# CFD Simulation Of Fully Enclosed Metallic Electronic Enclosure Under Forced Convection

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***Abstract***- *The purpose of an electronic enclosure is to house different electronic cards which dissipates heat during its operation. Each electronic cards have their own temperature limit under which they are safe to operate, if temperature exceeds the limit, electronic card may fail or life gets reduced. So it is very essential to calculate the temperature inside the enclosure before its fabrication. In this application Enclosure has an internal circulating axial fan for creating forced convection within the boundary of the enclosure. In this study CFD simulation is carried out to find required mass flow rate of fan and temperature inside enclosure under extreme environmental temperature.*

***Keywords***- Enclosure, CFD, Forced Convection, fan, mass flow rate

## I. INTRODUCTION

Electronics has a strong relationship with temperature, as the operation starts heat generation starts, so heat is to be removed immediately before it goes beyond the limit. As per the Arrhenius law per 10 degree Celsius rise in temperature will reduce the life of electronics by half. Not only the high temperature is the only culprit of electronics failure but also low temperature has failure effect on electronics. Therefore it is very important for a design engineer to calculate temperature of the environment in which the electronics will be operated. If the electronics is housed in an enclosure the internal temperature must be calculated to know the safe operation point.

This electronic enclosure is actually an antenna control unit for controlling satellite communication antennas. This antenna control unit houses several electronic cards such as controller card, modem card, digital video broadcasting card, Beacon receiver, display & processor. Each card has some heat dissipation rate which has been provided by the OEM and operating temperature of all mentioned cards are also known.

### 1.1 Specification of Cards & Enclosure

Size of Enclosure= 470mm(L)x350mm(W)x125mm(H)
Total wattage of the electronic cards= 30 watt
Enclosure Operating Temperature range= -30 to 55 degree Celsius
Minimum operating temperature among cards= 5 degree Celsius
Maximum operating temperature among cards= 75 degree Celsius
Type of enclosure- fully enclosed (air tight)

### 1.2 Electronic Cards Layout inside enclosure

All electronic cards and other required components are assembled in a compact enclosure on which CFD simulation will be performed. Figure-1 shows such typical assembly modeled in Solidworks software.

