China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1016-1024

ANALYTICAL STUDY OF R134A REFRIGERATION SYSTEMS WITH VARYING SIZE MICROCHANNEL CONDENSERS

Tejrao Ghormade[1, a]) Dr. Sachin Karale[2, b]) Dr. Gajanan Awari[3, c])

[1]Research Scholar, Department of Mechanical Engineering, G H Raisoni University, Amaravati, India, [2]Professor, Department of Mechanical Engineering, G H Raisoni University, Amaravati, India [3]Department of Automobile Engineering, Government Polytechnic, Nagpur, India

a) Corresponding author: ghormadet@gmail.com, b)sachin.karale@raisoni.net c)gkawari70@gmail.com

Abstract. Vapour compression refrigeration method is used in the vast majority of home refrigerators because of its efficient performance coefficient. Components like the compressor, condenser, expansion valve, and evaporator make up the system. Each part of the system is responsible for the overall performance, and may either boost or lower that performance. The study paper details the process of increasing a home refrigerator's COP by modifying the condenser configuration. Micro channel condensers have been shown to enhance the coefficient of performance (COP) of a refrigerator, as their greater surface area and unique geometric design contribute to more effective heat transfer. When the results of a micro channel condenser installation are compared to those of a standard refrigerator, it is clear that they are superior. A 2.20 and 2.63 percentage point increase in COP was achieved after installing a micro channel type condenser. The COP of a conventional home refrigerator serves as the reference standard.

INTRODUCTION

Heat exchangers, which facilitate superior heat transmission, are the most crucial pieces of machinery in energy systems. Vapour compression refrigeration cycles rely on the condenser and evaporator heat exchangers.

1. Environmental and energy issues with refrigeration cycles have motivated research towards more efficient evaporators, condensers, and refrigerants.
2. Due to its many advantages, including high heat transfer coefficients, small dimensions, low working fluid quantity, and mobility, microchannel heat exchangers have been more popular as condenser and evaporator in cooling systems in recent years.
3. Microchannel heat exchangers have been the subject of several studies in cooling systems. The performance of a lateral microchannel evaporator used in a data center's cooling system was quantitatively analysed by Zhan et al. 5 using Icepack software. Maximum air side temperature difference was 9.5 °C and refrigerant output side vapour quality difference was 0.15 under unfavourable environmental conditions. Microchannel condenser performance in a cooling system was studied by Tosun et al. 6 using a range of capillary integration sizes and concentrations of refrigerant. Two kinds of microchannel heat exchangers in a heat pump system were analysed for their defrost and frost performance using a CCD camera by Xu et al. 7. The effective operating time was cut by 40 minutes since they found that 800 grammes of water remained in the

microfluidic exchangers after four operational cycles. The system's capability was reduced by 27% as compared to its original value. Xu et al. 8 conducted an experimental and statistical analysis of the efficiency of microchannel condensers in R290 refrigerant-based household air conditioners. The microchannel condenser system's cooling capacity rose by 1.6% while the refrigerant charge dropped by 28.3%. In this experiment, Zhou and Hrnjak 9 analyse the outside

A microchannel heat exchanger to mitigate the radiative effects of R410a and R134a. It was discovered that R410a has a higher inertia than R134a, and that the high-quality distribution of R410a is less favourable than that of R134a. In rare cases, a microchannel heat exchanger may serve as both the cooling system's evaporator and condenser. In their study, Yatim and Cremaschi et.al 10 looked at the R134a cooling system's evaporator and microchannel condenser, as well as the impact of oil flow on pressure drops and heat transfer capabilities in microchannel heat exchangers. The evaporator's heat capacity dropped to the five to twelve percent range, and pressure was lost at an alarming rate. In this research, two different vapour-compression industrial cooling systems—one with a microchannel condenser and one with a regular condenser—were designed and evaluated. Both systems utilised R449a 11-19 as the refrigerant, and the machinery was identical with the exception of the condensers. Exergy, energy, and environmental characteristics of conventional and microchannel condensers will be compared and contrasted. The overarching concept of the research is that the industrial cooling system needs to increase cooling efficiency while decreasing energy consumption and carbon emissions.

