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## **NOISE REDUCTION OF COMMERCIAL APPLICATIONS: COMPRESSOR APPROACH**

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### **ABSTRACT**

During the last years, noise in commercial refrigeration has become more and more important and many of commercial appliance manufacturers have been devoting more attention to reduce the noise of their systems, aiming to fulfill the increasing demanding customer's requirements. Nowadays it is almost impossible to reach a very good refrigeration system noise level without taking into consideration the compressor as an important source; either by the level of noise directly radiated, either by the interaction with the system, it must be considered one of the main sources of noise in commercial applications. This interaction with the system also occurs as a result of gas pulsation and vibration levels, since both excite the components which fix the compressor to the system.

This paper presents the studies carried through during the development of a new family of commercial compressors. The work aims to identify, quantify and determine, through product and process sensitivity analyses, the generating sources of the noise, the ways of its transmission and the influence of the final irradiator in the compressor's total noise and vibration levels.

### **1. INTRODUCTION**

Aiming to increase its competitiveness, Embraco launched a new project of high performance compressor for commercial appliances. The new design basically aims to efficiency increase, capacity expansion, cost reduction, reliability improvements and reductions in noise, vibration and pulsation.

In order to succeed as a new design and considering the very strong targets, it was defined a multidisciplinary team with specialists from Brazil, Italy and Slovakia working on both product and process.

Focusing on final system result the project goals were reduction of 5 dB in total noise, 30% of vibration reduction and 30% of pulsation reduction when compared with the current product and. improvements in audibility and significant reductions in low frequency was expected with the aiming a better customer perception when the compressor is running in the system. The analyses were developed considering the total noise and 1/3 octave band to allow the sound quality improvement with strong impact on customer's perception.

To reach the goal of noise reduction it was developed an analysis procedure considering an investigation of the main paths of vibratory energy flow in the compressor and the identification of the main points to be modified. Attempting the detailed knowledge of the main causes of the noise permits to guide the approach and concentrate the modifications only in the parts that will affect the final result. This approach starts with a road map that defines each step in the noise analysis and the understanding of sound power level in the compressor and system.

## 2. PROBLEM IDENTIFICATION

### 2.1 – Road Map

The road map covers all analysis performed during this project focusing on product and process. Questions with clear answers help to identify the interactions between project stages must be part of the road map.

