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Development of a Vehicle Setup Characterisation Model for the MCR Sports 2000 Race Car

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Introduction

Vehicle setup is crucial in the world of racing; the right setup can give a huge advantage over competitors. Small adjustments to suspension components can fine-tune vehicle balance to exactly what the driver requires, giving them confidence to push the vehicle to its limit at all points on circuit (Milliken and Milliken, 1995).

Project Aims

- Create a model to characterise vehicle balance and handling for a variety of setups.
- Use basic weight transfer equations and apply them in a quasi-semi state fashion to analyse transient vehicle data.
- Build on fundamental equations by including transient tyre and damper effects mathematically.

Methodology

- A Simulink model was created to apply effects of weight transfer to the contact patch loads as the vehicle travels around the track (Bastow et al., 2004):

$$WT = \frac{m \cdot Ay \cdot h}{t}$$

Equation 1 - Fundamental weight transfer equation

- Equation one was applied laterally through elastic, geometric and damper weight transfer, and through longitudinal weight transfer to create a basic representation of vehicle balance.
- A tyre testing rig was developed to find vertical stiffness rates by measuring force applied and deflection.

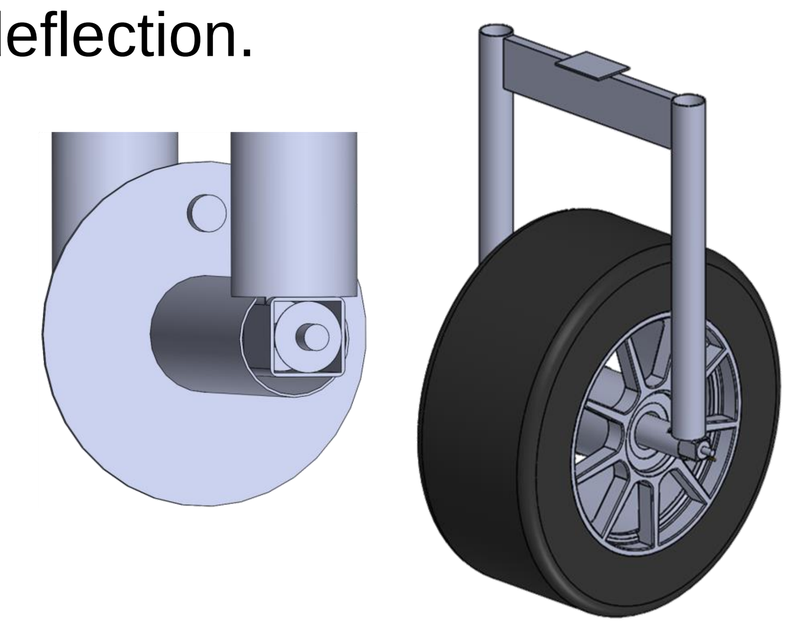

Figure 1 - Tyre testing rig

- Tyre stiffness was added into wheel rate as a spring in series:

$$Total\ Wheel\ Rate = \left(\frac{1}{Wheel\ Rate} + \frac{1}{Tyre\ Stiffness}\right)^{-1}$$

Equation 2 - Wheel rate equation

- Dampers create a resistive torque on the vehicle, reducing roll angle. This has to be subtracted from the overturning moment to mathematically model damper effect on roll angle (Alexander, 2015).

