Technical University of Berlin
Institute for Energy Engineering
Chair of Heating, Ventilation and Air Conditioning
Hermann-Rietschel-Institute

Development of a control strategy for surface heating systems to reduce pump energy demand, for need-based heat supply and simplified system integration of heating surfaces

Short Report

The research project was funded by the Research Initiative „Zukunft Bau“ of the Federal Institute for Research on Building, Urban Affairs and Spatial Development

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The responsibility for the contents of this report rests with the authors.

Short title:	Unsteady state operation of surface heating systems
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Research institution:	Technical University of Berlin Institute for Energy Engineering Chair of Heating, Ventilation and Air Conditioning Hermann-Rietschel-Institute
Project duration:	16.07.2013 - 31.12.2015 (29.5 months)
Project leadership:	Prof. Dr.-Ing. Martin Kriegel
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Motivation and initial situation

The project with the short title “unsteady state operation of surface heating systems“ was initiated in response to the rising auxiliary energy demand for heat distribution in buildings. The project idea is based on an intermittent heat supply.

The hot water mass flow rate and thus the pump energy demand can be reduced by increasing the supply temperature and the temperature difference across the heating surface. The heat up time can also be reduced after a cool down period.

Research objectives

A thin layer system based on capillary tubes installed in a parallel pattern and a conventional system based on heat tubes installed in a counter flow spiral pattern are built up and investigated at the institute’s thermal test facility.

Two office working environments are set up in order to provide realistic boundary conditions. Transmission and ventilation heat losses are produced by cooling the climate chamber adjacent to the test room (see Fig. 1). For an unsteady state operation of the surface heating systems applicable supply temperatures in the range of 40 to 55 °C and relative mass flow rates in the range of 0,55 to 1 (relative to the maximum mass flow rate) are identified. The heating water is conveyed by a frequency controlled pump. An additional controller for the return flow is not implemented. The heating systems pressure drop is dependent on the mass flow rate, functioning within the ranges mentioned above.

The heat supply is controlled using an on-off-controller. The reference variable is the operative room temperature measured in head height between the working environment and the outer wall adjacent to the climate chamber.

Fig. 1: Test chamber with two office working places

Measurements with steady state heat supply were used to create a reference basis for all following measurements. The transmission heat loss coefficient of the outer wall adjacent to the climate chamber and the heat conduction coefficients of the concrete layer and the carpet were also determined.

Both heating systems were operated at a supply temperature of approximately 35 °C. A thermographic camera was used to investigate the temperature along the concrete surface (see Fig. 2). The thin layer system's concrete surface reaches a nearly homogeneous temperature 15 minutes after starting the heat supply and the conventional systems concrete surface after 120 minutes.

Both systems were modeled in the object oriented programming language Modelica and investigated in dynamic thermal simulations. The simulation models were validated with experimental data (see Fig. 3) and used for parametric studies concerning the systems construction parameters (tube diameter, distance between tubes and concrete layer thickness).

