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Analysis & Flow Simulation on a Cold Plate with Electronics Housing Assembly

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Abstract— **Flow simulations have been used to determine the surface plot and flow trajectories of a fluid like the temperature and pressure of the solid body and the fluid itself, to cool down electronics housing we use a cold plate so that it won't overheat. In this report, there is a brief introduction to cold plate and electronics housing and their design in Solid works. And then how we made a split line on electronics housing so that we can apply heat load on it. In this report, we have studied about 3 types of cold plates: - parallel, series, and then the modified series. The material which is chosen is Aluminium because of its high relative strength and low relative weight than other metals, cheap cost and easy availability, and high corrosive resistance. It performs well in harsh atmosphere due to its high robustness and durability, capable of withstanding high impact with high malleable strength. It can put up good guard against electromagnetic interference. But before that, we have done some calculations on heat load and volumetric flow rate so that we can apply them while doing flow simulation. Pressure in parallel and series cases is very high so we have done another case which is modified series, in this case, pressure is less as compared to normal series flow.**

***Keywords*— Flow Simulation, Cold Plate, Heat Transfer, Coolant, Electronic Housing**

I. Introduction

Cold plates are the device that provide cooling by transferring the heat from the plates to the liquids or coolant that flows into the heat exchanger and release them in ambient environment or to the secondary cooling systems [1]. They can be of various type like rivers or cooling tower for the steam engines etc heat flow due to conduction going through the interface material to the cold plate and then to the channels [1]. Then with the help of convection it flows through the internal surface of fluid path to coolant which we are using. Cold plate is generally used in electronics cooling and the material that used in it is manufacturing is aluminium with an embedded coolant fill channel or metal tube. There are many other types of cold plate one of them is made with metal and they are joined together by wielding techniques and from inside surface fins provide cooling to the plate which are immersed in the coolant [1].

II. Literature Review

Embedded designed tube are the simplest type of cold plate, and are used in many places in cooling device. They are used to provide a continuous tube in a metal plate [2]. The coolant takes out the element heat and through it, to the secluded heat exchanger, where it is cooled before going in the cold plate again. The tubing in the plate can be constant or cut-off at one end and new at another start depend upon the usage requirement or linked by molten metal or soldered joints, but these joints can increase the risks for leakage [2]. The mostly and widely used tubed cold plate is an aluminium plate which is uncovered or exposed copper plate tube, the thermal performance can be altered and enhanced by dividing the tubes into different route or passageway [2].

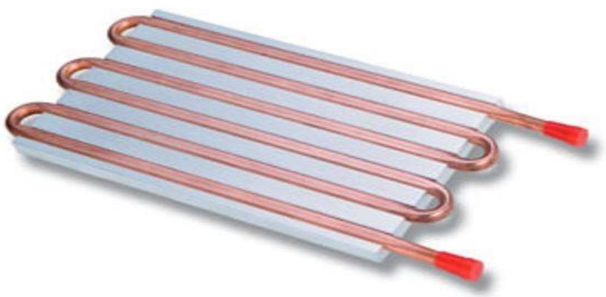


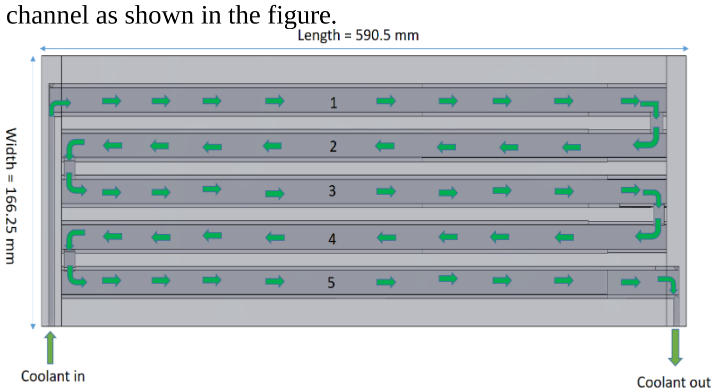
Fig 1. A Tubed cold plate consists of copper or stainless-steel tubing pressed into a metal plate