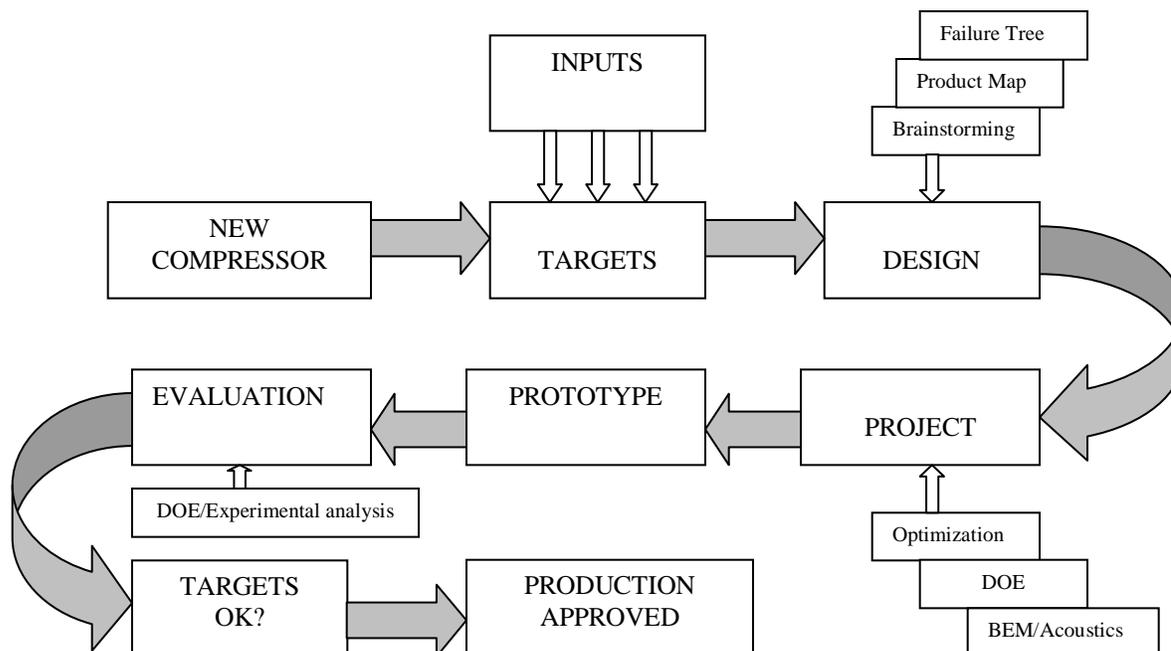


Figure 1: Simplified road map

### 2.1 – Problem Identification

In this part of the project the idea is just to correlate the goals on noise, vibration and pulsation to specific problems to be solved in the compressor design and using all tools available for that.

Problem identification is the first approach of the problem for a particular site, and answer the question:

What is the fundamental problem?

What information should be collected and assessed to confirm our understanding of the problem?

The main outcome of the problem identification stage is to set up the overall purpose and objectives of the compressor noise reduction and to determine the data requirements. This step is fulfilled by:

Clearly identify what aspect of the noise needs to be addressed;

Set the objectives of the compressor noise (what will and will not be considered), and

Identify which set information needs to be collected, analyzed and assessed.

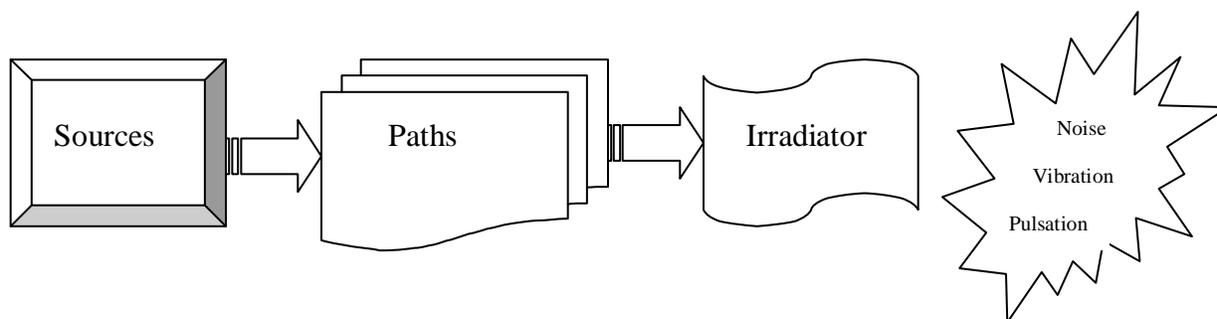


Figure 2: Vibratory energy flow

### 3. PHENOMENON ANALYSIS

#### 3.1 – Noise Characterization

The vibratory energy generated in the compressor sources is propagated through paths and then reaches the shell as direct noise (air-borne irradiation) or excites the refrigeration system with vibration and gas pulsation. Figure 3 shows the energy flow in this commercial compressor given inputs to reduce the noise.

