Kufa Journal of Engineering
Vol. 16, No. 4, October 2025, P.P. 179-190
Article history: Received 14 October 2024, last revised 26 December 2024, accepted 8 January 2025

AN EXPERIMENTAL STUDY TO COMPARE VERTICALLY HELICAL COIL RADIATORS AND STRAIGHT TUBE RADIATORS PERFORMANCE IN VEHICLE COOLING SYSTEM

Kareem Jafar Alwan [1], Radhwan A. Flayyih[2], Mohammed K. Khashan[3], Nawfel Muhammed Baqer Muhsin[4], and Muna S. Kassim[5]

[1] Najaf Technical Institute, Al-Furat Al-Awsat Technical University 31001 Al-Najaf, Iraq, Department of Power Mechanical Techniques, Email:karimjaefar@atu.edu.iq.

[2] Najaf Technical Institute, Al-Furat Al-Awsat Technical University 31001 Al-Najaf, Iraq, Department of Power Mechanical Techniques, Email:radhwan.abaas.inj@atu.edu.iq

[3] Najaf Technical Institute, Al-Furat Al-Awsat Technical University 31001 Al-Najaf, Iraq, Department of Aeronautical Technologies, Email:dr.khshan@atu.edu.iq.

[4] Najaf Technical Institute, Al-Furat Al-Awsat Technical University 31001 Al-Najaf, Iraq, Department of Aeronautical Technologies, Email:nawfel.muhammed@atu.edu.iq.

[5] Email: munasaljabri@gmail.com.

https://doi.org/10.30572/2018/KJE/160410

ABSTRACT

Heat exchangers are managed in numerous topics like motorized, training, turbine, energy plants, and water managements. A radiator is a heat exchanger of that category, when the air emerges surrounding the circle of the finned frames, and cools the fluid which requirement be abated. A small variation has been presented on the radiator intention to make it more effective, where the recent creation is a helical tube radiator lesser than the fin and tube air cooled radiator commonly applied today, and outstandingly in vehicles. The detached of this investigate is to measure the implementation distinction relating the function of a helically coiled heat exchanger to that of consecutive tube heat exchanger. From the upstairs it is assumed that heat transfer in helical spherical tubes are superior than in the perpendicular tubes due to the helical characteristics of the tubes. This explains why on the outer side of the pipe fluid moves slightly faster than on the inner side, this is commonly referred to as the curvature effect. Hydro experimental proves to reveal the manner, in which the effective thermal performance of helical coil radiator depends on the value of the water flow rates. The analysis was executed via the evidence records with WIT = 60 °C, AIT = 20 °C, and WFV extending from 0. 5 to 5 gallons per minute (gpm) Stylish and Modern. As of the overhead extension, it can be assumed that for The Vertically Helical Coil radiator, the relating fluctuation of the water instrument heat enhances with stream speed is minor than that of Stretch Tube Radiators. This indicates that Vertically Helical Coil radiator might have a greater heat transfer property as contrasted to the flat tube at shorter flow rates.

KEYWORDS

Helical coil, Plain tube, Vehicle Chilling Routines, Advanced, WFV.

1. INTRODUCTION

Lately numerous forms of heat exchanger edifices have been designed with the intend to enhance the ratio of heat transfer, and at the matching time to interest the least distance feasible. There is a characteristic model in which the solutions are in circles. Further, spiral heat exchangers are relatively small and take less extent of gap than the other enters. They also initiate lessen pressure reductions and excluding siphoning energy for the equivalent capacity since of the 'spiral' purpose method that offsets the self-scrubbing plunge by concluding the draggle force in fouled coats and scrapes sludge.

