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Design of automotive engine coolant hoses

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ABSTRACT

In this paper, we are present the performance of engine coolant hoses (radiator hoses) used in passenger cars by checking various physical behaviours such as hose leakage, hose burst, hose collapse or any mechanical damage as studied-thru design guidelines, CFD analysis and product validation testing and also check pressure drop of the hoses when engine will be running. The design term is more likely used for technical part modelling using CAD tool. Later on, we will focus on the transformation of the part design to process design. The process design term is more likely used for "tooling design" for manufacturing of the product using CAD Tool. Then inlet hose carries coolant from engine to radiator inlet tank, then coolant circulated in radiator and passed through radiator outlet tank to water pump of engine with the help of outlet hose. After that finding any leakage, Burst, damage or collapse of hose and pressure drop of the hose with the help of design checklist, CFD Analysis and product validation testing.

1. Introduction

The function of coolant hoses in a vehicle is to provide a flexible connection between the engine block and radiator. This can be used for the efficient cooling of automobile engines vehicle [1]. The hoses must be permit carrying of water at a high temperature and must be flexible for to avoid transmission of distorting loads to the radiator tank, and also throttle of the water supply [2]. These hoses are shaped hoses and size of the hose varies for different vehicles such as buses, Lorries, trucks, cars, jeeps, tractors etc. The radiator hose consists of three basic components :

(a) The Inner Tube (b) The Reinforcing Fibber and (c) The Rubber Cover [3]. The rubber lining is to withstand the temperature of hot water and cover compound to function effectively under the operating environment [4]. Most modern coolant hoses are made from

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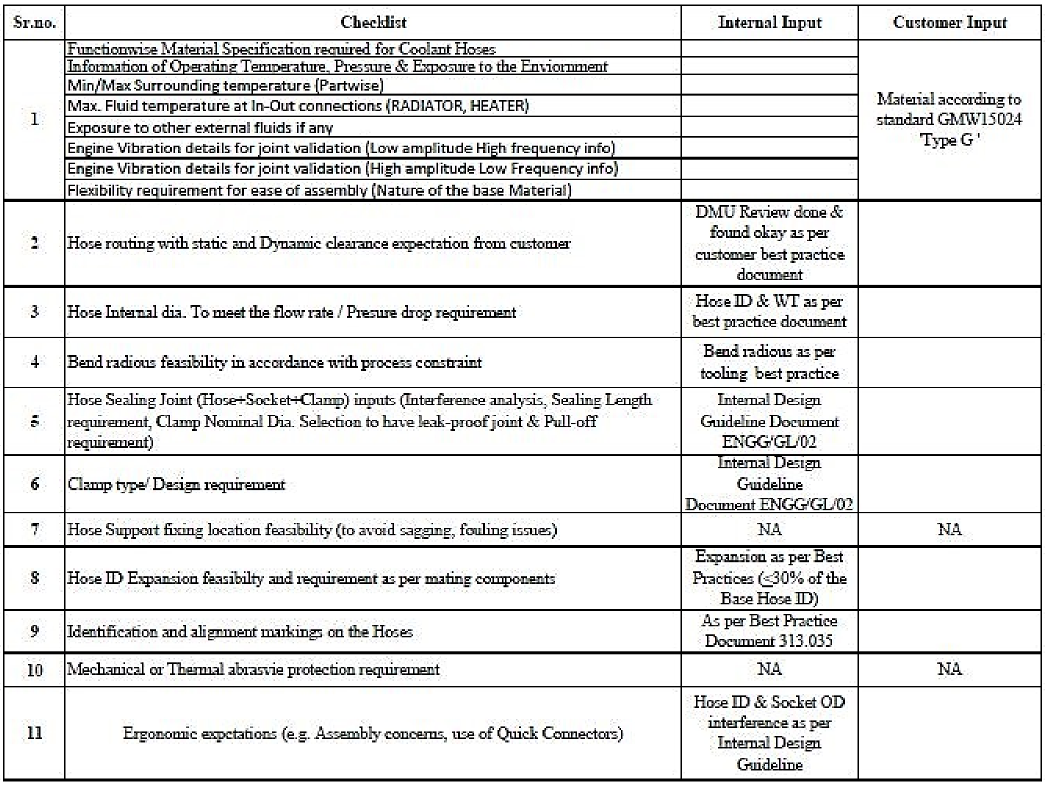
ethylene Propylene EPDM rubber, which can endure operating temperature ranging from -45 to +270 degrees F. Approximately about 90% of all automotive vehicle hoses can produced curved or moulded to fit specific application of vehicles, including branched hoses with three or more moulded [5]. Coolant hoses are also manufactured in universal - fit straight lengths that can withstand up to 2.5 bar working pressures in many commercial applications [6]. Most coolant hoses are manufacturers designed replacement clamps that will secure EPDM rubber [7]. Suppose your car engine is running it creates heat, the radiator cooling system hoses carry coolant through the radiator and back through the engine to keep it operating at an optimal temperature [8]. There are multiple hoses in a given system. An upper hose connects the top of the radiator to the top of the engine and a lower hose connects the bottom of the radiator to the water pump of the engine [10]. Scope of the study is expected to present better understanding of Engine cooling system and Design better quality Hose for long time used in Automotive Vehicle without any damage or burst or leak [11]. Remove physical behaviours such as hose leakage, hose burst or any mechanical damage with the help of design checklist, CFD Analysis and product validation testing.

