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Flat tube heat exchangers – Direct and indirect noise levels in heat pump applications

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HIGHLIGHTS

- The direct noise from a heat exchanger is negligible in heat pump applications.
- The design of the heat exchanger highly influences the noise from an outdoor unit.
- Flat tube heat exchangers can reduce the noise from the outdoor unit of a heat pump.
- Flat tube heat exchangers can increase the energy efficiency of a heat pump.

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ABSTRACT

In the outdoor unit of an air-source heat pump the fan is a major noise source. The noise level from the fan is dependent on its state of operation: high air-flow and high pressure drop often result in higher noise levels. In addition, an evaporator that obstructs an air flow is a noise source in itself, something that may contribute to the total noise level. To be able to reduce the noise level, heat exchanger designs other than the common finned round tubes were investigated in this study. Three types of heat exchanger were evaluated to detect differences in noise level and air-side heat transfer performance at varying air flow. The measured sound power level from all the heat exchangers was low in comparison to the fan sound power level (direct effect). However, the heat exchanger design was shown to have an important influence on the sound power level from the fan (indirect effect). One of the heat exchangers with flat tubes was found to have the lowest sound power level, both direct and indirect, and also the highest heat transfer rate. This type of flat tube heat exchanger has the potential to reduce the overall noise level of a heat pump while maintaining heat transfer efficiency.

1. Introduction

Sound affects humans in both positive and negative ways. Sounds with positive effects can be sounds we subjectively define as pleasant or relaxing. Noise is often defined as unwanted sound, sound that is loud, unpleasant or unexpected. Noise affects people in everyday life and in different ways depending on the type of noise, noise level, frequency characteristic, time of day and variance over time.

Some of the main health risks of noise identified by WHO are:

- Hearing impairment including tinnitus
- Annoyance
- Interference with speech communication
- Sleep disturbance and all its consequences on a long and short term basis
- Cardiovascular effects
- Hormonal responses (stress hormones) and their possible consequences on human metabolism (nutrition) and immune system
- Performance at work and at school.

Two of the major environmental noise sources in our society are traffic (road, rail and air) and industrial processes. A less known noise polluting product category is air source heat pumps. However, for air source heat pumps, a possible barrier for further

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market growth and customer acceptance is their noise level. The noise from an air source heat pump is a combination of several noise generating components. Some researchers stress the importance of identifying the most dominant noise sources in order to make suitable modifications [1,2]. In these studies, the main noise sources in a heat pump were identified in laboratory measurements in which the purpose was to evaluate where sound reducing measures would have the largest effect. The results show that the compressor and the fan most often are the two major noise sources. Other studies go more into detail and address the noise level of one or several specific components of the heat pump. Evans has demonstrated the importance of correct fan size selection in reducing inefficiency and low frequency noise generation [3]. Another example is a study of Yanagisawa et al. where the compressor noise was reduced by reducing shaft vibration [4]. The air flow path also influences the noise level. A grille that is attached to the air outlet of the outdoor unit increases the aerodynamic noise. Jiang et al. and Tian et al. described this phenomenon and identified the optimal grille design from a noise perspective [5,6]. However, no investigations have been found that show how the noise generated by the air flow through the evaporator contributes to the overall noise level of the heat pump.

The evaporator is an essential component in the heat pump since it exchanges heat from air to the refrigerant. The heat exchange area of the evaporator is most often optimized for high energy efficiency. The air flow through the heat exchanger gives rise to aerodynamic noise whose source strength is dependent on the heat exchanger design and the air velocity. In the present study we investigated these correlations and determined how the flow-induced noise contributes to the overall noise of the heat pump. The heat exchanger does not only generate noise by itself, it also has a large indirect effect upon the noise from the fan since it “sets” the required operating condition of the fan. As mentioned above, the fan is often identified as one of the dominating noise sources in a heat pump. The noise from the fan is dependent on the fan type, fan speed, air flow and pressure drop. A high pressure drop results in a high noise level. This paper takes a holistic view of the outdoor heat pump unit and investigates how the choice of heat exchanger type will influence the noise level from the fan. The overall aim of the study was thus to determine the extent to which the flow-induced noise contributes to the overall noise of the heat pump system. An additional goal of the study was to determine whether a flat tube heat exchanger, whose design induces laminar air flow, can achieve high heat transfer performance while keeping the pressure drop low.