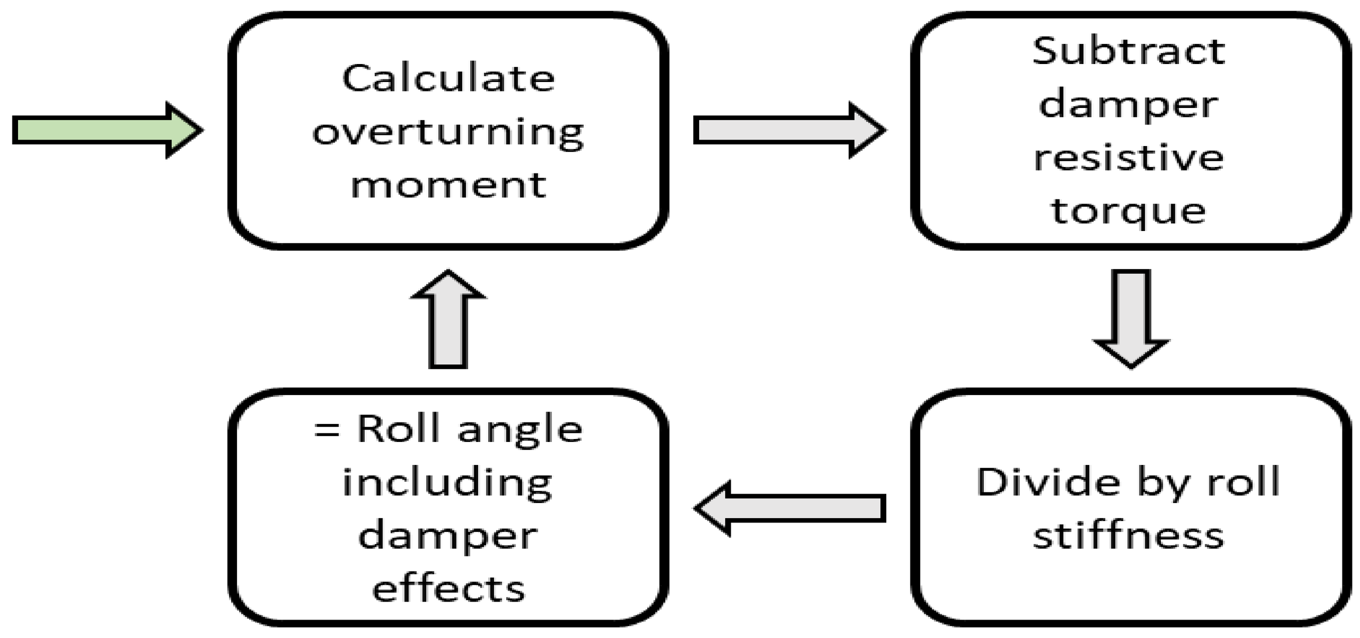

Figure 2 - Iterative loop for roll angle calculation

- Reducing the roll angle reduces the elastic weight transfer. Moreover, damper weight transfer was added to the model:

$$Damper\ WT = \frac{(Right\ Damper\ Force - Left\ Damper\ Force) \cdot Motion\ Ratio}{2}$$

Equation 3 - Damper weight transfer equation

- The model is based on mathematical analysis through Simulink, using blocks to represent each component. GUI controls allow the user to change vehicle setup.