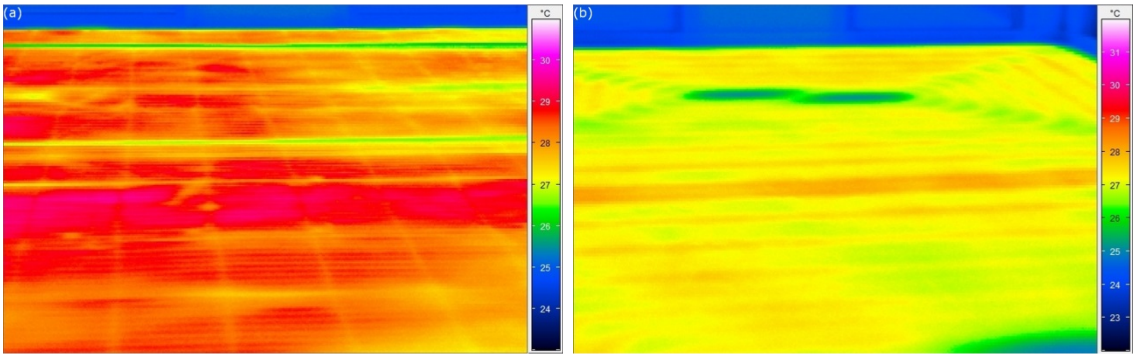

Fig. 2: Infrared pictures of the concrete surface of the thin layer system 15 minutes after (a) and of the thick layer 120 minutes after (b) the beginning of heat supply at a supply temperature of 35 °C

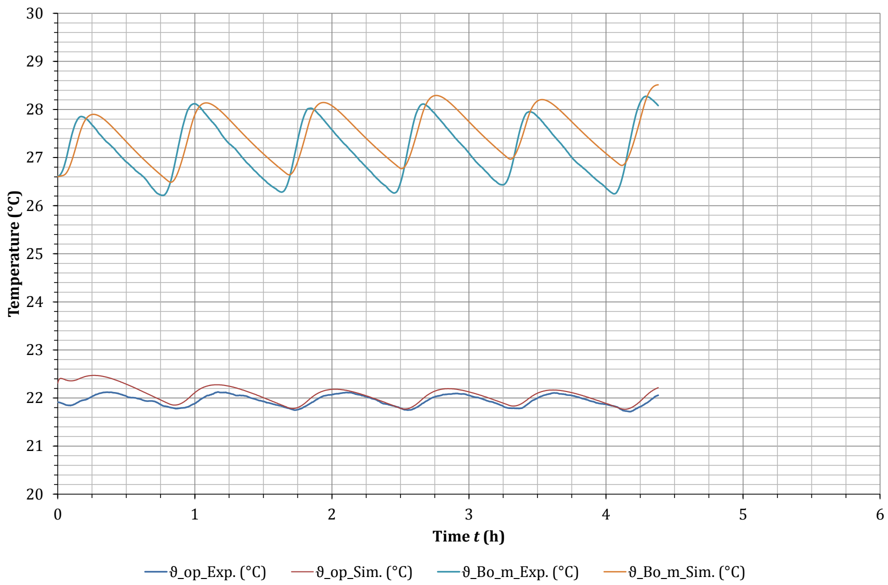

Fig. 3: Courses of the operative room temperature and the median floor temperature measured during the experiment (Exp) and simulated (Sim) at a supply temperature of 50 °C and a relative mass flow rate of 1 for the thin layer system (KRM)

The general cubic relationship between median relative electrical power demand (MRP) and relative mass flow rate is shown in Fig. 4. The power demand follows curve S_{real} when the distribution pump is controlled steadily. The power demand follows lines *A* to *D* when the distribution pump is controlled intermittently – depending on the current heat demand and the absolute mass flow rate during heat transfer. The intersections between lines *A* to *D* and curve S_{real} distinguish the absolute mass flow rate.

If the mass flow rate during the intermittent operation matches the mass flow rate during the steady operation at a supply temperature of 35 °C, the MRP follows line *A*. When the mass flow rate during the intermittent operation is reduced by a factor of 0,85, the MRP follows line *B* and so on. The median power demand during unsteady operation equals half the value during steady state operation when the duration of heat supply equals the duration between the beginnings of two heat supply impulses.

With increasing supply temperatures the temperature difference along the surface heating system rises and the MRP decreases accordingly.

