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The effect of hydronic balancing on room temperature and heat pump efficiency of a building with underfloor heating

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Abstract

Underfloor heating is a common solution in single-family houses and a suitable solution for nearly zero-energy buildings as a low temperature heating system. According to general practice, the underfloor heating systems should be balanced to assure stable room temperatures and avoid under heating in rooms with higher heat losses. The purpose of the presented study was to analyze the effect of hydronic balancing on the room temperature fluctuations and heat pump performance. The tests were performed at full-scale nearly zero-energy building test facility with under floor heating and an air-to-water heat pump. We measured room and floor temperatures and monitored the heat pump electricity use and heat output. The heat balance of rooms was disturbed with internal gains introduced to several rooms in cycles. The results showed that room temperature fluctuations slightly increased of an unbalanced system, however during all tests, the average temperature fluctuations during night time were below 0.2 °C, so both systems performed well. We identified a negative effect of balancing on the heat pump performance as higher COP was measured in case of an unbalanced system. The results allow to conclude that in the case of studied system with one manifold and relatively small loop length differences the balancing had negligible effect on system performance. However, the topic should be studied further in more unfavorable conditions.

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Keywords: Underfloor heating; hydronic balancing; indoor climate; heat pumps.

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1. Introduction

Underfloor heating (UFH) is amongst the most commonly used heating system types in single-family houses. Being a low temperature heating system suitable for heat pumps, UFH is a good alternative for low and nearly zero-energy buildings. Generally, the floors have large thermal capacities and that may cause unnecessary over-heating as the floor still emits heat, when room temperature has exceeded the set point due to solar or internal heat gains. Also the heat output of the heating system is affected by the thermal resistance of upper layers of the floor and e.g. higher water temperatures are needed, when the floor is covered with wood.

Several studies have been conducted to analyze the performance of UFH. Seo et al. [1] measured thermal conductivity and transfer performance of 21 replicates of wood flooring materials and pointed out that laminated wood flooring exhibited the highest thermal conductivity. Wolisz et al. [2] analyzed the effect of furniture and floor covering on the dynamic temperature behavior of underfloor heating rooms and detected significant effect of furniture and floor covering on the simulation results. Zhou and He [3] studied the performance of UFH system with different heat storage materials and heating pipes and showed that capillary mats provided more uniform vertical temperature distribution compared to polyethylene pipes and phase change material increased the discharging time of the floor, which makes it suitable for using in combination with solar hot water systems. Gao et al. [4] investigated the indoor air temperatures of different under-floor heating pipe layouts and the best layout method was uniformly laid UFH pipes at 400 mm spacing. Maivel and Kurnitski [5] studied operative temperature corrections for EN 15316-2 and showed that the correction of 0.25 K should be used for radiators and no correction factor should be used with UFH. In [6] they also studied the effect of heating system return temperature on heat pump performance and pointed out that highest heat pump efficiency was achieved with direct connection of heat pump and heating system with lowest return temperature. They also showed that simple calculation of return temperature might lead to under-estimation over 10% of heat pump seasonal performance. So far little work, if any, has been done regarding the hydronic balancing of UFH systems.

General construction practice involves adequate dimensioning of water flows in the UFH loops and hydronic balancing, however the quality of heating and ventilation system design and construction may fluctuate significantly in case of single-family houses. The UFH loops may be unbalanced and it is assumed that it may cause problems achieving comfortable temperature levels in larger rooms with higher heat losses. However, during the process of this study we did not find any materials supporting these assumptions. We conducted UFH measurements at Tallinn University of Technology (TUT) nearly zero-energy building (nZEB) technological test facility with a balanced and an unbalanced system to determine the effect of hydronic balancing on the heating system. We measured room and floor temperatures in several rooms of the building and monitored the performance of the UFH system with air-to-water heat pump. The heat balance of some rooms was disturbed by internal gains introduced in cycles and also solar gains. As a result we calculated the temperature deviations in case of balanced and unbalanced systems and compared the heat pump coefficient of performance (COP) under different conditions.

2. Methods

Three tests were performed during February and April 2016 in theTUT nZEB test facility:

- Test #1: System with manual balancing (Feb 12-23)
- Test #2: System without manual balancing (Mar 11-21)
- Test #3: System with manual balancing (Mar 28-Apr 04)

The test facility was a building with heated area of 100 m^2 (Fig. 1), timber frame walls, concrete floor and roof. Internal walls were made of light-weight blocks or gypsum boards with light-weight insulation in between. UFH was used during the tests and the temperature set point was 21 °C in all rooms and on-off control was used. There was one UFH manifold located in the technical room in the middle of the building. Table 1 describes the heat losses of the building, UFH loops and the position of presetting valves during the different tests. All the valves were open during the unbalanced test except, the valve of room no. 6, which was left in the same position during the unbalanced test to represent a room with higher heat losses. Internal heat gains were introduced in cycles to disturb the UFH system to