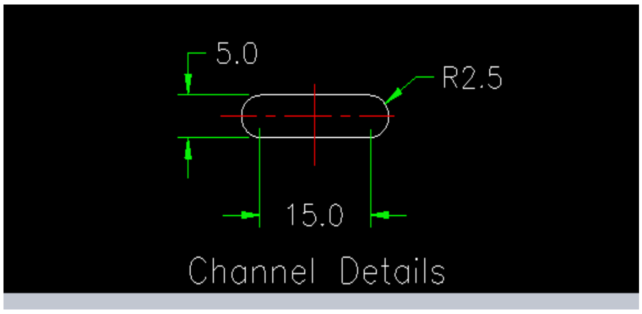
This type of designing of plate can be easily produced with minimum cost requirement and provide good thermal solution for cooling of components where the heat is inconsistent and varying from low to medium level. The thermal resistance can be minimized between the power device and the cold plate by putting coolant Tube directly connected with power devices base. Direct contact reduces thermal interface between device and fluids and might help in increasing the performance of the device or mechanism. A different type of cold plate which has thermal epoxy with metal plate surface. These types of cold plate are known as buried tube liquid cold plate. In this type of cold plate there is gap free dissipation and transfer of heat out of electronics devices between the tube and plate. The main feature of these kind of plates are they are fully buried into the surface of cold plate and are not in contact with outside environment. The coolant preference also affects the thermal performance. It is important to choose right material for tube. The coolant like water is in perfect sync with copper and some other coolant as well, while stainless steel is used for corrosive coolant.

Cold plates that we have designed for series and parallel flow

1. **Series flow**

In this case, coolant will go in from only 1 channel and pass through every channel by series flow, and comes out from only 1 channel as shown in the figure.



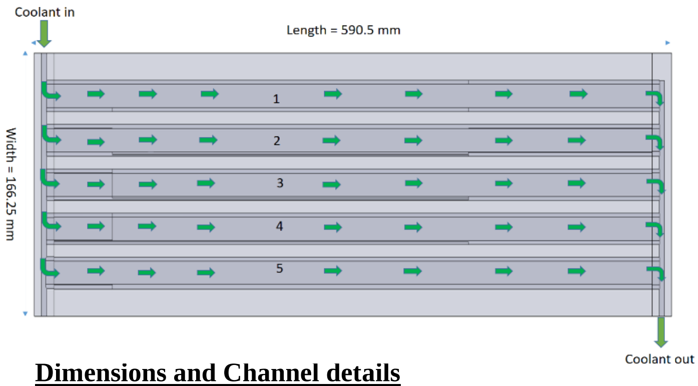


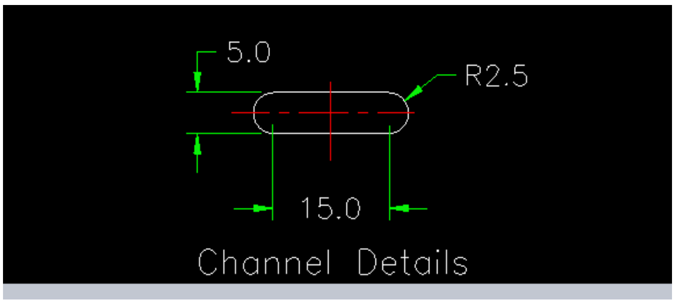
Dimensions and Channel details

- Length = 590.5 mm
- Width = 166.25 mm
- Height = 10 mm

2. **Parallel Flow**

In this case, fluid will go through all 5 channels at the same time and also come out from all 5 channels.





Dimensions and Channel details

- Length = 590.5 mm
- Width = 166.25 mm
- Height = 10 mm

3. **Modified series flow**

In this case, fluid will go through 1 channel and then it goes to 2 channels unlike series flow but it will go in like series flow, then it will come out from 2 channels. Using this type of arrangement will decrease the pressure of the fluid.