(Gopisetti et al., 2017) advertised heat transfer inquiries with esteems to spiral radiators and decided that the remarked incremental hotness were much advanced evaluated with numerous radiator classifications for water at 80°C. Althăr, Alhassan Salami Tijani et al. (Hasan, Ahmed and Bhuiyan, 2022) narrated that CuO nanofluid afforded improved heat transfer quantity judged to Al2O3 nanofluid that strengthen in heat transfer constant was more conspicuous at 0. 3 % and maximum visage flow stretching of 6L/min. Srbislav B et al. (Al-Dawody, Hamzah and Al-Mensory, 2018) reviewed the fouling influence in the borough heating heat exchangers with latitude helical tube coils; the strategy equivalence of the shell plane heat transfer coefficient and fouling consideration for district heating systems. Kong et al. (R and Ramsai, 2012) examined the heat transfer characteristic of a helical coiled heat exchanger for waste heat utilization from the combustion stack gases with deionized water. Performing their analysis, they found out that the coil pitch had a negligible effect on the overall heat transfer coefficient but concluded that a small coil diameter was optimal particularly when the water Reynolds number was below 3500. Bidabadi et al. (Gokulnathan et al., 2020) proposed the new design approach of spiral heat exchangers by means of the GA. This as an optimization technique assisted in identifying geometrical parameters that can effectively reduce pressure drop and at the same time enhance heat transfer rates. Pramod Purandare (Nilay, Gupta and Bagri, 2017) pointed out that The helical coils are suitable for the low reynolds number. Moreover, it is desirable to have a sufficiently large ratio of tube diameter to coil diameter so that high intensities of secondary fluid circulating inside the tubes could be achieved. Rahul Karath , et al. (Ningsih et al., 2022) In a study meant to enhance certain correlations in heat transfer in streams between concentric helical coils it was ascertained that the heat transfer of the coefficient distinctly depended on the gap between the concentric coils as much as the experimental result data indicated that an increase in the gap influences the coefficient of heat transfer. According to Mohammed Abu El Azm et al. (Missaoui et al., 2022) works on the modification of heat transfer effects, it is revealed that the taper angle of helical coils influences the heat transfer characteristics and the helical pitch also has an effect. (Siddique Ahmed Ghias et al., 2016) reported on the attempts to improve heat transfer coefficients of air flow through circular tubes with the help of partially decayed and swirling flows. The investigation concerning the heat transfer and flow parameters of the helical coiled tubes has been made to improve them for different coil pitches. Heat exchangers with conjugate heat transfer were investigated where three-dimensional flow through helical coiled tubes were considered to tackle anisotrophic characteristics that stems from turbulence and flow irregularities. (Karanth and others, 2013) Experimentations like the use of nanofluids like Alumina/water, CuO/water show a substantial increase than water as a coolant only. Thus, higher nanoparticle concentrations lead to higher rates of heat transfer but, at the same time, to an increase in the friction value. Heat dissipation characteristics of CuO/water nano-fluid was better than other tested mixtures represented by the highest heat dissipation rate. The percentage heat transfer enhancement achieved by adding 3% nanoparticles in the base fluid Al2O3/water was 37% and that, in the case of CuO/water was 53%. In a similar work by (Jabbar, Hachim and Alwan, 2023), Comparative analyses with diverse fluids which included ethanol, methanol and Al2O3/water at different concentrations as well as CuO/water as the coolant showed that CuO/water had recorded the highest outlet temperature of 355. K 38 C ethanol giving the least yield of 336. <|reserved_special_token_271|>, 91K in helical tube radiators. The presence of these results implies that ethanol with water has the best performance (Al-Araji, Almoussawi and Alwana, 2021). In the previous researches done between elliptical and helical tube radiators the results pointed out the better performance in the maximum temperature drop rate, high heat dissipating rate, compactness and high heat transfer coefficient for the helical tube radiators (Zheng et al., 2016).

This paper presents the experimental study to compare vertically helical coil radiators and straight tube radiators in vehicle cooling system. The primary goal was to enhance heat convection compared to traditional radiators. Additionally, it aimed to provide reliable mounting options, be visually appealing, and remain cost-effective. The design successfully achieved improved heat convection by exposing a larger surface area to the air

2. EXPERIMENTAL PROCEDURE

2.1. .Manufacturing of the Vertical Helical Tube Radiator

The Vertical Helical Tube Radiator was made by 4 turns of Helical Coils by using copper tubes with internal diameter of 10mm and total tube length of 2000mm While each coil made of 12 turns, turn diameter-120mm, and turn pitch-50mm Several fins were welded on the tube walls.

