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COMPARATIVE ANALYSIS OF AUTOMOBILE RADIATOR CONSIDERING DIFFERENT TUBE CONFIGURATIONS

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Abstract — *In today's world, 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 radia tor. In this paper, the model was done Pro-E software and imported in ANSYS-12. The analysis was done in CFX for considering straight tube and helical tube configuration. The coolant considered as an Ethylene Glycol. The overall pressure & temperature distribution of the coolant was evaluated for both straight tube & helical tube used in radiator. The maximum temperature drop occurs in the helical tubes compared to the straight tube. In case of helical tubes more heat dissipation occurs in the 15mm pitch compared to 20mm pitch.*

Keywords- *CFD, Radiator, Helical Tubes, ANSYS-CFX, Mass Flow Rate, Coolant, Numerical Simulations, Cross Flow Heat Exchanger, Fin.*

I. INTRODUCTION

Automobile manufacturers have challenge of developing compact and energy efficient cars which warrants a thorough optimization process in the design of all engine components. Radiators are one of the important parts of engine which are installed in automobiles to remove heat for better engine performance thus providing engine cooling and also heat removal during air-conditioning process. 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. Generally in an automobile, energy dissipated from the engine through radiator is not utilized but lost to the atmosphere.

II. LITERATURE REVIEW

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.

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,

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increasing the reliability of radiators, increasing the overall heat transfer coefficient between air flow and coolant and reducing the coolant pressure drop and power consumption of the coolant pump.

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 Straight Tubes.

The radiator considered is for 55 hp diesel engine.

Number of tubes	: 35
Fin type	: Hexagonal
Tube length	: 580 mm
Tube inner diameter	: 2mm
Tube outer diameter	: 4mm

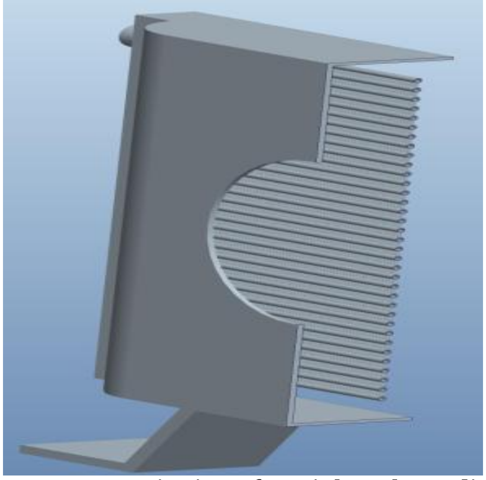

Figure 1: Isometric view of Straight Tube Radiator

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

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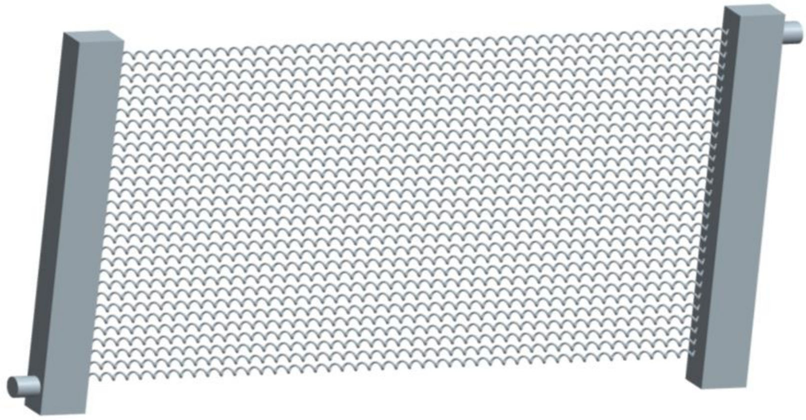

Figure 2: Helical tube radiator in Pro-E

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 Straight Tubes (Mass Flow rate 2.3 kg/sec)

Case I (a): Straight Tube using Ethylene Glycol Coolant

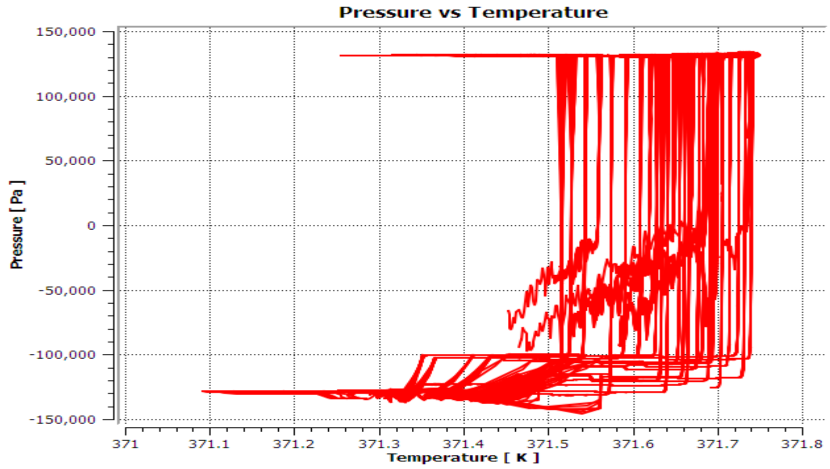

Figure 3: Flow diagram of different tubes related to the pressure & temperature In Straight Line Tube (Ethylene Glycol)

