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# The Optimisation of the Inlet Diameter and the Filter of the Muffler of the Hermetic Compressors

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# The Optimization of the Inlet Diameter and the Filter of the Suction Muffler of the Hermetic Reciprocating Compressors

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## ABSTRACT

The reciprocating hermetic compressors are one of the most important components for the domestic refrigerators in terms of energy consumption and noise level. When both noise level and the efficiency of the compressor are considered, the plastic muffler is the most critical component. The all parameters of the muffler affect both the noise level and the coefficient of the performance of the compressor. The filter, the inlet diameter of the muffler, the rooms inside the muffler and the thickness of the muffler are most important parameters for a plastic muffler of a hermetic compressor.

This paper investigates the optimization of the inlet diameter and the filter of the plastic muffler of the hermetic compressors. Here it is aimed to obtain minimum noise level and maximum efficiency of the compressor. The different mufflers were analyzed and tested with different mesh size filters. Then by using these different mufflers the compressors were tested in calorimeter room to measure the coefficient of the performance and in noise room to measure the noise level.

The results of these studies help to obtain an optimized hermetic compressor for the domestic refrigerators regarding noise level and energy efficiency.

## 1. INTRODUCTION

Today, related to a household refrigerator usage, the customer satisfaction business regarding noise level is very important issue for cooling engineers. The hermetic compressor with an optimized suction plastic muffler regarding noise level is one of the solutions for this issue. Besides new environmental regulations and associations and most of the governments supports the productions of high efficiency appliances that decreases using energy sources. That is for that again a suction plastic muffler optimization is very important for efficiency of the compressor and so for the energy consumption of the appliances.

For a consideration about energy consumption of a household refrigerator the hermetic compressor is the main component. A compressor is the heart of the refrigerator for the cooling cycle that increases the pressure and the temperature of the refrigerant. On the other hand, there are some critical components used inside compressor that affects the coefficient of performance of the compressor and noise level of the compressor. One of these components and the most important one is the suction plastic muffler. The all parameters of the suction plastic muffler affect both the noise level and the coefficient of the performance of the compressor. The filter, the inlet diameter of the muffler, the rooms inside the muffler and the thickness of the muffler are most important parameters for a plastic muffler of a hermetic compressor.

Within the scope of this study, it is considered that the optimization of the inlet diameter and the filter of the plastic muffler of the hermetic compressors. Here it is aimed to obtain minimum noise level and higher performance of the hermetic compressor. The different mufflers were analyzed and tested with different mesh size filters. Then by using these different mufflers the compressors were tested in calorimeter room to measure the coefficient of the performance, pulsation level and in noise room to measure the noise level.

It is aimed to obtain an optimized hermetic compressor for the domestic refrigerators regarding less noise level, less pulsation level and higher energy efficiency.

## 2. EXPERIMENTAL STUDIES

For experimental tests the compressors that have 90 kcal/h cooling capacity were used. As test parameters, 4 different mesh sizes for the filter of suction muffler and 3 different inlet diameter suction mufflers were used for the compressor prototypes. Besides in Figure 1 std. order means test number. For each combination five samples those have each 90 kcal/h cooling capacity were tested, so in totally, 60 tests were done (Figure 1).

| StdOrder | mesh size | inlet diameter |
|---|---|---|
| 1 | 50 | 6 |
| 2 | 50 | 7 |
| 3 | 50 | 8 |
| 4 | 60 | 6 |
| 5 | 60 | 7 |
| 6 | 60 | 8 |
| 7 | 70 | 6 |
| 8 | 70 | 7 |
| 9 | 70 | 8 |
| 10 | 90 | 6 |
| 11 | 90 | 7 |
| 12 | 90 | 8 |
| 13 | | |
| 14 | | |
| 15 | | |
| | | |
| | | |
| 58 | 90 | 6 |
| 59 | 90 | 7 |
| 60 | 90 | 8 |

**Figure 1:** Design of experiments

Wire mesh filters can be used in intake-air filtration systems and pre-filters positioned upstream of separation devices Three structural parameters were defined based on the characteristics of wire mesh filters: wire diameter, layer spacing and mesh size. (Haiou et al., 2015)

For this design of experiments, while the mesh size is the number of metal wire for 1 inch distance as seen in the figure 2 below the inlet diameter is the diameter (as milimeter) of the suction muffler for inlet zone as seen in the figure 3 below.

