient (C_d)	0,35
Frontal area (A_f)	2 m^2
Rolling resistance coeficient (f_r)	0,017
Air density (ρ)	1,22521 kg/m^3
Gravity constant (g)	9,8 m/s^2

Lab 2. Motor, converter and control

- Objectives
  - Implement a dynamic model of the complete vehicle (except the battery) including motor and control loops
  - Evaluate the performance requirements with the given vehicle and motor
- Main parameters to observe
  - Control Loop performance
  - Motor and converter limits vs. performance required
  - Propose adequate performance

Motor parameters

Parameter	Value
Rated power (P)	32 kW
Rated voltage (V)	400 V
Rated current (A)	89,5 A
Rated speed (rpm)	2840 rpm
Maximum speed (rpm)	6000 rpm
EMF constant (k_Φ)	1,2396 Vs/rad
Winding resistance (r_a)	0,35 Ω
Winding inductance (L_a)	6,5 mH