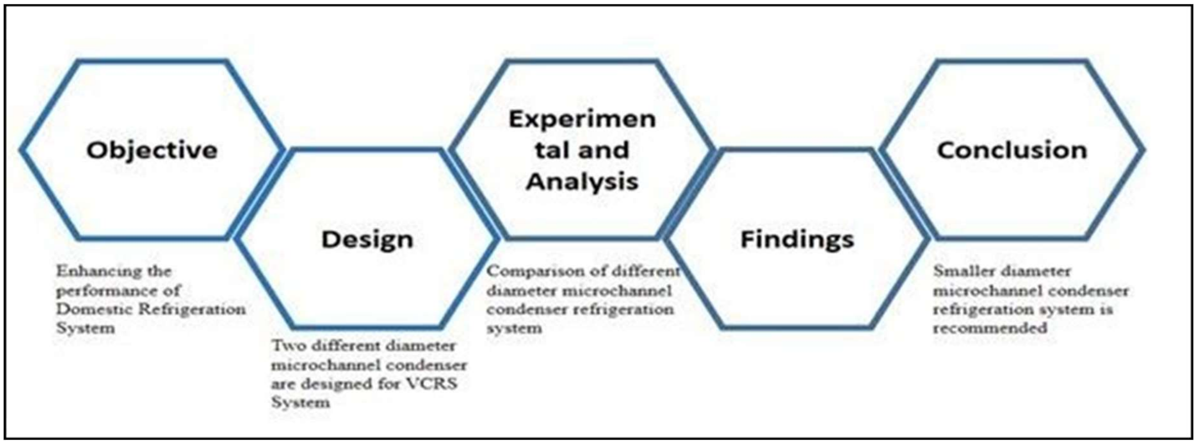

FIGURE 1. Methodology of Current Study

EXPERIMENTAL SETUP

The apparatus for conducting the experiment has been built. The apparatus has evolved to probe microchannel condenser functionality. There are now two micro channels, with diameters of 2mm and 0.6mm, respectively. One evaporator coil, a high- and low-pressure indication, a rotameter for measuring the mass flow rate of the refrigerant, and a set of valves are all that's needed to conduct the experiment.

Design of Experiment

The experimental design and development of a 1TR (tonne of refrigeration) VCR system using an air-cooled condenser is seen in Fig. 2. The 1 TR VCRS condenser that is now in use was investigated. The size and capacity of condensers used with R134a gas were studied. To match the current refrigeration output, a brand new microchannel condenser was developed. The numbers were crunched such that a micro channel condenser may be used instead of the current condenser. To determine the influence microchannel diameter has on refrigeration performance, two microchannel designs with the same surface area were created. Microchannel condenser dimensions are confirmed to be 0.6 mm in diameter and 46.6 m in length, both in accordance with the design.