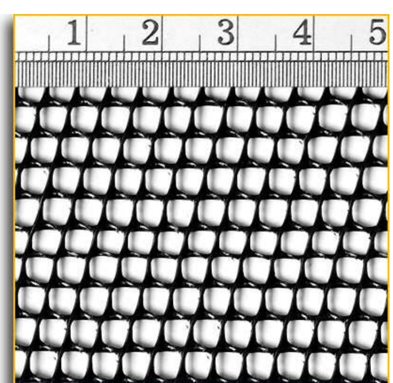


**Figure 2:** Mesh size of filter

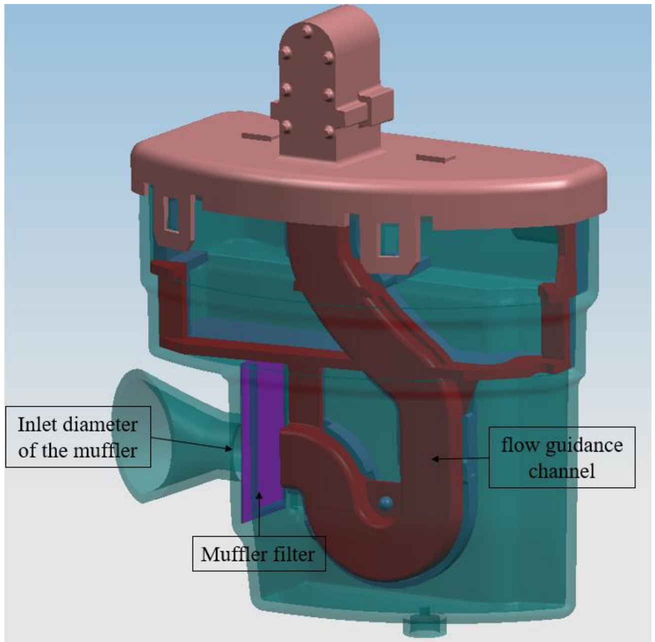


**Figure 3:** The inlet diameter, muffler filter and flow guidance channel of the suction muffler

In order to determine the coefficient of performance of the compressors and the pulsation level the calorimeter tests were done. With the compressor calorimeter the cooling capacity generated by the compressor is measured in two independent ways, while simultaneously the compressor input-power is measured. By dividing the cooling capacity with the input power, the efficiency (or C.O.P.) of the compressor is determined. In this experiment, measurements are performed under standard test condition, ASHRAE.

As mentioned, the cooling capacity generated by the compressor is measured in two independent ways. Figure 4 explains the first method; before the expansion process of the refrigerant the subcooling temperature and the condensation pressure are measured. With these two values the enthalpy before the expansion process can be determined. Assuming an adiabatic expansion the enthalpy after expansion is equal to the enthalpy before the expansion.

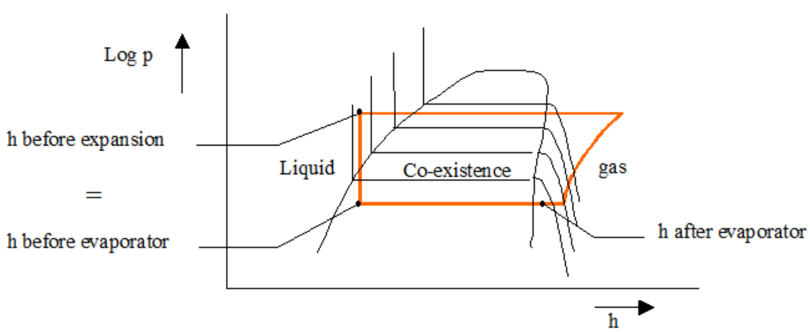


**Figure 4:** Cooling capacity determination

After the evaporator the superheating temperature and evaporation pressure are being measured. Using these values the enthalpy after evaporation can be determined. Also the refrigerant mass flow is being measured. By multiplying the enthalpy difference with the refrigerant mass flow the cooling capacity can be determined:

$$\dot{Q}_{cool} = (h_{after\ evaporator} - h_{before\ expansion}) \cdot \dot{m}_{refrigerant} \quad (1)$$