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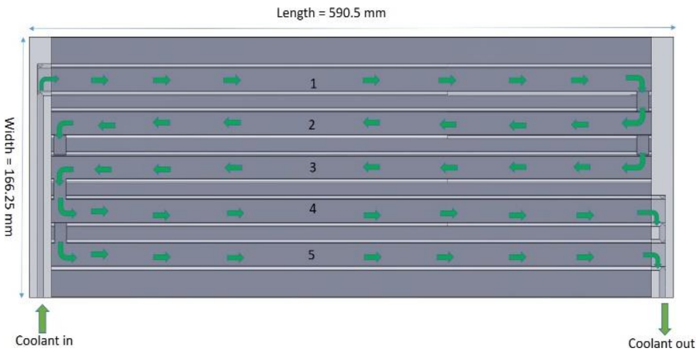
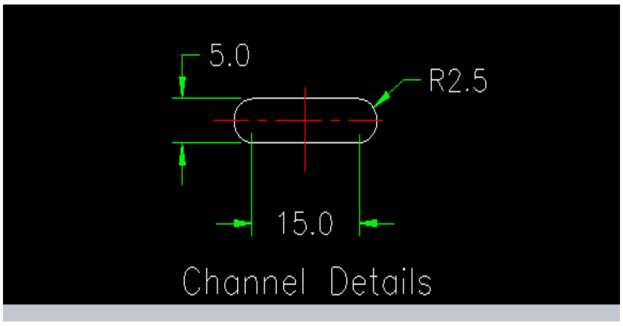




Dimensions and Channel details

- Length = 590.5 mm
- Width = 166.25 mm
- Height = 10 mm

III. Electronics housing

What is the purpose of an electronic enclosure?

An electronic enclosure is a protective box that used in electrical or electronic devices to safeguard electrical shock. Rigid plastics, metals like stainless steel and aluminium are usually used to create these enclosers [3].

An **electronic enclosure** is a case for electronic apparatus to equip displays meters, electrical buttons or switches, levers. It is also used to stop user from getting an electric shock and safeguard the apparatus from the surrounding hazards [3]. The only visible part which can be seen by user is encloser [3]. Design of encloser may also be pleasing to eyes along with utilitarian uses. Regulations may control the quality and characteristics of enclosers for electrical apparatus in dangerous locations, for example: - coal fields and petrochemical plants. Design and production for encloser can be used for many loads like: -

- radio frequency intervention,
- heat dispersion,
- electrostatic discharge protection.

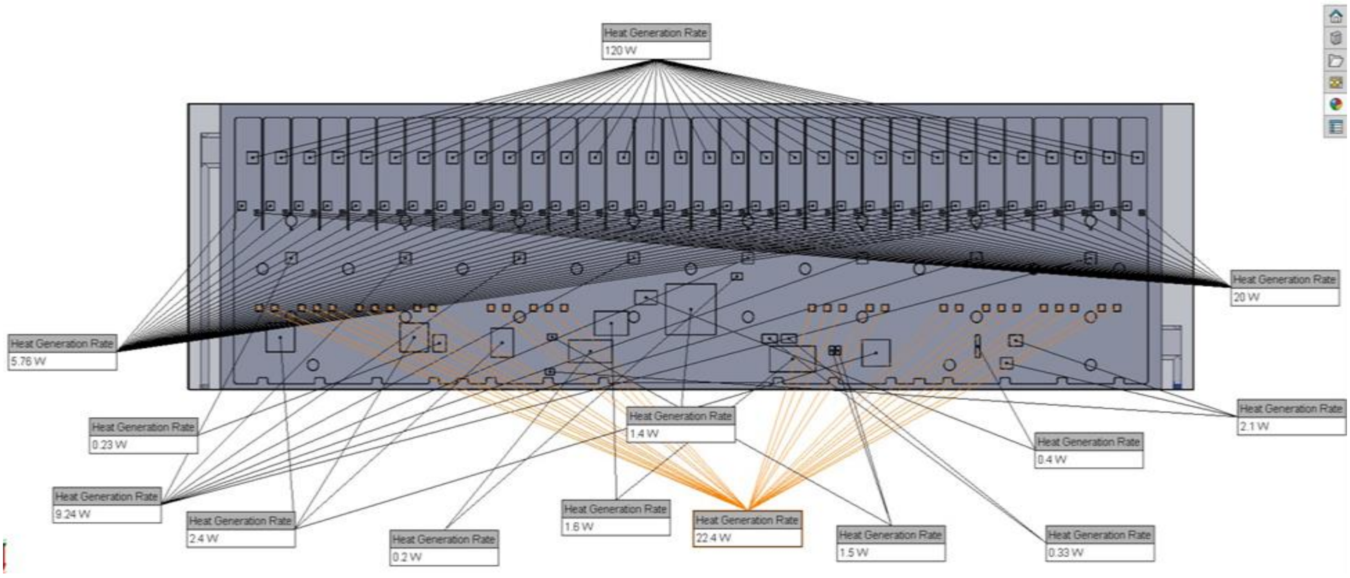
ABS is made of plastic case used in indoor application where harsh environments are not usually present. Polyvinyl Chloride (PVC), metals like stainless steel and aluminium are usually used to create these electronic enclosers. Painted metal enclosers made of steel may be galvanized [4]. When stronger cabinets are required materials like polycarbonate, fibreglass, glass-reinforced boxes are used and have a gasket to avoid humidity and dirt. For shielding of covered apparatus from electromagnetic interference, metal cases may meet the conductivity requirements [4].