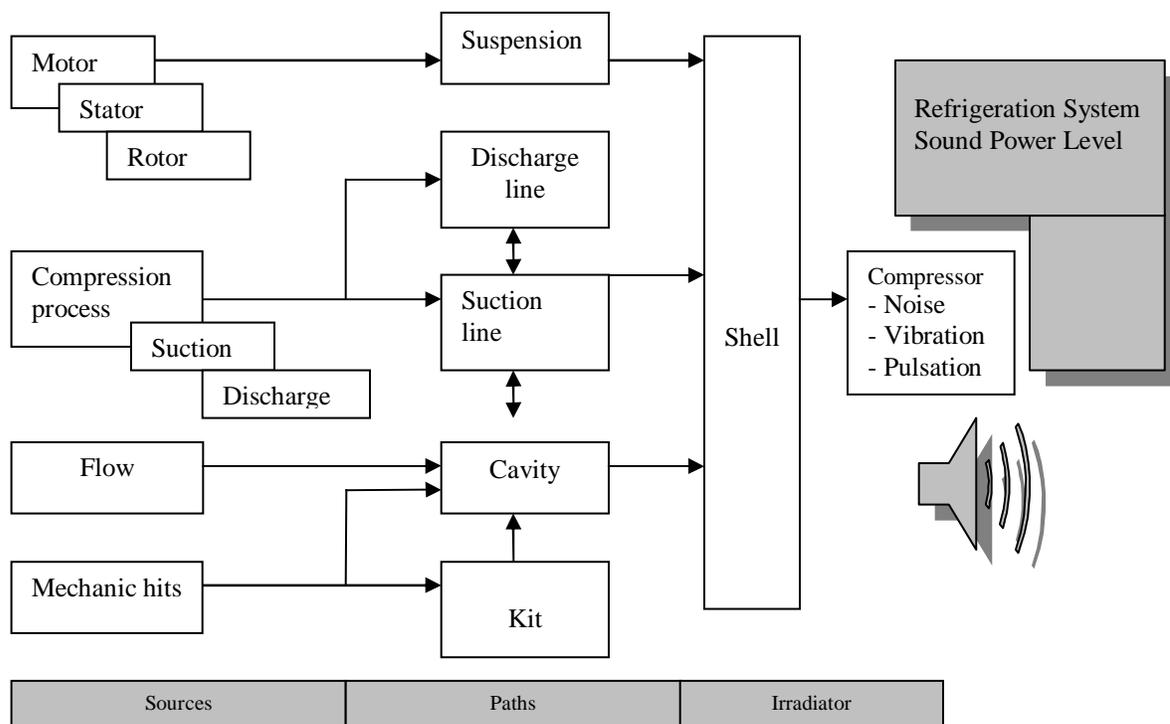


Figure 3: Vibratory energy flow

#### 3.2 – Noise contribution

The sensibility analysis permits to identify the contribution of each system and component to the frequency band

power and as consequence the total noise of compressor. Figure 4 depicts the contribution in frequency spectrum of the 5 components which bigger influence on total noise.

