TECHNOLOGIES FOR AUTONOMOUS VEHICLES

VEHICLE DYNAMICS

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Case study vehicle

- A car maker has asked a small consultancy firm to carry out some preliminary simulations of the expected longitudinal performance of a new **rear-wheel-drive electric passenger car**
- The expectation is that the model considers the **longitudinal motion of the vehicle body, front and rear wheel rotations, and the wheel slip, electric powertrain, and friction brake dynamics**, including the effect of the **longitudinal load transfers** in acceleration and deceleration
- The vehicle has a **single electric machine** with **150 kW peak power**, **310 Nm maximum torque**, and **16,000 rpm maximum speed**
- The car is characterised by a **single-speed transmission** with an overall **10.5:1 gear ratio**, and an **open differential**
- The **pure time delay** (between torque request and motor current variation) **of the electric powertrain amounts to 20 ms**, while the motor torque generation **time constant** is **50 ms**

Case study vehicle

- The **efficiency of the electric motor and inverter** can be assumed to be **0.90** for both traction and regeneration
- The **mechanical transmission efficiency** can be assumed to be **0.95** for both traction and regeneration
- The **torsional stiffness** of each half-shaft is **9000 Nm/rad**
- The usable **battery capacity** is **58 kWh**
- The **nominal battery voltage** is **800V**
- The tyres are **215/50R19**, and their **magic formula coefficients** (version 96) are provided in the **attached file** (Tyre_215_50_19.m), together with the magic formula implementation
- The values of the **tyre rolling resistance coefficients** are **0.009** (term independent from the vehicle speed) and **6.5 x 10^{-6} s^2/m^2** (term to be multiplied by the vehicle speed squared)
- **Reasonable tyre relaxation parameters** should be considered, including their variation as a function of the operating condition of the tyre

