

DESIGN AND ANALYSIS OF RADIATOR COOLANT OIL CIRCULATION IMPROVEMENT SYSTEM

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Mechanical Engineering

BY

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DEPARTMENT OF MECHANICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

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March - 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KARUNAKARAN R (37150094)** and **SRIRAM PRASHATH M (37150710)** who carried out the project entitled "DESIGN AND ANALYSIS OF RADIATOR COOLANT OIL CIRCULATION IMPROVEMENT SYSTEM" under my supervision of from October 2020 to March 2021.

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DECLARATION

We **KARUNAKARAN R (Reg. No.37150094)** and **SRIRAM PRASHATH M (37150710)** hereby declare that the Project Report entitled “**DESIGN AND ANALYSIS OF RADIATOR COOLANT OIL CIRCULATION IMPROVEMENT SYSTEM**” done under the guidance of **Dr. S. P. VENKATESAN, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 17.04.2021

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Cooling System assumes significant part to control the temperature off's motor. One of the significant parts in vehicle in cooling framework is the radiator. To escalate heat, move with least siphoning power inventive warmth move liquids called nanofluid have become the significant space of examination now a days. Hence, with the advancement of new innovation in the field of 'nano-material' and 'nano-liquid', it appears to proficiency utilize these advances in vehicle radiators to improve motors effectiveness, lessen weight of vehicle and size of radiator. In this paper, constrained convective warmth move in an Al and SiC based nanofluid has tentatively been contrasted with that of unadulterated water in a vehicle radiator. The nanofluid is blended in with ethylene glycol and the liquid is set up by sonication strategy. Various measures of nanoparticle have been added into these base liquids and its impacts on the warmth move execution of the radiator have been investigation done utilizing ANSYS FLUENT programming.

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LIST OF SYMBOLS AND ABBREVIATIONS

Al_2O_3	Aluminum Oxide
CNT	Carbon Nano tubes
CuO	Copper Oxide
CFD	Computational Fluid Dynamics
EG	Ethylene Glycol
Fe_3O_4	Iron Oxide
H_2O	Water
SiC	Silicon Carbide
SiO_2	Silicon Oxide
TiO_2	Titanium Oxide
UV	Ultra Violet

CHAPTER 1

INTRODUCTION

Modern Current car interior ignition motors produce a colossal measure of warmth. This glow is made when the fuel and air blend is lit in the consuming chamber. This impact causes the chamber to be obliged down inside the engine and makes power. Metal temperatures around the start chamber can outperform 1000° F. Out of this made warmth around 31-35% of the glow in start is changed over into capacity to drive the vehicle and its additional items. Another 36-40% of the glow is removed into the climate through the exhaust structure. The extra 35-40% ought to be taken out from the engine by the cooling structure to prevent the overheating of the engine oil, chamber dividers, chambers, valves, and various fragments by these breaking point temperatures, it is essential to feasibly mastermind this glow. Nevertheless, on occasion this glow can't be satisfactorily killed as a result of inefficient arrangement of radiator. This issue has been thought about for our endeavor work. Furthermore, superfluous cooling system cutoff can in like manner be destructive, and may impact engine life and execution. So our authoritative point is to examination an incredible coolant of nanofluids which controls the engine temperature inside a specific reach so engine stays inside top execution.

Radiators, additionally called heat exchangers are utilized to move heat starting with one medium then onto the next with the sole reason for cooling and warming. Vehicle radiator is by and large used to chill off the car motor that is utilized in bikes. In the event that this isn't achieving as expected, different inconveniences like thumping, cylinder distortion, and chamber misshaping and so forth happen in the framework. In the event that the radiator capacities appropriately, the cooling framework would work appropriately and consequently the motor execution would improve enormously. It has been seen that in inward ignition motors, the coolant is for the most part water-based just as likewise oil based. A water siphon is utilized to constrain the motor coolant to course, just as for a pivotal fan to drive air through the radiator. In this way an improvement interaction gets important to accomplish the best plan including best

execution, size, shape, and cost just as its viability. The blend of fuel and air is utilized for burning cycle in a motor of the car. It has been noticed that of the complete force that is created, just a part of the absolute produced power is really provided to the vehicle and the excess gets squandered as fumes gas and warmth. Yet, on the off chance that this overabundance heat isn't launched out from the motor, the motor temperature would ascend too high bringing about overheating of the motor. This additionally prompts issues like reduction in consistency of the greasing up oil, debilitating of the overheated motor (metal) parts, and expansion in pressure between the motor parts bringing about speedier wear of different motor parts. Thus a cooling framework gets essential here to eliminate this abundance heat delivered in the motor. Major car cooling frameworks chiefly involves different parts like radiator, water siphon, electric cooling fan, radiator pressure cap, and indoor regulator. Of every one of these segments, the radiator is the most noticeable piece of the framework as it is the one to move heat from the motor. The most widely recognized material utilized in the assembling of the radiator is aluminum and the most well-known sort of game plan utilized is that of the cross-stream kind of plan. The most broad coolant is the utilization of two working liquids, by and large air and coolant. As the air begins moving through the car radiator, the warmth gets moved from the coolant to the air. The principle motivation behind the air is to kill the warmth from the coolant, which thus makes the coolant leave the radiator at a very lower temperature than it entered at. In this current radiator plan, a typical course of action is utilized having equal cylinders on which aluminum balances are joined on them. These plans incorporate fundamental three methods of warmth move for example conduction between tube dividers and balances, and two methods of convection. Of these, one method of convection is because of the coolant moving through the cylinders and the subsequent one is brought about by the air coursing through the radiator. Among these we have related with each kind of warmth move, a warm opposition which thwarts the warmth move rate. It has been noticed that radiators of different cross-area are accessible on the lookout and these are utilized relying upon the boundaries like viability, material necessity, cost, kind of coolant included and so on Subsequently through different tests it has been noticed that roundabout cross-segment of radiator

requires least material when contrasted with different other cross-areas. Here this plan for the most part centers around the radiator having round cross-area and having tubes comprised of aluminum. The round cross-segment of radiator requires least material just as the issues of pressure fixation additionally get addressed.

1.1 Cooling System:

The cooling mechanism consists of the square and heads inside the engine, a water guide to circulate the coolant, an indoor controller to regulate the coolant's temperature, a radiator to cool the coolant, a radiator cap to control the system's squeezing factor, and a few lines for interconnecting hoses to transfer the coolant from the engine to the radiator and beyond to the vehicle's cooling system. Hotter system where hot coolant is used to warm up the vehicle's inside on a cold day.

Fundamentally, there are two sorts of cooling frameworks which are as per the following: 1. Air cooling framework 2. Fluid or Water-cooling framework is most broadly utilized in vehicles because of high cooling rate.

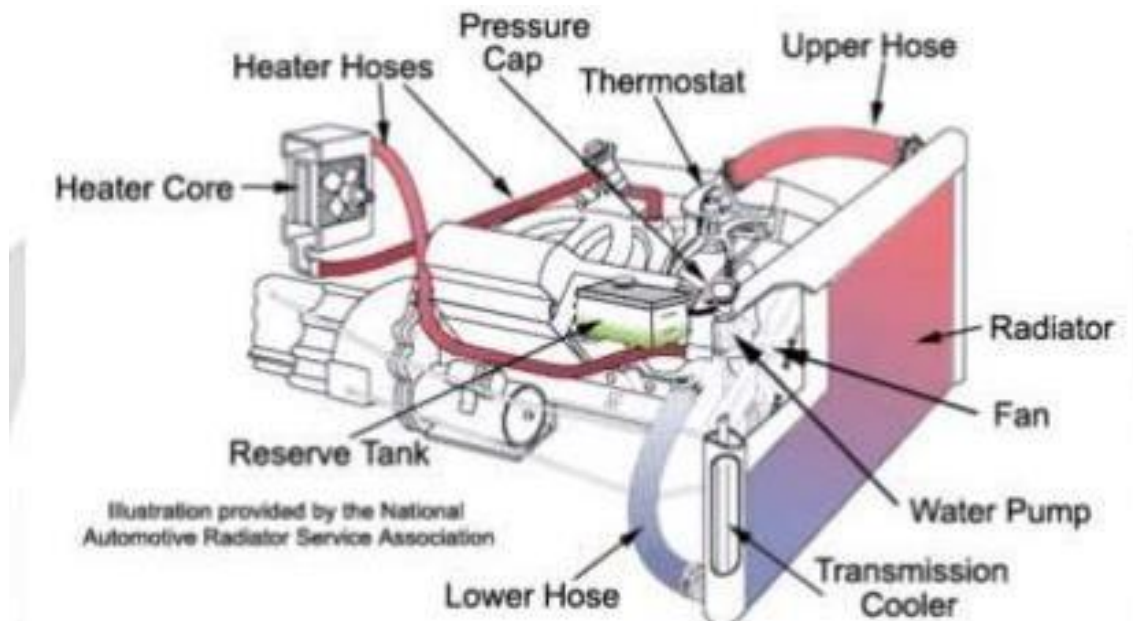
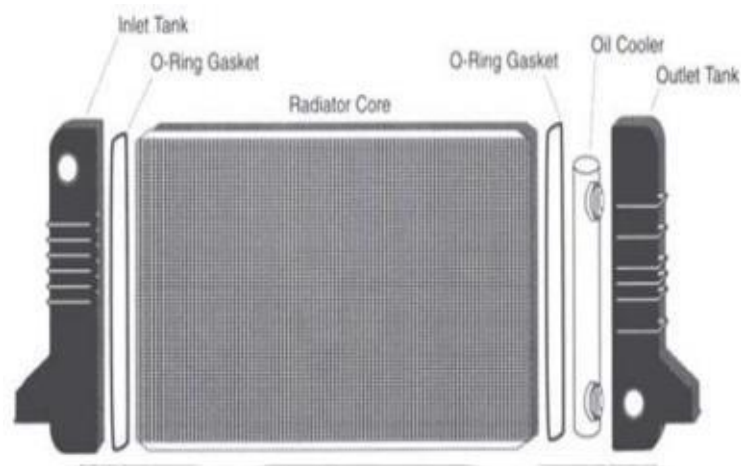


Fig 1.1: Cooling System

1.1.1 Radiator:

The radiator is a major section of cooling structure. It is a contraption planned to scatter the glow which the coolant has ingested from the engine during its stream. It is created to hold a great deal of water in tubes which outfit a colossal domain in contact with the air. It regularly contains a radiator community, with its water-passing on chambers and huge cooling an area, which are related with a getting tank (end cap) at the top and to an allocating tank at the base. Side stream radiators have their "end covers" on the sides, which grant a lower hood line. In movement, water is directed from the engine to the top (getting) tank, where it spreads over the most noteworthy places of the chambers. As the water goes down through the chambers, it loses its glow to the airstream which passes around the outside of the chambers when vehicle is continuing ahead a road the plastic tank on either side. On various vehicles, the chambers run vertically with the tank on the top and base. On more prepared vehicles, the middle was made of copper and the tanks were metal. The new aluminum-plastic structure is extensively more capable and traditionalist to manufacture. On radiators with plastic end covers, there are gaskets between the aluminum community and the plastic tanks to seal the structure and keep the fluid away from pouring out.

Fig: 1.2 Radiator



Radiators can be constructed with the tanks at the top and bottom of the core or on the sides. On the basis of these, radiators are classified as:

1.1.1.1 Down flow Radiator:

If the tanks are at the top and bottom, it is the Down flow radiator. In this radiator, the tubes are arranged vertically and the coolant flows from top to bottom.

