Techno-Science 6:2 (2023) 51-56

Techno-Science
Scientific Journal of Mehmet Akif Ersoy University
https://dergipark.org.tr/pub/sjmakeu

Original Research Article

hosted by Turkish JournalPark ACADEMIC

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF AIR PERMEABILITY OF AN EVAPORATOR

İsmet Faruk YAKA[1*], Afşin GÜNGÖR[2,3]

[1] *Akdeniz University, Faculty of Engineering, Department of Mechanical Engineering*
[2] *Akdeniz University, Department of Mechanical Engineering, Antalya, Turkey*
[3] *Kristal Endüstriyel, A.Ş., R&D Department, Antalya, Turkey*

ARTICLE INFO

Article History

Received	:	19/10/2023
Revised	:	02/12/2023
Accepted	:	02/12/2023
Available online	:	31/12/2023

Keywords
Industrial cooling, Monoblock refrigerator, Evaporator efficient, CFD

ABSTRACT

In this study, the air distribution in the evaporator of an industrial type monoblock refrigerator is investigated numerically and experimentally. Using the ANSYS program, 12 different points on the evaporator were determined and the velocity of these points were numerically determined, and the evaporator was divided into 5 different regions and the air flow rate change in these regions was examined. The simulated parts were also measured experimentally in a monoblock refrigerator. As a result, it is observed that there is an unbalanced air distribution on the evaporator, which has a negative effect on cooling performance and energy consumption. Thanks to the fins used to distribute the air flow more evenly, the difference in distribution between the left and right zones of the evaporator is reduced by 10.8 m3/h. As a result, a more balanced flow distribution was achieved with an improvement of approximately 10%.

1. INTRODUCTION

While the impact of global warming is increasing day by day, reducing carbon emissions within the framework of the green agreement has once again clearly demonstrated the importance of energy efficiency. Therefore, increasing the efficiency of energy consuming devices is of critical importance [1]. Today, refrigerators are one of the most basic appliances used both in residential buildings for individual use and in industrial kitchens such as cafes, hotels, restaurants, and commercial enterprises such as markets. One of the most important issues in refrigerator design is energy consumption. Energy consumption in households has a significant share in total energy consumption and refrigerators used in homes have a significant share in domestic energy consumption. In 2006, 29% of the total electrical energy consumption of the European Union Countries, which includes 15 countries (EU-15), was accounted for by domestic applications, while 14% of this energy was consumed by refrigerators. The total amount of energy used by refrigerators in the European Union countries was 102 TWh. In addition, in the 12 countries that joined the EU in 2004 (NMU-12), 26% of total electricity consumption was spent on domestic activities, 22% of which was consumed by refrigerators. For these countries, the amount of energy used by refrigerators was determined as 19.4 TWh [2-4]. Therefore, increasing the energy efficiency of refrigerators is one of the priorities among the green consensus targets [5].

Many studies have been carried out in the literature on the energy efficiency of refrigerators. When these studies are examined in detail, they are classified as experimental and numerical to improve cooling performance by designing cooling equipment and using different refrigerant gases, etc. Ragip et al. [5] numerically investigated the usability of R449A refrigerant gas as an alternative to R404A. Pence et al. [6] predicted the direct thermodynamic properties of R513A refrigerant such as temperature, pressure, enthalpy and entropy using artificial intelligence. Mançuhan et al. [7] developed a model to predict the effects of different refrigerants on the cooling capacity of an evaporator at different parameters. These parameters are mass flow rate, temperature, pressure and R134a, R404A, R290 and R410A were used as refrigerants.

