Comparative Analysis of Different sections of Evaporator Tubes in Domestic Refrigerator.

Dr. Chavali Shriramshastri[1]; Dr. Ramesh K Rathod[2]; Dr. Sham H Mankar[3]; Prof. Pravin Ingle[4]

[1] DY Patil University, Talegaon Dabhade,Ambi Pune. India. csrshastrijee@gmail.com
[2] Pimpri Chinchwad College of Engg & Research, Ravet, Pune. India. ramesh.rathod@pccoer.in
[3] Pimpri Chinchwad College of Engg & Research, Ravet, Pune. India. sham.mankar@pccoer.in
[4] Dr. D Y Patil Institute of Technology, Pimpri, Pune. India. pravin.ingle2013@gmail.com

Abstract: The Present paper aims to improve existing design of the evaporator tubes of the conventional domestic refrigerator. Conventional vapour compression refrigerator system (VCRS) uses circular cross-section of the evaporator tubes to form the evaporator coil of the refrigerator. In the present work alternate design of the evaporator tube where in the cross-section of tube is varied form namely Plain (round) , Round with V-shape notch, Round with Square shape notch and Round with U-shape notch profiles are studied and coefficient of performance of refrigerator is experimentally investigated. An experimental result are analyzed and shows that the coefficient of performance (CoP) of evaporator coil having V-notch and U- notch is higher than the CoP of the plain and having square shape notch. Also; from experimental investigations, it is found out that the maximum CoP achieved by the plain tube coil is 1.71 and by U- notched evaporator profile it is 1.98. Hence, we can conclude that evaporator with U-notched evaporator coil is most effective and has scope for better heat transfer rate.

Keywords: Domestic refrigerator; Notches; Evaporator; Coefficient of Performance.

INTRODUCTION

Domestic refrigerators are in use already more than 100 years and are extensively used to store foods which deteriorate at ambient temperatures. Generally, the refrigerator consists of a thermally insulated cabin and a heat pump (mechanical, electronic or chemical) that transfers heat from the inside of the refrigerator to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. The refrigerant absorbs heat by evaporating at low temperature and pressure and remove heat by condensing at a higher temperature and pressure. The refrigerator is an essential domestic appliance product, among the home appliances used today refrigerator is one of the most energy consuming device. It involves high energy consumption, and environmental detoriation. The majority of these refrigerators works on vapour compression cycle. Due to the development of refrigeration, the food industry expanded rapidly, though it has used the same technology for more than hundred years. It is estimated that more than 40% of food produced worldwide would spoil, if refrigeration is not used. Currently more than 1 billion domestic refrigerators are in use worldwide. In developed countries, the vapour compression systems utilizes around 30% of the total energy consumed and some malfunctioning events occurs in the system this percentage may even increase. Hence there is need of efficient equipment's which will have low energy consumption and a prolonged useful life..

