NOISE INVESTIGATION OF AIR-TO-AIR HEAT PUMPS

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Abstract: The purpose of this study is to investigate the noise generation of air-to-air heat pumps. With increased use of air source heat pumps a barrier for further market growth and acceptance is noise. Two heat pumps with different noise performance are selected to compare the sound power levels at similar conditions. Measurements are performed on both outdoor and indoor units to correlate the noise performance to entities such as compressor frequency and fan speeds.

The sound power level of the indoor unit is determined by the fan type and speed. Both indoor units show a similar relation between sound power level and fan speed, but the outdoor units show larger differences in sound power level due to the operating range of fan and compressor. Results show that it is important to keep the fan speed as low as possible, to reach indoor noise regulation limits. For the outdoor units part load operation can have larger effect to reduce noise levels.

Key Words: heat pumps, air-to-air, noise

1 INTRODUCTION

Due to European energy policy a number of European directives will raise the needs for improved energy efficiency using renewable heat sources. With increased use of air source heat pumps one of the barriers for further market growth and acceptance is noise. Noise from heat pumps can affect us indoors in our homes and outside our gardens in our leisure time. During sleep at night time noise can cause disturbance and there are indications that long term noise exposure induce health effects (Babisch 2005).

According to standards, noise from heat pumps is declared by the sound power level measured at full load operation. But variations in the sound level of an inverter-type heat pump is high enough to conclude that a single measurement based on steady state operation is not representative of real operation (Bessac 2004). Inverter heat pumps could perform with different noise characteristics depending on the heating demand. The heat demand depends on the outdoor climate, the properties of the building and the internal heat gain. In the long term a new methodology for rating the seasonal noise performance of heat pumps should be developed.

The purpose of this study is to investigate the noise generation of air-to-air heat pumps and to compare the sound power levels at similar conditions. Two heat pumps, both of inverter type and with different noise performance are selected. Measurements are performed on both outdoor and indoor units to correlate the noise performance to entities such as compressor frequency and fan speeds.

2 METHODOLOGY

2.1 Set-up

The sound power levels were determined according to ISO 3744:1994. The sound pressure was measured in 9 microphone positions on a parallelepiped measurement surface in a hemi-anechoic room. For the outdoor unit the measurement distance was 1m and for the indoor units the distance was 0,5 m. The temperatures were measured at the air inlets of the outdoor and indoor units. The fan speed of the outdoor and indoor units was measured with an optical tachometer and the values were verified with the stated rpm in the manual. The compressor is located in the outdoor units of both heat pumps and the frequency was measured with an accelerometer. The frequency was determined with a resolution of 3 Hz and verified by running one of the units in test mode at a specific frequency.

2.2 Operation

During the measurements the heat pumps were operated at as stable conditions as possible, regarding temperature at the air inlets of the indoor and outdoor units, compressor frequency and fan speed of both indoor and outdoor units. To vary the behaviour of the heat pumps the fan speed of the indoor units are adjusted from the remote control, where heat pump A has four settings and heat pump B has five settings. The vertical guiding vane that direct the airflow vertically is adjusted to observe differences in sound power level depending on the vane position. Figure 1 shows how the guiding vane is adjusted in five steps and as similar as possible for both models.

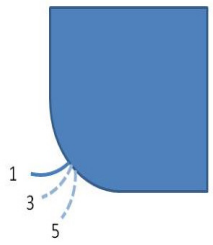


Figure 1. The vertical guiding vane was adjusted in five steps, where position 1 is at the top and position 5 is at the bottom.

2.3 Uncertainties

This investigation is based on relatively few measurements. The measurements that have been repeated at equal conditions show relatively constant results though. Based on this information we draw the conclusion that the uncertainties of the measurements are relatively low. For the A-weighted values the standard deviation of reproducibility are 1,5 dB according to the standard.

3 RESULTS

The results from the measurements are divided into two parts. The first part presents the results for the indoor units and the second for the outdoor units.

3.1 Noise generation of the indoor units

The heat pump user has the possibility to set the desired indoor temperature and adjust the fan speed of the indoor unit. In these measurements the indoor temperature is set to max, to run the units at full load. Figure 2 show that both models have a similar correlation between sound power level and the indoor fan speed, but they have very different spans of available indoor fan speed. Heat pump A can vary its indoor fan speed from 600 to 1300 rpm while heat pump B only has a span from 1000 to 1200 rpm.