Table 1 – Design checklist.



Sr.no.	Checklist	Internal Input	Customer Input
1	Functionwise Material Specification required for Coolant Hoses		Material according to standard GMW15024 'Type G '
	Information of Operating Temperature, Pressure & Exposure to the Enviornment		
	Min/Max Surrounding temperature (Partwise)		
	Max. Fluid temperature at In-Out connections (RADIATOR, HEATER)		
	Exposure to other external fluids if any		
	Engine Vibration details for joint validation (Low amplitude High frequency info)		
	Engine Vibration details for joint validation (High amplitude Low Frequency info)		
	Flexibility requirement for ease of assembly (Nature of the base Material)		
2	Hose routing with static and Dynamic clearance expectation from customer	DMU Review done & found okay as per customer best practice document	
3	Hose Internal dia. To meet the flow rate / Presure drop requirement	Hose ID & WT as per best practice document	
4	Bend radious feasibility in accordance with process constraint	Bend radious as per tooling best practice	
5	Hose Sealing Joint (Hose+Socket+Clamp) inputs (Interference analysis, Sealing Length requirement, Clamp Nominal Dia. Selection to have leak-proof joint & Pull-off requirement)	Internal Design Guideline Document ENGG/GL/02	
6	Clamp type/ Design requirement	Internal Design Guideline Document ENGG/GL/02	
7	Hose Support fixing location feasibility (to avoid sagging, fouling issues)	NA	NA
8	Hose ID Expansion feasibilty and requirement as per mating components	Expansion as per Best Practices ($\leq$30% of the Base Hose ID)	
9	Identification and alignment markings on the Hoses	As per Best Practice Document 313.035	
10	Mechanical or Thermal abrasvie protection requirement	NA	NA
11	Ergonomic expctations (e.g. Assembly concerns, use of Quick Connectors)	Hose ID & Socket OD interference as per Internal Design Guideline	

2. Experimental Methodology

In the experimental methodology, we are mention all step by step methods such as Design checklist, modelling, meshing, material and its properties, boundary condition and results etc.

2.1. Design Checklist for Engine coolant hoses

In this design checklist document, all point should be covered before modelling of the hoses. Check all the point mention in checklist for based on the customer Input and give design mock up review as per customer best practices as shown in table1.

2.2. Modelling engine coolant hoses

First step is that the design of automotive engine coolant (inlet radiator) hoses and automotive engine coolant (outlet radiator) hoses in solid works Cad Software [12]. These radiator inlet and outlet hoses can be design with appropriate dimension as per customer requirement. Customer only give idea about which type of hose to be require i.e. Size, Shape, and dimension etc. This type of hoses mostly used in the passenger car's engine is running it creates heat, the radiator cooling system hoses carry coolant through the radiator and back through the engine to keep it operating at an optimal temperature.

2.2.1. Radiator inlet hose

These radiator inlet hose can be design with the help of preliminary 3D cad data as per customer requirement. After carefully study of preliminary CAD data, we are collect useful data such as points and dimensions in X, Y, Z Co-ordinates. Then design radiator inlet hose as shown in figure 1

Fig. 1 – Inlet hose.