FIGURE 2. Experimental Setup

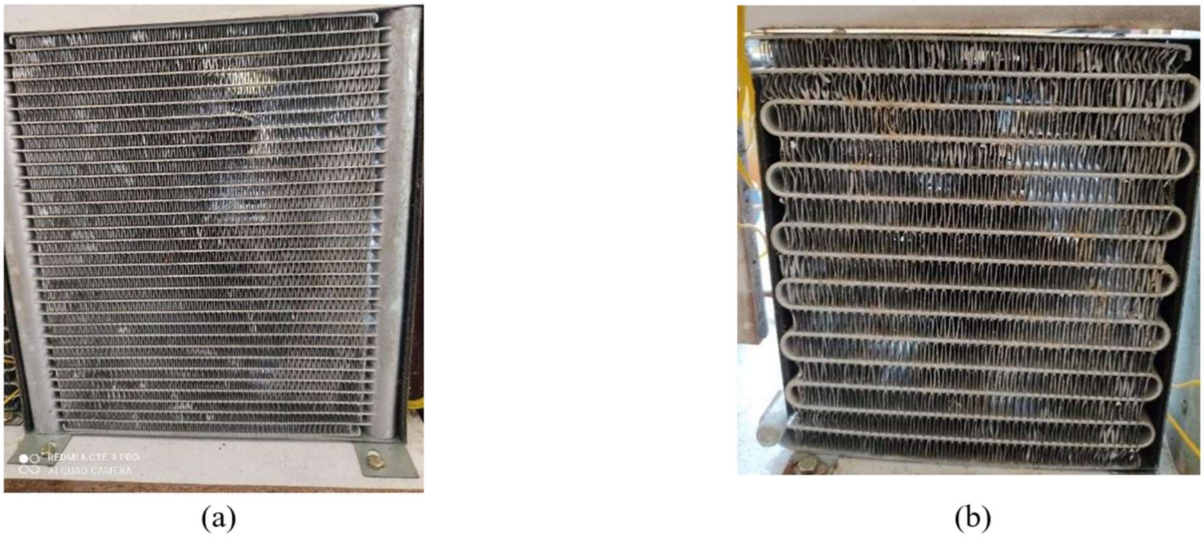
(a) (b)

FIGURE 3. Microchannel condenser

Experimental Procedure

Examining the condenser capacity, actual compressor power consumption, coefficient of performance, refrigerating capacity, and the product of overall heat transfer coefficient (U) and condenser surface area (A) of a VCR system using R134a was the focus of this study. Each experiment's evaporator temperature was maintained at a precise range between -10 and 15 degrees Celsius by adjusting the capillary tube's internal diameter. In order to raise the system pressure for research purposes, the compressor will kick on. Two valves are provided for regulating the flow from the backup condenser. When each condenser is operational, its corresponding fan is turned on and coupled to it. Condensation occurs at a steady pressure and refrigerant temperature reduces as it moves through a condenser. DTI is able to see this. The mass flow rate of the refrigerant is then determined by passing it through a rotameter. After the rotameter, the capillary tube is connected, and the pressure drops into a lower pressure range through an isentropic process. The refrigerant passes through the evaporator, where its low temperature and pressure allow it to absorb heat from its environment and evaporate. Once again, the vaporised refrigerant is sent on its way to the compressor. Each location's temperature is recorded. Compressor energy consumption is also shown using the energy metre. This is useful for investigating the whole setup.

RESULT AND DISCUSSION

Experiments have been conducted on a VCR system equipped with a microchannel condenser, with R134a evaporation temperatures ranging from -100 to 150C. When compared to a regular condenser, the performance of the VCR system was shown to improve with the addition of a microchannel. The efficiency of the VCRS system grows with decreasing microchannel diameter. R134a was used to conduct tests on the condenser and evaporation temperatures between -100C and 150C, as well as on the actual compressor power consumption, cooling capacity, coefficient of performance, and product of condenser surface area (A) and overall heat transfer coefficient (U)..

Actual Compressor Power Consumption

The compressor is one of the most important parts of a Vapour Compression Refrigeration system. An energy metre with a 3200 constant is used to determine the true compressor power consumption of the VCRS system. The measurements from the energy metre and the total time spent on the experiment were used to arrive at the final number. Error! Unable to locate the referenced source. utilising R134a and evaporation temperatures between -10 and 15 degrees Celsius, illustrates the actual compressor power consumption of microchannel condensers A and B. Under the same conditions, there is a 4-50C drop in the condensation temperature. This allows the microchannel condenser to function properly even when exposed to high temperatures. The compressor used more energy in a conventional condenser than it does in a microchannel condenser. The graph also shows that both the microchannel and the evaporative temperature have lower power requirements as the evaporative temperature rises from -100C to 150C. It was found that microchannel I required more than 15.5% more power from the compressor than microchannel II. At an evaporator temperature of 15 degrees Celsius, microchannel II's 0.192 kJ/kg uses the least energy of all of the condensers tested.

