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Improvement of intermittent central heating system of university building

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ABSTRACT

Most universities in Korea use intermittent central heating system which operates according to a preset intermittent schedule that is determined based on outdoor air temperature. This system is popular for university buildings due to its low initial cost and simple operation. But since it is not based on feedback control, the indoor thermal comfort is unsatisfactory. In this research, problem with the current control system is studied by experiment and dynamic simulation. The measurement shows that the indoor temperature rises to an uncomfortable range during heating and falls below comfortable range when heating is off. To solve this situation, an on–off control is implemented and simulated using a dynamic simulation program. Since there is a good agreement between experiment and dynamic simulation results, dynamic simulation is used to predict other results with different conditions of interest. The simulation shows that by implementing on-off control, the indoor space can be maintained within comfortable range, moreover using less energy. By reinforcing insulation to the walls that are exposed to the outdoor environment, heating energy can be saved further.

1. Introduction

Korea enjoys beautiful weather all the year round given by its four distinct seasons. But on the other hand, a lot of energy is used for heating and cooling. It is known that about 15% of the total energy consumed is used for air-conditioning in Korea. Generally, cooling is required from May to October and heating from November to April. There are about 350 universities and colleges in Korea and majority of them use intermittent central heating system during heating seasons. The advantages of this heating system are low initial cost, quick response and simple operation. It is not effective, however, since it operates according to a preset intermittent schedule that is determined based on the outdoor air temperature.

There are several works related to central heating system. Zanobini et al. adopted a digital control for central heating using several sensors for enhancing energy saving and comfort [1]. The user can choose one of the eight heating programs, from maximum economy to maximum comfort. Andersen et al. suggested pump control for eliminating oscillations in central heating system [2]. Cho and Azheer-uddin showed that predictive control of intermittently operated radiant floor heating system can improve efficiency [3]. Kim et al.'s work is related to economic analysis of combined heating and cooling for educational buildings [4].

A university building located in Seoul, Korea is chosen for this study. Indoor and outdoor thermal conditions are measured and compared with the dynamic simulation. Since current intermittent heating method causes thermal discomfort, improvement of control logic is suggested for better thermal comfort and energy saving using dynamic simulation. Generally, external walls of university buildings are poorly insulated. The effect of additional insulation on external walls on energy consumption is studied by dynamic simulation.

2. Intermittent central heating system

A lecture room of a university building located in Seoul, Korea is chosen for this study. The dimension of the lecture room is 7.2 m × 7.8 m × 3.0 m (height) as shown in Fig. 1. The wall facing south consists of two windows of which the width is 2.9 m and height 2.1 m each. This wall is exposed to the outer environment. Steam produced by a boiler is supplied to the two radiators installed beneath the windows facing south. The walls facing east and west are assumed insulated since they are adjacent to the other lecture rooms with the same thermal conditions. The blackboard and teacher's desk are on the west side wall. The north side wall is in contact with the corridor which is not fully air-conditioned, but at a different condition than the outdoor environment.

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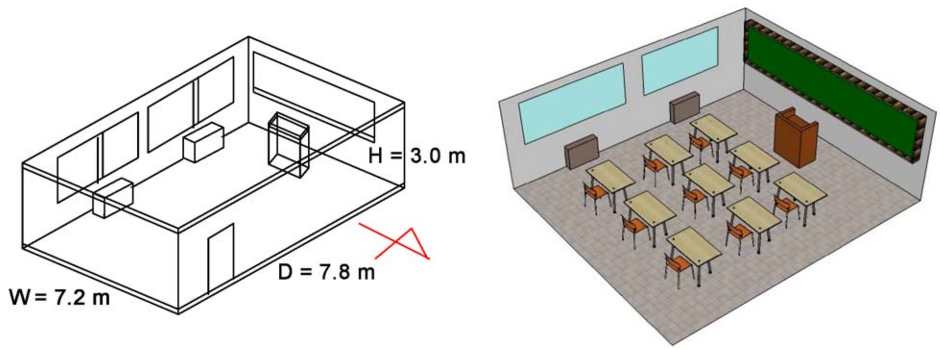

Fig. 1. Lecture room.

