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Reversing air-source heat pumps – Noise at defrost initiation and a noise reducing strategy

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ABSTRACT

With the increasing use of air source heat pumps, noise disturbance can be a barrier for further market growth and acceptance. Both steady state noise level and noise events influence reported noise disturbance. In this study one of the transient noise events was investigated: the noise initiated when the heat pump shifts to defrost mode. The results show that noise from a heat pump at defrost initiation was strongly dependent on the pressure differences in the system at the time of the shift. A reduced pressure difference resulted in a lower noise level. A control strategy that adds an idling time for the heat pump just before the shift of the 4-way valve is therefore suggested. This will have a small negative effect (<3%) on the heat capacity of the heat pump but the effect upon the COP will be negligible.

Pompes à chaleur aérothermiques réversibles – Le bruit au début du dégivrage et stratégie de réduction du bruit

Mots clés : Pompe à chaleur ; Réduction de bruit ; Différences de pression ; dégivrage ; Vanne 4 voies ; Energie ; COP

1. Introduction

An increasingly common source of environmental noise in society is the operation of air source heat pumps. For villa areas with low background noise levels heat pump noise may be considered disturbing and can be a barrier for further heat pump market growth and acceptance. Several researchers have identified the compressor and the fan as the dominating noise sources in a heat pump (Crocker et al., 2004; Fagot-Revurat and

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Nomenclature

Roman case letters

COP	coefficient of performance [–]
H	latent heat of fusion (melting) of water [kJ kg^{-1}]
LeqA	A-weighted equivalent sound pressure level [dB(A)]
m	mass of ice to melt during defrost [kg]
Q	energy (heat or electricity) [kJ]
T	temperature [°C]
t	time [s]
$\dot{W}$	power [kW]

Subscripts

c	complete heating cycle (heating + idling + defrost)
d	defrost period
e	electricity
f	fusion of water
h	heating period
i	idling period
in	indoor
out	outdoor

Fournier, 2003). Other authors have studied the noise from these components in detail in heat pump, air-conditioning and refrigeration applications (Yanagisawa et al., 2002; Ayers et al., 1981; Evans, 2003; Pearson, 2011; Lee et al., 2010; Heo et al., 2011). Less attention has hitherto been given to the system perspective of the noise generation. However some researches have addressed the noise impact of the physical design (grille and deflecting ring) of the heat pump (Tian et al., 2009; Hu and Ding, 2006). In previous research the authors of this article have studied the correlations between the noise and energy performance of air-to-air heat pumps and the impacts of heat exchanger design on the fan noise (Gustafsson et al., 2011; Gustafsson et al., 2014). Based on ongoing research, the authors suspect that transient heat pump noise, e.g. noise at defrost initiation, is especially disturbing. Deeper investigation of this topic is currently done.

In air source heat pumps, reverse operation defrost technology is often used. During defrost operation the refrigerant flow direction is reversed to circulate warm refrigerant to the frosted evaporator. The refrigerant heats the evaporator which in turn melts the frost. For many commercial products the worst outdoor conditions from a frosting point of view (around 2 °C), the evaporator must usually be defrosted approximately once per hour.

A 4-way valve is used to reverse the flow direction of the refrigerant. When the valve is shifted the unequal pressure levels in different parts of the systems are initially equalized and this pressure release action generates a hissing sound well above the stationary level. This type of transient noise is often considered to be very annoying (Hygge et al., 1999; Landström et al., 1999). Even though the shift to defrost mode does not occur more frequently than approximately once per hour it may still be important from an annoyance point of view since the noise may function as a reminder of the general noise of the heat pump. It may also cause sleep disturbance.

A patent describing a solution to the initial noise at defrost has been granted (Amick, 2013). It describes a solution with added compressor idling time before shifting to defrost mode. With the aim of improving the solution presented by Amick, the aim of the present study was to:

- investigate the physics of the noise generation from a heat pump when it shifts to defrost;
- find solutions and a strategy that could reduce the noise from the heat pump at defrost initiation;
- evaluate the strategy in terms of the energy performance of the heat pump system.

2. Methodology

The physics of the noise generated by a heat pump shifting to defrost was investigated by laboratory measurements on an air-to-air heat pump rig operated at different pressure levels. The sound pressure level from the heat pump and the pressure at the evaporator- and condenser side were measured before and during the shift. Finally a new control strategy for operating the compressor, fans, electronic expansion valve and 4-way valve (also called the reversing valve) was investigated with the aim of evaluating the effect of various control settings on the energy performance of the heat pump system.

2.1. *Laboratory setup*

The measurement object was an air-to-air mono bloc heat pump prototype where the compressor, the fans and the valves could be operated separately. The heat pump was installed in field conditions i.e. not in temperature-controlled spaces and the room where the measurements were conducted was not acoustically insulated. The prototype was built of the following components:

- Compressor: inverter twin rotary compressor, 13 cc, R134a
- Electronic expansion valve
- Evaporator: tube/fin (copper/aluminum) heat exchanger with 6 tube rows and 3 mm fin pitch. Air side heat transfer area of approximately 5 m^2.
- Condenser: tube/fin (copper/aluminum) heat exchanger with 2 tube rows and 2 mm fin pitch. Air side heat transfer area of approximately 6 m^2.
- Evaporator fan: Centrifugal fan with brushless DC motor
- Condenser fan: Tangential fan with brushless DC motor

The sound from the heat pump was recorded continuously with a portable digital recorder (Zoom H4n). A Norsonic sound pressure level meter was started for every individual measurement. Both meters were positioned next to each other 55 cm from the heat pump, as shown in Fig. 1. The sound pressure levels that were measured cannot be seen as absolute numbers since only one microphone position and no reference sound source was used. Standard deviation of the repeatability is estimated to be <1dB (A) based on the uncertainty of the measurement equipment and the source under test. The standard deviation of reproducibility is higher, but is not relevant