

CFD Modeling on Thermal Management of IC using Water Based Fe, Cu and Al Nanofluids

N. K. Kund



Abstract: In unrelenting civility, CFD codes are developed and simulated with water based Fe, Cu and Al nanofluids for foreseeing the heat alarms of ICs. The convective governing equalities of mass, force and drive are computed for envisaging the thermal issues of ICs. The time pace selected throughout the intact computation is 0.0001 s. The soundings affect CFD forecasts of temperature curve, temperature arena plus fluid-solid boundary temperature of IC. Corresponding fluid-solid boundaries temperatures of IC are viewed as 321, 309 and 313 K for water based Fe, Cu and Al nanofluids, one-to-one. The temperature of water-Cu nanofluid stands peak contiguous to the IC locality as it stands far less than the chancy temperature limit of 356 K. Further, the temperature of water-Cu nanofluid gently drops with improvement in aloofness from IC. Afterwards, this becomes surrounding temperature in the distant arena precinct. The analogous tinted temperature curve stands accessible. In addition, the congruent plot of temperature verses distance from IC stays revealed. The uneasiness of CFD compassionate position nearby the conveniences of jargons.

Index Terms: CFD Codes, Temperature Control, Fe, Cu and Al Nanofluids.

I. INTRODUCTION

An echo of elevated thermal tolerances in countless devices from interconnects to server are shown in figure 1. Electronics temperature control caught many routines for illustration. The standard temperature control arrayed heretofore for instance, atmospheric convection is inappropriate for extreme thermal flux treatments. In the preceding years the strange way of temperature control has compelled the researchers for the infuriating of nanofluid temperature control.

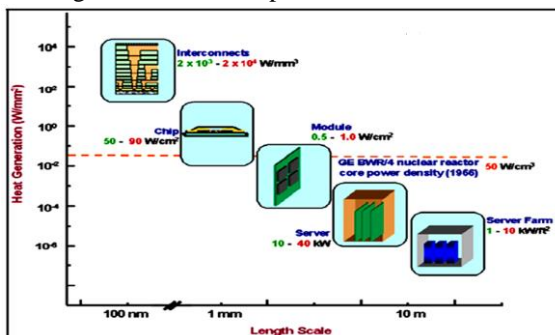


Figure 1. Progressive evolution of electronic devices

Revised Manuscript Received on August 30, 2019.

* Correspondence Author

N. K. Kund*, Department of Production Engineering, Veer Surendra Sai University of Technology, Burla (Sambalpur), Odisha, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

The nanofluid temperature control is undeniably strong as ambient temperature control is poor to deliver the drive as well. Numerical and experimental reviews on heat spreading over rectangular domain are existent in texts [1-7]. Computational and experimental work with solidification remain perceptible as well [8-25].

Nevertheless of the evidences that the nanofluid cooling equivocates the issues about the extreme heat battle as to ambient temperature control and hence, the treatment of nanofluid remains the significant drive of the extant exploration. Here, the temperature control of electronics by water based Fe, Cu and Al nanofluids are done numerically.

II. DESCRIPTION OF PHYSICAL CHALLENGE

Figure 2 establishes the physical issue in relation to the heat evolution from integrated circuit (IC) indicating the foot edge. Rest three edges are signposted through ambient situations. Here, the temperature controls of electronics is done through water based Fe, Cu and Al nanofluids. Besides, the thermophysical and model data of nanoparticles reflected in the existent analysis plus the ambient situation involved in the current path simulations, are amalgamated in Table 1.

