prof. Ing. Vladimír Vašek, CSc.
Department of automatic control
Faculty of applied informatics
Tomas Bata University in Zlín
nám. T. G. Masaryka 5555
760 01 Zlín
E-mail: vasek@fai.utb.cz

Dissertation Opponents review

Dissertation Thesis	**: Design and analysis of energy efficient indoor-climate control methods for historic buildings**
Student	**: Magnus Wessberg, MSc.**
Supervisor	**: Prof. Ing. Tomáš Vyhlídal, CSc.**
Study Field	**: Control and Systems Engineering**
University:	**: Czech Technical University in Prague, Faculty of Mechanical Engineering**

Opponents report is drawn up based on of appointment by the vice-dean of the Faculty of Mechanical Engineering of the Czech Technical University in the position of the opponent of the dissertation on 27. 5. 2019.

The presented dissertation contains 83 pages of the text, two annexes, 89 items in the list of used literature. The list of outputs of the dissertation author contains 11 items in the standard breakdown of the researcher.

The work deals with the current issues of monitoring and effective management of interior space in historical buildings. This issue can make a significant contribution to better preserving the cultural heritage of human society.

Achievement of the goal, contribution of the author

The thesis objectives are declared in chapter 3. The first objective is to propose and validate a methodology for shaping the heating power for intermittent heating in massive historic buildings about heat-up time and change rate of RH. The main goal of this objective is to design a model of the control strategy to adjust the heating power to ensure indoor climate safety with low energy consumption. The second objective, to perform validation and analysis of adaptive ventilation method for relative humidity control in historic buildings, is to find out whether adaptive ventilation is an efficient alternative to other climate control measures for lowering relative humidity to prevent mould growth. The third objective is focused on the design and validation of the improvement of indoor climate control methods in historic interiors to prevent mould growth. The main task of this objective is to evaluate selected climate control measures for lowering relative humidity to prevent mould growth in massive historic buildings in terms of energy efficiency, mould prevention effectiveness, and stable relative humidity.

It can be stated that the declared objectives of this dissertation were set with the knowledge of the issues realistically and that they were fulfilled in chapters 4, 5, and 6.

The main contribution of the author is the application and comparison of several methods and tools for the creation of a control system for the stabilization of the internal environment of historical buildings, susceptible to large changes in humidity depending on temperature changes. These changes always lead to the deterioration of their own buildings, as well as the objects placed in them, and to the formation of harmful moulds.

It is evident from the submitted list of scientific and research outputs of the author that he has continuously and sufficiently published partial results of his work both in journals and conferences.

Selected processing methods

The introductory part of the thesis justifies the solution of the subject matter, which is focused and consequently declares the goals, the fulfilment of which should contribute to the current state of knowledge and contribution. Chapter 2 briefly outlines the reasons for solving the problem of managing the internal climate of historic buildings concerning temperature and relative humidity to prevent mould growth. The following chapters 4, 5 and 6 present their own methods of solving the declared three goals. Chapter 4 addresses the intermittent short-term heating of massive historic buildings, typical of heating before church ceremonies. For this method, a hygro-thermal approximation model is proposed, the parameterization of which is based on an experimental measurement of the temperature and relative humidity response to a step change in the input heat power. To reduce the rate of relative humidity decrease, a method of a jump increase spread over time heating power is proposed. This methodology was validated on simulation models of three specific historical buildings (churches in Sweden). This chapter fulfils the first declared goal of work.

Chapter 5, which fulfils the second objective of the dissertations, is focussed on the issue of ventilating the interior of historic buildings, as a tool for stabilizing the relative humidity through adaptive ventilation. Frequent and significant changes in moisture can lead to mould in the interior of historic buildings that can damage both the building itself and the artefacts, that are located there. Therefore it is important to analyse this problem and try to set the correct ventilation control mode. The adaptive ventilation validation was realized in case studies of three historic buildings. The analysis demonstrated the effectiveness of adaptive ventilation about mould formation. However, in long-term operation, there are times when it is better to use other methods of relative humidity stabilization, such as sorption dehumidifiers. The next chapter describes a comparison of control methods with the emphasis on mould growth and fulfils the last objective of the work. In the case of three-year measurements, a historical building using three different interior modifications, namely sorption dehumidification, moisture-controlled heating and adaptive ventilation, a comparison of these methods was made in relation to the possibility of mould formation, internal environmental stability, and economic efficiency.

It can be stated that the methodology for the elaboration of the given topic of the thesis was

chosen appropriately, as evidenced by the successful fulfilment of the goals of the work and the expected outputs of the whole work.

The importance of work for practice

I consider it important that the results achieved by solving of this dissertation have a broad practical application in the field of monitoring and effective climate control of historic buildings environment, thus enabling the protection of artefacts located in these buildings to be enhanced. Historic buildings were built at the time when solutions to their internal climate were not taken into account, and the necessary technology was not available for this purpose. Therefore, to preserve the legacy of past generations, it makes sense to address this issue and seek solutions that minimize energy demand.

Formal level

From the formal point of view, it can be stated that the work is structured well; the continuity of individual chapters has a logical structure. Own graphic design is good. From the stylistic point of view, it is clear that the author can formulate technical problems.

Questions

In the defense, it would be appropriate for the disertant to comment on the following questions:

- How long did it take to measure the jump responses of temperature and humidity in specific churches and how much heating power was needed to make the responses measurable?

- What is the adaptability of the described adaptive ventilation? What is the subject of adaptation?

- In chapter 5.2, you talk about the instrumentation of the adaptive ventilation control system using Raspberry Pi or Arduino microcomputers, describing the internal capabilities of these types of computing. Then you describe the connection to LabView and experiments with this program system. Which variation did you use for your specific experiments?

Final evaluation

I consider the submitted work to be of high quality. Ph.D. student has demonstrated that he knows the scientific methods of working to solve a particular task. It brought new knowledge that can be seen in the innovative approach to monitoring and controlling the thermal and humidity environment in historic buildings. Doctoral thesis Magnus Wessberg MSc., is elaborated on a highly v professional level. It brings new knowledge, shows the professional abilities and competence of the doctoral student for independent creative scientific work, his

good theoretical and practical knowledge in the field of system identification, modelling, and automatic control.

In my opinion, the submitted dissertation meets the conditions for doctoral dissertation and therefore

I recommend to defend it

Zlín 25. 6. 2019

prof. Ing. Vladimír Vašek, CSc.