1.1.1.2 Cross flow Radiator:

If the tanks are at the sides, then it is the Cross flow radiator. In this radiator, the tubes are arranged horizontally and the coolant flows across the radiator from one tank to other.

1.2 Circulation system

It refers to the system used to circulate the coolant through the cooling circuit. The coolant is expected to take away the heat generated in the cylinder from the cooling jacket and reject that heat to the radiator tubes, from where it is transferred to the ambient air through fins. To ensure the close cycle reusability of the coolant it is repeatedly transported to and from cooling jacket (and radiator). This can either be done through natural circulation (thermosyphon) due to density difference between hot and cold fluid or by forced circulation by a fluid pump. To meet varied cooling requirements at different loads and speed conditions a flow control valve is installed.

- Radiator
- Connecting hoses
- Water jacket
- Recirculation pump
- Radiator fan
- Flow control valve

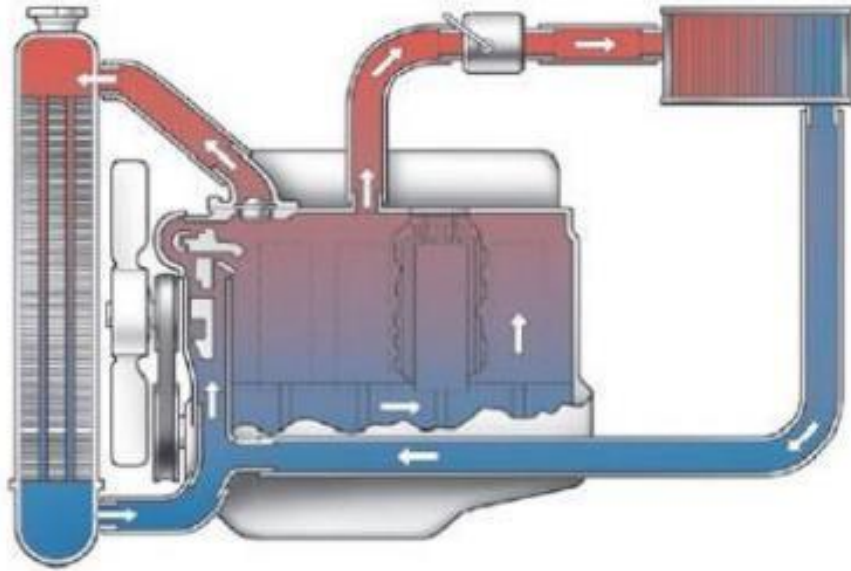


Fig 1.3: Circulation system

1.2.1 Automotive Radiator

Radiator is a device used in heat exchange applications to transfer heat from one fluid medium to another. In construction and working it is not different than any other heat exchanger. The main constructional features of automotive radiator are as follows:

- Inlet hose and reservoir
- Coolant carrying metallic tubes
- Outlet hose and reservoir
- Overflow valve
- Pressure release valve

Radiators are installed in such locations where they are exposed to maximum ambient air for maximum efficiency. Parallel tube radiators are most commonly used automotive radiators because of simplistic design, less initial and maintenance cost, long life and simple working. Smaller engines use thermo syphon (natural circulation) system but

bigger and high rated engines have to use forced circulation pump. The flow rate through the cooling circuit can be varied either manually or by thermostatic valve.

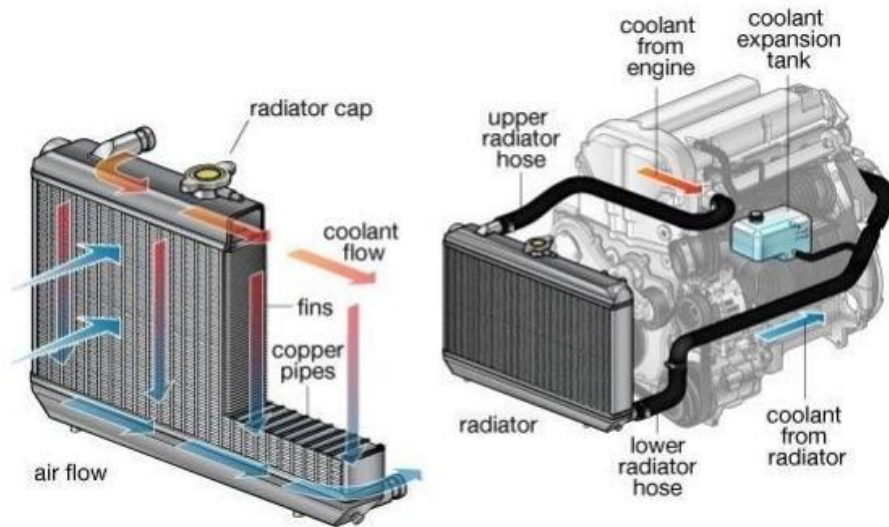


Fig: 1.4 Automotive Radiator

The automotive radiator can be in vertical tube or horizontal tube arrangement. The vertical tube arrangement allows coolant to flow in downward direction as it cools down. This allows for natural circulation of coolant hence these are typically used for thermo syphon systems. The coolant flows in horizontal direction in horizontal tube arrangement. It requires an external circulation pump for coolant flow. More controlled flow is possible in case of the latter. For sufficiently large stationary engines vertical tube radiators with recirculation pump are used with a fan for radiator air flow

1.2.2 Connecting hoses:

These are synthetic rubber based flexible pipes of suitable diameter and length. These connect the water jacket with radiator and coolant pump and maintain a closed system. The hoses are connected to above mentioned components with the help of hose clamps. The recently developed nylon based hoses are more durable and capable of bearing higher temperatures. The hoses are reinforced by polymer fibers to ensure high pressure and temperature bearing properties



Fig :1.5 Connecting hoses

1.2.3 Recirculation pump

It is used in forced circulation systems for recirculating the coolant in the cooling circuit. The pump is a typical centrifugal pump and is generally driven by a belt running through pulley attached to crankshaft. A v-belt is used to drive the pump pulley. The speed of pump depends on the speed of the engine, hence at higher speeds the coolant flow rate is higher and air flow velocity through radiator is also higher. This allows more heat to be taken away from the engine. In constant speed engines like used in power generation, the engine speed has to be kept constant. In India electricity is generated at 50 Hz, so a 4 pole alternator is required to run at 1500 RPM at all loads. This is achieved by governor controlled fuel flow. In such engines the crank driven pump will have same flow rate at all loads, hence the coolant temperature varies in accordance with load on engine. The jacket coolant outlet temperature varies almost linearly with load

1.2.4 Radiator Fan

In stationary engines or in automobile at rest there is negligible air flow across the radiator. This may result in overheating of the engine. To avoid this problem an air circulation fan is installed in front of radiator to ensure air flow across the radiator in all conditions. In stationary engines the fan is attached to the coolant pump pulley and it rotates at the pump speed. The belt connecting pump pulley and crank pulley is often called "fan belt". Modern automotive engines with horizontal radiator tube arrangement have an electric radiator fan. It only works when required i.e. when vehicle is stationary



Fig: 1.6 Radiator Fan

1.2.5 Flow control valve and pressure release valve:

These valves are installed in cooling system to ensure safety of the components. Flow control valve is fitted in coolant circuit typically at jacket coolant outlet. This valve opens and flow starts when engine has reached a predefined operating temperature. This ensures a quick engine warm up.

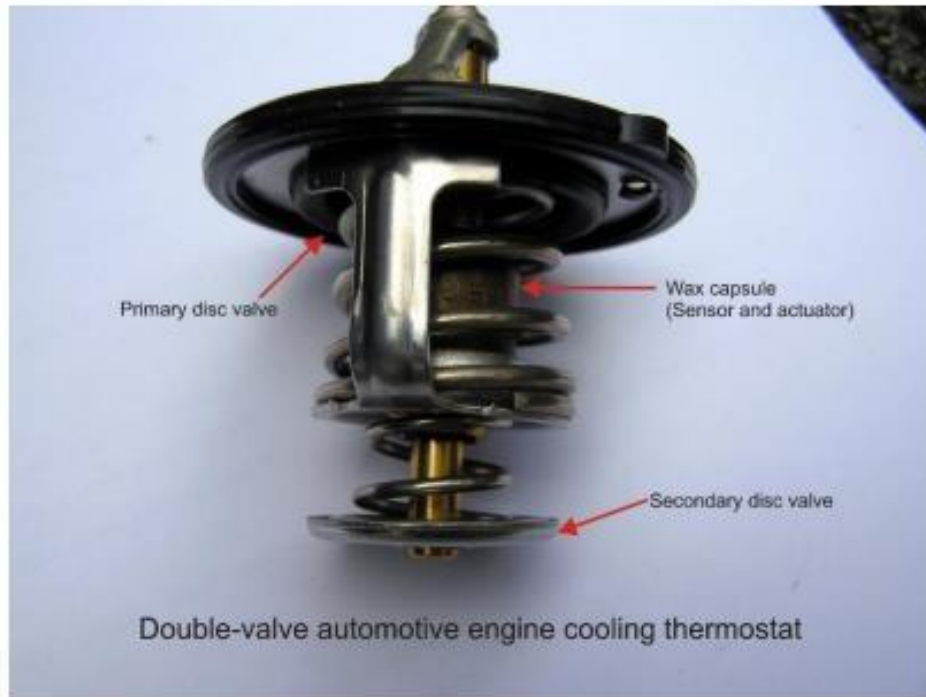


Fig : 1.7 Thermostat

Pressure release valve is typically integrated with radiator cap. When coolant becomes hotter it tends to expand, but is not allowed to do so due to non-flexible components. Therefore, the pressure in the system rises which can damage the coolant flow circuit. To release this excess pressure, a pressure actuated release valve opens to allow excess coolant to escape through drain pipe and pressure of the system retain previous values. The operation and principle is similar to pressure cooker.

In order to improve the performance of automotive radiators some kind of improvements in design or optimization in operating parameters are necessary so that overall efficiency can be increased. Parameters which affect the performance of radiator are:

- Working fluid
- Flow rate of fluid
- Air flow available in front of radiator
- Ambient air conditions

1.3 Advantage and limitations of radiator cooling

- Better temperature control
- Overall smaller system dimensions
- Easier to monitor the operating temperatures
- Take less time to attain a optimum temperature

Limitations

- Higher initial cost
- More chances of leakage.
- More component wear and tear.

1.4 Nano-fluids

It refers to a class of nano-sized metallic and non-metallic particles mixed in a liquid medium as colloidal solutions. The particle size (diameter) usually lies in the range of 5 nm to 150 nm. The metals and their oxides are most widely used in nano-fluid preparation. Some non-metallic materials for nano-fluid preparation are diamond, plastic, and CNT (carbon nanotubes). CNT is found to have superior thermal

properties in the entire material catalogue available, but its use usually limited due to higher cost. Preparation of nanoparticles is usually done by crushing at very low temperatures but the particle size is limited to 100nm. Newer methods like chemical and physical vapor deposition, electrochemical methods results in much smaller particle sizes. The morphology may be spherical, cylindrical or irregular shape. The spherical particles are most commonly found.

1.5 Nano-fluid preparation

1.5.1 One step method

The single-step readiness measure shows the amalgamation of nano-liquids in one-venture. A few single-step techniques have been created for nano-liquid arrangement. A reasonable force source is needed to deliver an electric curve between 6000-120000°C which dissolves and disintegrates a metal bar in the area where circular segment is made. The disintegrated metal is dense and afterward scattered by deionized water to deliver nano-liquids. A benefit of one-venture combination technique is that nanoparticle agglomeration is limited. However, primary issue is that solitary low fume pressure liquids are viable with such a cycle..