LITERATURE REVIEW

Todrov et.al. developed table top refrigerator evaporator, based on virtual prototyping. Four different geometries of serpentine curves were examined and axis was changed. The CFD models were developed containing more than 3400000 elements and 800000 nodes. Sushma Garad et.al. [2] studied numerical analysis of square notched twisted tape inserts in a tube by varying pitch with air as working fluid. Reynolds number was varied from 35000 to 45000. It was found that the heat transfer enhancement of square notched twisted tape double slot is about 19.57%, 44.31% and 75.59% for 150 mm, 125mm and 100mm pitch as compared with plane tube respectively. Bodius Salam et.al [3] experimentally investigated measurement of tube-side heat transfer coefficient, friction factor and heat transfer enhancement. Uniform heat flux condition was created by wrapping nichrome wire around the test section and fiber glass over the wire. Reynolds numbers were varied in the range 10000-19000 with heat flux variation 14 to 22 kW/m^2 for smooth tube and 23 to 40 kW/m^2 for tube with insert. David J. Kukulla et.al. [4] studied development of enhanced heat transfer through tubes. Heat transfer of the non textured stainless steel tubes were compared with the rigidized textured enhanced tubes. Tests were conducted in a parallel flow and counter flow arrangements. Also; rigidized enhanced tube configurations, were studied here over a wide range of temperature, flow and fouling conditions. The enhanced tubes were produced under ASTM/ASME 249 standards and are produced using various alloys. The increased heat transfer at low flow rates provides exciting advancement in tube design. The rigidized surface enhances heat transfer and minimizes cost and saves energy. The 2EHT series of enhanced tubes shows the results as given: 2EHT1, 2EHT2, 2EHT3, 2EHT4, increases the heat transfer by 117%, 138%, 106%, 123% respectively. P. Murugesan et.al., [5] Studied heat transfer and friction factor characteristics of circular tube fitted with plain twisted tapes (PTT) and U–cut twisted tapes (UTT) with twist ratios y = 2.0, 4.4 and 6.0 experimentally. The experimental results reveal that heat transfer rate, friction factor and thermal enhancement factor in the tube equipped with UTT significantly higher than those in the tube fitted with PTT and plain tube. At the same Reynolds number, the thermal enhancement factors for UTT are found to be greater than those for the PTT. With the use of PTTs, thermal enhancement factors were in a range between, 1.12 - 1.2, 1.03 -1.10 and 1.0 - 1.06 respectively for the twist ratios y = 2.0, 4.4 and 6.0. On the other hand the use of UTTs offered thermal enhancement factors in a range between 1.19 - 1.28, 1.07 - 1.16 and 1.03 - 1.11 respectively for the twist ratios y = 2.0, 4.4 and 6.0. S.Tabatabaeikiaet.al.,[6] studied heat transfer enhancement in heat exchangers by using different kinds of inserts and modifying heat exchangers tubes. It is found that increasing of inclined angle from 10 to 30 can increase heat transfer performance by 5 to 11%. V-cut twisted tape provided better heat transfer by around 10% compared to plane twisted tube at the same condition.

M. Khoshvaghat-Aliabadi et.al. [7] carried out comparative 3D analysis of thermal hydraulic performance on curved tubes viz. helical, spiral and serpentine with different geometrical parameters. The result shows that at the same geometrical and operating conditions the helical tube has better performance compare to the other ones. The geometrical parameters at the lower values display better performance in comparisons with higher ones.

U. Arunachalam et.al [8] carried out experimental study on flows in straight circular tube with and without V-cut twisted tape inserts using Al_2O_3-cu/water hybrid nanofluids as working fluid. Heat transfer coefficient for (0.01% cu+ 0.4% Alumina)- water hybrid nanofluid is 25.8% higher than that of water & with tape inserts it is 42% higher than that of water in plane tube.

EXPERIMENTAL SET-UP

Experiments were conducted on a Vapor Compression Cycle test rig. The experimental refrigeration cycle test rig consist of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand. The evaporator coils were modified by providing V- notch, U-notch and Square notch. The evaporator coil was manufactured from 6.34 mm copper pipe. The sections of modified coil are as shown in Fig.2, Fig.3 and Fig.4.

Fig. 1. Modified Evaporator coil with V- notch.

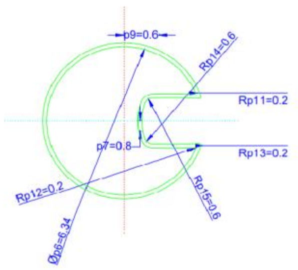

Fig. 2. Geometry with square-notch.

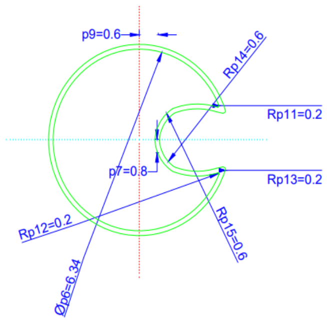

Fig. 3. Geometry with U-notch.

