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Thermal Design of Attendant Control Panel for Avionics through CFD

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Abstract

Attendant Control Panel (ACP) is a wall mounted unit which mainly integrates several Boeing 737NG system functions into a single control panel to provide the flight attendants with the ability to monitor and control cabin features. Thermal design has been developed to remove heat from the ACP through conduction and natural convection. Standoffs in the enclosure provided the effective conduction path to transfer heat from PWA (Printed Wire Assembly) to chassis. All critical device temperatures in the ACP are able to maintain well below the allowable temperature limit of 105°C without forced cooling. CFD(Computational Fluid Dynamics) simulations have been carried to analyze and improve thermal phenomena inside the ACP for three operating conditions namely normal operating (30°C), high operating (50°C) and short range operating (50°C to 60°C for 30 min) , using ANSYS Icepack, commercial CFD software. The thermal design of ACP is developed in this paper to maintain its operating temperature within the limits, without any electrical degradation.

Keywords: ACP - Attendant Control PanelL, PWA - Printed Wire Assembly, CFD - Computational Fluid Dynamics, LCD - Liquid Crystal Display, LRU - Line Replaceable Unit, PCB - Printed Circuit Board.

1. Introduction

Micro system technology is driven by specific requirements such as the high integration density of the single elements and the three-dimensional integration of the elements in a hybrid system. The use of new materials having specific properties, as well as the overall miniaturization of the systems have led to an increased importance on thermal management issues in this industry [1]. In any un-fanned environment, the air flow is to move vertically due to convection and the heated air's tendency. A conventional finned heat sink operates most efficiently when air is moving parallel to the orientation of its fins [2]. Similar to the fin configuration, a thermal design with standoffs offered the best performance to conduct heat from ACP. The thermal design of electronic equipment has a significant impact on the cost, reliability, and tolerance to different environments [3]. ACP enclosure houses two PWAs (baseboard and mezzanine) inside the cage body. The baseboard PWA is mounted on the chassis using nine standoffs and three rails. The mezzanine PWA is mounted on top of the baseboard PWA using four standoffs and one rail along its edge. An exploded view of the Attendant Control Panel (ACP) is shown in Figure 1.

2. Thermal Model

A Computational Fluid Dynamics (CFD) model of the Attendant Control Panel (ACP) is created using a commercial software package called ANSYS Icepack. It included the critical to flow and heat transfer such as shroud with perforations, switch panel, LCD (Liquid Crystal Display) panel, cage body with perforations, cage top, chassis, baseboard PWA with components, mezzanine PWA with components, harness, standoffs and rails. The critical components modelled on the PWA are considered on the basis

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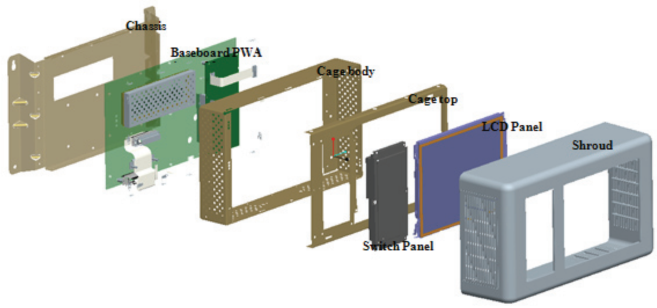

Figure 1. Exploded View of ACP.

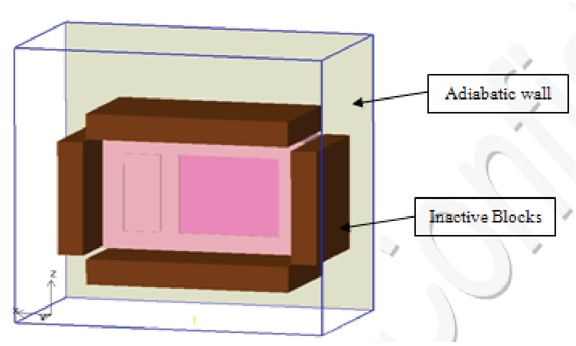

Figure 2. ACP-Thermal Model.

