Train Driving Performance Analysis and Control Using Inverse Simulation

Introduction
European railways have different control systems and each system is used by national rail companies to develop and maintain by themselves. It has resulted in a rise in passenger transportation cost because extensive investment in integration and engineering effort are required for cross border traffic. Accordingly, to understand train control system and related to the calculation equation of train dynamics, acceleration and deceleration profile by developing the mathematical model to demonstrate the simulation when train is approaching, leaving station and moving forward. These result will be used to analyze the performance of train’s operation and will increase the safety for passenger and smooth feeling while train approaching or leaving station.

Objectives
To develop an inverse simulation framework in Matlab by using a forward model of the train dynamics to demonstrate the control system when the input of vehicle dynamic is changing such as driving forces and braking forces.

Forward mathematical model
The model is based on Newton’s second law by using harmonic motion and friction.

\[
\sum F = m \cdot a
\]

\[
F_{\text{drive}} = F_{\text{Brake}} - F_R - F_C - F_g - F_D = (c \cdot \frac{\Delta y}{\Delta t}) - (k \cdot \Delta y) = m \cdot a
\]

Rolling friction
\[ F_R = \mu_R \cdot W = \mu_R \cdot m \cdot g \]

Curve resistance
\[ F_C = r_c \cdot m \cdot g = \frac{r}{r} \cdot m \cdot g \]

Gradient resistance
\[ F_g = m \cdot g \cdot \sin \alpha \]

Aerodynamic resistance
\[ F_D = \frac{1}{2} \cdot \rho \cdot C_D \cdot A \cdot v^2 \]

Harmonic motion
\[ F_{m-c}(t) = m \cdot \frac{\Delta^2 y}{\Delta t^2} + (c \cdot \frac{\Delta y}{\Delta t} + (k \cdot \Delta y) \]

Results from forward mathematical model
Train moves straight direction:
Train is starting to brake when displacement equal to 300, 500, 1000, 1500 and 2000 meter.

Inverse Simulation
Inverse simulation is a method to calculate the control inputs by using a forward model of the train dynamics to demonstrate the control system when the input of vehicle dynamic is changing such as driving forces and braking forces.

Trajectory profiles
The result from the forward mathematical model, it will be a trajectory profiles by using polynomial and integration to create desired value of acceleration, velocity and displacement.

Graphs 1 to 9 show the results of simulation and control for train movement in different conditions.

Conclusion
The result from forward model (graph 1) and trajectory profiles (graph 5) are the same. That is mean the mathematical model can use to be the desired value in inverse simulation. However, when compare the result from inverse simulation and desired output (graph 9), it has high error because jacobian and perturbation in inverse simulation is not calculated the control inputs to be equal to the desired value correctly. Therefore, this study will be develop and modify the jacobian part to recalculate new result of different train trajectory.

References