Numerical Modeling for Electronics Module Cooling Expending Water-Magnesium Oxide Nano fluid

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Abstract

The customary air cooling exercise is not suitable for the thermal management of electronics module. The current study includes an electronics module kept horizontally at the base, inside a square shaped chamber filled with MgO-Water nanofluid. The numerical studies are performed 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. Simulations are performed to predict the temperature fields and temperature contours. The trends of results are along the expected lines. The key model parameter taken is heat flux of 70 W/cm^2 linked with the electronics module. The MgO-Water nanofluid is witnessed as augmenting the electronics module cooling without any sort of thermal failure.

Keywords: Electronics Module, Numerical, Simulation, MgO-Water, Nanofluid.

1. Introduction

During the past several years, drive for momentous volume of research related to the design and development of effective cooling schemes is made. Wadsworth and Mudawar [1] examined on cooling of a multichip electronic module with confined 2D jets of dielectric liquid. Webb and Ma [2] studied about single phase liquid jet impingement heat transfer. Xuan and Roetzel [3] discussed about the conceptions of heat transfer correlation of nanofluids. Basak et al. [4] reported on effects of thermal boundary conditions on natural convection flows within a square cavity. He et al. [5] described about heat transfer and flow behaviour of aqueous suspensions of TiO_2 nanofluids flowing upward through a vertical pipe. Anandan and Ramalingam [6] reviewed on thermal management of electronics. Kurnia et al. [7] analyzed numerically on laminar heat transfer performance of various cooling channel designs. Yang and Wang [8] simulated a 3D transient cooling portable electronic device using phase change material. Zhu et al. [9] optimized the heat exchanger size of a thermoelectric cooler used for electronic cooling applications. Gong et al. [10] presented numerically on layout of micro-channel heat sink useful for thermal management of electronic devices.

From the quoted investigations, to the best of author' knowledge, it is perceived that there is not a single ample numerical study pertaining to the impacts of Water-MgO 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 by taking electronics module heat flux and duct inlet nanofluid velocity as the important model parameters. Eventually, the model results pertaining to the stated nanofluid are along the expected lines.

2. Description of Physical Problem

The spick-and-span drawing of a typical electronics module representing the base of a square shaped chamber is shown 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 coolants considered in the present investigations is MgO-water 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 concerned nanoparticles combined with the additional system data, are summarized in table 1.

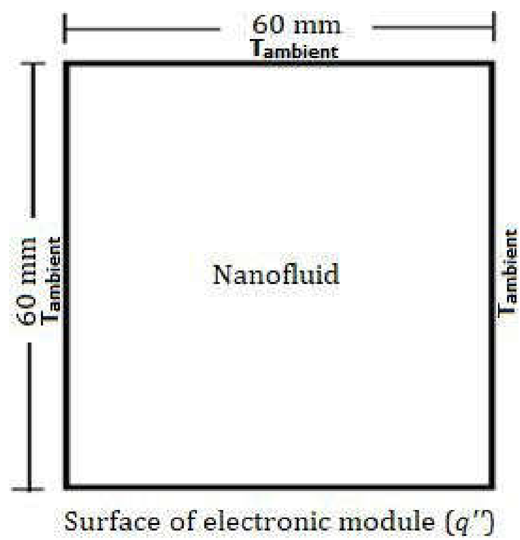

Figure 1. Schematic illustration of electronics module computational domain.

Table 1. Thermophysical properties of nanoparticles and model data

Nanoparticle Properties	MgO
Density, ρ (Kg/m^3)	3560
Specific heat, CP (J/kg-K)	955
Thermal conductivity, k (W/m-K)	45
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

3. Mathematical Formulation and Numerical Procedures

A. Generalized governing transport equations

The concomitant physical problem is converted into a set of governing transport equations which are solved using the related numerical procedures vis-à-vis both modeling and simulation. The related continuity, momentum and energy equations in 2D for a fully developed hydrodynamic and thermal flow situations are described in equations from (1) to (4), respectively. The compressibility and the viscous heat dissipation effects are neglected in the existing physical situation. On the other hand, the thermal buoyancy term (symbolized by $\rho g\beta\Delta T$) is included in y-momentum equation (3).

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

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

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

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

B. Numerical techniques

The transformed governing transport equations are solved by expending pressure based coupled framework relating to finite volume method (FVM) using the SIMPLER algorithm. As an outcome of this test, we have used 60 × 60 uniform grids for the final simulation. Corresponding time step taken in the simulation is 0.0001 seconds.

4. Results and Discussions

Numerical simulations are done to investigate the impacts of the MgO-water 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. Besides, the heat flux associated with the electronics module is taken as 70 W/cm^2.

