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Research Article

Design And Analysis Of Fin And Tube HeatExchanger

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ABSTRACT

This research delves into the complexprocess of constructing and analysing a fin and tube heat exchanger while taking conjugate heat transfer into account. Broad heat exchangers are used in a wide range of industrial applications, thus it is crucial to make sure their design is optimised for optimal thermal performance. This study examines the intricate details of heat transport and the interactions between fluids and solids inside the heatexchanger using advanced computational fluid dynamics (CFD) models. The subtleties of fluid flow, material qualities,and important design elements are investigated in order to improve heat exchanger efficiency.

The researcher's conclusions are highlighted, highlighting the crucial function of fin and tube heat exchangers in systems like HVAC and refrigeration systems, and various industrial processes

Keywords—:Fins, Heat Analysis, Methods, Modelling, fin tube heat exchanger, conjugate heat transfer

I. INTRODUCTION

For the electric motor and motor controller of an electric car to operate effectively and last a long time, the radiator cooling system is essential. The goal of this system is to control and monitor the temperature of these crucial parts in order to keep them from overheating while in operation. An EV's electric motor, which receives power from the motor controller, is the engine of the propulsion system. These parts have the capacity to produce a great deal of heat when they are operating, which could cause serious damage and reduced efficiency if it is not controlled. Similar to other internal combustion engine vehicles, the radiator cooling system uses a coolant fluid and a network of cooling pipes to dissipate heat. This is achieved by conduction and convection, which remove extra heat from the motor and
controller. in charge. In order to help maintain ideal operating temperatures, a radiator cooling system usually consists of a heat exchanger (radiator), fans, and a pump that circulates coolant.

Heat exchangers are vital parts of many businesses and are crucial for controlling thermal processes and energy conservation. Fin and tube heat exchangers have gained the most attention among these, their adaptability and efficiency in transporting heat between fluids have drawn attention. With a particular emphasis on conjugate heat transfer, this research undertakes a comprehensive investigation into the design and analysis of a fin and tubeheat exchanger. This project is important because heat exchangers are used in power production, HVAC systems,refrigeration, and chemical processes, among other applications.

This study is to contribute to more effective and sustainable thermal management solutions by enhancing the design and performance of fin and tube heat exchangers.

A multidisciplinary approach is necessary in the field of heat exchangers due to the intricate interaction between fluid dynamics, heat transmission, and solid construction. Conjugate heat transfer analysis is essential for a thoroughunderstanding of the thermal behaviour inside the heat exchanger since it takes into account both the fluid and solid domains. High-performance heat exchangers are becoming more and more necessary as environmental and financial concerns drive a greater emphasis on energy efficiency. In order to satisfy these requirements, this study not only designs an ideal fin and tube heat exchanger but also thoroughly investigates the properties of heat transfer and the complex thermal connection between the solid constituents and the fluid streams. By these efforts, this research advances the field of heat exchanger technology and broadens its uses in many industrial and environmental settings.

II. LITERATURE REVIEW

The research work under consideration represents a significant advancement in the field of thermal engineering as it presents the Tube Element Method (TEM) as a novel approach to the complex problem of uneven airflow in fin-and-tube heat exchangers. These heat exchangers are essential components in many different industrial applications, and airflow distribution across their fin surfaces has a big impact on how well theyfunction. The study's authors are aware of the shortcomings of the current computation methods in handling with nonuniformity of airflow and proposed TEM as a potential remedy. Using tests using a three-row heat exchanger outfitted with seven flow circuits, they successfully validate TEM and demonstrate its ability to predict thermal performance in difficult fluid flow topologies. The investigation's main finding is that airflownonuniformity has a negative impact on heat exchanger efficiency. The study highlights the non-uniformity of thisefficiency loss and its dependence on multiple variables, including the quantity of heat transfer units (NTU), the heat capacity rate ratio (C*), and the particular fluid flow circuitry utilised in the heat exchanger. The TEM method presented in this study proves to be a very useful tool for thermal design and assessment, especially when dealing with the real-world challenges of fin-and-tube heatexchangers operating in nonuniform airflow settings. Thisapproach could completely change the way that heat exchanger design and optimisation panorama, guaranteeing their efficacy and efficiency even in the face of complex airflow conditions. It will therefore be advantageous to numerous companies that depend on these essential heat exchange systems.[1]

