Islamic University of Technology

Department of Mechanical and Production Engineering

NUMERICAL STUDY ON THERMAL PERFORMANCE ANALYSIS OF RADIATOR: EFFECT OF THE NUMBER OF PIPES

A Thesis by

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Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Mechanical Engineering

Wednesday, June (2022)

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CERTIFICATE OF RESEARCH

This thesis titled “NUMERICAL STUDY ON THERMAL PERFORMANCE ANALYSIS OF RADIATOR: EFFECT OF THE NUMBER OF PIPES”

Submitted by

YAYA OUSMANOU (170011078) and

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has been acknowledged as adequate as part of the requirements for a Bachelor of Science in Mechanical Engineering degree.

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<u>DECLARATION</u>

I henceforth declare that the work, titled ″ NUMERICAL STUDY ON THERMAL PERFORMANCE ANALYSIS OF RADIATOR: EFFECT OF THE NUMBER OF PIPES," is a genuine document of our research conducted as part of the requirements for the certificate of a B.Sc. (Mechanical Engineering) degree at Islamic University of Technology, Gazipur, Dhaka, in the year 2022, under the supervision of Md. Abul Kalam Azad, Assistant Professor, Mathematics, MPE, IUT.

This thesis has not been submitted in part or in its entirety to any other university for the academic award.

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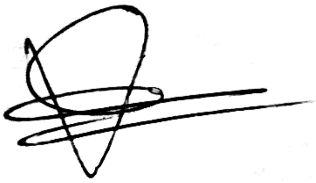

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ABSTRACT

The car Radiator is one the most important of its parts which plays a very important role in the heat transfer of the engine. Our study is based on the number of pipes or tubes in a car radiator. By varying the number of tubes while designing the car radiator, a two-dimensional laminar flow analysis of the car radiator and heat transfer with one of the nanofluid: Al_2O_3 and H_2O, mixed with water that circulates inside the tubes of a car radiator have been studied to evaluate their advantage over the base of the number of tubes. The effects of different pipes number configurations with an identical geometric cylinder on the heat transfer rate and pressure drop were investigated. Convective heat transfer coefficient in the developing and developed regions along the tubes with the higher number of tubes showed marked improvement over the less number. The local and average friction factors, as well as the heat transfer ratio, rise as the number of pipes and volumetric concentration of Nano fluids increase. By varying the number of tubes, quantitative findings of the rise in the heat transfer coefficient and friction factor with increasing volumetric concentrations of nanofluids are reported. For evaluating overall performance, the degree of performance statistics was provided. All of the designs with 15, 25, and 30 cylinders were studied. Despite the fact that the 30 pipes design had the best of the overall in terms of performance, the results revealed that among these geometries, the radiator with the highest thirty (30) tubes had the best thermal performance, while the 15 pipes configuration had the lowest pressure loss. After that, the impact of varying tube counts on radiator performance was investigated. Finally, the three radiators were compared, and the radiator with the most tubes, which in our case was thirty, was determined to have the best layout.

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Nomenclature

Parameter	Definition
cp	Heat capacity at constant
d	Diameter, (mm)
g	Gravitational acceleration, (m/s2)
k	Thermal conductivity, (W/m.K)
m	Mass flow rate, (kg/s)
n	Number of tubes, for a single U-tube
p	Pressure, (Pa) or (bar)
Q	Specific heat transfer rate, (W/m)
Q	Heat transfer rate, (kW)
R	Specific thermal resistance, (m.K/W)
Sp	Tube or pipe spacing, (mm)
t	Time, (sec)
tp	Pipe thickness, (mm)
T	Temperature, (K)
ΔT	Temperature difference, (K)
v	Water flow velocity, (m/s)

Chapter 1

INTRODUCTION

Heat exchangers are one of the most widely used pieces of machinery in a variety of industries throughout the world. Heat exchangers are used in a variety of applications, including heating, ventilation, and cooling; oil and gas industry applications like condensers, waste heat economizers, and boilers; power plant applications like cooling towers, air preheaters, refrigeration, and food processing; and more. Air-cooled automobile radiators are one of the most fascinating uses of heat exchangers in the automotive sector [1]. The physical characteristics of vehicle radiator coolants, their mixes, and geometries have been examined by a number of researchers [2]. Due to the rising need for high-tech cooling solutions, substantial research has been done in recent years on innovative cooling technologies [3]. Many industrial operations generate significant amounts of heat. Thermal scientists should explore innovative and appealing cooling ways due to the capacity/load augmentation of thermal equipment such as heat exchangers, as well as to meet the trend of miniaturizing devices and, therefore, lowering volume [4], cost, and energy usage. Recent advancements in manufacturing techniques and nanotechnology have enabled the production of a new generation of fluids known as nanofluids, which might be useful for cooling applications. Choi13 was the first person to introduce Nano fluids [5]. Many researches from across the world afterwards validated nanofluids' improved thermal characteristics. A nanofluid is a two-phase mixture consisting of a continuous phase of liquid (water, ethylene glycol, aluminium oxide etc.) and a dispersed phase of nanoparticles (very small particles with size below 50 nm). The thermal conductivities of nanofluids have been shown to be much greater than those of basic fluids [6]. Nanofluids have the potential to improve convective heat transfer coefficients. Radiators are heat exchangers that transmit heat and thermal energy from one medium to another in order to cool or heat it. The heat from the engine is transferred to the fluid in a car radiator to keep it cold [7]. The heat is then transferred to the outside air via a radiator. The quest for more powerful engines in smaller hood areas has resulted in the development of insufficient heat dissipation rates in car radiators are a concern. Fuel and air provide power in a car engine. combustion in the engine Only a part of the produced energy is used to power automobiles; the rest is squandered in the form of heat and exhaust. The radiator assembly includes the radiator, an electric cooling fan, a water pump, a thermostat, and a radiator pressure cap [8]. Overheating of the engine, cylinder distortion, and wear between engine parts arise from insufficient heat dissipation in the automobile radiator. To address the issue of high-power generation and limited radiator size, the car radiator must be modified to be more compact while yet providing excellent heat transfer performance [9].

1.1 SOME DEFINITIONS

1.1.1 Car Radiator

Placed in the front of a car and attached to other parts of heat exchangers, such as intercooler, condenser [10]. A Car radiator is an element that helps eliminating the excess of heat inside the engine. It is one of the engine's important components for cooling system, including a liquid coolant, hoses to make circulation of the coolant, a fan, a thermostat which is a monitoring system of the coolant temperature.

1.1.2 Nano fluids

Nanofluids have the potential to be the foundation of heat transfer fluids in a variety of applications [11]Due to the presence of dispersed Nano particles with high thermal conductivity, they are projected to provide higher thermal performance than traditional fluids.

Numerous studies have recently indicated that nanofluids have improved thermal conductivity and have a better heat transfer rate.

Nanofluids have unique properties that could make them useful in a wide range of heat transfer applications, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, as well as engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, grinding, and machining [12].

They have a higher thermal conductivity and a lower convective heat transfer coefficient than the base fluid. Understanding the rheological behavior of nanofluids has been discovered to be critical in determining their suitability for convective heat transfer applications.

1.1.3 Aluminum Oxide

Aluminum oxide is made up of Al, a light silvery white metal from the periodic table's major Group 13, and Oxygen, a chemical element with the symbol O and atomic number 8.

These Al2O3 crystals are white and odorless, insoluble in water [13]. The physical and chemical properties vary depending on the preparation process; different methods result in distinct crystalline modifications. Chemically, the type generated at such high temperatures is fairly harmless.

1.1.4 Water Velocity

The velocity of water refers to the rate during which water flows. The volume of water passing per minute is commonly used to calculate flow rates.

1.1.5 Heat Exchanger

A heat exchanger is an instrument that releases energy from one stream to another. Both cooling and heating operations employ heat exchangers. A massive wall may split the elements to avoid combining, or they may be in direct touch [15].

1.2 Application

A radiator is a water tank that is used to cool anything that is hot. Water combined with anti-freeze is used to cool down the heat transferred or radiated from hot engines in big vehicles, small automobiles, or ship engines, as well as nuclear energy reactors [16]. A car engine will become heated in 5 to 10 minutes if it is not fitted with a radiator. If the heat continues to rise, the engine will be damaged.

Literature Review

Peyghambarzadeh et al. [17] Studied the radiator cooling performance using Al_2O_3 – Water Nanofluid. They found that heat transfer rate increases with increasing value of the fluid circulation. Inside the surface of the samples, a standard car radiator is used, and the effects of operating conditions on its heat transfer capabilities are evaluated. The following results were made after measuring experimental heat transfer coefficients in the automotive radiator using two different working liquids: pure water and water-based nanoparticle volume fraction at varied concentrations and temperatures. [18]

Zhang et al. [19] investigated numerically by simplifying the flow and partially sealing off the CRFM at high vehicle speeds, the air duct increases both the airflow rate through and flow uniformity over the radiator, and secondly, it lowers hot air re-circulation at vehicle3 idling circumstances. For road cars, these advantages could lead to the use of a smaller radiator and a reduction in total drag, improving fuel efficiency. However, there have been few studies comparing various air-duct designs for a full-scale vehicle model. In this context, this work uses a 3D CFD technique to examine the impacts of air-duct design and grille opening size on radiator cooling performance and cooling drag under various operating situations. The study entails multiple air-duct shape and front grille aperture design variations. The findings are evaluated based on a number of essential cooling airflow metrics, including airflow homogeneity, total mass flow rate via the radiator and front grille aperture, and overall vehicle drag.

Dimoudi and Androutsopoulos [20] investigated the cooling performance of a radiator which utilizes water as a fluid medium They discovered that changing the spacing between the discs had no effect on heat transfer. There is currently no experimental work on the flow of nanofluids in flat tube geometries, although it is strongly recommended as a future research area.

Many recent investigations have demonstrated that the base fluid behaves like a single-phase fluid due to the low particle volumetric concentration of nanoparticles. The computed results for skin friction and the Nusselt number in the fully developed region for a single-phase fluid accord well with the data available from Shah and London (1978). Calculations of heat transmission for Al2O 3 and CuO nanofluids with changing temperatures. When compared to the base fluid, the pumping power required for the same amount of heat transfer is 82 percent lower for an Al2O3 nanofluid with a 10% concentration and 77 percent lower for a CuO nanofluid with a 6% concentration. For nanofluids moving in the flat tubes of a radiator, new Nusselt number correlations have been presented for both the entrance and fully developed areas.

Yadav and Singh [21] examined a complete numerical parametric set on automotive radiator, with water being appealing to be the best coolant even due its limitations. This research presents a comprehensive collection of numerical parametric analyses on car radiators. Two methods have been used to represent radiators: one is the finite difference method, and the other is the thermal resistance idea. A radiator is mounted in a test setup and various factors such as coolant mass flow rate, inlet coolant temperature, and so on are adjusted throughout the performance evaluation. In addition, a comparison of different coolants is presented. One coolant is water, and the other is a 40:60 blend of water and propylene glycol.

