Computational analysis of Formula Student car and control dynamics

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Project Aims:

- Develop and implement a computer-simulation to aid design decision making and provide performance estimates.
- Create a base model to be developed by the Formula Student team in future.

1. Longitudinal Vehicle Model:

During pure longitudinal acceleration the vehicle motion can be described by

$$F_x - F_{Drag} - F_{RR} - mg\sin\phi = ma_x$$

where F_x is the driving force, F_{Drag} is the aerodynamic drag and F_{RR} is the rolling resistance. The driving force is governed by the power-train and tyre dynamics. A schematic of the torque flow within the modelled power-train can be seen in Figure 2. Pneumatic tyre dynamics are highly non-linear and the forces produced can be modelled as a function of Slip ratio and load (see Figure 3). Slip ratio is the normalised velocity difference of the rotational wheel speed and the vehicle speed (in the longitudinal case).

An example result of this model for a 75m acceleration can be seen in Figure 4, which suggests that the vehicle accelerates from 0 to 60 mph in 3.518 seconds.

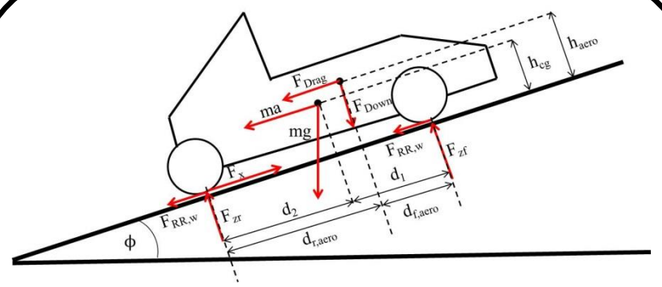

Figure 1: Forces on the FS car during straight-ahead driving.

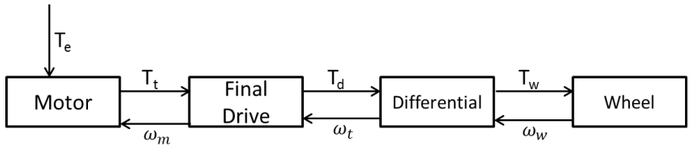

Figure 2: Power-train schematic depicting the flow of torque and velocity in the model.

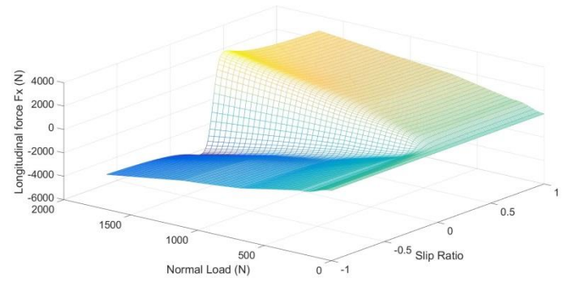

Figure 3: Longitudinal tyre forces as a function of slip ratio and normal load.

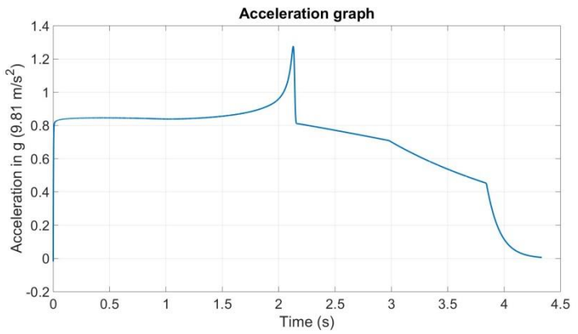

Figure 4: Example acceleration graph for a 75m acceleration.

2. 4-Degrees of Freedom Model:

It was also attempted to model the vehicle planar motion parallel to the ground. However, the model displayed oscillatory and incorrect behaviour for the simplest of inputs. Example outputs can be seen in the Figure below, in which the acceleration in y (red) should theoretically remain 0 at all times.

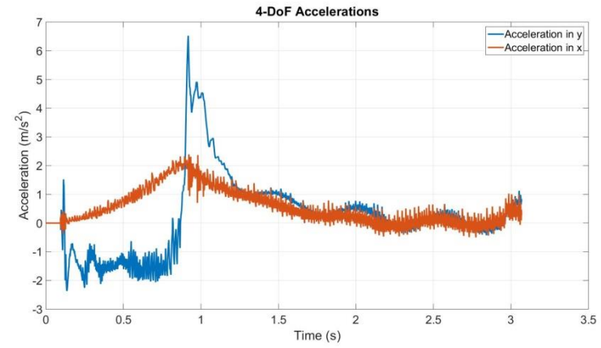

Figure 5: Incorrect 4-DoF model outputs

3. Conclusion and future work:

Although the 4-DoF model does not work, the longitudinal model produces good results. It can be used as a design tool to quantify effects of design alterations. Furthermore the models derived should form a suitable basis for future team members to provide a more advanced model.

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BRISTOL ELECTRIC Racing
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