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Numerical Investigation on Electronic Cabinet with interrupted Fin heat sink using CFD

Lakshminarasimha N[1], Dr M S Rajagopal[2], Megaha Shukla[3]
[1,3]Assistant Professor, Mechanical Engineering Department, New Horizon College of Engineering, Bengaluru, Karnataka, India
[2]Professor and Chairman, Mechanical Engineering Department, Dayananda Sagar University, Bengaluru, Karnataka, India

ABSTRACT

Heat dissipation is one of the most challenging tasks in any product design more so in thermal design of Electronic Cabinets, as heat generated by these components may exceed its operating temperature limits leading to failure of components. Research shows that, for every 10^{0}C temperature rise above ambient temperature of the Cabinet, the life of the electronic components is reduced by half. Hence limiting the temperature of components below its operating temperature range becomes a major criterion in designing any electronic system. In this present work, CFD analysis has been carried out using ANSYS Fluent on Electronic Cabinet of size *358mm x 78mm x 252mm* consisting five heat sources with total heat dissipation of 150W. Cabinet is designed for two exhaust fans each of 48 CFM. The analysis is carried out by providing interrupted fin heat sink. The results of interrupted fin heat sink are compared with the results of continuous fin heat sink. It is found that nearly there is 2% reduction in the pumping power cost using interrupted fin heat sink due to lower pressure drop and also installing interrupted fin heat sink reduces the weight of the Electronic system. The result obtained for temperature rise in a Cabinetfound to be 3^{0}C which is below the threshold limit. Analysis results of temperature rise and inlet velocity was validated with analytical results and hence satisfies.

Keywords : Temperature rise, fin heat sink, CFD, ANSYS Fluent, Electronic Cabinet

I. INTRODUCTION

Electronic Cabinet provided with fan provides better cooling up to 10% than the Cabinet without fans, [1]. Also provision to fin heat sink increases the surface area in contact with cooling medium surrounding it. Heat sink is manufactured using most common materials such as Copper and Aluminium, since these materials have good thermal conductivity allowing heat to pass through it.

In present work,Cabinet is provided with exhaust fans andheat sourcepanel is provided with interrupted Aluminium fin heat sink to study the effect of cooling in maintaining the Cabinet temperature rise. The analysis is carried out using ANSYS Fluent as CFD tool provides optimum solution for an Electronic Cabinet thermal design.

II. LITERATURE SURVEY

Literature survey is carried out to understand state of art of work carried on Thermal Management of Electronic Cabinet and also to understand Selection of fans, Boundary conditions and Turbulent Models. The summary of the journals are as discussed below:

Hoffman Pentair Company, [1], [2003], this technical data sheet highlights the design parameters required in thermal design of an Electronic Cabinet. It provides the required basic parameters in selection of Fan and Calculating Temperature rise for a Cabinet.

MahendraWankede, et.al, [2], [2010], in this work the PCBS generating 100W is enclosed in an Aluminium enclosure. The experimental results are validated with analytical results. The results show that enclosure with fans provides 20% reduction in temperature than without fans.

Lakshminarasimha N, [3], [2015], this journal deals with the study on 150W generating heat source enclosed in an enclosure. The CFD analysis results are validated with analytical results. Journal highlights the analytical formulas required to calculate the temperature rise, Inlet velocity and Total heat transfer rate in an enclosure.

Bud Industries Inc, [4], [2007], this industrial data sheet provides overall thermal design aspects required for an Electronic Cabinet.

Though the present state of work is not similar to the literatures found as discussed above, the effort has been made to carry out the present work with available literatures.

III. METHODOLOGY

The step in analysis consists of Geometry, Meshing and Analysis; these are carried out using ANSYS Products and as discussed in the following sections.

A. Geometry

Fig. 1 shows the Geometry model of Electronic cabinet with interrupted fin heat sink. It consists of the following:

1. Five heat sources
2. Interrupted fins in 10 rows
3. Back plate
4. left side Cabinet opening as inlet
5. Two exhaust fans at right side of the Cabinet