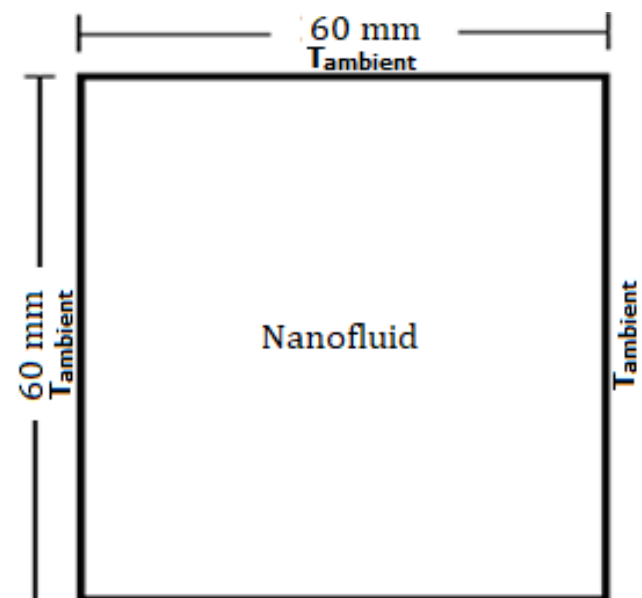


Figure 2. Illustrative sketch of IC computational zone

Table 1. Thermophysical properties and model data.

Nanoparticle Properties	Fe	Cu	Al
Density, ρ (Kg.m ⁻³)	7875	8941	2701
Specific heat, C_p (J.kg ⁻¹ .K ⁻¹)	451	386	905
Heat conductivity, k (W.m ⁻¹ .K ⁻¹)	80	402	238
Model Data	Values		
Cavity size	60 mm		
IC size	60 mm		
Ambient temperature	300 K		
IC heat transfer rate/area	70 W/cm ²		

III. COMPUTATIONAL EXERCISE

As putative overhead, the figure 2 issues the CFD workbench aimed at computing the physical topic course. To facilitate the CFD forecasts the binding stages such as constructing geometry and purview, meshing and initialization are followed to run the simulation. Here, the prevailing equalities (as termed below through equalities 1-4) of mass, force and drive beside the edge states are chosen. Linearized equalities are computed through the CFD codes. After the development of computations, CFD codes form the shapes and curls through that numerous graphs stand strained to amalgam the CFD forecasts through the prognoses. With the later dispensation the forecasts are scrupulously explored intended for accepting overgenerous permeations.

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

X-momentum:

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

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:

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

In the synchronous analysis, CFD codes remain developed and executed with water based Fe, Cu besides Al nanofluids for envisioning the heat concerns of ICs. The convective governing equalities of mass, force and drive are computed for envisaging the thermal issues of ICs. The time step chosen all over the whole computation is 0.0001 s.

IV. RESULTS AND DISCUSSIONS

CFD codes are developed and accomplished with water based Fe, Cu and Al nanofluids. It envisages the impacts on temperature control of ICs. The soundings affect CFD forecasts of temperature fields, temperature contours and fluid-solid boundaries temperatures of ICs.

Influence of Water-Fe Nanofluid on IC Thermal Cooling

Figure 3 bares the CFD ridge of temperature field besides the tinted measuring scale screening the temperature values over K. It stands viewed at the documented archetype statuses bearing in mind the water-Fe nanofluid for IC temperature control. The fluid-solid boundary temperature of IC is viewed as 321 K. This stands far less than the chancy limit of 356 K temperature wished for the objective of outwitting thermal cataclysm of IC. The temperature of water-Fe nanofluid looks extreme nearly IC neighborhood.