Hertzberg and Mattick [22] analyzed experimentally the emittance of a submillimeter droplets of Dow fluid. It revealed that, LDR is proven to be an appealing solution for liquids with a G0/p > 0.02cm3/gm ratio, where G0 is the droplet emittance at the rejection temperature. The necessity for low vapor pressure limits the number of fluids that can be used, and only a few - - D o w 705 silicone fluid and some liquid metals have been identified so far that meet this criterion and have useful G0/p values. The findings of experiments utilizing a droplet stream of Dow 705 fluid show that LDRs using this fluid could be up to an order of magnitude lighter than sophisticated solid surface radiators. The radioactive properties of the LDR droplet sheet were found to be the most important factor in the performance of the liquid droplet radiator. The sheet can be precisely defined by a spatially uniform emissivity, according to an examination of radiation transmission from a rectangular droplet sheet, and a compromise between a minimal mass and a minimum area sheet yields an optical depth "r = 1/2 percent.

The power/mass of an LDR is thus related to the ratio of droplet emittance e, to liquid density P; that is, it is very dependent on the fluid used.

The geometry investigations of vertical, horizontal, corrugated and wavy-corrugated configurations by Baou et al. [23] showed that several topologies with identical porous volume were studied in this work, including horizontal, vertical, corrugated, and wavy-corrugated porous fins. Following the selection of the wavy-corrugated configuration as the best porous media in terms of coefficient of performance (COP), the performance of three distinct porous material types was compared. Finally, by comparing the radiator to a traditional radiator, the impact of using the best porous fin arrangement and material on improving overall performance was demonstrated. The answer is obtained in a steady state using a 3D numerical simulation for this investigation.

Babu et al. [24] performed the effects of nanofluid Carboxyl graphene which suggested that nanoplateles increases the effectiveness of the radiator by a factor of 27.38% and 23.41% for inlet temperatures of 40 °C and 50 °C respectively, as long as they can be kept stable for lengthy periods of time.

The goal of this research is to learn more about graphene nanofluids and how they behave. The influence of nanofluid carboxyl graphene on radiator performance is investigated in the current paper. At three concentrations of 0.02, 0.03, and 0.04 vol percent carboxyl graphene nanoplatelets are introduced to 50:50 ethylene glycol–distilled water.

The liquid flow rate is regulated between 3 and 6 LPM, while the incoming liquid temperature to the radiator is kept constant between 40 and 50 degrees Celsius.

It has been observed by Charyulu et al. [25] that the radiator core's properties for any number of tube rows, as well as the water and air flow rates, thus will assist the designer in determining the appropriate number of tube rows for a particular application. Variable fouling factors were used to assess performance. Fouling factors from the literature are used to measure performance. Because the quality of fluids in India, such as air, water, and oil, differs from TEMA norms and also changes from region to region, it is regarded desirable that the heat exchange's performance be tested using various fouling parameters. The performance and cost-effectiveness of various materials for n and tube building. The number of tube rows required for the radiator is selected using a nomograph. During the analysis, all aspects influencing the performance of a core with a specific fin pitch are addressed, including fluid flow rates, inlet temperature of fluids, fouling factors, and construction materials.

Leong et al. [26] raised studies on automotive cooling system and as a result of utilizing ethylene glycol-based copper nanofluids as coolants, this study was aimed to explore the heat transfer characteristics of an automobile car radiator. An automobile radiator employing nanofluids is compared to a radiator using traditional coolants in terms of thermal performance. The impact of copper nanoparticle volume fraction with base fluids on the thermal performance and potential size reduction of a radiator was also investigated. Because copper nanoparticles have a better thermal conductivity than other nanoparticles like alumina, they were chosen for this investigation. The correlation developed by Tsai and Chein was used to determine the dynamic viscosity of nanofluids in this study. In an automobile car radiator, this parameter affects the mass flow rate of nanofluids. Because the nanofluids have a higher dynamic viscosity, the mass velocity of the nanofluids rose as the volume percent of copper nanoparticles increased.

Mihalakakou et al. [27] investigated the system of cooling for buildings with radiative dynamic cooling, with primary goal of assessing the energy potential of a nighttime lightweight wind-screened radiator in real-world climatic circumstances, as it is used to cool a renovated historical building in Italy, and to determine the system's feasibility.

The cooling system's effectiveness and cooling potential are studied and presented in a way suitable for designers' usage. A mathematical model was used to calculate the dynamic thermal performance of a lightweight metallic radiator covered by a single polyethylene wind screen.

M'hamed et al. [28] worked out thermal performance of an automotive radiator employing MWCNT–water–glycol as a new coolant. For this purpose, it appealed that the heat transfer coefficient and thermal performance of the Perodua Kelisa 1000CC radiator system using MWCT nanocoolant based on water/ethylene glycol have been evaluated using an experimental test rig.

The MWCNT nanocoolant had a greater average heat transfer coefficient than the base fluid. MWCNTs outperform water and Ethylene-Glycol in terms of thermal conductivity, aspect ratio, specific surface area, specific gravity, and thermal resistance.

Jadar et al. [29] studied Convectional coolant in automobile radiator with forced convection heat transfer. It has been discovered that using nanofluids, we may obtain smaller radiators with the same or slightly higher thermal performance, resulting in lighter and smaller radiators with lower initial investment, lower repair and maintenance costs, lower emission rates, and lower NOx output. Typically, the largest volume concentration of nanoparticles results in the greatest heat transfer increase and the greatest need for pumping power at the same time. Using anon-fluids, on the other hand, will minimize the pumping power required due to the nano-fluids' increased heat carrying capacity. This study reviews all of the studies that have been conducted on the use of nanofluids in car radiators. There are two types of studies: experimental and numerical. Here you will find all of the study specifics.

Mounika et al. [30] investigated the variation of speed of an automobile. The more power the engine must create, the better the cooling system must be. The engine coolant (ethylene glycol) travels through the radiator's tubes, where heat is transferred from the coolant to the environment using heat transfer techniques such as conduction and convection. As a result, during the cooling process through the fins, the velocity of air striking the radiator becomes a critical parameter. The graph depicts the fins' efficiency as a function of the Reynolds number of the air passing through the radiator at various speeds. When a car moves at a high speed, the engine generates a significant amount of heat.

Chapter 2

2.0 MATHEMATICAL MODELLING

The radiator consists of 25 tubes of circular cross section, one inlet header and one outlet header. The length of the tubes being 584 mm. The inner and outer diameters of the tubes are 7mm and 9mm respectively. The dimensions of the radiator are shown in Table 1

Inner diameter	7 mm
Outer diameter	9 mm
Tube length	584 mm
Number of tubes	25
Width	30 mm
Height	360 mm
Length	644 mm

Table1: Dimensions of the tube's radiator

2.1 Model description

We used three dimensions for modeling our car radiator which has three axis x, y, z. Hence it has three domains. With 318 number of boundaries; and 736 number of edges; and 424 number of vertices.

For Nano fluid, we used the mixture of two liquids which are liquid water and aluminum oxide. Each one of them has its separate characteristics. In our study we neglect the inertial term or stokes flow. Our flow is an incompressible flow because we conduct our study under laminar flow. As we used metal for the body of the radiator there is no means of porosity.

Beside the radiator with 25 number of tubes we designed in SOLIDWORKS three other radiator with different number of pipes. Radiator with 30 pipes, radiator with 21 pipes because with 21 pipes because if we make it 20 pipes the inlet and the outlet will be at the same side. And finally, a radiator with 15 pipes.

Description: The figure below is the figure of a car radiator with the minimal number of tubes. The number of tubes is 15 tubes. This car radiator is lighter in weight than all the other radiator and has a lesser performance too due the minimal number of tubes used.

Figure 1: Car radiator with 15 number of pipes

Description: The beolow figure is the figure of a car radiator with 21 number of tubes. It has 21 number of pipes because if we make 20 pipes both the inlet and the outlet will at the same side. Either the inlet side or the outlet side. It has six pipes difference with the above one and has a greater performance than the radiator with 15 pipes.

Figure 2: Car radiator with 21 numbers of pipes

Description: The figure below is the figure of a car radiator with 25 number of pipes. This car radiator is heavier in weight than all the above radiator and it has a better performance too due the number of tubes used.

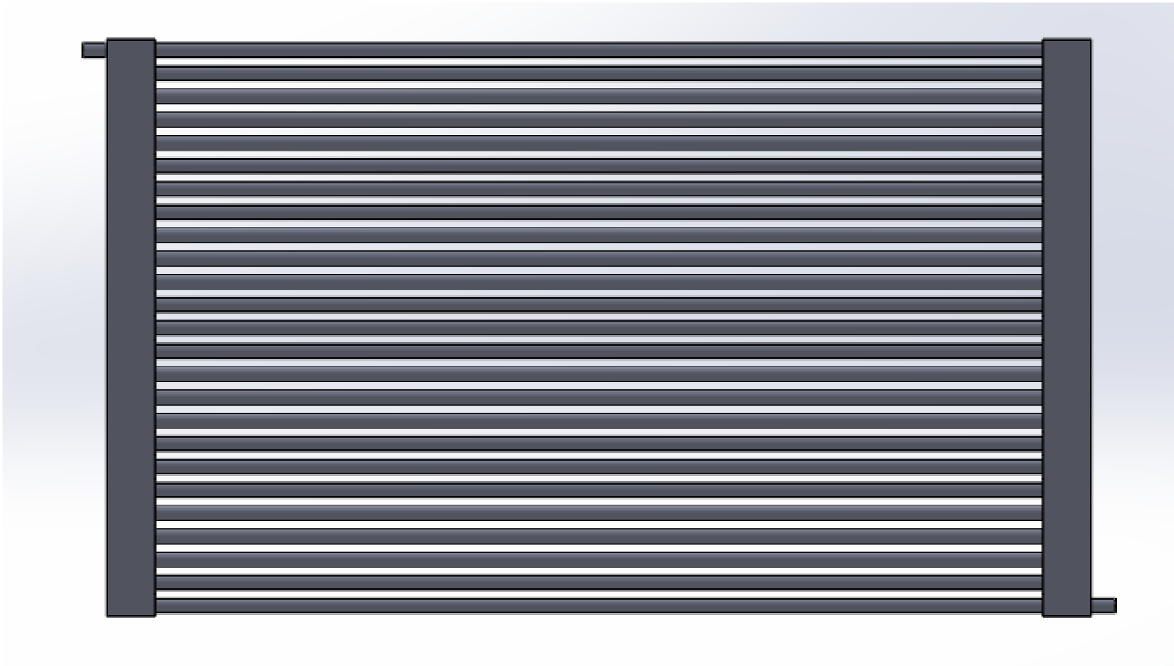


Figure 3: Car radiator with 25 numbers of pipes

Description: The figure below is the figure of a car radiator with 30 numbers of pipes. This car radiator is heaviest in weight than all the above radiator and it has a greater performance than all the other radiator due to its maximum number of tubes used.