of heat dissipation more than 20 MW (Heat generation of 5MW/m3) power and/or having more than 5 mm height as per D6-44800-1 document. Equipment is mounted on a wall which is assumed as adiabatic in the thermal model. Four inactive blocks which act as potential obstructions are modelled around the ACP. Figure 2 shows the thermal model with inactive blocks surrounding the LRU (Line Replaceable Unit). Three operating conditions normal, high and short time are considered for the analysis based on the environments of air planes under different flight regimes. Table 1 specifies these operating conditions. Thermal requirements for the model are extracted from Boeing's D6-44800-1 and MIL-STND-1472F based on equipment class. In the present analysis ACP comes under equipment class III b. Ambient air temperature behind the Panel and the ambient air temperature surrounding the equipment installed are considered as different as per ACP equipment class. Table 2 specifies the thermal requirements for ACP.

3. Thermal Design

In the initial design some components on the mezzanine PWA and baseboard PWA are beyond the temperature limits (105°C for most of the components). A thermal solution is required to cool the components. The possible mode of heat transfer is conduction, convection heat transfer is limited perforated area which cannot be increased due to structural issues and radiation heat transfer is not possible because of inactive blocks around ACP. An aluminium rail is introduced to conduct the heat from the PWAs to chassis as one of possible method to enhance cooling rate. The aluminum rails and stainless steel standoffs provide the conductive heat transfer path from the baseboard PWA to chassis. Heat is removed through convection from the surface of PWAs and chassis. The mezzanine PWA is mounted using a rail and four standoffs on the baseboard PWA. A portion of heat dissipated by the mezzanine PWA is con-

Table 1. Operating Conditions

Condition	Ambient Temperature (oC)	Duration (min)	Thermal margin Requirement
Normal operating	30	Steady State	Positive after Derating 15 degree Celsius from manufacturer Junction Temperature
High operating	50	Steady State	Positive
Short time operating	60/50	0–30	Positive

Table 2. Heat Flow - Baseboard PWA

Baseboard PWA	Heat Flow(W)
Total Power of Baseboard PWA	6.696
Heat Conducted from Mezzanine PWA Standoffs	0.922
Heat Conducted from Mezzanine PWA Rail	0.334
Total Heat inflow	7.952
Heat Conducted to Baseboard PWA Standoffs	0.642
Heat Conducted to Baseboard PWA Rail	4.474
Total Conducted Heat outflow from Baseboard PWA	5.115
% of Heat flow through Conduction	**64.33**
% of Heat flow through Convection	**35.67**

ducted through the standoffs and rails to the baseboard PWA. A portion of heat is carried away by the natural convection.

4. Boundary Conditions

The model is analyzed for heat transfer from the individual components, modules and PCB to internal ambient air and temperature distribution within the unit using CFD techniques. The entire solution domain is discredited into small computational volumes and mass, momentum and energy equation is solved for the computational domain. Ambient conditions and thermo physical properties corresponding to the ambient temperature are assigned to the problem domain and turbulent zero equation models are used as it is economical and accurate for most electronic cooling application. Computational domain is extended to capture the velocity and thermal profile around the enclosure. Grid constraints like minimum elements in fluid gap and solid region is greater than 4 elements and size ratio of 2 are given to capture the results in optimized condition. Grid sensitivity has been carried out and optimum grid cell count is reached for better solution. The cumulative total grid cells in all directions are 4.1 million cells. Solver is set to optimum settings like 0.001 for flow and 1e-7 for energy and solver termination criteria is set based on flow and energy equation.