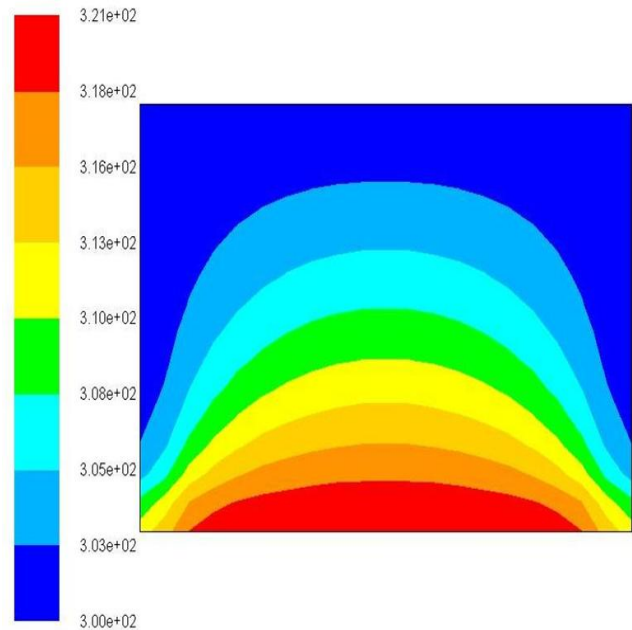


Figure 3. Temperature field with water-Fe nanofluid

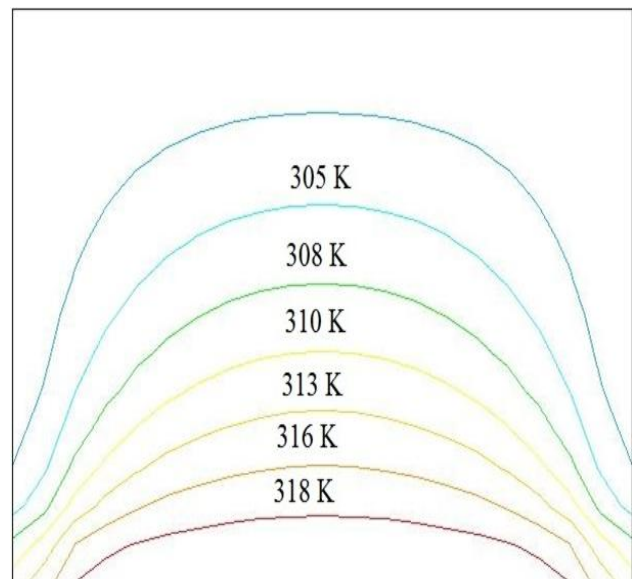


Figure 4. Temperature contour with water-Fe nanofluid

Also, the temperature of water-Fe nanofluid smoothly drops with improvement in aloofness from IC. Afterwards, this becomes surrounding temperature in the aloof arena precinct. The equivalent tinted temperature contour remains available in figure 4 as well.

Influence of Water-Cu Nanofluid on IC Thermal Cooling

Figure 5 bares the CFD ridge of temperature field besides the tinted measuring scale screening the temperature values over K. It stands viewed at the documented archetype statuses bearing in mind the water-Cu nanofluid for IC temperature control. The fluid-solid boundary temperature of IC is viewed as 309 K. This stands far less than the chancy limit of 356 K temperature wished for the objective of outsmarting heat commotion of IC.