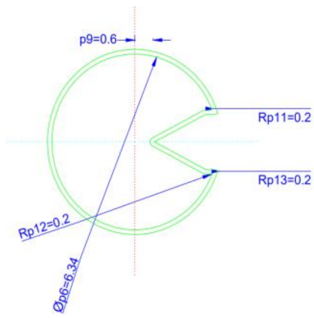

Fig. 4. Geometry with V- notch.

Fig. 5 Experimental Set-up.

Results

[A]. Evaporator with plain tube evaporator coil

Fig. 6 In this study, the Coefficient of Performance of modified evaporator coil has been experimentally investigated. First the experiment was carried out on plain tube evaporator. The diameter of coil of evaporator tube was 6.34mm. The CoP of system initially increases upto 1.81 and then, it is observed that it remains almost constant after 36 minutes of operation. The maximum CoP of the system with evaporator having plain coil is 1.71.

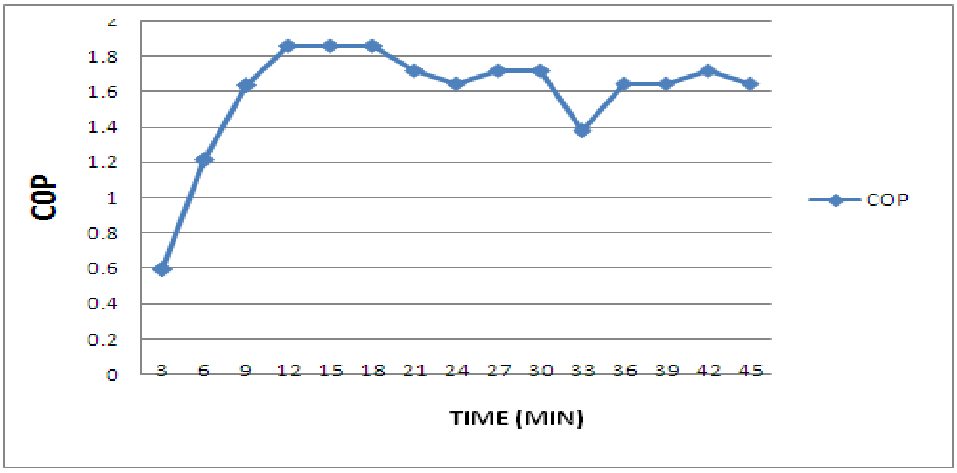

Fig.6. CoP Vs Time, for Evaporator without enhancement

[B]. Evaporator with square notched evaporator coil

Fig. 7 The test conducted on evaporator coil with square-notch, the graph shows the variation of CoP against time .The CoP of the setup increases steadily. The CoP of system initially increases and it is observed that it is stable after 30 minutes. The average CoP achieved by the system is 1.58 and it is less than plain tube evaporator. Hence, we can conclude that the square notched profile of evaporator tube reduces the CoP. of the system.

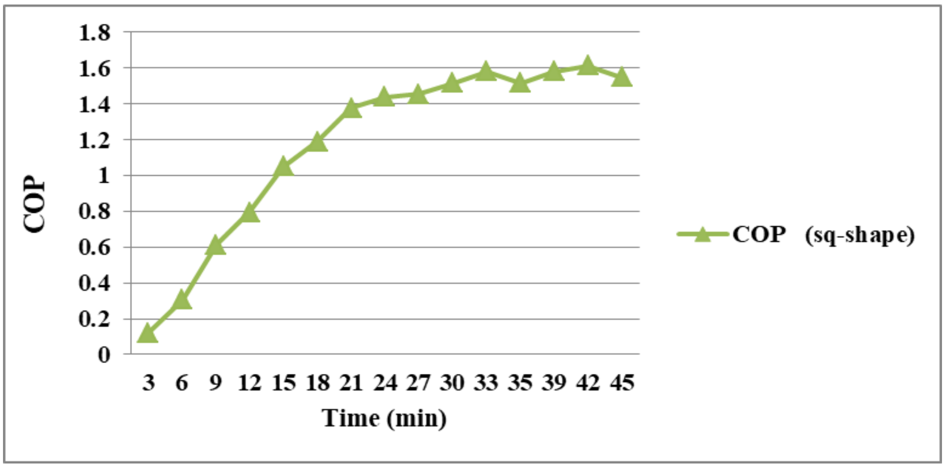

Fig.7. COP Vs Time, for Evaporator with square notched profile

[C]. Evaporator with V-notched evaporator coil

Fig. 8 shows the variation of CoP against time for the VC model with evaporator tube with V- shape notch. The CoP of the setup increases steadily. The CoP of system initially increases and it is observed that it is stable after 30 minutes. The average CoP achieved by the system is 1.88 and it is more than plain tube evaporator.