The reviewed study offers a thorough experimental investigation of the features of heat transfer and the thermal stresses that fin-and-tube heat exchangers experience. Its main goal is to assess how different fluid mass flow rates impact heat transfer efficiency. Apart from the actual study, the authors employ ANSYS software to perform an exhaustive examination of the thermal stresses that arise in the fins and tubes, specifically when adjusting the fins' width and the tubes' diameter. In order to get experimental data, fluid mass flow rates must be systematically adjusted while maintaining a given temperature. The results of these experiments are then contrasted with theoretical forecasts.The main conclusions of this study highlight a clear relationship between the thermal stresses that arise and thediameter of the tubes and the fin width. More specifically,the research shows that higher fin and tube diameters lead to higher thermal stresses in the fins and tubes. Moreover, it indicates that the valve controlling fluid flow is fully open when the maximum levels of thermal stresses appear. By clarifying how different operating conditions and geometric characteristics affect heat transfer and thermal stress, this research significantly advances the field of heat exchanger design and performance evaluation. The knowledge gained from this research can be extremely useful in directing the assessment and designof heat exchangers, enabling engineers to enhance their efficiency and reliability across a wide spectrum o applications.[2]

domain of finned tube heat exchanger optimisation; these are often used parts in air conditioning systems. It's The main goal is to reduce pressure drop and increase these heat exchangers' heat transfer efficiency. The addition of more fins to the heat exchanger's design is the main focus of the optimisation procedure. In order to achieve this, the optimisation framework has a volume constraint that allows for the explicit addition of additional fins to increase the heat transfer area. Remarkably, the primary goal still stands to minimise pressure drop, ensuring that adding these additional fins won't negatively impact performance in general. The research methodology verifies the efficacy of the optimised fin structures through numerical methodologies and 3D conjugate heat transfer simulations. The study's results clearly demonstrate the potential of using topologyoptimization as a calculated tactic to increase thermofluid equipment efficiency. As a result, this study provides priceless new information for the development of air conditioning systems and related applications.[3] the development and assessment of fin and tube heat exchangers with air cooling that use R32 and R410A refrigerants. A significant portion of the study was devoted to emphasizing the advantages of R32 over R410A, including lower refrigerant charge requirements and better performance. The testing results clearly showedthat R32 had a higher heat transfer coefficient, especially in the vapour and two-phase stages, indicating that it could be a more effective refrigerant. While it is importantto note that R32 did have a greater pressure drop, its significantly improved heat transfer qualities make it a viable option for a variety of applications. These findings are highly relevant to the optimisation of condenser designs in air conditioning systems, offering insightful information for improving the systems' efficacy and efficiency—a critical consideration in the energy-conscious world of today.[4]

Using ANSYS CFX-11, this comprehensive numerical study investigated the pressure drop and heat transfer behaviours of a four-row fin-and-tube heat exchanger withboth plain and wavy fin structures. The study included tests in both laminar and turbulent flow scenarios, clarifying the various impacts of these different fin shapeson the heat exchanger's functionality. Additionally, the study carefully verified the accuracy and reliability of its numerical results by contrasting them with experimental data.The investigation's conclusions were very instructive.They demonstrated the better performance of wavy fins over plain fins, exhibiting advantageous pressure drop properties combined with enhanced heat transfer characteristics. Additionally, the study highlighted the benefits of an in-line tube layout, emphasising its higher efficiency relative to the staggered setup at particular Reynolds numbers. These findings are highly significantin the field of heat exchanger design. providing essential information that can be applied to a wide range of businesses in order to design heat exchange systems that are more effective and efficient.[5].

III. METHODOLOGY

1. design

Understanding the basics of finned tube heat exchangersis thought to be essential to comprehending how they improve heat transmission. Finned tubes with aluminium fins were selected for this study due to their high heat conductivity (about 237 W/m·K). Finned heat exchangers work on the basic idea of greatly increasing the surface area available for heat transmission. Fins are added to the outside of the tubes to increase the area that may be used for heat exchange, which improves heat transfer efficiency.
In this case, there are several ways that heat is transferred:conduction from the fin to the tube, convection between the air and fin surfaces, and conduction through the fins. The description of heat transmission processes within the fins relies heavily on the heat conduction equation. Aluminium was selected as the fin material due to its exceptional thermal conductivity, which guarantees effective heat conduction.
The fins' geometry is a crucial element that is heavily influenced by design criteria, such as their height, thickness, and spacing, all of which have an effect on the heat exchanger's efficiency of heat transfer.

