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Assessment of the Energy Performance of an Air Source Heat Pump by Response Surface Methodology

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Abstract

Air source heat pumps (ASHP) are preferable to traditional heating systems because of their high efficiency and energy-saving potential. Moreover, they can be coupled with renewable energy sources. In this work the performance of a two-stage ASHP unit is presented. Experimental data were collected in winter mode. Due to the scarcity of reliable experimental data, a response surface methodology (RSM) was applied with the aim of extending the data sample. The new database was analyzed to point out the performance of the ASHP by varying the supply water temperature to the indoor terminals in different ambient conditions. It was possible to draw curves showing the relationship between ASHP performance (power consumption and COP), supply water temperature and ambient temperature. An optimal configuration of the system that minimizes the power consumption of the HP while maintaining the internal comfort was assessed to be: 30°C for the supply water temperature and 2.4 m^3h^{-1} for the supply water flow rate when the ambient temperature is 10°C.

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Keywords: air source heat pump; fan coil; RSM.

1. Introduction

Air source heat pumps (ASHP) are well-known heating systems, more efficient than conventional systems as they can reduce CO_2 emissions while coupled with renewable sources. ASHP can be combined with different indoor terminals of HVAC systems in buildings. However, capacity control of

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the ASHP is needed to reduce power consumption and enhance system performance, as presented by Xue et al. [1], where the capacity of the heat pump (HP) is modified to match the energy demand by means of the compressor load regulation. Similarly, Safa et al. [2] show that for a two-stage variable capacity ASHP the performance can be improved if a reduction in operating cyclic time and speed of the device is applied. Another important parameter to be adjusted and controlled during HP operation is the supply water temperature of the heat pump as it can increase the heat pump performance, as stated by Gao et al. in [3].

In the present work the performance of a two-stage ASHP unit (with two compressors running contemporary or individually) is presented while it is operated with several supply water temperatures, under variable outside ambient temperature and with different indoor temperature set-points. After collecting the experimental data, the response surface methodology (RSM) is applied to extend the available sample [4] and to determine the relationships between inputs and outputs of the ASHP system in order to highlight the best system configuration in terms of efficiency.

2. Methodology

The studied ASHP was operated in a test rig. The experimental data were previously analyzed and therefore used to perform the response surface methodology, in order to draw conclusions about the system performance and optimization. The system setup and the test room are described below, together with the RSM basic theory.

2.1 Lab room and experimental setup

The test room is an experimental system built inside the Green Energy Laboratory (GEL) in Minhang campus owned by Shanghai Jiao Tong University. This room is equipped with a two-stage air to water heat pump, providing both heating and cooling, coupled with ceiling and floor fan coil units (FCU) and radiant floor (heating only) as indoor terminals, as shown in Figure 1.

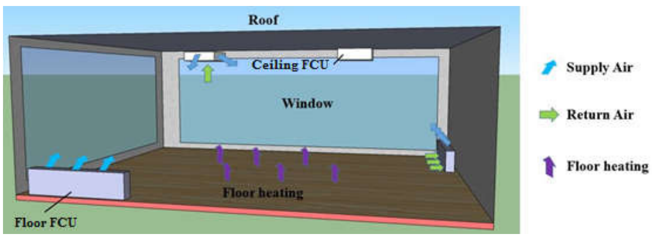

Fig. 1. Schematic of the different indoor terminals in the test room

The air source heat pump serves the test room and 4 other rooms in GEL, for a total area of 292 m^2. The heating capacity of the ASHP is 39.5 kW with a nominal power of 12.2 kW (each compressor is about 6 kW). The user can set the supply water temperature and the indoor room temperature. The HP runs until both set points are reached. The capacity of the HP varies accordingly: for a big heating request the two compressors work together, for smaller requests only one compressor runs. During the tests the three types of terminals were operated one by one under different conditions and only in heating mode.

Table 1 provides the specifications of the measurement equipment: flow meters records the water flow rate that supplies the indoor terminals, thermal resistance measures the temperature in the hydronic water circuit, temperature loggers are used for measuring the rooms and ambient temperatures and current transformers are needed for the energy consumption calculation.