# Numerical Investigations on Thermal Behaviors of Electronics Module with Water-Silicon Dioxide Nanofluid

**Dr. Nirmal Kumar Kund**
Associate Professor, Department of Production Engineering
Veer Surendra Sai University of Technology, Burla, Odisha, India

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**ABSTRACT** *The usual air cooling practice is inappropriate for high heat flux electronics devices. For that, the thermal management of electronics module is very much vital to its smooth operation. The present investigations involve an electronics module kept horizontally at the base, inside a square shaped chamber filled with Water-$SiO_2$ nanofluid as coolant. The numerical studies are carried out to obtain the heat transfer behavior of electronics module for maintaining its temperature within the safe limit. For that, a 2D numerical model is being developed which also includes thermal buoyancy. The continuity, momentum and energy equations are solved to predict the thermal behavior. The simulations are performed to predict the temperature fields and temperature contours. The trends of results are along the expected lines. The key model parameter considered is heat flux of 70 W/cm$^2$ associated with the electronics module. The Water-$SiO_2$ is observed as the nanofluid possessing better cooling characteristics to electronics module without any sort of thermal issues.*

***Keywords:****Electronic Device;Chip;Electronics Module; Simulation; Nanofluid; Water-$SiO_2$.*

## I. Introduction

Bearing in mind the current trend of constant increase in both packaging and power densities in modern day's electronics devices, the search for the suitable cooling techniques, motivated the investigators around the globe. Webb and Ma [1] studied about single phase liquid jet impingement heat transfer. Xuan and Roetzel [2] discussed about the conceptions of heat transfer correlation of nanofluids. Basak et al. [3] reported on effects of thermal boundary conditions on natural convection flows within a square cavity. He et al. [4] described about heat transfer and flow behaviour of aqueous suspensions of TiO2 nanofluids flowing upward through a vertical pipe. Anandan and Ramalingam [5] reviewed on thermal management of electronics. Kurnia et al. [6] analyzed numerically on laminar heat transfer performance of various cooling channel designs. Yang and Wang [7] simulated a 3D transient cooling portable electronic device using phase change material. Zhu et al. [8] optimized the heat exchanger size of a thermoelectric cooler used for electronic cooling applications. Gong et al. [9] presented numerically on layout of micro-channel heat sink useful for thermal management of electronic devices. Naphon et al. [10] demonstrated on thermal cooling enhancement methods intended for electronic gadgets.

## II. Objectives of Present Research Work

From the above-mentioned literature, to the best of author' understanding, it is quite clear that there is not a single comprehensive numerical study relating to the effects of Water-$SiO_2$ nanofluid on heat transfer performance of electronics modules. With this standpoint, the present paper demonstrates numerical investigations with the stated nanofluid on thermal characteristics of electronics modules. And also, the numerical model includes additional key factors like inertia, viscosity and gravity effects apart from the usual issues concerning the present physical problem. However, the stated model ignores both compressibility and viscous heat dissipation effects. The model is very well demonstrated for the detailed numerical investigations on the influences of the already stated nanofluid (as it significantly affect the cooling characteristics) by taking electronics module heat flux and duct inlet nanofluid velocity as the important model parameters. Finally, the model predictions concerning about the said nanofluid are also along the lines of expectations.

## III. Description of Physical Problem

The neat illustration of a usual electronics module representing the base of a square shaped chamber is portrayed in the figure 1. It describes about the overall heat transfer from the electronics module kept horizontally at the base of square shaped chamber. The coolant considered in the present investigations is Water-$SiO_2$ nanofluid. A 2D model is considered to save computation/simulation time by ignoring end effects in the transverse direction. The model includes thermal buoyancy, viscosity along with the gravity effect as well. The fluid flow is considered to be laminar and incompressible. The ambient together with the no slip boundary condition is specified at the walls. For cooling of the electronics module, a convective boundary condition in the form of heat flux is introduced at the base to simulate the overall temperature variation inside the square chamber due to heat transfer. The thermo-physical properties of several nanoparticles alongside the additional system variables, are presented in table 1.

