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Comparative Analysis of Helical tube Automobile Radiator considering different Coolants used CFD

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Abstract - *The thermal conductivity of heating or cooling fluids is a very important property in the development of energy-efficient heat transfer systems. Thermal conductivity of the fluids is one of the basic properties taken into account in designing and controlling the process. Automobile radiators are becoming extremely important in terms of performance of vehicle and maximum heat dissipation, also they are highly power-packed with increasing power to weight or volume ratio. The flow behaviour & temperature profile prediction in the radiator tubes are very useful information & is of great importance to the designer. CFD is very useful tool in accessing the preliminary design and performance of the radiator. In this paper, the model was done Pro-E software and imported in ANSYS-12. The analysis was done in CFX for three different coolants considering helical tube configuration. The coolants considered ware Ethylene Glycol, Propylene Glycol & Methanol. The overall pressure & temperature distribution of the coolant was evaluated for helical tubes used in radiator. There were taken two pitch of Helical tubes as 15mm & 20 mm Pitch. Methanol in the helical tube radiator has got maximum temperature drop compared to Propylene Glycol & Ethylene Glycol. Compared to 15mm Pitch & 20mm Pitch Helical tube Radiator, 15mm Pitch Helical tube used in radiator is more heat dissipation compared to 20mm Pitch Helical tube used in Radiator.*

Keywords*- CFD, Pro-E, Radiator, Helical Tubes, ANSYS-CFX, Mass Flow Rate, Ethylene Glycol, Propylene Glycol, Methanol, Cross Flow Heat Exchanger.*

I. INTRODUCTION

Thermal radiator is an important part of an automobile engine, and it has the functions of preventing engine from overheating and regulating engine temperature. High temperatures in an engine can cause oil to thin, engine parts to expand, lubrication to break down, and moving parts to be damaged. A more effective radiator will reduce engine temperature in the hot environments, while consume less power from the engine, therefore, the engine thermal efficiency can be increased. Automobile manufacturers have challenge of developing compact and energy efficient cars which warrants a thorough optimization process in the design of all engine components. Today's engine require higher output with decreased space available for cooling air circulation which necessitates a better understanding of the complex cooling fluid flow characteristics and thermal performance of the radiator is necessary as the performance, safety and life of engine depends on effective engine cooling. About 30% of the thermal energy generated is dissipated to the coolant circulating in the engine-cooling jacket. The hot coolant coming out of engine jacket is to be cooled in a radiator and circulated again.

II. LITERATURE SURVEY

Lee Poh Seng (2003) determination of certain thermo-physical properties of nanofluids. The properties of nanofluids at desired temperature, particle size and concentration can be estimated using the regression equations developed to evaluate the viscosity and thermal conductivity for water based nanofluids. the model which gives the lowest deviation is selected base on few aspects such as coefficient of equation, maximum and minimum deviation.

Nguyen et al. (2008) has proposed a formula for calculating viscosity of nanofluids for 47 and 36 nm particle-sizes and particle volume fractions of 1 and 4% with particle volume concentration, φ and temperature, *T* respectively.

Hilde Van Der Vyer et al. (2003) conducted a CFD simulation of a 3-D tube-in-tube heat exchanger using Star-CD CFD software and made a validation test with the experimental work. The authors were fairly successful to simulate the heat transfer characteristics of the tube-in-tube heat exchanger. This has been used as the base for the procedures of CFD code validation of a heat exchanger.

Vikashkumar et.al (2003) done A three dimensional numerical simulation study has been carried out to predict air flow and temperature distribution in the tube type heat exchanger associated with large electrical motor. Due to symmetry in geometrical construction, a section of heat exchanger has been considered for CFD analysis by using PHOENICS software. The k - ε turbulence model has been used to solve the transport equations for turbulent flow energy and the dissipation rate.

Witry et. al.,(2003) carried out CFD analysis of fluid flow and heat transfer in patterned roll bonded aluminium radiator, in which FLUENT's segregated implicit 3-D steady solver with incompressible heat transfer is used as the tool. Here the shell side airflow pattern and tube side water flow pattern are studied to present the variation of overall heat transfer coefficients across the radiator ranging from 75 to 560 W/m^2-K.

Chen et al, (2001) made an experimental investigation of the heat transfer characteristics of a tube-and-fin radiator for vehicles using an experimental optimization design technique on a wind tunnel test rig of the radiator. The authors have developed the regression equations of heat dissipation rate, coolant pressure drop and air pressure drop. The influences of various parameters like the air velocity, inlet coolant temperature and volume flow rate of coolant on heat dissipation rate, coolant pressure drop and air pressure drop have been discussed in detail by means of the numerical analyses. The results provide a basis for the theoretical analysis of heat performances and structural refinement of the tube-and-fin radiator.