Every two of the helical coil contains another helical coil that is made of copper tubes with inner diameter of 6 mm and total length of 1500 mm The secondary coil has the turns of 13, the diameter per turn is 80 mm and the pitch is 50 mm as shown below; Fig.1.

Fig .1. Vertical Helical Tube Radiator

2.2. Selection of the Straight Tube Radiator

A straight tube radiator depicted in the figure below; Fig. 2 It was done to make sure the coolant capacity of the manufactured vertical helical tube radiator and the standard existed to provide a basis for comparison.

Fig .1. Straight Tube Radiator

2.3. Connecting the vertically helical coil radiators and straight tube radiators and Measurement Methods

The two heat exchangers were coupled with a closed-cycle coolant circulation system comprising of a coolant pump, an exhaust fan, a coolant chamber comprising of water, the heater, coolant input pipe from the chamber to the pump, the input pipe from the heat exchanger, and the output pipe also from the heat exchanger back to the chamber. Since the main cause of deterioration was deemed to be thermal, a string of thermocouples was deployed to monitor the temperature of the coolant in the tank, at the outset of the heat exchanger and at the output of the coolant after passing through the heat exchanger, as depicted in Fig. 3.

The results were obtained from tests with a saturation temperature at the water inlet of 60°C, incoming air temperature of 20°C, and from ten seasons of flow rates of 0.

Fig.3. Connecting the vertically helical coil radiators and straight tube radiators

Table 1 is the tabulation of the data acquired from the experiment on Vertically Helical Coil and Table 2 is the tabulation of the data acquired from experiment on Straight Tube Radiator. These are the tabulations of the pre and post heat exchanger air temperatures, the coolant temperature in the system tank and at the inlets, and the outlet of the heat exchanger.

Table .1. Vertically Helical Coil radiator

Flow rate / gpm	water-in Temp.	water out Temp.	Air-in Temp.	Air-out Temp.	Tank Temp.	Δp /mm
0.5	57.6	52	20	23	60	355
1	59	53	21	24	62	350
2	60	55	21	26	60.7	320
3	60	56	20	27	60.2	260
4	67.5	64.4	19	26	67	200
5	66	64	20	28	66	150

Table .2. Straight Tube Radiator

Flow rate/ gpm	Temp. water - in	Temp. water out	Temp. Air-in	Temp. Air-out	Temp. Tank	Δp /m m
0.5	56	53	20	22.5	59.5	350
1	57.7	53.7	21	23	59.2	340
2	57.8	54.6	21	24	58.8	320
3	57.3	54.1	20	25.5	57.8	260
4	56.8	54.8	19	24.5	56.8	200
5	56.2	54	20	26	56.2	150

2.4. Ambient Conditions

The paper lacks crucial information regarding ambient conditions such as:

2.4.1. Ambient Temperature

Although the air inlet temperature was stated as 20°C, the overall laboratory or environmental temperature could influence heat transfer rates, especially if the system is open to ambient surroundings.

2.4.2. Humidity Levels

Relative humidity can impact the cooling performance of air-cooled radiators. Higher humidity reduces air's capacity to absorb heat, potentially altering the results. Including ambient temperature and humidity data would strengthen the analysis and provide a more realistic understanding of the radiator's performance under real-world conditions.

2.4.3. Simultaneous Testing Under Similar Conditions

The paper does not explicitly mention whether the experiments for both radiators were conducted simultaneously under identical conditions. However, for a scientifically valid comparison, it is critical to ensure the following:

2.4.4. Identical Water Inlet Temperatures

While the paper states the water inlet temperature was 60°C for both radiators, the actual variability during testing isn't clarified. Consistent inlet temperatures are essential for accurate comparisons.