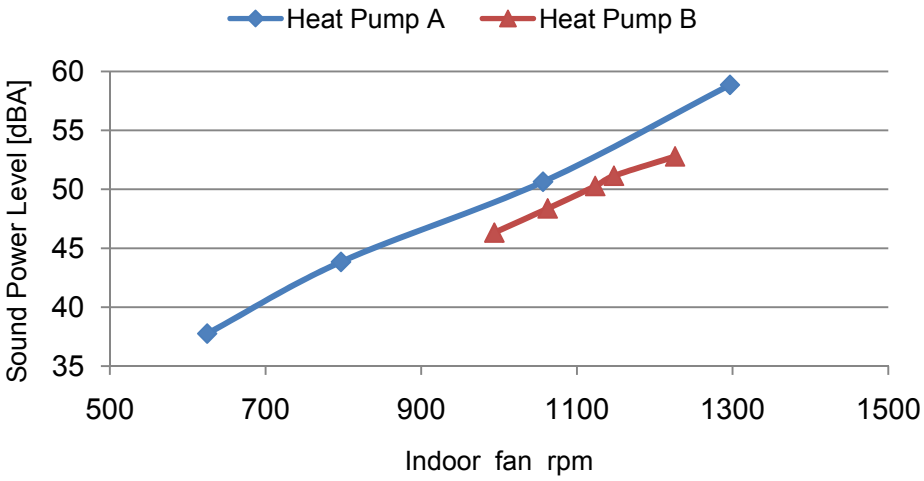


Figure 2. Sound power level of indoor units in relation to the indoor fan speed. The models have similar correlation between sound power level and fan speed, but have very different spans of available fan speed.

The user also has the possibility to set the direction of the air flow coming out of the indoor unit, by setting the position of a vertical guiding vane. Figure 3 shows the sound power level relative position 1 (upper position). The results show that the position of the vertical guiding vane can affect the sound power level, though the dependency on vane position is rather different. Heat pump B shows the strongest dependency with a relative difference of 2 dB between position 2 and position 5, while heat pump A shows the biggest difference between position 1 and position 2. Both models have a maximum when the guiding vane is in the second upper position. These results are measured at the second highest fan speed, so the effect could be stronger at higher airflows.

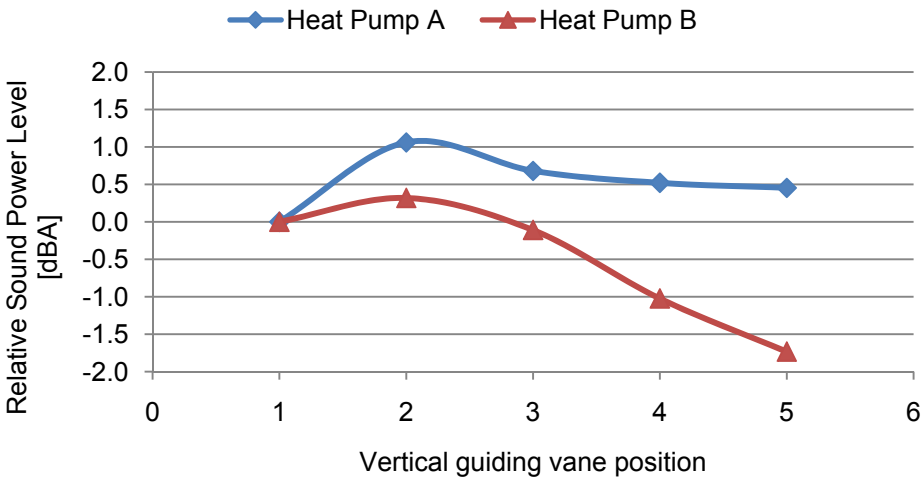


Figure 3. Relative sound power level of the indoor units as a function of the position of the vertical vane. Heat pump B show the strongest dependency where the guiding vane affect the sound power level up to 2 dB.

Additional measurements were made to verify any correlation between the indoor unit sound level and temperature. The sound pressure was measured as the temperature inside the room increase. The sound pressure was measured in three positions with a distance of 0,5 m from the unit and presented as an average. Figure 4 shows that the relative difference is within 1 dB and we draw the conclusion that the indoor temperature does not affect the sound level. Taking the same measurement series and correlating the sound pressure levels to compressor frequency gives an indication if any vibrations are transferred through the piping. Figure 5 show an indication that the sound pressure level of heat pump B increase with increasing compressor frequency. But the variations are really small and lie within the measurement uncertainties.

