Mathematical performance analysis of a temperature controlled bulk storage room

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1 Introduction

We consider a bulk storage room for agricultural food products. A ventilator enforces the air circulation, and the air is cooled down by a cooling device, see Figure 1. Cold air flows usually upwards through the bulk. Inside

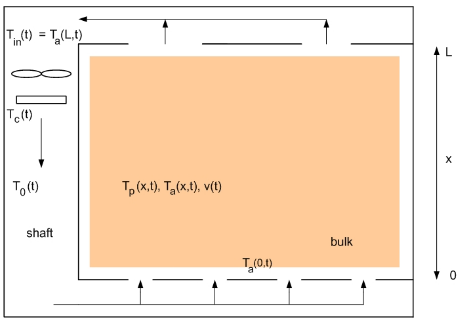

Figure 1: Schematic representation of a bulk storage room.

the bulk, the air warms up and consequently the products at the top will be some degrees warmer than those at the bottom, see [1]. A larger airflow will decrease these spatial variations, but will be costly. Model-based control design is a nontrivial task, since a standard model that describes the time- and spatially dependent temperatures will consist of a set of nonlinear partial differential equations.
Systems design is strongly correlated to controller design. The controller adds dynamics to the system, causing it to behave differently than the uncontrolled system. For storage room design, it is therefore desirable to design the plant and controller simultaneously, instead of separately.

2 Method

We started with the results in [2], where a basic physical model was derived and validated with experimental results. An open loop control law, which explicitly depends on all the physical model parameters, was successfully constructed. The controller determines the times when to switch between two discrete inputs. This input switching is realistic since often in practice the ventilator is switched on and off on a regular basis. Then we defined two criteria that indicate the performance of the system. The performance criteria are the total energy usage by the cooling device and the ventilator, and the temperature difference between the products at the top and at the bottom of the bulk. The controller as well as the performance criteria are closed expressions that contain all the prior physical knowledge. The relationship between each design criterium and the design parameters consists of a single expression and is therefore easily computed. Since some analytical relations could not be found in the literature, they are identified experimentally. These relations describe the energy usage of the ventilator, and the effectiveness of the heat exchanger, both as functions of the airflow.

3 Results

The following design tradeoffs were observed. The total energy usage is minimized by a low temperature of the cooling device, but the temperature difference over the bulk is minimized by a high temperature of the cooling device. Further, the temperature difference is decreased by a more powerful ventilator. However, the tradeoff here is that such a ventilator will be more expensive in purchase. The energy usage is decreased by a lower bulk. The tradeoff is that for a fixed bulk volume, a lower bulk means a larger floor area, which is usually more expensive than a higher roof.

4 Acknowledgement

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References

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