Figure 4: Car radiator with 30 number of pipes

2.2.2 Governing Equations

The flow is a laminar flow and the general forms of the equations of energy and fluid flow that control the process in the radiator are stated below. These relations represent the cylindrical forms of heat transfer and fluid flow as known by Fourier's law for the solid domains and the Navier-Stokes, energy, and continuity equations in the fluid domain. The following boundary conditions were implemented in the present work:

Fluid Domain

The governing equation for the flow domain, continuity, Navier-Stokes, and energy in an incompressible flow are defined by the following formulae.

Continuity Equation.

$$\frac{1}{r}\frac{\partial(rUr)}{\partial r}+\frac{1}{r}\frac{\partial u\theta}{\partial\theta}+\frac{\partial uz}{\partial z}=0 \quad (2.1)$$

Navier-Stokes Equation

$$\rho\left(\frac{\partial ur}{\partial t}+ur\frac{\partial ur}{\partial r}+\frac{u\theta}{r}\frac{\partial ur}{\partial\theta}+uz\frac{\partial ur}{\partial z}-\frac{u\theta^2}{r}\right)$$
$$=\rho gr-\frac{\partial p}{\partial r}+\mu[\frac{\partial}{\partial r}\left(r\frac{\partial ur}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 ur}{\partial\theta^2}+\frac{\partial^2 ur}{\partial z^2}-\frac{2}{r^2}\frac{\partial u\theta}{\partial\theta}-\frac{ur}{r^2}] \quad (2.2)$$

$$\rho\left(\frac{\partial u\theta}{\partial t}+ur\frac{\partial ur}{\partial r}+\frac{u\theta}{r}\frac{\partial u\theta}{\partial\theta}+uz\frac{\partial u\theta}{\partial z}+\frac{uru\theta}{r}\right)$$
$$=\ \rho g\theta-\frac{1}{r}\frac{\partial}{\partial\theta}+\mu(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u\theta}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 u\theta}{\partial\theta^2}+\frac{\partial^2 u\theta}{\partial z^2}+\frac{2}{r^2}\frac{\partial u\theta}{\partial\theta}-\frac{u\theta}{r^2} \quad (2.3)$$

$$\rho\left(\frac{\partial uz}{\partial t}+ur\frac{\partial uz}{\partial r}+\frac{u\theta}{r}\frac{\partial uz}{\partial\theta}+uz\frac{\partial uz}{\partial z}\right)=\rho gz-\frac{\partial p}{\partial\theta}+\mu[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial uz}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 uz}{\partial\theta^2}+\frac{\partial^2 uz}{\partial z^2} \quad (2.4)$$

Energy Equation

$$\frac{\partial T}{\partial t}+ur\frac{\partial uz}{\partial r}+\frac{u\theta}{r}\frac{\partial T}{\partial\theta}+uz\frac{\partial T}{\partial z}=\frac{q}{cp}+a\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 T}{\partial\theta^2}+\frac{\partial^2 T}{\partial\theta^2}\right]+\frac{\varphi}{\rho cp} \quad (2.5)$$

Where the viscous dissipation rate is:

$$\varphi=2\mu\left[\left(\left(\frac{\partial ur}{\partial u}\right)^2\right)+\left(\frac{1}{r}\frac{\partial u\theta}{\partial\theta}+\frac{ur}{r}\right)^2+\left(\left(\frac{\partial uz}{\partial z}\right)^2\right)\right]$$
$$+\mu\left[\left(\left(\frac{1}{r}\frac{\partial ur}{\partial\theta}+\frac{\partial u\theta}{\partial r}+\frac{u\theta}{r}\right)^2\right)+\left(\frac{\partial u\theta}{\partial z}+\frac{1}{r}\frac{\partial uz}{\partial z}\right)^2+\left(\left(\frac{\partial uz}{\partial r}+\frac{\partial ur}{\partial r}\right)^2\right)\right] \quad (2.6)$$

These formulas capture the current forms of the flow variables in the laminar flow. Our work is not time-dependent variables, and also the gravity does not affect the flow of the water, so the gravity terms (g), was removed from the standard paradigm

Solid Domains

In the solid domains of the model, the following general Fourier's law is applicable:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial\theta}\right)+\frac{1}{r^2}\frac{\partial}{\partial\theta}\left(r\frac{\partial T}{\partial\theta}\right)+\frac{\partial}{\partial z}\left(r\frac{\partial T}{\partial Z}\right)+q=\frac{1}{\alpha}\frac{\partial T}{\partial t} \quad (2.7)$$

For a stable scenario, the power production per given volume (and the temperature fluctuations over period assumed to be zero inside this expression.

COMSOL Multiphysics 5.4 software in which T is the temperature, t is the period, q is indeed the intensity, c is the heat capacity, k is the heat capacity, heat transfer is recognized in the procedure of clean conduction of heat and the resulting sustainable energy formula can be published as

$$\rho c \frac{\partial}{\partial \varepsilon} \int_A Tdv = \int_A \lambda \mathrm{V} \nabla \mathrm{T} \cdot \mathrm{ndA} \_\_\_\_\_\_\_\_\_\_\_ (1)$$

T is the heat,

t is the period,

q is the intensity,

The energy conservation equation of the fluid in the pipes is if resistive temperature distribution along the liquid routes is ignored.

$$\rho 1 c 1 A t \frac{\partial}{\partial t} \int_L TtdL + \alpha U \int_L (Tt - Ti)dL = mct(Tt, in - Tt, out) \quad (2)$$

where an is really the fluid's radiative heat flux, m_ is its flow rate, If is its pass flow area, and U is its volume is the conduit interior L is the fluid cell's perimeter diameter. The subscript I signifies the pipe interior surface, while f specifies the fluid. The input and outlet are indicated by the subscripts in and out simultaneously. Conservation of energy is demonstrated in Eq. (2). the GHE's on-time performance No fluid would be delivered during the off-season o the pipe (U-tube) On the correct, there is a word (RHS) is used here. Equation (2) equals zero. As a result, forced convective heat in the opposite flank, the transfer coefficient in the second phrase (LHS) of Eq. (2) becomes the rate of heat exchange via convection. Because the thermal capacity of the pipe wall is so low, it is often overlooked. As a result, in the tube's circular path, the heat cycle can be modeled as a quasi-continuous action.

2.2.3 Boundary Condition

The car radiator is a heat exchanger and every heat exchanger uses its boundary to transfer heat from one side to another. One most important aspect of fluid is applicable in our study is that there is no slip condition at boundary layer, means the velocity at the boundary is zero. While the inflow velocity or inlet velocity is 0.028 m/s. the velocity field component was set as normal inflow velocity. And also, our liquid is just flowing through the pipes from the inlet to the outlet.

Description: The below figure is the figure describing the path that the fluid mixture is following: the boundary contour of the radiator. The hot mixture of fluid coming out of the radiator is going to the radiator through the inlet side of the radiator and leaving the radiator through the outlet side.

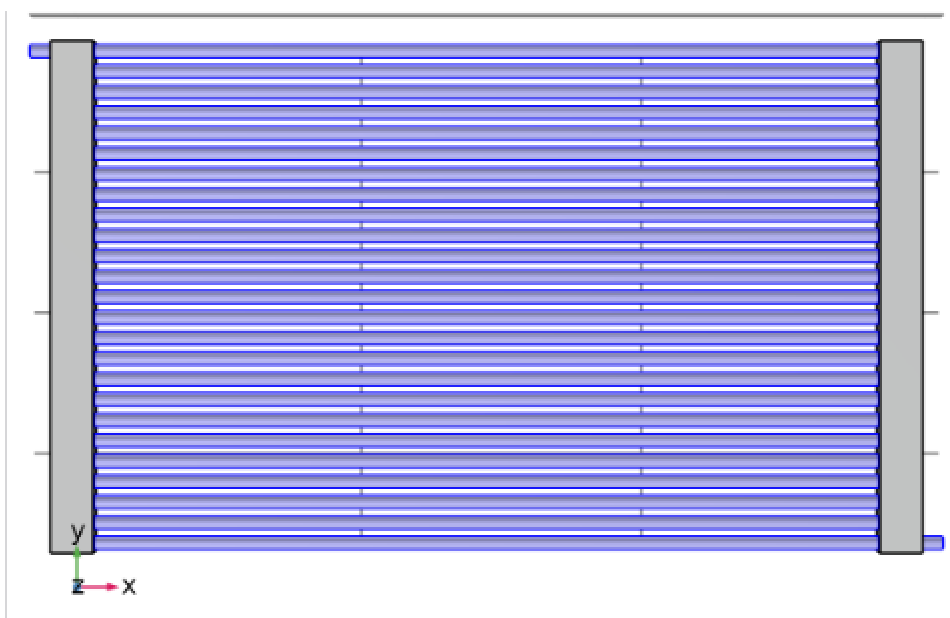


Fig 5: boundary contour of radiator where the liquid is flowing

2.2.4 Materials

The materials we used are liquid water (H20 water liquid) and aluminum oxide to have a Nano fluid. Each one of them has its own characteristics and properties. For the laminar flow we need to set several parameters before getting the study properly. Failure of setting the parameters will lead to several errors' messages generated from COMSOL and also the study wouldn't be conducted properly. We defined the thermal conductivity, the heat capacity, the density, the dynamic viscosity. The tables below show the parameters of water and the aluminum oxide.

Name	Value	Unit
Thermal conductivity	0.6	W/(m.k)
Heat capacity	4182	J/(kg.K)
Density	998.2	Kg/m^3
Dynamic viscosity	0.001003	Pa.s

Tabele2: Physical properties of the liquid water

Description: The figure below is the variation of the alpha liquid contain in the mixture of the nanofluid. Before 100 on the variation, the curve is not straight then after the curve become straight line till the infinity.