2. modeling

The first step in the procedure is to choose SolidWorks software and use it to model a fin tube heat exchanger in 3D. The exact proportions and geometry are thought to becrucial. The dimensions chart for the model is shown below:

Tube Diameter (D)	10mm
Fin thickness	0.5mm
Tube Material	Aluminium
Tube Length (L)	260mm
Fin Type	Plain
Fin width(w)	45mm
Fin length	210mm

Fig1.dimensions

Fig2. Inlet pipe

After the materials and proportions are known, the parts are painstakingly put together in the CAD programme. A detailed model is made that closely mimics the real-world arrangement by combining several rows and layers of finned tubes. To improve heat transfer efficiency, a varietyof fin geometries and patterns are taken into consideration, with a preference for louvred fins and staggered patterns. The fluid flow routes are precisely modelled, taking into consideration a parallel flow configuration in which hot fluid is injected at 90°C and cool fluid at 30°C. The analysis of fluid dynamics is madeeasier by this thorough representation, which also enables additional heat transfer efficiency optimisation.

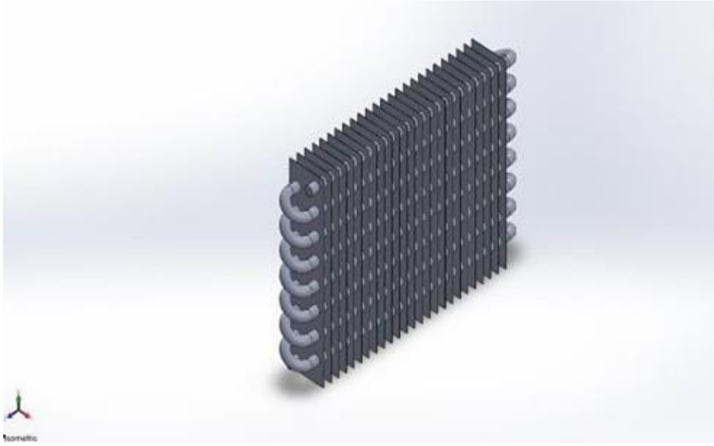

Fig 3. Assembly

3. CFD Analysis

- **Geometry and Meshing:**

ANSYS CHT analyses begin with the definition and meshing of the 3D geometry. For the geometry to faithfully depict the physical system, it must be separated into solid and fluid zones. Boundary conditions and material attributes are assigned to the solid components. Then, using the proper element types and sizes, meshingis completed for the solid and fluid domains. For heat transfer calculations between the two domains to be facilitated, it is imperative that mesh interfaces line precisely. In order to adequately capture temperature gradients and heat transfer phenomena inside the system, a refined mesh must be achieved.

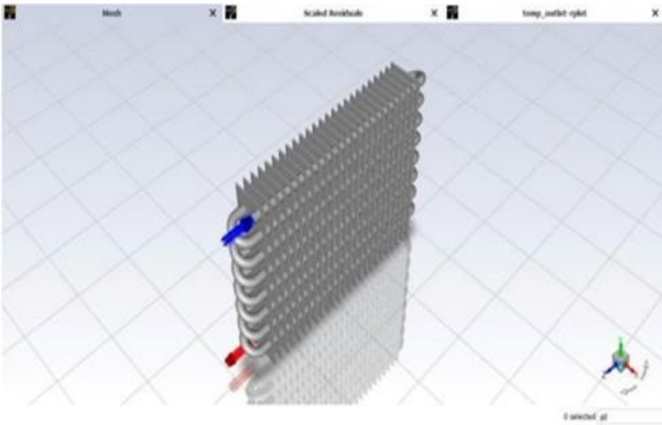

Fig 4. Mesh

- Boundary Conditions and Solver Configuration: Boundary conditions for the fluid domain are defined in ANSYS Fluent. This involves customising the conditions at the outflow as well as the entrance, such as temperatures and velocities. Appropriate turbulence, if any, is relevant

Models are selected. Furthermore, heat transfer happens atthe solid-fluid interfaces, where wall boundary conditions are set. To guarantee precise thermal interactions, these wall boundary conditions set heat fluxes, wall temperatures, and heat transfer coefficients.