Balkan and Aksoy [8] experimentally and numerically (CFD) investigated the effect of the location of the evaporators inside the chamber on the thermal and velocity distributions for a cold storage with citrus fruits. Avcıoğlu [9] numerically and experimentally investigated the temperature distribution in the refrigerator compartment of a refrigerator which is used

* Corresponding Author: ismetfarukyaka@hotmail.com

To cite this article: YAKA I.F., GUNGOR A., (2023). Numerical and Experimental Investigation of Air Permeability of an Evaporator. *Scientific Journal of Mehmet Akif Ersoy University*, vol. 6, no. 2-p.51-56

extensively in domestic use and made various improvements. Pakdil [10] experimentally and numerically investigated the temperature distribution with air flow by modeling the operating time of a no-frost deep freezer as a closed system in detail. Pegallapati and Ramgopal [11] a thermohydraulic model of a domestic refrigerator evaporator is developed. The effect of varying the number of fins and fin spacing on airflow and heat transfer is investigated by keeping the refrigerator evaporator width and heat transfer area constant. It is found that increasing the number of fins contributes positively to heat transfer. Belman-Flores and Gallegos-Muñoz [12] the thermal and flow analysis of the evaporator with finned surface and the evaporator with finless surface in a refrigerator with diffusion absorption technology was carried out. It is concluded that the finned surface has better air distribution and thermal efficiency than the finless surface.

The evaporator is one of the most important equipment in the creation of internal cooling air in refrigerators. This equipment, which provides the contact of the refrigerant with the internal air and heat transfer, makes a significant contribution to the cooling efficiency. One of the main parameters affecting the efficiency of the evaporator is a design that will provide high heat transfer and determining the distribution of the internal air on the evaporator and making improvements accordingly. From this point of view, in this study, in order to investigate the distribution of air flow through the evaporator, the distribution of air flow through the evaporator in an industrial type monoblock refrigerator was investigated numerically and experimentally.

2. METHODS

In this study, the distribution of air flow through the evaporator in an industrial monoblock refrigerator is investigated numerically and experimentally. The general view of the monoblock refrigerator and the location of the evaporator are given in Figure 1. The indoor air is taken into the cooling chamber by a fan positioned at the top of the refrigerator, passed through the evaporator and transferred back to the indoor environment. Thanks to this circulation, the lower part where the products to be cooled are kept at the desired temperature.

In the experimental part of the study, instantaneous air flow velocity measurements were taken from the determined points to determine the air distribution over the evaporator. Figure 1 shows in detail the air velocity measurement points and the parts where these points are also used in the simulation.

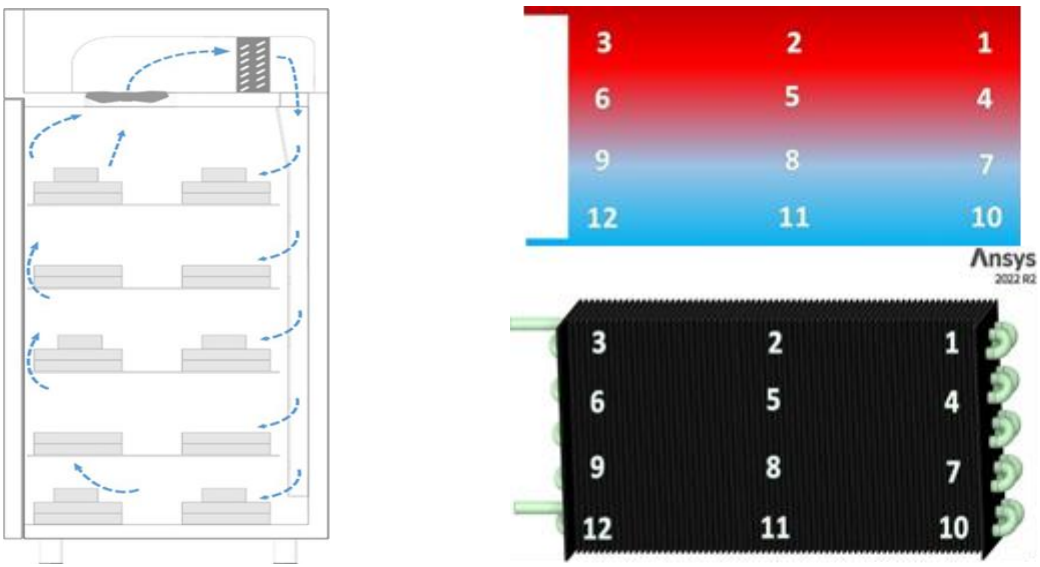

Fig 1. An Industrial Monoblock Refrigerator and Evaporator Speed Measurement Points

