

Analysis and Optimization of Central Processing Unit Process Parameters

**Kaja Bantha Navas R¹ Budi Venkata Chaitana Vignan² Margani Durganadh³,
Chunduri Rama Krishna⁴**

School of Mechanical Engineering, Sathyabama University, Chennai, India

E-mail: ¹sumai244@gmail.com, ²vignanchaitanya@gmail.com,
³nadhu511@gmail.com

Abstract. The rapid growth of computer has made processing more data capable, which increase the heat dissipation. Hence the system unit CPU must be cooled against operating temperature. This paper presents a novel approach for the optimization of operating parameters on Central Processing Unit with single response based on response graph method. These methods have a series of steps from of proposed approach which are capable of decreasing uncertainty caused by engineering judgment in the Taguchi method. Orthogonal Array value was taken from ANSYS report. The method shows a good convergence with the experimental and the optimum process parameters.

1. Introduction

Computer cooling is the process of removing hot air from the system unit components. In earlier days, it was possible to cool most of the components of personal computer using natural convection, but later modern components require more effective active cooling. To cool these component fans are used to move hot air away from the components and draw cool air over them. In addition to it, the normal operation of system unit can be disturbed by other causes such as dust, poor air flow and poor heat transfer. Dust acts as a thermal insulator and impeding air flow there by reducing heat sink and fan performance. The poor air flow is due to friction against system unit components and improper orientation of fan can reduce the amount of air flowing through a case. The air is the most commonly used cooling medium. The cooling of system unit can be improved by supplying air directly to the components thereby improving air exchange in the system unit. The forced convection cooling is commonly used for system unit. System unit is also known as the computer data or central processing unit. The system unit is the most important part of a desk top personal computer. It may be known as the brain behind every action of a PC since in executes all the function performed by the personal computer. The system unit consists of several devices. The following components are listed as CPU/Heat Sink, Accelerated Graphical Port, SMPS, Hard Disk Drive, RAM, CD/ DVD, Mother Board and Processor.

The rapid development in desktop personal computer is has made processing more data possible which increase loads, which in turn increases the heat dissipation and temperature. Unless the heat is removed the temperature of the device will keep on increasing which leads to decrease in efficiency and caring house to the computers of system unit. The system unit must be cooled to satisfy the operating temperature unit hence keeping the temperature of heat source. The heat transfer process with heat generating components such as CPU - Heat Sink, Hard Disk Drive, RAM, AGP, CD/DVD and adaptive cards generates more heat. In computer the processor, AGP, RAM are increasing the



speed. Also these components need to be kept within a specified temperature range to prevent overheating and instability. Many components are required to be kept within a specified temperature range to prevent overheating and instability. The major heat generating components in CPU and its capacity (in Watts) are CPU-70, AGP-25, HDD-20, CHIPSET-10, SMPS-75 and FDD-10.

2. Literature Survey

Several researchers have worked on heat transfer in system via CFD among other, Yu and Webb (2001) simulated a complete pc which used an 80 W CPU with the addition of other components (AGP, PCI) a total of 313 W of heat was dissipated in to the system. This domain was solved with software ANSYS icepack. To decrease complexity, CPU heat sink was modelled as a volume resistance having the same time impedance as the detailed geometry. The cooling of PCI cards and baffle were improved by the analysis. Argento, Joshi and Oysterman (2001) has studied and verified system level electronic packaging in thermal design. In a complex computer CFD is a good approach to explore various design alternatives quickly with accuracy. There has been much success in the thermal design of complex electronics system using CFD Lech et al used Flotherm code to simulate detailed flow and temperature fields within a computer chassis with two fans. Emrezturk and iiker Tari (2007) had drawn a CFD road map for forced cooling heat transfer analysis in a computer chassis and the main sources of error in CFD analysis arise in numerical models including turbulence model. Icepack is used for pre processing and fluent is used for simulation and post processing. Biswas et.al(2006) studied the air flow in a compact electronic enclose and investigated the pressure loss due to the inlet and outlet and use of fan curves obtained from the manufacturing was considered and the fan curve may need to be modified if the fan is not closely ducted. Evely vet.al (2003) used Flotherm software has a perspective on the current CFD as a design tool to predict component temperature on PCB. Their computation predicted on the component operating temperature in an accuracy range of 30c to 220c with up to 35% error. They suggested that components junction temperature would need to be experimentally measured.

3. Parametric Study for System Units

The main objective of the parametric study is to investigate the effect of various parameters in the CPU case. There are power dissipation of the processor, fan speed, Ambient air temperature and air intake area. The range of parameter which the Anandakrishnan .M and Balaji.C, (2009) considered is given in table 1. The power dissipation in processor is between 60 w to 130 w and the ambient temperature of a system unit in desktop personal computer is between 240⁰ c and 390⁰ c .