Sridhar Maddipatla, (2001) presented a method to design automobile radiator by coupling CFD with a shape optimization algorithm on a simplified 2D model. It includes automated mesh generation using Gambit, CFD analysis using Fluent and an in-house C-code implementing a numerical shape optimization algorithm. The flow simulations using FLUENT were performed using the classical simple algorithm with a k-ε turbulent model and second order upwind scheme. It involves calculating the overall pressure drop and mass flow rate distribution of the coolant and air in and around the single tube arrangement of an automotive radiator.

Yiding Cao et al. (1992) introduced heat pipe in radiator. Heat pipes including two-phase closed thermosyphons are two-phase heat transfer devices with an effective thermal conductance hundreds of times higher than that of copper. For the terrestrial applications, gravity is often used to assistant the return of the liquid condensate and no wick structure is needed inside the heat pipe, and this type of heat pipes is often referred to as two-phase closed thermosyphons. Using heat pipes in automotive radiator have benefits like higher effectiveness of heat exchange due to the counter-flow mode, increasing the reliability of radiators, increasing the overall heat transfer coefficient between air flow and coolant.

Seth Daniel Oduro (2009) studied the effect of sand blocking the heat transfer area of the radiator and its effect on the engine coolant through experiments and a mathematical model. The results indicated that the percentage area covered resulted in a proportional increase of the inlet and outlet temperatures of the coolant in the radiator. Regression analysis pointed out that every 10% increase area of the radiator covered with silt soil resulted in an increase of about 1.7^0C of the outlet temperature of the radiator coolant. Similarly, using clay as a cover material, 10% of the area covered of the radiator resulted in an increase of about 2^0C of the outlet temperature of the radiator coolant.

III. ANALYSIS OF RADIATOR

Analysis is done in ANSYS-12 software with using CFX. The analysis is done on both helical tube and straight tube radiator model and then performance comparison is done to understand importance of particular configuration with help of ANSYS software.

Input Data (Seth Daniel Oduro (2009))

Air inlet velocity	: 4.4 m/s
Air inlet temp	: ambient temp
Coolant inlet temp	: 98.75^0C
Outside temperature	: 25^0C
Coolant mass flow	: 2.3 kg/s, 2.0 kg/sec, 1.0 kg/sec & 0.5 kg/sec.
Flow region	: Laminar
Mass & Momentum	: Free slip wall

Overall heat transfer co efficient across the radiator ranges from 75 to 560 W/m^2-K

Radiator Specification for Helical Type Tubes:

Number of tubes	: 29
Helical type tube mean diameter	: 30mm
Pitch	: 15mm & 20mm
Inner diameter of tube	: 2 mm
Outer diameter of tube	: 4 mm

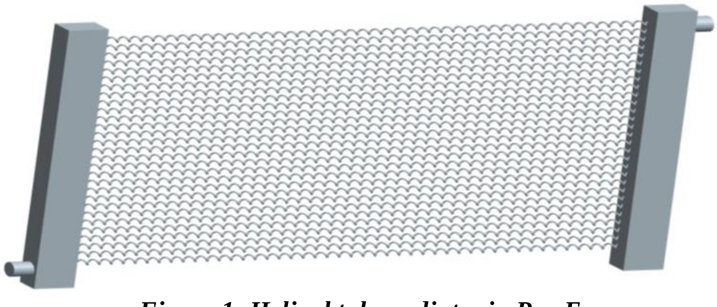

Figure 1: Helical tube radiator in Pro-E

Assumptions

In order to solve the analytical model, the following assumptions are made:

Coolant flow rate is constant and there is no phase change in the coolant. Heat conduction through the walls of the coolant tube is negligible. Heat loss by coolant was only transferred to the cooling air, thus no other heat transfer mode such as radiation was considered. Coolant fluid flow is in a fully developed condition in each tube. All dimensions are uniform throughout the radiator and the heat transfer surface area is consistent and distributed uniformly. The thermal conductivity of the radiator material is considered to be constant. There are no heat sources and sinks within the radiator. There is no fluid stratification, losses and flow misdistribution. Momentum condition: Tube wall is stationary.

Case-I: Analysis of Radiator with Helical Tubes (mass flow rate =2.3 kg/sec) (Pitch-15mm and 20mm)

Case-I-A: Analysis of Radiator with Helical Tubes (Pitch – 15mm)

Case I-A (a): Using Ethylene Glycol Coolant

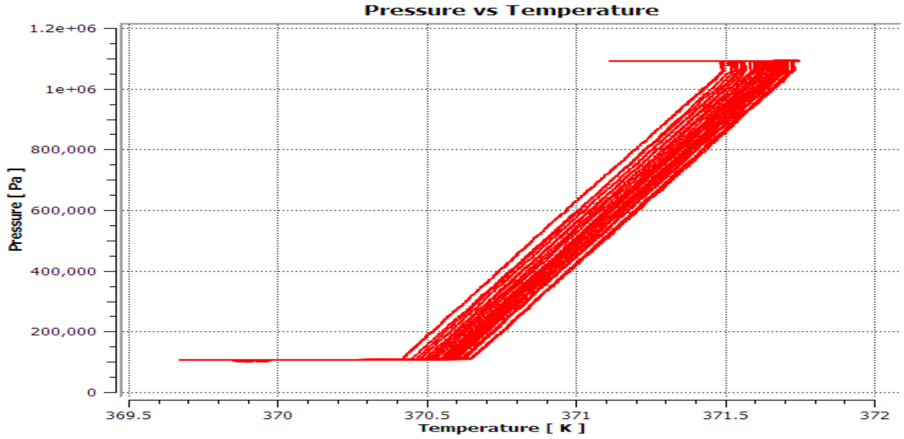

Figure 2: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (15mm pitch-Ethylene Glycol)

