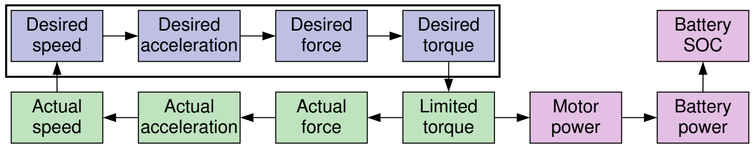
Desired acceleration force

- In this lesson, you'll learn how to model first four boxes:



- Detail: Calculate vehicle desired acceleration $[\mathrm{m\,s^{-2}}]$ as

$$\text{desired acceleration} = (\text{desired speed } [\mathrm{m\,s^{-1}}] - \text{actual speed } [\mathrm{m\,s^{-1}}])/(1\ [\mathrm{s}])$$

- Compute net desired acceleration force $[\mathrm{N}]$ at the road surface

$$\text{desired acceleration force} = \text{equivalent mass [kg]} \times \text{desired acceleration}$$

Equivalent mass

- Equivalent mass $[\mathrm{kg}]$ combines maximum vehicle mass $[\mathrm{kg}]$ and equivalent mass of rotating inertias $[\mathrm{kg}]$

$$\text{equiv. mass} = \text{maximum vehicle mass} + \text{rotating equiv. mass}$$

$$\text{rotating equiv. mass} = ((\text{motor inertia} + \text{gearbox inertia}) \times N^2 + \text{number of wheels} \times \text{wheel inertia})/(\text{wheel radius})^2$$

where gearbox ratio N $[\mathrm{u/l}]$ = (motor RPM)/(wheel RPM), gearbox inertia $[\mathrm{kg\,m^2}]$ is measured at motor (not output) side

- Wheel radius $[\mathrm{m}]$ is assumed to be that of the rolling wheel; *i.e.*, taking into account flattening due to load

Two drag forces acting on vehicle

- Four other forces are assumed to act on the vehicle
- The first two of these forces $[\mathrm{N}] = [\mathrm{kg\,m\,s^{-2}}]$ are

$$\text{aerodynamic force} = \frac{1}{2}(\text{air density } \rho\,[\mathrm{kg\,m^{-3}}]) \times (\text{frontal area } [\mathrm{m^2}]) \times (\text{drag coefficient } C_d\ [\mathrm{u/l}]) \times (\text{prior actual speed } [\mathrm{m\,s^{-1}}])^2$$

$$\text{rolling force} = (\text{rolling friction coefficient } C_r\ [\mathrm{u/l}]) \times (\text{max. vehicle mass [kg]}) \times (\text{accel. of gravity } [9.81\ \mathrm{m\,s^{-2}}])$$

- Rolling force is computed to be zero if prior actual speed is zero

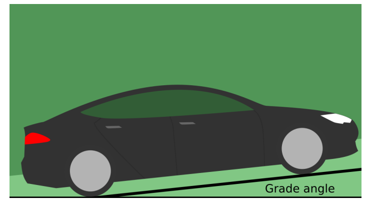
Two more drag forces acting on vehicle

- Remaining two forces acting on vehicle are

$$\text{brake drag} = \text{constant road force}$$

$$\text{grade force} = (\text{maximum vehicle mass [kg]}) \times (\text{accel. of gravity } [9.81\,\mathrm{m\,s^{-2}}]) \times \sin(\text{grade angle [rad]})$$

where grade angle is present (or average) slope of road (positive is an incline, negative is a decline)

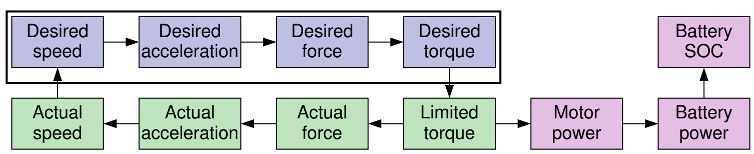


Computation of demanded motor torque

- Can now compute desired demand torque at motor

$$\text{demanded motor torque [N m]} = \text{wheel radius [m]} \times (\text{desired acceleration force} + \text{aerodynamic force} + \text{rolling force} + \text{brake drag} + \text{grade force})/N \text{ [u/l]}$$

- Have now completed all the computations up to desired/demanded motor torque



Summary

- You have learned how to compute desired motor torque to meet desired speed exactly
  - Compute desired acceleration
  - Compute desired road force
  - Compute desired motor torque
- However, due to motor, battery, drivetrain limitations, cannot always meet the desired torque demand
- Next step is to compute and place limits on achievable torque

Credits

Credits for photos in this lesson

- Truck tire showing rolling radius on slide 2, Pixabay license `https://pixabay.com/en/service/terms/`, cropped from `https://pixabay.com/en/truck-mature-axis-drive-heavy-duty-2917881/`
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Vehicle modeling equations are from T. Gillespie, *Fundamentals of Vehicle Dynamics*, Society of Automotive Engineers Inc, 1992