1.5.2 Two step method

Two-step method measure is broadly utilized in the blend of nano-liquids by blending base liquids in with economically accessible nano powders got from various mechanical, physical and compound courses like processing, granulating, and sol-gel and fume stage techniques. A ultrasonic vibrator or higher shear blending gadget is for the most part used to mix nano powders with have liquids. The continuous utilization of ultra-sonication or mixing is needed to lessen molecule agglomeration. Combining carbon nanotube-based nano-liquids can also be done using a two-venture approach. Pyrolysis is used to produce single-walled and multi-walled carbon nanotubes, which are then suspended in base liquids with or without the use of surfactants. Since the powders essentially complete due to solid vandalism, dependability is a major issue innately associated with this operation. Van der Walls power among nanoparticles.

CHAPTER 2

LITERATURE SURVEY

Xuan et al. (2000) [1] proposed totally different techniques for preparing numerous nanofluids with numerous base liquids. They planned that the degree division, shape, measurements and properties of the nanoparticles influence the nice and cozy conduction of nanofluids. variety of[some|many} relationships with reference to Nusselt number has likewise been shown up at. The proportion of the nice and cozy conduction of the nanofluid to it of the bottom fluid shifts from one.24 to 1.78 if the degree a part of the ultrafine particles increments from two.5% to 7.5%.

S. Leong et al. [2] examined the exhibition of auto vehicle radiator worked with nanofluid based coolants. Ethylene glycol-based copper nanofluid is utilized for the investigation of warmth move attributes. The writers presumed that warmth move rate increments with expansion in nanoparticle focus; about 3.8% of warmth move upgrade was accomplished with expansion of 2% copper nanoparticles. It is additionally assessed that 18% of front facing territory can be decreased with option of 2% of copper nanoparticle into the coolant.

Mujumdar et al. (2006)[3] introduced an audit of warmth move attributes. The primary spotlight is on the job of convective warmth move in constrained and free convection conditions. They arranged hypothetical models for thickness and warm conductivity computations. They further proposed that molecule fluid collaboration and the development between the molecule and fluids assume significant parts in influencing the convective warmth move execution of nanofluids.

Minta et al. (2007)[4] They introduced the method of compelling warm conductivity estimations of alumina/water and copper oxide/water nanofluids. Impact of volume portion, temperature and molecule size was researched. Readings were taken at encompassing temperature just as over a moderately huge temperature range for different molecule volume divisions up to 9%.

Duangthongsuk et al. (2009) [5] They investigated the warm conductivity and consistency of TiO₂ nanofluid with volume obsession going from 0.2 to 2 %. A transient hot-wire gadget is used for assessing the warm conductivity of nanofluids however the Bohlin rotational rheometer (Malvern Instrument) is used to measure the consistency of nanofluids. The temperature extent of the test was 15 to 35°C. The results show that the conscious thickness and warm conductivity of nanofluids extended as the particle obsessions extended and are higher than the assessments of the base liquids. Warm conductivity of nanofluids extended with growing nanofluid temperatures and, then again, the thickness of nanofluids reduced with extending temperature of nanofluids. The conscious warm conductivity and thickness of nanofluids are not equivalent to the expected characteristics from the current associations and the data uncovered by various subject matter experts. The new thermo real connections are proposed for expecting the warm conductivity and consistency of nanofluids..

Chen et al. (2009) [6] A strategy is proposed for foreseeing the successful warm conductivity of weaken suspensions of nanoparticles (nanofluids) in light of rheology. This strategy utilizes the rheological information to surmise microstructures of nanoparticles quantitatively. It was then joined into the Hamilton–Crosser condition to anticipate the viable warm conductivity. The procedure is approved tentatively by utilizing four distinctive sort of nanofluids made of TiO₂ nanoparticles and titanate nanotubes scattered in water and ethylene glycol. It is reasoned that the adjusted Hamilton–Crosser condition effectively anticipated the compelling warm conductivity of the nanofluids.

Wen et al. (2009) [7] This of examination on heat move uses of nanofluids to distinguish the paper presents basic audit restricting variables in order to push forward their further turn of events. They contended that most momentum research is as yet centered around warm conductivity, disregarding the modification of different properties by nanofluids particularly consistency and surface properties. Impact on bubbling warmth move has additionally been examined. An inside and out comprehension of the cooperation's between particles, stabilizers, the suspending

fluid and the warming surface will be significant for applications. Between disciplinary cooperation among nanomaterials, colloid science, physical science and designing scientists will be important to design appropriate nanofluids and speed up their applications.

Sundar et al. (2013) [8] Trial examinations and hypothetical assurance of successful warm conductivity and thickness of attractive Fe₃O₄-water nanofluid were accounted for in this paper. The nanofluid was set up by combining Fe₃O₄ nanoparticles utilizing the substance precipitation strategy, and afterward scattered in refined water utilizing a sonicator. The two examinations were directed in the volume fixation range 0.0% to 2.0% and the temperature range 20 °C to 60 °C. The warm conductivity and thickness of the nanofluid were expanded with an expansion in the molecule volume fixation. Straightforward connections were created for the assessment of warm conductivity and consistency by considering molecule volume focus and temperature dependent on the test information.

Farooky et al. (2013) [9] Warm conductivity of ethylene glycol and water blend based Al₂O₃ and CuO nanofluids has been evaluated probably at different volume obsessions and temperatures. The base fluid is a mix of 50:50% (by weight) of ethylene glycol and water (EG/W). The atom obsession up to 0.8% and temperature range from 15°C–50°C were considered. Both the nanofluids are showing higher warm conductivity appeared differently in relation to base fluid. Under same volume center and temperature, CuO nanofluid warm conductivity is more appeared differently in relation to Al₂O₃ nanofluid. Another association was made subject to the test data for the appraisal of warm conductivity of both the nanofluids.

Khedkar et al. (2014) [10] Warmth move attributes of TiO₂–water nanofluids as a coolant in concentric cylinder heat exchanger are introduced in this paper. The warmth exchanger is created from copper concentric internal cylinder with length 1 m. The nanofluid is the combination of water as base liquid and TiO₂ particles in nano size. The outcomes acquired from the nanofluids cooling in concentric cylinder heat exchanger are contrasted and those from base liquids (water) as coolant. Impacts of gulf stream pace of hot liquids, Reynold's number and arrangement of nanofluids on

concentric cylinder heat exchanger are thought of. It is seen that the normal warmth move rates for nanofluids as a cooling media are higher than those for the water which is additionally utilized as cooling media, and this increments with centralization of nanofluid piece. The consequences of this investigation have innovative significance for the productive plan of concentric cylinder heat exchanger to upgrade cooling execution at low warmth transition cooling frameworks.

Maddah et al. (2014) [11] They contemplated liquid progression of the Al_2O_3 nanofluid for a scope of Reynolds number (5000 to 21,000) with a scope of strong volume portion (0.2% to 0.9%).in a level twofold line heat exchanger fitted with altered bent tapes under violent stream conditions. The warm exhibitions of the warmth exchanger with nanofluid and altered curved tapes were assessed for the appraisal of generally speaking improvement in warm conduct. Summed up connections were created for the assessment of Nusselt number, erosion factor and warm execution factor under violent stream conditions. Acceptable arrangement between the current relationships and got exploratory information approve the proposed connections.

Experimental works on Radiators with Nanofluids

Sai Kiran. S et.al contrasted the consequences of CFD investigation and the trial results and discovered them to be in acceptable concurrence with one another. As per him, the Brownian movement of the nanoparticles assumes a fundamental part in progress in heat move pace of radiator. As the nanoparticles move haphazardly in the liquid it brings about the reduction of the limit layer thickness and along these lines improving the warmth move. It is seen that nanoparticle fixation assumes a significant part towards heat move improvement.

Hashem Abadi et al. (2011) [11] In this paper, the glow moves execution of unadulterated water and unadulterated EG has been differentiated and their matched mixes. In addition, different proportions of Al_2O_3 nanoparticle have been added into these base fluids and its effects on the glow move execution of the vehicle radiator have been settled likely. Liquid stream rate has been changed in the extent of 2–6 l every second and the fluid channel temperature has been changed for all of the tests.

The results show that nanofluids unquestionably improve heat move diverged from their own base fluid. In the best conditions, the glow move redesign of about 40% diverged from the base fluids has been recorded. Diminished radiator estimating has also been discussed.

Hussein et al. (2014) [12] In this paper, heat move improvement utilizing TiO₂ and SiO₂ Nano powders suspended in unadulterated water is introduced. The test course of action combines a vehicle radiator, and the consequences for heat move improvement under the working conditions are investigated under laminar stream conditions. The volume stream rate, inlet temperature and nanofluid volume fixation are in the degree of 2–8 lpm, 60–80 °C and 1–2% autonomously. The outcomes showed that the Nusselt number reached out with volume stream rate and perhaps stretched out with narrows temperature and nanofluid volume fixation. The descend into sin condition for input (volume stream rate, delta temperature and nanofluid volume focus) and reaction (Nusselt number) was found. The consequences of the evaluation showed that essential information cutoff points to overhaul heat move.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 Aim

This project aimed

Cooling framework assumes significant part to control the temperature off's motor. One of the significant parts in vehicle in cooling framework is the radiator. To reinforce heat, move with least siphoning power creative warmth move fluids called nanofluid have become the critical space of investigation now a days. To decrease overabundance of warmth from motor and to transmit heat from motor to the air around.

3.2 Scope

The Scope of the Project is to check the capability of coolant varying the debilitating levels. To keeps up the engine working temperature where it works most capably. To brings the engine up to the advantage working temperature as quick as could truly be considered typical.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 Methodology:

The model is made on solid works software in 3D. When model is made then it will easily import in ANSYS for further Analysis.