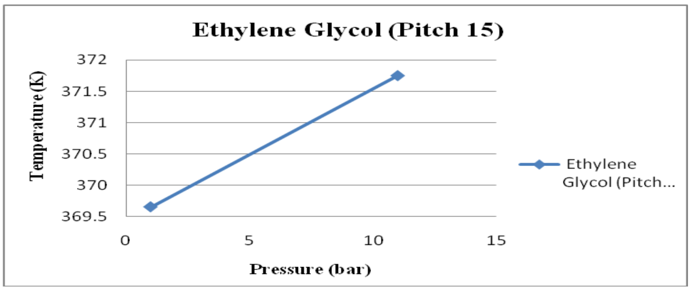

Figure 3: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Ethylene Glycol)

From figure 2 & 3 it is seen that ΔT=2.1 K and ΔP=10 bar

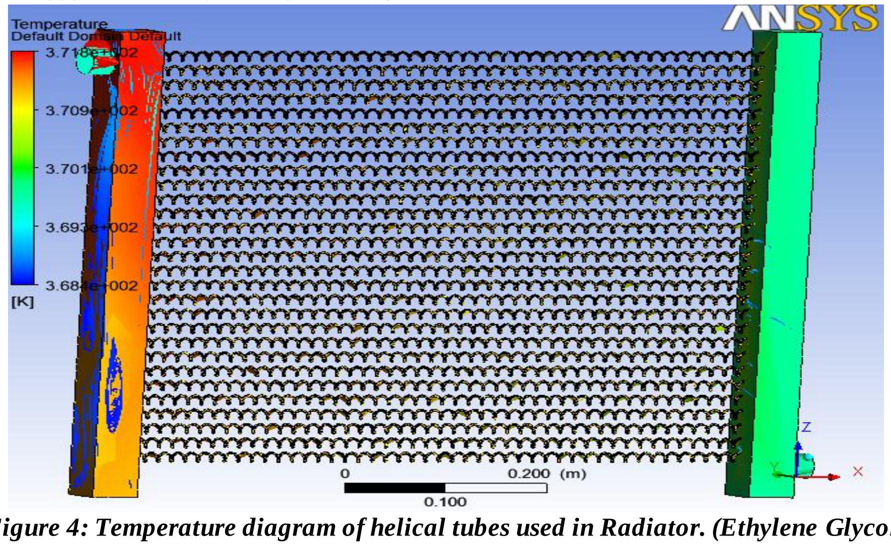

Figure 4: Temperature diagram of helical tubes used in Radiator. (Ethylene Glycol)

Figure 4 shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 369.65 K, minimum temperature.

Case I-A (b): Helical Tube Using Propylene Glycol Coolant

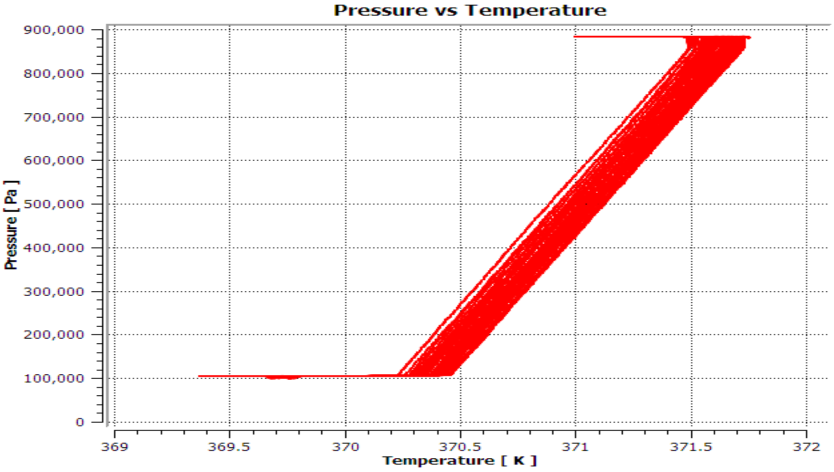

Figure 5: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (15mm pitch-propylene Glycol)

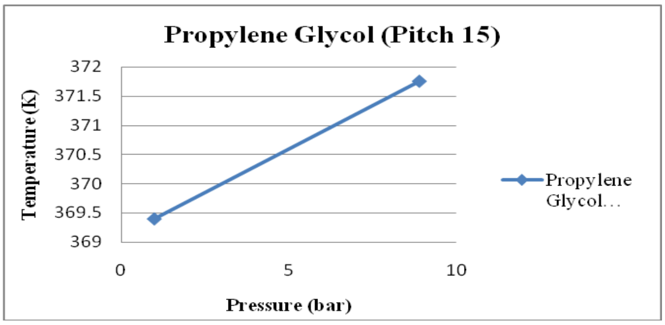

Figure 6: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Propylene Glycol)

From figure 5 & 6 it is seen that ΔT=2.35 K and ΔP=7.9 bar.

