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IMPROVED MEASUREMENT METHOD FOR HEAT PUMP NOISE

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Abstract: Today heat pump noise is evaluated as an A-weighted sound power level measured in one operating condition, normally referred to as the standard rating condition. The A-weighted level at the standard rating condition is what the consumer will read on the European energy label and the A-weighted level is the main indicator for noise pollution. However, the A-weighted level at one operating condition can give poor reflection of the actual noise, due to varying thermal load and operating states. Development of new noise indicators are needed to give the consumer better guidance of the declared noise level, as the A-weighted level can be insufficient to assess noise annoyance. This study investigates the noise behavior of air- and ground-source heat pumps, to identify the variation in noise level over time and at different loads. Both types of heat pumps have a noise character which is dominated by tonal noise in the low frequency region, a reason to use the C-weighted level for more sufficient prediction of annoyance. An indication of strong dominance of low frequency noise is given if the difference between C- and A-weighted levels is above 10 dB. The results from this study show that this is very often the case, but the C-weighted level can vary while the A-weighted level is steady. This behavior is more common with ground source heat pumps, because of the absence of masking noise from the fan. This suggests that separate evaluation methods for air- and ground-source heat pump might be needed.

Keywords: Noise, Heat Pump, Rating, Method

1 INTRODUCTION

The information on the European energy label has many advantages. The consumer is given the possibility to make an aware choice, but the information is still easy to interpret and have useful meaning. A disadvantage with the information regarding noise is the mismatch between seasonal coefficient of performance (SCOP) and the A-weighted sound power level at standard rating condition. Compared to the SCOP the sound power level is like a snapshot of an arbitrary operating condition. The operating behavior of a heat pump is expected to be varying and cyclic, which poses a challenge of how one in a general sense evaluates noise from of heat pumps. Bessac showed that one single operating condition is not enough to evaluate the noise performance of variable capacity heat pump (Bessac 2004) and Gustafsson et al showed that the part load operation of a variable capacity air source heat pump has an important impact on the sound power level (Gustafsson et al 2011). There are also other aspects that may influence the noise experience and annoyance. Leventhall suggests in a review of low frequency sounds that time varying patterns add to the level of

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annoyance (Leventhall 2004). This is of special interest when comparing fixed and variable capacity heat pumps. Variable capacity heat pumps have longer operating times and fewer stops, but also varying noise levels within an operating cycle. Fixed capacity heat pumps have a steady noise level within the operating cycle, but an intermittent control that regulates the operation. This suggests that they perhaps need to be treated differently when defining a standard rating condition. It also means that it is more difficult to define a standard rating condition for a variable capacity heat pump, if the aim of the rating is to relate to a common operating condition.

The development of new noise indicators including more variables can give the consumer better guidance and a more meaningful comparison between heat pumps. In the current project the aim is to develop a refined measurement method based on how different loads and other aspects influence the subjective experience. In this first stage of the study the focus is thus on how different analysis methods may differentiate between sounds from heat pumps.

2 MEASUREMENT PROCEDURE

The aim of the measurements performed in the present study was to investigate how the heat pumps sound in situ. This to get an overview on how air source and ground source heat pumps vary in noise level and characteristics over time. Heat pump noise is rated by their A-weighted level, but if there is a strong dominance of sound energy in the lower frequencies the A-weighted level can be insufficient to assess the perception of the noise. Additionally the behavior of the variable heat pump could have a direct impact on the A-weighted sound pressure level (L_{eq}), as the A-weighting filter will suppress low frequencies when the compressor operates in the lower frequency region.

It was therefore decided to measure both the A- and C-weighted sound level and the 1/3 octave band levels. Field measurements were conducted on heat pumps installed in single family houses in Sweden during January to March. The heat pumps were monitored for 48 hours using a Norsonic 140 sound level meter was placed at 1 meter distance in front of the heat pumps and at a height of 1.2 meter.

3 RESULTS AND DISCUSSION

As a first step a comparison was conducted between a fixed and a variable capacity ground source heat pump. As expected the variation in compressor frequency of the variable capacity heat pump has direct impact on the A-weighted level and the operating time is also longer, see figure 1. The fixed capacity heat pump operates in shorter cycles, but with a quite stable noise level. The difference in the time variant noise level between the capacity control strategies is of importance for the perception when observed over a longer time span, but for the rating purposes the sound power level is sampled at one point in time. This suggests that the challenge in the improvement of the measurement methodology is to join these two aspects into one rating value that reflect useful meaning for the consumer.