Aluminium

Aluminium is used because of its basic properties like: -

- low cost,
- guard against electromagnetic interference,
- lightweight,
- able to tolerate high impact with high malleable strength,
- performed well in harsh environments and it is sturdy,
- relative strength,
- corrosive resistance.

Solidworks model of electronics housing with split lines



The purpose of making split lines is so that we can apply heat load in our electronics housing

S. No.	Heat load numbers	Total Heat load in watts
1.	32x3.75 watt	120 watts
2.	32x0.18 watt	5.76 watts
3.	32x0.625 watt	20 watts
4.	8x1.155 watt	9.24 watts
5.	32x0.7 watt	22.4 watts
6.	4x0.6 watt	2.4 watts
7.	1x0.23 watt	0.23 watts
8.	3x0.5 watt	1.5 watts
9.	3x0.7 watt	2.1 watts
10.	2x0.1 watt	0.2 watts
11.	2x0.8 watt	1.6 watts
12.	2x0.165 watt	0.33 watts
13.	2x0.2 watt	0.4 watts
14.	1.4x1 watt	1.4 watts
	Total	**187.56 watts**

Heat load in the electronics housing

Internal heat dissipation = 187.56 watts
Electronics housing area = 921012.5 mm^2 = 0.092102 m^2
Fluid final temperature = 32°C
Fluid initial temperature = 25°C
d_t (temperature difference) =7°C total heat load = 187.56 watts

Fluid type

Before doing the calculation for volumetric flow rate we need to assign a fluid whose properties we will be using in this calculation.

The fluid that we are using is 50/50 Ethylene-Glycol + Water (EGW) Mix

Why we do not use water as coolant

In our simulation we are not going to use water as coolant. Though it is quite common and has many plus points like: -

- Good specific heat
- Thermal conductivity is high
- Higher viscosity value

These are some points that makes it an effective cooling fluid. Water is 10 time more effective than that of an air-cooling system. Water is used in high power data centres etc [4].

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The most important reason why water is not used as coolant is because of its electrical conductivity and corrosive in nature problems. These problems are the reason why water is not used in every electronics device as a coolant, but we can overcome these problems by adding some additives to make it behave the way we want still water is a good choice for high power devices to cool [5].

Why 50/50 Ethylene-Glycol + Water (EGW) Mix

The main disadvantage of water is that it freezes at a very high temp (0 degree) than comparing to other coolants. But in some countries or regions where environmental temp is always below 0-degree water is ineffective and creates problem for us, so that's why we will be using 50/50 ethylene glycol + water mixture as our coolant because its freezing point is way below than that's of waters, though we may have to sacrifice some thermal performance it is good for working in the lower temperature. This coolant is generally used in aircrafts, automotive application and even some computing application [5].

Items | Item Properties | Tables and Curves

Property	Value
Name	50/50 Ethylene-Glycol + Water (EGW) Mix
Comments	
Density	1050 kg/m^3
Dynamic viscosity	0.004 Pa*s
Specific heat (Cp)	3300 J/(kg*K)
Thermal conductivity	0.4 W/(m*K)

This is a user-defined fluid

Calculation for volumetric flow rate

The volumetric flow rate in a heating system can be expressed as

$$q = h / (C_p * \rho * d_t) \ [6]$$

where,

q = volumetric flow rate (m^3/s),

to find, h = heat load (kJ/s, kW) = 0.18756 (kW), for 1 electronics housing since we are using 2 electronics housing so heat load will be

$$h = 0.18756*2 = 0.37512 \text{ (kW)}$$

$$C_p = \text{specific heat (kJ/kg°C)} = 3.3\text{(kJ/kg°C)}$$

$$\rho = \text{density } (kg/m^3) = 1050 (kg/m^3)$$

$$d_t = \text{temperature difference (°C)} = 7 \text{ (°C)}$$

$$q = 0.37512 / 3.3*1050*7 = 1.546*10\text{-}5 \ m^3/s = 0.92760 \text{ l/min}$$

• we are done with our calculation part, now we have to do flow simulation in Solidworks, there are some conditions while doing flow simulation.