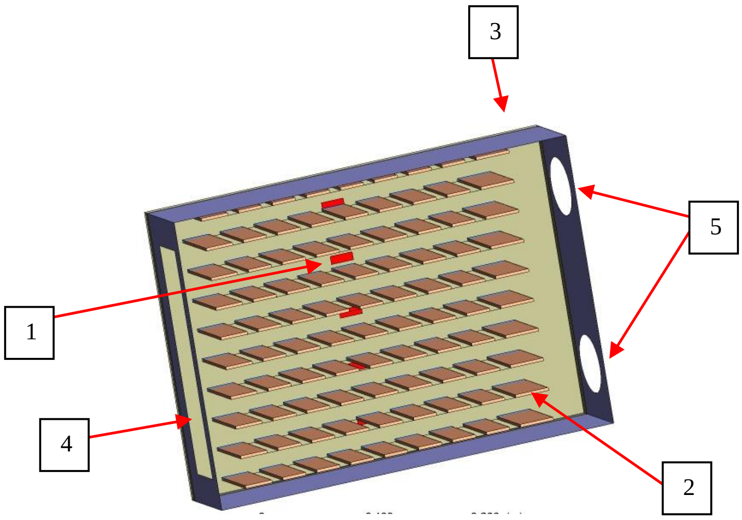

Fig.1: Electronic cabinet with interrupted fin heat sink

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B. Meshing

The model is meshed with Hexagonal elements. It consists of 133690 elements. Fig. 2 shows the cut plane of the Hexagonal meshed model.

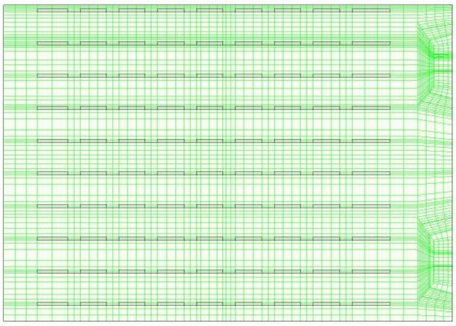

Fig.2: Cut plane of Hexagonal meshed model

Fig. 3 shows the mesh convergence plot. The Residual monitors for continuity, momentum, k and epsilon are maintained to be 1e-3 and for energy maintained to be 1e-7. The results are converged at 87 iterations (see Fig. 3).

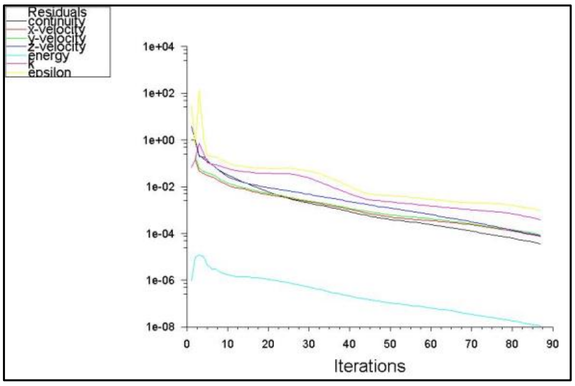

Fig. 3: Mesh convergence plot

C. Solution Methodology

The Electronic enclosure is with uninterrupted fin heat sink and with two exhaust fans of 48 CFM *(see eqn. 1)*. The heat sources are with heat flux boundary condition generating total heat of 150W. The walls are with no slip condition andthe flow is considered to be incompressible and turbulent. Since flow is turbulent, k-epsilon turbulent model is solved for obtaining results and SIMPLE discretization scheme is used to solve for turbulent parameters and momentum equations.

The total air flow requirement for the Electronic Cabinet in CFM, [4] is calculated using eqn.1 and temperature rise in a cabinet is calculated using eqn. 2.

Total CFM $= (1.76 \times Q)/\Delta T$ ………….. eqn. 1

$\Delta T = \frac{Q}{\dot{m}\, C_p}$ ……………………. eqn. 2

$\dot{m} = \rho \times A \times V$ ………………………... eqn. 3

Where,

Q= Total heat dissipated in a cabinet in Watts

$\dot{m}$= mass flow rate in kg/s

ρ= Density of air= 1.2 kg/m^3

A= Area of inlet/outlet in m^2

V= Velocity at inlet or outlet in m/s

C_p= Specific heat of air = 1005 J/kg. K

ΔT = Temperature rise in °C

IV. MATHEMATICAL MODEL

In Fluent, each and every elements of the meshed domain are converged for continuity, momentum and energy equations. Since the flow is considered to be turbulent, two more equations are converged i.e. k- epsilon turbulent equation model, where k is the turbulent kinetic energy and epsilon is the turbulent dissipation rate, [5].

The advantages of k- epsilon model, [6] are:

- simplest turbulent model as it requires only initial/boundary condition for solution
- Most widely validated and well established
- Wide application in industrial relevant flows with excellent performance

The limitations of k- epsilon model, [6] are:

- More expensive
- Poor performance for rotating, swirling and curved boundary flows

V. RESULTS DISCUSSION AND VALIDATION

The analysis and analytical results obtained for velocity, temperature, Temperature rise and pressure for Electronic Cabinet are discussed in this section and as follows:

A. Velocity contour, vector and stream line plots

Fig. 4 shows the velocity contour plot for an Electronic cabinet with interrupted fin heat sink. The maximum velocity of 13.37m/s was found at outlet. The velocity contour plot for an Electronic cabinet with continuous fin heat sink (not shown) shows maximum velocity at the outlet similar to Electronic cabinet with interrupted fin heat sink and its velocity found to be 13.01 m/s.Also for both the cases the inlet velocity was approximately found to be 6 m/s.