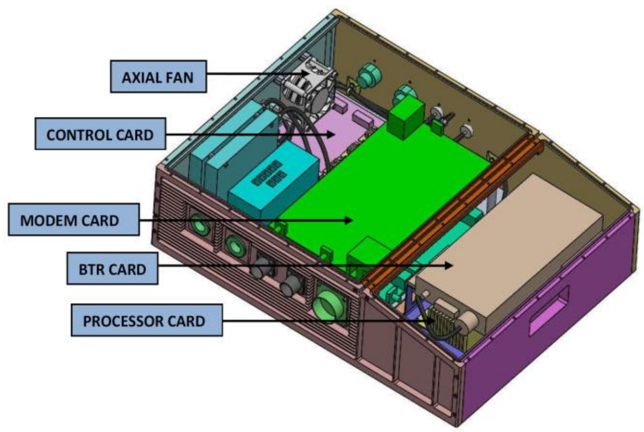


**Figure-1:** Electronic components Layout in enclosure

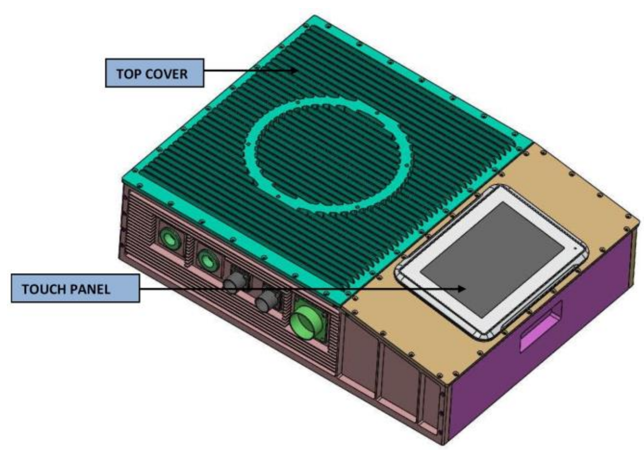


**Figure-2:** Enclosure shown with covers & touch panel

## II. LITERATURE REVIEW

### Theory and Governing Equations

CFD is applied to solve a problem that involves fluid flows. The basic fundamental equation for any problem is Navier-Stokes equation. The Navier-Stokes is simplified as per the physics of the problem. In CFD this equations are called mathematical model that is solved using numerical methods. In this paper time independent flow equation with turbulence are used and the flow is considered as Steady, inviscid and incompressible. In flow simulation continuity and momentum in x, y & z direction is solved to find the physical properties of the fluid in motion such as velocity, pressure, mass flow rate etc. The K-epsilon(2 equation) turbulent model is used in this simulation and in order to find out the temperatures inside enclosure energy is coupled to the flow simulation thus the governing equations that software will solve are:

- Mass Conservation Equation
- Momentum Conservation Equation
- Energy Conservation Equation
- Turbulent Kinetic Energy (TKe)
- Turbulence Dissipation Rate (TDr)

In this problem it is also noted that the enclosure is fully enclosed so the fluid is not crossing the enclosure while it is being circulated within the enclosure. Only energy can cross the boundary of the enclosure.

## III. METHODOLOGY

### 3.1 Selection of Fan

Before selection of a fan it is important to know the total resistance of the system. The system resistance is found by carrying out flow simulation. The system resistance is then plotted as mass flow rate versus pressure drop in the system. The fan is then selected from the OEM catalogue and the fan curve is matched with the system resistance curve. The point where these two curves intersect that is the operating point of the selected fan. The Plot between Pressure & mass flow rate is shown in Figure-3.

Size of the selected fan is 60mmx60mmx38mm, maximum mass flow rate is 50 CFM & Maximum Static Pressure is 600 Pa. So, the useful mass flow rate of the fan is 0.015 Kg/s.

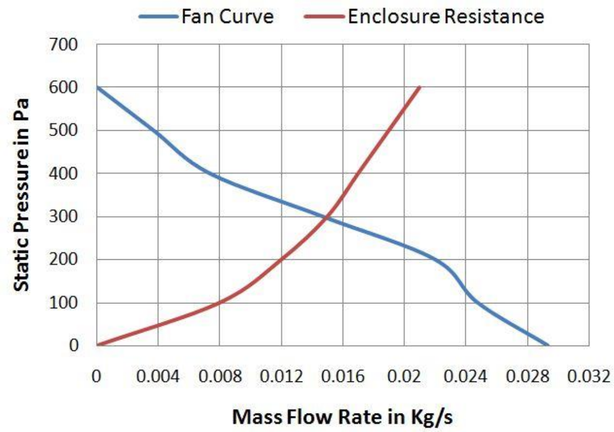


**Figure-3:** Plot between pressure & mass flow rate

### 3.2 CFD Simulation Steps

CAD model of the problem is made in Solidworks Software and the CAD model is imported as geometry in STAR CCM+ Software to carry out CFD Simulation. The further steps are as follows:

a) Preprocessing involves geometry defeaturing & clean up, Meshing & boundary condition
b) Solvers to solve the problem with standard software codes
c) Post Processing is used to plot results obtained by carrying out the simulation

### 3.3 Computational Model

Computational model is the domain on which CFD is performed. CAD model of computational domain of this problem is shown in Figure-4 below. The size of the domain is L=470mm, W=350mm & H=125mm. Those components that are not heat source are subtracted from the air domain and components that are dissipating heat are made solid. The interface between solid and air domain are generated in STAR CCM+. Axial Fan is installed inside the airtight enclosure that will circulate air within the enclosure and reduce the thermal resistance by mass and momentum transfer.

Figure-5 shows the meshed model of the computational domain. The mesh is unstructured with polyhedral elements and the growth of the element has been increased near the solid and air domain interface for accurate & fast convergence of the problem as shown in Figure-6.

Total number of meshed elements is 603000.

