Robust Control System for Active Wheelset Steering of Railway Vehicles Based on Sliding Mode Control

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EXTENDED ABSTRACT

1 Introduction

Active wheelset steering is one of the active suspension solutions for railway vehicles that aims to improv the curving performance and stability of the wheelsets [1]. This active solution has been studied and developed to overcome the drawbacks of the passive system. Railway vehicles are usually subjected to disturbances and any operation is constituted with uncertain parameters, especially in the wheel-rail interface. Therefore, a robust controller for active wheelset steering is preferred to deal with parameter variations due to a wide range of operating conditions.

2 Methodology

In this paper, a robust sliding mode controller with integral action (SMC+I) is designed and implemented for the active steering wheelset of a railway vehicle to achieve perfect rolling conditions during curve negotiation. Sliding mode control (SMC) is chosen as this nonlinear control method provides robust control against disturbances and uncertainties of nonlinear dynamics [2]. It has a fast dynamic response and guarantees finite-time convergence. The robustness of the controller is obtained by deriving the control inputs (u) with bounds of known uncertain parameters including equivalent conicity (λ_{eq}) and creep coefficients. The control input is a combination of the equivalent term (u_{eq}) obtained from the nominal model and a switching term (u_{sw}). This approach leads to the reduction of the switching input amplitude. A continuous approximation by using a saturation function instead of a sign function in the switching term, $sgn(s) \approx sat(s/\gamma)$, is applied to provide continuous control. However, zero steady-state error is not guaranteed when using this continuous approximation. The integral action (I) is therefore introduced to the sliding surface function for achieving the zero steady-state error [3]. The sliding surface function is given as:

$$s = e + \dot{e} + \int e \, . \qquad (1)$$

Various control strategies for active wheelset steering have been proposed including radial control and perfect steering control [4]. The perfect steering control based on wheelset lateral displacement is considered in this study. This strategy aims at obtaining pure rolling conditions which leads to zero longitudinal creep forces and equal lateral creep forces in all wheelsets. The desirable lateral displacement is therefore given as:

$$y_{ref} = \frac{b_0 r_0}{\lambda R} \, . \qquad (2)$$

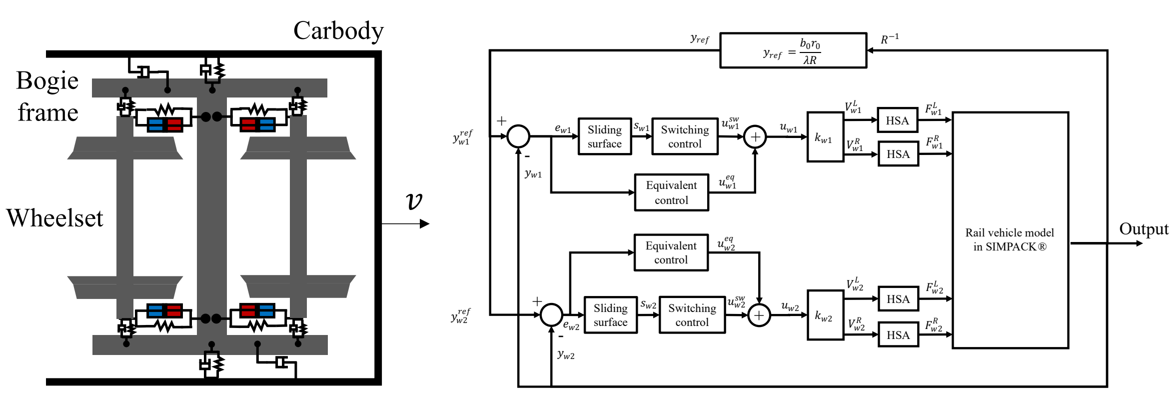


Figure 1: Active wheelset steering configuration (left) and schematic of robust Sliding Mode Control for leading bogie (right)

A railway vehicle with two two-axle bogies is modelled in SIMPACK®. Each solid-axle wheelset is connected to a bogie frame with primary suspension elements and two steering actuators are connected in parallel to longitudinal primary springs as illustrated in Figure 1 (left). The longitudinal primary springs are kept ensuring the stability on tangent track; however, the stiffness of these springs is reduced to 8 MN/m from 30 MN/m in the conventional setup. The designed SMC+I controller in Figure 1 (right) is implemented in MATLAB/Simulink® for co-simulation. Hydraulic servo actuators (HSAs) shown in Figure 2 are also modelled with Simscape hydraulic libraries in MATLAB/Simulink® to represent the actuation scheme of the active steering system. The co-simulation is executed to evaluate the performance of the designed controller.

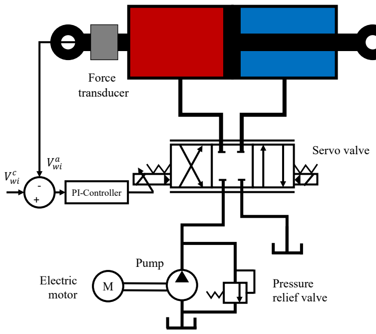
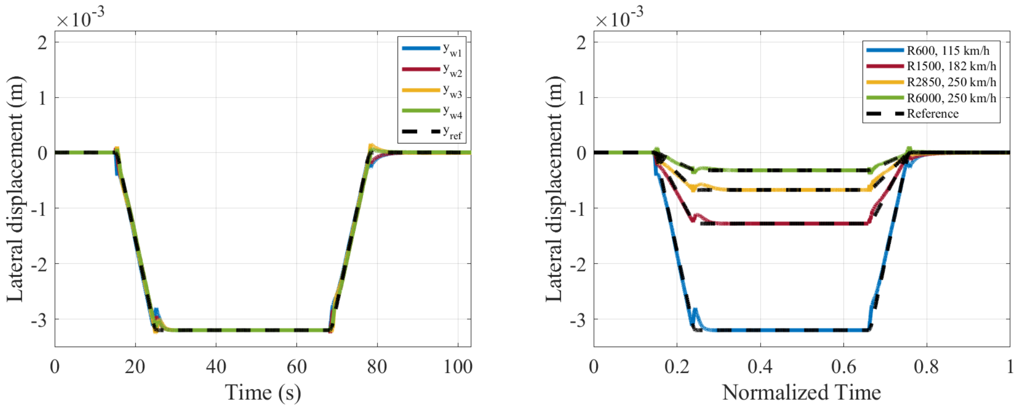


Figure 2: Hydraulic servo actuator model

3 Result and discussion

Figure 2a shows the wheelset lateral displacements when the vehicle operates at 115 km/h on a curve track of 600 m with track cant of 160 mm which gives a non-compensated lateral acceleration (NLA) of 0.65 m·s^{-2}. The results in Figure 2b illustrate the performance of the designed controller for an active wheelset steering system under four different curve radii and operating speeds. The designed controller guarantees stability, finite-time convergence, and zero steady-state errors for all running scenarios. These results indicate the performance and robustness of the designed SMC+I controller in a variety of operating conditions.



(a) (b)

Figure 3: Wheelset lateral displacements, all wheelsets R=600m (a), leading wheelset in various running conditions (b).

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