EXPERIMENTAL INVESTIGATION OF FROST ON AN AIR-SOURCE HEAT PUMP EVAPORATOR

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EXTENDED ABSTRACT

OVERVIEW

The application of heat pumps for buildings heating systems in the cold or transitional season of the year is increasingly common not only in Lithuania but also in other European Union countries. Due to the growing popularity of air to air or air to water heat pumps in the building sector, the problem of evaporator heat exchanger freezing is also increasing in importance. As the outdoor temperature drops, the heat pump's efficiency – coefficient of performance for heating (COP) decreases. At high relative humidity there is also a risk of the evaporator heat exchanger to start freezing. This increases the energy consumption of the system, has a negative effect on heat exchange. Given the need for experimental and numerical research, the aim of this work is to analyse and present the characteristics of air source heat pump (ASHP) in the presence of the risk of freezing and to qualitatively assess the COP reduction due to frost formation. This paper investigates the operation of an ASHP in the cold season, observes the freezing of the evaporator as environmental conditions change. An experimental stand was constructed for this research; the necessary measuring devices and a camera were installed for visual observation of the experiment and assessment of frost formation. The experiments were carried out during the transitional - cold season of the year. It was found that frost formation on the evaporator started when the outdoor temperature was <3.5 °C and the relative humidity reached 88%. The defrost cycle took an average of 5 minutes. The impact of evaporator freezing on the operation and efficiency of the system - COP - has been assessed.

METHODOLOGY

The object of the research is an evaporator of the ASHP Panasonic WH-UD07HE5-1, located in the Laboratory of Building Energy and Microclimate Systems of Vilnius Gediminas Technical University. The operation mode of the heat pump heating circuit during the cold season of the year is analysed. The conditions under which the frost layer begins to form on the evaporator including the peculiarities of its formation and influence on the operation mode and efficiency of the – ASHP are investigated. According to the manufacturer's specifications, the heat output of the ASHP is 7 kW, and the COP is 4.46 when the ambient air temperature is 7 °C and the secondary circuit supply water temperature is 35 °C. The design air flow rate of the evaporator is 2760 m^3/h.

Temperature, humidity, air flow rate, ambient air parameters were measured during the experiment. In addition, a video camera (GoPro HERO7 Silver) mounted under the hood perpendicularly to the heat exchanger was used for visual observation of the experiment and assessment of the frost formation. All measurement results were recorded every 1 minute.

From the ASHP experimental operation data, its efficiency factor for heating – COP – was calculated as the ratio between the amount of heat received by the heat pump and the electricity consumption. The amount of electricity consumed by the heat pump was calculated knowing the current, voltage and duration of the experiment. The power factor (cos(φ)) was taken 0.97. The amount of heat received by the heat pump in the external unit (secondary - water circuit) was calculated knowing the measured water flow rate, temperature difference between supply and return temperatures in the water circuit, water density and specific heat capacity at constant pressure.

During the recording of heat pump operation data and visual monitoring of its evaporator, the data was analysed to examine the defrosting process of the heat exchanger and to assess the reduction in COP due to frost formation on the evaporator. Depending on the ambient weather conditions during the experiments, it was decided to distinguish three different periods when the typical days have such temperatures and humidities:

1) positive average ambient temperature (~4°C) and average relative humidity (~86%);
2) negative ambient temperature (from –7 to –1°C, about –3°C) and average relative humidity (~93%);
3) average temperature about (0°C) and average relative humidity (~95%).

RESULTS

The experiments were performed during the 2020 heating season. Three different periods are selected for the analysis: from November 11, 5 p.m. to November 12, 1 p.m.; from December 1, 5 p.m. to December 3, 2 p.m.; and from December 15, 4 p.m. to December 17, 1 p.m.

These periods were chosen because at that time frost formation was observed on the evaporator of the heat pump, and the heat exchanger defrosting processes occurred. The set parameters for the supply and return water temperature in the external heat pump unit were 50 °C and 45 °C, respectively. Figure 1 shows a comparison of the results for all three time periods.

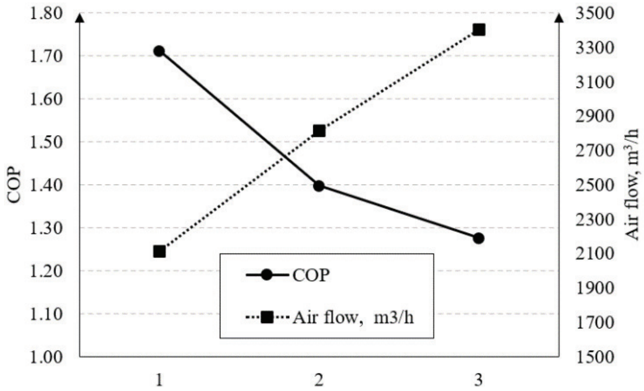

Fig. 2 Comparison of all three periods – variation of air flow and COP depending on ambient temperature and relative humidity. 1 - average ambient temperature 4.02 °C, relative humidity 85.82 %; 2 - average ambient temperature 0.51 °C, relative humidity 94.90 %; 3 - average ambient temperature -2.80°C relative humidity 92.54 %;

CONCLUSIONS

With the popularity of ASHP installations in cold and temperate climates, there is a need to assess the impact of climatic conditions on the operation of such equipment - efficiency. The article experimentally and visually examines the effect of air source heat in the presence of negative, about 0 °C and positive ambient air temperature, when there is a risk of freezing the heat pump evaporator. Experiments have shown that:

1. Frost formation on the evaporator's heat exchanger plates starts when the outdoor air temperature is less than 3.5 °C and the relative humidity reaches 88%.
2. The frozen evaporators defrost cycle takes an average 5 minutes. The defrost cycle remains the same during the different experiments, regardless of the ambient air parameters, only its frequency varies.
3. The frost defrost process alone reduces the COP by 10.74% compared to the same period as evaporator freezes but defrost process does not happen. In other cases examined the COP has fallen even more (up to 20.99% the average ambient air temperature was -2.80 °C).
4. During the experiments, the dependence of the extracted air flow on the ambient air temperature is observed. The average air flow rate is found to decrease as the ambient temperature rises.

Keywords: heat pump, evaporator, frost formation, efficiency, experiment, transitional - cold season.