The model of the evaporator at the top of the industrial type monoblock refrigerator used in the experimental part of the study and given in Figure 1 was prepared and numerical flow simulation was performed in ANSYS FLUENT simulation program. The system used for simulation has 64 GB ram and Intel® Xeon® W-1250 3312 Mhz 6 CPU (6 logical) processor. In the numerical model, the SIMPLE method was used to solve for air assuming incompressible flow. The largest mesh size within the flow boundaries is 2 mm. The smallest mesh size is of the order of 0.05 mm with a mesh cell count of 4850000 and an orthogonal quality of 19.0%. Both inlet and outlet boundary conditions are left as atmospheric pressure, with an effective pressure condition of 0 Pa. Air flow was generated using 'frame motion' with a fan rotating at constant speed. A 'steady' solution was performed where the flow is stable. The solution step time was set to allow the fan to rotate 0.25 degrees. The solution was terminated after the 'residuals' dropped below 1E6 and the output air flow rate was stable. Each solution took between 3-6 days with the current system specifications. The mesh structure view of the evaporator is shown in Figure 2 and the flow diagram of the simulation is detailed in Figure 3.

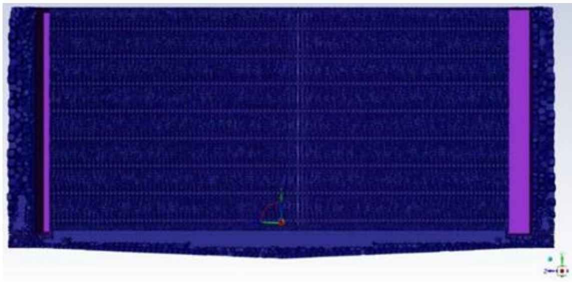

Fig 2. Evaporator Mesh Overview

The numerical model developed for the simulation and the flow diagram of this model are given in Figure 3. In the developed numerical model, the flow rate variation was analyzed with a precision of 0.1% and if convergence was not achieved, the numerical simulation was continued.