Water-Magnesium Oxide nanofluid

With the stated model conditions, in order to study the effect of Water-MgO nanofluid on the thermal behavior of the electronics module, the numerical simulations are conducted, by taking into consideration the thermophysical properties of the specified nanofluid.

Figure 2 illustrates the simulated results of the temperature field (together with the colored scale bar exhibiting the temperature values in terms of K) as observed at the stated model conditions by considering Water-MgO nanofluid as coolant. The surface temperature of electronics module is found to be 328 K (which is also within 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-MgO nanofluid is maximum near the vicinity of electronics module. And also, the temperature of the Water-MgO 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. The trends of results are along the expected lines as well.

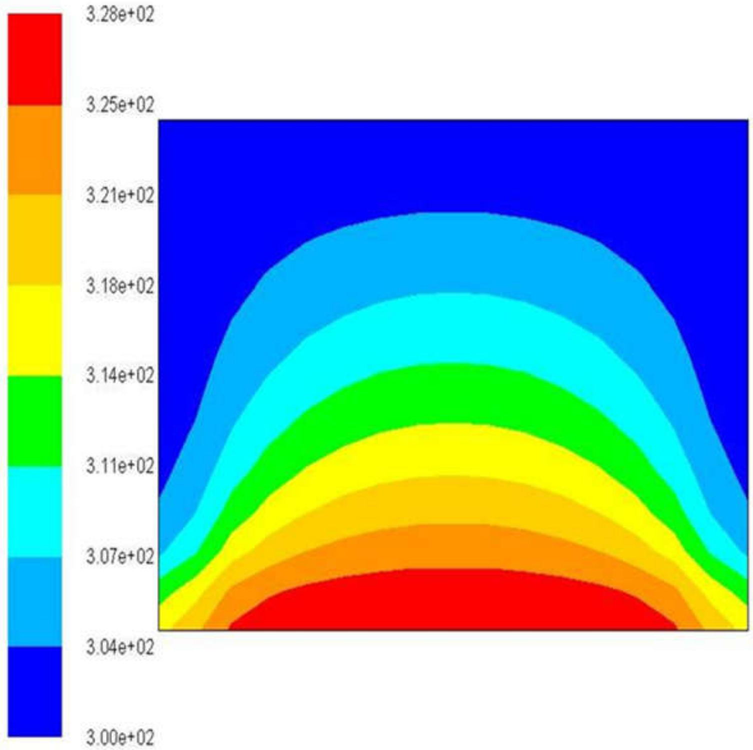

Figure 2. Temperature field with Water-MgO nanofluid as coolant.

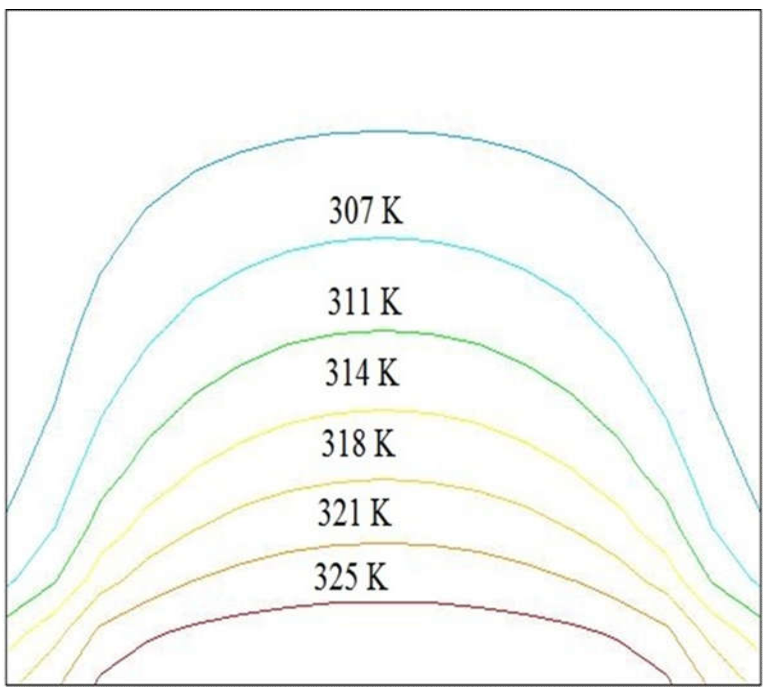

Figure 3. Temperature contour with Water-MgO nanofluid as coolant.

5. Conclusion

A 2D model relating to the electronics module is developed to envisage the thermal performance with the MgO-water nanofluid as coolant. The model includes 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 by taking electronics module heat flux of 70 W/cm^2 as the important model parameter. The predictions of the model pertaining to the 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 stated model situations, it is witnessed that the MgO-Water nanofluid offers suitably effective cooling performance as the module temperature is quite below the safe limit. Therefore, the said model together with the nanofluid can be applied forthwith in electronics manufacturing houses.

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