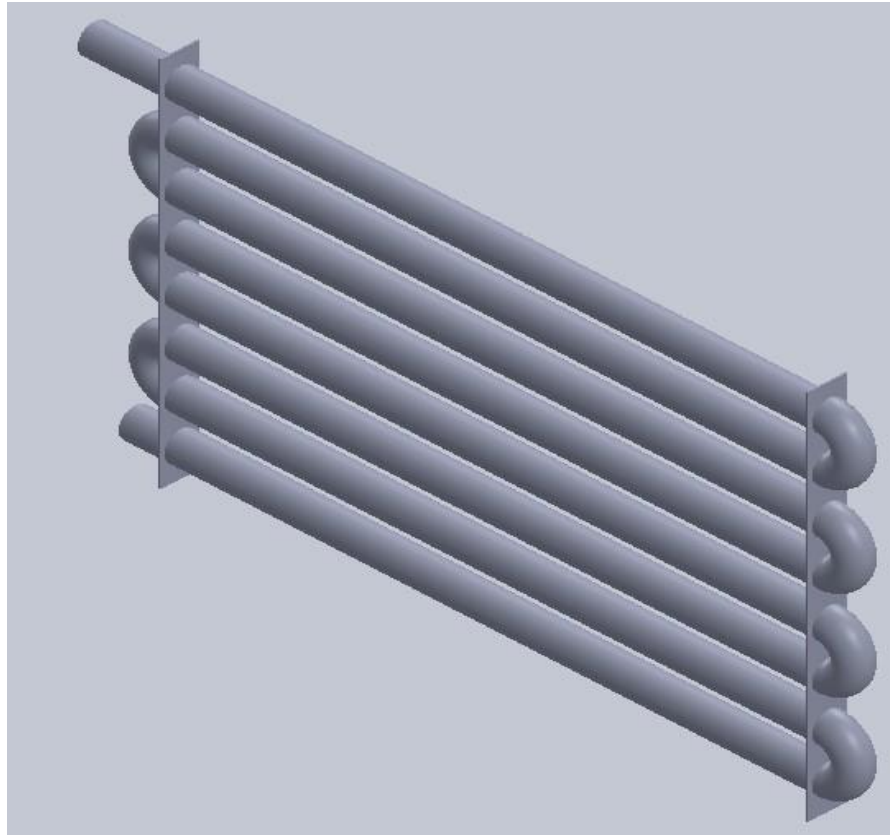


Fig: 4.1 Design of radiator

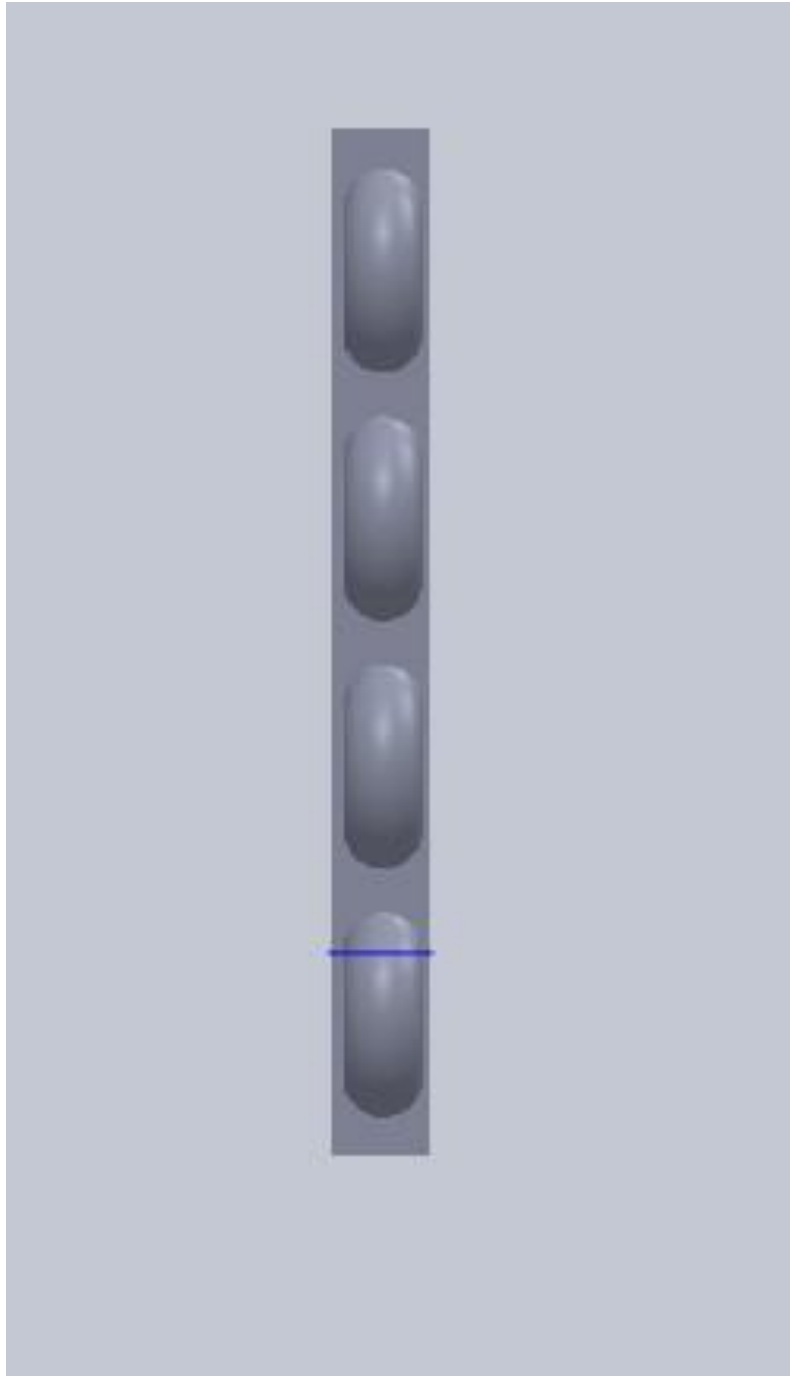


Fig :4.2 Side view of radiator model

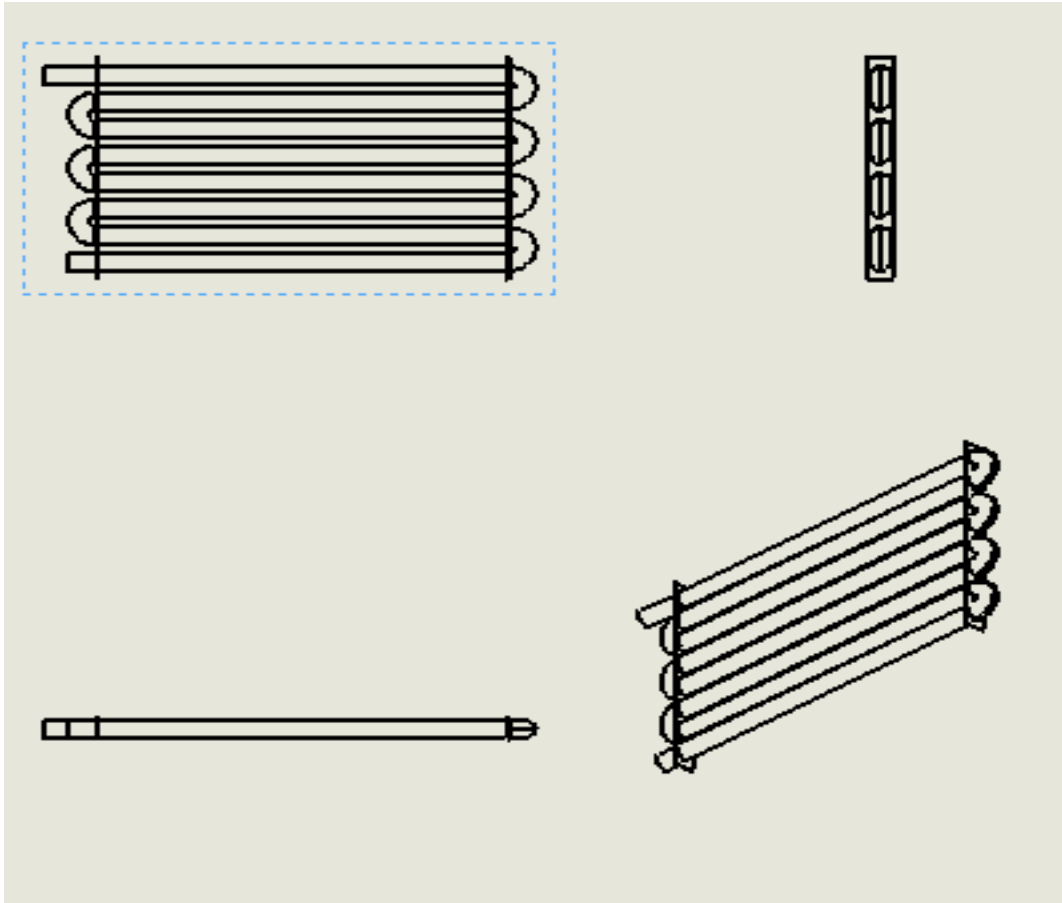


Fig :4.3 Drafting

4.2 Material used:

4.2.1 Aluminum Oxide (Al_2O_3):

Al_2O_3 is an electrical cover anyway has a by and large high warm conductivity for a creative material. Aluminum oxide is insoluble in water. In its most by and large happening clear construction, called corundum or α -aluminum oxide, its hardness makes it sensible for use as a harsh and as a section in cutting mechanical assemblies.

aluminum oxide is obligated for the opposition of metallic aluminum to continuing on. Metallic aluminum is responsive with biological oxygen, and a thin passivation layer of aluminum oxide structures on any uncovered aluminum surface in various picoseconds. This layer shields the metal from additional oxidation. The thickness and properties of this oxide layer can be upgraded utilizing an affiliation called anodizing. Various composites, for example, aluminum bronzes, abuse this property by reviewing a level of aluminum for the mix to improve deterioration block. The aluminum oxide made by anodizing is normally unclear, in any case release helped oxidation cycles, for example, plasma electrolytic oxidation accomplishes a colossal level of clear aluminum oxide in the covering, improving its hardness.

Properties:

Density	- 3.95 g/cm^3
Specific heat	- 500 j/kg-k
Thermal conductivity	- 3.85 w/m-k
Viscosity	- 3600 kg/m-s

4.2.2. Silicon Carbide (SiC):

Unadulterated SiC is characterless. The gritty hue to dull shade of the mechanical thing results from iron degradations. The rainbow-like gleam of the pearls is a result of the unstable film obstacle of a passivation layer of silicon dioxide that structures on a shallow level.

The high sublimation temperature of SiC makes it critical for coarse and hotter parts. Silicon carbide doesn't crumble at any known temperature. It is likewise altogether inert falsely. There is right by and by much interest in its use as a semiconductor material in contraptions, where its high warm conductivity, high electric field breakdown strength and high most essential stream thickness make it more consoling than silicon for staggering gadgets. SiC besides has an incredibly low coefficient of warm development and encounters no stage changes that would cause discontinuities in warm new development.

Properties:

Density	- 3.21 g/cm ³
Specific heat	- 510 j/kg-k
Thermal conductivity	- 3.8 w/m-k
Viscosity	-3000 kg/m-s

4.2.3. Ethylene glycol

Ethylene glycol, in addition called ethane-1,2-diol, the most un-complex individual from the glycol get-together of regular mixes. A glycol is a liquor with two hydroxyl packs on connecting carbon particles. The key name ethylene glycol from a certified viewpoint signifies "the glycol got from ethylene." Ethylene glycol is a certain, sweet, genuinely gooey fluid that ascends at 199 °C. Its most standard use is as a vehicle liquid force. A 1:1 strategy of ethylene glycol and water ascends at 130 °C and freezes at -38 °C, filling in as a baffling coolant in vehicle radiators. Ethylene glycol is fundamentally harmful; creatures or people that drink the arrangement become cleared out and may kick the bucket

Properties:

Density	- 1.12 g/cm ³
Specific heat	- 3100 J / kg
Thermal conductivity	- 0.258 w/m-k
Viscosity	-16.1 cP

4.3. Geometrical modeling:

First the math of the model is made in Solid works. Liquid stream (familiar) module is chosen from the workbench. The plan modeler opens as another window when the calculation is double tapped.

4.3.1. Sketching

Utilizing portraying choice three concentric circles are made in XY-plane in three unique representations. A straight line is likewise made in sketch 4 along the stature of the helical cylinder at the middle.

4.3.2. Sweep

By then the three circles were cleared about the central rotate with pitch 40 mm and number of turns is 1.5. From the beginning the mean circle distance across is 50mm and thereafter it is vacillated for different assessments of D/d. By then using Boolean action the covering volumes are deducted and singular stages were picked.