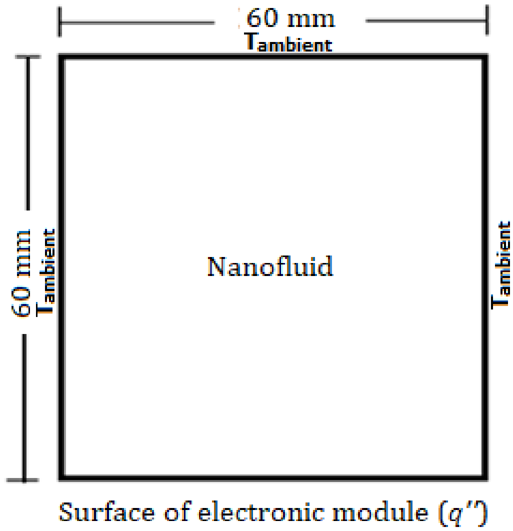


**Fig 1. Schematic of electronics module computational domain.**

**Table 1. Thermophysical properties and model data**

| **Nanoparticle Properties** | **$SiO_2$** |
|---|---|
| Density, $\rho$ ($Kg/m^3$) | 2648 |
| Specific heat, $C_P$ (J/kg-K) | 745 |
| Thermal conductivity, $k$ (W/m-K) | 10.4 |
| **Model Data** | **Values** |
| Height/Width of chamber | 60 mm |
| Length of electronics module | 60 mm |
| Ambient air temperature | 300 K |
| Electronics module heat flux | 70 $W/cm^2$ |

## IV. Mathematical Formulation and Numerical Procedures

The 2D continuity, momentum and energy equations are described as follows.

*Continuity equation:* $$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad (1)$$

*X-momentum equation:* $$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \quad (2)$$

*Y-momentum equation:* $$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\rho g\beta\Delta T \quad (3)$$

*Energy equation:* $$\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \quad (4)$$

As an outcome of the grid-independence test, 60 × 60 uniform grids have been used for the final simulation. Corresponding time step taken in the simulation is 0.0001 seconds.

## V. Results and Discussions

Numerical simulations are carried to study the effects of Water-$SiO_2$ nanofluid on cooling behaviors of electronics module in terms of temperature distributions (i.e. temperature contours/fields) and surface temperatures of electronics modules. To begin with, the size of the square chamber is taken as 60 mm. Furthermore, the heat flux related to the electronics module is consider as 70 $W/cm^2$.

### *Water-$SiO_2$ Nanofluid as Coolant*

With the specified model conditions, to study the influence of Water-$SiO_2$ nanofluid on the thermal behavior of the electronics module, the numerical simulations are conducted, by considering the thermophysical properties of the specified nanofluid.

Figure 2 demonstrates the simulated results of the temperature field (in conjunction with the colored scale bar displaying the temperature values in terms of K) as observed at the specified model conditions by taking into account the Water-$SiO_2$ nanofluid as coolant. The surface temperature of electronics module is found to be 349 K (which is very near to the safe limit of 356 K temperature as desired in order to avoid the thermal failure of the electronics module). As expected, the temperature of the Water-$SiO_2$ nanofluid is maximum near the vicinity of electronics module. And also, the temperature of the Water-$SiO_2$ nanofluid gradually decreases with the increase in the distance from the electronics module and then it becomes equal to the atmospheric temperature in the far field region. The corresponding temperature contour is also demonstrated in figure 3. Here also, the trends of results are along the lines of expectations.

