Pressure drop analysis of flow through pin fin channel

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Abstract – *A traction inverter is an equipment in all electric or hybrid vehicles, which converts DC current from the battery to AC which in turns drives an electric motor to propel the vehicle. During its usage, they tend to generate a large amount of heat (1). Pressure drop analysis of inverters becomes important to regulate the amount of load which is faced by the electric pump pumping coolant to the inverter.*

This paper deals with the pressure drop analysis of a pin fin coolant channel using ethylene glycol 50/50 as the coolant. Three different designs are considered with pin fin diameters of 4mm, 6mm and 8mm with temperature varying from -17.8C to 80C. The study will be useful to analyze the behavior of ethylene glycol 50/50 for design of coolant system for automotive inverter of any electric vehicle.

Key Words: Inverter, pressure drop, ethylene glycol, electric motor, cooling, Ansys

1. INTRODUCTION

Design of a traction inverters for electric and hybrid vehicles is crucial since they tend to generate a lot of heat owing to the high voltages of ~800V at which they operate. Most of the high voltage inverters used in electric vehicles are 800V now a days. Ethylene glycol 50/50 is the coolant being used in inverters for its cooling, since it's an antifreeze and has excellent cooling characteristics over a wide range of temperatures.

Most of the coolant channels for these inverters use a pin fin design for heat dissipation from the power modules to the coolant [2]. Since the coolant to the inverter is being circulated by an electric pump, coolant channels are usually designed to effectively dissipate heat as well as meet the requirement of pressure drop which the pump can handle. Too much pressure drop can lead to excessive pumping load on the pump even though it means larger pin fins and thus more efficient heat transfer from the power modules.

Ansys Fluent provides an effective way to run pressure drop simulations on the coolant channel designs. Volume extract feature of Ansys Space Claim has been used to extract the coolant flow path and watertight geometry is used for analysis.

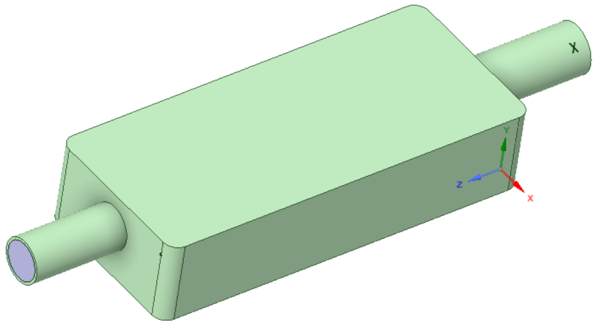

Figure-1: Coolant Channel Design

Coolant channel dimension: 140mm x 60mm

Characteristic length of pipe: 14mm

Pin fin diameters: 4mm, 6mm and 8amm

Temperatures of ethylene glycol 50/50: -17.8C, 0C, 40C, 60C and 80C

Total number of fins: 65

Distance between pin fin centers: 10mm along length and width of the channel

2. MODEL GEOMETRY AND MESH GENERATION

The 3D geometry of coolant channel was made in 'Ansys Space Claim' and the volume extract for coolant path was done using the same tool. Volume extract meshing was done using 'Ansys Fluent meshing' tool in 'Ansys Workbench'.

Below is the figure of what the volume extract looks like,

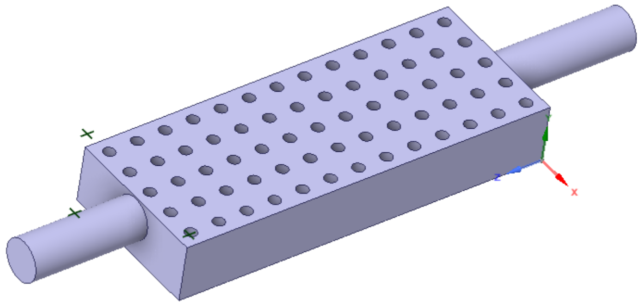

Figure-2: Volume extract of coolant flow path

The meshed volume looks as below,

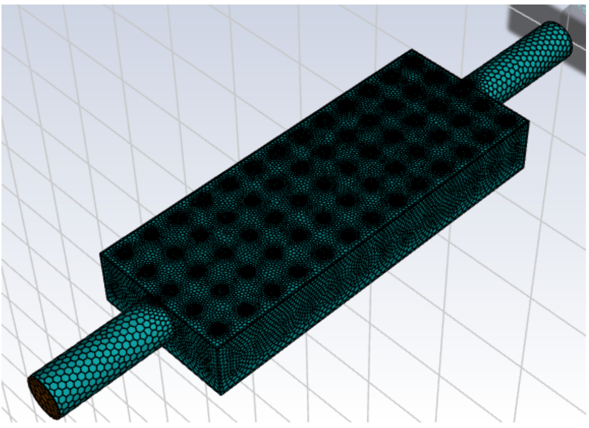

Figure-3: Meshed volume extract

The flow is mostly laminar except at the analysis temperature of 40C and 60C where it becomes Turbulent. The room temperature considered is 300K.