2.4.5. Same Ambient Conditions

The testing should account for identical air temperatures (stated as 20°C in the paper) and airflow rates during operation.

2.4.6. Flow Rates

Both radiators were tested at identical flow rates ranging from 0.5 to 5 gallons per minute (gpm). To improve clarity and reliability, the experiment should confirm that these conditions were monitored simultaneously, as fluctuations during sequential testing could impact results.

3. RESULTS AND DISCUSSIONS

In order to make a comparative analysis between the Vertically Helical Coil radiator Table 1 and the Straight Tube Radiator Table 2 based on the provided data, in the experimental setup, temperature and pressure measurements were taken at specific locations to evaluate the performance of both the Vertically Helical Coil Radiator and the Straight Tube Radiator:

3.1. Temperature Measurements

3.1.1. Tank Temperature

The coolant temperature in the tank was monitored to assess the overall impact of the radiator system on the coolant storage temperature. The performance of both radiators remains fairly close in terms of the tank temperatures, which are between 56. Vertical Coil range from 2 o C to 67 o C for the Vertically Helical Coil radiator and 56. 2°C to 59. No change from base case for the Straight Tube Radiator temperature, 5°C for the Cross Flow Cooler. This indicates a small fluctuation in how these radiators impact on the temperature of the surrounding tank.

3.1.2. Water Inlet and Outlet Temperature

Thermocouples were installed at the inlet and outlet of the heat exchangers to measure the temperature difference of the water before and after passing through the radiator. This difference is crucial to determining the radiator's heat transfer efficiency.

3.1.3. Air Temperature

Thermocouples measured the air temperature before entering and after leaving the radiator to assess how much heat the air absorbed from the coolant. It has been observed that the Vertically Helical Coil radiator mainly works at a relatively higher temperature of supplying air compared to the Straight Tube Radiator case. This may be hinting towards a probably higher heat transfer coefficient for the Vertically Helical Coil radiator from water to air.

3.1.4. Flow Rate vs. Water Temperatures

The increase in the form of water difference between the outlet and inlet temperature shows that the Vertically Helical Coil radiator indicates a significantly higher rise with the flow rate tending to decrease, than the Straight Tube Radiator. This indicates that the Vertically Helical Coil radiator could provide a better heat transfer compared to the Straight Tube Radiator when the flow rate is low.

3.2. Pressure Measurements:

3.2.1. Pressure Drop (ΔP)

Pressure was measured across the heat exchanger to calculate the drop caused by the coolant flowing through the system. This helps in determining the flow resistance of each radiator design. The experimental apparatus consisted of a closed-loop cooling system with a pump, heater, fan, water tank, and connecting pipes, allowing controlled and precise measurements. As in the case with pressure drop, both radiators exhibit fairly similar behavior as the flow rate increases. Again, in the pressure drop, the Vertically Helical Coil radiator is likely to have a slightly higher drop than in the Straight Tube Radiator at different flow rates.

3.3. Heat Transfer Efficiency

From the above results, therefore, the following conclusions can be made: Water outlet temperature of Vertically Helical Coil radiator rises as the flow rate increases and it fluctuates as compared to that of Straight Tube Radiator. This may infer that the Vertically Helical Coil radiator with a lower flow rate of water could do a better heat transfer.

3.4. Practical Considerations

Based on the heat transfer rate characteristics and the pressure drop across the tube bank, engineers must choose between Vertically Helical Coil and Straight Tube Radiators; this is if certain conditions, such as heat transfer efficiency, pressure drop, and space limitations, are met. The one to be preferred would therefore lie in considering the factors above to the best realization of the radiator in the intended use.

The comparative of the outlet and inlet temperatures between vertically helical coil radiators and straight tube radiators is indicated in the Fig.4 below.