2.2.2. Radiator outlet hose

These radiator inlet hose can be design with the help of Preliminary 3D cad data as per customer requirement. After carefully read preliminary cad data, we are collect relevant data such as points & dimensions in X, Y, Z Co-ordinates. Then design radiator inlet hose as shown in figure 2

Fig. 2 – Outlet Hose.

2.3. Material properties

After completing modelling of radiator inlet and outlet hoses so give material and its properties for solid body EPDM rubber material (Ethylene propylene diene monomer) and fluid body coolant ethylene glycol + water as shown in table 2 and 3

Table 2 – Mechanical Properties of EPDM Rubber.

Density	1105 kg/m^3
Specific heat	2 kJ/kg-K
Thermal conductivity	0.2 W/m-K

Table 3 – Mechanical Properties of Ethylene glycol+Water.

Temperature	100-125°c
Density	1111.4 kg/m^3
Specific heat	2.415 kJ/kg-K
Thermal conductivity	0.252 W/m-K

2.4. Meshing

Ansys fluent meshing process provide physics content that help to automate the meshing process. For an initial design, a mesh (tetrahedral) can often be generated in batch with an initial solution run to locate regions of interest. Further refinement can then be made to the mesh to improve the accuracy of the solution. There are physics preferences for structural, fluid, explicit simulations as shown in figure 3.

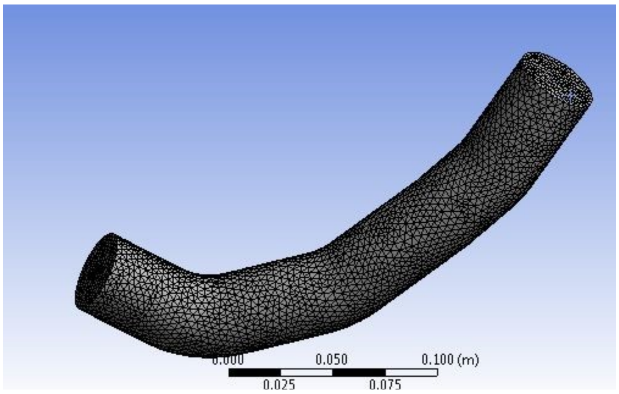


Fig. 3 – Inlet Hose Meshing.

In the mesh generation 26373 nodes, 136330 elements are generated. Near wall of the Hose, the elements were created so as to capture the fine boundary layers. Patch dependent method is used for meshing. After application of smoothing the mesh quality of 0.89 was obtained as shown in table 4.

Table 4 – Mesh Quality.

Nodes	26373
Elements	136330
Mesh quality	0.89

Initially radiator outlet hose is meshed by using Ansys fluid flow with tetrahedral elements and the global element scale factor 1 as shown in figure 5.

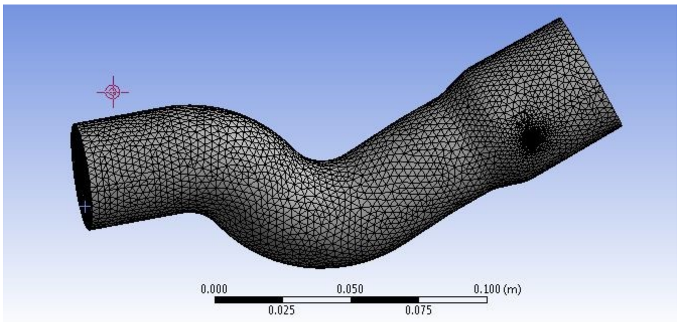


Fig. 4 – Outlet Hose Meshing.

Initially, radiator Outlet hose is meshed by using Ansys fluid flow with tetrahedral elements and the global element scale factor 1. In the mesh generation 22424 nodes, 106396 elements are generated as shown in table 5.

Table 5 – Mesh quality.

Nodes	22424
Elements	106396
Mesh quality	0.85

2.5. Boundary Condition

In this mesh files of created models for radiator inlet and outlet. Then these files imported in Ansys fluent. Ansys fluent is analysis software for solving fluid flow problem easily. The Fluid domain is obtained for coolant ethylene glycol + water and rubber domain is obtained for solid with material properties of EPDM rubber as shown in table 6.

