Hybrid modelling and control of a brake valve with dry friction

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Abstract: Mechanical systems with dry friction in between some of their moving elements possess important applications in several industrial areas like brake systems in vehicles. Therefore, their advanced control is a practically important and theoretically challenging problem.

Our investigated model consists of a simplified brake-valve model in which the flow rates are in the form of $u\sqrt{p_1 - p_2}$ where u is the discrete valued input (an on/off switch), p_1 and p_2 are the control and the target pressure, respectively. In addition, the friction-coefficient of the brake valve is a nonlinear function of its speed that describes the conditions of dry friction. In order to model the hybrid behaviour a state-transition diagram of an automaton was applied to represent the discrete event part. As a continuous sub-model, a set of differential and algebraic equations associated to the states of the given automaton have been constructed based on first engineering principles [1]. Since the model shows highly nonlinear behaviour, linearization had to be done over its working domain with dividing that into several regions. In addition, the continuous time non-linear model equations have been discretized appropriately.

The physical model and the controller was designed to keep the inner pressure within a given region by switching the brake valve on and off.

A state-feedback controller was designed for the obtained piece-wise affine hybrid model. The algorithm runs over a polyhedral partition (since the cost function is a piece-wise affine function over a set of polyhedra) of feasible states and it ensures the stability of the system. The Matlab-toolbox called $\mathbb{MPT}$ (Multi-Parametric Toolbox) has been used to create the controller [2].

The effect of the design parameters (the prediction horizon, the weight value for the output regulation and the discretizing time) on the controller performance have been investigated by simulation experiments. It has been found that the careful choice of these parameters is critical in the controller design.

The detailed results will be presented in the final paper.

References

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