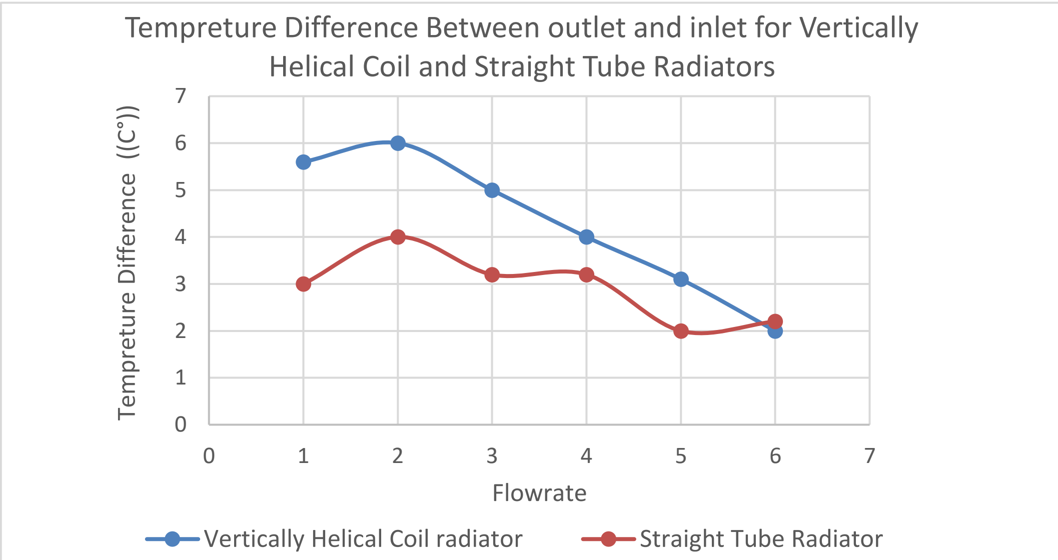

Fig.4 comparative between outlet and inlet temperatures for vertically helical coil radiators and straight tube radiators.

3.5. Temperature Difference Trends:

Vertically Helical Coil Radiator: Thus as the flow rate rises from 4 to 8C/ min or Fahrenheit from 40. Detection also reveals that at higher flow rates, the radiator has lower effectiveness of transferring heat from water to air. Straight Tube Radiator: In the same manner, the variation in temperature reduces as the flow rate increases having almost the same pattern as that of the helical coil radiator.

3.6. Comparison: Practical Similarities in the Heat Exchangers

To ensure a fair comparison between the Vertically Helical Coil and Straight Tube Radiators, certain parameters were standardized:

3.6.1. Coolant Volume Capacity

Both radiators were designed to handle the same coolant capacity to ensure identical fluid volumes for heat exchange.

3.6.2. Surface Area and Pipe Dimensions

The helical coil radiator was made of copper tubes with an inner diameter of 10 mm (primary coil) and 6 mm (secondary coil), while the straight tube radiator had a similar pipe diameter. The total tube length in both designs was comparable (2000 mm for the helical coil and an equivalent length for the straight tube radiator), ensuring a similar heat exchange surface area. These standardizations ensured the primary difference in performance arose from the design (straight vs. helical coil), rather than variations in size or capacity.

4. CONCLUSIONS

Comparison: However, at the same flow rate the Vertically Helical Coil Radiator normally has a larger temperature difference between the outlet and the inlet than the Straight Tube Radiator. This led to the conclusion that the Straight Tube Radiator might have better heat transfer capacity per unit of flow than the capacity of the Vertically Helical Coil Radiator. Also The Vertically Helical Coil radiator, the corresponding fluctuation of the water outlet temperature increases with flow rate is lesser than that of Straight Tube Radiators ,and Vertically Helical Coil radiator might have a superior heat transfer characteristic as compared to the flat tube at lower flow rates. The experimental setup and the comparative analysis between the Vertically Helical Coil and Straight Tube Radiators were well-detailed in terms of design and basic measurement parameters. However, the following aspects should be clarified or improved:

1. Provide detailed simultaneous testing conditions, ensuring identical water inlet temperatures, ambient conditions, and airflow during testing.
2. Include ambient temperature and humidity data to better assess the radiators' performance under realistic scenarios.
3. Confirm exact similarities (e.g., pipe diameter, surface area) to further justify the fairness of the comparison.

