2008

Optimization of Discharge Valve Leaf for Performance

Tolga Yaroglu
Arcelik A.S. Compressor Plant

Serkan Kara
Arcelik A.S. Compressor Plant

OPTIMIZATION OF DISCHARGE VALVE LEAF FOR PERFORMANCE

Tolga YAROĞLU [1], Serkan KARA [1]
ARCELIK A.S. Eskisehir Compressor Plant, Department of Product Development
Eskisehir-TURKEY
Tel:+90-222-2134656 & 90-222-2134654, Fax: +90-222-2134344
e-mail: tolga.yaroglu@arcelik.com , serkan.kara@arcelik.com

ABSTRACT

The objective of this study is to optimize the discharge valve leaf of a hermetic reciprocating compressor used in household appliances. The cooling capacity and EER (Energy Efficiency Ratio) values are calculated using a simulation software for valve leaves with different shapes and stiffness values. The prototypes for the mentioned samples are prepared and performance tests are performed on new model compressors. The calculated and measured results are compared to check the software and the results are validated. Also the optimum valve leaf shape is determined to be used in the compressor.

1. INTRODUCTION

The suction and discharge valve leaf characteristics significantly influences the performance of reciprocating hermetic compressors. Especially the cooling capacity and EER (Energy Efficiency Ratio) values are mainly effected. To obtain maximum performance, a need arises to specify the optimum valve leaf. In this study, the discharge leaf optimization will be performed. A simulation model will be analyzed and an experimental validation will be performed on a new model compressor in order to finalize the design.

2. THEORETICAL BASIS OF THE METHOD

During design period, closing time adjustment is critical for leakage occurred from discharge manifold to cylinder hole (swept volume) after compression process. Discharge valve must be closed at top dead center at the end of the compression cycle but discharge valves used for hermetic reciprocating compressors for household refrigerator are controlled by pressure equalization. So it is very difficult to close the valve at just top dead center. It is very critical to optimize discharge valve leaf that must be closed near to top dead center as much as possible. Unfortunately there are limited parameters to optimize closing time. The most important parameter is the stiffness of the valve. As a result, the stiffness of discharge valve leaf is very important viewpoint of thermodynamic efficiency.

Natural modes of valve leaves are basis to define the stiffness of leaves. Generally, first natural frequency value is enough to see the effect of structural characteristic of leaves to closing time. In this study, leaves having different first natural frequencies means having different shapes and thickness from 320Hz. to 520Hz. are investigated. First natural frequencies of leaves are calculated using a special purpose finite element code.

3. SIMULATION AND IDENTIFICATION

A special code developed for cycle simulation of reciprocating compressors is used for calculations. This simulation code takes into account many data like valve plate and leave geometry, bearing data, electro-motor data, and mechanism data during calculation. This is an integrated software for reciprocating compressor analysis. Simulation code works in time domain. Some features and explanations are as follows about the code;

- The first law of thermodynamics is used directly in the modeling of in cylinder and gas exchange processes,
- Thermodynamic formulations are based on the exact real gas properties of R134a and R600a,
- Several options including different flow and force models are provided for the modeling of valve flow through orifices,
- Suction and discharge manifold control volumes can be included in the modeling of in-cylinder and gas exchange processes,
- Mechanism and electro-motor characteristics are simultaneously taken into account during cycle simulation,
- Finite element structural model is used for the determination of the modal characteristics of suction and discharge valve leaves. Modal analysis is performed in displacement and stress domains,
- The motion of suction and discharge valve leaves can be modeled by using a multiple number of modes,
- Cylinder heat transfer and leakage can be taken into account,
- Discharge valve leakage can be taken into account.

Simulation results;

Compressor cooling capacities are calculated for 5 different discharge valves having different stiffness by changing the shape or thickness. First natural frequencies of them are between 312-520Hz. Results are plotted on below graph.