The direct and indirect noise of three different types of heat exchanger was compared. One was a conventional type of heat exchanger with round tubes and the other two were flat tube heat exchangers. Fig. 1 shows cross sections of parts of a flat tube heat exchanger and of a round tube heat exchanger. The sound power level was measured as a function of air flow and was correlated with the air-side heat transfer performance.

Table 1
Dimensions of FFC, MPET and B5 heat exchangers.

Dimension			FFC	MPET	B5
Height	H	mm	250	250	250
Width (tube length)	W	mm	458	460	500
Depth	D_e	mm	152	118	217
Tube pitch, transversal	$T_{p,t}$	mm	10	23.1	25
Tube pitch, longitudinal	$T_{p,l}$	mm	19		21.7
Fin pitch	F_p	mm	3.61	3.95	4.0
Fin thickness	δ_{fin}	mm	0.11	0.20	0.20
Fin lengths	F_l	mm	7.7	19.1	
Hydraulic diameter (air side)	$d_{h,a}$	mm	4.8	6.3	
Fin depth	F_d	mm	19	45	
Tube depth	T_d	mm	13.6	45	
Tube wall thickness	δ_{tube}	mm	0.2	0.4	
Hydraulic diameter (liquid side)	dh,b	mm	3.32	2.06	
No of tubes transversal to air flow	$N_{tube,t}$	–	25	10	10
No of tubes longitudinal of air flow	$N_{tube,l}$	–	8	2	10
No of passes (HEs) liquid side	n	–	4	2	
No of parallel tube rows in each pass	$N_{tube,p}$	–	2	1	
No of parallel HEs long to air flow	$N_{HE,p}$	–	1	1	
Tube outer diameter	D	mm	–	–	10
Tube inner diameter	d	mm	–	–	9.3

2. Methodology

This study is partly based on results obtained in an experimental study by one of the present authors (CHS) [7], in which the heat exchange properties of several heat exchangers with different geometric properties were evaluated. Three of these heat exchangers were selected for the present purpose, on the basis of their different geometric properties. Two of the heat exchangers had flat tubes and one of them had round tubes. In the present study we investigated whether the flat tube heat exchangers would reduce the direct flow-induced noise at the same time as reducing the load on the fan (a lower pressure drop for a given heat transfer capability). The dimensions of the heat exchangers are presented in Table 1 (see Figs. 2–4 for a description of nomenclature). The three heat exchangers had almost the same cross-sectional area at their air intake, but their volumes differed considerably. The sound power level was measured as a function of the air flow rate and the heat transfer coefficient was derived from the experimentally obtained correlations.

2.1. Measurement objects

One of the heat exchanger types, denoted “MPET”, consisted of MultiPort Extruded Tubes with folded serpentine flat (plain) fins on the air side. The cross-section of the MPE tubes of the heat exchanger can be seen in Fig. 2. Both the fins and the tubes were of aluminum and the heat exchanger was assembled by a controlled atmosphere brazing process using a cladding material (AlSi). This type of heat exchanger, with flat fins, is rather unusual, as louvered fins are more commonly used.

The second heat exchanger type that was evaluated is denoted “FFC” (Flat Fin Core). This heat exchanger type consists of plain

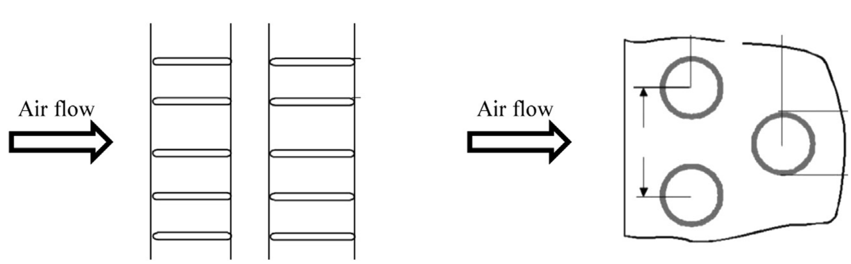

Fig. 1. Cross sections of a flat tube (left) and a round tube (right) heat exchanger.