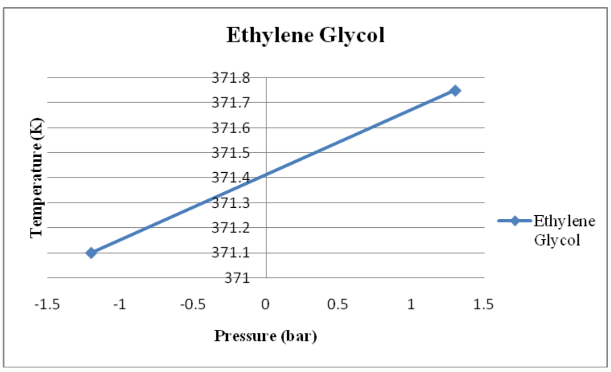

Figure 4: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Straight Line Tube (Ethylene Glycol)

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From figure 3 & 4, it is observed that the ΔT is 0.65 K and ΔP is7.5 bar.

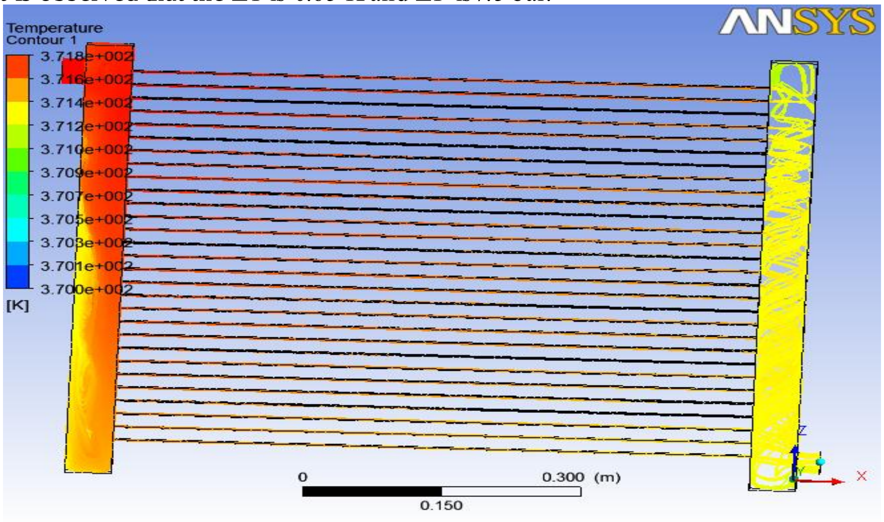

Figure 5: Temperature diagram of Straight Line of Tube. (Ethylene Glycol)

Figure 5 shows that temperature range in radiator indicated with different colours. Inlet has 371.75 K, the maximum temperature & outlet has 371.10 K, minimum temperature.

TABLE 1: Case I- Analysis of Radiator with Straight Tubes (Mass Flow rate = 2.3 kg/sec)

Coolant	Inlet Pr. (bar)	Outlet Pr. (bar)	ΔP (bar)	Inlet Temp. (K)	Outlet Temp. (K)	ΔT (K)
Ethylene Glycol	1.3	-1.2	2.5	371.75	371.1	0.65

Case-II: Analysis of Radiator with Helical Tubes (mass flowrate =2.3 kg/sec) (Pitch-15mm and 20mm)
Case-II-A: Analysis of Radiator with Helical Tubes (Pitch – 15mm)
Case II-A (a): Using Ethylene Glycol Coolant

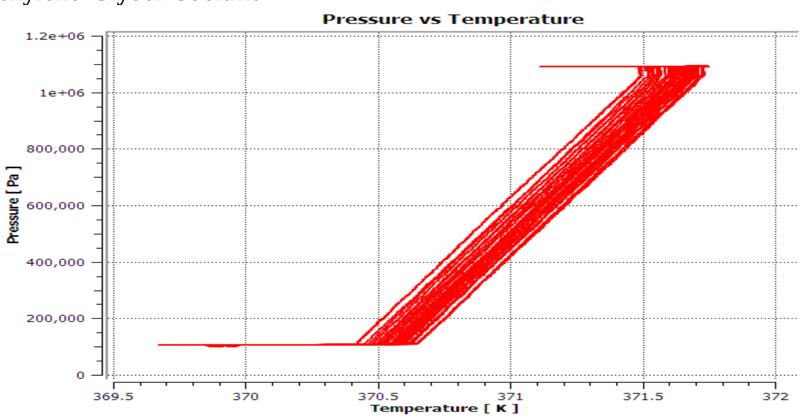

Figure 6: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (15mm pitch-Ethylene Glycol)