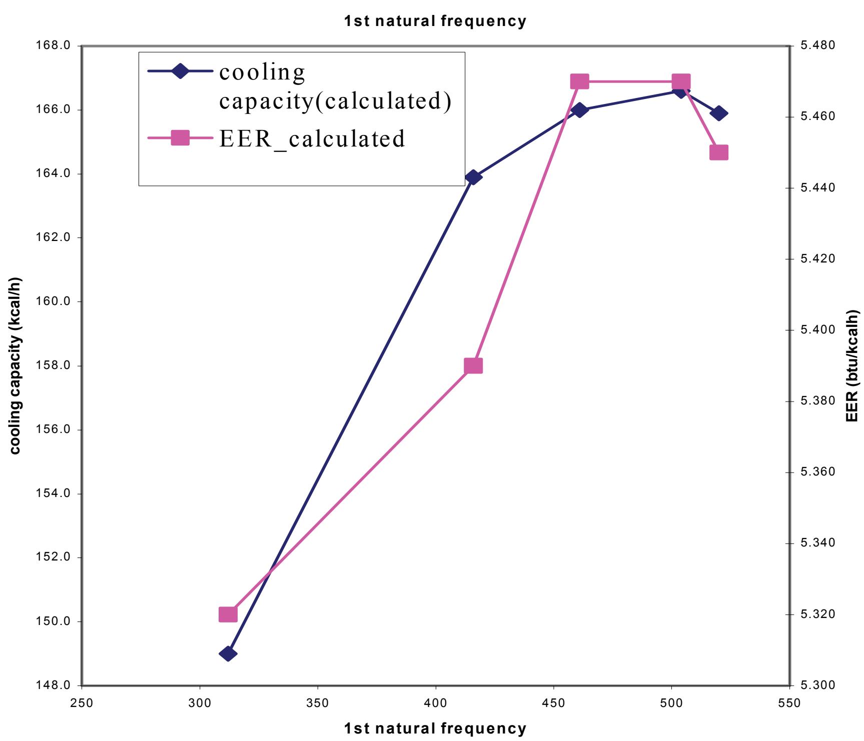

Fig. 1. EER and cooling capacity variation versus 1st natural frequency.

4. EXPERIMENTAL VALIDATION

In order to specify the effect of discharge valve stiffness on compressor performance, there is a need for valve samples with different stiffness values. In this study, two methods are used to change the stiffness; changing thickness (t) and changing shape (e.g. width of the leaf w. See fig.2).

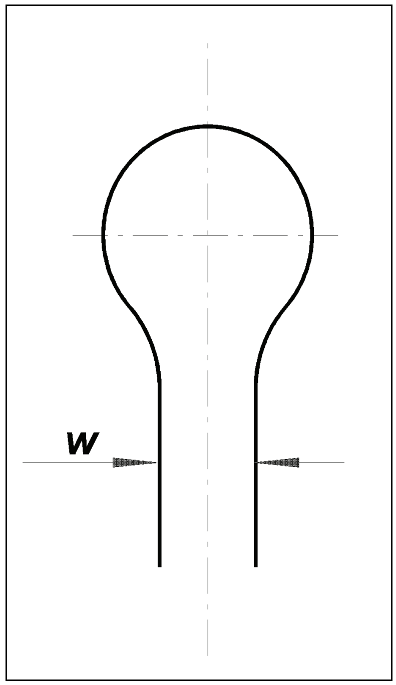

Fig. 2. Discharge valve leaf shape and width

4 different thickness and 3 different width values are used with a result of 12 combinations. The specified thickness and width values with resultant combinations are listed in Table 1.

Table 1. Alternatives for width and thickness combination

w	t	w	t	w	t
4	0.15	5	0.15	6	0.15
4	0.20	5	0.20	6	0.20
4	0.25	5	0.25	6	0.25

To reduce the number of tests, it is decided to use only 5 combinations. The selected combinations and the first natural frequency values calculated in the previous section are given in Table 2.