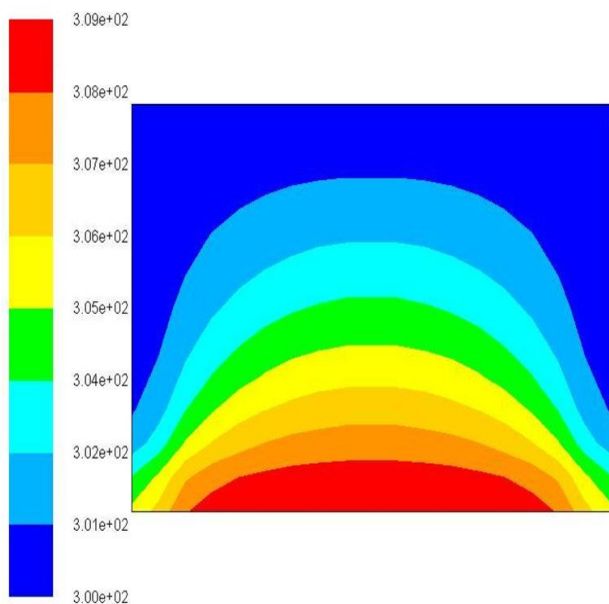


Figure 5. Temperature field with water-Cu nanofluid

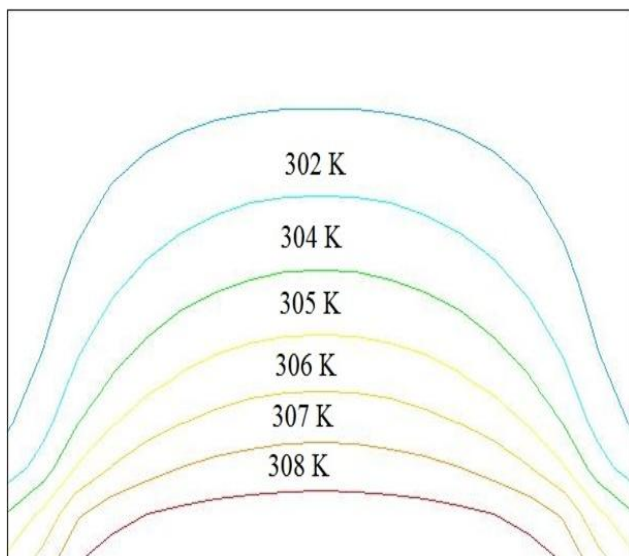


Figure 6. Temperature contour with water-Cu nanofluid

The temperature of water-copper nanofluid stays extreme neighboring to the IC vicinity. Further, the temperature of water-copper nanofluid gently drops with improvement in aloofness from IC. Afterwards, this becomes surrounding

temperature in the aloof arena precinct. The equivalent tinted temperature contour remains available in figure 6 as well.

Influence of Water-Al Nanofluid on IC Thermal Cooling

Figure 7 bares the CFD prediction of temperature field besides the tinted measuring scale screening the temperature values over K.

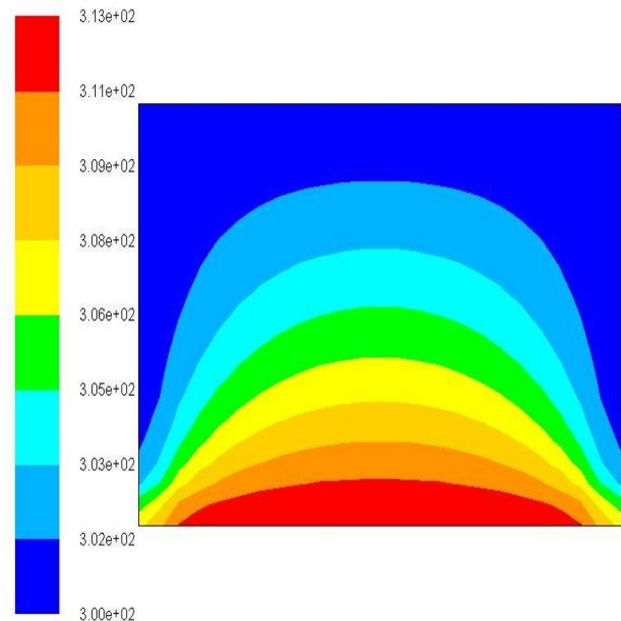


Figure 7. Temperature field with water-Al nanofluid

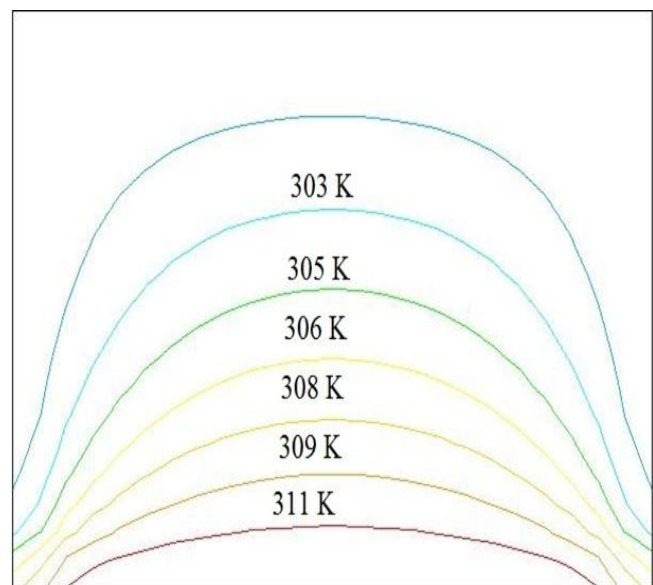


Figure 8. Temperature contour with water-Al nanofluid

It seems representative at the anticipatable essential prominences bearing in mind the water-Al nanofluid for IC temperature control. The fluid-solid boundary temperature of IC is viewed as 313 K. This stands far less than the chancy limit of 356 K temperature wished for the objective of outwitting thermal cataclysm of IC.