The evaporation process takes place inside a thoroughly insulated vessel and it is assumed here that there is no heat transfer between the vessel and the ambient. Inside this vessel an electrical heating element is positioned. To keep the vessel at an equal temperature the heating element has to generate an amount of heat equal to the cooling capacity of the evaporator. (Compressor Calorimeter Manuel, 2003)

$$\dot{Q}_{cool} = \dot{Q}_{heater} \quad \textbf{(2)}$$

**Figure 5:** Compressor room

Pulsation level is measured by pressure transducer on the exhaust line. This transducer's pressure range is between 3,5 and 35 bar and it is connected compressor exhaust line with leakproof valve.

Sound pressure level measurements made on the hemispherical surface in a semi-anechoic room in according to ISO 3741 and ISO 3745 standards in 1/3 octave frequency bands in the frequency range of 100 Hz to 10 kHz.

Controls are carried out by taking background sound measurements with 10 microphones at regular intervals.

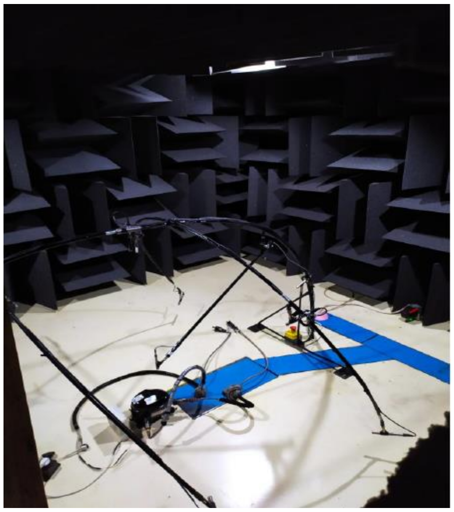

**Figure 6:** Sound pressure level measurement room

In order to determine noise level of the compressors the noise tests were done. These all tests were done for each combination. Moreover, the noise tests were done for 250 Hz, 630 Hz, 2500 Hz and 3150 Hz as frequency bands.

## 3. EXPERIMENTAL RESULTS

As seen in Figure 7, according to the General Model Analysis of all test results it is seemed that there are no remarkable changes on the power, the cooling capacity and the coefficient of the performance of the compressors.

**General Linear Model: cooling capacity (kc; power (Watt); ... versus mesh size; muffler**

| Factor | Type | Levels | Values |
|---|---|---|---|
| mesh size | fixed | 4 | 50; 60; 70; 90 |
| muffler inlet diameter | fixed | 3 | 6; 7; 8 |

Analysis of Variance for cooling capacity (kcal/h), using Adjusted SS for Tests

| Source | DF | SeqSS | AdjSS | AdjMS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 0,329 | 0,576 | 0,192 | 0,06 | 0,979 |
| muffler inlet diameter | 2 | 0,194 | 0,346 | 0,173 | 0,06 | 0,945 |
| mesh size* muffler inlet diameter | 6 | 2,240 | 2,240 | 0,373 | 0,12 | 0,993 |

S = 1,74583   R-Sq = 2,16%   R-Sq(adj) = 0,00%

Analysis of Variance for power (Watt), using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 0,5143 | 0,5130 | 0,1710 | 0,19 | 0,900 |
| muffler inlet diameter | 2 | 0,8360 | 0,9624 | 0,4812 | 0,55 | 0,584 |
| mesh size* muffler inlet diameter | 6 | 2,8573 | 2,8573 | 0,4762 | 0,54 | 0,775 |

S = 0,939034   R-Sq = 10,42%   R-Sq(adj) = 0,00%

*

Analysis of Variance for COP (W/W), using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F |
|---|---|---|---|---|---|
| mesh size | 3 | 0,0007094 | 0,0007009 | 0,0002336 | 0,41 |
| muffler inlet diameter | 2 | 0,0001627 | 0,0001436 | 0,0000718 | 0,13 |
| mesh size* muffler inlet diameter | 6 | 0,0017932 | 0,0017932 | 0,0002989 | 0,53 |

| Source | P |
|---|---|
| mesh size | 0,746 |
| muffler inlet diameter | 0,882 |
| mesh size* muffler inlet diameter | 0,786 |

S = 0,0238480   R-Sq = 10,26%   R-Sq(adj) = 0,00%

**Figure 7:** The change on the power, the cooling capacity and the efficiency of the compressor for experiments

As seen in Figure 8, according to the General Model Analysis of all test results it is seemed that there are no remarkable changes on 250 Hz, 2500 Hz and 3150 Hz frequencies regarding noise level of the compressors. Whereas according to the muffler inlet diameter it is seemed that there is some change on 630 Hz frequency regarding noise level of the compressor.