Table 2. Predetermined combinations and corresponding natural frequencies

		w (mm)		
		4	5	6
t (mm)	0,15	312		
	0,20	416	461	504
	0,25	520		

After selecting the natural frequencies and preparing the valve leaves, the performance tests are planned. To determine the effect of the valve leaf on performance, calorimeter tests are performed to find the cooling capacity and EER (Energy Efficiency Ratio) values. First, the base tests are performed for 3 different "New Model" compressors. Then the prepared 5 different valve leaves are exchanged with the current valve leaf one by one and the calorimeter tests are repeated. To eliminate the variation between 3 different samples, the difference between the base test and the other 5 new valve leaf tests are recorded. Then the average difference for Cooling Capacity and EER are calculated. The cooling capacity and EER versus natural frequency graph is given in fig. 3.

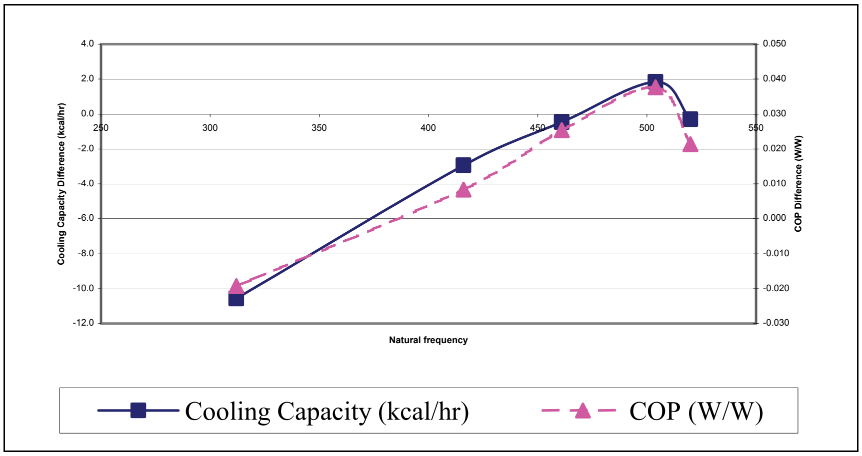

Fig. 3. Cooling capacity&COP change vs. natural frequency of discharge valve leaf

5. SUMMARY AND CONCLUSIONS

Simulation and test results are shown in figure 4 and figure 5 for cooling capacity and EER (Energy Efficiency Ratio). As seen in figures, results are very similar and simulation code is helpful to analyze and develop valve characteristics. According to both test and results of simulation, importance of discharge valve leaf stiffness is found out.

Compressor performance is affected approximately %3.5 on EER and %7 on cooling capacity by changing natural frequency of discharge leaf between 312Hz and 520Hz.