3.1 Power Dissipation of CPU

The processor may not dissipate its maximum amount of heat all the time. It will vary depending upon the computational work it performs. The profile is obtained by varying the power dissipation value of the processor over the range of 60 to 130 W. while other parameters are kept constant. It can be seen that maximum CPU case temperature has a linear dependence on the power dissipation rate and the order temperature are less sensitive to the power dissipation of the processor. The thermal design power and maximum case temperature of a processor are the maximum values of the thermal profile. By design the thermal solution must meet the thermal profile for all system operating conditions and processor power levels.

3.2 Fan Speed

Since the processor is cooled by forced convection. The fan speed will exert a significant influence on the heat transfer characteristics. An increase in the fan speed will increase the velocity of the air flow over the heat sink and hence the heat transfer coefficient. This will improve the heat transfer from the processor and reduce its temperature. Simulation was done for different fan speed that was varied over the range of 2850 rpm to 5000 rpm. The corresponding flow velocities were 2.33 m/s and 4.29 m/s respectively. For each fan speed the corresponding fan performance curve was given as the heat sink

fan boundary conditions. The nature of the plot shows that maximum CPU case temperature has a non linear dependence on fan speed. The temperature of other components also shows a non linear variation with fan speed.

Table 1. Power dissipation in Processor

Parameters	Range
Power Dissipation of the processor (watts)	$60 \leq Q \leq 130$
Fan speed (rpm)	$2850 \leq N \leq 5000$
Ambient temperature ($^{\circ}$ c)	$24 \leq T \leq 39$
In take area (m^2)	$0.0036 \leq A \leq 0.0084$

3.3 Ambient Air Temperature

The ambient air temperature at which the system has to work may vary depending upon the weather conditions or geographical variations. The effect of ambient temperature on CPU case temperature was studied by varying the air inlet temperature from 2400° c to 3900° c. The air properties were changed accordingly. Maximum CPU case temperature and the temperature of the other components with the intake air temperature .It can be seen that the variation is more or less linear. Usually air circulates through the system cabin by induced draught produced by an exhaust fan. Air vents on cabin walls are provided at appropriate locations to make air in to the cabin cool, proper vending is a key element in any good thermal design providing an insufficient amount of venting does not allow enough air into the system for adequate cooling. Providing too much venting can decrease the air velocity across the system components resulting in less heat transfer through forced convection. In order to study the effect of air intake area on the CPU case temperature, the former was varied over the range $0.0036 m^2$ to $0.0084 m^2$ the maximum temperature decreased linearly from 77° c to 70.50° c .

4. Simulation of System Units

By experimental method it is very difficult to predict the performance of air velocity inside the system unit. So by the Simulation it is easier to carry out the air velocity and analysis of heat transfer in system unit. The boundary conditions is used here are Inlet velocity - 1 to 6 m/s, Pressure-1atm, Temperature -300 K to 312 K. The Analysis is made for various parameters. Then the calculation activities are started for the given number of iterations. The load consideration taken is 70W/2.8 GHz processor load.

The desktops components standard sizes are selected as follows in meters. CD/DVD- $0.051 \times 0.175 \times 0.17$, FD- $0.05 \times 0.14 \times 0.010$, HDD- $0.024 \times 0.155 \times 0.098$, CPU/HS- $0.048 \times 0.048 \times 0.089$, AGP- $0.082 \times 0.145 \times 0.005$, RAM- $0.03 \times 0.16 \times 0.005$, SMPS- $0.085 \times 0.140 \times 0.150$, CHASSIS- $0.45 \times 0.47 \times 0.21$, MOTHER BOARD- $0.26 \times 0.23 \times 0.005$. Before starting simulation process we must provide an initial solution to be fixed for attaining the final solution. By selecting the entire flow field and the solution is computed from all zones. The meshed modelled is imported to ANSYS FLUENT. In model, the energy equation is enabled. The standard K- epsilon model is used in this analysis. The material used for this analysis is fluid- air.

The boundary conditions are

Inlet velocity – 1 to 6 m/s

Pressure – 1 atm

Temperature – 300 K To 312 K

The meshing of the Desktop computer components such as CD/DVD, HDD, AGP, CPU-Heat Sink & SMPS are done. The meshing of CD/DVD is shown in figure 1.