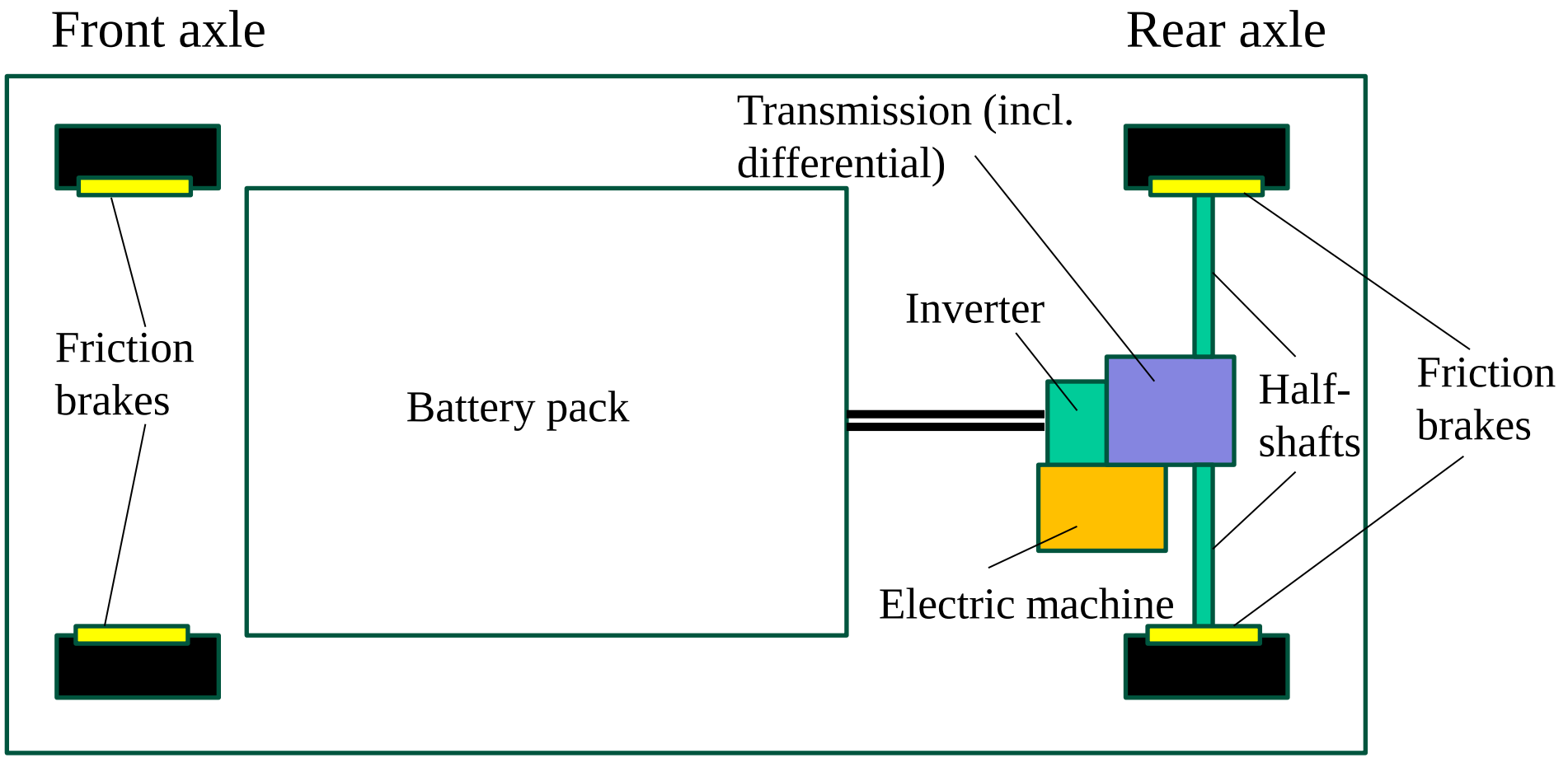
Homework – Section 2

Case study vehicle

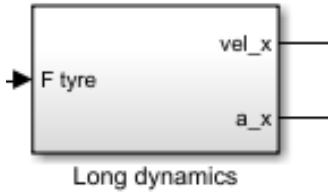
- The **friction brakes** are electro-hydraulic and are seamlessly and **individually controlled**
- The **pressure** – and thus torque – **generation deadtime of the friction brakes** is **20 ms**, while the **rise time** is **25 ms**[1]
- The **static front-to-rear friction brake torque distribution** is **75:25** (for the same pressure level on the front and rear axles)
- The **kerb weight** is **1812 kg**, the **wheelbase** is **2.77 m**, and the **centre of gravity height** is **0.55 m**
- In the same conditions, the **front-to-rear mass distribution** is **50:50**
- The **vehicle frontal area** and **aerodynamic drag coefficient** can be assumed to be **2.36 m²** and **0.27**
- All the other parameters and characteristics can be based on **reasonable assumptions**

[1]D. Tavernini et al., "An Explicit Nonlinear Model Predictive ABS Controller for Electro-Hydraulic Braking Systems," in IEEE Transactions on Industrial Electronics, vol. 67, no. 5, pp. 3990-4001, May 2020, doi: 10.1109/TIE.2019.2916387.