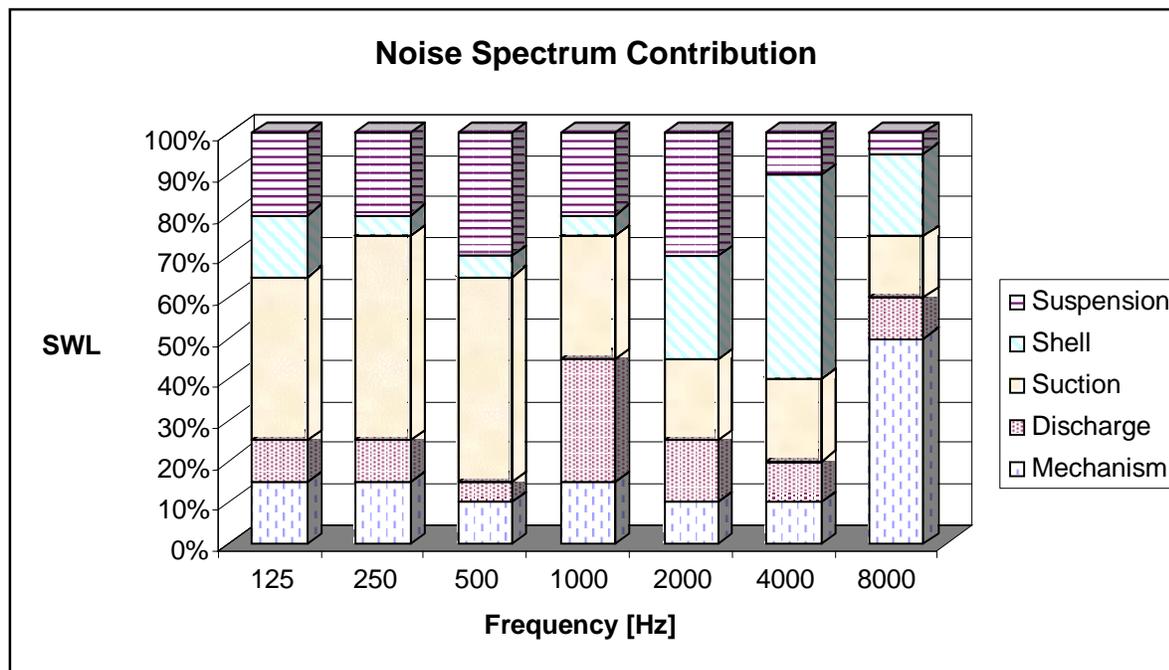


Figure 4: Contribution of the components on noise

#### 4. PRODUCT ANALYSIS

##### 4.1 – Product Map

Product maps are used to simply the function description of a product and to assist in the organization of the correlations between components and product. It is very important to characterize the product with its parameters, supplying basic information for use of any tools important to the product analyze too. The product map shows the existing correlations between components and subsystems of the product and is achieved following steps:

- Project sketch and components identification;
- Incorporate all specific needs of the project;
- Show the functional connections, identify interfaces;
- Identify product parameters;

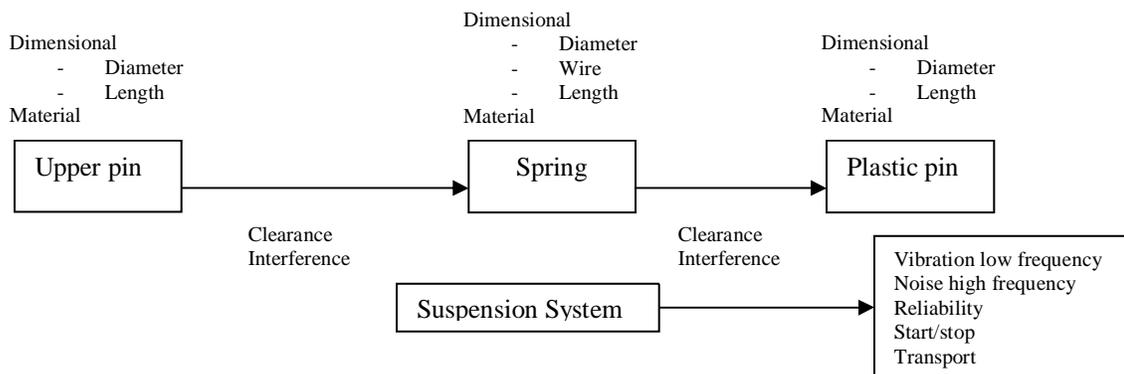


Figure 5: Product map example

### 4.2 – Root cause diagram

Root cause analysis is a generic term used commonly to refer to structured problem solving. Below the root causes of the noise, vibration and pulsation are showed and results linked with a systemic process solutions.