Table 1
Heating schedule.

Case	T_{out} (°C)	During semester		During winter vacation	
		Time	Total time	Time	Total time
1	−1 to 5	08:00–10:00 13:00–14:30 18:00–20:00	5 h 30 min	08:00–10:00, 13:00–14:30	3 h 30 min
2	−5 to −1	08:00–11:00 13:00–15:30 18:00–20:30	8 h 00 min	08:00–11:00, 13:00–15:30	5 h 30 min
3	−10 to −6	08:00–11:30 13:00–16:00 18:00–21:00	9 h 30 min	08:00–11:30, 13:00–16:00	6 h 30 min
4	Below −10	08:00–11:30 13:00–16:00 18:00–21:30	10 h 00 min	08:00–11:30, 13:00–16:00	6 h 30 min

In this intermittent central heating system, heating is done 2–3 times a day based on a preset heating schedule that is dependent on the outdoor temperature and time of the season. Normal heating is done from Monday through Friday. On Saturdays, heating is done only in the afternoon. During winter vacations, no heating is done in the evening. If the outdoor temperature becomes very low, heating is done during 4–5 am to avoid water freezing in the pipes. Table 1 shows four cases of heating schedule based on the outdoor temperature.

3. Measurement

Since uncontrolled number of students enter and leave lecture rooms, accurate indoor thermal conditions cannot be measured during semester. Therefore experiment was carried out during winter vacation since the access to the classrooms can be prohibited. T-type thermocouple (accuracy 0.1 °C) and relative humidity sensor (accuracy 3%) were used to measure the indoor thermal conditions. Sensors for measuring the indoor thermal conditions were located at the center of the room and 1 m above the floor. Since inserting a temperature sensor into the steam pipe of the radiator is difficult, T-type thermocouple is attached on the surface of the inlet steam pipe and a 2.5 cm insulation material is covered around it to minimize heat loss. Portable data logger is used for measuring and recording outdoor temperature (accuracy 0.3 °C) and relative humidity (accuracy 5%). Outdoor temperature and humidity, indoor temperature and humidity, and steam temperature supplied to the radiator were measured and recorded by a data logger.

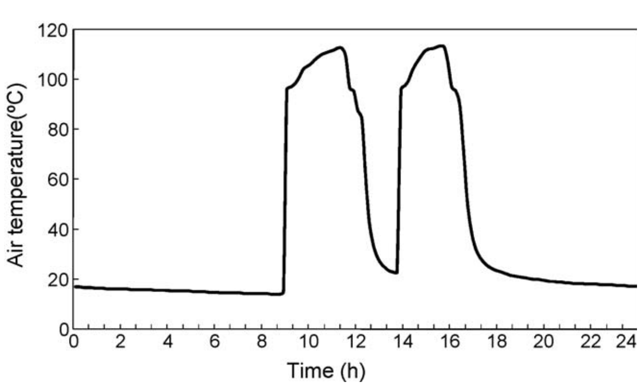

Fig. 2. Inlet steam temperature.

Fig. 2 shows variation of inlet steam temperature to the radiator measured on February 1st, 2007. Minimum outdoor temperature during this period was −9.8 °C.

4. Dynamic simulation

TRNSYS program developed by Solar Engineering Laboratory, University of Wisconsin at Madison is used for dynamic simulation [6]. Materials and overall heat transfer coefficients of walls, ceiling and floor is given in Table 2.

Two 5-split cast iron radiators are installed in the lecture room. For a standard operating condition of 102 °C steam temperature and 18.5 °C indoor temperature, heating capacity of a radiator is 650 kcal/h per an area of m^2. Measurement shows that the average temperature of steam is 105 °C, and indoor temperature 20 °C, thus the correction factor C_s becomes 1.02 as calculated in the following