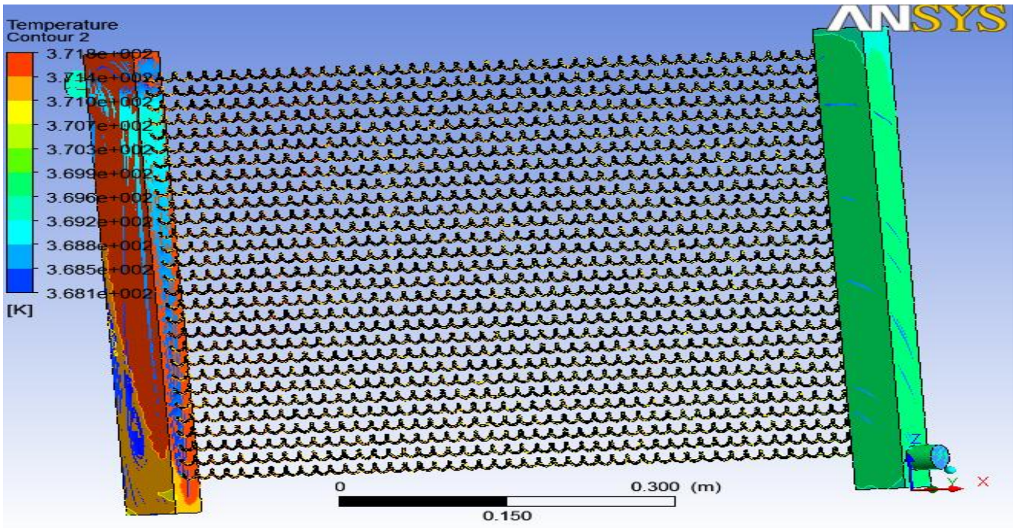

Figure 7: Temperature diagram of helical tubes used in Radiator. (Propylene Glycol)

Figure 7 shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 369.4 K, minimum temperature.

Case I-A (c): Helical Tube Using Methanol Coolant

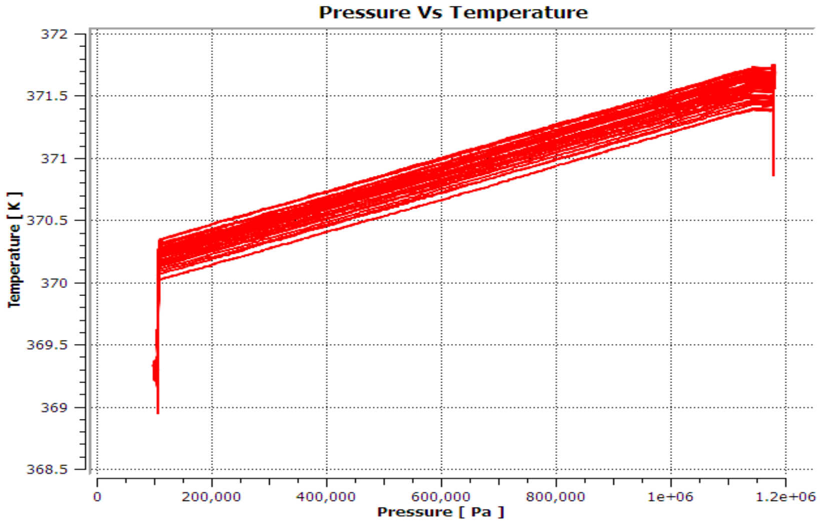

Figure 8: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (15mm pitch-Methanol)

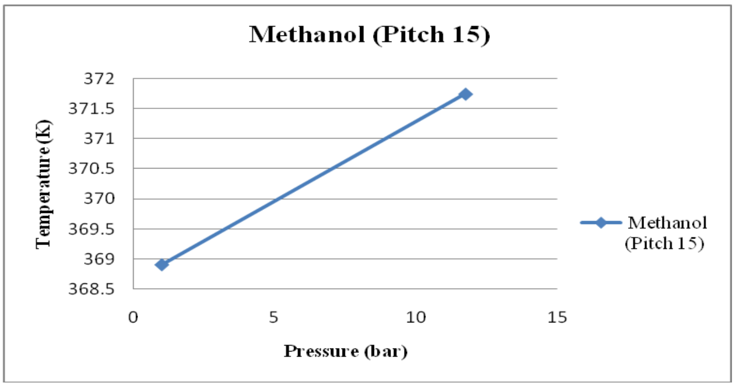

Figure 9: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Methanol)

From figure 8 & 9 it is seen that ΔT=2.85 K and ΔP=10.75 bar.

