EVALUATION REPORT

Thesis title: Heat flow control of water-to-air heat exchanger

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Thesis outline

The thesis focuses on theoretically advanced topic of mathematical modelling and control of a heat water-to-air exchanger. The key difficulty lies in the fact that the manipulated variable is the water mass flow in the tubes of the exchanger, which structurally affects the system properties. Due to this, the problem needs to be solved as a distributed parameter system of infinite-dimensional nature. Practical motivation of the given work is in optimizing the temperature and heat flow control of building heating systems.

After a short introduction, thesis motivation and state of the art sections, the mathematical model in the form of a partial differential equation is presented. The model is analysed in detail and then, utilizing a finite volume method, a finite order approximation of the model is derived following the work by the thesis supervisor [7] and resulting in a hybrid model of the heat exchanger. Consequently, the way of discretizing the continuous part of the model is briefly outlined.

The modelling chapter is followed by a chapter on control algorithms of the heat exchanger. Due to varying the mass-flow, causing variable transportation delay phenomenon, classical PID control is inefficient. Therefore, special controllers developed for the given task are applied. In particular, these are Shang [15] and Sandoval [15] controllers. These controllers are described in application to control of either the exchanger outlet temperature or exchanger heat flow, including a brief discussion on the implementation aspects.

After the theoretical parts, a chapter on testbed design and its construction is presented. The testbed is considered as a physical model of a building heating system of one pipe circuit structure and with a single radiator circuit with flow control by a pump. The conceptual design is followed by description of the selected testbed components (heater, cooler, actuators, sensors, electronic and control units). In the experimental part coming next, all the considered controllers are carefully cross-compared, on the simulation model first (briefly) and on the testbed (in more detail).

In the last, conclusion section, the thesis contributions are outlined and next steps in the given research are proposed. The testbed redesign is discussed with the aim to extend the operational ranges, which are relatively narrow at the current stage. The practical aspects, difficulties during the experiments, construction mistakes and their suggested remedies are also discussed in more detail in Appendix A.

Thesis evaluation

The thesis is written on 63 pages in a very good English. The thesis is reasonably structured, the state of the art is well outlined. Graphical presentation of the results is also on a very good level. The amount of work with results (both theoretical and practical) presented in the thesis is far above the MSc thesis average. This however brings some weaker aspects of the thesis - some parts are rather brief and insufficiently described. In particular it is the *Section 2.3.1 - Heat exchanger discretization*, which should be concluded by a final form of the model, and the related *Section 5.1 Simulation experiments*, which shows just results, but does not say much on the model used and its parameters. Besides, sometimes it is not clear if the work was performed by the student or if it is a result of the team work.

To conclude, taking into account the complexity of the topic solved in the thesis and the fact that the models and controllers were not only described and analysed theoretically, but were also implemented and tested experimentally, **I propose the thesis for the defence** and evaluate it by the **grade A**.

Questions

1) Outline the final model of the heat exchanger in the form used for simulations. Which parameters have been used for the simulation in Section 5.1. – Are they the parameters of the testbed identified in the following Section 5.2.1 – *Model identification*?

2) When discretizing the continuous time part of the model, a simple Euler explicit method was applied. This may bring considerable constraints on the sampling interval considering the stability and simulation error. Has this aspect been taken into account?

3) An alternative approach to approximate the heat exchanger model with varying mass flow might be in considering a model with variable time delays. Structurally, this model might be considerably simpler. Has this possibility been taken into account?

4) I really appreciate the variety of controllers considered in the thesis and their cross-comparison. Even though some of the implementation aspects have been discussed, still, a bit more attention could have been paid to this problem. A sort of implementation summary, including the (state space) schemes of the controllers, would be helpful to see. This could be included in the defence presentation.

5) At the defence, it should be outlined what the contribution of the student to particular stages of the presented results is. In particular, it is not clear if it was the student who proposed and constructed the testbed. This should be clarified at the defence.

In Prague, June 5th 2017

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