Estimation of Condition Between Rail and Wheel from Measured Values of a PQ Wheel

Introduction
The derailment quotient, obtained by dividing lateral force, Q with vertical wheel load, P is a index to evaluate safety in railway vehicles. It is investigated with a PQ wheelset, shown in the right figure. As the one owned by RTRI can measure tangential force in the longitudinal direction, feasibility to estimate the attack angle and friction coefficient is examined.

Method
The lateral displacement of the wheel, \( y \), and the attack angle, \( \psi \) are estimated by Kalman filter with the wheelset model shown in the right figure, whose equation of motion are

\[
\begin{align*}
    m\ddot{y} + 2k_{22}\dot{y} + k_{y}y - 2k_{22}\dot{\psi} &= 0 \\
    mi^{2}\ddot{\psi} + 2k_{i1}b_{2}\dot{y} + k_{x}b_{1}^{2}\dot{\psi} + \frac{2k_{11}b_{1}y}{r_{0}} &= 0,
\end{align*}
\]

where \( k_{i1} \) and \( k_{22} \) are longitudinal and lateral creep ratio, \( m \) is the mass of wheel, \( v \) is the velocity, \( i \) is radius of gyration, \( \gamma \) is tread gradient and \( r_{0} \) is radius of wheel at the neutral point.

In the curved section, the changes from the steady state values of the lateral displacement, \( \Delta y \) and the attack angle, \( \Delta \psi \), obtained as below, are used as state variables.

\[
\psi = \psi_{0} + \Delta \psi, \quad y = y_{0} + \Delta y, \quad \text{where} \quad \psi_{0} \text{ and } y_{0} \text{ are steady state values.}
\]

Results and discussion
The estimated and simulated values of the attack angles are shown in the figures below, the upper one is estimated one and the lower one is the simulation result in the test track including the curves of several curvatures. The friction coefficient estimated in the sharp curved section, R120m and R160m, is shown in the right figure.

As the estimated and simulated values are similar in the sharp curved section, the validity is shown. The friction coefficient is observed to be saturated around 0.5, which is reasonable results.

Publications
Murata K., Kaizuka T., Suzuki M., Hondo T., Miyamoto T., Nakano K., State Estimation Between Rail and Wheel from Values of a PQ Wheelset Measured in Passing a Curve Using Lateral-force Estimation Equation, J-Rail2018
Murata K., Takemura Y., Suzuki M., Miyamoto T., Nakano K., Estimation of Friction Coefficient between Rail and Wheel from Measured Values of PQ Wheelset Using Kalman Filter, The Fourth International conference on Railway Technology RAILWAYS 2018, 3-7 September, 2018
Murata K., Takemura Y., Kaizuka T., Suzuki M., Miyamoto T., Nakano K., Estimation of Friction Coefficient between Rail and Wheel in curve of various curvature from Measured Values by PQ wheelset Using Kalman Filter. J-RAIL2017