Table 6 – Boundary Condition.

		Pressure (bar)	Temperature (K)	Coolant Flow rate (lpm)
Inlet Hose	In	2.5	373	20
	Out	2.5	-	-
Outlet Hose	In	2.5	360	20
	Out	2.2	-	-

3. Results and discussion

3.1. Pressure Distribution

3.1.1. Time period 1 hr

The figure 6 shows that pressure contour in the radiator inlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for time period 1 hr. From the above result it is concluded that the pressure drop of Inlet hose is 0.030 bar. Maximum pressure is 2.530 bar and minimum pressure is 2.50 bar after 2000 iteration. If pressure drop is minimum so design is more effective. Also slightly drop the temperature of the hose.

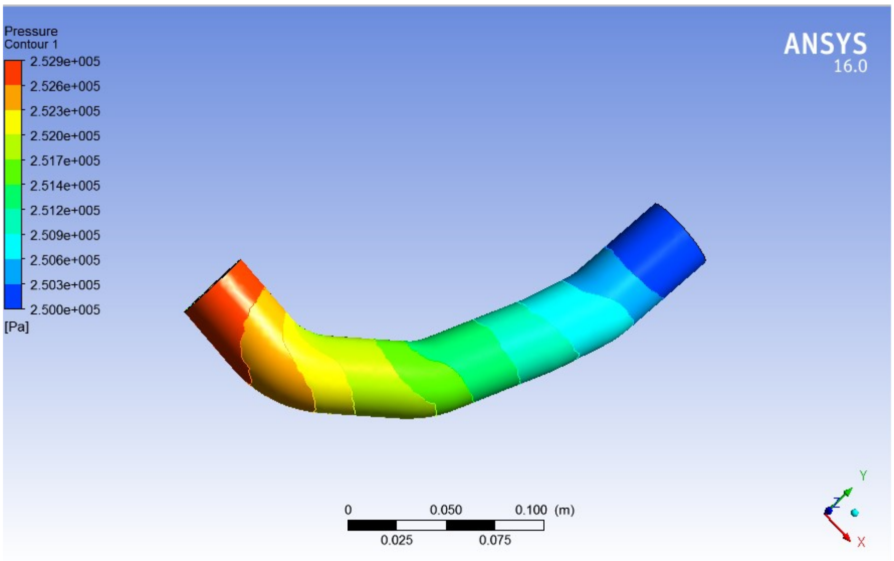


Fig. 5 – Pressure contour for coolant hose at 20 lpm flow rate for time 1 hr.

The figure 7 shows that pressure distribution in the radiator outlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for time 1 hr. From the above result it is observed that pressure drop of outlet hose is 0.027 bar. Maximum pressure is 2.507 bar and minimum pressure is 2.48 bar respectively. The pressure drop occurs in the bend of hose i.e. if number of bend increases so pressure drop also increases. So it is concluded that total pressure drop of the radiator Inlet and Outlet hoses are 0.057 bar.

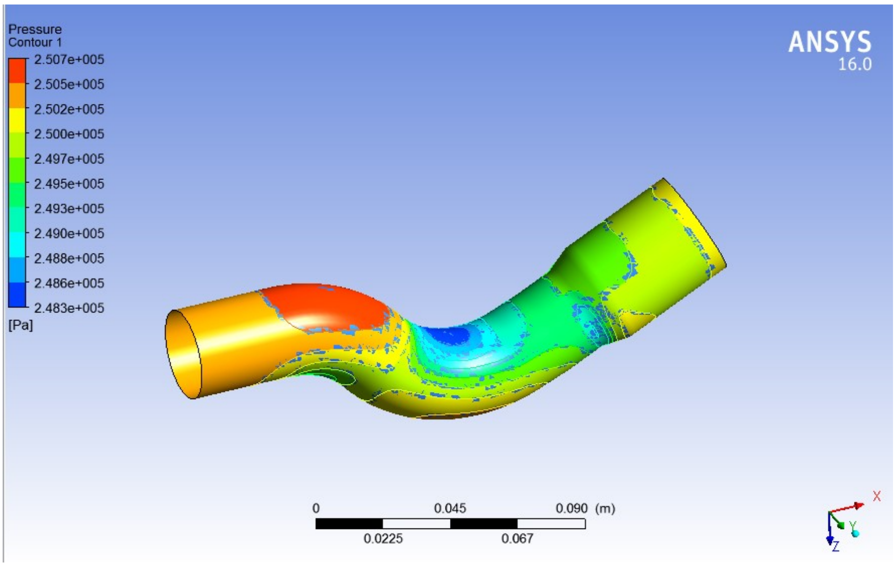


Fig. 6 – Pressure contour for coolant hose at 20 lpm Coolant flow rate for time 1 hr.