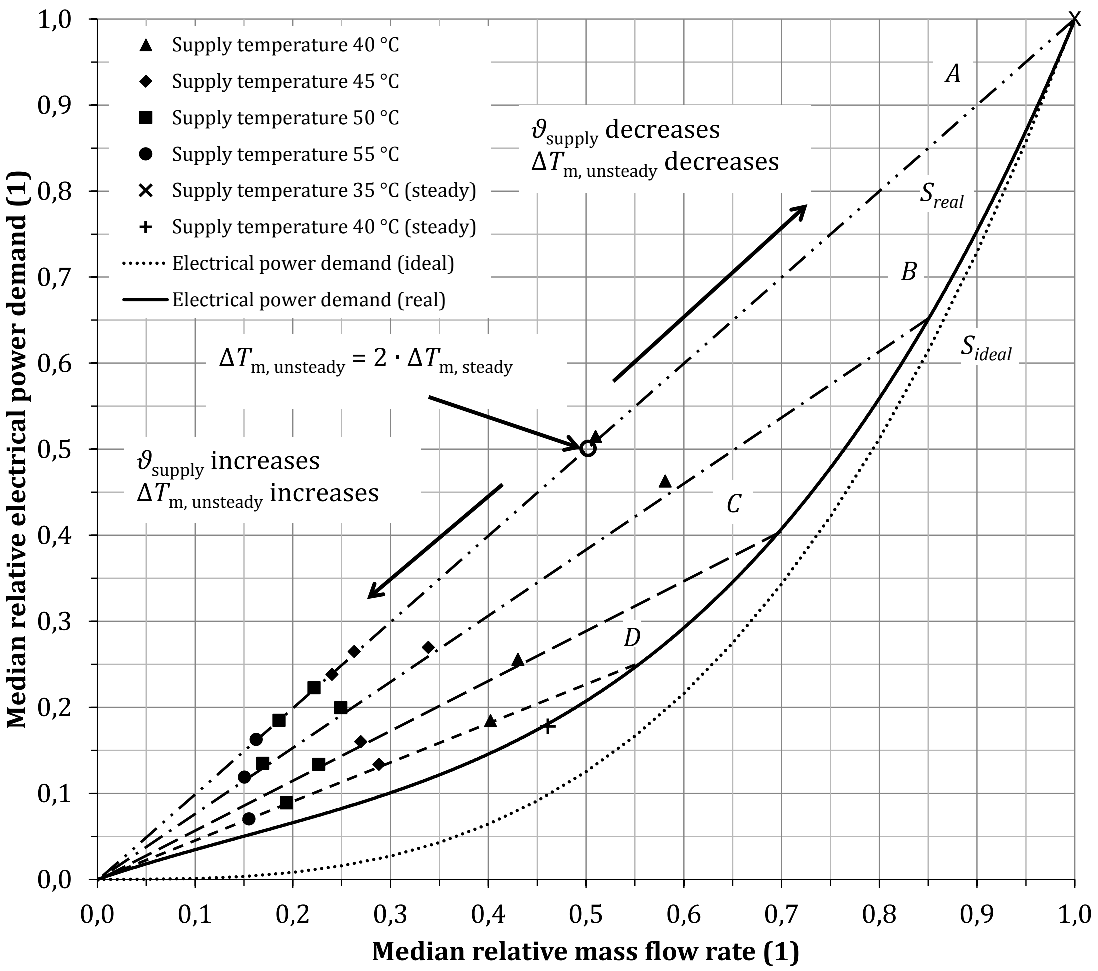

Fig. 4: Course of relative electrical power demand over relative mass flow rate during continuous control (curve S_{real}) and during intermitted control (lines *A* to *D*)

Heat-up measurements were conducted in order to evaluate the system's response time after a cool down period. After the test chamber was cooled to approx. 16 °C, the time to increase the operative room temperature from 18 to 22 °C was measured.

Full year simulations based on the weather data set from TRY 2011 region 4 were conducted to assess the response time of the system's control strategies during unsteady outer conditions.

According to DIN EN 1264, the maximum allowed surface temperature is 29 °C; this temperature was temporarily exceeded during the unsteady state operation of the thin layer system. First examinations with test subjects showed that the changing surface temperature is not perceived and negative impacts on the thermal sensation do not occur.