4.3.3. Merging

The model has 3 areas and 3 bodies after clear action. Thusly, all of the 3 areas are picked using control and changed over into 1 segment. At the end it will have 1 area and 3 bodies. The 3 bodies are named as follows:

1. Inlet fluid (fluid)
2. Thickness volume (solid)
3. Outlet fluid (fluid)

4.3.4. Dimensions:

4.1. Discriptions of the Solid works model

Material used	Aluminum
Coolant used	Ethylene glycol
Space between tubes	2.2cm
Length of the tube	2 cm
Thickness of the tube	0.3 cm
Tube length	40 cm
Number of fins	34
Additives	Aluminum oxide and Silicon Carbide

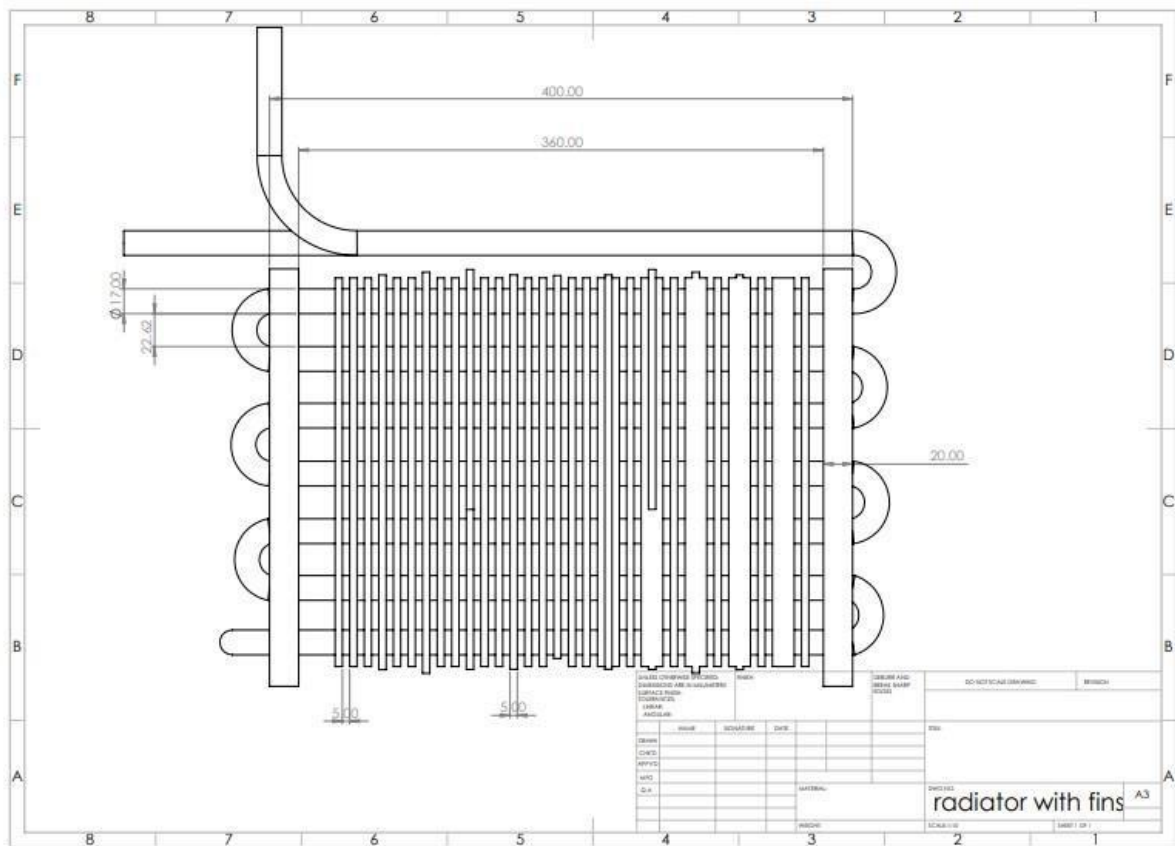


Fig :4.4: 2D View of Radiator

4.4 Model import to Ansys:

The model is made on solid works software in 3D. When model is made then it will easily import in ANSYS for further Analysis.

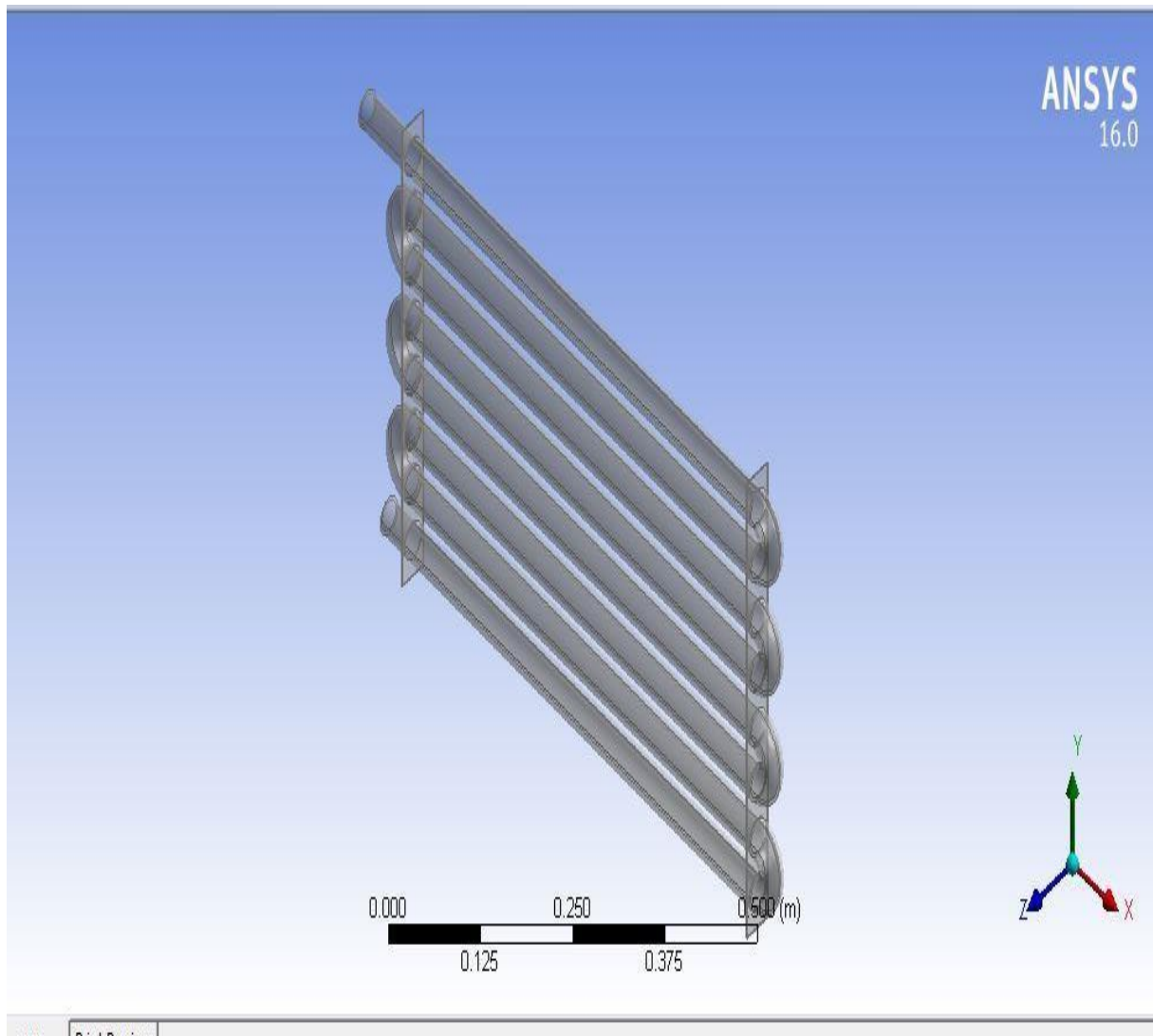


Fig: 4.5: Model of radiator

4.5. Meshing

Ensuing to naming the different zones and picking the reasonable, fitting sort, assessing and the sort of center, following cross segment was made. In free cross segment a for the most part coarser grid is delivered. It contains both tetrahedral and hexahedral cells having three-sided and quadrilateral faces at the cutoff points. Thereafter, a fine cross section is made using edge assessing. In this, the edges and regions of high squeezing element and temperature tendencies are finely fit.

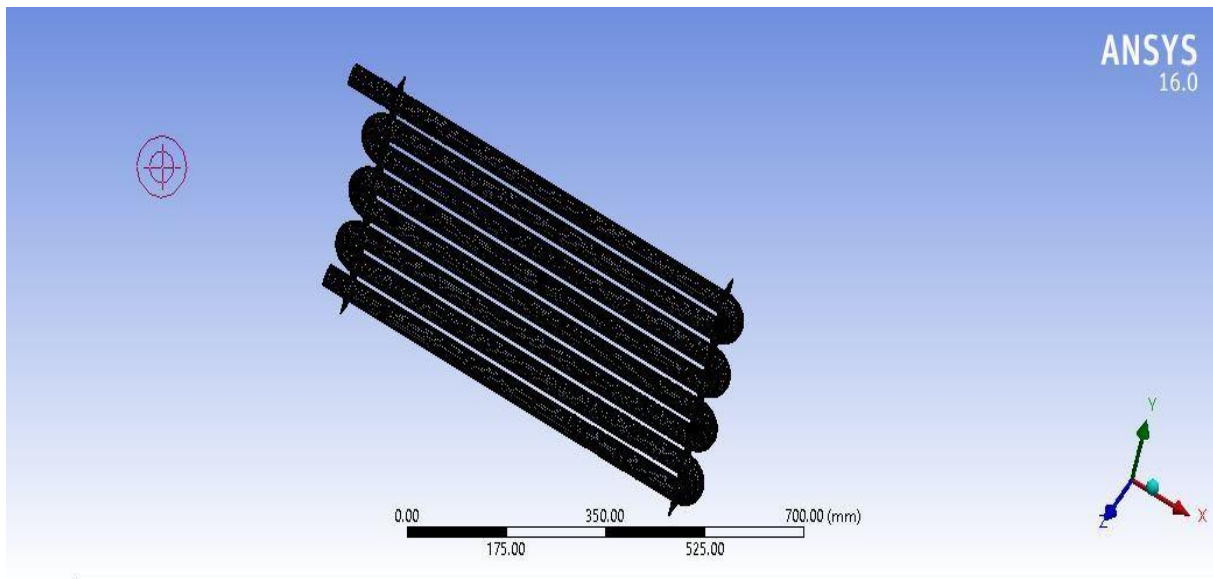


Fig :4.6 Meshing

4.6. Boundary Condition

Limit conditions were applied for different zones. Since it is a chamber in-tube heat exchanger, there are two deltas and two outlets. The channels were described as speed bays and outlets were portrayed as squeezing factor outlets. The force source pressures were saved default for instance pneumatic stress. The hot fluid temperature at channel was 670 C and cold fluid narrows temperature was kept 250 C. The other divider conditions were portrayed fittingly. The incorporating air temperature was kept 280 C and convective warmth move coefficient between outside divider and including was 2600W/m² K.

CHAPTER 5

RESULT AND DISCUSSION

5.1 CFD Analysis:

Utilizing computational liquid fantastic programming accessible to utilize like in Ansys. Diversion of the vehicle radiator is done. Utilizing nano liquids in the vehicle radiator, improved warm conductivity of the liquid is settled presumably to do the evaluation on the wonderful endeavors it cost more and time also gobbles up group. More space and work expected to do remotely and some different negatives seen. Nonetheless, programming assessment utilizing PC is helpful considering the way that, its decreased and less expense required showed up distinctively comparable to the reasonable work. Cutoff conditions, cycle respects, input respects, effectively factors in PC stood apart from supportive. where in exploratory it's limit to do tests over and over by fluctuating in input respects like cutoff conditions for models. To get the higher warmth move rate, and constant expansion in the warm conductivity of the liquid, the aluminum oxide nano molecule is the one it will give refreshed yield from the radiator, blending is finished by the specific volumetric groupings of the nano liquids to the central liquid like water and differentiation the nano molecule fixation to from 1% to up to the 8% to the water and made pass through the straight of the radiator for evaluation reason. In this evaluation considered just the one piece of the vehicle radiator as warmth exchanger to do the assessment, the radiators made to with long rectangular bits and at both side 34 fines are to makes to pass on the shine from the plate. Balances are so planned to the plate that solitary little piece of the forefronts is spoken with the long plate. The course of action of the shine exchanger front line, is made utilizing Solid works plan in Ansys programming. radiators typically face distinctive customary conditions to work, so these need to come out crazy cold and ludicrous hot conditions to work attainably with no issue, with better ability and long life. Such the model made to arrangement utilizing the unfathomable devices.