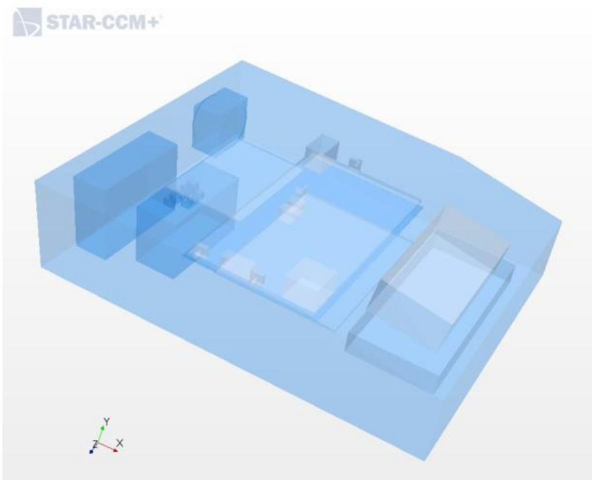

**Figure-4:** Computational Domain

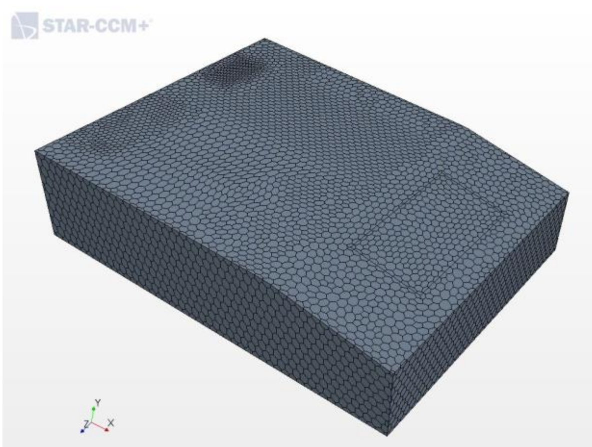

**Figure-5:** Polyhedral Unstructured mesh

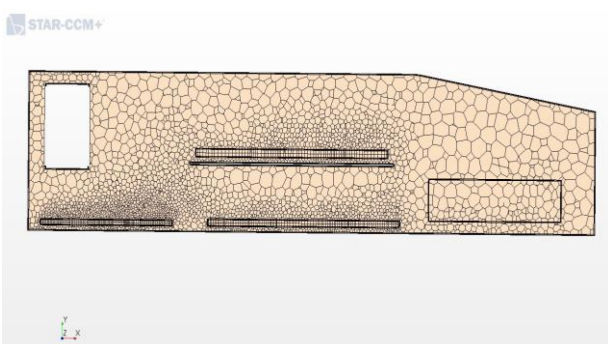

**Figure-6:** Mesh in X-Y Plane

### 3.4 Boundary Conditions & Heat Load

Boundary condition applied in the computational domain is as follows:

**Inlet condition**

Mass flow rate= 0.015 Kg/s
Temperature= Field Function of surface average outlet
Initial Temperature= Ambient as per the case

**Outlet condition**

Pressure Outlet

**Ambient Temperature**

Case-1: 55 Degree Celsius
Case-2: -30 Degree Celsius

Heat transfer through outer walls of enclosure is assumed to be Natural convection & heat transfer coefficient is estimated from empirical correlations and applied on the outer walls.

Type of flow is Steady and Turbulent

Stationary and no Slip condition applied on walls & turbulent model used is K-Epsilon

Fins on outer walls is neglected in CFD simulation

Table-1: Heat dissipation rate of different electronic components inside enclosure:

| S.No | Card Name | Heat dissipation rate (Watt) | Operating Temperature(°C) |
|---|---|---|---|
| 1 | Control Card | 10 | -30 to +75 |
| 2 | Modem Card | 6 | +5 to +75 |
| 3 | DVB Card | 2 | +5 to +75 |
| 4 | Display | 6 | -30 to +85 |
| 5 | BTR | 6 | -20 to +75 |

## IV. RESULTS AND DISCUSSION

### 4.1 Introduction

The Enclosure is intended to be used between -30 °C to +55 °C so two load cases has been solved. In one condition enclosure is kept at ambient temperature of +55 °C and temperature inside enclosure is calculated. The temperature distribution at different plane inside enclosure is shown in Figure-7a, 7b, 7c. From the temperature distribution it is clear that maximum air temperature around cards inside enclosure is 76 °C and further presence of fins at the outer wall which is neglected in CFD simulation will produce a cooling effect of 3 °C (cooling through fins has been calculated analytically). As the maximum temperature around different electronic components is 73 °C and maximum operating temperature among different cards/components is 75 °C, so the cards are safe to operate at an ambient temperature of 55 °C.