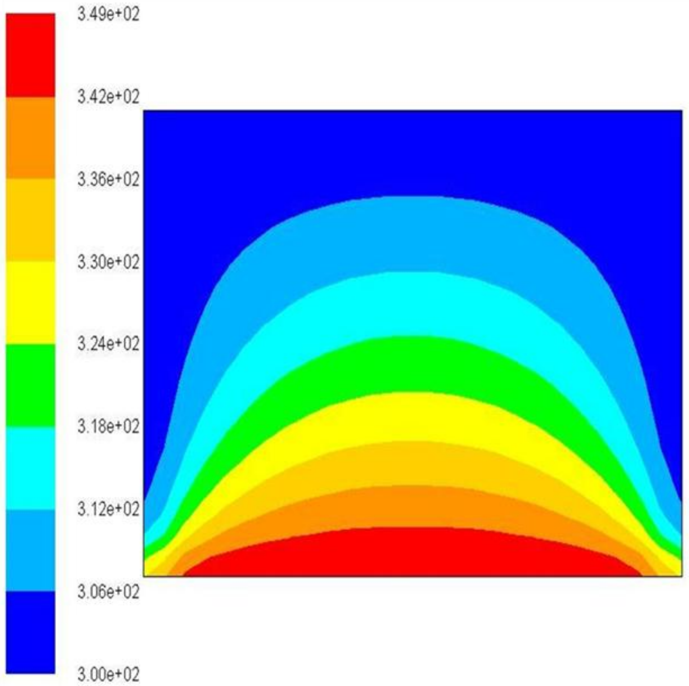


**Fig 2. Temperature field with Water-$SiO_2$ nanofluid as coolant.**

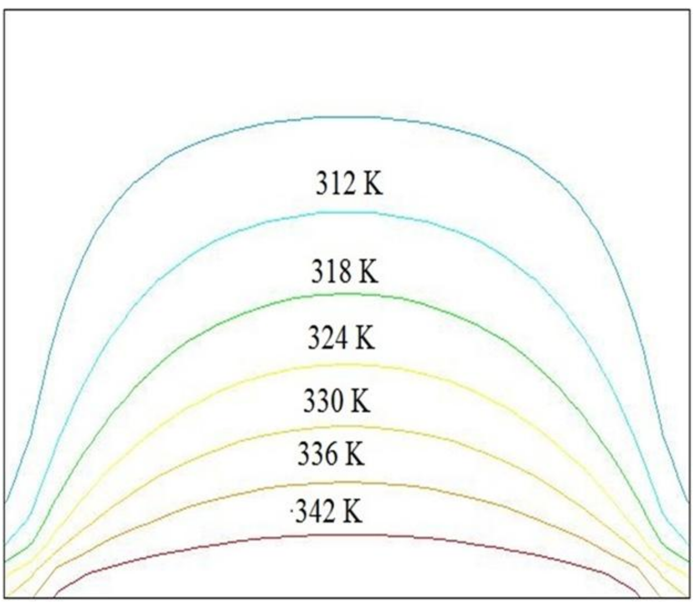


**Fig 3. Temperature contour with Water-$SiO_2$ nanofluid as coolant.**

## VI. Conclusion

A numerical model relating to the electronics module is developed to predict the thermal behavior with Water-$SiO_2$ nanofluid as coolant. The model comprises additional key factors like inertia, viscosity, gravity and thermal buoyancy effects apart from the usual issues concerning the present physical problem. However, the specified model ignores both compressibility and viscous heat dissipation effects. The model is very well demonstrated for the detailed numerical investigations on the influences of the already stated nanofluid (as it significantly affect the cooling characteristics) by taking electronics module heat flux of 70 W/$cm^2$as the important model parameter. The predictions of the model pertaining to the stated nanofluid are along the expected lines. Direct comparison with other numerical models of electronics modules is not possible because of the absence of such models in the literature. However, the experimental comparison with an in-house experimental setup is planned for the future. With the said model conditions, it is observed that the Water-$SiO_2$ nanofluid provides suitably effective cooling behavior without any such thermal failure and is the better one as the electronics module temperature is far below the safe limit. Therefore, the specified model together with the nanofluid can be used directly in industries to augment heat transfer for cooling of electronics modules.

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