Ethylene Glycol have poor convective warmth move execution and hence high conservativeness and reasonableness of warmth move frameworks are fundamental to accomplish the essential warmth move. Among the endeavors for overhaul of warmth move the utilization of nano-molecule added substances to fluids is more prominent and right now an immense number of appraisals are given to this subject. PC assisted design with displaying with assessments are given in radiator parts is orchestrated by taking basically a singular piece of the certifiable radiator, which is utilized for assessment. One of the vital gigantic part in assessment of model is coordinating of the model.. in addition, next one is the encapsulation of the front line which has a more surface region stood apart from other piece of the fine where standard cross section can be taken, and for at side of the fines it made cut from different fines so it really single harmony yet our comprehend in and appraisal we made indistinguishable piece of balance so one cut part fine side is taken discontinuous conditions to the going with part balance to begin proceeds from that part, so at this part extremely fine lattice is finished. Basic necessity procedure of the undertaking is clarified previously. By applying the information sin, the cutoff conditions. we can get the appraisal results from the radiators changing the channel nanofluid focuses to the water.

5.2. Analysis of SIC

Diversion delayed consequences of the of the temperature, pressure and the speed are shown the figure. These generation results made to differentiate and the amusement assessments of the plain water and with that updated heat move regards will get. Entertainment results are procured with four limits like Heat move Mass stream rate and Temperature and the speed sections from speculations limits its easy to examination the nanofluids enough. Expansion in the general warmth move co-gainful the brand name wind show that increment with % of nano liquids. the nano liquid advancements in X-pivot to that the warm conductivity of the liquid comparatively builds in the mean time. Augmentation in the shine move co fruitful with temperature Hence from this we can derive that from our undertaking by utilizing the nano liquids to the base coolant that will upgrade the warm conductivity of the

liquid what's more warmth passing on restriction of fluid.

5.2.1. Convergence of Simulation:

The blend of Simulation is expected to get the limits of the shell and chamber heat exchanger in outlet. It moreover gives careful assessment of limits for the essential of warmth move rate. Cognizance, X-speed, Y-speed, Z-speed, energy, k, epsilon is the piece of scaled waiting which need to join in a specific district. For the movement, X-speed, Y speed, Z-speed, k, epsilon should be under 10^{-4} and the energy should be under 10^{-7} . Accepting these all characteristics in same manner, course of action will be joined. The course of action was joined at 10th cycle. The going with figure 5.1 shows the extra plot for the above accentuations.

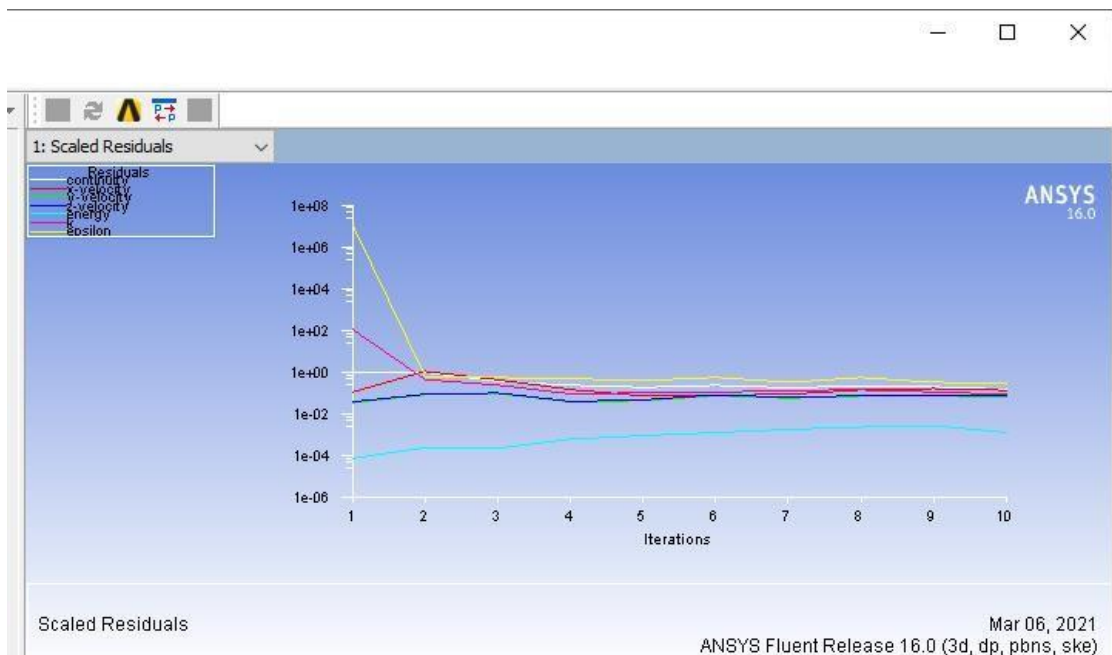


Fig 5.1: Scaled residuals of Sic

5.2.2 Pressure contour:

Pressure factor Distribution across the shell and cylinder heat exchanger is given beneath in Fig.5.2. With the expansion in Baffle tendency point pressure drop inside the shell is diminished. Pressing factor changes generally from gulf to outlet. The shapes of static pressing factor is appeared in all the figure to give a nitty gritty thought idea.

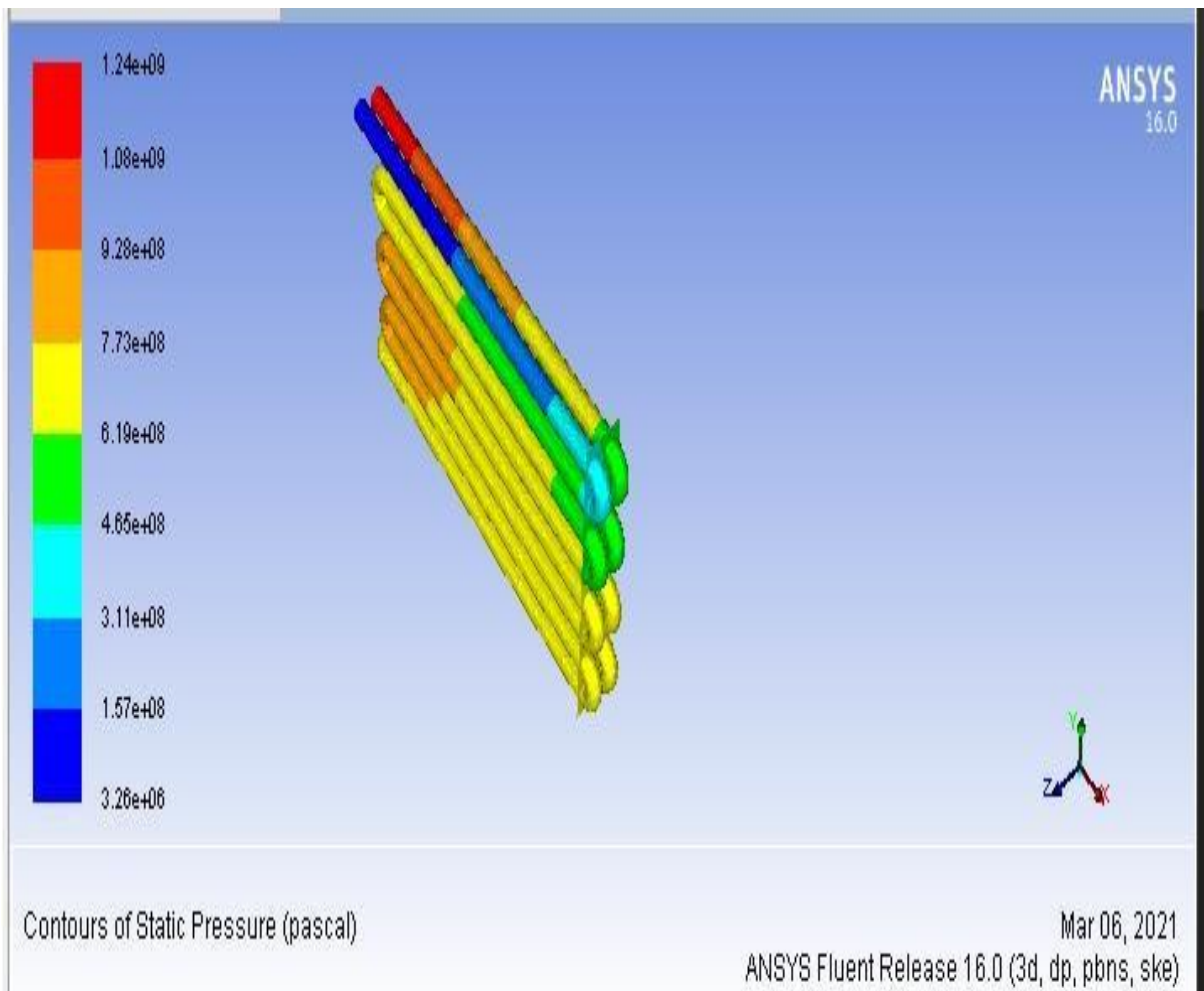


Fig.5.2: Contours of Static Pressure of SiC

5.2.3 Temperature Contour:

The temperature Contours plots across the cross segment at various confuse along the Radiator will give a thought of the stream in detail. The temperature dissemination across tube outlet at are given in Fig 5.3.

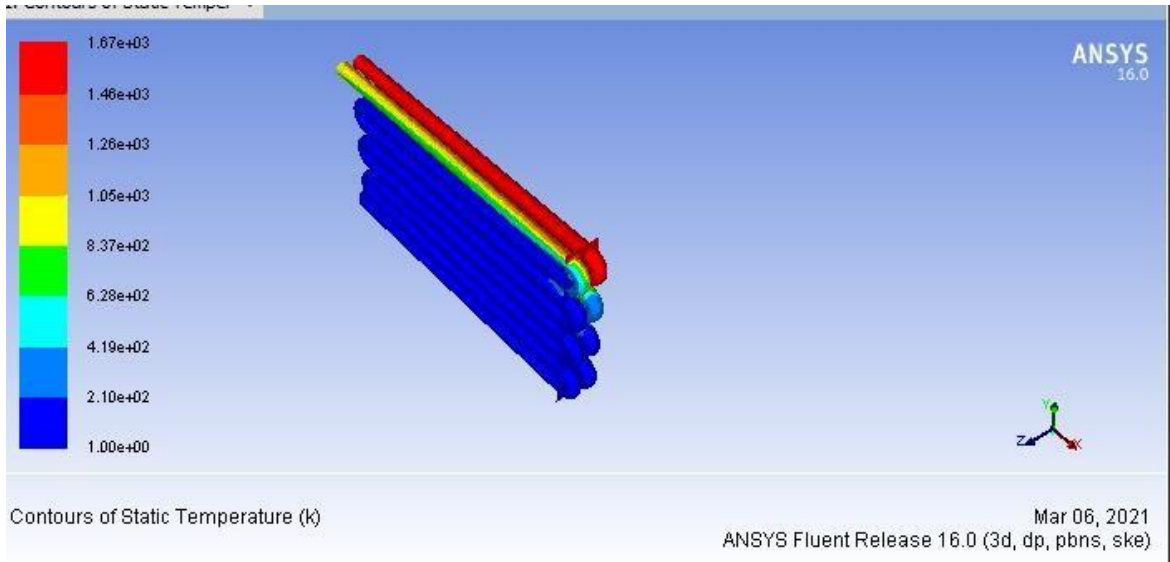


Fig 5.3: Contours of Static Temperature of SiC

5.2.4 Velocity Contour:

Velocity profile is analyzed to comprehend the stream circulation across the cross segment at various situations in Radiator. Beneath in Figure 5.4 is the speed profile of Radiator at various Area. The Radiator is displayed thinking about the plane evenness. The speed profile at delta is same. Outlet speed shift cylinder to helical cylinder and disturbance happen in the shell locale as revealed before.