5. Results and Discussion

In the present work, CFD simulations are carried to analyse the heat flow in ACP as shown in Figure 3. Steady state simulations are carried for normal and high operating conditions and transient for short term. The percentage heat flow through conduction and convection from the PWAs is determined and tabulated in Table 2 and Table 3. The total heat flow into the baseboard PWA is 7.952 W includes the heat dissipated by the PWA (6.696 W), heat conducted from the four mezzanine PWA Standoffs (0.922W) and one mezzanine PWA rail (0.334 W) to the baseboard PWA. The total heat conducted from the baseboard PWA to the baseboard PWA standoffs and three rails is 5.115W. Analysis shows that 64.33% of heat is transferred through conduction. Hence, conduction is the dominant mode of heat transfer in the case of Baseboard PWA and 4.474 W (56.26% of total heat inflow) is lost through conduction from rails. This shows that rails are the main heat flow paths from the baseboard PWA. In the mezzanine PWA, 55.75% of heat is lost through convection. This is because the mezzanine PWA is mounted near the perforations on the bottom face of the shroud.

Figure 4 shows the steady state results for normal operation condition of the shroud, switch panel. Figure 5 shows the steady state results for normal operation condition of PWA. Figure 6 shows the steady state results in high operating condition. Figure 7 shows the temperature variation w.r.t to time (transient results). The results showed that the ACP design meets the temperature requirements as mentioned in Table 4.

6. Conclusions

A preliminary thermal analysis has been carried out and the thermal design of ACP is developed to maintain its

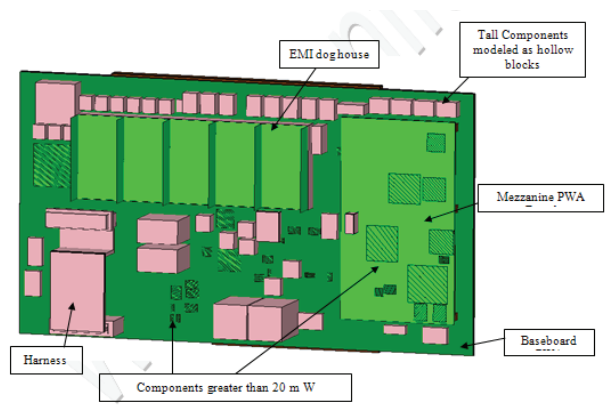

Figure 3. PWAs Assembly in ACP.

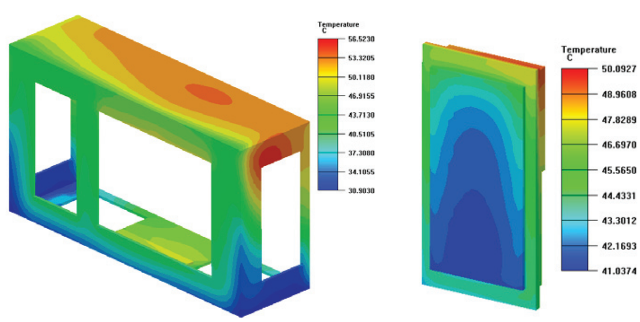

Figure 4. Normal operating condition results - Shroud and Switch Panel.

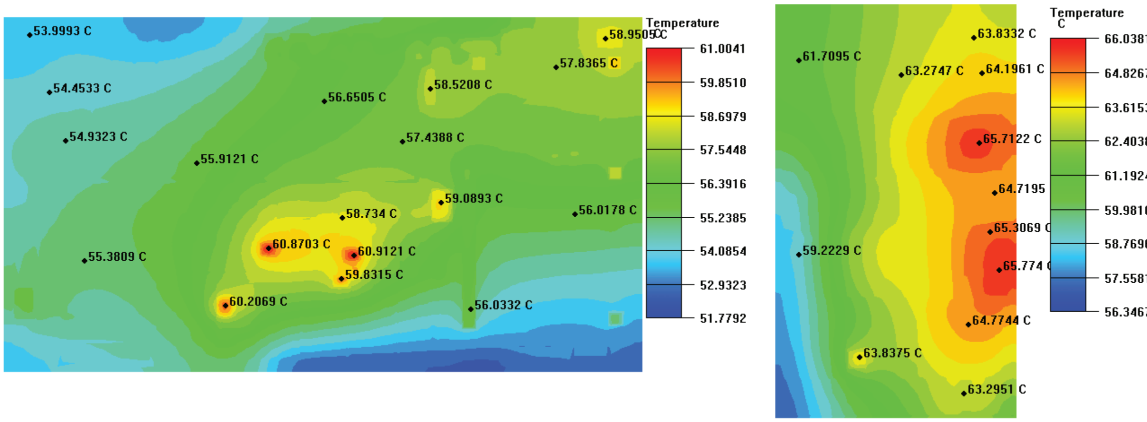

Figure 5. Normal operating condition results – PWA Contours.