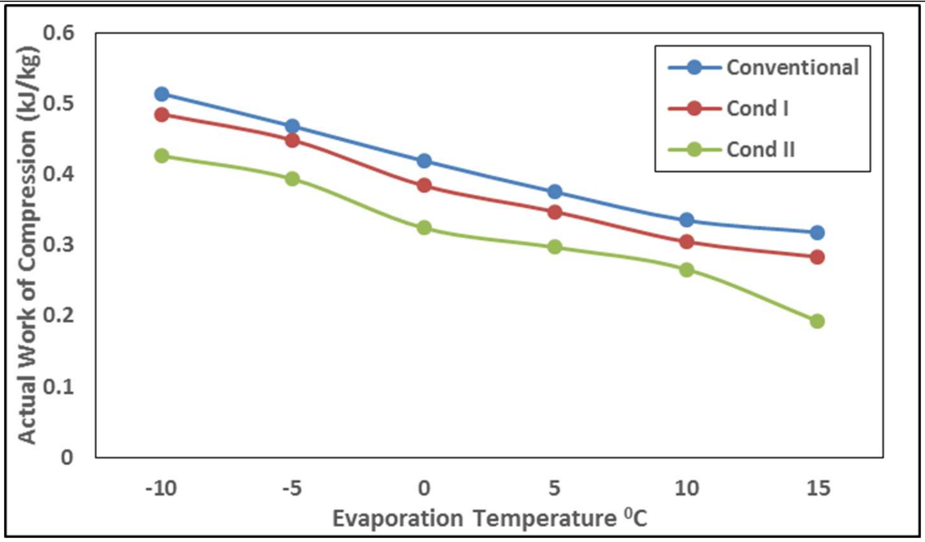

FIGURE 4. Actual Power consuption by compressor using different condenser

Condenser Capacity

When the cooling effect of the evaporator is added to the heat produced by mechanical compression, the resulting temperature is equal to the amount of heat rejected by the condenser. Therefore, the evaporator in a VCR system is more diminutive than the condenser. The condenser's capacity is equal to the product of the refrigerant's mass flow rate in kilogrammes per second and its enthalpy of latent heat in kilojoules per kilogramme.

Condenser I and II’s R134a condenser capacities at evaporation temperatures between -10 degrees Celsius and 15 degrees Celsius are shown in. A microchannel condenser requires less space than a conventional condenser to provide the same refrigeration capability. It aids in shrinking the VCRS system, making it more manageable. The impact of a microchannel condenser has been seen; smaller-diameter microchannels have higher overall condenser capability heat required for evaporation. Condenser capacity increases as evaporative temperature rises, demonstrating the influence of evaporative temperature. Microchannel condenser II, i.e., with a narrower diameter, displays the highest condenser capacity. At an evaporation temperature of 15°C, the condenser's output is at its highest, at 1.74 kW. Thus, it can be claimed that the system's condenser capacity is enhanced by decreasing the width of the microchannel condenser and raising the evaporative temperature.