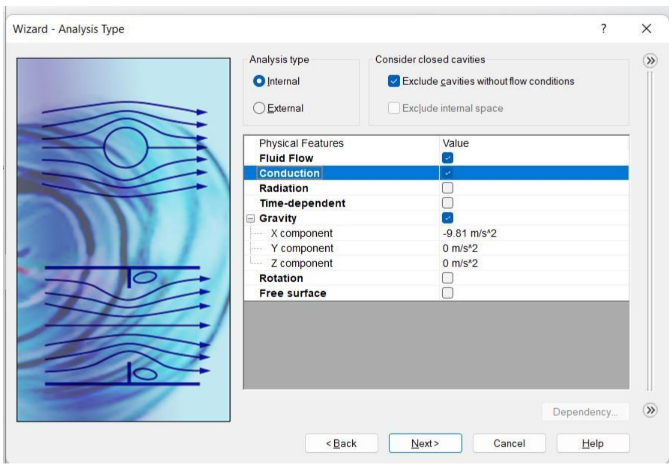

Fig. 1 Analysis Type

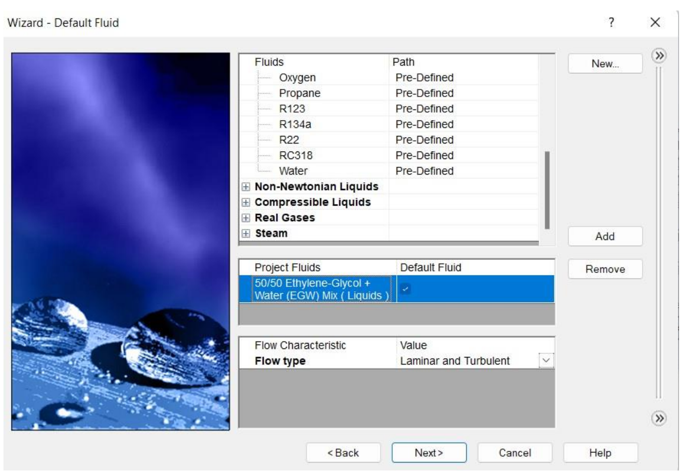

Fig. 2 Fluid selection

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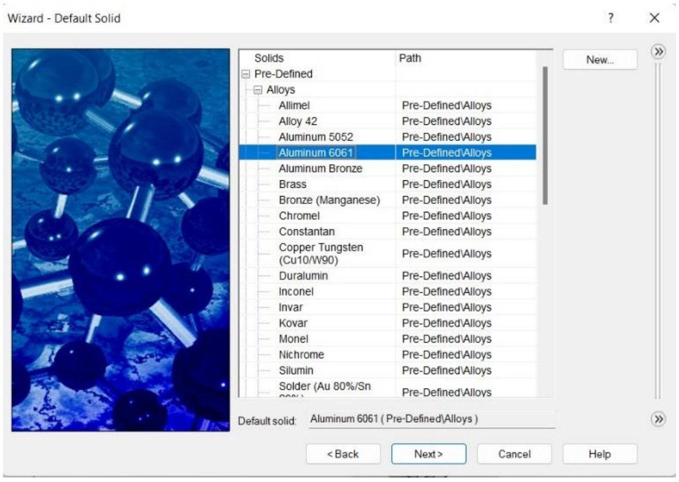


Fig. 3 Material selection

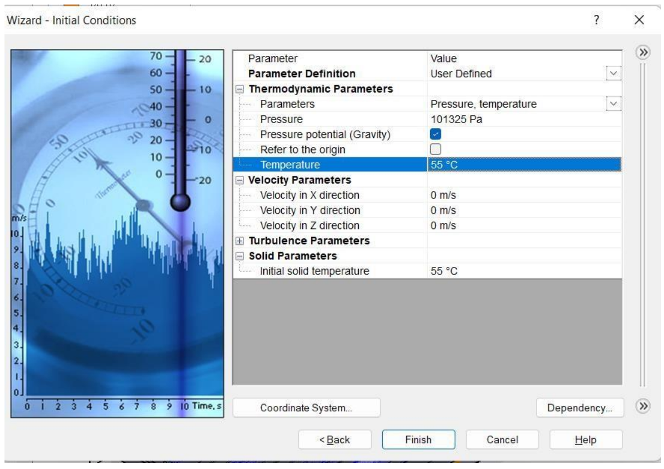


Fig. 4 initial conditions

IV. RESULTS

Surface plot Temperature and Pressure for series design.

