

Experimental electro-mechanical brake model with disk wiping

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This document accompanies the model files of an experimental electro-mechanical brake system, which are available on the web site of the *Workshop on Applied Verification for Continuous and Hybrid Systems* (<http://cps-vo.org/group/ARCH>). This example was originally used in the scope of [SO15] but has since been expanded. The original files used for that paper are also still available from the workshop website. For a description of the physical system, see [SO15].

This model implements several improvements over the original:

- The discrete behavior of the controller has been extracted into a Stateflow chart, so that it is now easier to see the hybrid automaton structure of the model.
- This Stateflow automaton has been expanded to also allow for aborted brake attempts (if the driver releases the brakes during caliper positioning) and for an immediate reaction to brake pedal activations during the release phase.
- A *disk wiping* feature has been added to the controller. Disk wiping is a feature of braking systems that is used to clean the braking disk by periodically making light contact with the brake caliper. An additional input signal *wipe* has been added: if it is strictly positive, disk wiping is activated, otherwise it is deactivated. A braking request from the driver always has priority over disk wiping, so even if wiping is requested, it will only be carried out if the desired braking force is zero.
- Since the force control is also carried out based on position values (i.e., a braking force is applied by setting the position target of the caliper beyond the brake disk), force control is now called “small position control” in the controller. “Big position control” is the actual position controller. The conversion from a desired force to a position set point takes place in a Matlab block before the Stateflow chart. The Stateflow chart, as well as the continuous controllers then operate solely on position values.

Possible requirements to be checked (informal) The following list contains requirements that are assumed to hold, even though we did not formally check them. They are given in natural language, as this is the de facto standard in practice.

- After a positive braking force is requested, it should be reached with an error margin of 10 percent within 0.02 time units.
- For braking forces between 0 and 500, the current I should always stay below 2500.
- If disk wiping is requested and the requested braking force is 0, contact with the brake disk ($F > 0$) should be achieved within 0.02 time units.

- If no braking force is requested, the actual braking force should return to a value below 150 within 0.02 time units (even when disk wiping is requested).
- For an input signal where the requested braking force is constant at 0, if disk wiping is continuously requested for at least 0.1 time units, the average braking force over this interval should be below 30.

Disclaimer The model is an example created for use with formal verification tools in order to evaluate model-based testing and verification techniques. This model is not used in any Bosch product. It is provided "as is", with no warranty of any kind. It may not be redistributed without the expressed written consent of Robert Bosch GmbH.

References

- [SO15] Thomas Strathmann and Jens Oehlerking. Experience report: Verifying properties of an electro-mechanical braking system. In *2nd Workshop on Applied Verification on Applied and Continuous Systems (ARCH 2015)*, 2015.