Optimal Acceleration of a Heavy-Duty Truck

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Abstract

A heavy-duty truck propelled by a diesel engine often have a gearbox in order to select suitable load points for the engine operation. By selecting appropriate gears, the fuel economy of the vehicle could be improved over a driving mission, which may also reduce the pollutant emissions released from the vehicle. This work examines an acceleration from 5 to 30 km/h, using a model describing the engine air path dynamics, to find which gears that should be used. The developed method indicates which gears that should be used during the acceleration and which gears that could be skipped.

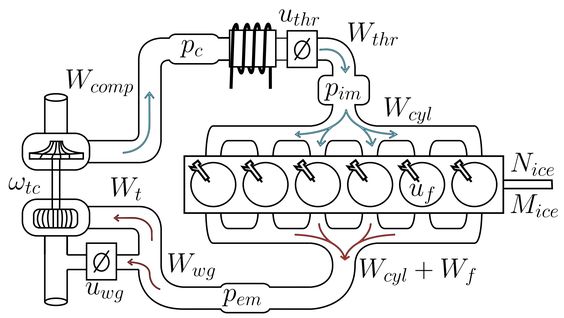

Figure 1: Schematic of a diesel engine model. The model is published in [2]. The model is available open source at: `www.fs.isy.liu.se/Software/`

Chassis, driveline and engine models

The engine used to examine the acceleration is developed in [2]. The engine is connected to a stiff driveline with a clutch, gearbox and final drive. A gear shift is in [1] described with three phases: vehicle in gear, clutch active and clutch slip. Using three phases for each gear, the fuel optimal control problem to accelerate the vehicle can be constructed and solved.

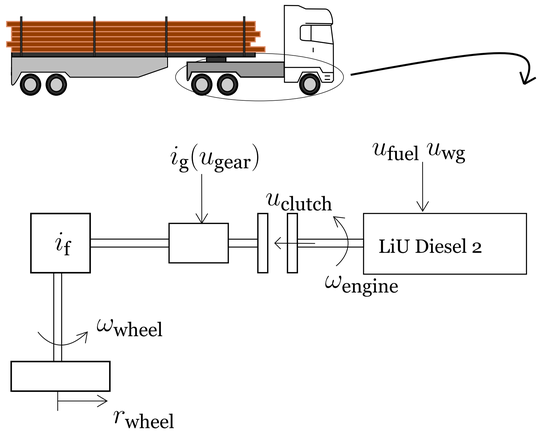

Figure 2: Schematic of the vehicle driveline. [1]

Optimal control

A general optimal control problem could be formulated as:

$$
\begin{aligned}
\min\ & J = \int_{t_{\text{start}}}^{t_{\text{end}}} \dot{m}_{\text{fuel}} \\
\text{s.t.}\quad & \dot{x} = f_{\text{vehicle}}(x(t), u(t)) \\
& u_{\min} \leq u(t) \leq u_{\max} \\
& x_{\min} \leq x(t) \leq x_{\max} \\
& t_{\text{end,min}} \leq t_{\text{end}} \leq t_{\text{end,max}} \\
& h(t) \leq 0 \\
& g(t_{\text{end}}) = v_{\text{final}}
\end{aligned}
$$

By connecting multiple phases with different models describing the state dynamics $f_{vehicle}$, the acceleration scenario can be studied. In [1] a method to construct the fuel optimal acceleration problem is described. The scenario when a 40 ton truck is accelerated from 5 to 30 km/h is studied.

Results

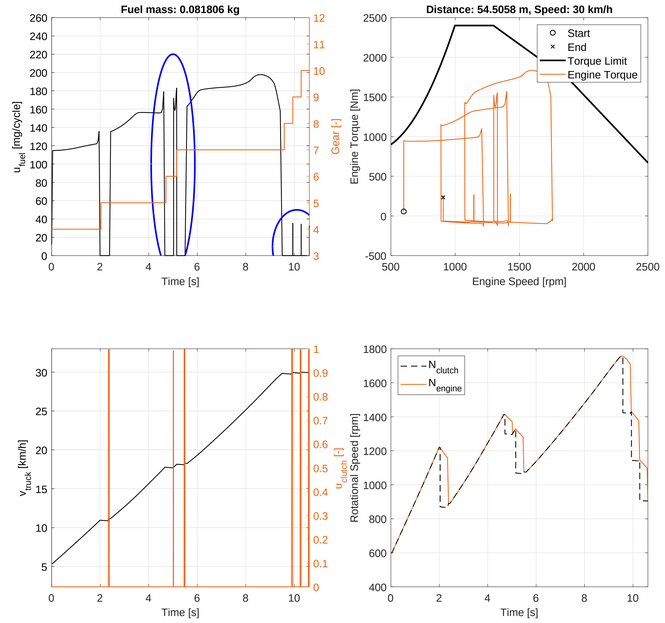

Figure 3: Fuel optimal acceleration. The results are from [1]. The blue circles points out gears that could be skipped to improve fuel economy.

References

[1] Kristoffer Ekberg and Lars Eriksson. Development and analysis of optimal control strategy for gear changing patterns during acceleration. 9th IFAC Symposium on Advances in Automotive Control AAC 2019, Orléans, France.

[2] Kristoffer Ekberg, Viktor Leek, and Lars Eriksson. Validation of an Open-Source Mean-Value Heavy-Duty Diesel Engine Model. Proceedings of The 59th Conference on Simulation and Modelling 2018, Oslo, Norway.

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