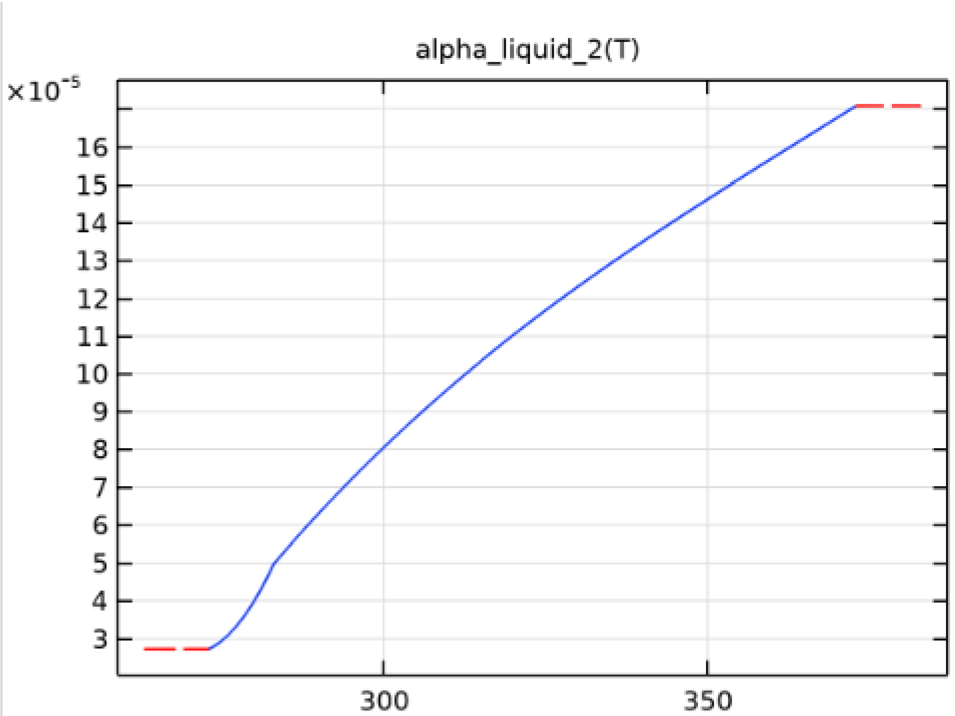


Fig: Alpha liquid

Description: The figure below is the graph of the C-liquid 2 (T). It's showing the description of the variation of the temperature. The shape is a straight light

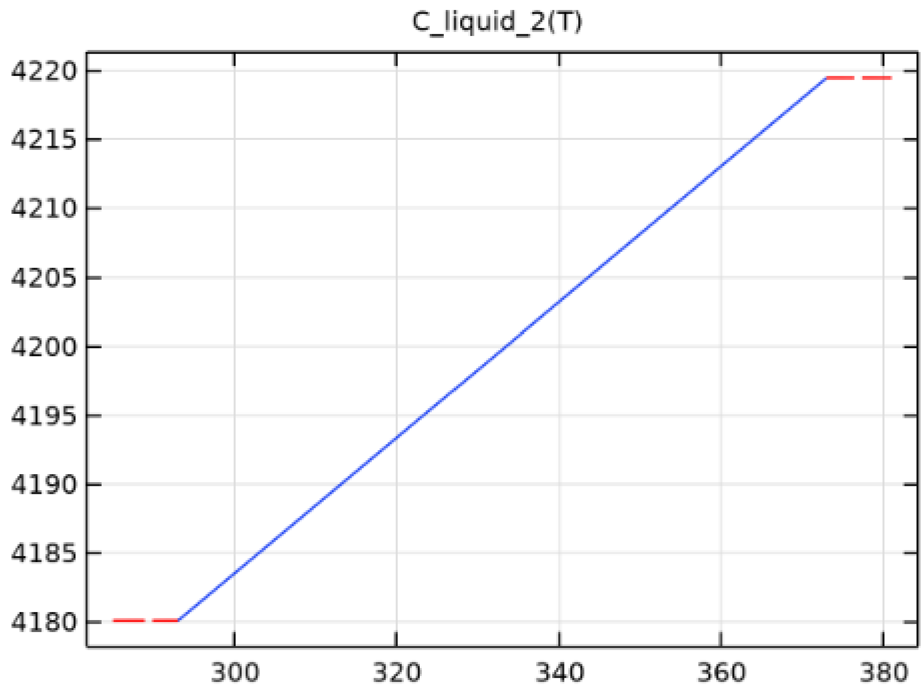


Fig: C-liquid

Description: The figure below is the graph of K-liquid-2(T) it is also showing the variation of the temperature and it has a square root shape.

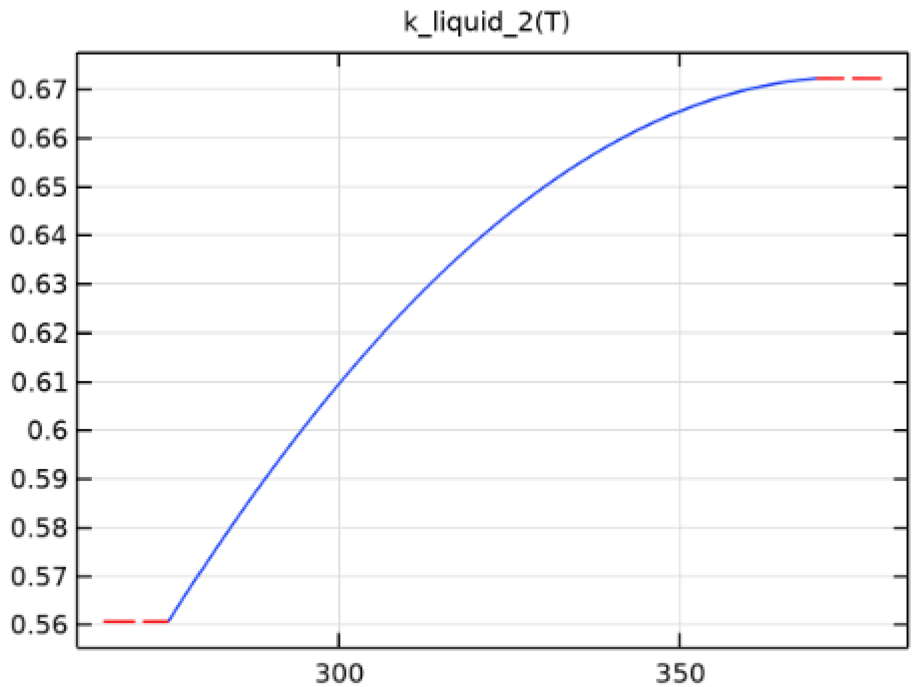


Fig: K-liquid

For the aluminum oxide it is Al_2O_3 gamma liquid it has also a specific set of characteristics and properties. Here we defined the density, the dynamic viscosity, the thermal expansion, the specific gas constant.

Name	Value	Unit
Thermal conductivity	1.30385	W/mK
Heat capacity	3197.47	J/Kg-K
Density	1243.17	Kg/m3
Dynamic viscosity	0.00125375	Kg/m

Table3: Physical properties of the aluminum oxide

Description: The figure below is the variation of the alpha liquid contain in the mixture of the nanofluid. Here the variation of the alpha-liquid is a straight line.

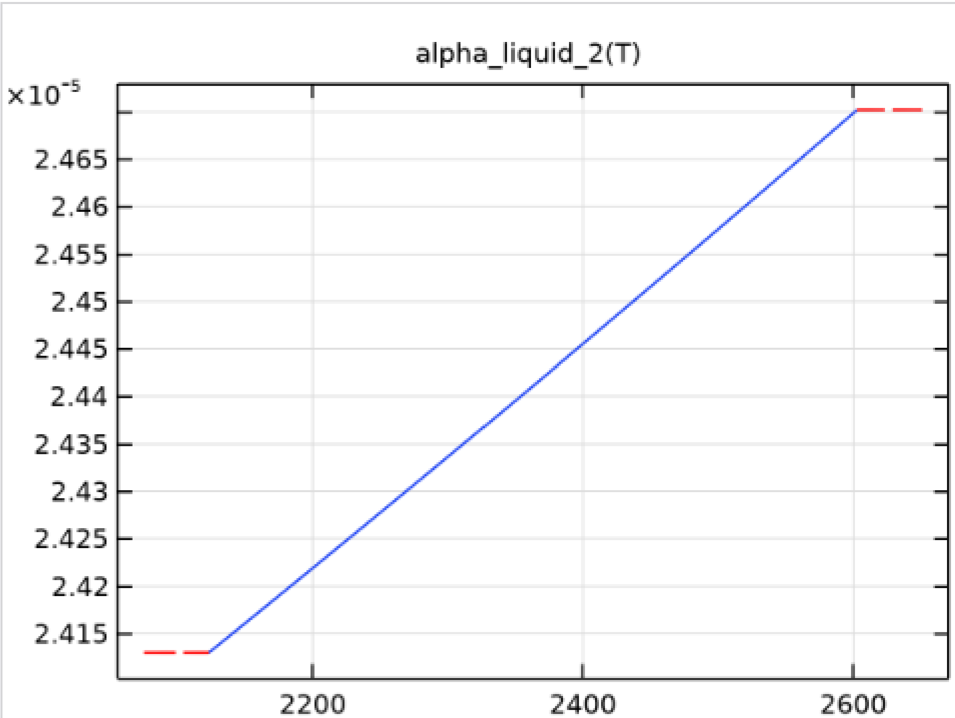


Fig: Alpha liquid of the aluminum oxide

Description: The figure below is the variation of the Eta curve. It is showing the variation of the aluminum oxide. It has a shape closer to the shape of 1by x but it has a bigger slope than it.