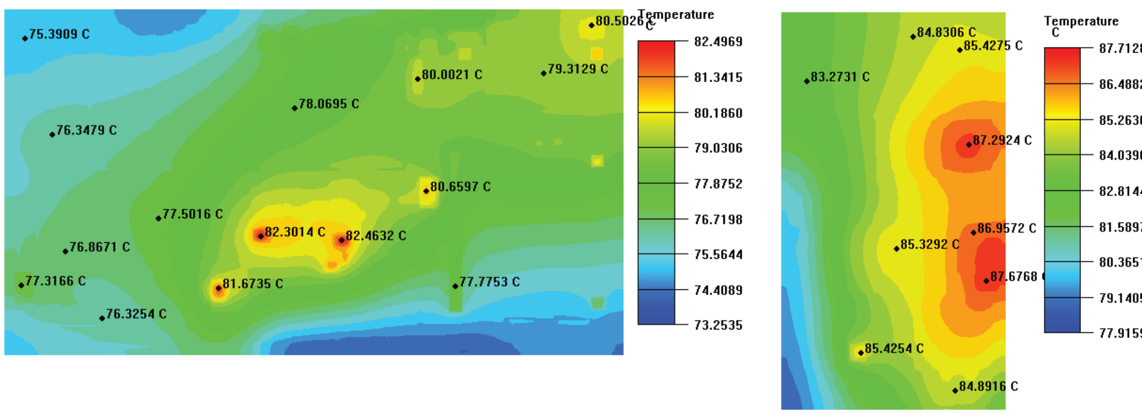

Figure 6. High operating condition results – PWA Contours.

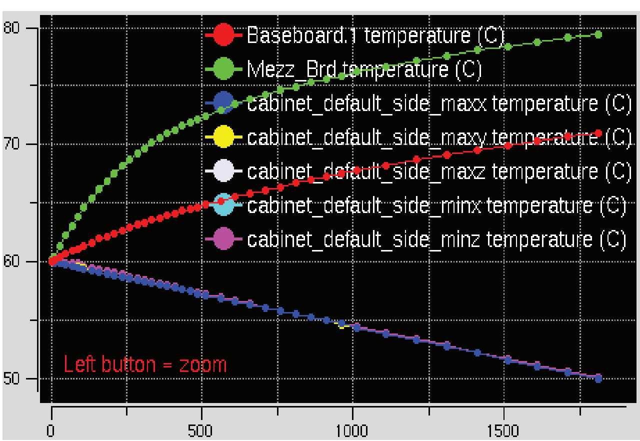

Figure 7. The temperature variation w.r.to time. (Short time operating results).

operating temperature within the limits in order to function without any electrical degradation. The further scope involves consideration of heat sink to enhance cooling rate.

Table 4. Temperature Requirements

Component	Material	Temperature limit as per MIL-STND-1472F (oC)	Temperature limit as per D6-44800-1 (oC)
Switch Panel Touch temperature	Plastic	69.00	Tambient + 45 *
Shroud Face Temperature	Plastic	N/A	45.00 (On all sides)

Table 3. Heat Flow - Baseboard PWA

Mezzanine PWA	Heat Flow (W)
Heat Conducted to the Mezzanine PWA Standoffs	0.355
Heat Conducted to the Mezzanine PWA Rail	0.973
Total Heat Conducted	1.323
Total Power Applied	3.001
% of Heat flow through Conduction	**44.24**
% of Heat flow through Convection	**55.75**

7. References

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