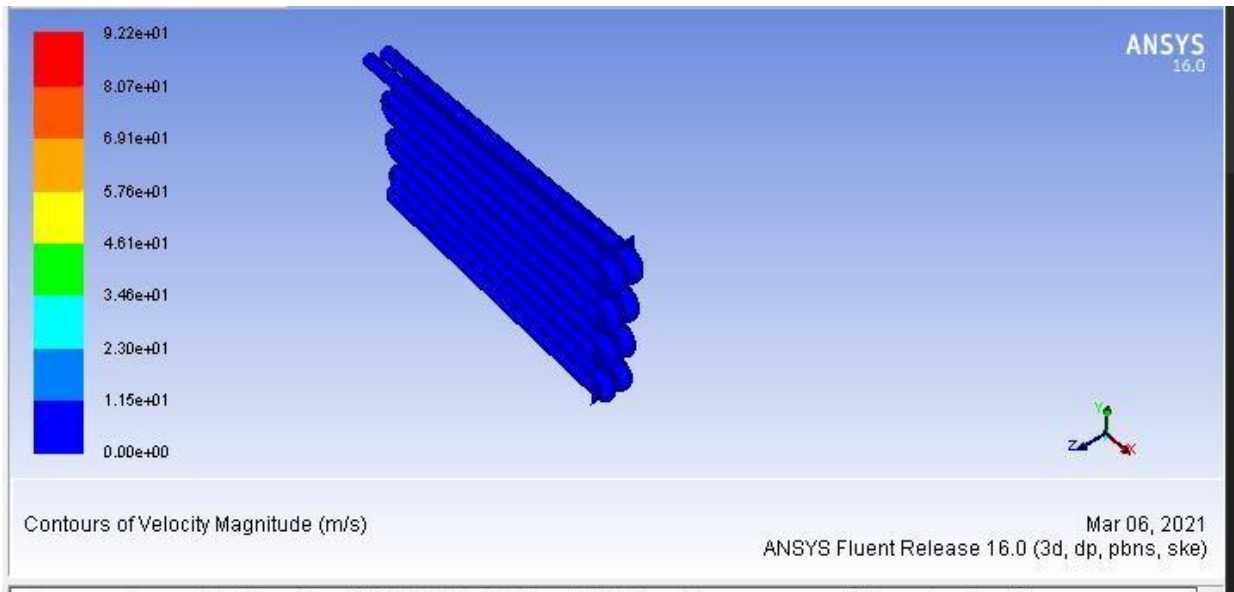


Fig 5.4: Contours of Velocity Magnitude

5.2 Analysis of Al_2O_3

Simulation Reenactment aftereffects of the of the temperature, pressure and the speed are shown the figure. These recreation results made to contrast and the reproduction estimations of the plain water and with that improved warmth move esteems will get. Reenactment results are acquired with four boundaries like Heat move Mass stream rate and Temperature and the speed parts from postulations boundaries it's not difficult to examination the nanofluids adequately. The mixing of Simulation is expected to get the limits of the shell and chamber heat exchanger in outlet. It furthermore gives exact assessment of limits for the essential of warmth move rate. Congruity, X-speed, Y-speed, Z-speed, energy, k, epsilon is the piece of scaled excess which need to join in a specific area. For the intelligibility, X-speed, Y speed, Z-speed, k, epsilon should be under 10^{-4} and the energy should be under 10^{-7} . If these all characteristics in same manner, plan will be consolidated. The plan was consolidated at 10th cycle. The going with figure 5.5 shows the waiting plot for the above accentuations.

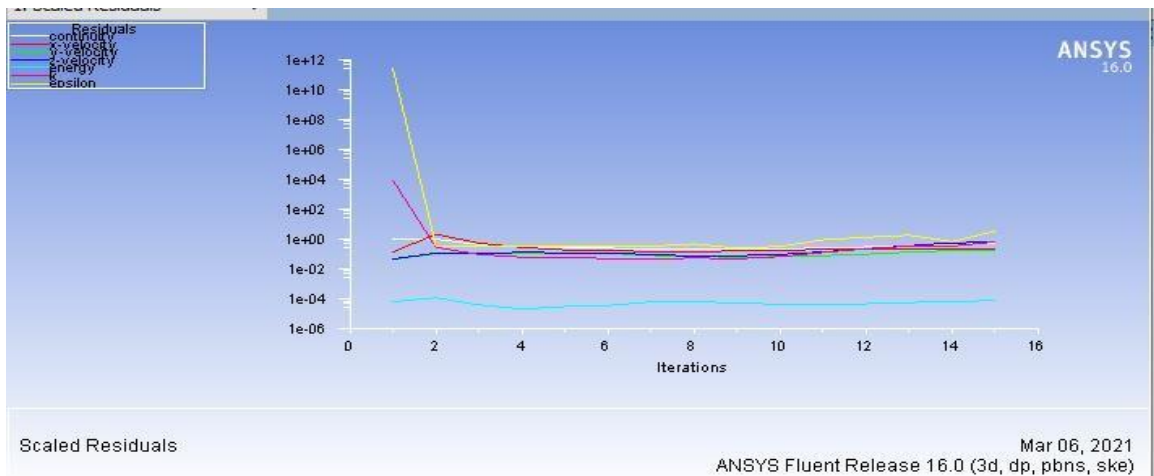


Fig 5.5 Scaled residuals of Al_2O_3

5.3.1 Pressure Contour:

Pressure factor Distribution across the shell and cylinder heat exchanger is given underneath in Fig.5.6. With the increment in Baffle tendency point pressure drop inside the shell is diminished. Pressing factor fluctuate generally from channel to outlet. The forms of static pressing factor is appeared in all the figure to give a nitty gritty thought.

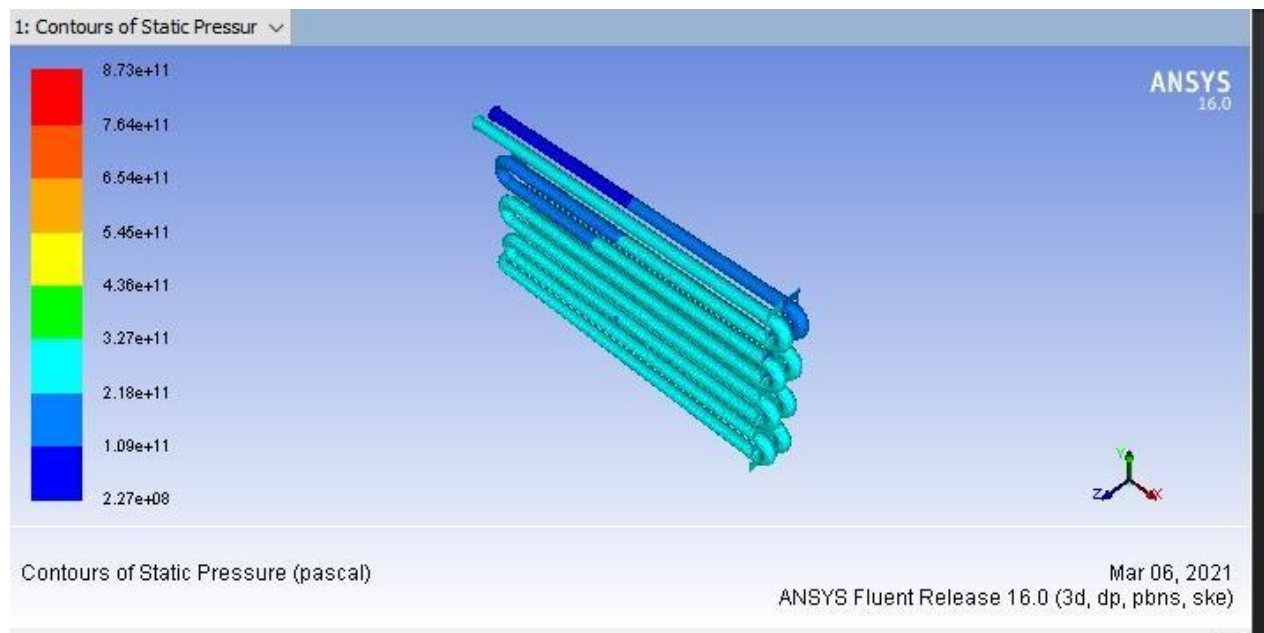


Fig 5.6 Contours of Static Pressure of Al_2O_3

5.3.2 Velocity Contour:

Velocity profile is analyzed to comprehend the stream dissemination across the cross segment at various situations in Radiator. Beneath in Figure 5.7 is the speed profile of Radiator at various Area. The Radiator is demonstrated thinking about the plane balance. The speed profile at delta is same. Outlet speed differ cylinder to helical cylinder and disturbance happen in the shell area as revealed before.

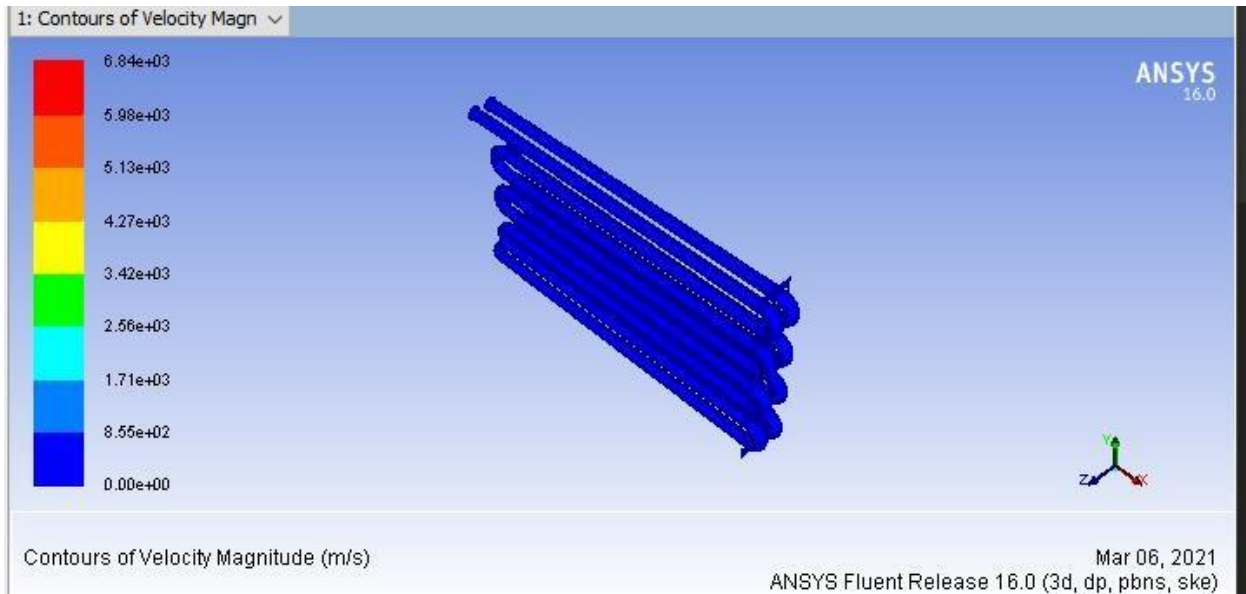


Fig 5.7 Contours of Velocity Magnitude of Al₂O₃

5.3.3 Temperature contour:

The temperature Contours plots across the cross segment at various confuse along the Radiator will give a thought of the stream in detail. The temperature conveyance across tube outlet at are given in Fig 5.8.