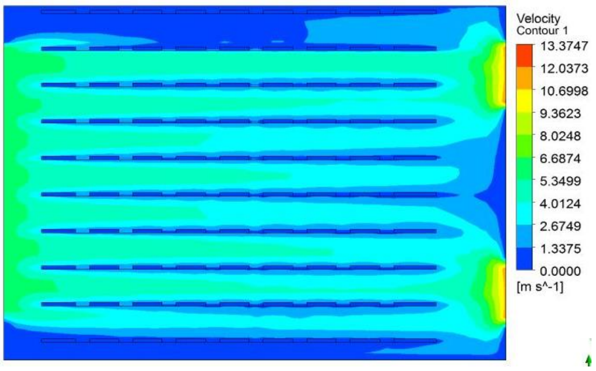

Fig. 4: Velocity contour plot for an Electronic cabinet with interrupted fin heat sink

Fig. 5 and Fig. 6 shows the vector and stream line plot for an Electronic cabinet with interrupted fin heat sink; it signifies the direction of flow of the fluid and captures the circulation zones in the domain.

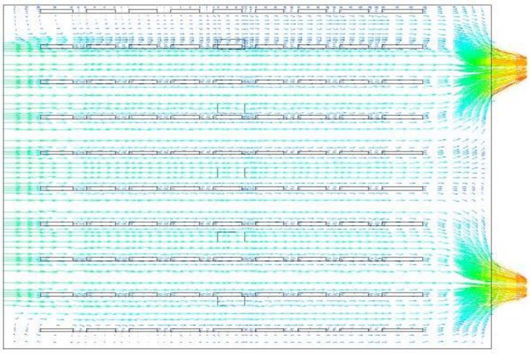

Fig. 5: Vector plot for an Electronic cabinet with interrupted fin heat sink

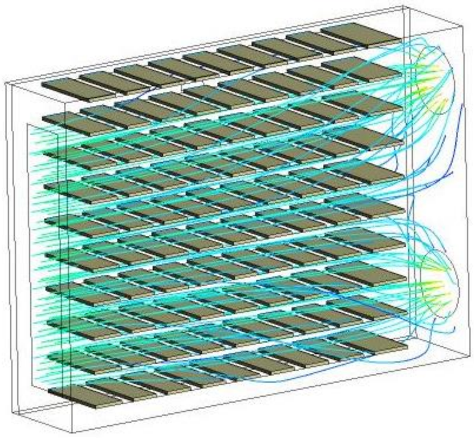

Fig. 6: Stream line plot for an Electronic cabinet with interrupted fin heat sink

Also analytically the result is validated for inlet velocity of the cabinet using eqn. 4. Analytical result shows inlet velocity of 5.64m/s and hence satisfies the analysis result.

Considering flow to be incompressible Applying continuity equation for inlet and outlet of the cabinet,

$A_iV_i = A_oV_o$ ………….. eqn. 4

Where,

A_i and A_o are the areas of inlet and outlet in m^2

V_i and V_o are the velocity at inlet and outlet in m/s

B. Temperature contour plots

Fig. 7 shows the temperature contour plot for an Electronic cabinet with interrupted fin heat sink. The maximum temperature of 51.12^{0}C was found at heat source. The temperature contour plot for an Electronic cabinet with continuous fin heat sink (not shown) shows maximum temperature at the heat source similar to Electronic cabinet with interrupted fin heat sink and its temperature found to be 45^{0}C.Comparing both the cases, there is an increase in the temperature of heat source about 6^{0}C for an Electronic cabinet with interrupted fin heat sink.

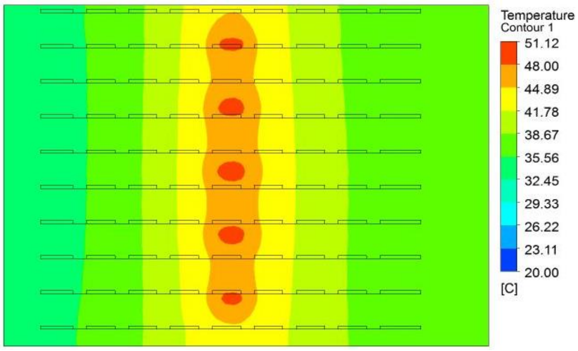

Fig. 7: Temperature contour plot for an Electronic cabinet with interrupted fin heat sink

C. Temperature rise

Fig. 8 shows the Temperature contour plot highlighting temperatures at inlet and outlet of the cabinet with interrupted fin heat sink. The inlet temperature was found to be 20^{0}C andoutlet temperature approximately found to be 23^{0}C. Therefore temperature rise in a cabinet is about 3^{0}C. Also, temperature rise in a cabinet is calculated analytically using eqn. 2 and result shows the temperature rise of about 2.8^{0}C and hence satisfies the analysis result. The result obtained for temperature rise for the cabinet with continuous fin heat sink is same as the result of cabinet with interrupted fin heat sink.