3.1.2. Time period 3 hr

The figure 8 shows that pressure contour in the radiator inlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for time 3 hr. From the above result it is observed that the pressure drop of Inlet hose is 0.020 bar. Maximum pressure is 2.514 bar and minimum pressure is 2.494 bar at the end of 3 hours.

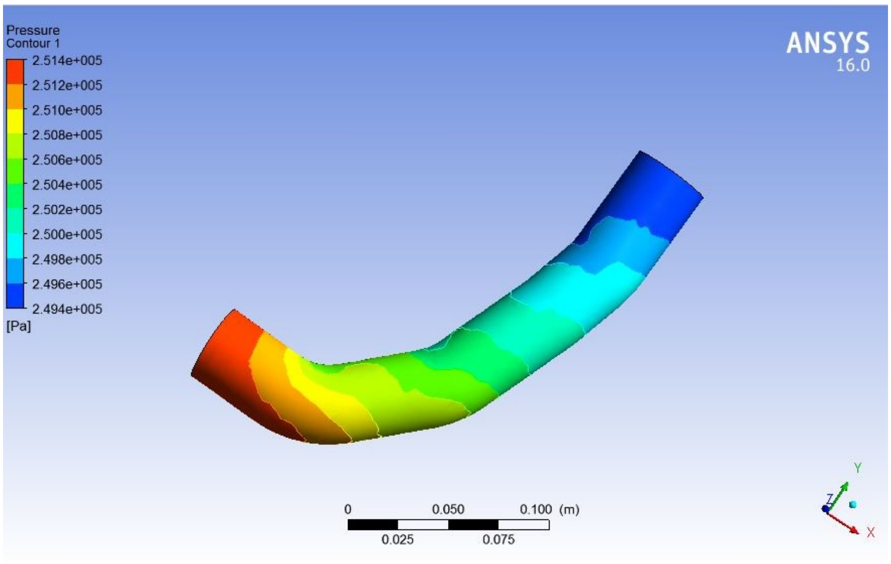


Fig. 7 – Time Period 3 hr.

The figure 9 shows that pressure distribution in the radiator outlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for 5000 Iterations for 3 hr. From the above result it is observed that pressure drop of outlet hose is 0.025 bar. Maximum pressure is 2.488 bar and minimum pressure is 2.463 bar respectively. It is concluded that total pressure drop of the radiator Inlet and Outlet hoses from time period after end of 3 hours is 0.07 bar.

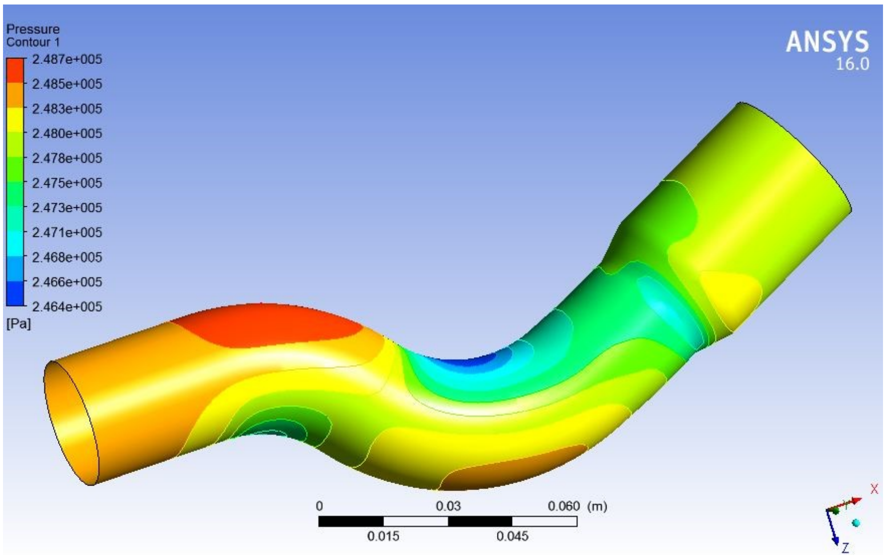


Fig. 8 – Time Period 3 hr.