For analysis of Turbulent flows, SST k-ω turbulence model is used in Fluent where Laminar model for Laminar flows.

Minimum orthogonal quality for all the simulation runs is 0.5.

3. CFD Analysis of Flow

Fluent is a software based on Navier Stokes equation.

According to the law of conservation of mass in a closed physical system mass of medium cannot neither increase nor

decay.

We obtain the following equation of flow continuity:

$$p/ t+\nabla .(p v)=0$$

where:

t -time [s],

v - fluid flow rate [m/s],

p -fluid density [kg/m^3].

Navier-Stokes equation is used for conservation of mass and momentum of flowing fluid. [3]

3. CFD Analysis Boundary Settings

The properties of Ethylene Glycol 50/50 are used from the website mentioned at the below link,

https://www.engineeringtoolbox.com/ethylene-glycol-d_146.html [4]

The flow rate of the coolant is considered to be constant at 3LPM for all the geometries and temperatures.

The mass flow rate through the channel will be dependent on the density at each analysis temperature. Below are the values,

Temperature (°C)	**Mass flow rate (g/s)**
-17.8	55
0	54.5
26.85	53.85
40	53.35
60	52.75
80	52.1

Table-1: Mass flow rate for different coolant temperatures

For Reynolds number calculation, to determine whether the flow is laminar or turbulent, below link is used,

https://www.omnicalculator.com/physics/reynolds-number [5]

The analysis is run till solution converges in Fluent.

Laminar flows have Reynold number below 2000 while turbulent flows have Reynold number more than 3500.

4. RESULTS AND DISCUSSION

Below table highlights the pressure drop values at different temperature for 4mm pin find diameter. Flow rate is 3LPM.

Fluid Temperature **(°C)**	Pressure drop (Pa)
-17.8	341.3
0	223.3
26.85	134.7
40	127.4
60	113.4
80	206.2

Table-2: Pressure drop for 4mm diameter pin fin

Below table highlights the pressure drop values at different temperature for 6mm pin find diameter. Flow rate is 3LPM.

Fluid Temperature (°C)	Pressure drop (Pa)
-17.8	414.2
0	273.7
26.85	177.1
40	169.7
60	156.7
80	253.4

Table-3: Pressure drop for 6mm diameter pin fin

Below table highlights the pressure drop values at different temperatures for 8mm pin find diameter. Flow rate is 3LPM.

Fluid Temperature (°C)	Pressure drop (Pa)
-17.8	661.1
0	440.4
26.85	305.4
40	285.8
60	264.6
80	408.8

Table-4: Pressure drop for 8mm diameter pin fin

Below chart shows the trend of pressure drop at different temperatures for pin diameter of 4mm, 6mm and 8mm respectively.

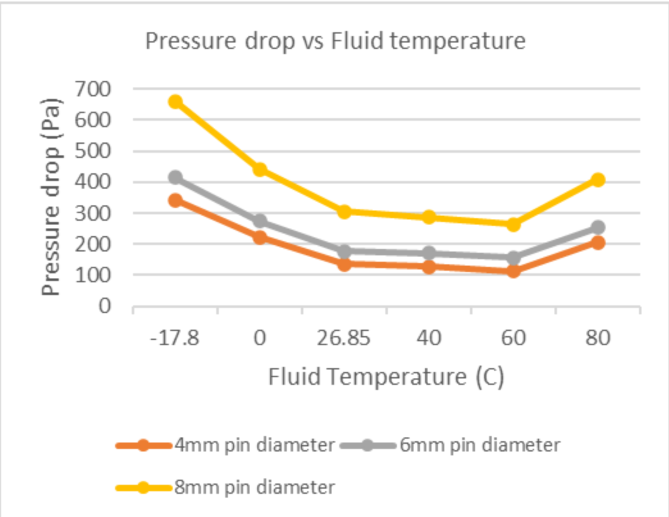

Chart -1: Pressure drop vs Fluid Temperature plot

Sample paragraph Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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3. CONCLUSIONS

Conclusions drawn from above results in the last section are as below,

1. For all the pin fin designs under consideration, pressure drop decreases drastically with increase in the fluid temperature and then increases at a temperature of around 60C. More pressure drop at low temperature of 17.8C is due to the high density of ethylene glycol 50/50 solution.

2. Pressure drop at a particular temperature value is highest for 8mm pin diameter and lowest for 4mm pin diameter. Higher pin diameter implies less space for coolant to flow leading to higher pressure drop.

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[4] https://www.engineeringtoolbox.com/ethylene-glycol-d_146.html

[5] Reynolds Number Calculator (omnicalculator.com)

BIOGRAPHIES

Ayush Lal is a Senior Mechanical Engineer at Aptiv in Michigan. He graduated from Michigan Technological University in 2017.