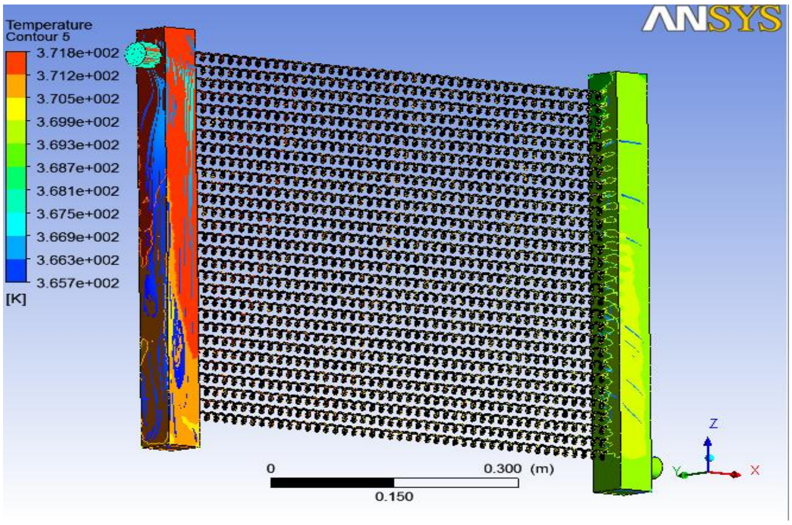

Figure 10: Temperature diagram of helical tubes used in Radiator. (Methanol)

Figure shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 368.9 K, minimum temperature.

Case I-A (d) Comparison of Propylene Glycol, Ethylene Glycol & Methanol of Coolant

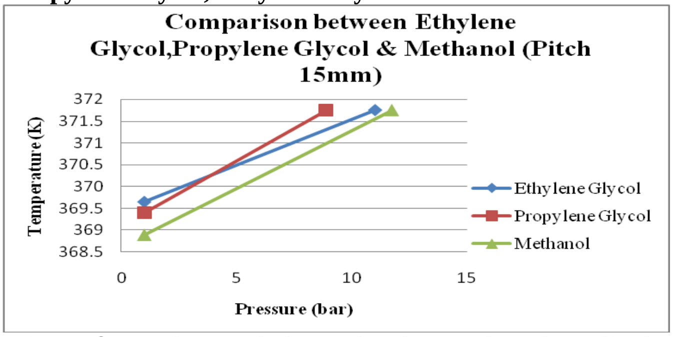

Figure 11: Comparison of Propylene, Ethylene Glycol & Methanol. (Helical Tube-15mm pitch)

From figure it is found that maximum temperature drop occurs in Methanol compared to the Propylene Glycol & Ethylene Glycol whereas minimum pressure drop occurs in Propylene Glycol compared to the Ethylene Glycol & Methanol.

TABLE 1: Case I-A, Analysis of Helical Type Tube Radiator (Pitch = 15mm, Mass Flow Rate = 2.3 kg/sec)

Coolant	Inlet Press. (bar)	Outlet Press. (bar)	ΔP (bar)	Inlet Temp. (K)	Outlet Temp. (K)	ΔT (K)
Ethylene Glycol	11	1.0	10	371.75	369.65	2.1
Propylene Glycol	8.9	1.0	7.9	371.75	369.4	2.35
Methanol	11.75	1.0	10.75	371.75	368.9	2.85

Case I-B: Analysis of Radiator with Helical Tubes (Pitch: 20mm)
Case I-B (a): Helical Tube Using Ethylene Glycol Coolant

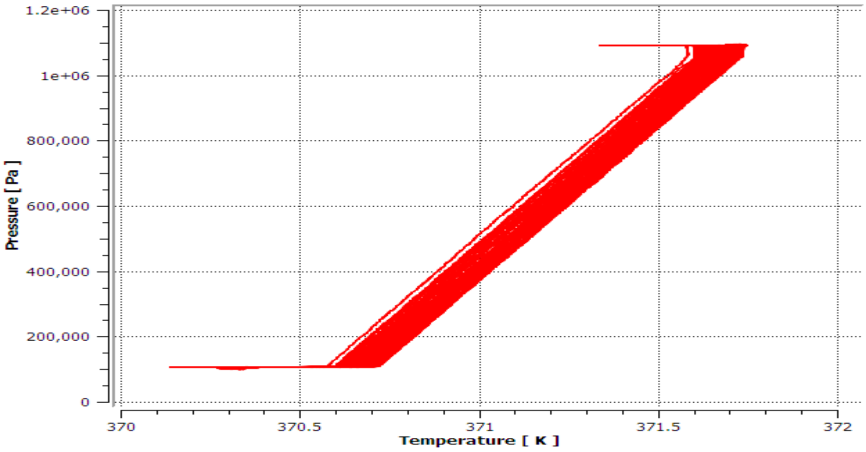

Figure 12: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (20mm pitch-Ethylene Glycol)