These additions would address the current gaps in the study and ensure a more robust evaluation.

5. REFERENCES

Al-Araji, K.M., Almoussawi, M.A. and Alwana, K.J. (2021) ‘The Heat Transfer Performance of MWCNT, CuO, and Al2O3 Nanofluids in an Automotive Engine Radiator’, E3S Web of Conferences, 286. doi:10.1051/e3sconf/202128601009.

Al-Dawody, M.F., Hamzah, D.A. and Al-Mensory, M.F. (2018) ‘Experimental and CFD analysis of heat transfer in a double pipe helical coil heat exchanger’, International Journal of

Mechanical and Production Engineering Research and Development, 8(4), pp. 959–968. doi:10.24247/ijmperdaug2018103.

Gokulnathan, E. et al. (2020) 'Review of heat transfer enhancement on helical coil heat exchanger by additive passive method', Materials Today: Proceedings, 37(Part 2), pp. 3024–3027. doi:10.1016/j.matpr.2020.08.725.

Gopisetti, N. et al. (2017) 'EFFECT OF PITCH NUMBER IN OVERALL HEAT TRANSFER RATE IN DOUBLE PIPE HELICAL HEAT EXCHANGER Heat transfer enhancement using nanoparticles View project EFFECT OF PITCH NUMBER IN OVERALL HEAT TRANSFER RATE IN DOUBLE PIPE HELICAL HEAT EXCHANGER', (December). Available at: https://www.researchgate.net/publication/322103833.

Hasan, M.J., Ahmed, S.F. and Bhuiyan, A.A. (2022) 'Geometrical and coil revolution effects on the performance enhancement of a helical heat exchanger using nanofluids', Case Studies in Thermal Engineering, 35(May), p. 102106. doi:10.1016/j.csite.2022.102106.

Jabbar, H.A., Hachim, D.M. and Alwan, K.J. (2023) 'Heat transfer fluids in parabolic trough collector (PTC): A review study', AIP Conference Proceedings, 2776, pp. 1–14. doi:10.1063/5.0135997.

Karanth, V.K. and others (2013) 'Numerical Analysis of a Helical Coiled Heat Exchanger using CFD', International Journal of Thermal Technologies, 3(4), pp. 126–130.

Missaoui, S. et al. (2022) 'Effects of pipe turns on vertical helically coiled tube heat exchangers for water heating in a household refrigerator', International Journal of Air-Conditioning and Refrigeration, 30(1). doi:10.1007/s44189-022-00005-5.

Nilay, A., Gupta, V. and Bagri, S. (2017) 'Performance Analysis of Helical Coil Heat Exchanger Using Numerical Technique', 5(3), pp. 152–156.

Ningsih, E. et al. (2022) 'Performance Simulation on the Shell and Tube of Heat Exchanger By Aspen Hysys V.10', Jurnal Rekayasa Mesin, 13(3), pp. 701–706. doi:10.21776/jrm.v13i3.1078.

R, T.K.R. and Ramsai, R. (2012) 'Numerical study of fluid flow and effect of inlet pipe angle In catalytic converter using CFD', 1(7), pp. 39–44.

Siddique Ahmed Ghias, A. et al. (2016) 'Experimental Study of Thermal Performance of Coil in Shell Heat Exchanger', Indian Journal of Science and Technology, 9(13). doi:10.17485/ijst/2016/v9i13/90571.

Zheng, W. et al. (2016) ‘Numerical and experimental investigation of a helical coil heat exchanger for seawater-source heat pump in cold region’, International Journal of Heat and Mass Transfer, 96, pp. 1–10. doi:10.1016/j.ijheatmasstransfer.2016.01.022.