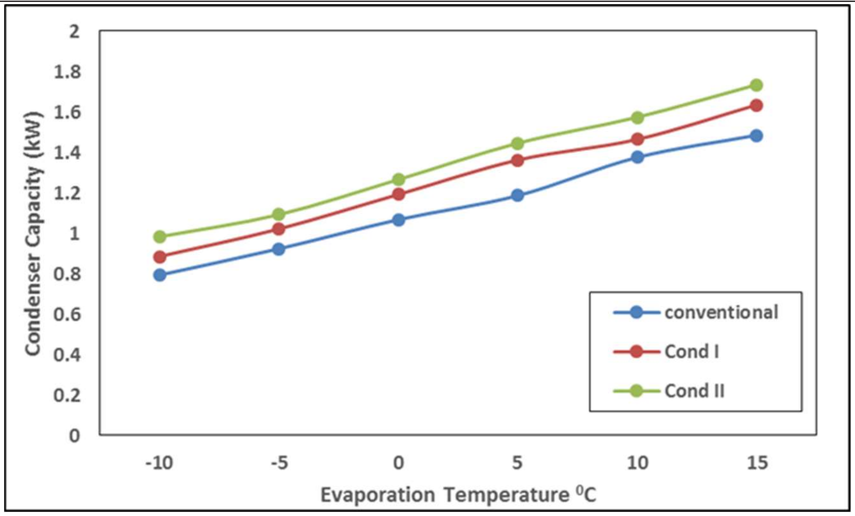

FIGURE 5. Condenser capacity for varying evaporative temperature

Product of Surface Area of Condenser and Overall Heat Transfer Coefficient

By multiplying the condenser's surface area by its total heat transfer coefficient, we may get its capacity per degree of average temperature difference. The thermal performance of a heat exchanger is equal to the product of the condenser's surface area and the overall heat transfer coefficient; a higher UA value indicates a more efficient heat exchanger.

Condenser I and II with R134a at evaporation temperatures between -10 and 15 degrees Celsius have total heat transfer coefficients that are shown in Fig. 6. A microchannel condenser requires less space than a conventional condenser to provide the same refrigeration capability. It aids in shrinking the VCRS system, making it more manageable. Microchannels of smaller diameter have a higher heat transfer coefficient in comparison to those of larger diameters over the whole evaporative temperature range, as seen in. The total heat transfer coefficient improves with increasing evaporative temperature, therefore its influence may be seen. Microchannel condenser II, i.e. the one with the smaller diameter, has the highest global heat transfer coefficient. Overall, the highest heat transfer coefficient is seen at an evaporation temperature of 15 degrees Celsius, or 0.217 kW/K. It follows that raising the evaporation temperature and decreasing the microchannel condenser's width both enhance the system's heat transfer efficiency.

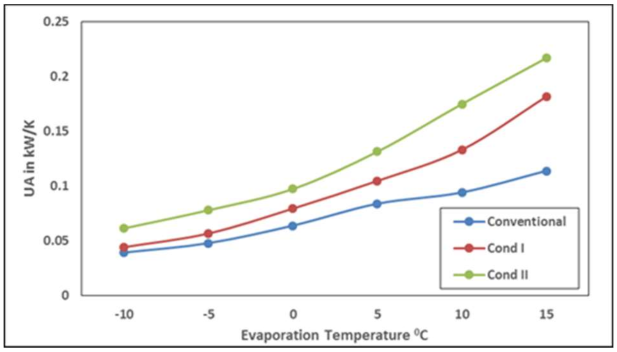

FIGURE 6. Overall Heat transfer coefficient of Condenser for varying evaporative temperature

Refrigerant Capacity

The refrigeration capacity of a refrigeration system is the pace at which it extract heat from the chilled chamber. The overall cooling effect generated in evaporator is determined by product of the refrigerants the enthalpy differential (kJ/kg) and the mass flow rate in (kg/s) between the evaporator's intake and exit.

Fig. 7 shows the refrigeration capacity VCRS system for microchannel condenser I and II with R134a refrigerant at evaporation temperature ranging from -100C to 150C. From it has observed that the effect of microchannel condenser, the microchannel with smaller diameter has better refrigeration capacity than larger diameter throughout the evaporative temperature. The effect of evaporative temperature can also see, the refrigeration capacity increases with increase in evaporative temperature. The maximum refrigeration capacity can be seen for microchannel condenser II i.e. with smaller diameter. The maximum refrigeration capacity is observed for 150C evaporative temperature i.e. 1.18 kW. So, it can be stated that the reduction in diameter of michrochannel condenser and increase in evaporative temperature improves the refrigeration capacity.