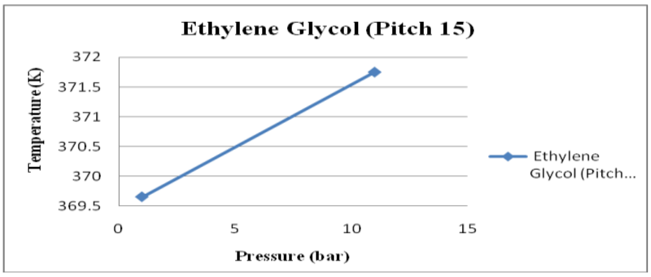

Figure 7: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Ethylene Glycol)

From figure 6 & 7 it is seen that ΔT=2.1 K and ΔP=10 bar

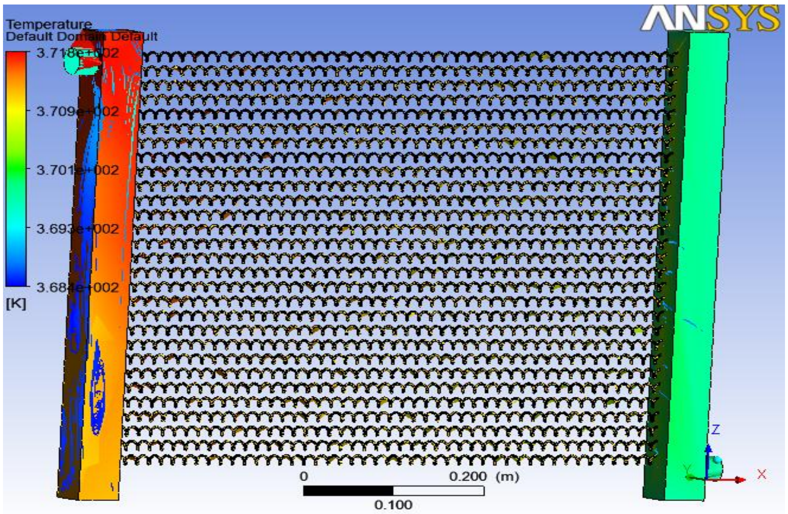

Figure 8: Temperature diagram of helical tubes used in Radiator. (Ethylene Glycol)

Figure 8 shows that temperature range in radiator with different colour. Inlet has 371.75 K, the maximum temperature & outlet has 369.65 K, minimum temperature.

TABLE 2: Case II-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

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

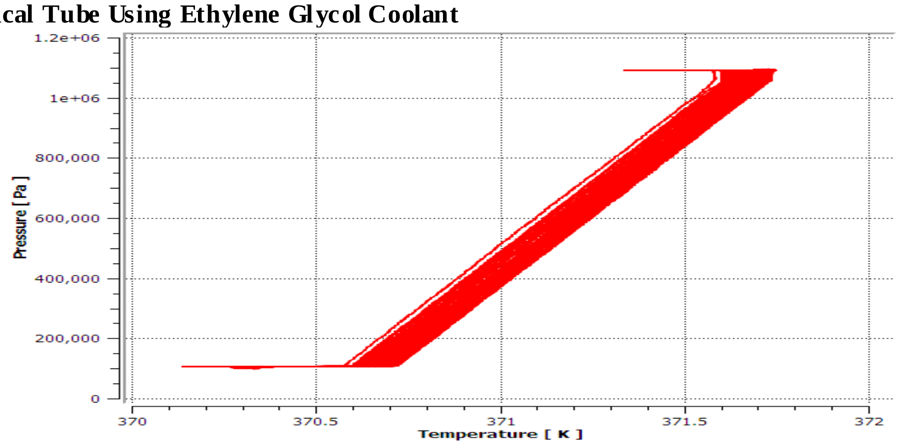

Figure 9: Flow diagram of different tubes related to the pressure & temperature In Helical type Tube (20mm pitch-Ethylene Glycol)

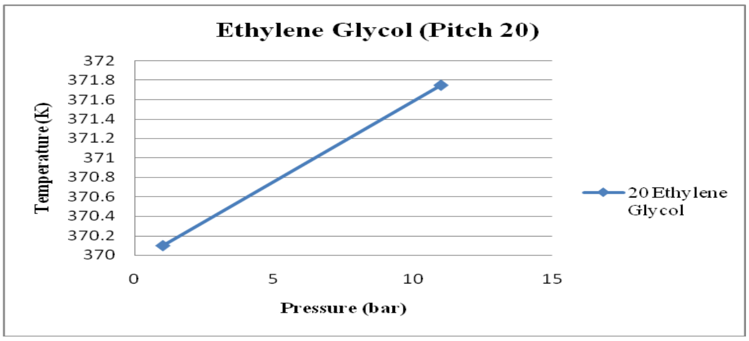

Figure 10: Inlet & Outlet Temperature VS Inlet & Outlet Pressure of Helical Tube (Ethylene Glycol)

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From figure 9 & 10 it is seen that ΔT=1.65 K and ΔP=10 bar.