In Figure-8a, 8b Velocity vector has been shown. From the distribution it is observed that maximum velocity occurred at the inlet of fan and become stagnant on base and corners of the enclosure.

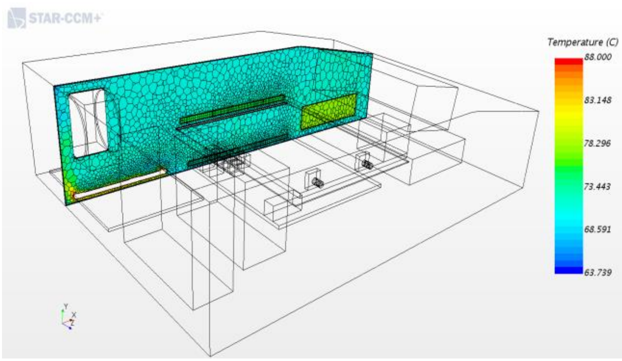


**Figure-7a:** Temperature distribution on X-Y plane passing through fan centre

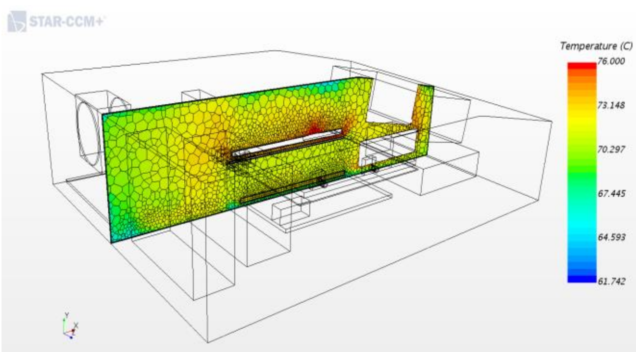


**Figure-7b:** Temperature distribution on X-Y plane (At mid of enclosure)

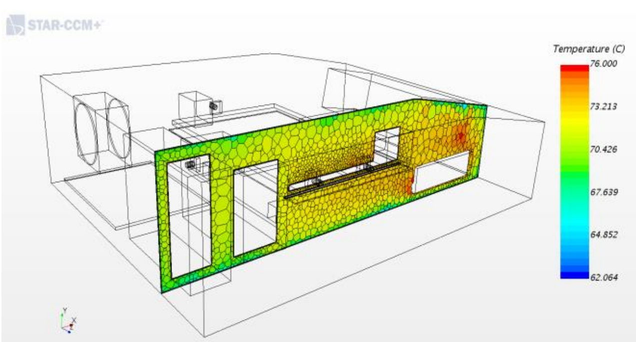


**Figure-7c:** Temperature distribution on X-Y plane (enclosure other end)

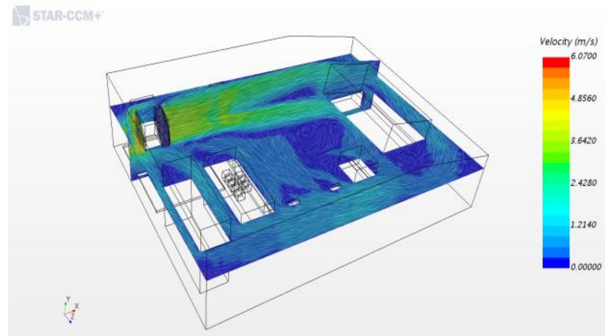


**Figure-8a:** Velocity vector on X-Y & X-Z Plane

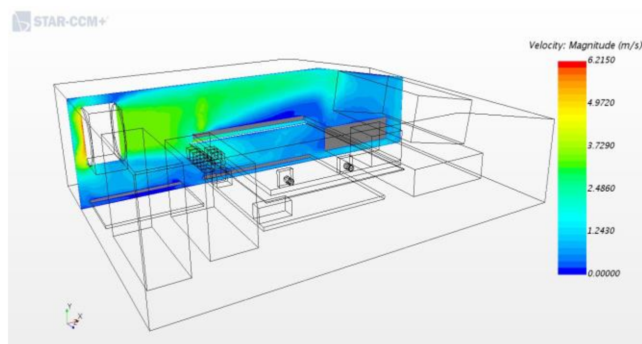


**Figure-8b:** Velocity Vector on plane passing through fan

In other condition the enclosure is kept at an ambient temperature of -30 °C and temperature inside the enclosure is calculated. Minimum operating temperature among various installed electronic cards is 5 °C so the temperature inside the enclosure must be above 5 °C for the safe operation. To get this temperature inside enclosure 2 heater of 40 Watt rating installed below modem card (Center of enclosure) and CFD Simulation carried with this heat load. Temperature distribution inside enclosure is shown in Figure-9a, 9b & 9c.