Tritely, the temperature of water-Al nanofluid stands peak contiguous to the IC locality. Further, the temperature of water-Al nanofluid gently drops with improvement in aloofness from IC. Afterwards, this becomes surrounding temperature in the distant arena precinct. The consistent tinted temperature plot remains accessible in figure 8.

Table 2 summarizes the fluid-solid boundaries temperatures of ICs witnessed with water based Fe, Cu and Al nanofluids. Though the trends of fields/contours results are similar, however, the discrepancies are caused by the distinctions within nanoparticles' thermophysical properties agglomerated inside table 1. Figure 9 displays the equivalent plot of IC temperature verses nanofluid.

Table 2. Summary of IC temperatures along with nanofluids.

Nanofluid	IC Temperature (K)
Water-Fe	321
Water-Cu	309
Water-Al	313

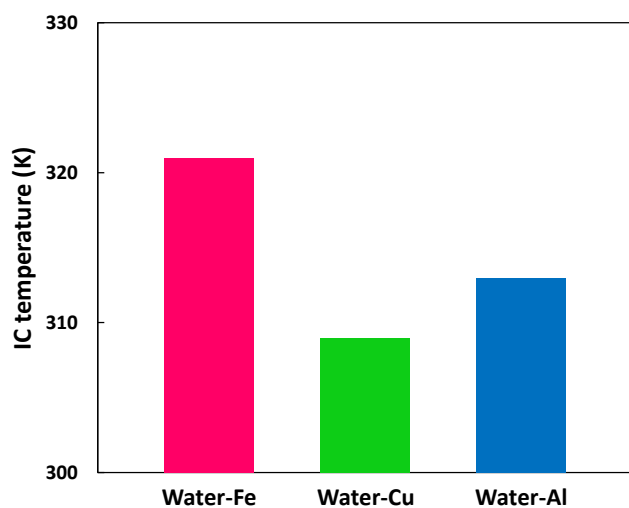


Figure 9. IC temperature vs. nanofluid

V. CONCLUSION

In committed responsiveness, CFD codes are established and set out with water based Fe, Cu and Al nanofluids for envisioning the heat alarms of ICs. The convective governing equalities of mass, force and drive are computed for envisaging the thermal issues of ICs. The time pace selected throughout the intact computation is 0.0001 s. The soundings affect CFD forecasts of temperature field, temperature contour and fluid-solid boundary temperature of IC. Corresponding fluid-solid boundaries temperatures of IC are viewed as 321, 309 and 313 K for water based Fe, Cu and Al nanofluids, one-to-one. The temperature of water-Cu nanofluid remains top neighboring to the IC neighborhood, nonetheless, it stands pretty below the dangerous temperature limit of 356 K. Additionally, the temperature of water-copper nanofluid gently drops with improvement in aloofness from IC. Afterwards, this becomes surrounding temperature in the distant arena precinct. The analogous tinted temperature curve stands accessible. Besides, the harmonizing graph of temperature against distance from IC stays exposed. The

establishment of CFD exploration remain along with the sensitivities of presentations.

ACKNOWLEDGMENT

The essential support from VSSUT Burla for realizing this investigation is greatly acknowledged. Indeed, the author is grateful to the reviewers and journal editorial board for their meticulous and insightful reviews to this article.