Analysis of Variance for 630 Hz noise level, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 1,124 | 1,302 | 0,434 | 0,11 | 0,952 |
| muffler inlet diameter | 2 | 213,551 | 197,389 | 98,694 | 25,54 | 0,000 |
| mesh size* muffler inlet diameter | 6 | 12,104 | 12,104 | 2,017 | 0,52 | 0,788 |

S = 1,96580   R-Sq = 58,87%   R-Sq(adj) = 47,84%

Analysis of Variance for 2500 Hz noise level, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 27,80 | 42,11 | 14,04 | 0,74 | 0,536 |
| muffler inlet diameter | 2 | 22,13 | 33,91 | 16,95 | 0,89 | 0,418 |
| mesh size* muffler inlet diameter | 6 | 77,14 | 77,14 | 12,86 | 0,68 | 0,670 |

S = 4,36306   R-Sq = 14,00%   R-Sq(adj) = 0,00%

Analysis of Variance for 250 Hz noise level, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 21,771 | 21,298 | 7,099 | 1,19 | 0,327 |
| muffler inlet diameter | 2 | 3,205 | 3,373 | 1,866 | 0,31 | 0,734 |
| mesh size* muffler inlet diameter | 6 | 23,824 | 23,824 | 3,971 | 0,66 | 0,680 |

S = 2,44736   R-Sq = 16,58%   R-Sq(adj) = 0,00%

Analysis of Variance for 3150 Hz noise level, using Adjusted SS for Tests

| Source | DF | SeqSS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 45,41 | 53,32 | 17,77 | 0,99 | 0,408 |
| muffler inlet diameter | 2 | 49,93 | 62,13 | 31,06 | 1,73 | 0,191 |
| mesh size* muffler inlet diameter | 6 | 59,04 | 59,04 | 9,84 | 0,55 | 0,769 |

S = 4,24149   R-Sq = 17,31%   R-Sq(adj) = 0,00%

**Figure 8:** The change on the noise level (250 Hz, 630 Hz, 2500 Hz, 3150 Hz) of the compressor for experiments

As seen in Figure 9, according to the General Model Analysis of all test results it is seemed that there is some change on the pulsation level of the compressors.

Analysis of Variance for Pulsation, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| mesh size | 3 | 1,1278 | 1,0422 | 0,3474 | 1,44 | 0,245 |
| muffler inlet diameter | 2 | 2,8169 | 2,9953 | 1,4976 | 6,21 | 0,004 |
| mesh size* muffler inlet diameter | 6 | 1,6809 | 1,6809 | 0,2801 | 1,16 | 0,345 |

S = 0,490914   R-Sq = 36,28%   R-Sq(adj) = 19,18%

**Figure 9:** The change on the pulsation of the compressor for experiments

As seen in Figure 10, according to the General Model Analysis of all test results it is seemed that for the 7 mm muffler inlet diameter the pulsation level of the compressors decreases.

**General Linear Model: Pulsation versus Muffler inlet diameter**

| Factor | Type | Levels | Values |
|---|---|---|---|
| muffler inlet diameter | fixed | 3 | 6; 7; 8 |

Analysis of Variance for Pulsation, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| muffler inlet diameter | 2 | 2,8797 | 2,8797 | 1,4399 | 5,70 | 0,006 |
| Error | 50 | 12,6266 | 12,6266 | 0,2525 | | |
| Total | 52 | 15,5063 | | | | |