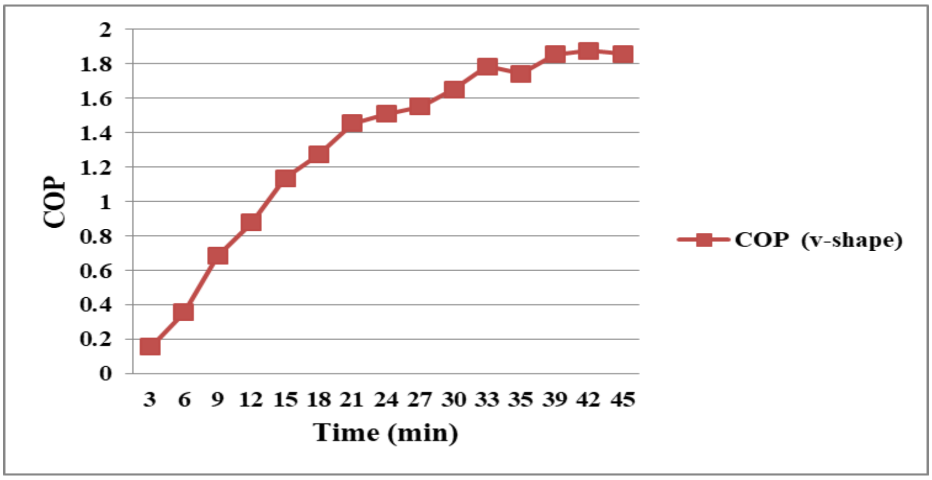

Fig.8. CoP VS Time for evaporator with V- notched profile

[D]. Evaporator with U-notched evaporator coil

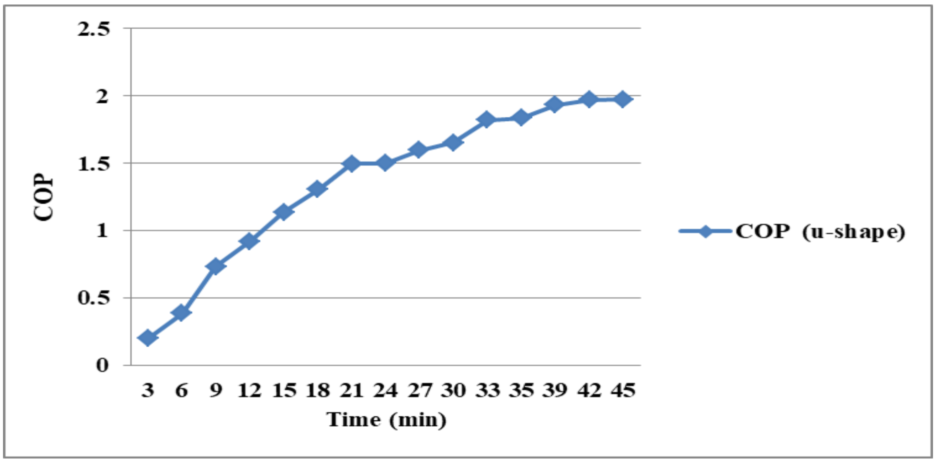

Fig.9. CoP VS Time for evaporator with U- notched profile

Fig. 9 shows the variation of CoP against time for the VC model with evaporator tube with U- shape notch. The CoP of the setup increases steadily. The CoP of system initially increases and it is seen to be stable after 30 minutes. The maximum CoP achieved by the system is 1.98 and it is more than plain tube evaporator, square notched tube evaporator and V- notched tube evaporator. Hence, the U- notched profile is proved to be most effective by experimental method.