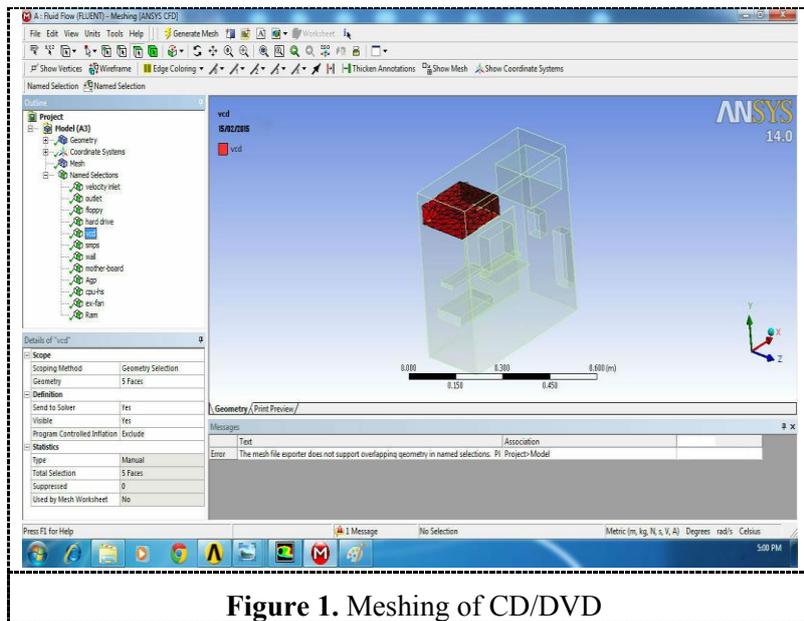


Figure 1. Meshing of CD/DVD

The Analysis is made for various parameters by varying the ambient temperature & air velocity at constant atmospheric pressure and heat dissipation is computed from all zones. Then the calculation activities and the calculation are started for the given number of iterations. The load consideration taken is 70W/2.8 GHz processor load. Before starting simulation process we must provide an initial solution to be fixed for attaining the final solution. There are two types of initialization, they are as follows: Initialize the entire flow field selected and the solution is computed from all zones. Then the calculation activities and the calculation are started for the given number of iterations. The various heat dissipation of components are studied and heat dissipation taken from earlier studies by Emre ozturk et.al. (2007) are given in the table 1 and 2. The system parameters path diagram is shown in figure 2.

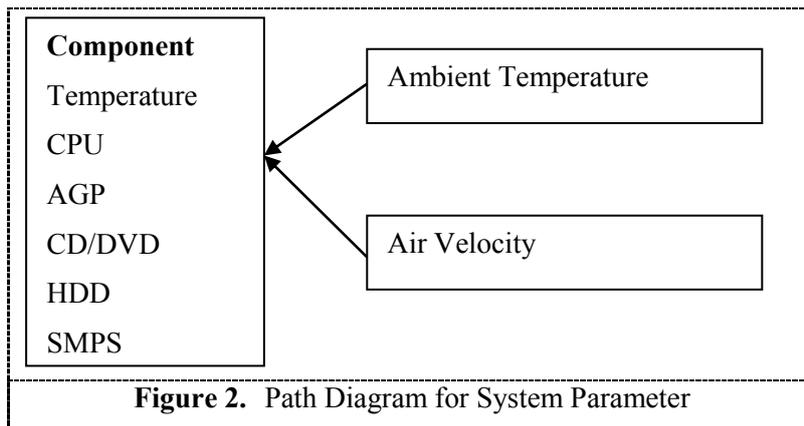


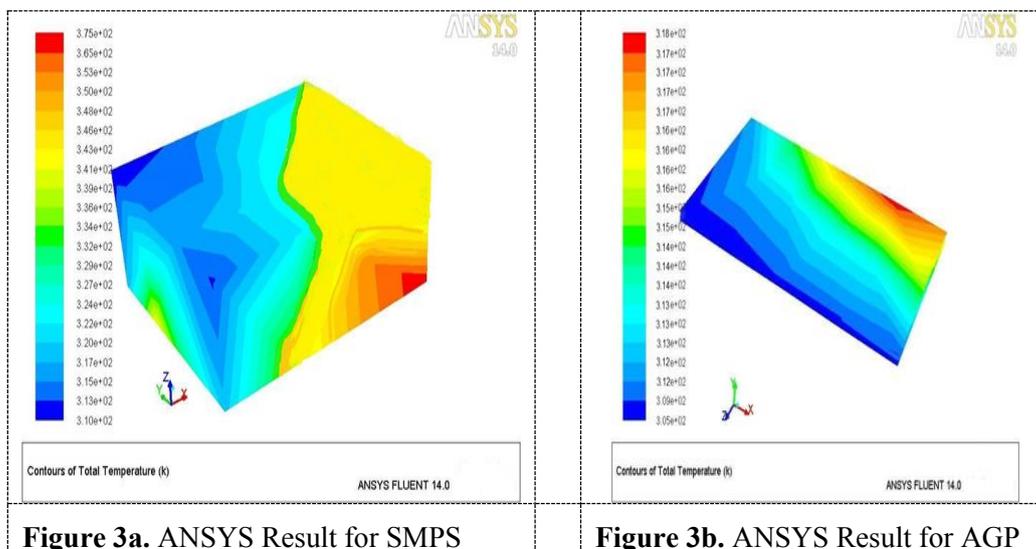
Figure 2. Path Diagram for System Parameter