REFERENCES

1. N. K. Kund, P. Dutta, 2010, Numerical simulation of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Nonferrous Met. Soc. China, Vol. 20, pp. s898-s905.
2. N. K. Kund, P. Dutta, 2012, Scaling analysis of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Indian Institute of Metals, Vol. 65, pp. 587-594.
3. N. K. Kund, 2014, Influence of melt pouring temperature and plate inclination on solidification and microstructure of A356 aluminum alloy produced using oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 24, pp. 3465-3476.
4. N. K. Kund, 2015, Influence of plate length and plate cooling rate on solidification and microstructure of A356 alloy produced by oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 25, pp. 61-71.
5. N. K. Kund, P. Dutta, 2015, Numerical study of solidification of A356 aluminum alloy flowing on an oblique plate with experimental validation, J Taiwan Inst. Chem. Ers., Vol. 51, pp. 159-170.
6. N. K. Kund, P. Dutta, 2016, Numerical study of influence of oblique plate length and cooling rate on solidification and macrosegregation of A356 aluminum alloy melt with experimental comparison, J. Alloys Compd., Vol. 678, pp. 343-354.
7. N. K. Kund, 2018, Effect of tilted plate vibration on solidification and microstructural and mechanical properties of semisolid cast and heat-treated A356 Al alloy, Int. J. Adv. Manufacturing Technol., Vol. 97, pp. 1617-1626.
8. N. K. Kund, 2019, EMS route designed for SSM processing, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 382-384.
9. N. K. Kund, 2019, Cooling slope practice for SSF technology, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 410-413.
10. N. K. Kund, 2019, Comparative ways and means for production of nondendritic microstructures, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 534-537.
11. N. K. Kund, 2019, Simulation of electronics cooling deploying water-zinc oxide nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1076-1078.
12. N. K. Kund, 2019, Numerical studies on fuel cell cooling introducing water-copper nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1079-1081.
13. N. K. Kund, 2019, Computational modeling of fuel cell expending water-zinc oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 424-426.
14. N. K. Kund, 2019, Investigations on modeling and simulation of electronics cooling exhausting water-aluminum nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 660-663.
15. N. K. Kund, 2019, Numerical study on effect of nozzle size for jet impingement cooling with water-Al₂O₃ nanofluid, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 736-739.
16. N. K. Kund, 2019, Experimental investigations on impacts of nozzle diameter on heat transfer behaviors with water jet impingement, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 745-748.
17. N. K. Kund, 2019, Comparative CFD studies on jet impingement cooling using water and water-Al₂O₃ nanofluid as coolants, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 545-548.

18. N. K. Kund, 2019, Experimental studies on effects of jet Reynolds number on thermal performances with striking water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2195–2198.
19. N. K. Kund, D. Singh, 2019, CFD studies on heat transfer and solidification progress of A356 al alloy matrix and Al₂O₃ nanoparticles melt for engineering usages, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2043–2046.
20. N. K. Kund, S. Patra, 2019, Simulation of thermal and solidification evolution of molten aluminum alloy and SiC nanoparticles for engineering practices, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2047–2050.
21. N. K. Kund, 2019, Numerical Modeling on Heat Dissipation from Electronics through Water-Titanium Carbide Nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8.
22. N. K. Kund, 2019, CFD Modeling on Influence of Impinging Spout Strength for Device Cooling with Water-Al₂O₃ Nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8.
23. N. K. Kund, 2019, Computational Modeling on Fuel Cell Cooling with Water Based Copper Oxide Nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8.
24. N. K. Kund, 2019, Modeling and Simulation on IC Cooling Using Water Centered SiO₂, TiC and MgO Nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8.
25. N. K. Kund, 2019, CFD Simulation on IC Thermal Cooling through Water Involved TiO₂, AlN and CuO Nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8.

AUTHORS PROFILE



Dr. N. K. Kund has obtained both M.Tech. & Ph.D. in Mechanical Engineering from Indian Institute of Science Bangalore. He has also obtained B.Tech.(Hons) in Mechanical Engineering from IGIT Sarang, Utkal University Bhubaneswar. He has published several research papers in international journals and also guided many research scholars, besides, wide teaching and research experience. He is presently working as Associate Professor in the Department of Production Engineering, VSSUT Burla (A Government Technical University).