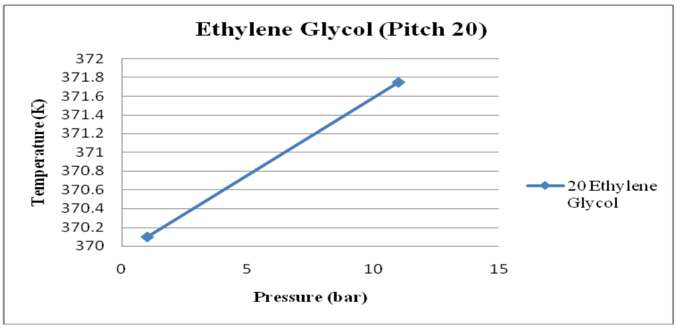

Figure 13: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Ethylene Glycol)

From figure 12 & 13 it is seen that ΔT=1.65 K and ΔP=10 bar.

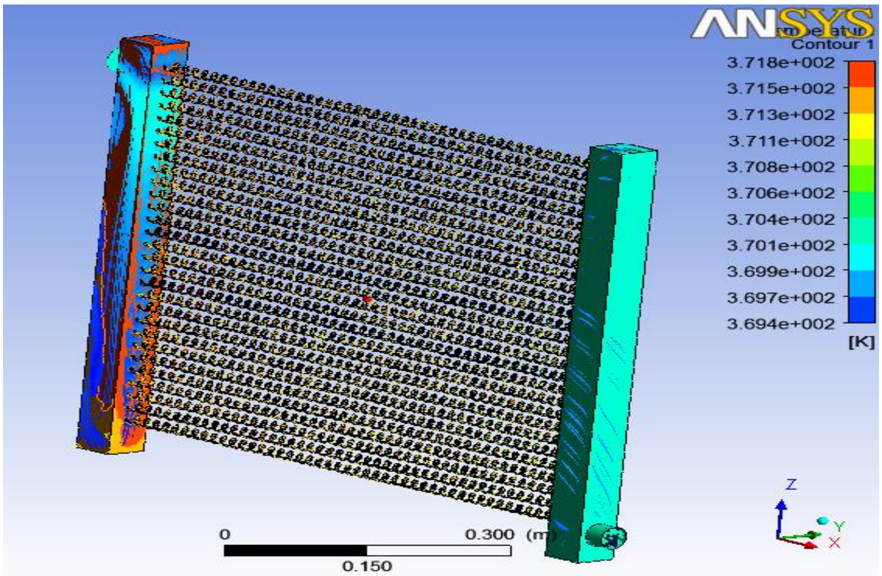

Figure 14: Temperature diagram of helical tubes used in Radiator. (Ethylene Glycol)

Figure shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 370.10 K, minimum temperature.

Case I-B (b): Helical Type Tube with Coolant using Propylene Glycol (Pitch-20mm)

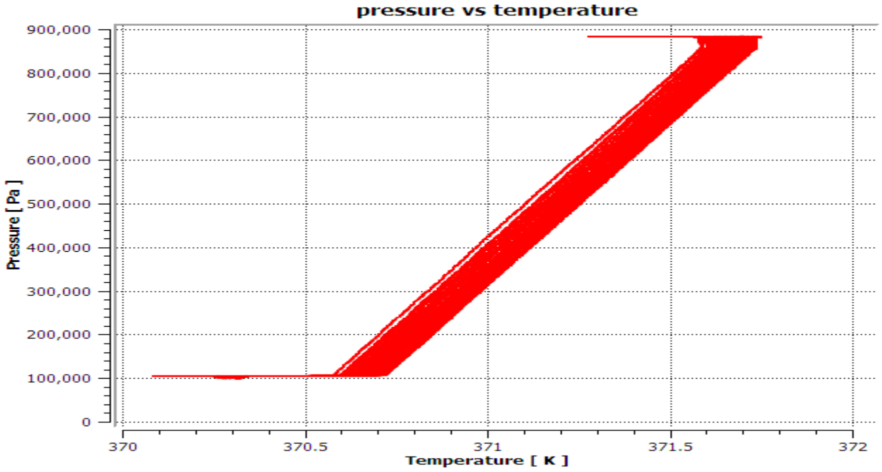

Figure 15: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (20mm pitch-Propylene Glycol)

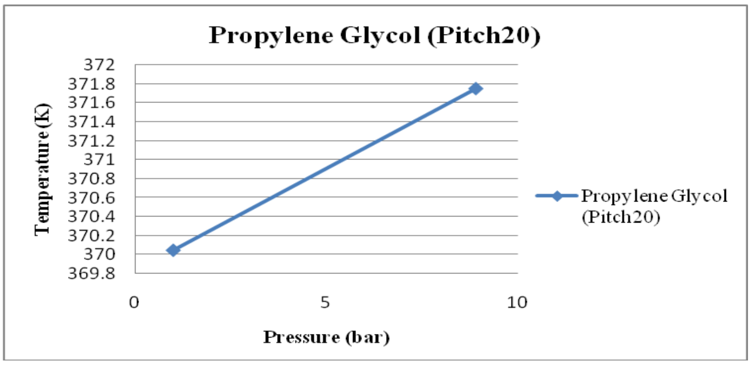

Figure 16: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Propylene Glycol)

From figure 15 & 16, it is seen that ΔT=1.70 K and ΔP=7.9 bar.