Table 2. Desktop Component's Heat dissipation and Temperature

Components	Heat Dissipation (W)	Temperature (K)
CPU	70	406
AGP	25	320
HDD	20	311
SMPS	75	415
CD/DVD	20	311

5. Temperature Distribution in Various Components using ANSYS

The Temperature of various components plays a vital role in the performance of the system unit. The temperature variation is due to the ambient temperature, Heat dissipation of the components, velocity of air at inlet, etc. The influence of all these factors on temperature was studied. The 3D modelling and analysis of system unit has been carried out with the help of solid works and ANSYS. The analysis of operating conditions such as varying ambient temperature, air inlet velocity and convective heat transfer coefficient with the post processing facility in the software, the contour plots for temperature and vector plots for velocity has been generated for various operating conditions and the significance of various parameters considered in this study. In order to predict the flow of air inside the system unit, the velocity vector was analyzed. The air enters from the inlet and the flow is shifted downwards near the processor and then cooled by the convective walls and finally exits through the outlet. The heat transfer process with heat generating components such as CPU, Hard Disk Drive, AGP, HDD and Adaptive Cards have been generating more and more which impact on Performance of the system unit. The temperature variation is due to the ambient temperature, Heat dissipation of the components and velocity of air at inlet. To keep the these components CPU, Hard Disk Drive, AGP, HDD need to be within a specified temperature range, the study made with various air velocity, Ambient temperature & constant atmospheric pressure to prevent overheating and instability. The temperature distribution of AGP, CD/DVD, CPU-Heat Sink, Hard Disc Drive, SMPS are from ANSYS Result for SMPS and ACP is shown in figure 3a and 3b.



6. Impact of Air Velocity in System Unit

The Variation in air inlet velocity influences the temperature distribution of system so temperature and atmospheric transfer are kept constant and the variation of component's temperature with respect to the inlet velocity has been analysed. It is observed that the temperature of various components decrease significantly. When the velocity is increased from 1 m/s to 6 m/s. The temperature range for various components such as CPU, AGP, CD/DVD, SMPS and HDD are 300 K, 306 K and 312 K.

7. Process Parameters Optimization

An experiment was conducted using array concept and data were collected from ANSYS report. The objective is to minimize the response (Components temperature), we have taken smaller –the better type of quality to compute S/N ratios. Here factors considered are ambient temperature & Air velocity; the response is component's (AGP, CD/DVD, CPU, HDD and SMPS) temperature. The components temperature achieved for the ambient temperature of 300 K, 306 K and 312K as well as the velocity of 1 m/sec, 3 m/sec and 6 m/sec with respect to components as shown in table 3. The table 4 represents operating parameters (Factors) and its level.

Table 3. Experimental Data From ANSYS Report

AGP (Y ₁)		Velocity (m/sec)		
Temperature (K)	1	3	6	
300	315.9	314.5	314	
306	316	315	314	
312	316.5	315.5	314.5	

CD/DVD (Y ₂)		Velocity (m/sec)		
Temperature (K)	1	3	6	
300	308.5	307.5	307	
306	307.5	306.5	306	
312	308.9	308	307	

CPU/Heat Sink (Y ₃)		Velocity (m/sec)		
Temperature (K)	1	3	6	
300	362	358	350	
306	362	358	350	
312	370	365	358	

HDD (Y ₄)	Velocity (m/sec)		
Temperature (K)	1	3	6
300	310	309.5	309.3
306	310.2	309.7	309.3
312	310	310.3	309.7

SMPS (Y ₅)	Velocity (m/sec)		
Temperature (K)	1	3	6
300	379	372	368
306	380	382	375
312	380	376	372

Table 4. Factors and Levels for Operating Parameters

Operating Parameters	Symbol	Unit	Low	Medium	High
Temperature	A	K	300	306	312
Velocity	B	m/sec	1	3	6