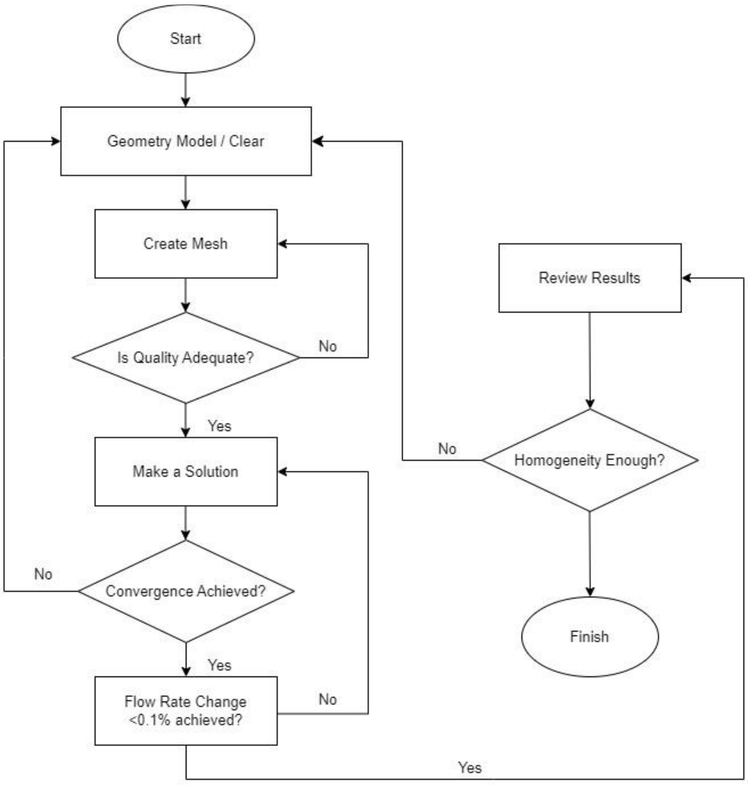

Fig 3. Simulation Flow Diagram

3. RESULTS AND DISCUSSION

In this study, where the air permeability of an evaporator is investigated experimentally and numerically, the experimental measurements made at 12 different points and the numerical simulation results of these points are given in Table 1 below. In Table 1, the ratio of the experimental and simulation results to each other and the error rate are given. Points 3, 6, 9 and 12 are at the inlet and outlet points of the refrigerant to the evaporator. Points 2, 5, 8 and 11 are in the middle part of the evaporator and points 1, 4, 7 and 10 are at the end of the evaporator.

When the experimental and simulation values of the velocity distribution of the part of the evaporator where points 3, 6, 9 and 12 are located are examined, it is seen that the simulation value is above the experimental value at points 12 and 6, and the experimental value is above the simulation value at points 3 and 9. At points 2, 5 and 8 and 11 in the middle points of the evaporator, the experimental values at points 2 and 5 are above the simulation value, but the values of both points are close to each other. At point number 8, the simulation value is very low compared to the experimental value and on the contrary, at point number 11, the experimental value is considerably lower than the simulation value. If we look at the points at the end of the evaporator, the experimental results of points 1, 4 and 10 are higher than the simulation, but the situation is the opposite at point 7.

Table 1. Experimental and Simulation Velocity Distribution Results

Measurement Point	Speed [m/s]		Error
	Simulation	Experiment	
1	0.52	0.86	0.40
2	2.32	3.15	0.27
3	1.27	1.54	0.18
4	0.89	0.91	0.03
5	2.63	3.37	0.22
6	0.55	0.44	0.25
7	1.82	1.2	0.51
8	0.35	1.49	0.77
9	0.17	0.29	0.42
10	1.9	2.54	0.25
11	0.51	0.32	0.41
12	0.52	0.36	0.39

The flow rate distribution of the air over the evaporator is given in Figure 4 and Table 2 below. In order to determine the distribution according to the flow rate, the evaporator was divided into 5 zones. These points, 1 is the lowest part, 2 and 3 are classified as right and left side, 4 and 5 are classified as left and right inner regions, respectively.

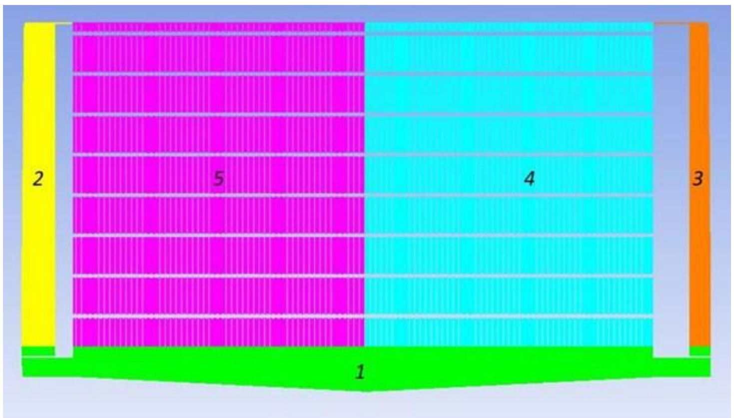

Fig 4. Evaporator Zonal Separation

When the flow distribution is analyzed, it is determined that the flow density passes through the regions numbered 4 and 5 with 84.6%. The fact that most of the flow passes through these points is a good value in terms of cooling efficiency. However, there is an air loss of 4.9% from points 2 and 3 without including cooling and a significant air loss of 10.5% from sub-area 1. This shows that the cooling air is unevenly distributed over the evaporator and the efficiency is low. In addition, the air distribution of 84.6% is also unbalanced at points 4 and 5 with a difference of 20%. The above-mentioned cooling air losses and uneven distribution have a negative effect on the cooling efficiency of the evaporator.