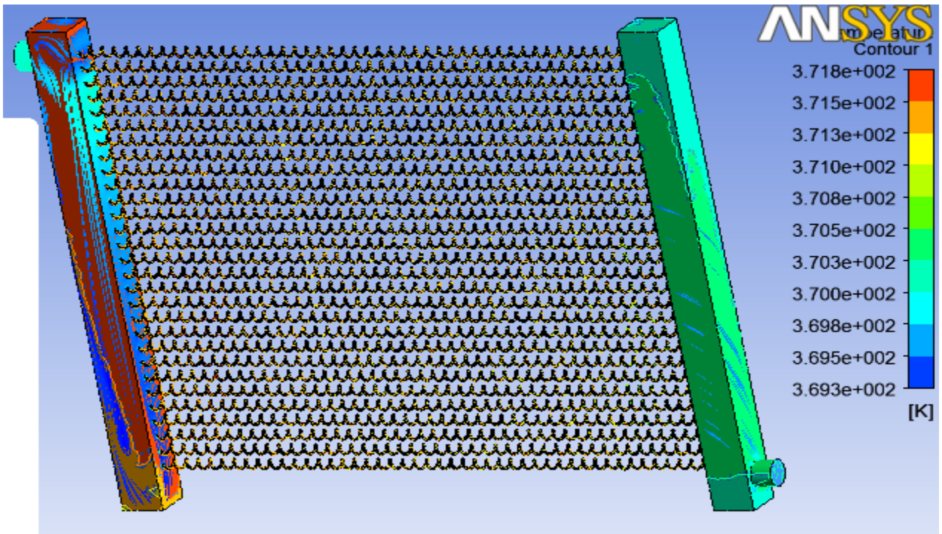

Figure 17: Temperature diagram of helical tubes used in Radiator. (Propylene Glycol)

Figure shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 370.05 K, minimum temperature.

Case I-B(c): Helical Type Tube using Methanol (Pitch-20mm)

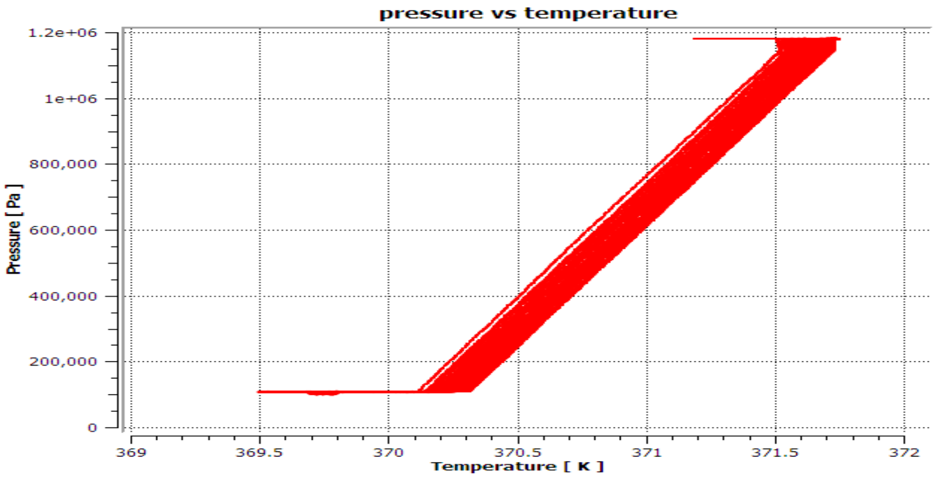

Figure 18: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (20mm pitch-Methanol)

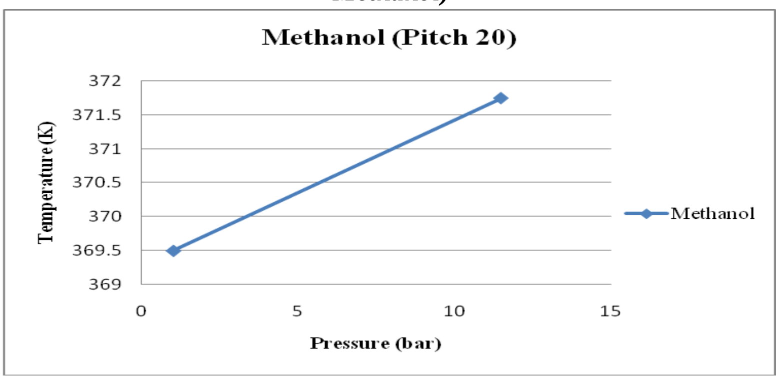

Figure 19: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Methanol)

From figure 18 & 19 it is seen that ΔT=2.25 K and ΔP=2.25 bar.