3.1.3. Time period 5 hr

The figure 10 shows that pressure contour in the radiator inlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar. From the above result it is concluded that the pressure drop of Inlet hose is 0.027 bar. Maximum pressure is 2.517 bar and minimum pressure is 2.49 bar at the end of 57000 iterations. Maximum pressure flow is starting of the hose.

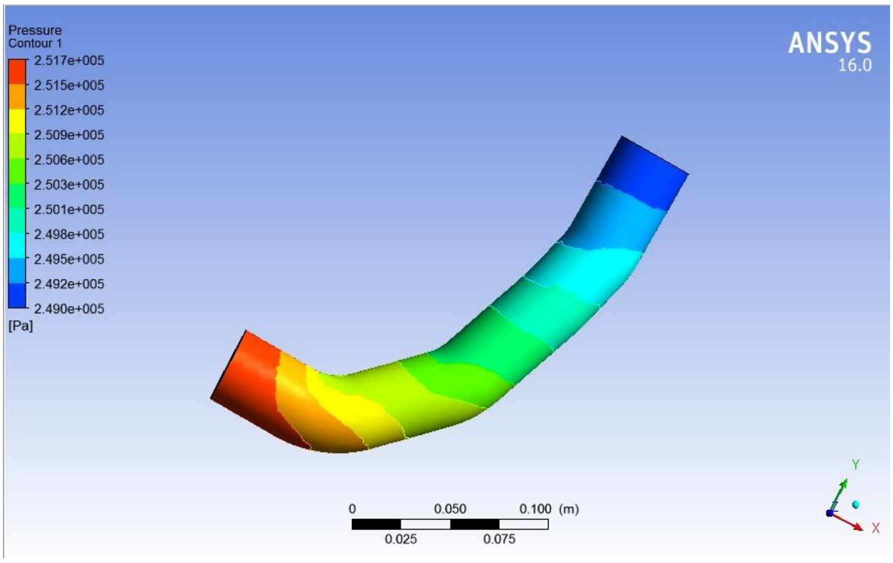


Fig. 9 – Time Period 5 hr.

The figure 11 shows that pressure distribution in the radiator outlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for 5 hours. From the above result it is observed that pressure drop of outlet hose is 0.016 bar. Maximum pressure is 2.478 bar and minimum pressure is 2.463 bar respectively. The pressure drop occurs in the bend of hose. So it is concluded that total pressure drop of the radiator Inlet and Outlet hoses from time period of after end of 5 hours is 0.10 bar.

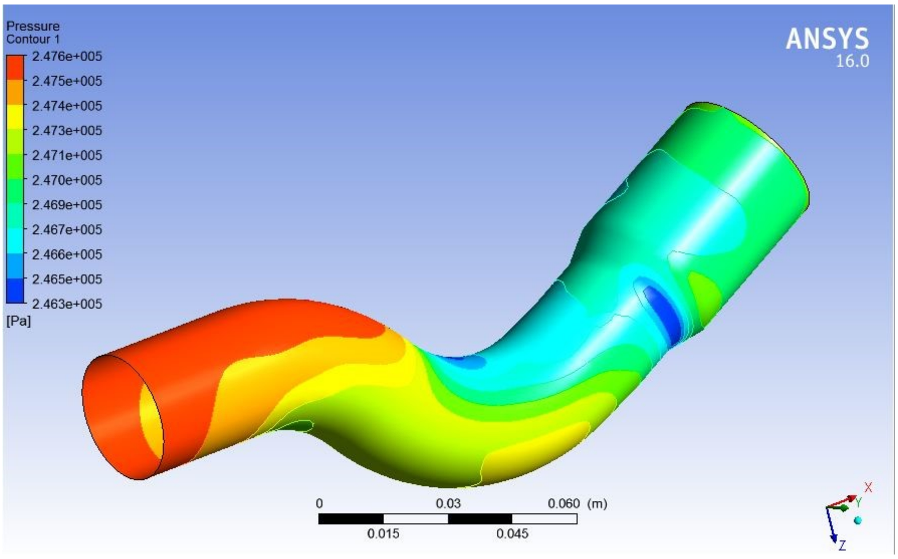


Fig. 10 – Time period 5 hr.