Conclusion and key findings

The reduction of the specific energy demand can be achieved for both examined systems. Increasing the supply temperature from 35 °C (steady state) to 50 °C (unsteady state) and decreasing the relative mass flow rate from 1 to 0.7 leads to a reduction of the specific energy demand of approx. 88 % for the thin layer system and approx. 86 % for the thick layer system.

As expected, the response time of the thin layer system is lower than the response time of the thick layer system (see Fig. 5). Increasing the supply temperature from 35 to 55 °C leads to a reduction of the room's heat up time from 18 to 22 °C by a factor of 4.6 for the thin layer system and by a factor of 2.6 for the thick layer system.

If the existing or planned heating generator provides supply temperatures above 35 °C, the auxiliary energy demand of the distribution pump can be significantly reduced. The replacement of return flow addition to control the supply temperature is generally recommended in combination with the unsteady state operation.

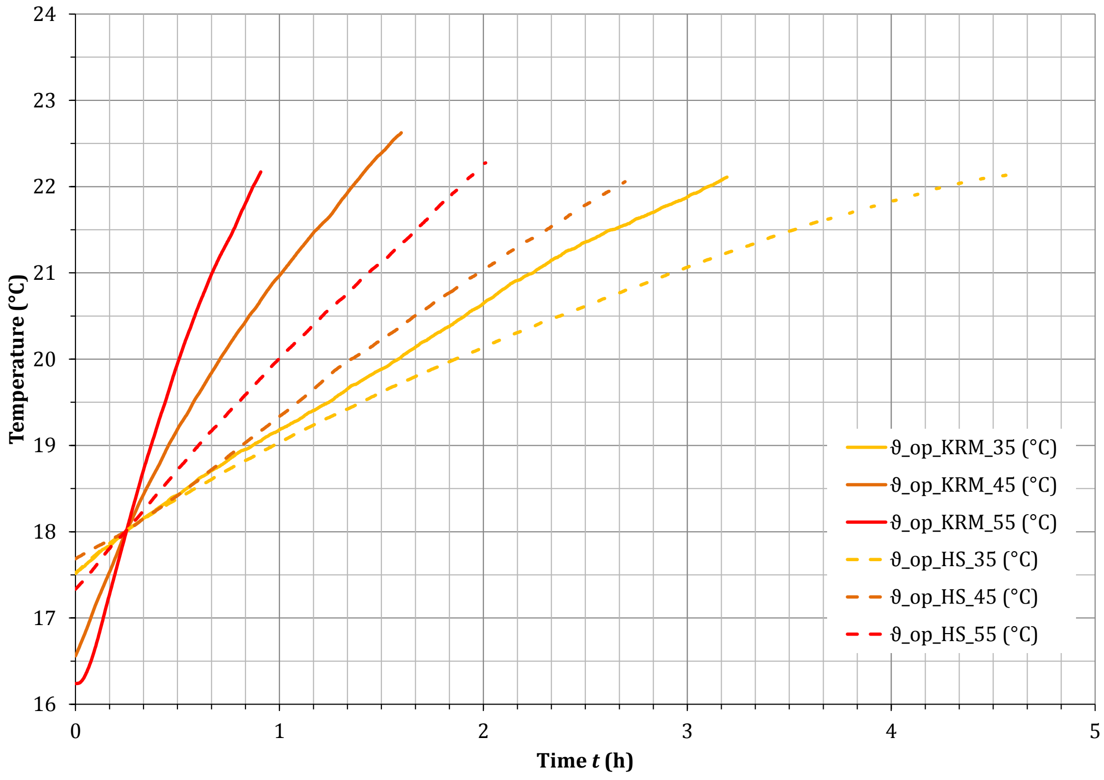

Fig. 5: Course of the operative room temperature during the heat up measurements at different supply temperatures and a relative mass flow rate of 1 for the thin layer (KRM) and the thick layer system (HS)

Imprint

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