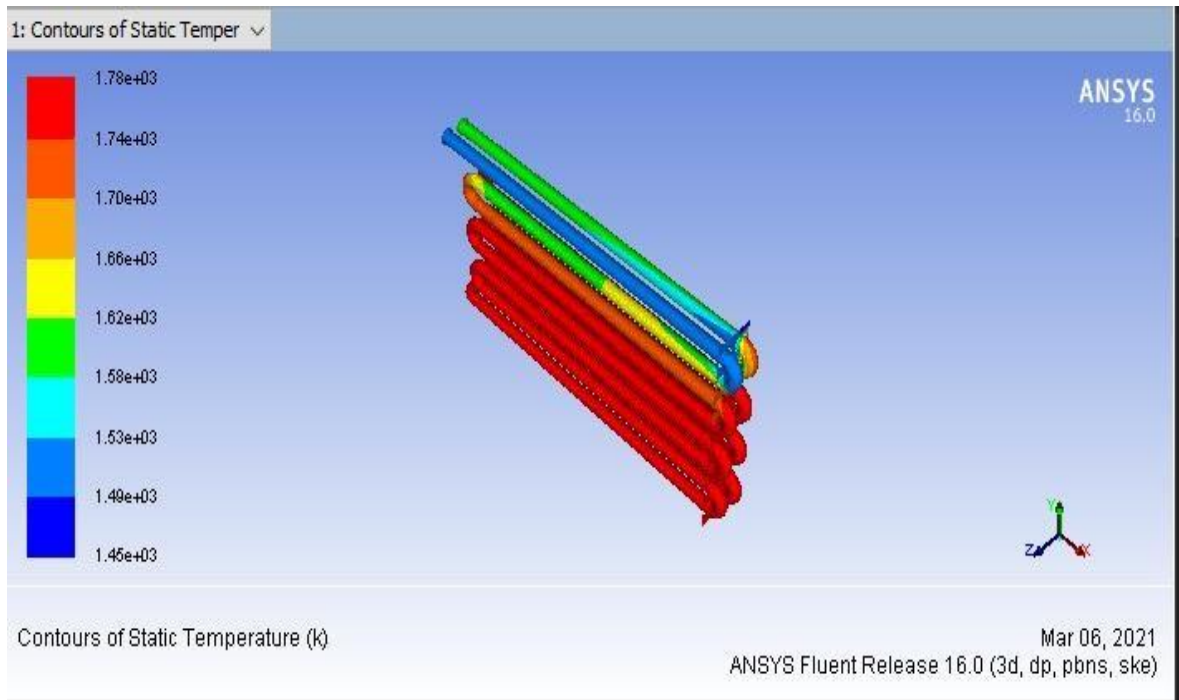


Fig 5.8 Contours of Static Temperature of Al_2O_3

5.3 Pressure and velocity results:

The heat moves and stream qualities of a radiator can be seen from the shape charts of speed and pressing factor distributions.

5.4.1 SIC nano fluids:

Table 5.1 Pressure and velocity results of Sic

S.no	Parameters	Min	Max
1	Pressure contour	1.24	9.28
2	Velocity vector	1.15	9.22

5.4.2 Al₂O₃ nano fluids:

Table 5.2 Pressure and velocity results of Al₂O₃

S.no	Parameters	Min	Max
1	Pressure contour	1.09	8.73
2	Velocity vector	1.71	8.55

5.4 Temperature:

The heat moves and stream attributes of a radiator can be seen from the form graphs of Temperature distributions.

5.5.1 SIC:

Table 5.3 Temperature results of Sic

S.no	Inlet Temp T1(C)	Outlet Temp T 0 (C)	Time
1	65	58	60
2	70	62	120
3	75	65	180
4	80	72	240
5	85	75	300
6	90	80	450
7	95	84	510

5.5.2 Al₂O₃:

Table 5.4 Temperature results of Al₂O₃

S.no	Inlet Temp T₁(C)	Outlet Temp T₀ (C)	Time
1	65	43	60
2	70	51	120
3	75	64	180
4	80	71	240
5	85	75	300
6	90	83	450
7	95	84	510

CHAPTER 6

CONCLUSION

The capability of coolant has been checked by changing the debilitating levels. Various readings are seen and diagrams are plotted which portray the coolant efficiency at that particular coolant. From this examination radiator, we derive that Efficiency of radiator increases. Warm conductivity of the framework increments. The advancement of nano-particles to the coolant can improve vehicle and in-your-face motor cooling rates. In addition, help in a lessened size cooling structure by clearing out heat from motor. More inconspicuous and lighter radiators, which thusly advantage basically all parts of vehicle execution and lead to expanded efficiency. Nano liquids will have a more fundamental application in heat move issues.

1. Efficiency of the warmth move of nanofluids will more analyzed plain water. Warm conductivity of the framework increments.
2. The generally speaking warmth move coefficient increments with upgrading with volumetric stream pace of the nanofluid essentially.
3. The expansion of nano-particles to the coolant can possibly improve auto rationale and rock-solid motor cooling rates.
4. The in general warmth move coefficient marginally with expanding channel temperature of the nanofluid. Heat transfer rate is high.
5. Density of nanofluid is high.
6. Thermal conductivity is high.
7. Temperature difference of inlet and outlet of radiator is high.
8. Preparation of mixture of nanofluid is easy.
9. It is cheaper and easily available.

REFERENCES

- [1] Azmi WH, Sharma KV, Mamat R, Anuar S. Nanofluid properties for forced convection heat transfer: An overview. *Journal of Mechanical Engineering and Sciences*. 2013;4:397-408.
- [2] Das SK, Choi SU, Yu W, Pradeep T. *Nanofluids: Science and Technology*: Wiley 2007.
- [3] Devireddy Sandhya, Mekala Chandra Sekhara Reddy, and Veeredhi Vasudeva Rao, "Improving the cooling performance of automobile radiator with ethylene glycol water based TiO₂ nanofluids", *International Communications in Heat and Mass Transfer* 78, 121–126, 2016.
- [4] Gabriela Huminic AH. Application of nanofluids in heat exchangers: A review. *Renewable and Sustainable Energy Reviews*. 2012;16:5625–38.
- [5] Hussein AM, Sharma KV, Bakar RA, Kadrigama K. Heat transfer enhancement with nanofluids – A review. *Journal of Mechanical Engineering and Sciences*. 2013;4:452-61.
- [6] K.Y. Leong, R. Saidur, S.N. Kazi, and A.H. Mamunc, "Performance investigation of an automotive car radiator operated with nanofluid based coolants", *Applied Thermal Engineering* 30, 2685-2692, 2010.
- [7] Mahendran M, Lee GC, Sharma KV, Shahrani A. performance of evacuated tube solar collector using water-based titanium oxide nanofluid. *Journal of Mechanical Engineering and Sciences*. 2012;3:301-10.
- [8] M. Reza Azizian HŞA, Tuna Okutucu. Effect of nanoconvection due to brownian motion on thermal conductivity of nanofluids. *IASME / WSEAS International Conference on Heat Transfer, Thermal Engineering and Environment* 2009.

- [9] Peyghambarzadeh SM, Hashemabadi SH, SeifiJamnani M, Hoseini SM. Improving the cooling performance of automobile radiator with Al₂O₃/water nanofluids. *Applied Thermal Engineering*. 2011;31:1833-8.
- [10] Peyghambarzadeh SM, Hashemabadi SH, Hoseini SM, SeifiJamnani M. Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiator. *International Communications in Heat and Mass Transfer*. 2011;38:1283-90.
- [11] Ravisankar B, Tara Chand V. Influence of Nanoparticle Volume fraction, particle size and temperature on thermal conductivity and viscosity of nanofluids- A review. *International Journal of Automotive and Mechanical Engineering*. 2013;8:1316-38.
- [12] Rahman MM, Kadirgama K, Ab Aziz AS. Artificial neural network modeling of grinding of ductile cast iron using water based SiO₂ nanocoolant. *International Journal of Automotive and Mechanical Engineering*. 2014;9:1649-61.
- [13] S. Senthilraja, M. Karthikeyan and R. Gangadevi, "Nanofluid applications in future automobiles: comprehensive review of existing data", *Nano-Micro Letter*, Volume 2, 306-310, 2010.
- [14] S.M. Peyghambarzadeh, S.H. Hashemabadi, M. SeifiJamnani, S.M. Hoseini, "Improving the cooling performance of automobile radiator with Al₂O₃ /water nanofluid", *Applied Thermal Engineering* 31, 1833–1838, 2011.
- [15] S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, Y. Vermahmoudi, "Experimental study of overall heat transfer coefficient in the application of dilute nanofluids in the car radiator", *Applied Thermal Engineering* 52, 8-16, 2013.
- [16] Sujith Kumar CS, Suresh S, Rajiv K. Heat Transfer Enhancement by Nano Structured Carbon Nanotube Coating. *International Journal of Scientific & Engineering Research*. 2012;3(6):1-5.

- [17] Syam Sundar L, Sharma KV. An experimental study on heat transfer and friction factor of Al₂O₃ nanofluid. *Journal of Mechanical Engineering and Sciences*. 2011;1:99-112.
- [18] Syam Sundar L, Sharma KV. Laminar Convective Heat transfer and friction factor of Al₂O₃ nanofluid in circular tube fitted with twisted tape inserts. *International Journal of Automotive and Mechanical Engineering*. 2011;3:265-78.
- [19] Usri NA, Azmi WH, Mamat R, Abdul Hamid K. Forced convection heat transfer using water- ethylene glycol (60:40) based nanofluids in automotive cooling system. *International Journal of Automotive and Mechanical Engineering*. 2015;11:2747-55.
- [20] Vithayasai S, Kiatsiriroat T, Nuntaphan A. Effect of electric field on heat transfer performance of automobile radiator at low frontal air velocity. *Applied Thermal Engineering*. 2006;26:2073-8.
- [21] W.H. Azmi, K. Abdul Hamid, N.A. Usri, RizalmanMamat, and K.V. Sharma. "Heat transfer augmentation of ethylene glycol: water nanofluids and applications - a review", *International Communications in Heat and Mass Transfer* 75, 13–23, 2016.
- [22] Yogeswaran M, Kadirgama K, Rahman MM, Devarajan R. Temperature analysis when using ethylene-glycol-based tio₂ as a new coolant for milling. *International Journal of Automotive and Mechanical Engineering*. 2015;11:2272-81
- [23] Zakaria I, Michael Z, Mohamed WANW, Mamat AMI, Azmi WH, Mamat R, et al. A review of nanofluid adoption in polymer electrolyte membrane (pem) fuel cells as an alternative coolant. *Journal of Mechanical Engineering and Sciences*. 2015;8:1351-66.