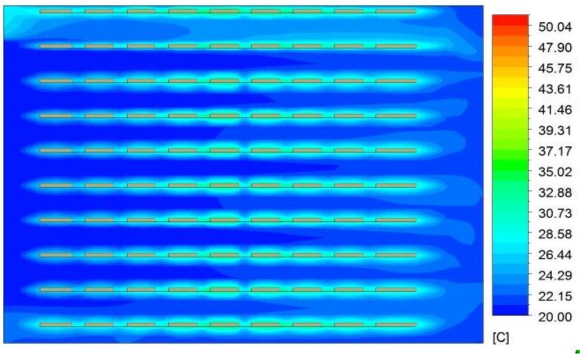

Fig. 8: Temperature contour plot highlighting temperatures at inlet and outlet of the cabinet with interrupted fin heat sink

D. Pressure results

The pressure contour plots were plotted for both Electronic cabinets with interrupted and continuous fin heat sink, the result obtained are tabulated as shown in Table 1.

TABLE 1
PRESSURE RESULTS AND PUMPING POWER REQUIREMENT

Cabinet type	**Inlet pressure (p_i) in N/m^2**	**Outlet pressure (p_o) in N/m^2**	**Pressure drop (Δp) in N/m^2**	**Pumping Power requirement (W)** ***(see eqn. 5)***
Cabinet with interrupted fin heat sink	-24.39	-97. 59	73.19	3.29
Cabinet with continuous fin heat sink	-18.63	-93.34	74. 701	3.36

In order to pump fluid in a steady state, the power requirement, [7] is given and calculated by:

Power= $\int v\, dp = \frac{\dot{m}}{\rho} \Delta p$ ………….. eqn.5

Where, Δp is pressure drop= $p_i - p_o$ in N/m^2,

$\dot{m}$ is mass flow rate in kg/s, ρ is density of fluid in kg/m^3

From Table 1, it can be observed that there is 2% reduction in pumping power cost for the cabinet with interrupted fin heat sink as because there is reduction in pressure drop for the cabinet with interrupted fin heat sink compared to Cabinet with continuous fin heat sink. The pressure contour plot forthe cabinet with interrupted fin heat sink is as shown in Fig. 9.

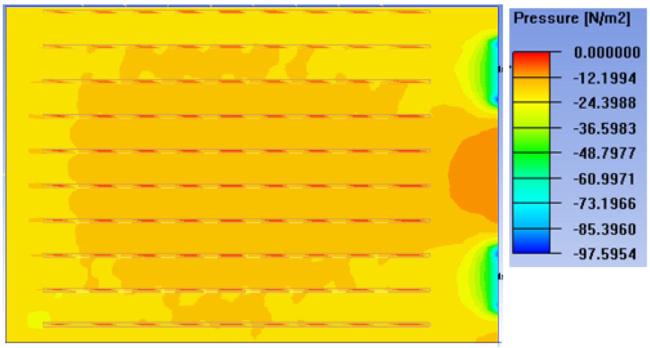

Fig. 9: Pressure contour plot for the cabinet with interrupted fin heat sink

VI. CONCLUSION

CFD Analysis was carried out for the Electronic cabinet with interrupted and continuous fin heat sink and results obtained for the velocity, temperature, temperature rise and pressure were plotted and compared between both. Also the analysis results of temperature rise and inlet velocity is validated analytically and hence satisfies. Comparing results of velocity shows negligible difference among both the cases, where as temperature results shows that there is increase in temperature of heat source by 6^{0}C for an Electronic cabinet with interrupted fin heat sink. Though there is increase in temperature, the temperature rise of both the cabinets was found to be same and it is about 3^{0}C which is below 10^{0}C. Also pressure results were plotted, it was found that there is a reduced pressure drop for the Electronic cabinet with interrupted fin heat sink and therefore there is reduction in pumping power cost compared to Electronic cabinet with continuous fin heat sink. Also installation of interrupted reduces the overall weight of the Electronic system.

Interrupted fin heat sink can be recommended for requirement of lower pumping power cost but not recommended for lower operating temperature application, as there is increase in heat source temperature and continuous fin heat sink can be recommended for applications where there is requirement of both lower pumping power cost and lower operating temperature.

CFD tool is very effective in determining the velocity, temperature and pressures for Electronic cabinet problems and these results obtained become a ready reckoner for beginner engineers in decision making in provision to fins. Present work is not exhaustive; it can be extended further for different cases of analysis by varying fin numbers, fin shapes, fin size, and changing fan locations. Also analysis results can be experimentally validated.

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