2012

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ABSTRACT

Refrigeration equipments, in particular domestic refrigerators, are devices that are present in our day to day. Often, these devices are very close to our workplaces, laser or rest, where the noise produced by such sources can be intense enough to cause discomforting sensations, fatigue, or even to prejudice the communication between the people. Thus, the concern with the noise produced from these devices has gained a great importance both for consumers and for manufacturers of refrigerators. Thinking in area of control of noise and vibrations, is of great importance the precise knowledge about the dynamic behavior of the components of the refrigerator, and the iteration between them, so that efficient designs and / or optimization can be realized. Many difficulties have been encountered in the identifying the main means of propagation of vibration energy and acoustic energy in a refrigerator. Thus, this paper presents a study about identification of energy path in the interaction between compressor and refrigerator, using experimental techniques of "elimination" of energy paths from compressor. The results and conclusions, related to the end of the work, show the level of importance of the contribution of each path in the total noise of a refrigerator, showing goods evidences of the main paths to invest and reduce the total noise.

1. INTRODUCTION

The main objective of this work is to make a study about identification of energy paths in interaction between compressor and refrigerator. For this, some experimental techniques were done. Initially, the sound power of a system, composed by a freezer and a fridge, was measured in the original configuration into a reverberation chamber. Then, one of the paths was “eliminated” from the source, i.e., an energy path from the compressor, and the sound power was measured again. So, step by step, each path was eliminated from the source and the sound power was measured to each configuration. Finally, with each sound power measured, the contribution of each path to the system noise was evaluated.

2. CONFIGURATIONS EVALUATED

The study object was a Liebherr refrigerator with two compartments, one freezer and one fridge, that had one condenser, two evaporators and one compressor Embraco EM2C 70 CLT, as shown in the Fig. 1, called the original configuration or reference. It was assumed that the acoustic/vibration energy from the compressor, that contributes to the total noise, pass through discharge/suction tube, discharge/suction pulsation, isolators and compressor shell (irradiation).

Figure 1: Refrigerator in this original configuration (reference)

To isolate the vibration transmission from the compressor to the refrigerator was development a device which did make the compressor be supported on the floor, shown in fig. 2a. The vibration transmission through the suction/discharge pipes was “eliminated” by introducing on this path a piece of flexible tube (plastic) which had 100 mm of length and the same original diameter of the tube, as illustrated in fig. 2b.

Figure 2: (a) Compressor supported on the floor. (b) Flexible tube (plastic) in the suction of the compressor.

For these three path isolators (support, suction tube and discharge tube) were done eight measures of sound power of the system, related the combination of each path isolated with the others. The Table 1 summarizes all configurations evaluated with these path isolators.

Table 1: Configurations measured with the compressor assembled on the original position of the refrigerator

Configuration†	**Suction tube**	**Discharge tube**	**Support compressor**
HHG	**H**ard (original)	**H**ard (original)	**G**round
HHS (reference)	**H**ard	**H**ard	**S**ystem base plate
FHG	**F**lexible	**H**ard	**G**round
FHS	**F**lexible	**H**ard	**S**ystem base plate
FFG	**F**lexible	**F**lexible	**G**round
FFS	**F**lexible	**F**lexible	**S**ystem base plate
HFG	**H**ard	**F**lexible	**G**round
HFS	**H**ard	**F**lexible	**S**ystem base plate

† The first letter indicates the kind of suction tube (H=hard; F=flexible); the second the kind of discharge tube and the last where the compressor was supported (G=ground; S=system base plate).

To isolate the acoustic irradiation from the compressor was developed a steel box with 1 inch of thickness. So the compressor without his shell was put into the steel box and the noise irradiation was "isolated". However, due to the fact that this box was very heavy, it was support on the floor and out of the housing of the refrigerator. In the steel box also was developed a device like a cylindrical muffler to reduce the discharge pulsation of the compressor, and the suction pulsation was reduced by making the gas to pass through the internal volume of the box. These configurations are shown in fig. 3.

Figure 3: (a) Compressor within the steel box. (b) Assembly of the steel box in the system

In the same way, a combination between the pulsation isolators was done to evaluate the contribution of these paths. So, four sound powers were measured related to each pulsation configuration. The Table 2 summarizes all pulsation configurations evaluated to the compressor within thick box.