[E]. Comparison of Performance of modified profiles

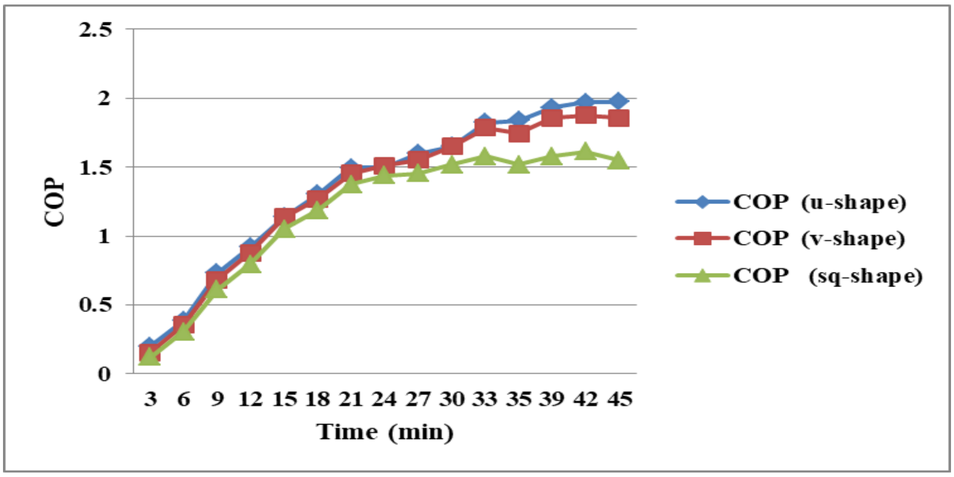

Fig.10. CoP Vs Time for Evaporator modified profiles.

Fig. 10 shows that the Coefficient of Performance for plain, U-notched, V-notched and square notched evaporator profile. It is clear from the graph that CoP. of square notched profile is minimum over the entire range and CoP. of U-notched profile compressor is maximum. Hence, the U-notched profile is most efficient out of the three evaporator profiles.

CONCLUSION

The validation has been carried out using Ansys 16.0 software. The input temperature applied to the coil is 0°C by considering convective heat transfer coefficient as 340 W/mm^2. The maximum energy dissipated is 53.22 W/mm^2 by the plain coil. The maximum energy dissipated is 56.431 w/mm^2 by the square notched coil. The maximum energy dissipated is 59.66W/mm^2 by the V-notched coil. The maximum energy dissipated is 63.86 W/mm^2 by U-notched coil.

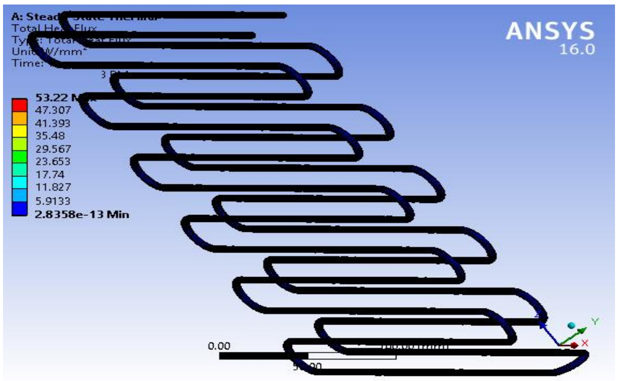

Fig. 11. Output of steady state thermal heat transfer for Plain tube evaporator coil.