Computed S/N ratio with respect to listed operating parameters using the formula $S/N \text{ ratio} = -10 \log \{1/n \sum Y_i^2\}$. Table 5 represents Signal to Noise Ratio for operating parameters. The total response values are tabulated in table 6. Average effects and Rank for operating parameters are listed in table 7

Table 5. S/N ratio for Operating Parameters

Trial	A	B	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	S/N ratio
1	1	1	315.9	308.5	362	310	379	-50.53
2	1	2	314.5	307.5	358	309.5	392	-50.57
3	1	3	314	307	350	309.3	368	-50.37
4	2	1	316	307.5	362	310.2	388	-50.57
5	2	2	315	306.5	358	309.7	382	-50.52
6	2	3	314	306	350	309.3	375	-50.42
7	3	1	316.5	308.9	370	310	380	-50.57
8	3	2	315.5	308	365	310.3	376	-50.56
9	3	3	314.5	307	358	309.7	372	-50.59

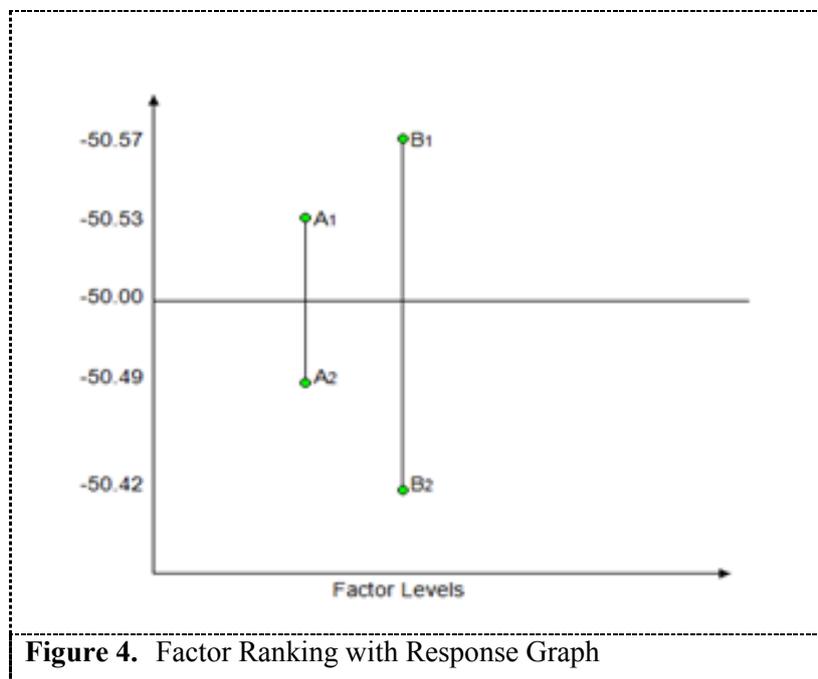
Table 6. Total Response for Operating Parameters

Factor	Level 1	Level 2	Level 3
A	-151.47	-151.53	-151.58
B	-151.71	-151.62	-151.25

Table 7. Average Effect and Rank for Operating Parameters

Factor	A	B
Level 1	-50.49	-50.57
Level 2	-50.51	-50.54
Level 3	-50.53	-50.42
Difference	0.04	0.15
Rank	2	1

From the figure 4, Factor B has given main impact to reduction in component temperature.

**Figure 4.** Factor Ranking with Response Graph

8. Predicting Optimum Condition

It can be seen that factor B is significant since it is Rank 1. Hence the predicted optimum response in terms of S/N ratio is given by

$$\begin{aligned} \mu)_{\text{optimum}} &= \mu)_{\text{mean}} + \{ \text{Average Effect Value for Factor)}_B - \mu)_{\text{mean}} \} + \{ \text{Average Effect Value for} \\ &\text{Factor)}_A - \mu)_{\text{mean}} \} \dots\dots\dots (1) \\ &= - 50.51 + \{-50.57 - (-50.51)\} + \{-50.53 (-50.51)\} \\ &= - 50.59 \end{aligned}$$

It is observed that from the table 5, that the S/N ratio is - 50.59 and it is correspond to experimental trail no. 9 which predicted the yield of - 50.59. From this we can 50.59 and it is correspond to experimental trail no. 9 which concludes the optimum condition obtained is at 6 m/sec.

9. Conclusion

Based on the analysis conducted on the system unit of desktop personal computer for various operating and boundary conditions, a good flow is developed in CFD software based on the detailed study of flow models, heat transfer models and solution controls. The CPU's component temperature is observed with respect to the change in operating parameters. In this paper, single response problem was taken with two independent variables such as ambient temperature and air flow and optimum component temperature values were determined by response graph method

10. References

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