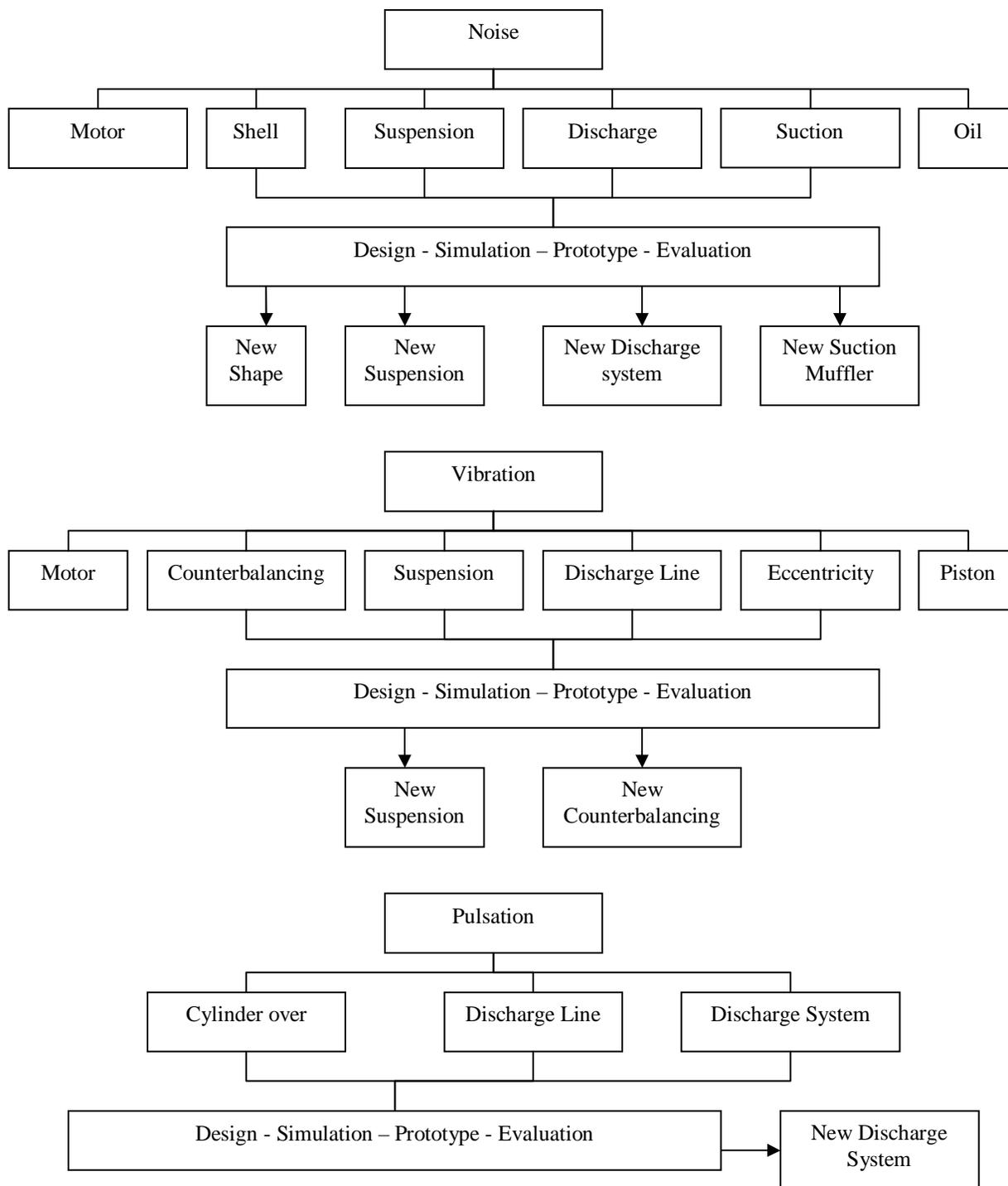


Figure 6: Root cause diagram of noise, vibration and pulsation

## 5. RESULTS

### 5.1 – Development

Some of the most important changes in this project to reach the targets are shown in figure 7.