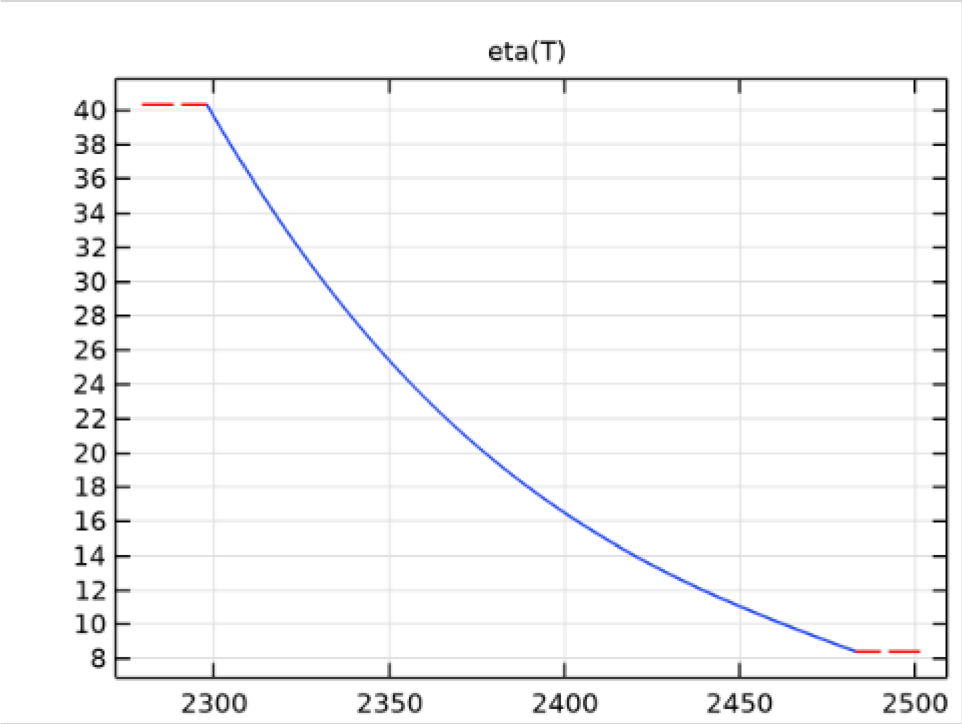


Fig: Eta curve of the aluminum oxide

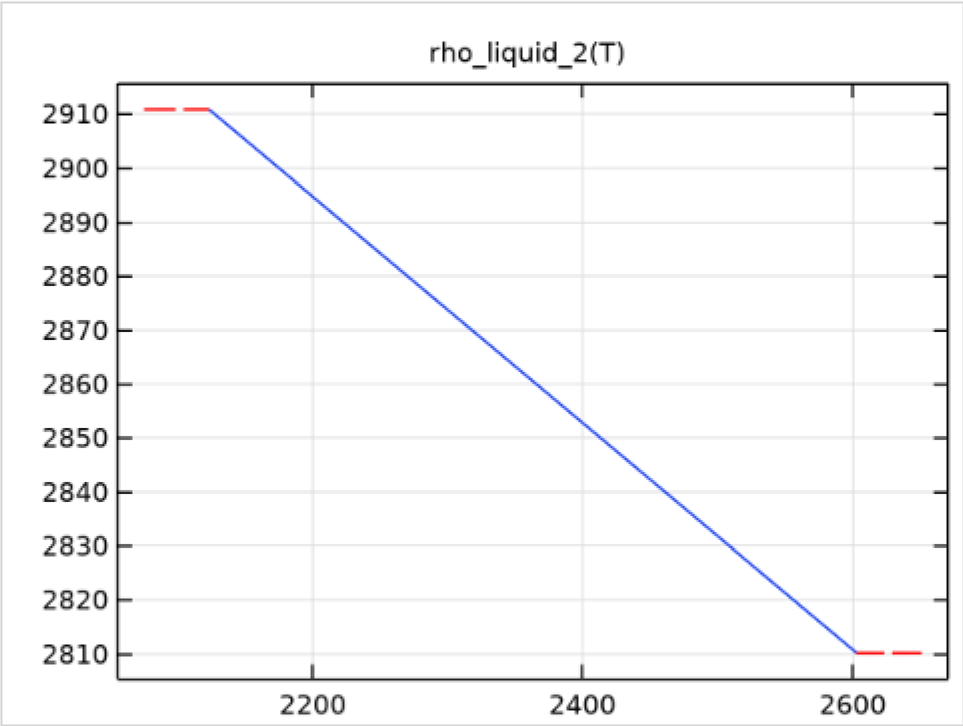


Fig: Rho liquid of aluminum oxide

2.3 Grid Study

2.3.1 Geometry Meshing

The meshing process of the model shows how the tetrahedral element type was used to run the model. We used three different meshing analysis to get different results. Based on this result we analyzed our study. We used in COMSOL to get different sized of the mesh. The finer the meshing, the computational time will more.

Description: The figure below is the image of the radiator after meshing processs. The area that is darker has more element and having thicker metal.

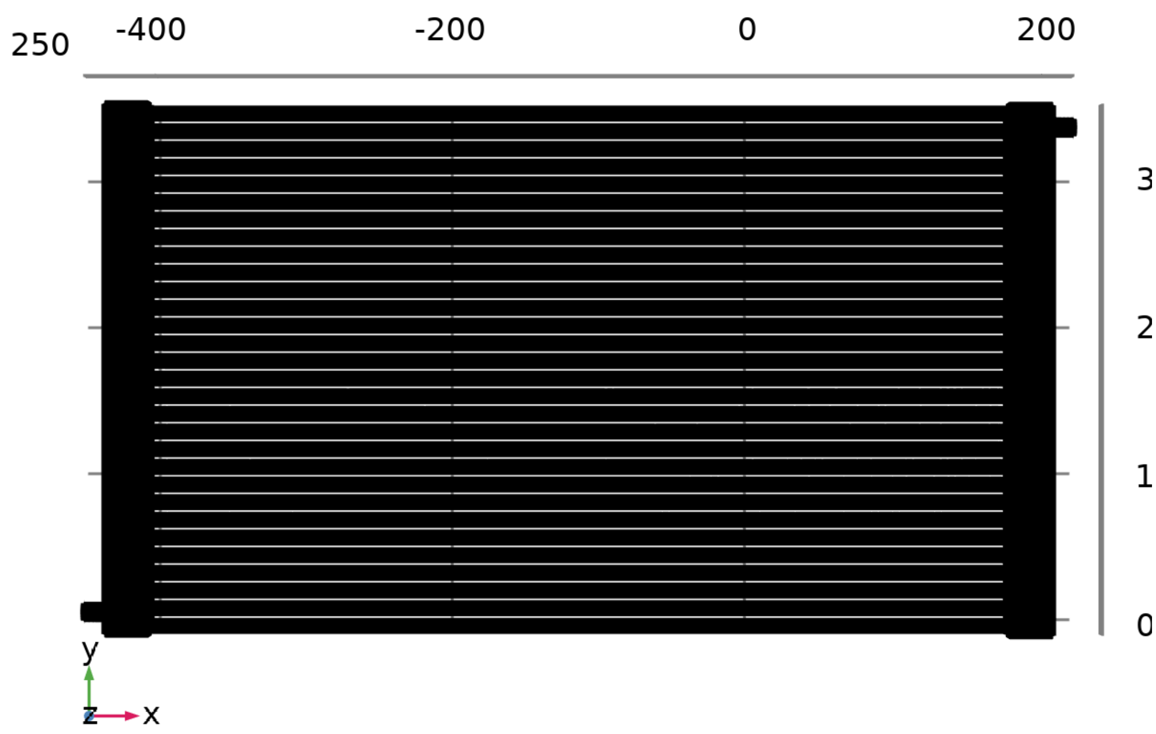


Fig: Meshing of the radiator

Next is the mesh, to properly define the physical shape of the shape of the object, the object is broken into small pieces. We've studied three different types of the mesh analysis coarse, extremely coarse and extra coarser.

For the extremely coarse we get maximum element size of 34.3 and the minimum element size is 7.27, the resolution of narrow regions is 0.3 and the maximum element growth rate is at 1.4.

Description	Value
Calibrated for	
Maximum element size	34.3
Minimum element size	7.27
Resolution of narrow region	0.3
Maximum element growth rate	1.4
Predefined sized	Extremely coarse

Table4:

For the coarser we get maximum element size of 13.5 and the minimum element size is 4.16, the resolution of narrow regions is 0.5 and the maximum element growth rate is at 1.25 and the curvature factor is 0.8.

Description	Value
Calibrated for	
Maximum element size	13.5
Minimum element size	4.16
Resolution of narrow region	0.5
Maximum element growth rate	1.25
Predefined sized	Coarser

Table 5:

For the extra coarser we get maximum element size of 193 and the minimum element size is 34.8, the resolution of narrow regions is 0.2, the maximum element growth rate is at 1.85.

Description	Value
Calibrated for	
Maximum element size	193
Minimum element size	34.8

Resolution of narrow region	0.2
Maximum element growth rate	1.85
Predefined sized	Extra coarser

Table6:

We can see from the three different meshing, the number of maximum elements is increasing and in the heat diagram we can see that the meshing has only affected the regions where the mass is very big, at the sides of radiator. Where it is red, it has a very difficult meshing analysis and is difficult to divide it into smaller pieces. And the regions where the color is green the green is good to go with, and for the part that is in yellow it is quite acceptable but needs more improvements

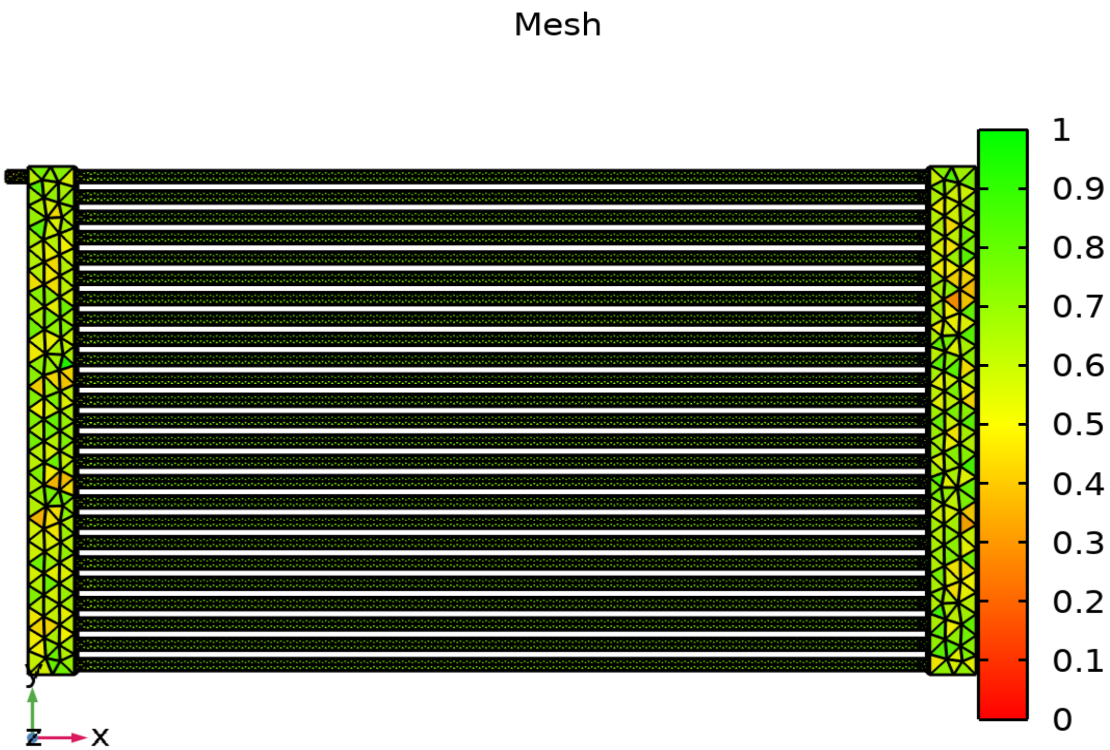
Chapter 3

3.1 RESULTS AND DISCUSSION

The variations in mean fluid temperature, average temperature, and the number of tubes temperature along the car radiator are shown in the previous figures. When the heat coming from the engine enters the radiator this is exactly what happens. When a fluid with a higher intake temperature than the tubes one, the fluid loses heat as it descends. As a result, as seen in the previous picture, the fluid temperature drops as it descends. On the other hand, as the fluid moves upward from the cars to the radiator the temperature steadily drops. Furthermore, the temperature of the nanofluid reduces significantly as heat flows through the back-fill material anywhere along. Similarly, the numerically calculated radiator surface temperature drops from roughly 5 degrees when the number of tubes increases by 40% compared to its original size.

