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Stochastic modeling of operating conditions and parameter uncertainties for assessing the lateral stability of long combination vehicles

Jiangtao Yu[1*], Wei Huang[2], Yuping He[1]
[1]Department of Automotive and Mechatronics Engineering, University of Ontario Institute of Technology, Oshawa, Canada
[2]National Research Council Canada, Ottawa, Canada
*jiangtao.yu@ontariotechu.net

ABSTRACT

Long combination vehicles (LCVs) have been increasingly utilized for highway freight transportation due to their improved fuel economy and reduced greenhouse emissions. However, LCVs exhibit poor high-speed stability and low-speed maneuverability owing to their multi-unit structures, large sizes, and high centre of gravity (CG). Given the unique dynamic features of these large vehicles and varied operating conditions, LCVs' lateral stability is difficult to predict. To increase the safety of LCVs, various active safety systems (ASSs), e.g., active trailer steering, have been proposed. To date, simulation has been widely used to develop these ASSs. High fidelity simulations may provide excellent insights into the dynamics features of LCVs under a predefined operating condition. However, under varied operating conditions and in the presence of vehicle parameter uncertainties, it is difficult to use simulation for reasonably evaluating the lateral stability of LCVs with different designs of ASSs, and the associated dynamic analysis cost is high. To address this problem, we propose an effective simulation method, which consider varied operating conditions (e.g., different road conditions) and vehicle model parameter uncertainties (such as payload variations) using Monte Carlo based stochastic modeling method. The numerical simulations are executed on a comprehensive platform, which consists of TruckSim for LCV modelling, MatLab/SimuLink for controller design, and Python for data management and analysis. With the specified operating conditions and vehicle model parameter uncertainties in terms of variation range, mean, and standard deviation, the Python software generates the required data for co-simulations. The LCV model and operating condition are developed in TruckSim package considering the predefined vehicle parameter uncertainties and varied operating conditions. The ASS is design in Simulink. With the intended virtual tests specified by the Python software, the co-simulations are conducted by integrating the LCV model and the ASS control system. The co-simulation results will be analyzed by the Python software to attain the associated stability performance measures. Co-simulations are conducted to study an A-double dynamics under a single lane-change maneuver with forward speed ranging from 85 to 95 km/h, road surface friction coefficient ranging from 0.35 to 0.9, trailer payload ranging from 17000 to 19000 kg, and the height of trailer CG ranging from 2250 to 2350 mm. The co-simulations provide required performance measures reflecting the impacts of the above variation factors. It is demonstrated that the proposed stochastic modelling technique successfully achieves the full matrix of performance measures by conducting much smaller number of simulation runs.