Table 2: Configurations measured to evaluate the path pulsation

Configuration†	Suction pulsation	Discharge pulsation
IO	**I**nternal volume	**O**riginal
IM	**I**nternal volume	**M**uffler (cylindrical)
OM	**O**riginal	**M**uffler (cylindrical)
OO	**O**riginal	**O**riginal

† The first letter indicates the kind of suction pulsation (I=internal volume of the box; O=original) and the second the kind of discharge pulsation (M=cylindrical muffler; O=original).

All sound power measures was done into a reverberation chamber using a B&K rotating boom with a B&K microphone type 4189 and a 4 channels signal analyzer pulse B&K. The measures was done following the standards ISO 3741 (1999), NBR 13910-1 (1997) and NBR 13910-2 (1998). The measurements was done in steady-state of the refrigerator, i.e., when all signals were stable.

3. METHODOLOGY FOR EVALUATION

To evaluate the contribution of each path was necessary to include another path called "others" that some part of the energy dissipates. So, the seven paths were: others, discharge pulsation, suction pulsation, structural vibration transmission by suction tube, structural vibration transmission by discharge tube, structural vibration by isolators and the irradiation by shell. To relate these paths with the noises measured, the equation (1) was developed as:

$$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \textit{Suction Tube} \\ \textit{Discharge Tube} \\ \textit{Isolator} \\ \textit{Irradiation} \\ \textit{Suction Pulsation} \\ \textit{Discharge Pulsation} \\ \textit{Others} \end{pmatrix} = \begin{pmatrix} \text{HHS} \\ \text{FHS} \\ \text{HFS} \\ \text{HHG} \\ \text{FFG} \\ \text{HFG} \\ \text{FHG} \\ \text{FFS} \\ \text{OO} \\ \text{IO} \\ \text{OC} \\ \text{IC} \end{pmatrix}. \qquad (1)$$

On the equation (1) the values 0 or 1 in the first matrix refers to whether exist (1) or not (0) some of the paths listed in the second matrix. Each element of the right-hand-side matrix refers to each sound power measured which is a vector that contain the frequency components in a 1/3 octave band.

4. RESULTS

With the sound power measured to each configuration, i.e., related to the energy paths, the contribution of each energy path was calculated according to equation (1). The result obtained, in a 1/3 octave band, is shown in fig. (4).

