Compressor Noise Source Identification in Low Frequency

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COMPRESSOR NOISE SOURCE IDENTIFICATION IN LOW FREQUENCY.

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Abstract

The quiet operation, mainly during the rest hours, is one of the most important “quality characteristics” required to a household refrigerator, together with a low consumption, from the customer point of view. One of the most annoying noise source in a compressor arises from the excitation of the cavity resonance; it is well known that the frequency of the cavity is dependent mainly from the temperature of the compressor. Usually this frequency is in the 500 Hz region. In this paper we show the process of investigation to identify and solve this kind of problems. After having identified the potential noise source by experimental techniques, we started a numerical analysis to simulate the acoustical characteristics of the cavity and the suction muffler. By this analysis we managed to identify that the behavior of the muffler was not adequate in a very specific temperature range. By means of the numerical analysis, supported by experimental techniques, the muffler correction was identified. The comparison between the numerical and experimental results is also presented. The implementation of this correction lead to the reduction of 6 dB at 500 Hz in the noise of the compressor installed on a refrigerator.

INTRODUCTION

The quiet operation of a refrigerator is becoming a significant parameter for the evaluation of the “quality” of the appliance. The European Community is requiring that the household appliances have to be labeled not only according the energy consumption class, but also with the sound power level emitted by the appliance. The development of compressors with efficiency levels higher and higher, is required to satisfy the performances of the top class refrigerators, from the energy consumption view point. The actions done to reduce the suction losses in order to improve the efficiency level of the compressors, are quite often in conflict with the normal noise reduction techniques. It is therefore necessary to carefully study the suction line of the compressor to avoid possible noise sources.

The perception of sound by a human subject is affected by, among several causes, the “non constancy” of the sound in relation with time. In a refrigerator, one of the noise sources that is varying with the running time of the compressor, is the excitation of the cavity resonance. The frequencies corresponding to the cavity excitation are normally very annoying.

SOURCE IDENTIFICATION

In the development phase of the application of a new medium efficiency compressor on a household refrigerator, an annoying noise, varying with time, was detected by noise time history measurement, as well as by results of a jury analysis.

The frequency analysis of the noise signal is indicating a major contribution in the 500 Hz and 3150 Hz regions. The time history of the mentioned third octaves, shows that the higher changes with time is
in the 500 Hz frequency. In figures 1 and 2 are reported the frequency analysis of the noise signal and the time history of the 500 Hz 1/3 octave band.

The fact that the sound pressure in the 500 Hz third octave is varying with the running time, and therefore with the compressor temperature, drove the investigation to identify the shell cavity excitation. The experimental measurements were carried out in a semianechoic room, recording sound level and shell vibration with a narrow band analyzer as function of the shell temperature. The cavity response is reported in fig 3.
It must be pointed out that the cavity excitation is happening at a temperature that is quite lower in comparison with the normal operating conditions of a compressor installed on a refrigerator.

ACOUSTIC CAVITY AND MUFFLER ANALYSIS

As the cavity excitation is related to the suction conditions, the investigation has been concentrated on the cavity and the suction muffler. A numerical analysis to simulate the shell acoustic cavity and the suction muffler was started.

The acoustic cavity modal analysis was performed using a Finite Element Method software (Ansys package); the results showed some resonance frequencies in the 500 Hz 1/3 octave band, as listed below. How showed in figure 3, the problem happened when the third acoustic cavity mode is excited.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Frequency [Hz]</th>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>432</td>
<td>diagonal</td>
</tr>
<tr>
<td>2</td>
<td>478</td>
<td>diagonal</td>
</tr>
<tr>
<td>3</td>
<td>535</td>
<td>lateral</td>
</tr>
<tr>
<td>4</td>
<td>702</td>
<td>up to down</td>
</tr>
</tbody>
</table>

Tab. 1 - Acoustic cavity modal analysis results.
The muffler response was predicted using a Boundary Element Methods software (Sysnoise package). The way the muffler was designed for production, allows the possibility of a leakage in the conjunction of the internal parts; this leakage was simulated as small holes in the inlet tube. The muffler model must be as simple as possible; the mesh size must be optimized to have the lowest possible number of nodes and elements, in order to minimize the computation time and the size of the output files, without loosing in precision and quality of the results.

The differences between the same muffler with leakage and without leakage is showed in figure 4, where is clear that the leakage decreases the transmission loss in 500 Hz and 3150 Hz 1/3 octave bands; the excitation of the cavity is therefore more easy.

![Muffler Transmission Loss](image)

**Figure 4 - Muffler Transmission Loss.**

**EXPERIMENTAL VERIFICATION**

Based on the results obtained from the numerical analysis, the suction muffler has been modified in order to eliminate the problem related to the internal leakage. The modified muffler was assembled on a prototype compressor and tested to evaluate the reduction in the cavity excitation.

The final test was performed on the appliance; the noise measurement carried out on the refrigerator confirmed the reduction in noise level in the 500 Hz region as time history and therefore as sound pressure level. The time history sound pressure level and the noise spectra of the modified compressor in comparison with the original one, are reported in fig 5 and 6.

The advantage related to the use of the modified muffler is clearly evident and was also confirmed by a jury listening.
CONCLUSION

The result shows the important contribution of the numerical analysis performed with the use of powerful simulation tools to solve problems related to compressors noise. The numerical analysis makes possible to decrease the time needed to solve the above mentioned problems and the results will be even better as early this tools were used. The simulation can reduce costs related to the number of prototypes and tests and in the same time is helpful to improve the knowledge of noise problems.
The modification introduced in the muffler has been proved to be effective in reducing the appliance noise. It is important to point out that the change in the muffler has not introduced any penalty in the compressor capacity and E.E.R.