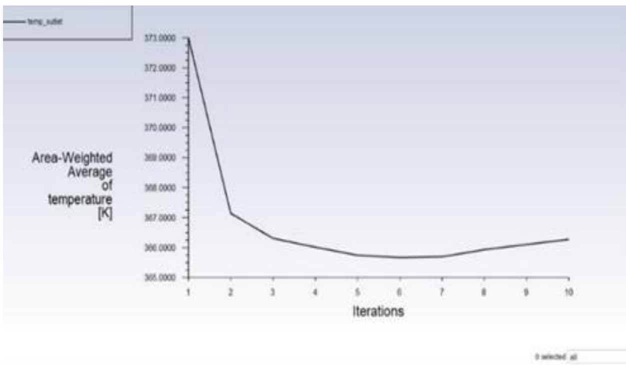

Fig 5. Temp_outlet-rplot

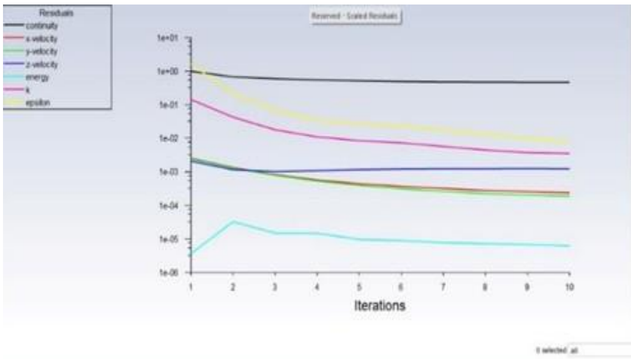

Fig 6. Scaled residual

IV. CALCULATIONS:

Flow for water was set at 19 LPM as the basic requirement for Emrax 228 motor was 9.5 LPM and rangeof flow for Motor Controller is 8-12 LPM. So considered
9.5 LPM.
Q = M * Cp * (To – Ti).For Motor,
Ti = To – Q / (M * Cp)
= 50 – 4.8 / ((9.5/60) (4.187))
= **42.75 °C.**
For Motor Controller, Ti = To – Q / (M * Cp)
= 65 – 4 / ((9.5/60) (4.187))
= **58.98 °C.**
Now,
The radiator inlet temperature should be combining temperature of 2 outlet water pipes one from motor and other from motor controller,

$$T_f = \frac{c_w \cdot m_w \cdot T_w + c_g \cdot m_g \cdot T_g}{c_w \cdot m_w + c_g \cdot m_g}$$

Where,
Tw = Temperature Liq1.Tg = Temperature Liq2.Tf = Final Temperature.
Cw = specific capacity of Liq1.Cg = specific capacity of Liq2.mw = Mass of Liq1.
mg = Mass of Liq2.
The final temperature (Tf) results to **57.5 ˚C**.
Radiator out temperature must be lower than the inlet water temperature of motor and motor controller so the outlet temperature would be **42˚C**.
Now, Considering 42˚C as input to the motor and motorcontroller,
For Motor,
To = Ti + Q / (M * Cp)
= 42 + 4.8 / ((9.5/60) (4.187))
= **49.240 ˚C.**
For Motor Controller, To = Ti + Q / (M * Cp)
= 42 + 4 / ((9.5/60) (4.187))
= **48.0337˚C.**
The Final Temperature (Tf) = **48.63˚C**

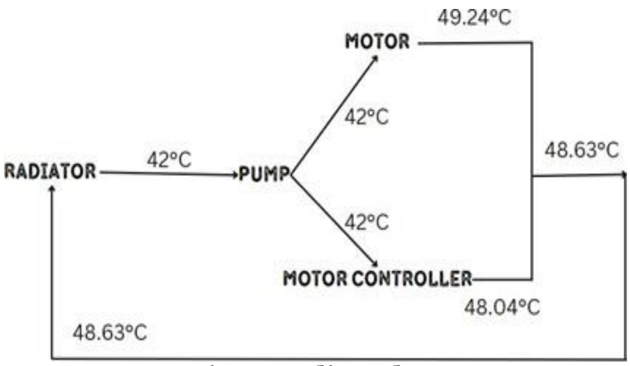

Fig.3 Cooling Flow

Fig . cooling flow

Assuming an air cooled heat exchanger of an air cooled heat exchanger is between the ranges of 300- 450 W/m2K. Let us assume its value be equal to 350 W/m2K

Therefore, using energy balance equation

ma × Cph × (Thi - Tho)= mw × Cpc × (Tco – Tci)100×4.18(48 – 42)= 525.35×1× (Tco – 30)

Tco= 34.8 °C

Heat transfer (q)= ma × Cph × (Thi - Tho)

= 100× 4.18× (6) = 2508 Watt

Let us assume Heat exchanger is counter Flow in nature,we get

Q1 =Thi - Tco

= 48 – 34.8 = 13.2 oC

Q2 = Tho – Tci

= 42 – 30 = 12 oC

Log Mean Temperature Difference(θm), (θm)counterflow = (θ1 - θ2) / Ln (θ1 / θ2)

= (13.2 – 12) / Ln (13.2 – 12)