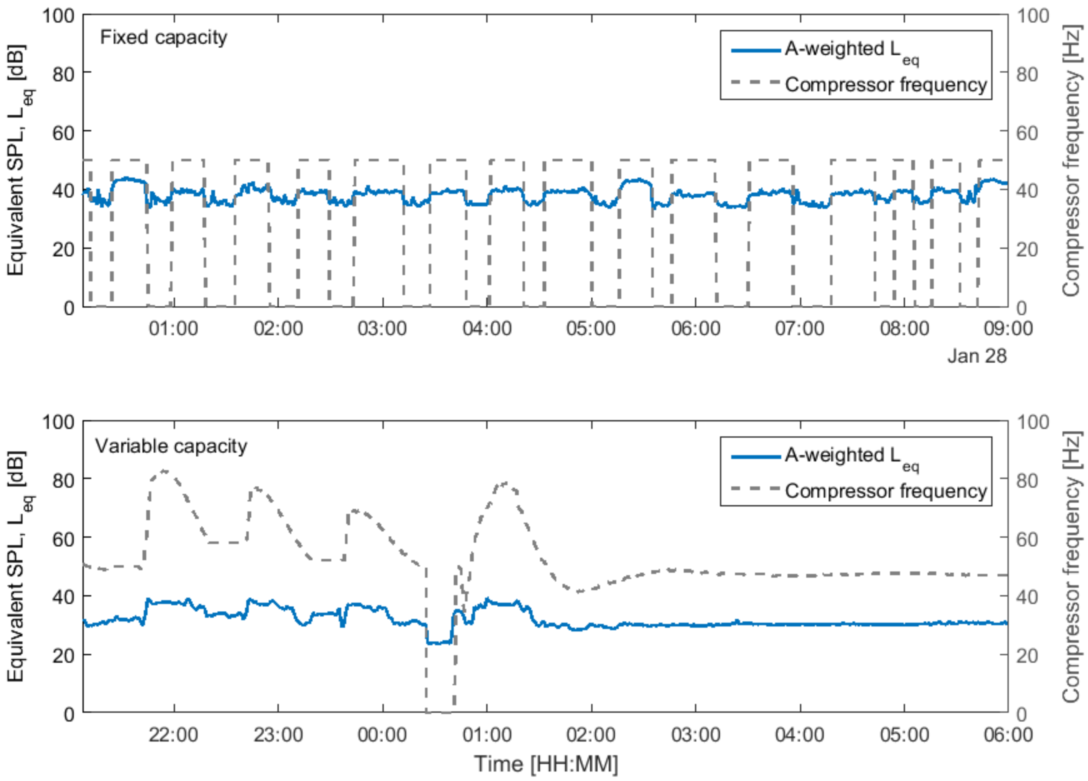

Figure 1 The operating behaviour of a fixed (top) and a variable (bottom) capacity heat pump. The dashed line (- -) shows the operating frequency of the compressor and the solid line (-) shows the A-weighted sound pressure level (L_{eq}).

A second hypothesis was that there might be necessary to measure not only A-weighted levels but also C-weighted levels. Heat pump noise is today rated by their A-weighted level, but when there is a dominance of sound energy in the lower frequencies the A-weighted level may be insufficient to assess the perception of the noise. A comparison between the C- and the A-weighted level can give an indication of whether there is a dominance of low frequency noise. If the difference is above 10 dB it can be assumed that the low frequency is dominating and therefore affecting the annoyance. Use of the A-weighted levels have been debated, in a larger questionnaire of residents exposed to noise from heat pumps and ventilation the dB(A) noise levels could not predict annoyance and often dB(C) levels are suggested as more relevant to this type of sounds (Persson Waye et al 2001). In a recent study on road traffic noise the low frequency content was however of less importance, suggesting that the choice of weighing might be dependent on the source of stimuli (Torija 2015). In figure 2 an operating sequence of the measure of a ground source heat pump is shown. When the compressor frequency is adjusted from 70 Hz to 100 Hz the difference between the C- and A-weighted levels is decreased to more than half of the preceding difference. Throughout the sequence the A-weighted level remains stable, but the change in the C-weighted level can have an influence on the perception of the noise. This behavior is common for a ground source heat pump, where the noise character is entirely related to the compressor. It should be noted that the measurement uncertainty is high in lower frequencies and has not been evaluated at this stage, but the results suggest that there is a clear need to further investigate the behavior of the ground source heat pump.