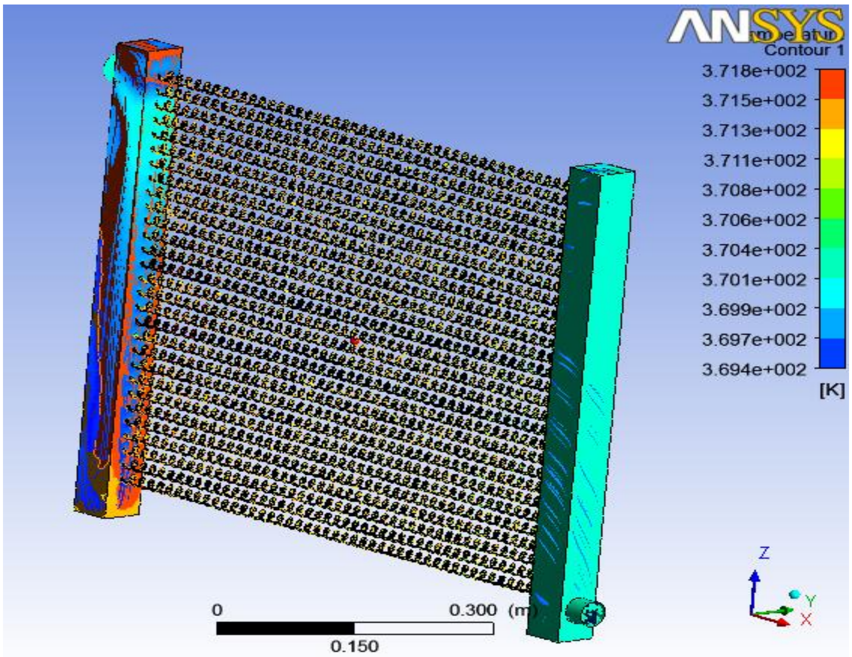

Figure 11: Temperature diagram of helical tubes used in Radiator. (Ethylene Glycol)

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.

TABLE3: Case II-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

Case-III: Comparison of Straight Tube and Helical Tube

Case- III (a): Comparision between Straight Tube and Helical Tube with Pitch 15mm & 20mm (Ethylene Glycol, for Mass Flow rate = 2.3 kg/sec)

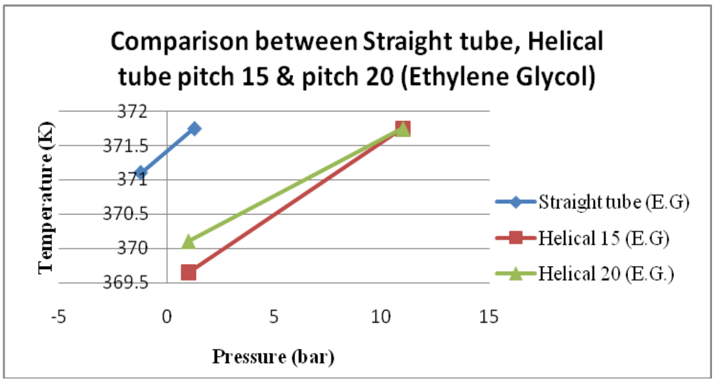

Figure 12: Comparision Between Straight line tube,Helical tube used in Radiator which Pitch 15mm & 20mm (Ethylene Glycol)

From above figure shows that Helical tubes type Radiator has more heat drop compared to the Straight tube type radiator & more heat dissipation occurs in the 15mm pitch compared to 20mm pitch & compared to helical tube radiator between 15 mm pitch & 20 mm pitch, more heat dissipation rate get in 15mm pitch compared to the 20mm pitch helical tubes used in radiator & also compared pressure drop of straight tubes & helical tubes used in radiator more pressure drop get in helical tubes used in radiator.

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IV. CONCLUSION

- Helical tubes type Radiator has more heat drop compared to the Straight tube type radiator.
- Compared to the Straight tubes radiator & Helical tubes radiator; Helical tubes more heat drop compared to the straight tubes.
- Maximum pressure drop get in helical tubes radiator compared to the straight tube radiator.
- Helical tubes radiator more heat dissipation occurs in the 15mm pitch compared to 20mm pitch.

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