Results

The meshing result of our computation, we can see where the metal is more in quantity the meshing is safer and it is showing green colo. In an overall observation from our figure the car radiator is safer to be used because it has no red color on it.



The figure below shows the variation of the upward and downward temperature of the fluid. We can see that the fluid temperature is varying within a very nice temperature for working of a car. The radiator is cooling the fluid to below 25 degree, which is very nice for the working of the car engine.

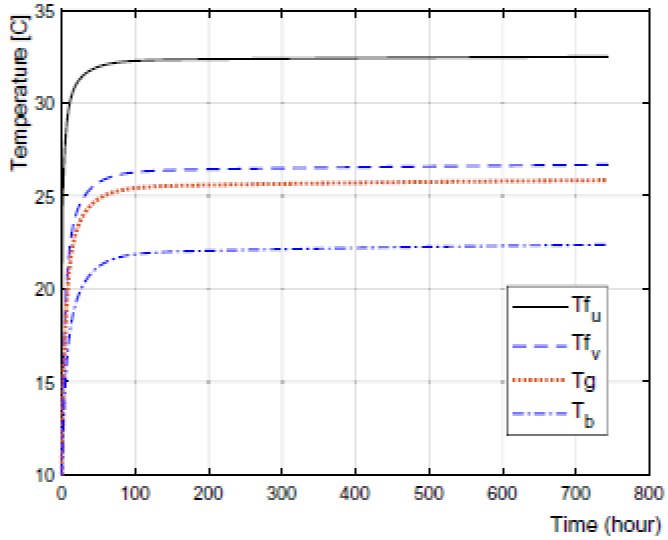


Fig 3.11: Average upward and downward flow fluid temperature

TABLE 3. RESULTS TABLE

Description	Value
Solver	Smoothed aggregation AMG
Maximum number of DOFs at coarsest level	80000
Strength of connections	0.02
Construct prolongators componentwise	On
Prolongator smoothing	Off

Basic type the table

From the comsol software, the part that is showing the isosurface of the liquid is used to show the velocity profile of the flowing liquid, we set in our study that it following no slip condition. And also the variation of the velocity does not affect that much the cooling process of the radiator.

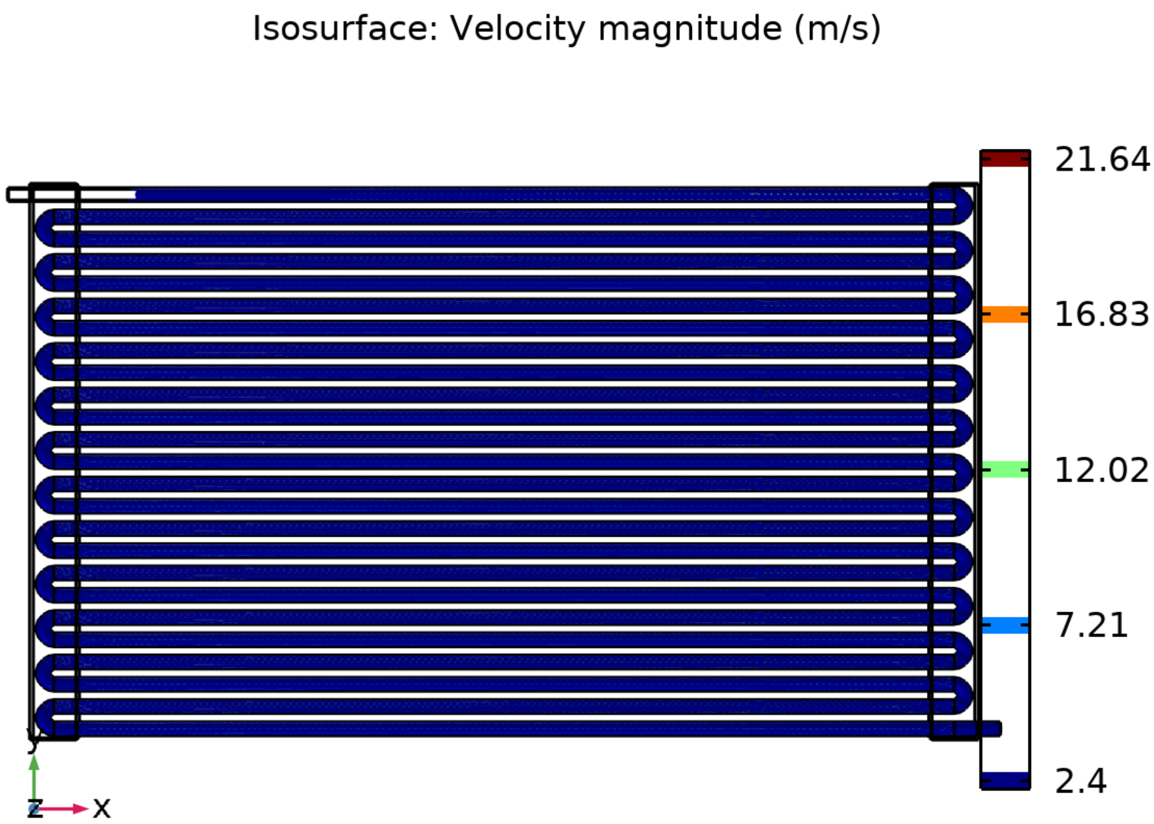
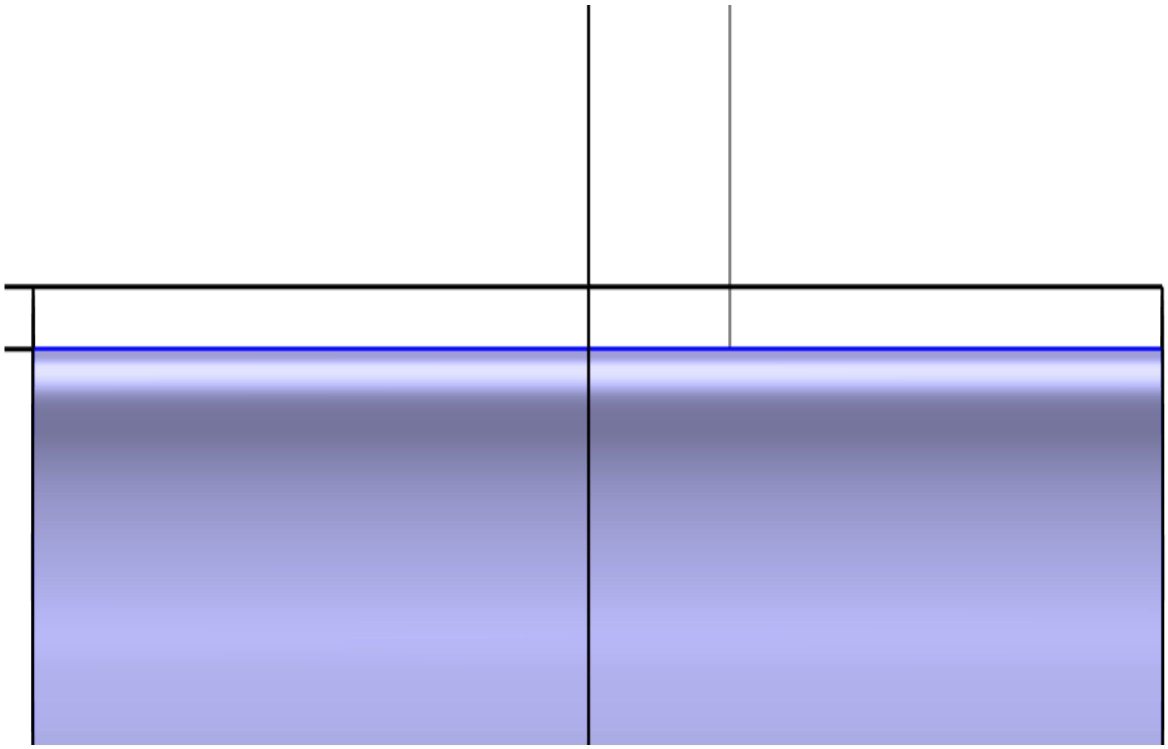


Fig: H20(water) [Liquid]

The figure below is showing the close look of a single pipe.

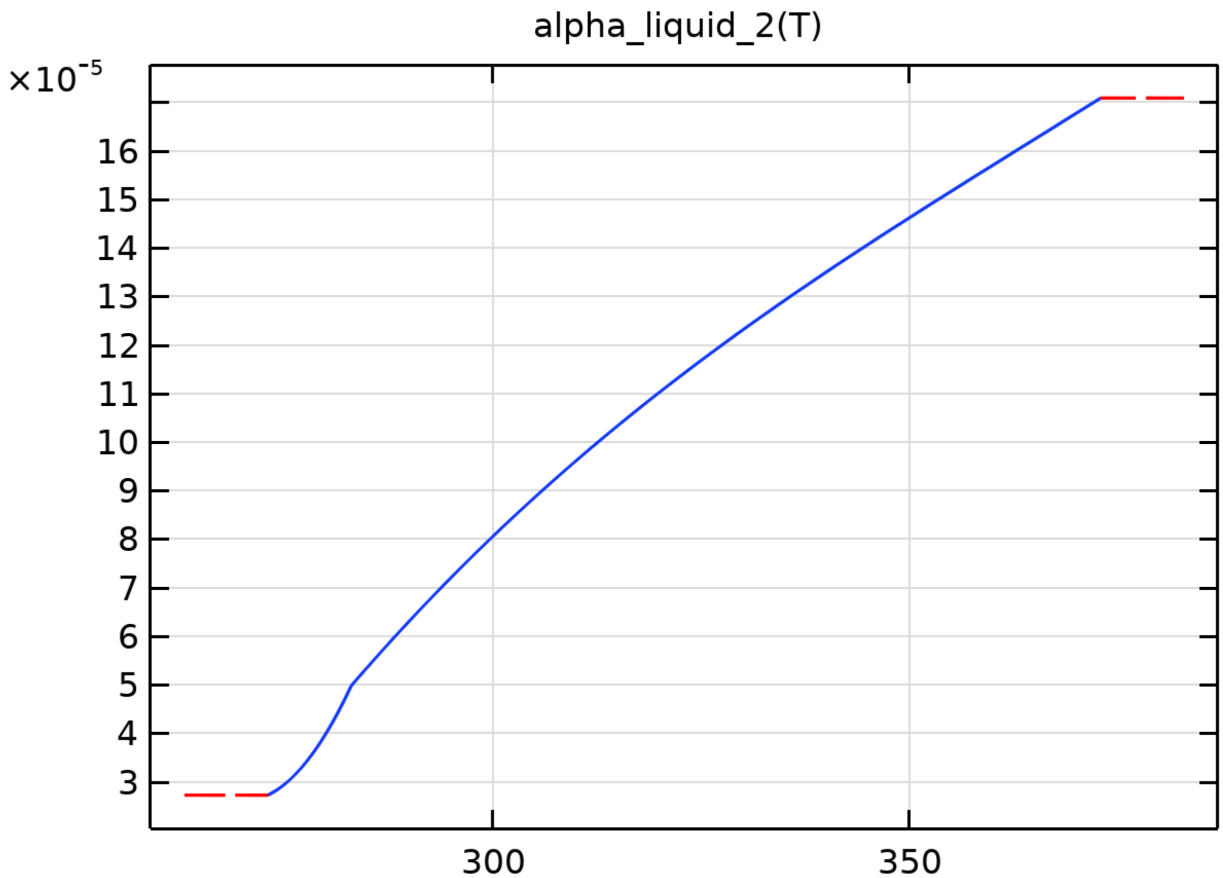


H20(Water)[Liquid]