From the temperature distribution it is clear that minimum air temperature around electronic cards inside enclosure is 8 °C.

As the minimum temperature around different electronic components is 8 °C and minimum operating temperature among different cards/components is 5 °C, so the cards are safe to operate at an ambient temperature of -30 °C.

Furthermore location of the heater is chosen closer to the modem card as among all cards modem card is sophisticated one so it was recommended by their manufacturer that the air temperature around this card should not drop below its minimum operating point.

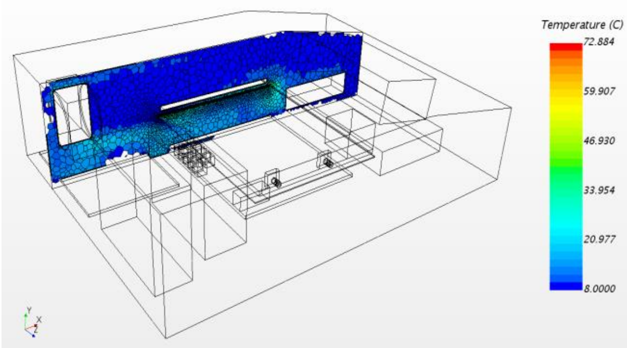


**Figure-9a:** Temperature distribution on X-Y plane passing through fan centre

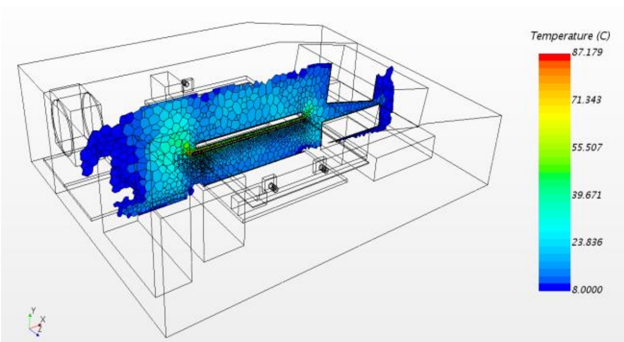


**Figure-9b:** Temperature distribution on X-Y plane (At mid of enclosure)

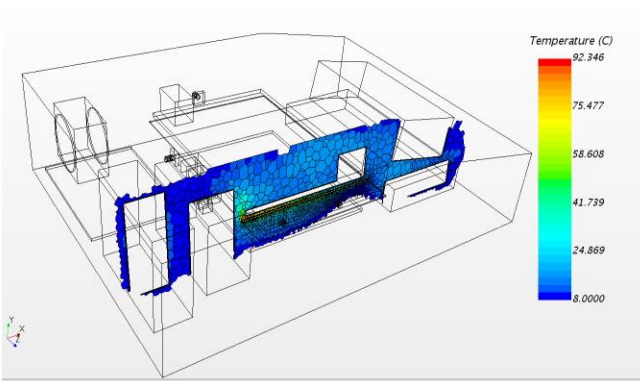


**Figure-9c:** Temperature distribution on X-Y plane (enclosure other end)

### 4.2 Conclusion

CFD Analysis has been carried out on electronic enclosure consisting of various electronic cards with a total dissipating heat of 30 Watt. These cards have been cooled through forced convection by providing optimum amount of air flow in an air tight enclosure.

From this study the best location of the fan inside the enclosure which will produce the adequate cooling effect was decided as well as under low ambient temperature the heater wattage and their location inside enclosure was determined. From this study it was found that CFD analysis can improve the thermal design by reducing the experimental cost, time and energy.

This paper will induce more engineers to explore the studies on application of CFD in electronics industries and take up the real challenges of fast moving technologies with innovative and reliable products.

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