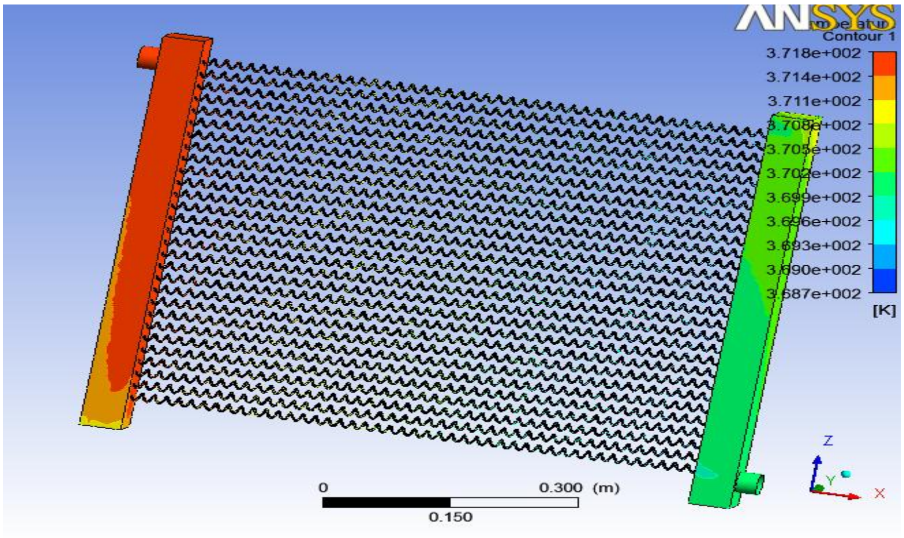

Figure 20: Temperature diagram of helical tubes used in Radiator. (Methanol)

Figure shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 369.5 K, minimum temperature.

Case I-B (d): Comparison of Propylene Glycol, Ethylene Glycol & Methanol (Helical Tube-20mm pitch)

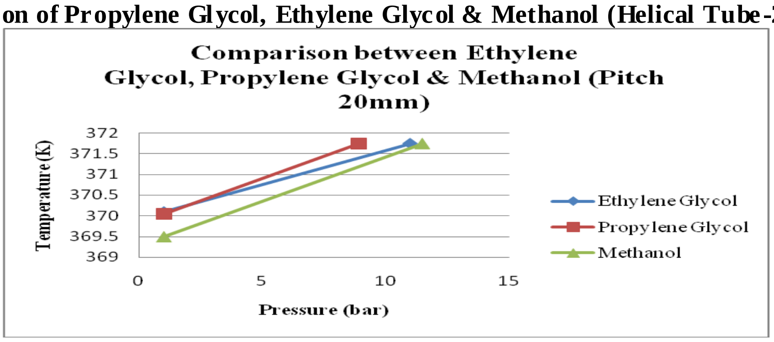

Figure 21: Comparison of Propylene, Ethylene Glycol & Methanol. (Helical Tube-20mm pitch)

Figure 21 show that maximum temperature drop occurs in Methanol compared to Propylene Glycol & Ethylene Glycol whereas minimum pressure drop occurs in Propylene Glycol compared to Ethylene Glycol & Methanol.

TABLE2: Case I-B-1, Helical Type Tube Radiator (Mass Flow rate = 2.3 kg/sec, Pitch = 20mm)

Coolant	Inlet Press. (bar)	Outlet Press. (bar)	ΔP	Inlet Temp. (K)	Outlet Temp. (K)	ΔT (K)
Ethylene Glycol	11	1.0	10	371.75	370.10	1.65
Propylene Glycol	8.9	1.0	7.9	371.75	370.05	1.7
Methanol	11.5	1.0	10.5	371.75	369.5	2.25

CONCLUSION

- For helical tubes Radiator in both 15mm Pitch & 20mm Pitch; there are used three coolants Ethylene Glycol, Propylene Glycol & Methanol; Methanol maximum temperature drop compared to Propylene Glycol & Ethylene Glycol. So, there is Methanol which is best among three coolants, related to heat dissipation.
- Maximum pressure drop get in Methanol compared to the Ethylene Glycol & Propylene Glycol, so friction is more occurs in Methanol compared to Ethylene Glycol & Propylene Glycol.
- Minimum pressure drop get in Propylene Glycol compared to Ethylene Glycol & Methanol.
- Compared to 15mm Pitch & 20mm Pitch Helical tube Radiator, 15mm Pitch Helical tube used in radiator is more heat dissipation compared to 20mm Pitch Helical tube used in Radiator.

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