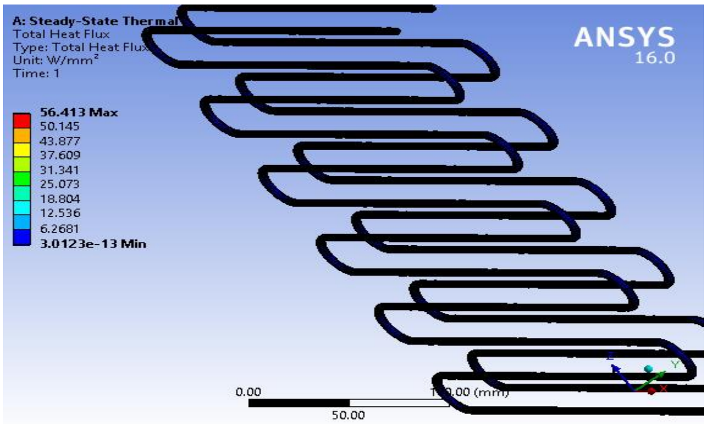

Fig.12. Output of steady state thermal heat transfer for Square notched tube evaporator coil.

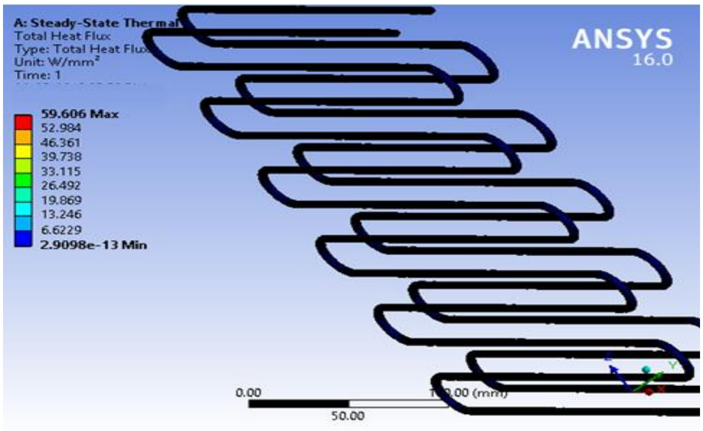

Fig.13. Output of steady state thermal heat transfer for V-notched tube evaporator coil.

An experimental result are analyzed and shows that the coefficient of performance (CoP) of evaporator coil having V-notch and U- notch is higher than the CoP of the plain and having square shape notch. Also; from experimental investigations, it is found out that the maximum CoP achieved by the plain tube coil is 1.71 and by U- notched evaporator profile it is 1.98. Hence, we can conclude that evaporator with U-notched evaporator coil is most effective and has scope for better heat transfer rate.

REFERENCES

[1] GeorgiTodorov, “Thermal CFD study and improvement of table top fridge evaporator by virtual prototyping” .Case studies in Thermal Engineering 10 (2017)434-442.

[2] Sushama Garad, R.D.Shelke and H.N.Deshpande “Numerical Analysis of square Notched Twisted Tape Inserts in A Tube”.American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN : 2320-0936 Volume-6, Issue-6, pp-251-261.

[3] Bodius Salam,Sumana Biswas, Shuvra Saha, Muhammad Mostafa K Bhuiya “Heat transfer enhancement in a tube using rectangular-cut twisted tape insert”. Procedia Engineering 56 (2013) 96 – 103.I. S.

[4] David Kukulka. “Development of enhanced heat transfer tubes” .Chemical engineering transactions, 21, 985-990.

[5] P. Murugesan , K. Mayilsamy, S. Suresh “Heat Transfer and Friction Factor in a Tube Equipped with U-cut Twisted Tape Insert”. Volume 5, Number 6, Dec. 2011 ISSN 1995-6665 Pages 559 – 565.

[6] S. Tabatabaeikia, H. A. Mohammed, N. Nik-Ghazali, and B. Shahizare “Heat Transfer Enhancement by Using Different Types of Inserts”. Advances in Mechanical Engineering Volume 2014, Article ID 250354, 13 pages.

[7] M. Khoshvaghat-Aliabadi“Comparative analysis on thermal hydraulic performance of curved tubes: Different geometrical parameters and working fluids”. Energy 91 (2015) 588-600.

[8] U. Arunachalam& M. Edwin “Experimental studies on laminar flow heat transfer in nanofluids flowing through a straight circular tube with and without V-cut twisted tape insert”. Heat Mass Transfer DOI 10.1007/s00231-017-2162-9.