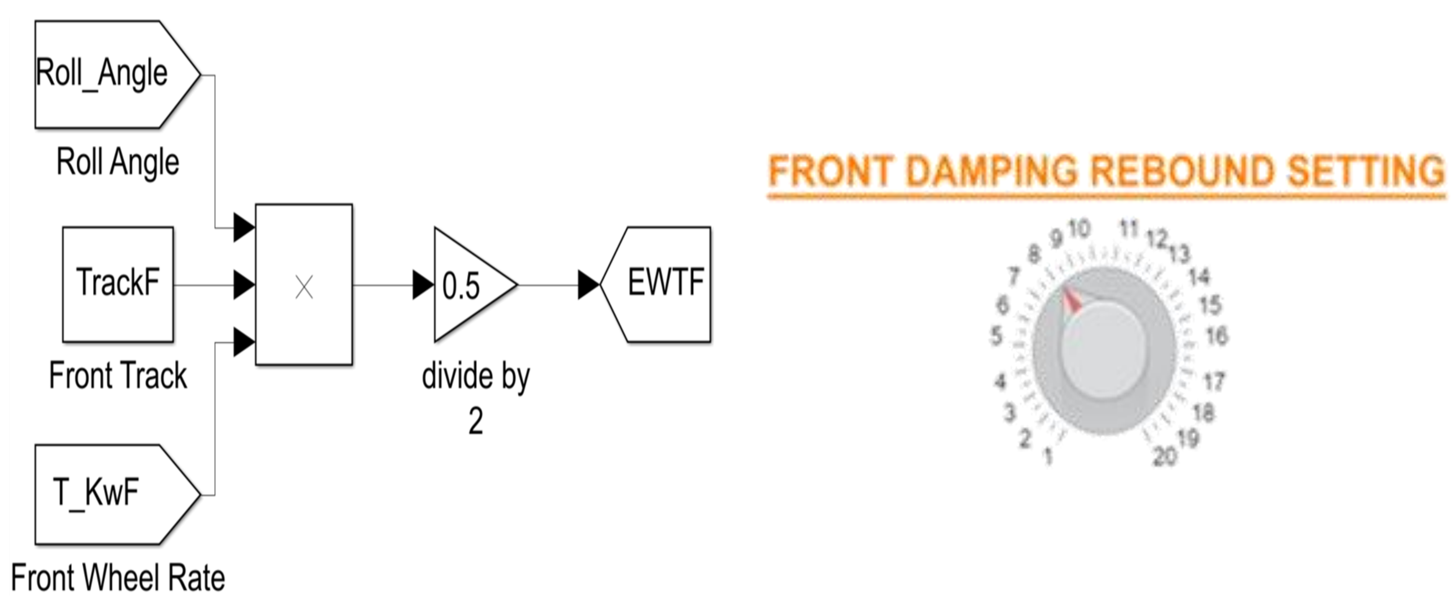

Figure 3 - Simulink equation subsystem and GUI controller example

Results

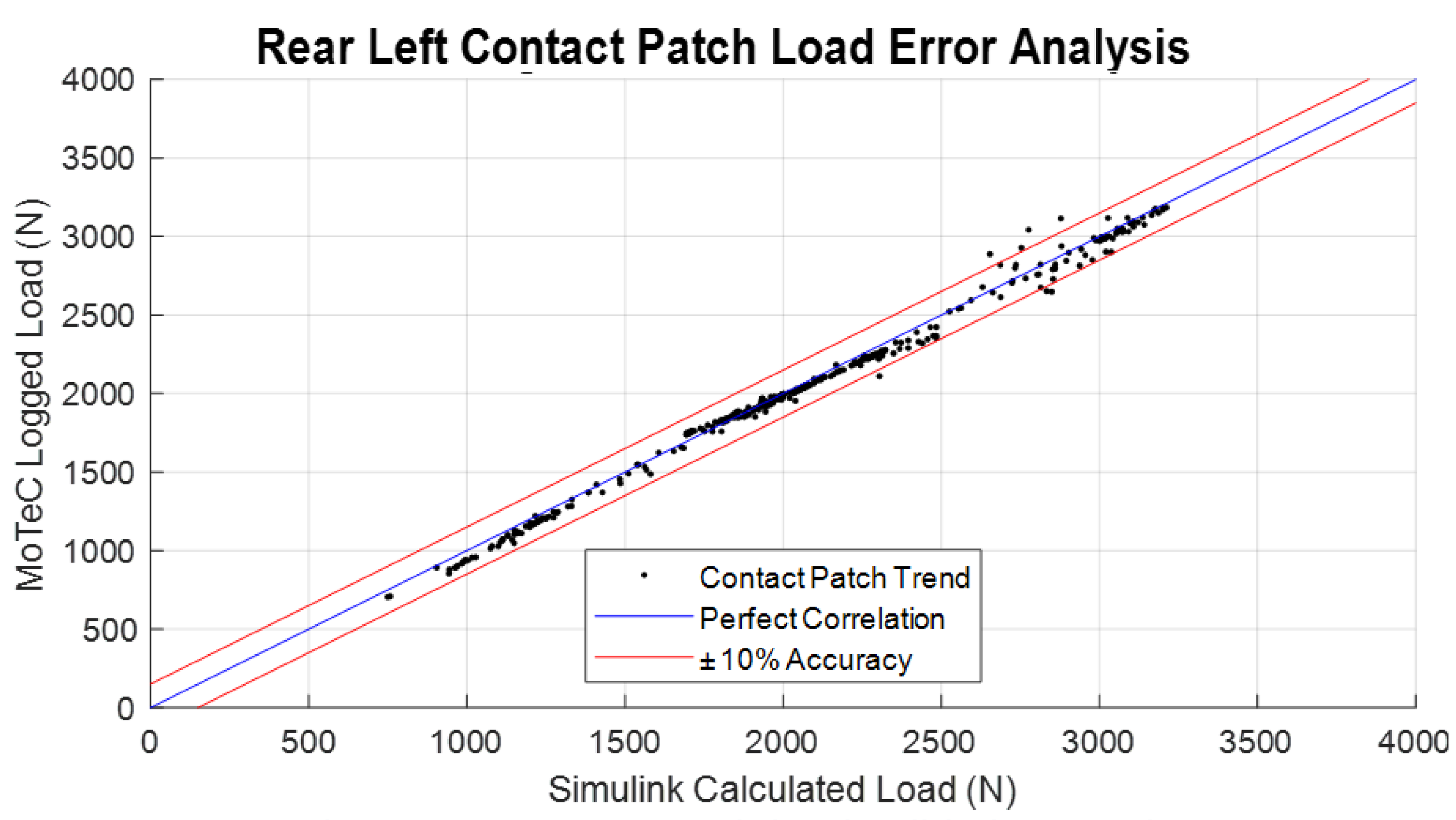

Figure 4 - Contact patch load validation graph

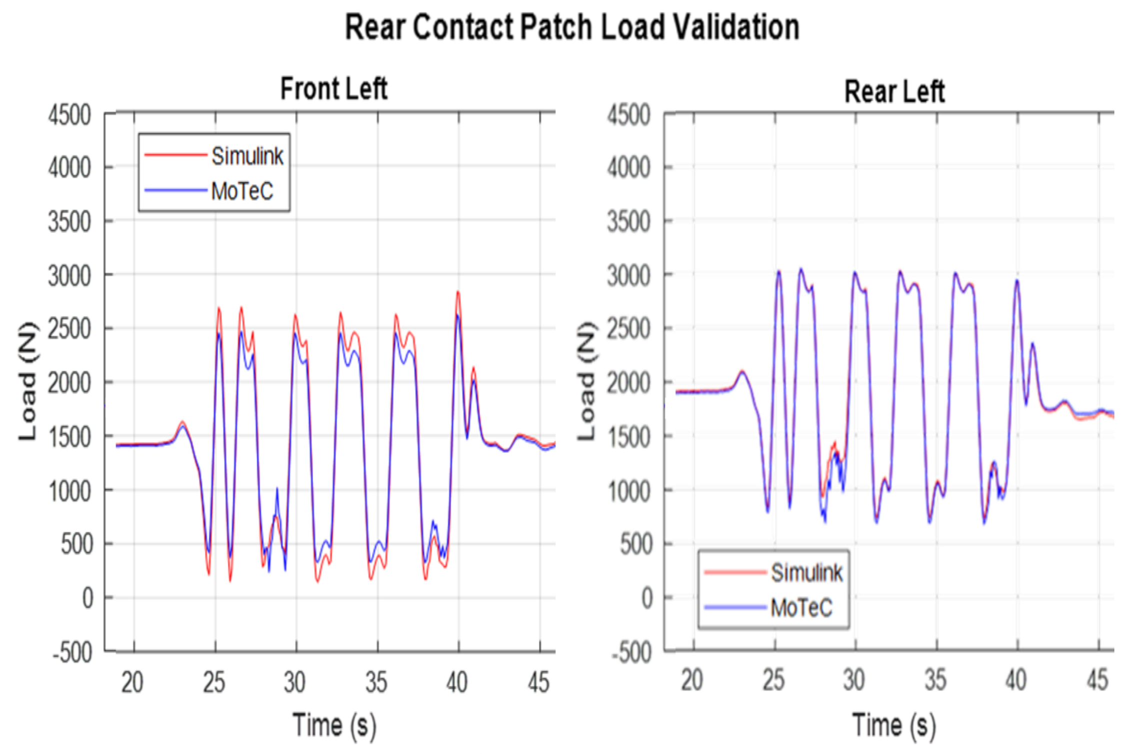

Figure 5 - Section of graph to show correlation of calculated and simulator contact patch loads

- Figure 4 compares calculated contact patch loads to actual values, from simulator data. Most values lie within a ±10% error region.
- Calculations for the front do not correlate as well as the rear, this is thought to be due to incorrect vehicle data, not calculation error.
- The model was tested against various changing roll stiffness and damping rate setups; centres of weight transfer were analysed.
- The results followed trends expected by the author from existing knowledge and research, validating the mathematics behind the model.

Conclusion

- Fundamental weight transfer equations can be implemented in a quasi-steady state fashion to analyse vehicle handling with good correlation to real world data.
- The inclusion of transient data further improved the accuracy of results.
- This model proved a good way to solidify and build upon existing knowledge, as well as forming a useful trackside tool for team M-SportEng.

Referenced Work

- Bastow, D., Howard, G. and Whitehead, J. P. (2004) Car suspension and handling. Bury St. Edmunds: Professional Engineering Publishing.
- Milliken, W. F. and Milliken, D. L. (1995) Race Car Vehicle Dynamics.
- Alexander, D. (2015) Chassis Tuning With Dampers. Available at: https://nasaspeed.news/tech/suspension