3.1.4. Time period 10 hr

The figure 12 shows that pressure contour in the radiator inlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for 10 hours. From the above result it is observed that the pressure drop of Inlet hose is 0.027 bar. Maximum pressure is 2.507 bar and minimum pressure is 2.480 bar at the end of 10 hours.

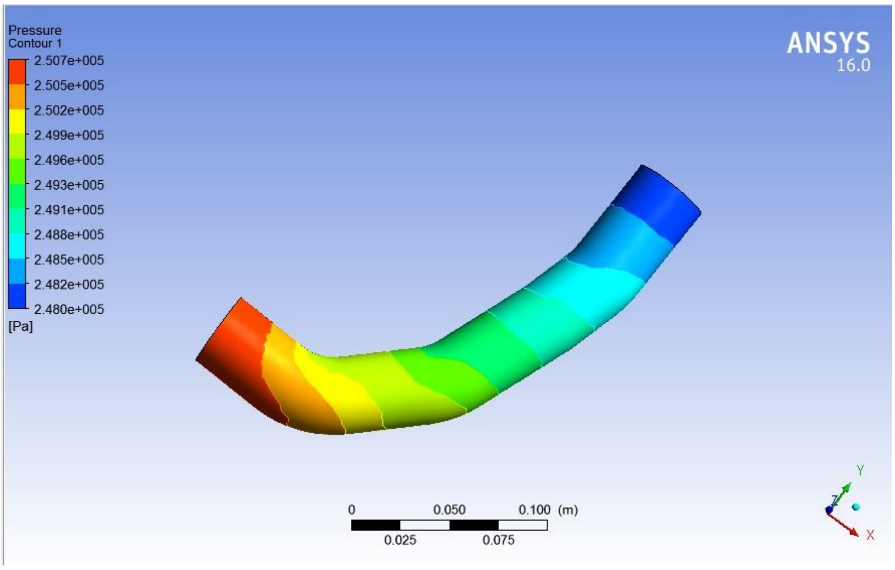


Fig. 11 – Time Period 10 hr.

The figure 13 shows that pressure distribution in the radiator outlet hose at coolant flow rate 20 lpm and inlet pressure is 2.5 bar for 10 hours. From the above result it is observed that Pressure drop of outlet hose is 0.013 bar. Maximum pressure is 2.448 bar and minimum pressure is 2.430 bar respectively. The pressure drop occurs in the bend of hose. So it is concluded that total pressure drop of the radiator Inlet and Outlet hoses from time period 10 hours. is 0.112 bar.

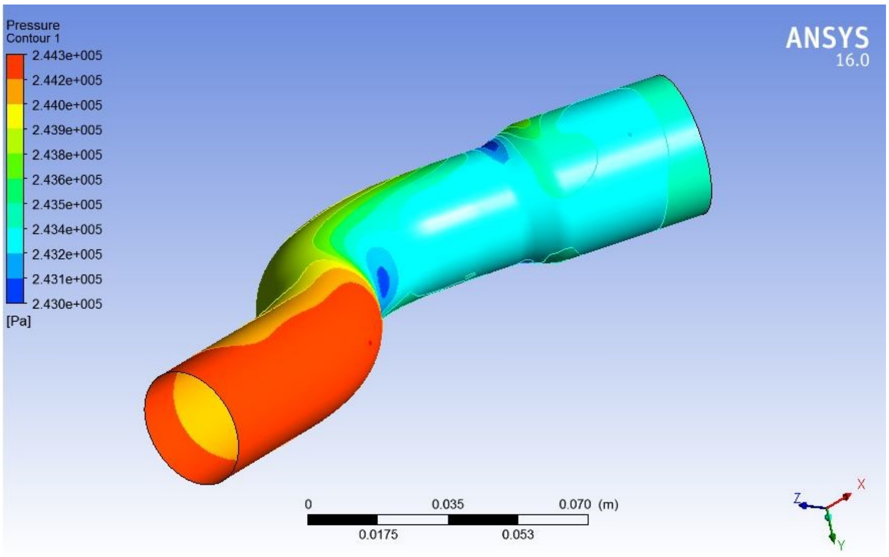


Fig. 12 – Time period 10 hr.