Table 2. Evaporator Regional Flow Results

	Region	Flow rate [m^3/hour]	% Rate
1	Under Evaporator	21.2	10.5
2	Evaporator Side Right	4.5	2.2
3	Evaporator Side Left	5.5	2.7
4	Evaporator Inside Right	65.1	32.3
5	Evaporator Inside Left	105.4	52.3
	Total	201.6	100.0

According to the regional flow rate results in Table 2, various improvements were made on the system. The general view of the improvements made is given in Figure 5 and the results obtained are given in Table 3. Between the evaporator and the fan, 3 fins were added to direct air over the evaporator. The positions of these fins were adjusted so as not to disturb the current flow trend and to provide a balanced flow over the evaporator.

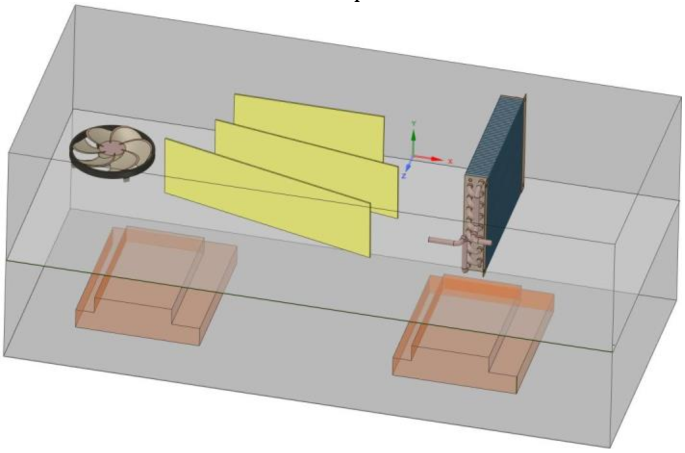

Fig 5. Condenser Fin Improvement

As a result of this improvement, a more balanced flow distribution was obtained in the 4th and 5th regions of the evaporator compared to the initial situation. A positive balanced distribution of 5.7% has been obtained with a flow rate increase of 10 m3/hour approximately in the left region inside the evaporator. In addition, this improvement has resulted in a total reduction of 4.1 m3/hour in the amount of air passing through the evaporator bottom zone. 3.2 m3/hour of this reduction was added to the left and right zones inside the evaporator. In this way, 1.95% improvement was made in the under-evaporator area. As a result, directing the air between the fan and the evaporator with simple fins has helped to provide a more balanced air distribution over the evaporator.

Table 3. Regional Flow Results with Evaporator Fin Addition

	Region	Flow rate [m^3/hour]	% Rate
1	Under Evaporator	17.1	8.6
2	Evaporator Side Right	4.8	2.4
3	Evaporator Side Left	6.1	3.0
4	Evaporator Inside Right	75.9	38.0
5	Evaporator Inside Left	95.6	47.9
	Total	199.5	100.0

4. CONCLUSIONS

In this study, the air distribution of an industrial type monoblock refrigerator evaporator was investigated by experimental and simulation methods. According to the experimental and simulation results of the velocity and flow distributions in the study, it is observed that there is no balanced velocity and flow distribution over the evaporator. This unbalanced distribution will cause the efficiency of the evaporator to decrease, more air circulation to achieve the desired cooling values, and therefore more intensive fan use and more intensive compressor use. When all these situations come together, the overall cooling efficiency will decrease and energy consumption will increase. In this respect, various improvements and analyzes for a more balanced air distribution on the evaporator are important for future studies.