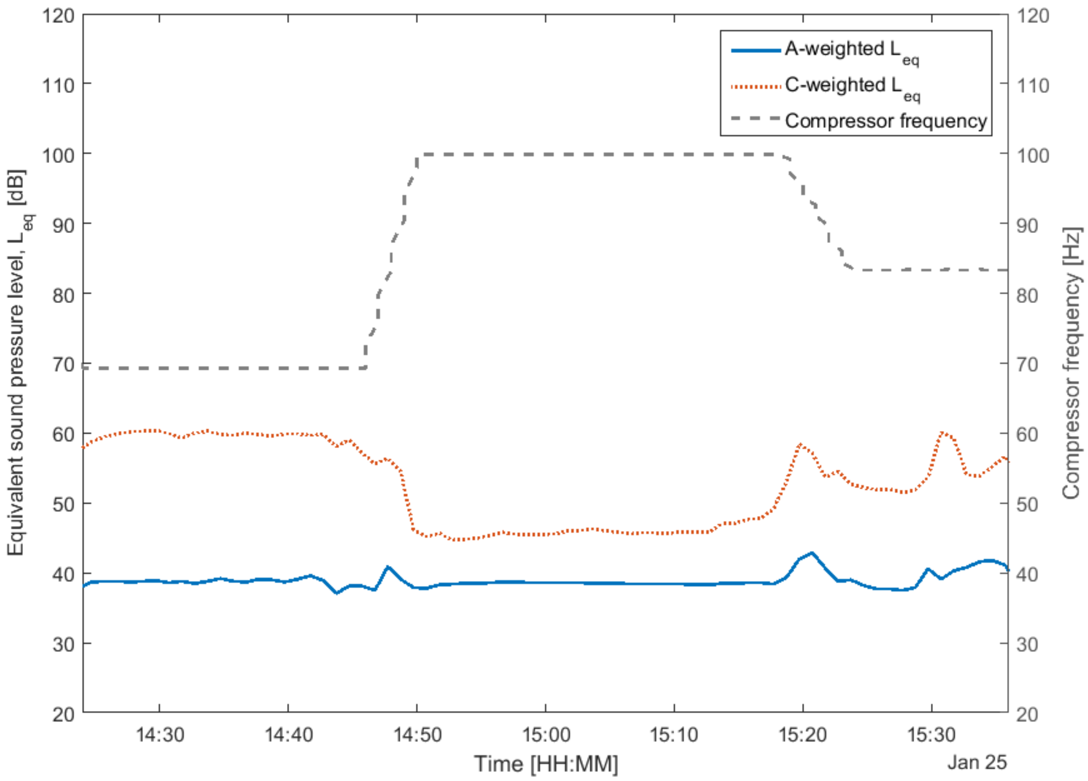

Figure 2 Operating sequence of a ground source heat pump. The dashed line (- -) shows the operating frequency of the compressor, the dotted line (··) shows the C-weighted sound pressure level and the solid line (-) shows the A-weighted sound pressure level.

For an air source heat pump the fan appears to have an influence on the noise level as it has a broadband noise spectrum and it can also have a masking effect on the compressor noise. This has an impact on the frequency spectrum of the noise, where the tonal character of the compressor noise is suppressed. A comparison between the 1/3 octave band frequency spectra of an air source and a ground source heat pump is shown in figure 3. The spectrum of the ground source heat pump has dominant sound energy radiated in low frequencies below 500 Hz and there is less sound radiation in the higher frequencies. There are also distinct peaks in the spectrum related to the operating frequency of the compressor, which is not as clear in the frequency spectrum of the air source heat pump. When comparing the noise spectra the dominance of the low frequencies and the attenuated high frequencies of the ground source heat pump raise questions if the A-weighted level solely is suitable for the rating of heat pump noise.

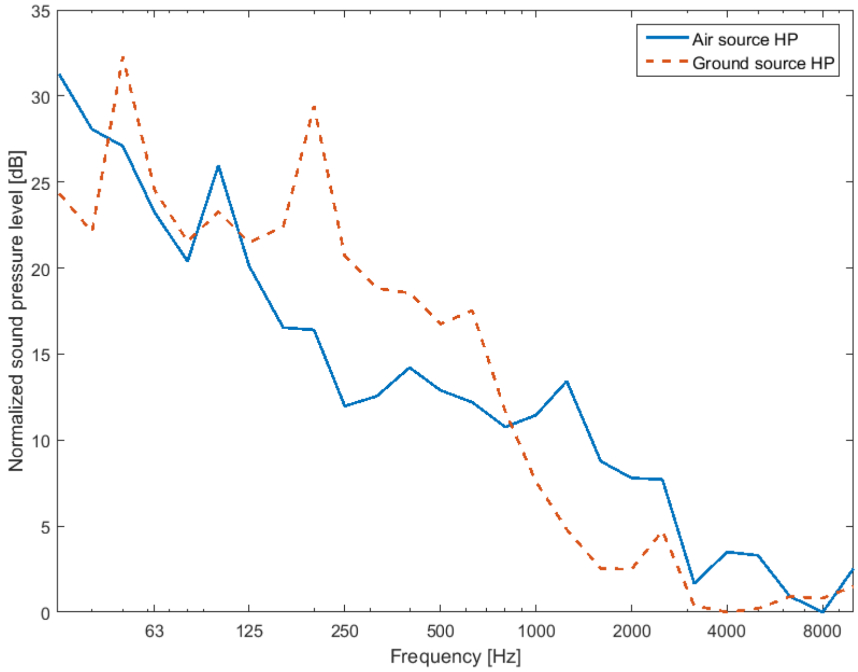

Figure 3 Frequency spectra in 1/3 octave bands of an air source and a ground heat pump. The dashed line (- -) shows the dominance of the low frequencies of a ground source heat pump and the solid line (-) shows how the influence of the fan suppress the tonal character of the compressor for an air source heat pump.

4 CONCLUSION

Capacity control has a clear impact on time variant noise level and the adjustment of the compressor frequency of a variable capacity heat pump has an influence on the A-weighted sound pressure level. For some operating sequences of ground source heat pumps the C- and A-weighted level have a difference that indicate strong dominance of low frequency noise. The results from this study will be used in a second step of the project to evaluate the perceptual responses to different kinds of heat pumps. At this stage however the results suggest that it is of interest to further investigate the possibility to use separate evaluation methods for air source and ground source heat pumps in order to give the consumer a better ability to make an informed choice.

5 REFERENSES

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