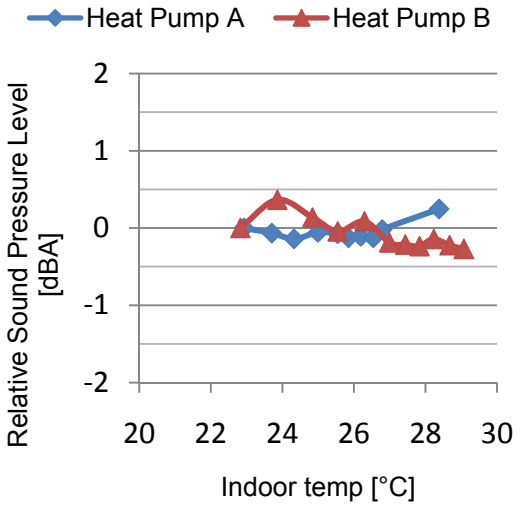


Figure 4. Relative sound pressure level of the indoor units in relation to the indoor temperature

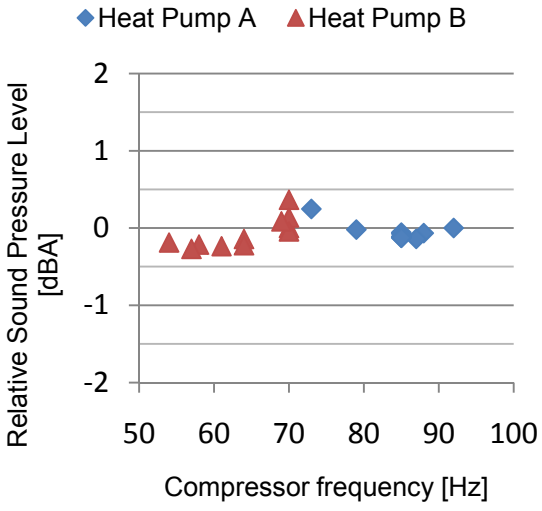


Figure 5. Relative sound pressure level of the indoor units in relation to the compressor frequency

3.2 Noise generation of the outdoor units

The operation of the outdoor units was controlled via the setting of the indoor unit. The results show that there are differences in the control of both the outdoor fan and compressor. Figure 6 shows the A-weighted sound power levels and the dependency on fan speed. Heat pump B has a small working range and changing the speed seems not to affect the sound level. Heat pump A clearly shows a dependency of fan speed, as the sound power level increase when the fan accelerates. The differences are probably due to different sizes and dimensions of the fan, where heat pump B does not have to accelerate as much to transport the same amount of air. Figure 7 instead shows the dependency of the compressor frequency. The results are similar, where heat pump B shows no dependency and sound level of heat pump A again increases when the compressor increases its frequency. The sound level increase 2 dB when the fan accelerates from 610 to 770 rpm and another 2 dB when the frequency of the compressor increases from 48 to 74 Hz.

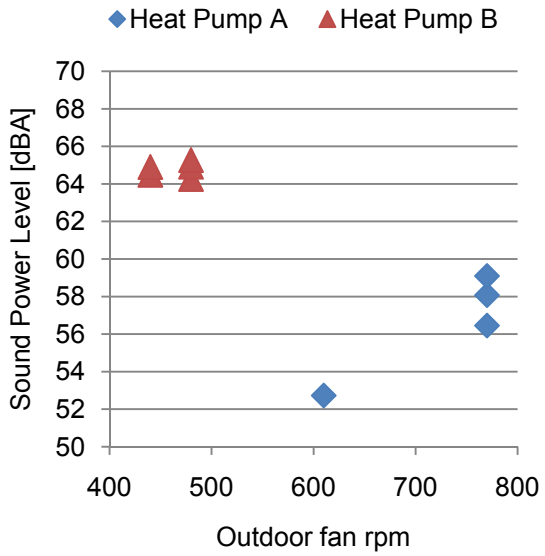


Figure 6. Sound power level of the outdoor units as a function of the outdoor fan speed.