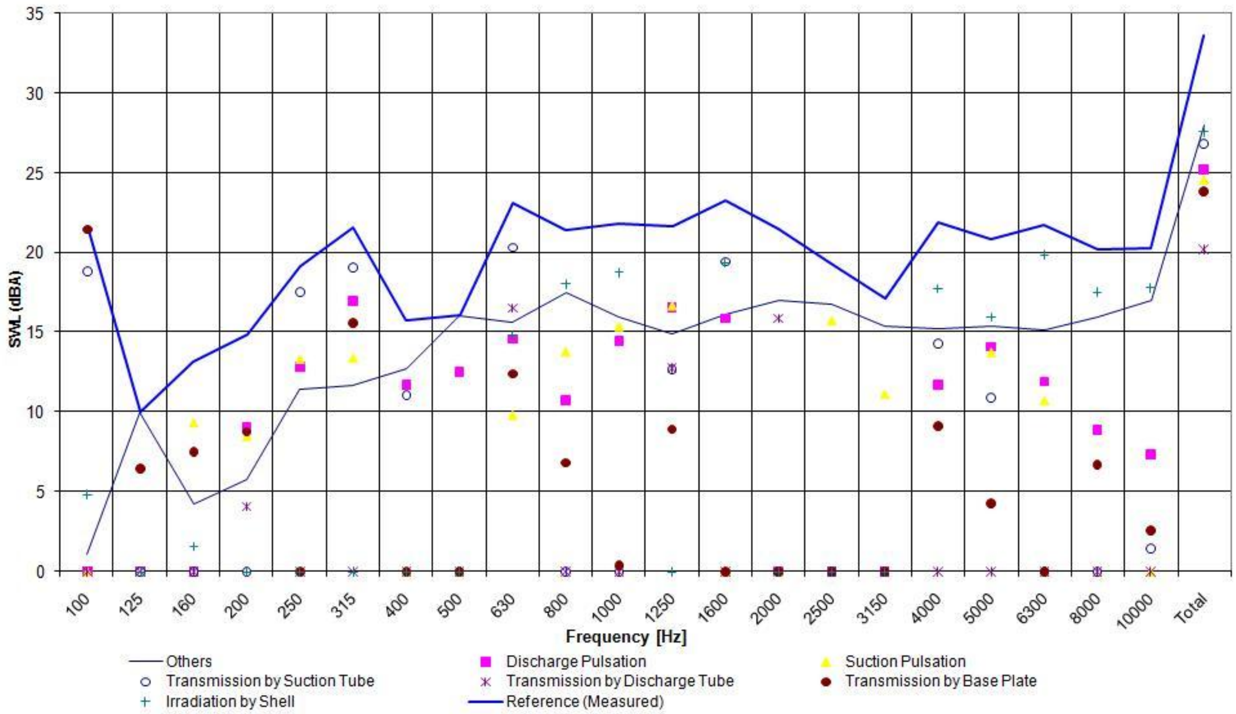

Figure 4: Contribution of each energy path in the noise in 1/3 octave band

The blue curve (reference) refers to the original sound power of the refrigerator. We can see that the influence of the others paths is great in comparer to some paths. On the other hand, some results are known to be characteristics to the source, like the transmission by base plate that has great components in low frequency and the noise irradiated by the shell compressor in high frequency. The results are also presents in fig. (5) by percentages of the total noise related to each path.

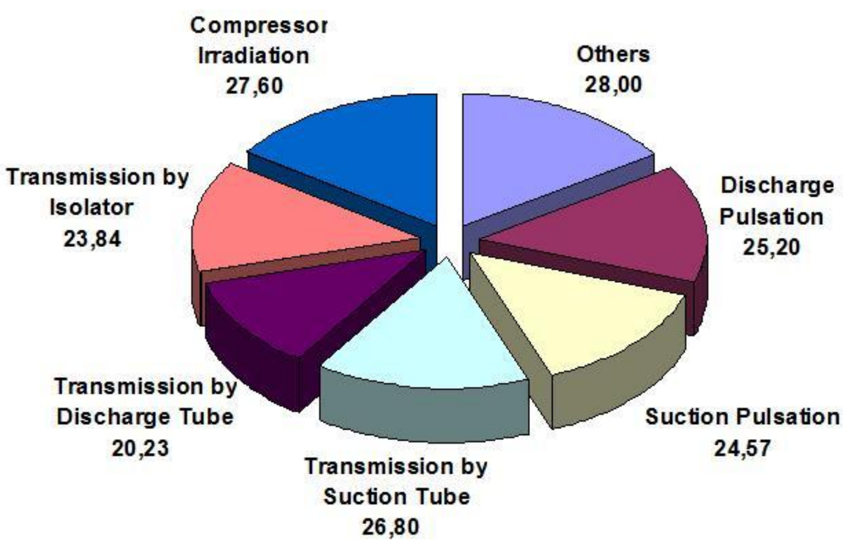

Figure 5: Contribution of each energy path in percentage

5. CONCLUSIONS

The identification of the energy path in the interaction between compressor and refrigerator was evaluated by making sound power measures of a set of differs assembles of the compressor in the refrigerator. An equation that computes the contribution of each energy path was developed. The results showed that the “others noise” is very influent, being evidenced by the gas flow noise in the moment that the freezer is working. The path more contributive to the total noise is the compressor irradiation followed by transmission by suction tube. The isolator has a big component in the band of 100 Hz. Over to the 3150 Hz, the compressor irradiation is the main source.

REFERENCES

ISO 3741:1999. *Acoustics – Determination of sound power levels of noise sources using sound pressure - Precision methods for reverberation rooms,* International Organization for Standardization, Geneva, 1999.

NBR 13910-1:1997. *Diretrizes de Ensaios para Determinação de Ruído Acústico de Aparelhos Eletrodomésticos e Similares – Parte 1 – Requisitos Gerais,* Associação Brasileira de Normas Técnicas, 1997.

NBR 13910-2:1998. Diretrizes de ensaios para a determinação de ruído acústico de aparelhos eletrodomésticos e similares, Associação Brasileira de Normas Técnicas, 1998.

ACKNOWLEDGEMENT

The first author are grateful to EMBRACO, which finances this research, to teacher Renato Barbieri who contributed to this work and especially to God for the opportunities he gave me.