S = 0,502526   R-Sq = 18,57%   R-Sq(adj) = 15,31%

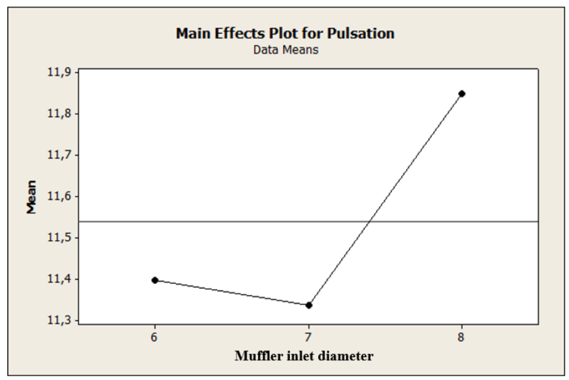


**Figure 10:** The change on the pulsation of the compressor for experiments

As seen in Figure 11, according to the General Model Analysis of all test results it is seemed that for the 7 mm muffler inlet diameter and for the 630 Hz frequency the noise level of the compressors decreases.

**General Linear Model: 630 Hz versus Muffler inlet diameter**

| Factor | Type | Levels | Values |
|---|---|---|---|
| Muffler inlet diameter | fixed | 3 | 6; 7; 8 |

Analysis of Variance for 630 Hz, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Muffler inlet diameter | 2 | 223,62 | 223,62 | 111,81 | 30,38 | 0,000 |

S = 1,91847   R-Sq = 51,60%   R-Sq(adj) = 49,90%

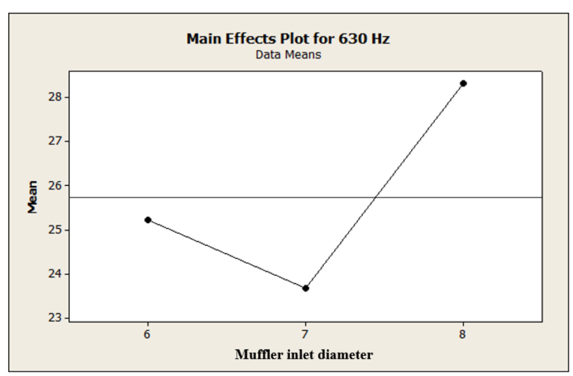


**Figure 11:** The change on the noise level (630 Hz) of the compressor for experiments

## 4. CONCLUSIONS

In a reciprocating compressor, a piston and a suction valve induce a highly impulsive pressure pulse, which is the main noise source of the compressor. A suction muffler is generally used to control this impulsive noise. However, the muffler has adverse effects on the performance of a compressor because the refrigerant undergoes an additional pressure drop and heat transfer when passing through the compressor. Therefore, the flow and acoustic performances of the muffler must be considered simultaneously when designing it. (Kim et al., 2016)

In this paper, the optimization of the inlet diameter and the filter of the plastic suction muffler of the hermetic compressor is investigated. Here it is aimed to obtain minimum noise level and maximum efficiency of the compressor. For this reason, three different inlet diameters and four different mesh size filters are tested in calorimeter and sound pressure level measurement rooms. Then results are evaluated via General Linear Model.

On the basis of these results, it is seen that there are no remarkable changes on the power, the cooling capacity and the coefficient of the performance of the compressors. In addition, there are no remarkable changes on 250 Hz, 2500 Hz and 3150 Hz frequencies regarding noise level of the compressors. On the other hand, for the 7 mm muffler inlet diameter, the 630 Hz frequency noise and pulsation level of the compressors decreases.

## NOMENCLATURE

| | |
|---|---|
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| COP | Coefficient of Performance |
| ISO | International Organization for Standardization |
| SPL | Sound Power Level |
| DF | Degrees of freedom |
| Seq SS | Sequential sums of squares |
| Adj SS | Adjusted Sum of Squares |
| Adj MS | Adjusted Mean of Squares |
| F | F-test value that shows whether the factor in test is associated with the response |
| P | Probability value |
| R-Sq | The coefficient for the model of analysis |
| R-Sq (adj) | Corrected R2 |

**Subscript**

| | |
|---|---|
| rpm | Revolutions per minute |
| kcal/h | kilocalorie per minute |

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Kim S., Cheong C., Park J., Kim H., Lee H., 2016. Investigation of flow and acoustic performances of suction mufflers in hermetic reciprocating compressor. International Journal of Refrigeration, 69, 74–84 http://dx.doi.org/10.1016/j.ijrefrig.2016.05.006