Data Article

Field monitoring data on a residential exhaust air heat pump system (air-to-air heat pump)

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\textbf{A B S T R A C T}

This data article presents the raw data used in the article “Experimental and analytical evaluation of exhaust air heat pumps in ventilation-based heating systems”\textsuperscript{[1]}. The data set contains measurement results of a field monitoring on a residential exhaust air heat pump system (air-to-air heat pump) in Germany. This data could be used to investigate the dynamic behavior and performance of the exhaust air heat pump systems. The data set contains air temperature and humidity of all four sides of the heat pump unit. Moreover, the electrical consumption of the unit and the dynamic pressure difference on the exhaust side (as indication of the air volume rate) could be also found in the data set.

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Abbreviation: EHA1, Exhaust air condition 1 (After air-to-air heat exchanger), EHA2, Exhaust air condition 2 (After evaporator), ETA, extract air from building, Evap., Evaporator, COP, Coefficient of performance, HEX, heat exchanger, HP, heat pump, HRV, Heat Recovery Ventilation, ODA, Outdoor Air; SUP1, Supply Air condition 1 (after air-to-air heat exchanger), SUP2, Supply Air condition 2 (after condenser), T, Temperature, X, Humidity.

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Specifications Table

| Subject | Renewable Energy, Sustainability and the Environment |
|---------|-----------------------------------------------------|
| Specific subject area | Air to Air Heat Pump Technology |
| Type of data | MATLAB Data |
| Figure | |
| How data were acquired | Type K Thermocouple for temperature |
| | STHP-2–1–05 for humidity |
| | Pitot tube for dynamic pressure difference |
| | Testo 6351 for pressure difference transmitter |
| | Current transformer for electrical power |
| | Tracer gas for air volume rate |
| Data format | Raw and smoothed |
| Parameters for data collection | Humidity data was recorded as relative humidity and converted to absolute humidity. |
| | Dynamic pressure difference was used as an indication of air volume rate. |
| Description of data collection | The measurement period was 55 winter days with an interval of 1 second. |
| | Logging and conversion of signals were conducted using a modular I/O system; the fieldbus controller Ethernet 750–881 from WAGO Kontakttechnik. |
| Data source location | Stuttgart, Germany |
| Data accessibility | Descriptions and figures are provided with the article, measurement data is uploaded in a public repository. |
| | repository name: Mendeley Data |
| | Shirani, Arsalan (2021), “Field monitoring data on a residential exhaust air heat pump system (air to air heat pump)”, Mendeley Data, v3 [2] |
| | Link to raw date: http://dx.doi.org/10.17632/smymkjcbxx.3 |
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Value of the Data

- The presented data could be used for better understanding the functionality of exhaust air to air heat pump and heat recovery ventilation technologies and compare the heat pump power and performance to the other heat pump technologies.
- The data is interesting for the building energy engineers, heating system developers and researchers working on the heat pump and heat recovery technologies.
- The data could be used to understand and model the dynamic behavior of exhaust air heat pumps and heat recovery ventilation units.

1. Data Description

The data set containing two MATLAB structures is uploaded in a public repository [2]. Each field of the MATLAB structures contains one raw measured data or one smoothed measured data. Data smoothing is conducted using MATLAB function “smoothdata” with a Gaussian-weighted moving average filter with a window length of 120 time steps. Raw and smoothed measured data of the air temperature [in °C] and air humidity [in kg/kg] on all four side of the unit could
be found on the data set [2]. Moreover, the measured electrical consumption of the unit [in Watt], as well as dynamic pressure difference on the exhaust air side of the unit [in Pa] are available on the data set. The date and time of the measured data is also available in “date” field. Measurement period was 55 winter days (during December 18th, 2019 and February 12th, 2020) with an interval of 1 second.

2. Experimental Design, Materials and Methods

Fig. 1 shows a hydraulic illustration of the measured exhaust air heat pump (EHA-HP) and the position of the installed sensors. Air temperature and humidity on all four sides of the unit (outdoor air, extract air coming from the building, supply air to the building and exhaust air leaving the house) and electrical power consumption of the unit (compressor and ventilators) were measured and logged. Logging and conversion of signals were conducted using a modular I/O system; the Fieldbus controller Ethernet 750–881 from WAGO Kontakttechnik.

The air temperature (T) is measured with type K thermocouples from RS PRO. The calibration of thermocouples is conducted based on a calibration bath method. The air humidity (X) is measured using STHP-2–1–05 sensors from NodOn. Electrical power consumption (P_el) of the unit is measured using plug-in current transformer from WAGO Kontakttechnik.

Table 1 gives an overview of the applied measurement methods and used sensors.

In addition, the dynamic pressure difference (as an indication of the air volume rate) on the exhaust side was logged during the measurement period (ΔP_{dyn}). Finally, the air volume rates of the unit at different ventilation levels was measured using Constant injection tracer gas method, as described in [3]. Fig. 2 shows the experimental set up for the tracer gas measurement.

