Session 3b: Brakes

Improving heavy vehicle emergency braking systems

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Heavy Goods Vehicles (HGV’s) have considerably lower maximum retardation rates than passenger cars, and typically take 40% more distance than cars for stopping on dry roads, contributing to their higher rate of involvement in fatal accidents than any other road vehicles. The mandatory use of anti-lock braking systems (ABS) on air-braked vehicles in Europe has mitigated this problem somewhat. However, current heavy vehicle ABS uses an inefficient finite-state control approach, which works on cycles of predicting and superseding the limits of tyre-road adhesion, and then reducing the brake pressure to allow the wheel to rotate again. The compressibility of air, long air pipes, and relatively slow pneumatic control valves create time delays that limit the speed of response. Consequently, truck ABS systems typically cycle at frequencies of approximately 1 Hz. The ‘fill and dump’ process uses a lot of compressed air, which requires energy to generate and large reservoirs for storage.

An alternative approach to ABS is wheel slip control, which optimizes tyre slip continuously during braking, thereby maximizing deceleration while maintaining vehicle manoeuvrability. Preliminary estimations with a proof-of-concept control system and vehicle simulation predict reductions of up to 25% in stopping distance relative to conventional ABS. However, this is conditional on improvements in the speed of response of conventional pneumatic braking hardware to enhance controllability. The goal of this research project is to develop a practical wheel slip control system suitable for commercial use on articulated vehicles. Both novel methods of actuation and advanced controller designs are being investigated.

A practical, made-for-purpose high-speed brake actuator is currently being developed to provide the response times and flow rates necessary for accurate slip control under all road conditions. Considerations are being made in the design process for space constraints, durability, and ease of manufacture. Once constructed, the actuator will be tested with the slip controller on a hardware-in-the-loop (HiL) rig that has hardware components consisting of an air receiver, slip control modulator, brake actuator, and a brake caliper. These are connected to a real-time simulation of the braked wheel and vehicle dynamics, enabling the control algorithm and hardware to be tested under realistic conditions in the laboratory. Following these HiL tests, design revisions will be made to adapt the actuator to a full-scale, instrumented experimental vehicle, which will be used to evaluate the complete slip control system.

When testing on the full-scale vehicle, the slip controller will require knowledge of several states and parameters that are impractical to measure in commercial systems. Consequently, sliding mode observers and nonlinear regression techniques are currently being investigated to estimate these unmeasurable quantities in real-time under various road and vehicle conditions. The algorithms are being validated both in simulation and against data from experiments with the aforementioned experimental vehicle.