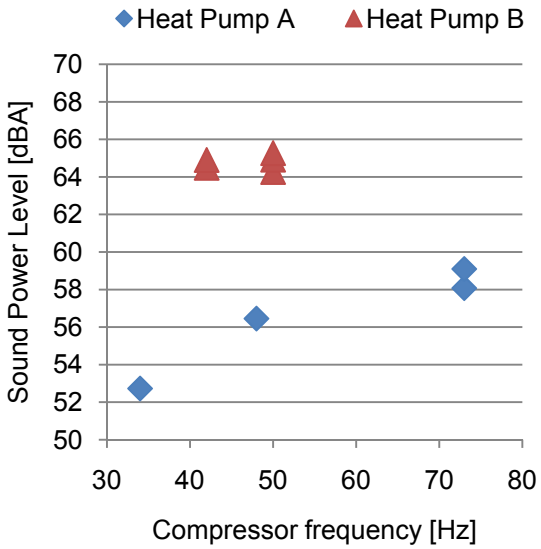


Figure 7. Sound power level of the outdoor related to the compressor frequency.

Since the sound pressure is measured in 9 positions around the units, an attempt is made to determine the direction of the sound radiation. The sound pressure levels measured in each microphone position is normalized to the calculated sound pressure levels with semi spherical radiation as a point source. Figure 8 show the sound radiation at the highest and lowest fan setting of the indoor unit. The resolution of 0.05 corresponds to a difference of approximately 3 dB, which is a noticeable change. Position 1 corresponds to the front (air outlet) and the compressor side is at position 7. Both units have the strongest radiation on the compressor side and at the air inlet. At position 6 both units show a 3 dB difference between the highest and lowest indoor fan speed setting, but heat pump A show a higher level at the lowest fan speed. At position 6, heat pump B has a sound pressure level 9 dB higher than position 2, which is more than a doubling in level. This is probably due to differences in the construction and absorption around the compressor.

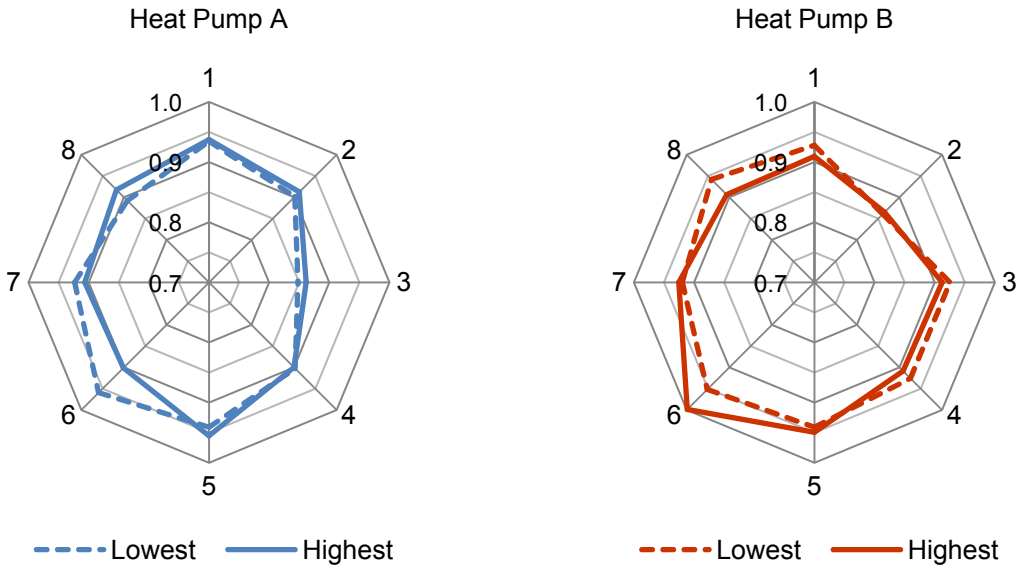


Figure 8. Sound radiation at the highest and lowest fan setting of the indoor unit. Both outdoor units have the strongest radiation on the compressor side and at the air inlet.

4 DISCUSSION

In this study the noise performance of two rather similar heat pumps are investigated. The sound power level has been correlated to fan speeds and compressor frequency. The results show that there are differences in the noise performance when operated at similar conditions.

To put the results from this study into context Figure 9 compare the results from the measurements with Swedish noise regulation. The full lines correspond to the outdoor units and the dotted lines to the indoor units. The outdoor noise limit is calculated from a guideline value given as sound pressure level and with an assumed distance of 4.5 meters to the neighbours plot border. The indoor limit is calculated for a normal room with an assumed absorption area of 10 m^2.