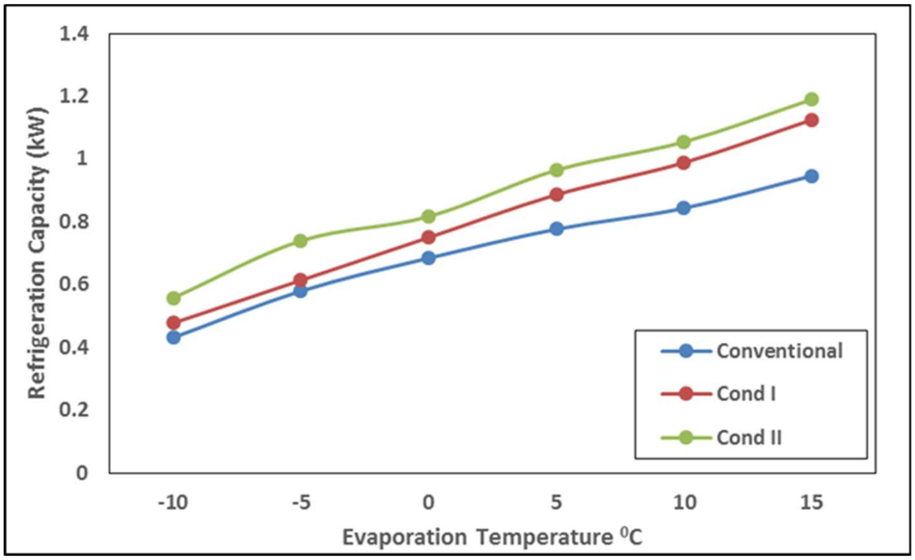

FIGURE 7. Refrigeration capacity of condenser for use of different condenser

Coefficient of Performance

The coefficient of performance for a vapour compression refrigeration system is the ratio of the necessary refrigeration effect to the effort of the compressor. The COP is one of the most important metrics for measuring a business's success.

Evaporation temperatures between -10 and 15 degrees Celsius were used to calculate the COP of the VCRS system using microchannel condenser I and II filled with R134a refrigerant (see Fig. 8). As can be shown in Fig. 8, the impact of a microchannel condenser shows that a smaller-diameter microchannel consistently achieves a higher coefficient of performance (COP) than a larger-diameter microchannel over the whole evaporative temperature range. The evaporation temperature has an obvious impact as well, with a higher temperature leading to a higher COP. Microchannel condenser II, i.e., with a smaller diameter, has the highest COP. For an evaporative temperature of 15 degrees Celsius, the highest COP is recorded (2.64). The system's COP may be improved by decreasing the microchannel condenser's diameter and increasing the evaporative temperature.