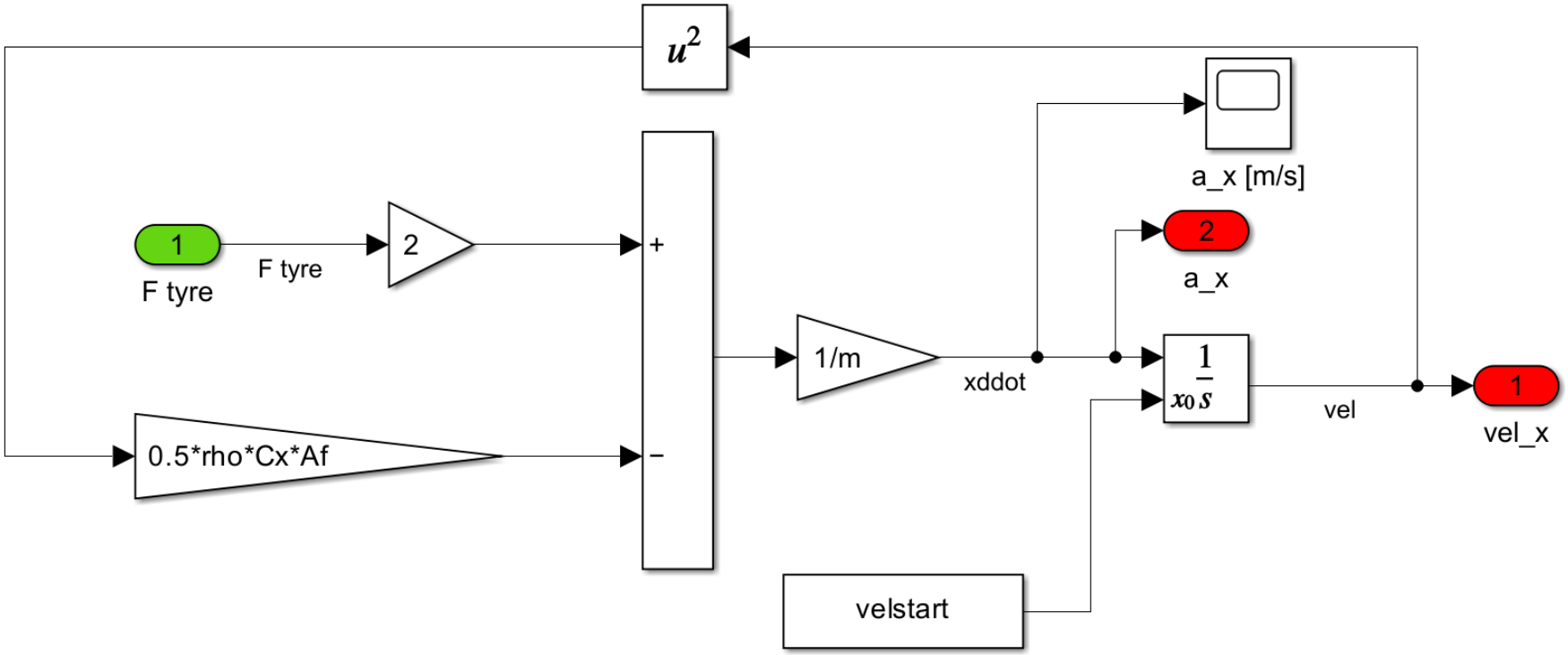
Case study vehicle



Expected outputs – the vehicle model

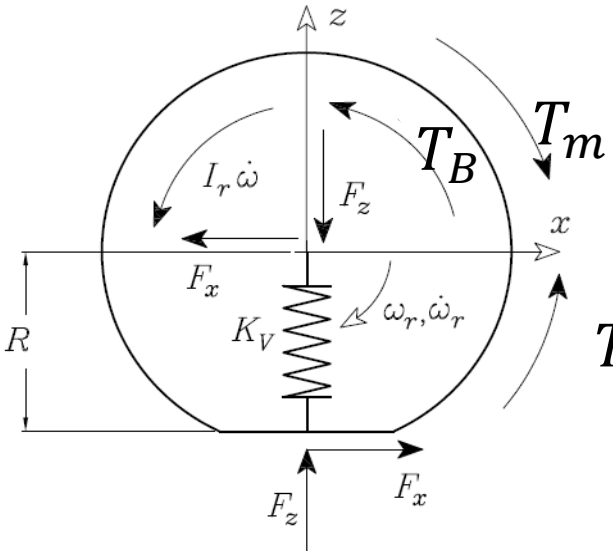


- Vehicle subjected to longitudinal tyre forces
- Vehicle subjected to aerodynamic drag