5. ACKNOWLEDGEMENTS

The experimental and numerical investigations in this article were carried out with Kristal Endüstriyel A.Ş. within the scope of the project titled "Increasing the efficiency of industrial type monoblock refrigerators". We would like to thank Mr. Ramazan Kaynakçı, Chairman of the Board of Directors of Kristal Endüstriyel A.Ş., Kristal Endüstriyel R&D team and Kristal Endüstriyel A.Ş. for their great support within the scope of the study.

REFERENCES

[1] Şimşek, B., Özkan, M., Güngör, A., (2020). International Practices on Climate Change and Emissions Trading. Scientific Studies on The Edge of Global Warming Ankara: Nobel Publishing House.

[2] Akkaya, M., Çamdalı, Ü. (2021). Ev Tipi Bir Buzdolabının Analitik İncelenmesi ve Tasarımı. Mühendis ve Makina, vol. 62(704), p. 395-414, https://doi.org/10.46399/muhendismakina.867834

[3] Bertoldi, P., Atanasiu, B. (2007). Electricity consumption and efficiency trends in the enlarged European Union. IES-JRC. European Union.

[4] Sakallı, Ö. (2012). Ev Tipi Buzdolaplarında Enerji Tüketimine Etki Eden Parametrelerin İncelenmesi, Doctoral dissertation İstanbul Technical University.
[5] Yıldırım, R., Kumaş, K., Akyüz, A. Ö. Güngör, A. (2023). Numerical Analysis of Using R449A Refrigerant Alternative to R404A in Cooling Systems: 3E-Analysis (Energetic, Exergetic, and Environmental). Politeknik Dergisi , , 1-1 . DOI: 10.2339/politeknik.1073335
[6] Pençe, İ., Yıldırım, R., Çeşmeli, M. S., Güngör, A., Akyüz, A. (2023). Evaluation of machine learning approaches for estimating thermodynamic properties of new generation refrigerant R513A. Sustainable Energy Technologies and Assessments, vol. 55, p. 102973, https://doi.org/10.1016/j.seta.2022.102973
[7] Mançuhan, E., Mutlu, T., Yıldırım, B. K., Titiz-Sargut, S. (2019). Mathematical Model of a Finned Tube Evaporator Using Different Refrigerants. International Journal of Advances in Engineering and Pure Sciences, vol. 31, p. 66-74, https://doi.org/10.7240/jeps.497386.
[8] Balkan, F., Aksoy, A. B. (2022). Soğuk Hava Odasında Evaporatör Yerleşiminin Depo Ürünlerine Etkisinin CFD Analizi. Mühendis ve Makina, vol. 63(707), p. 222-249, https://doi.org/10.46399/muhendismakina
[9] Avcıoğlu, S. (2012). Ev Tipi Statik Buzdolabı Soğutucu Bölmesinde Sıcaklık Dağılımının Deneysel ve Sayısal İncelenmesi, Doctoral dissertation İstanbul Technical University.
[10] Pakdil, M. B. (2011). No-frost Derin Dondurucu İçindeki Sıcaklık Dağılımı ve Hava Akışının İncelenmesi, Doctoral dissertation İstanbul Technical University.
[11] Pegallapati, A. S., Ramgopal, M. (2021). Effect of heat transfer area distribution on frosting performance of refrigerator evaporator. International Journal of Heat and Mass Transfer, vol. 175, 121317, https://doi.org/10.1016/j.ijheatmasstransfer.2021.121317.
[12] Belman-Flores, J. M., & Gallegos-Muñoz, A. (2016). Analysis of the flow and temperature distribution inside the compartment of a small refrigerator. Applied thermal engineering, vol. 106, pp. 743-752, https://doi.org/10.1016/j.applthermaleng.2016.06.065.

Techno-Science *Paper ID: 1378325*