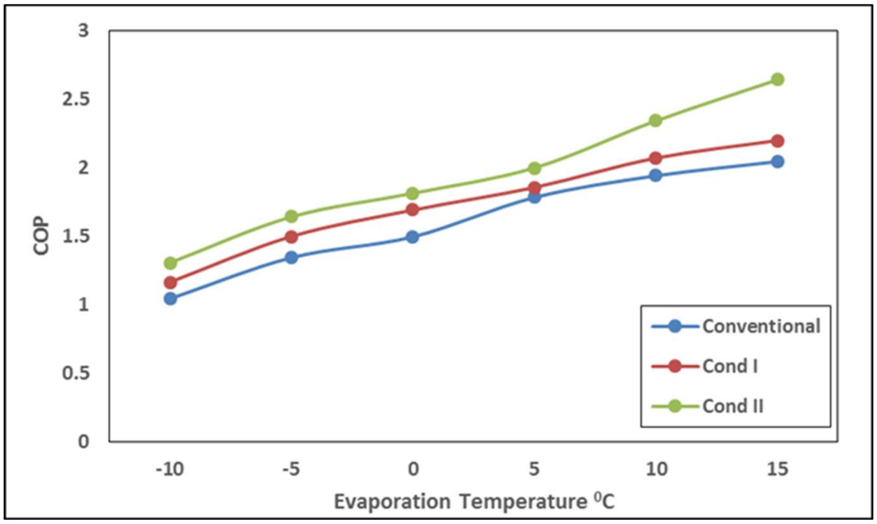

FIGURE 1. Coefficient of Performance for Micro channel Condenser

CONCLUSION

The vapour compression system is a popular choice for both residential and commercial refrigeration. The goal of the research is to shrink the system down to an acceptable size without sacrificing performance. Therefore, efforts have been made to lessen the bulk of compressors. Reducing the diameter of the condenser coil is one way that the microchannel condenser has found to save space without sacrificing performance in the refrigeration system. Research into the performance of condensers has shown that when coil diameter reduces, condenser capacity improves. The maximum condenser capacity of 1.74 kW is attained with a 0.6 mm diameter condenser using a total heat transfer coefficient and surface area of 0.217 kW/K. Compressor performance as a function of microchannel diameter was also studied, and it was found that as the condenser coil diameter increased, so did the compressor's actual power consumption. Condensers with a diameter of 0.6 mm have the lowest power consumption per kilogramme at 0.192 kJ/kg. The impact of microchannel diameter on the system's COP and cooling performance was also investigated. The refrigeration effect and COP were shown to improve with decreasing condenser coil diameter. Maximum refrigeration effect is stated as 1.18 kW and COP is noted as 2.64. The results of this comprehensive analysis show that, at a given evaporative temperature, the performance of a refrigeration system may be improved by decreasing the diameter of the microchannel condenser coil.

REFERENCE

1. M. Mohanraj, Y. Belyayev, S. Jayaraj, and A. Kaltayev, Renew. Sustain. Energy Rev. 83, 90 (2018).

2. A.E. Gürel, Ü. Ağbulut, A. Ergün, and I. Ceylan, Eng. Sci. Technol. an Int. J. 23, 365 (2020).

3. C.Y. Park and P. Hrnjak, Int. J. Refrig. 31, 822 (2008).

4. E. Moallem, L. Cremaschi, D.E. Fisher, and T. Hong, Exp. Therm. Fluid Sci. 88, 326 (2017).

5. B. Zhan, S. Shao, H. Zhang, and C. Tian, Appl. Therm. Eng. 164, 114550 (2020).

6. M. Tosun, B. Doğan, M.M. Öztürk, and L.B. Erbay, Int. J. Refrig. 98, 428 (2019).

7. B. Xu, Q. Han, J. Chen, F. Li, N. Wang, D. Li, and X. Pan, Appl. Energy 103, 180 (2013).

8. B. Xu, Y. Wang, J. Chen, F. Li, D. Li, and X. Pan, Measurement 90, 338 (2016).

9. Z. Fang, X. Feng, Z. Zheng, X. Zhou, L. Li, Y. Huang, H. Wang, and F. Liu, Exp. Heat Transf. 32, 267 (2019).

10. L. Cremaschi and A. Saad Yatim, Sci. Technol. Built Environ. 25, 272 (2019).

11. M. Aktaş, M. Koşan, E. Arslan, and A.D. Tuncer, Proc. Inst. Mech. Eng. Part A J. Power Energy 233, 588 (2019).

12. F. Khalid, I. Dincer, and M.A. Rosen, Sol. Energy 112, 290 (2015).

13. R. Smith and O. Delaby, Chem. Eng. Res. Des. Kingdom) 69, (1991).

14. M. Koşan, M. Demirtaş, M. Aktaş, and E. Dişli, Sol. Energy 199, 657 (2020).

15. K. S. Rambhad, P. V. Walke, V. P. Kalbande, Solid Desiccant Dehumidification and Regeneration Techniques, International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Vol. 2, Issue. 1, pp1-5

16. P. Makhnatch, A. Mota-Babiloni, J. Rogstam, and R. Khodabandeh, Int. J. Refrig. 76, 184 (2017).

17. L. Vaitkus and V. Dagilis, Int. J. Refrig. 76, 160 (2017).

18. P. Fernando, B. Palm, P. Lundqvist, and E. Granryd, Exp. Heat Transf. 20, 57 (2007).

19. A. Ergün, A.E. GÜREL, and İ. CEYLAN, Gazi Üniversitesi Fen Bilim. Derg. Part C Tasarım ve Teknol. 6, 824 (2018).