3.2. Velocity Streamline

Figure 14 shows that velocity of coolant in the Inlet Hose at the Coolant flow rate 20 lpm and Temperature 373 k. The velocity of coolant is maximum at the inlet and goes to decreases till the exit of the tube.

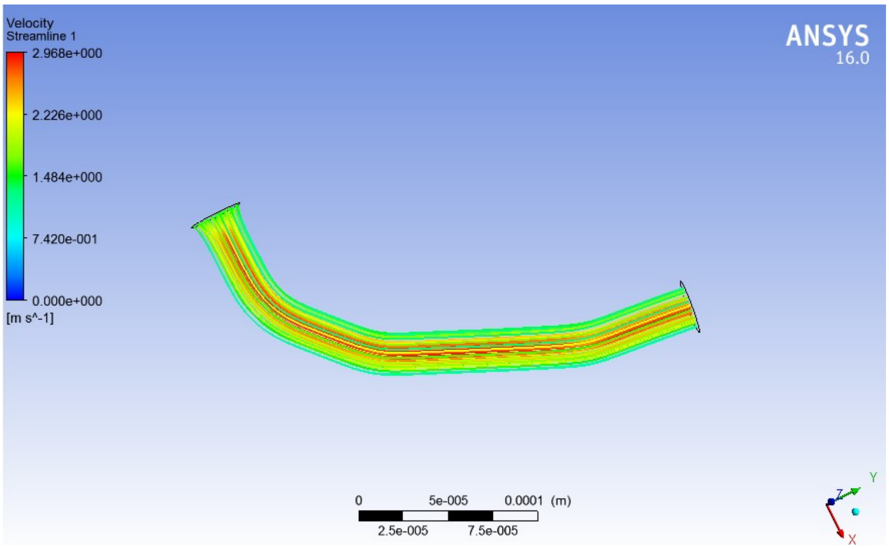


Fig. 13 – Velocity streamline for Inlet Hose at 20 lpm coolant flow rate.

Figure 15 shows that velocity of coolant in the Outlet Hose at the Coolant flow rate 20 lpm and Temperature 360 k. The velocity of coolant is maximum at the inlet and goes to decreases till the exit of the tube.

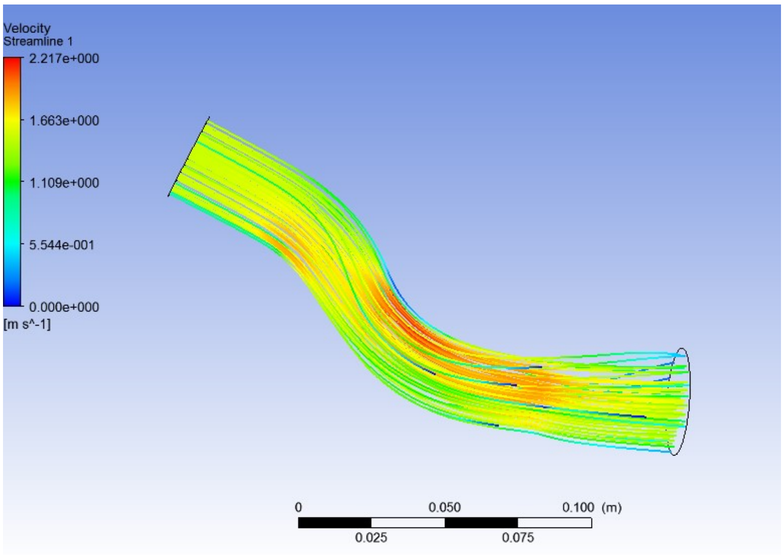


Fig. 14 – Velocity streamline for Outlet Hose at 20 lpm coolant flow rate.

4. Conclusion

In CFD Analysis, it is observed that the overall pressure drop at radiator outlet is 0.112 bar at an I input pressure 2.5 bar for testing durations 10 hours. So it is in line with the engine cooling system requirement. Hence we conclude that there is no potential failure could occur such as overheating, overpressure and also ensure the long life product performance.

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