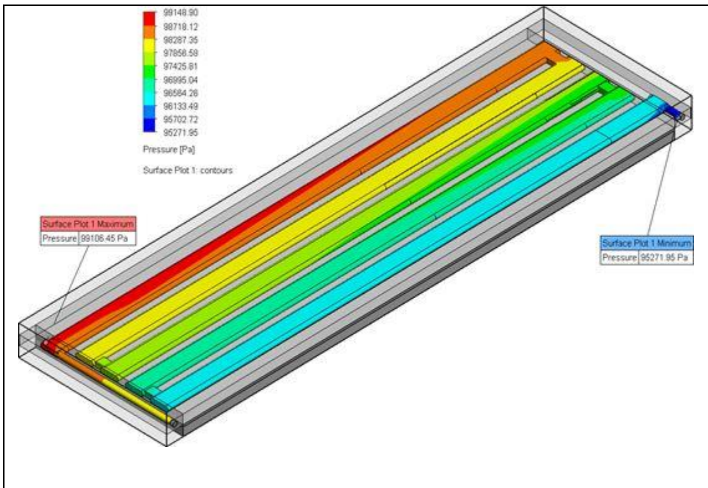


Fig. 5 fluid Pressure

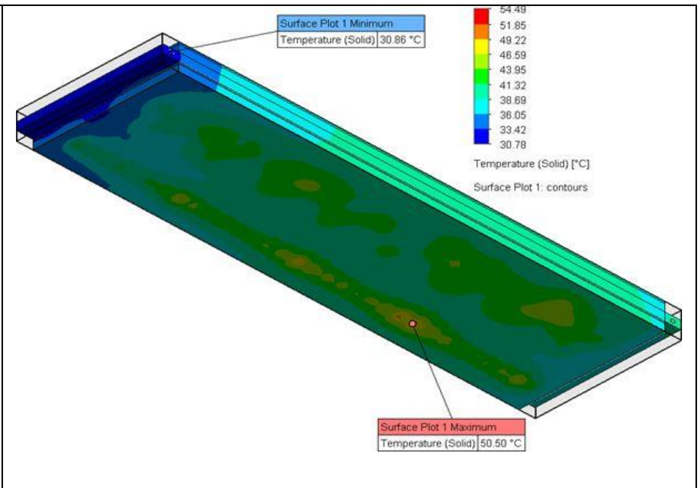
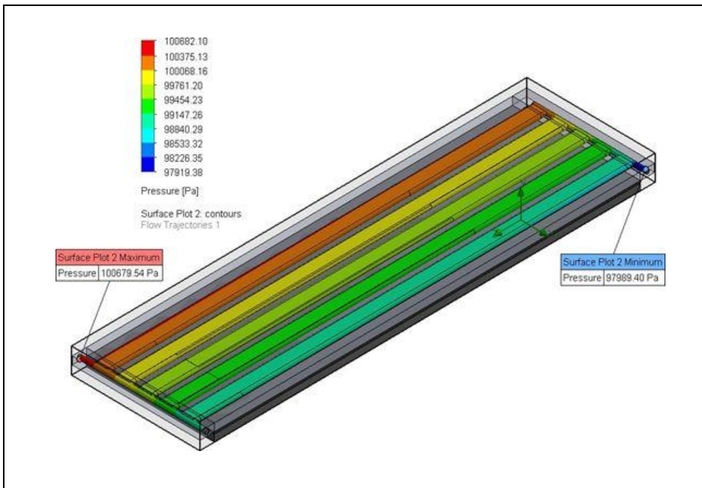


Fig. 6 solid body temperature of whole assembly

Surface plot Temperature and Pressure for Parallel design.