Table 2 summarizes the measured air volume rates and ventilators’ powers usage in different levels.

The measurements were conducted in an efficient house with a living area of 185 m² in Stuttgart, Germany. The EHA-HP was installed in a ventilation-based hybrid heating system as the central heating source of the building. Fig. 3 illustrates the air temperatures and the
Table 1
Overview of applied measurement methods and sensors.

| Value             | Sensor/measurement method | Measurement accuracy | Manufacturer                   |
|-------------------|---------------------------|----------------------|---------------------------------|
| Temperature       | Type K Thermocouple       | ±0.004 × |t| [°C]                  | RS PRO                          |
| Humidity          | STPH–2–1–05               | ±2 [%]               | NodOn                           |
| Dynamic pressure difference | Pitot tube | ±2 [%]               | Mueller Messinventurte          |
| Pressure difference transmitter | Testo 6351 | ±0.3 [Pa] | Testo                           |
| Power             | Current transformer       | ±1 [%]               | WAGO Kontakttechnik             |
| Air volume rate   | Tracer gas                | ±5 [%]               | LumaSense Technologies          |

Table 2
Summary of measurements on air volume rates.

| Ventilation level | Dynamic pressure difference [Pa] | Air volume rates [m³/h] | Ventilators’ power usage [W] |
|-------------------|----------------------------------|-------------------------|-------------------------------|
| 1                 | 1.5                              | 91.2                    | 20                            |
| 2                 | 5                                | 184.6                   | 50                            |
| 3                 | 12                               | 249.4                   | 123                           |
| 4                 | 26                               | 341.1                   | 334                           |

Fig. 2. Experimental set up, tracer gas method.

Table 3 gives an overview of the measured electrical energy consumption as well as minimum and maximum power of the power consumption of the unit. Moreover, based on number of defrost cycles and heat pump run time, it could be seen that the heat pump runs a defrost process approximately every one hour.
Fig. 3. Air temperatures and electrical consumption of the unit on 10 sample winter days.

Fig. 4. Sample of a defrost process.

Table 3
Summary of measured data of the exhaust air heat pump.

| Description                                           | Value | Unit   |
|-------------------------------------------------------|-------|--------|
| Total electrical energy input                         | 261   | [kWh]  |
| Minimum power (HRV mode, ventilators level 1)         | 20    | [W]    |
| Maximum power (heating mode, ventilators level 2)     | 650   | [W]    |
| Number of defrost cycles                              | 667   | [Cycles]|
| Heat pump run time                                    | 681   | [Hours]|
Fig. 5. Air temperatures in the heat recovery ventilation mode.

Table 4  
Summary of measured temperatures, including min, max and average values.

| Description                                                                 | Value  | Unit  |
|----------------------------------------------------------------------------|--------|-------|
| Average outside air temperature (ODA)                                      | 4.1    | °C    |
| Average extract air temperature (ETA)                                      | 18.5   | °C    |
| Average supply air temperature (SUP2)                                      | 20.9   | °C    |
| Average supply air temperature during HP run time (SUP2)                   | 34.8   | °C    |
| Minimum supply air temperature (SUP2)                                     | 11.6   | °C    |
| Maximum supply air temperature (SUP2)                                      | 46.8   | °C    |
| Average exhaust air temperature (EHA2)                                     | 2.2    | °C    |
| Average exhaust air temperature during HP run time (EHA2)                  | -3.44  | °C    |
| Minimum exhaust air temperature (EHA2)                                    | -11.7  | °C    |
| Maximum exhaust air temperature (EHA2)                                    | 16.8   | °C    |

The periods, which the SUP2 (temperature after the unit) is lower than the ETA (extract air temperature coming from building), the unit works in heat recovery ventilation mode and the heat pump is switched off. In this mode, the electrical consumption of the unit is around 50 W and it contains the electrical consumption of the ventilators. Fig. 5 shows a sample day, in which the unit works only in the heat recovery ventilation mode. The heat recovery efficiency ($\eta$) is calculated using the following equation:

$$ \eta = \frac{\vartheta_{\text{SUP}} - \vartheta_{\text{ODA}}}{\vartheta_{\text{ETA}} - \vartheta_{\text{ODA}}} $$

Table 4 summarizes the measured air temperatures of the unit. The average values of SUP2 and EHA2 is calculated separately for both HP run time and the whole measurement period.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships, which have, or could be perceived to have, influenced the work reported in this article.
CRediT Author Statement

Arsalan Shirani: Conceptualization, Methodology, Software, Investigation, Data curation, Writing – review & editing, Visualization; Alexander Merzkirch: Conceptualization, Methodology, Investigation; Jennifer Roesler: Investigation; Stephan Leyer: Conceptualization, Supervision; Frank Scholzen: Conceptualization, Supervision; Stefan Maas: Conceptualization, Supervision.

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