Mechanical Engineering Doctoral Defense

Modeling, Control, and Evaluation of Tire Blowout for Partially and Highly Automated Vehicles

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Abstract

Tire blowout often occurs during driving, which can suddenly disturb vehicle motions and seriously threaten road safety. Currently, there is still a lack of effective methods to mitigate tire blowout risks in everyday traffic, even for automated vehicles. To fundamentally study and systematically resolve the tire blowout issue for automated vehicles, a collaborative project between General Motors (GM) and Arizona State University (ASU) has been conducted since 2018. In this dissertation, three main contributions of this project will be presented.

First, to explore vehicle dynamics with tire blowout impacts and establish an effective simulation platform for close-loop control performance evaluation, high-fidelity tire blowout models are thoroughly developed by explicitly considering important vehicle parameters and variables. Second, since human cooperation is required to control Level 2/3 partially automated vehicles (PAVs), novel shared steering control schemes are specifically proposed for tire blowout to ensure safe vehicle stabilization via cooperative driving. Third, for Level 4/5 highly automated vehicles (HAVs) without human control, the development of control-oriented vehicle models, controllability study, and automatic control designs are performed based on impulsive differential systems (IDS) theories.

Co-simulations Matlab/Simulink® and CarSim® are conducted to validate performances of all models and control designs proposed in this dissertation. Moreover, a scaled test vehicle at ASU and a full-size test vehicle at GM are well instrumented for data collection and control implementation. Various tire blowout experiments for different scenarios are conducted for more rigorous validations. Consequently, the proposed high-fidelity tire blowout models can correctly and more accurately describe vehicle motions upon tire blowout. The developed shared steering control schemes for PAVs and automatic control designs for HAVs can effectively stabilize a vehicle to maintain path following performance in the driving lane after tire blowout.

In addition to new research findings and developments in this dissertation, a pending patent for tire blowout detection is also generated in the tire blowout project. The obtained research results have attracted interest from automotive manufacturers and could have a significant impact on driving safety enhancement for automated vehicles upon tire blowout.

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