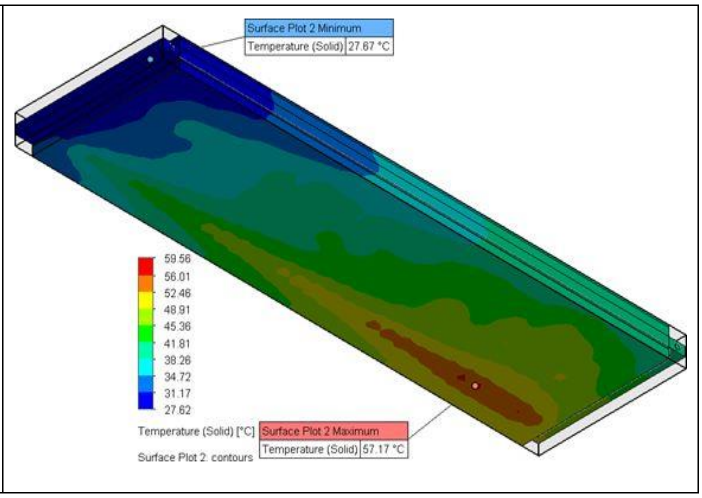


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Fig. 7 fluid Pressure

Fig. 8 solid body temperature of whole assembly

Surface plot Temperature and Pressure for Modified Series design.

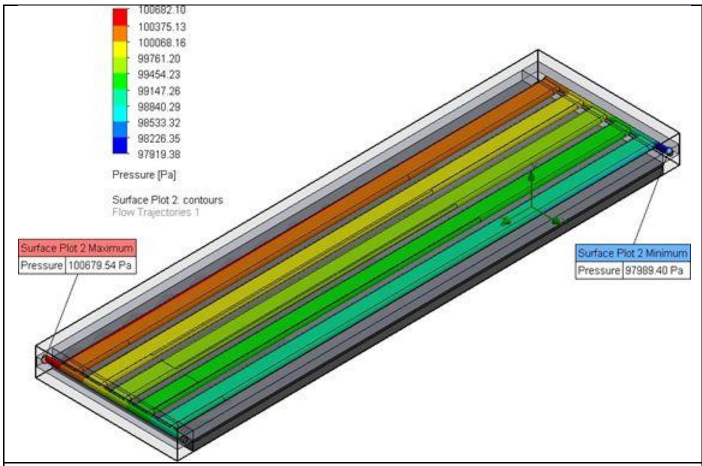

Fig. 9 fluid Pressure

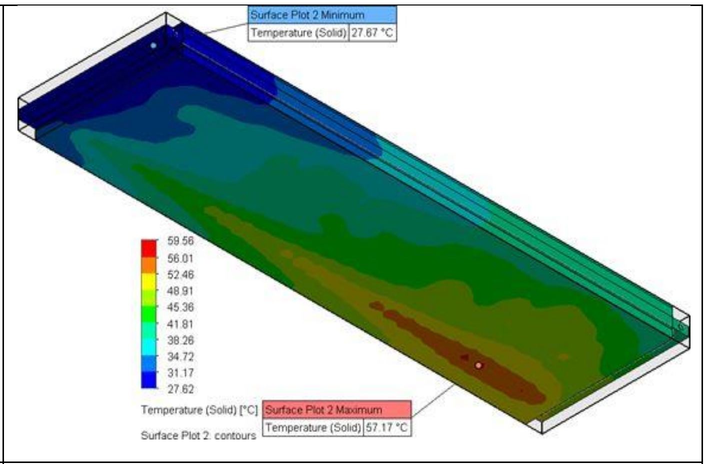

Fig. 10 solid body temperature of whole assembly

TABLE 1
Temperature and Pressure for all types of assembly.

	Temperature (fluid)		Temperature (solid)		Pressure	
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Series flow	25°c	41.40°c	30.86°c	50.50°c	95271.95 pa	99106.45 pa
Modified series flow	25°c	41.40°c	29.85°c	50.22°c	94942.98 pa	97998.29 pa
Parallel flow	25°c	51.06°c	27.67°c	57.17°c	97989 pa	100679.54 pa

V. CONCLUSION

In parallel series assembly case, the required temp of fluid is below 55°c i.e., 41.40°c which is sufficient to say that our cold plate is working properly. In the series flow case, we have done another case so that we can decrease pressure in the series flow assembly that case is known to be modified series flow. This case is much like a series flow but instead of using all 5 channels for series flow we are only using 3 channels by connecting them, fluid goes from 1 channel then to 2 and finally comes out from 2 channels so that the pressure and temperature can be reduced. The least temperature for fluid and solid body is for the modified series flow and its pressure is also somewhat in the average range so we will be using the modified series flow model for our work.

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