= 13.34 oC

Total Flow Rate Area,

[2] (A) = n × (p / 4) × d 2

= 25 × (p / 4) × (10 × 10-3)2

= 7.85 × 10-5 m2

For correction factor required dimensions, we find P andR

[2] P = (Tco – Tci) / (T – Tci)

= (34.8 – 30) / (48 - 34.8)

= 0.3

[2] R = (Thi – Tho) / (Tco – Tci)

= (48 – 42) / (34.4 - 30)

= 1.36

Hence, from the chart correction factor (F) = 0.9

Area of the heat transfer(A) after considering correctionfactor is given as,

A = q / (U ´ F´ qm(counterflow))

= 2508 / (120 x 0.9 x 13.34)

= **0.7 m2**

V. RESULT AND DISCUSSION

A heat exchanger was used with the following specifications: a tube diameter of 10 millimetres, an inlet hot fluid temperature of 48.63°C, an inlet cold fluid temperature of 30°C, a mass flow rate of 100 kg/hr for hot fluid and 525 kg/hr for cold fluid, and a fin spacing of 2 mm. The project focused on the design and analysis of a fin and tube heat exchanger with a focus on conjugateheat transfer. The heat exchanger demonstrated an amazing heat transfer rate of 2508 W, and the temperatureprofiles demonstrated the effective movement of heat from the hot fluid to the cool fluid. These analysis results were very promising. Within the tubes, well-distributed velocity profiles were found by the fluid flow study. The computational fluid dynamics analysis demonstrated how well the solid constituents controlled the heat transmission, with both the fluid and solid components' temperature distributions performing well

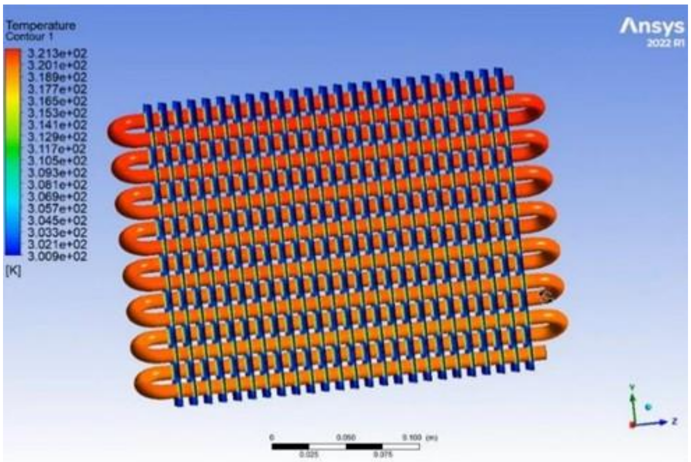

Fig 5. Temperature contour(I)

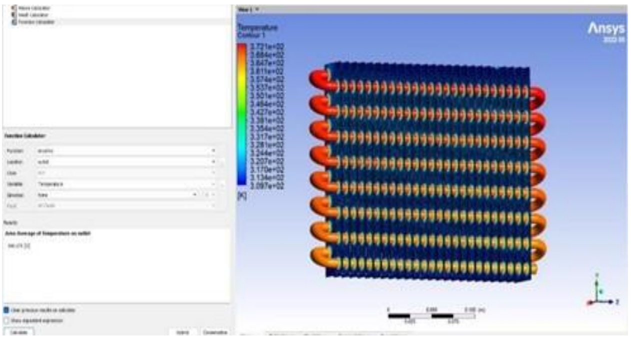

Fig 6. Temperature contour(ii)

VI. CONCLUSION

The exploration of fin and tube heat exchanger design and conjugate heat transfer analysis represents a noteworthy advancement in the field of thermal engineering. The intricate interactions between geometry, materials, and fluid dynamics in these heat exchangers have been better understood because to this research. The significant heat transfer rates attained attest to the efficiency of the design and the thorough analysis carried out. Through the use of sophisticated software tools and accurate modelling approaches, we have achieved remarkably accurate replication of real-world circumstances.

In terms of future directions, this study offers encouraging directions for investigation. Improvements in manufacturing techniques and materials science could improve the efficiency of fin and tube heat exchangers. Adding state-of-the-art materials and creative fin designscan result in even more effective heat transmission procedures. Furthermore, heat exchanger designs based on actual operating conditions can be optimised through the integration of machine learning and artificial intelligence algorithms. Further research avenues includeinvestigating alternative cooling fluids with better thermal characteristics. By expanding the scope of this research to encompass larger heat exchanger systems andincorporating them into networks, energy-efficient solutions with far-reaching consequences can be achieved across diverse industries. Fin and tube heat exchangers as a whole are still a vibrant and innovative industry that offers enhanced thermal efficiency.

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