Water was used as the heat transfer medium as it has a very high heat transfer effectiveness, however it doesn’t contain high heat transfer conduction as it may evaporate easily at any temperature above 100 degrees Celsius. Moreover, for this experiment, water was found to be the most perfect heat transfer medium to be used.

Piecewise

Description: The figure below is the variation of the alpha liquid contain in the mixture of the nanofluid. Before 100 on the variation, the curve is not straight then after the curve become straight line till the infinity.



Boundary Layer partially presented, Turbulence is reduced by laminar fluid flow, but it is encouraged by turbulent fluid flow.

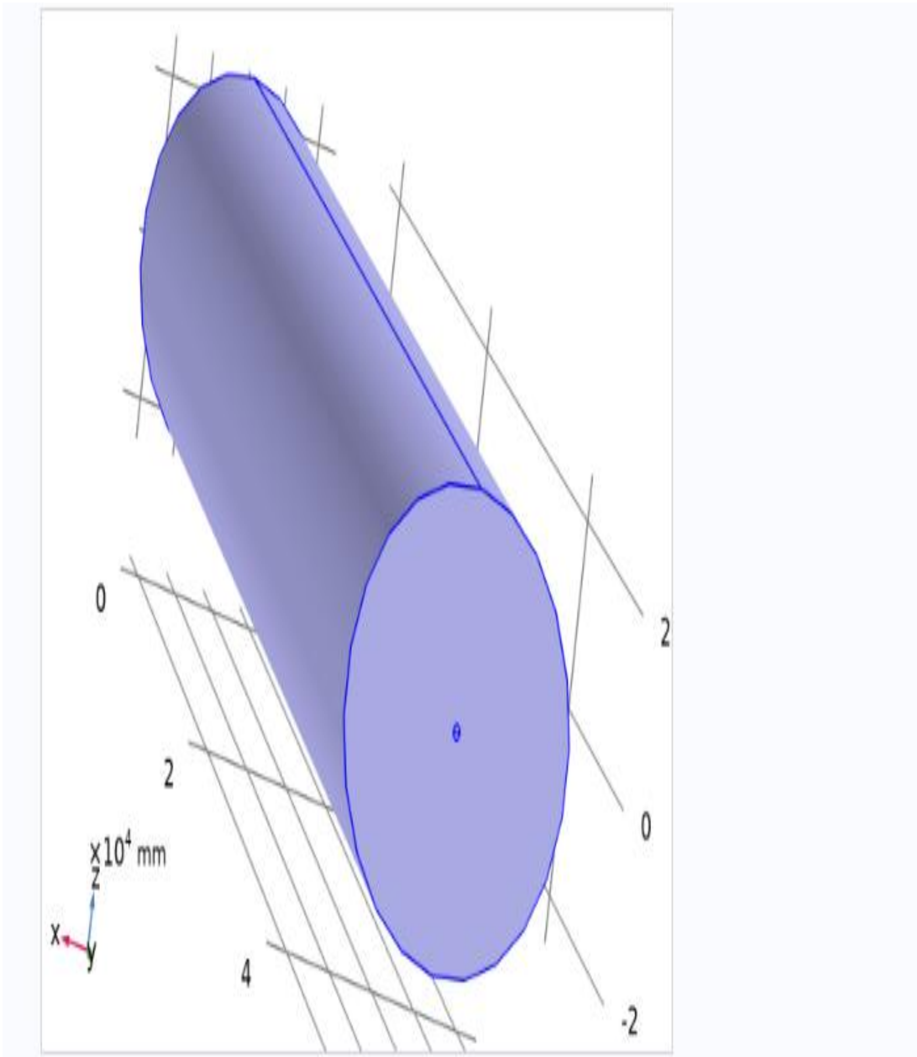
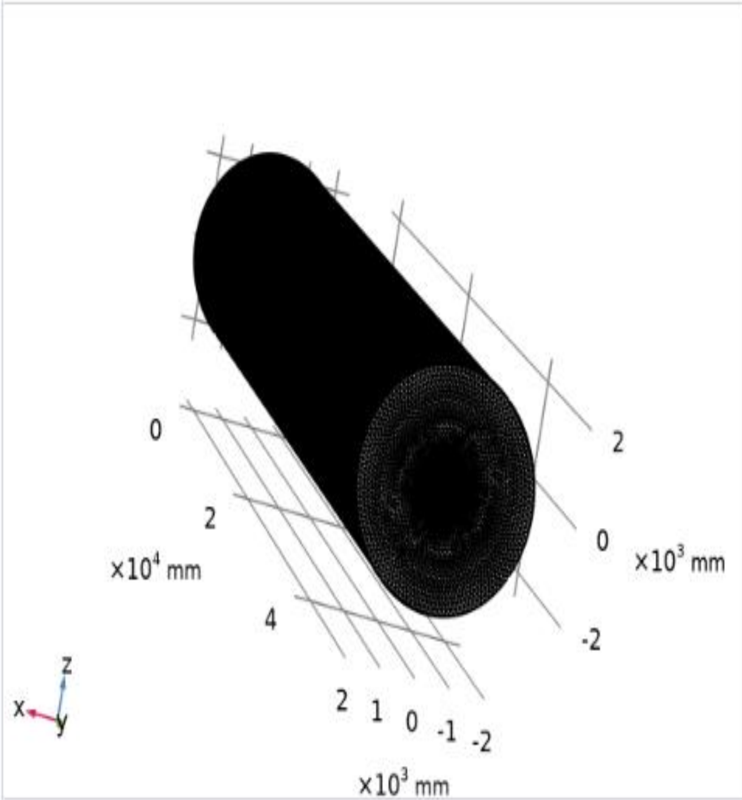


Figure: boundary layer In comparison to coarser meshes, finer meshes suggest improved load distribution inside the unit. This idea is particularly interesting and necessary for the mesh within the loading region, and even a coarser mesh is sufficient away from the loading.


0
2
×10⁴ mm
4
2
0
×10³ mm
-2
2 1 0 -1 -2
×10³ mm
z
x
y

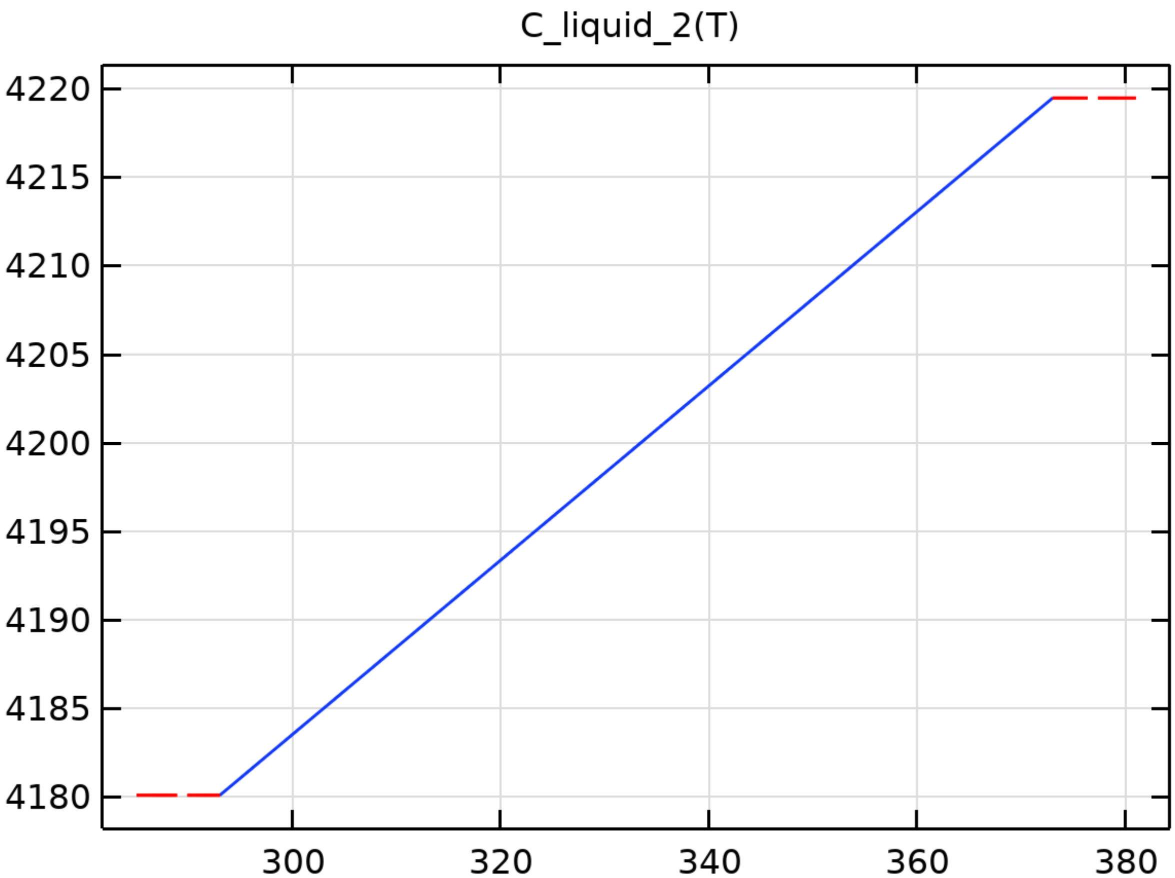


Fig: Water Velocity of (0.5) m/s

Boundary value issues are crucial because they mimic a wide range of processes and uses, including solid mechanics, heat transfer.