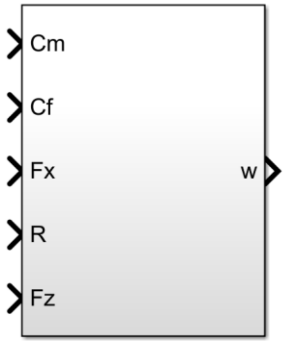


Expected outputs – the vehicle model

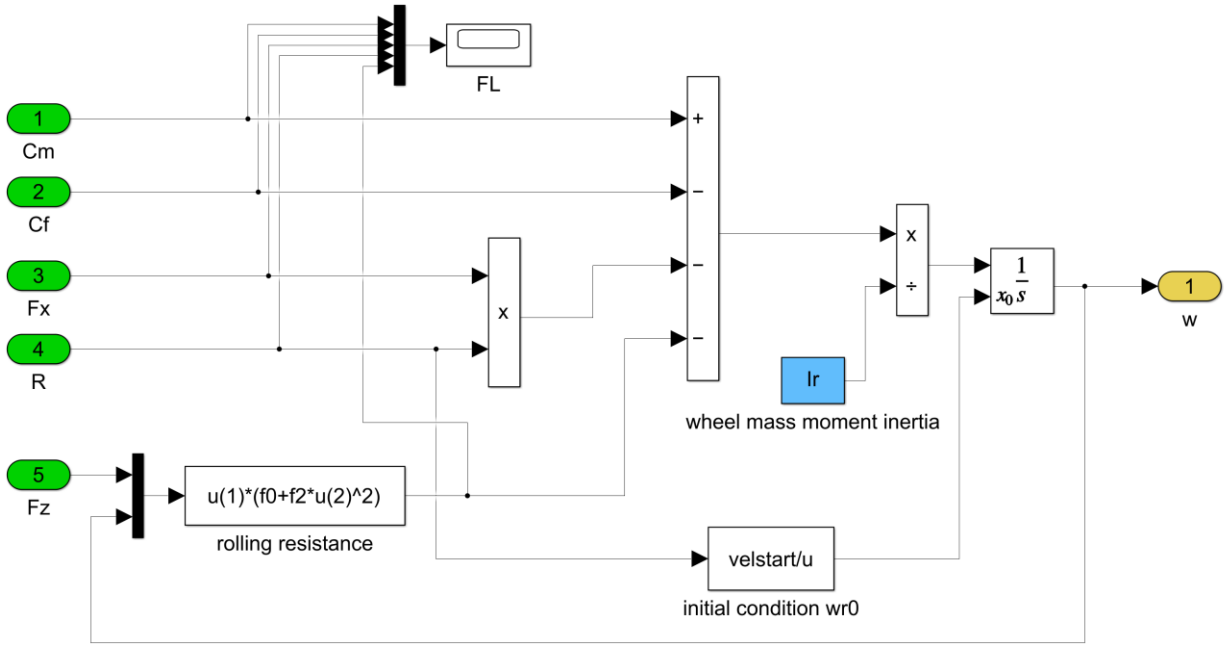
Rotational wheel dynamics



$$\dot{\omega}_r = \frac{T_m - T_B - T_R - F_x R}{I_r}$$



wheel dynamics FL1



Homework – Section 2

Expected outputs – the simulations

- Simulation of a **longitudinal acceleration test** in high tyre-road friction conditions, with potential consideration of the intervention of the traction control system
- Computation of the relevant **acceleration times**
- Computation of the **rolling resistance, aerodynamic drag, electric powertrain, transmission and longitudinal tyre slip power losses** during the same test
- Computation of the **energy consumption** and **achievable range** at different constant speeds, including consideration of the previous power loss contributions
- Execution of **tip-in and tip-off tests** to evaluate vehicle drivability[2]
- Execution of **acceleration and braking tests** to compute the **level of recuperated energy** during the deceleration
- Execution of **emergency braking tests** in dry and wet tarmac conditions, with computation of the **resulting stopping distances**, and the potential consideration of the **electronic brake distribution (EBD)** and **anti-lock-braking system (ABS) interventions**

[2]Direct yaw moment control actuated through electric drivetrains and friction brakes: Theoretical design and experimental assessment - ScienceDirect

Homework – Section 2

Longitudinal dynamics model and simulations

Concise project report

- Model layout (short description + manoeuvre parameters)
- Outputs (some figures + comments)
- Analysis of main results (e.g., regenerative braking capability, autonomy, etc...)
- Maximum length: 5 pages

Project full (working) model

- Initialization (Matlab script)
- Simulink model
- Results analysis (Matlab script)

Assessment details

- Submission deadline: 9 June 2024
- Discussion at the end of the module, before the exam session