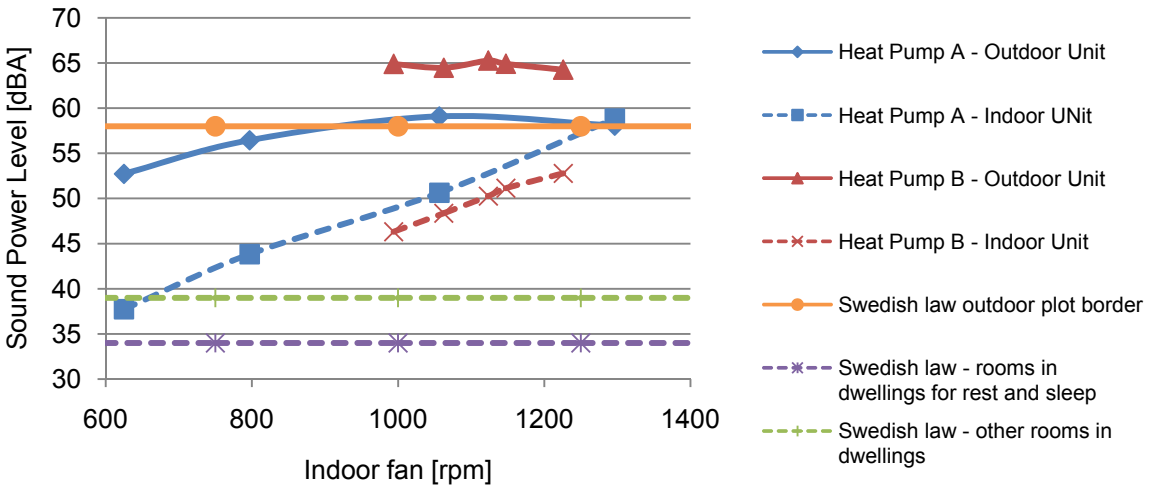


Figure 9. Sound power level of the heat pumps in relation to Swedish noise regulations.

The comparison show that the sound power levels of the indoor units are well above the Swedish regulation limits, with the exception for the lowest fan speed according to this model. The outdoor unit of heat pump A performs well in this comparison, with levels around the limit at the plot border. Heat pump B performs at a constant level around 65 dBA, due to the small working range of both fan and compressor during our measurements. The question is how they perform in other outdoor conditions. Part load operation results in lower noise levels (Gustafsson et al. 2011), but with varying outdoor temperature the noise performance is not clear.

Both heat pumps show similar linear correlation between the sound power level of the indoor unit and its fan speed, but have very different spans of available indoor fan speed. Heat pump A can vary its indoor fan speed from 600 to 1300 rpm while heat pump B only has a span of 1000-1220 rpm. Figure 9 shows that low fan speed is important to improve the noise performance and to reach noise regulation limits in rooms for rest and sleep.

The sound power level is also dependent on the position of the guiding vane that directs the air flow vertically. This dependency is strongest for heat pump B. This can probably be explained by differences in the positioning of the fan in relation to the casing which gives the outgoing air different directions. Both models reach a maximum in sound power level when the guiding vane is in the second highest position.

Neither of the indoor units shows any correlation between the sound power level and the compressor frequency. Initially we thought that the sound from the compressor would be transferred through the refrigerant pipes, but this seems not to be the case. Heat pump B show a small indication that this could be the case, but too small to draw general conclusions. If the overall noise levels of the indoor unit decrease, other noise sources such as heat exchangers and refrigerant flow could be more dominant.

The sound power level from the outdoor unit is quite different for the two heat pumps. The sound power level of outdoor unit of heat pump A is dependent on both the outdoor fan speed and the compressor frequency, while heat pump B shows no such correlations at all, the sound power level is constant independent of compressor and fan speed. Constant noise levels are not the expected behaviour, but a wider range of operating conditions would probably reveal if this is the real case.

5 CONCLUSION

There are large differences in the noise performance between two rather similar air-to-air heat pumps.

The sound power levels of the indoor units are strongly dependent on the type and speed of the fan. Low fan speed is important to reach indoor noise regulation limits. The vertical guiding vane and the position of the fan in relation to the casing also affect the sound levels, but not with the same significance.

Based on the results from these measurements there is no correlation between the sound power levels of the outdoor units and the fan speed as well as compressor frequency.

6 REFERENCES

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