The figure below describe the water temperature distribution at different flow velocity.

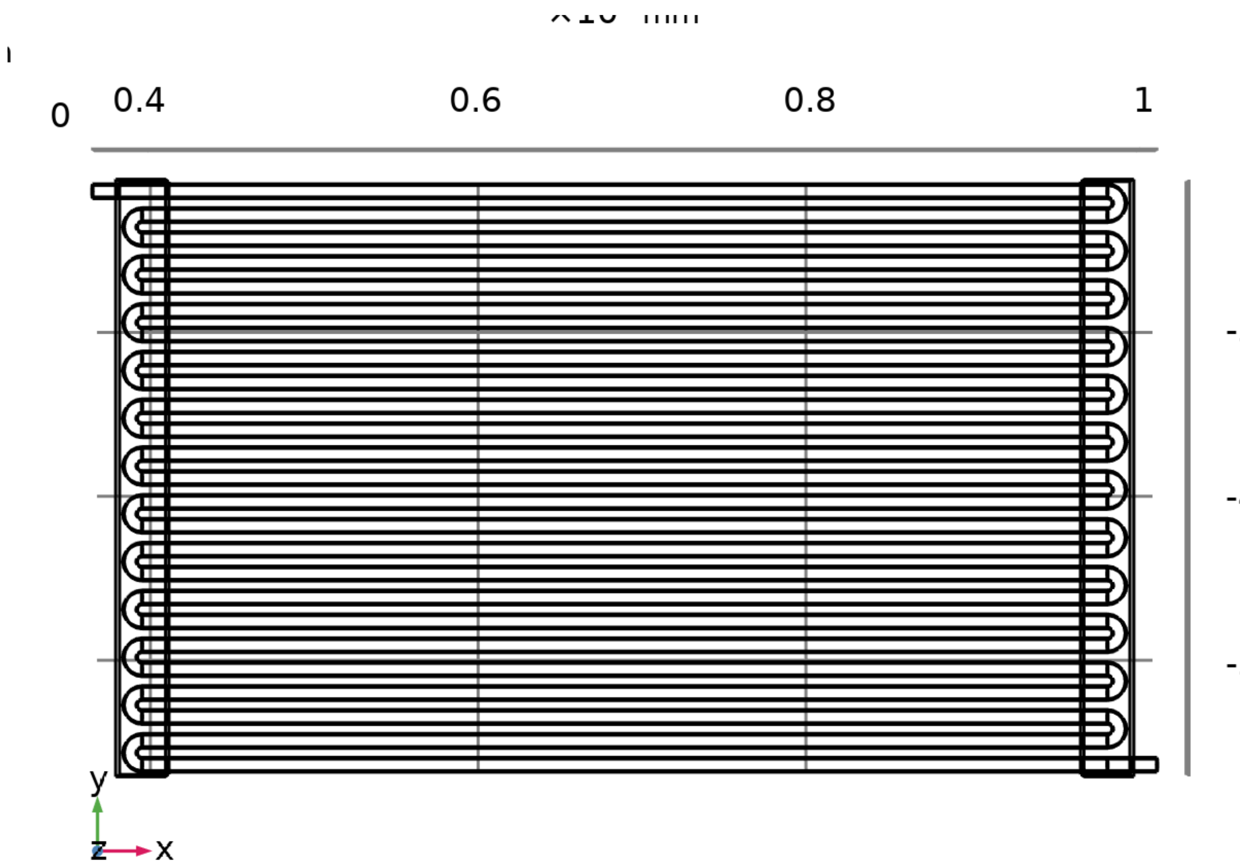


Fig: Water temperature distribution comparison at different flow velocities for the tube

The figure below shows the variation of the velocity, at the inlet it has started with a velocity of 0.2m/s and following a curvature similar to the square function shape.

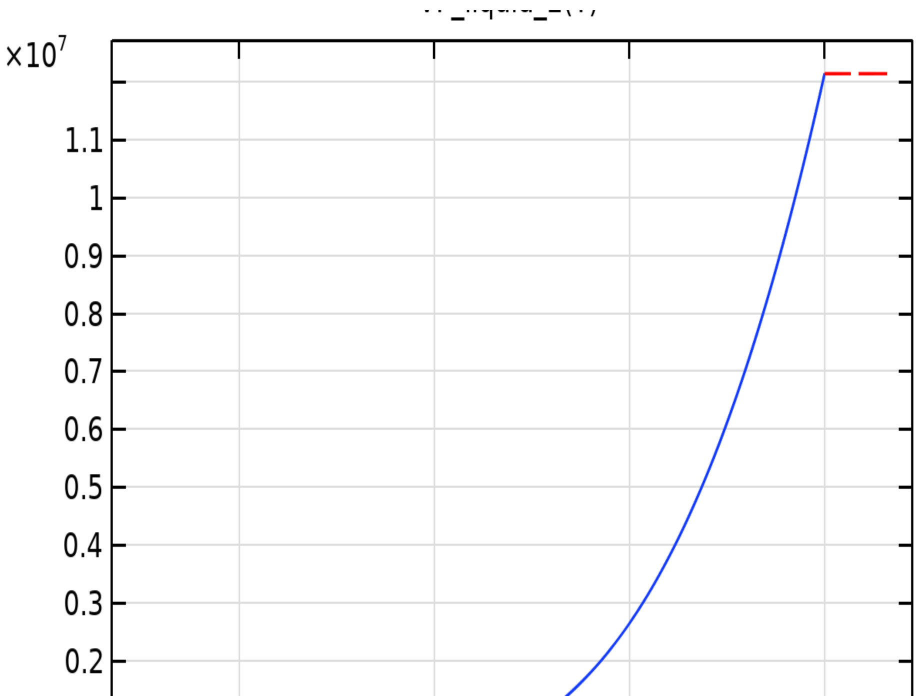


Fig : Water Velocity of (0.2) m/s

Description: The figure below is the variation of the alpha liquid contain in the mixture of the nanofluid. Here the variation of the alpha-liquid is a straight line.

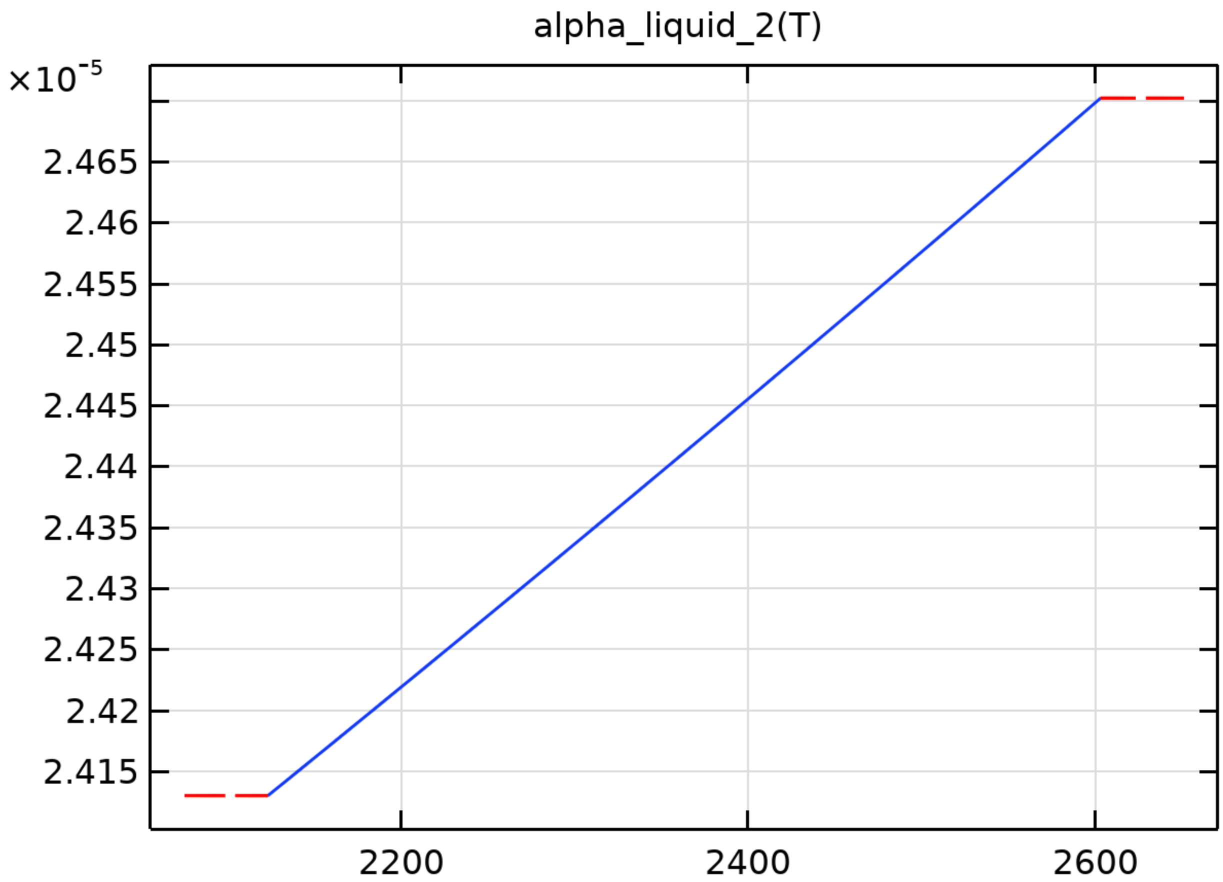


Fig 3.12c: Water Velocity of (0.4) m/s

Chapter 4

4.1 CONCLUSION

. In summary, most scholars have focused on the influence of radiator shutter thickness, spacing, height, width, and angle on the effects of the heat dissipation system. However, there is no systematic study on the influence of the number of tubes on the heat dissipation performance. Therefore, the number of tubes is set as the research object, the influence law of the of the number of tubes for the heat transfer performance of the radiator was analyzed. In this study we found that with the variation of the number of the tube, the radiator performance decrease two point five percent (2.5%) each. At 30 pipes we got the performance of 79.5 %, then decrease, 77.5%, again to 75.5%, then 73.5%, and finally to 71.5 %.

4.2 Recommendations

We've concluded that the heat performance of our radiator decrease by 2.5 % by decreasing five tube. Hence the technology is moving rapidly towards nano technology, this 2.5% is a great performance. Because it decrease considerably the weight of the radiator. And it will the decrease the weight of the vehicle. When the vehicle is light the car engine will required little energy to its own weight and indirectly with a little of energy we safe fuel burning in the combustion chamber of the radiator. In the future study, engineers can focus on the length and width of the radiator. Because the length and the width of the radiator affect considerably the weight of the radiator and indirectly the weight of car.

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