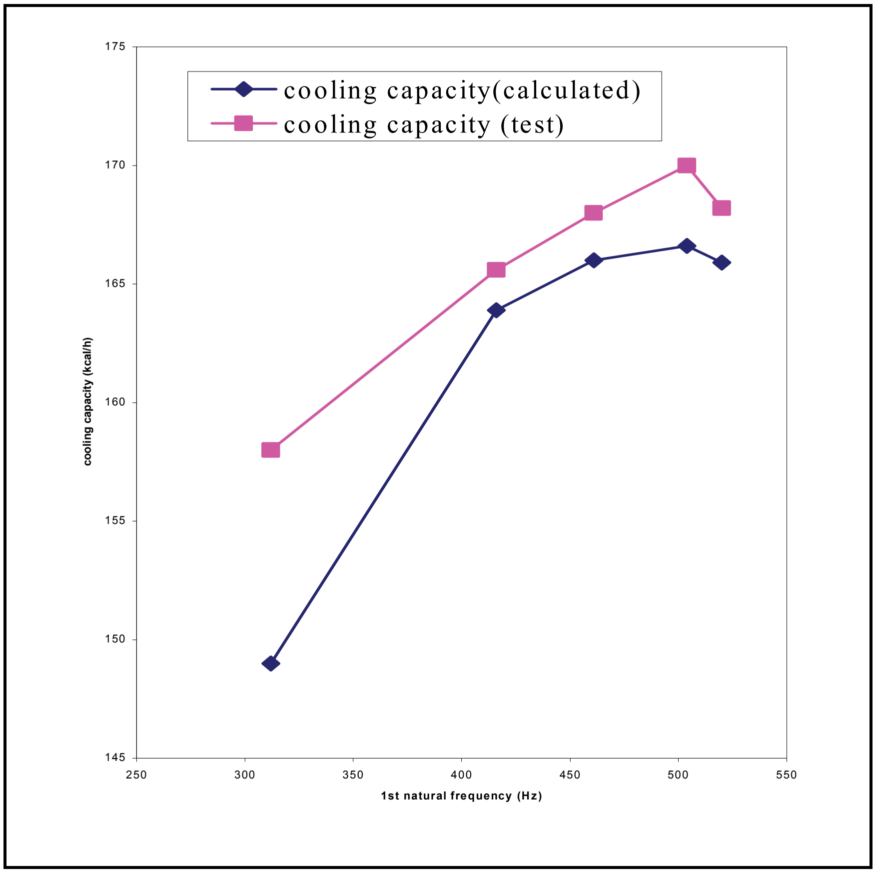

Fig. 4. Cooling capacity & COP change vs. natural frequency of discharge valve leaf

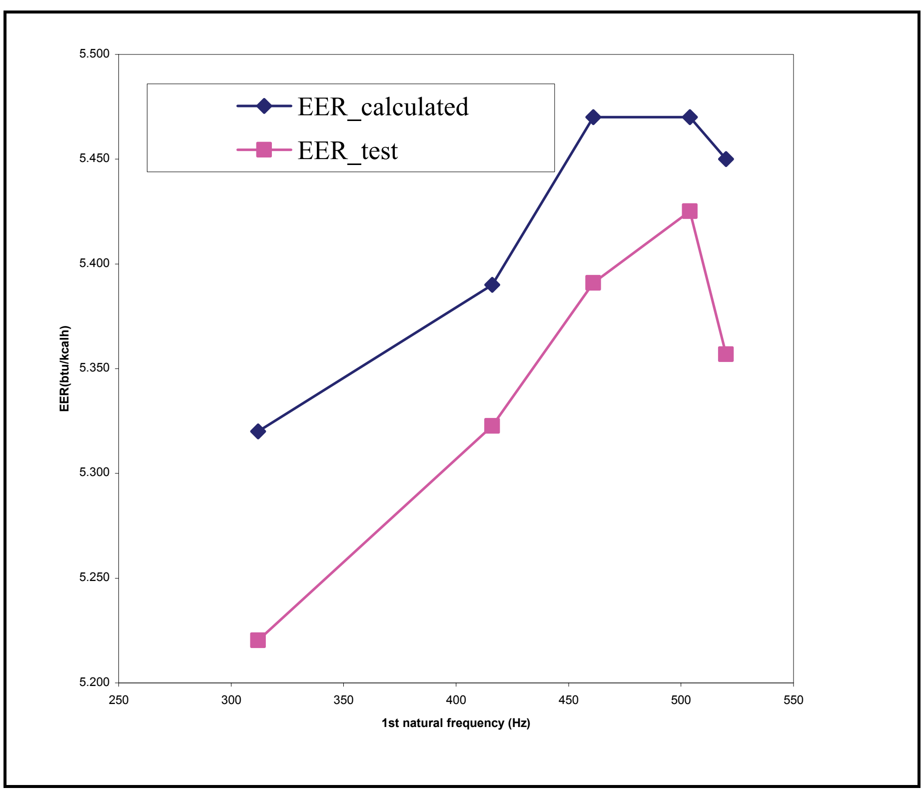

Fig. 5. Cooling capacity &COP change vs. natural frequency of discharge valve leaf