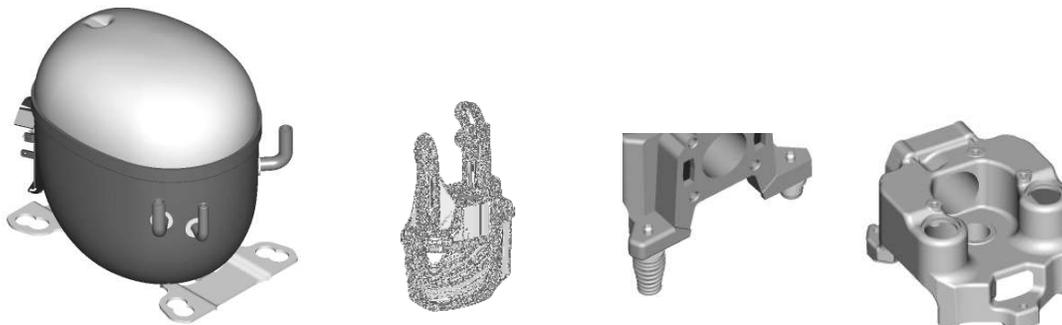


Figure 6: New shell, muffler, suspension and crankcase

### 5.2 – Noise

The noise result of one model is depicted in figure 8, where the 1/3 octave band is compared with the previous design.

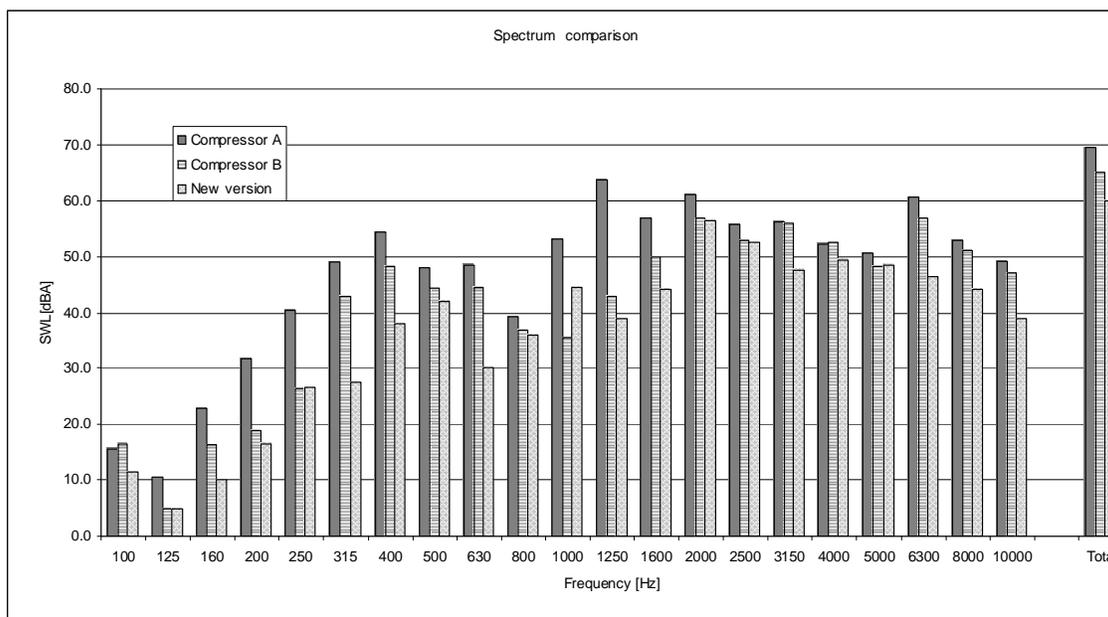


Figure 8: Noise comparison of new version versus previous design

### 5.3 – Pulsation

Model	Discharge Pulsation Level [dB]		
	160	158	150
Previous design	160	158	150
New version	150	147	143

Table 1: Discharge pulsation comparison

## 5.4 – Vibration

Model	Vibration Level [mm/s]		
Previous design	6.01	5.70	5.0
New version	2.20	1.90	1.81

Table 2: Compressor vibration comparison

## 6. CONCLUSIONS

The new compressor presents a significant total noise reduction, as well as reduction in important frequency bands which has strong impact in sound perception by final customers. Another important aspect is the reductions in discharge pulsation and vibration above 30% which improves the noise of the refrigeration system. In conclusion the project succeeded in its objectives and a better noise characteristics are favored by this new model application.

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