Numerical Studies on Fuel Cell Cooling Introducing Water-Copper Nanofluid

N. K. Kund

Abstract*: Thermal management of fuel cell is unquestionably crucial for concrete accomplishment. Present isometrics embraces fuel cell encapsulated within an enclosure having side openings. Water-copper nanofluid is supplied to the indicated enclosure. Numerical computations are run for receiving thermal recitals of fuel cell to retain it within safety boundary. Thus, an x-y plane computational model is proven in reality. Continuity, momentum on top of energy equivalences are unraveled for anticipating the heat transfer accomplishments. Computations are executed for foreseeing thermal fields and contours. Trends of forecasts are along the anticipated lines. Model parameters introduced are surface heat transfer/area of 10 W/cm^2 as well as water-copper coolant velocity of 8 m/s at entrance of enclosure. Water-copper nanofluid is observed to bring superlative concert with no heat transfer apprehensions.

Index Terms*: Computational, Fuel cell, Enclosure, Cooling, Thermal, Water-copper, Nanofluid.

I. INTRODUCTION

Sighted amazing energy adaptation competence, no emission risk, little noise and potential uses, energy cells stay listed for future targets. Many methodologies for thermal supervision of PEM fuel cell organisms are very courteously deliberated in text [1]. Numerical modeling plus computation rehearses are too pronounced sumptuously in texts [2-11]. The acute assessments of different cooling skills for PEM fuel cell loads are fabulously labelled [12].

Fuel cells engender power via electrochemical reactions by transmuting chemical energy. Energy cells espouse its recognition for ingenious power productions by considering its high energy conversion ratings. Scientists athwart the sphere are still working.

The above cited texts reveal no wide-ranging computational probe on sways of water-copper nanofluid over thermal concert of energy cells. Accordingly, present artefact make palpable about computational explorations using enumerated nanofluid over thermal sorts of energy cells. Into the bargain, computational model embrace other imperative issues such as torpor, viscidness and gravitational things lying on common issues vis-à-vis current somatic problem. Nevertheless, enumerated model overlooks compressibility as well as viscous degeneracy influences. Computational model is established for exhaustive researches on impacts of listed coolant by captivating energy cell heat transfer rate per unit area as well as coolant velocity at enclosure inlet as vital model factors. To finish, predictions of model relating to this coolant are alongside foreseeable lines.

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* Correspondence Author
N. K. Kund*, Department of Production Engineering, Veer Surendra Sai University of Technology, Burla, Odisha, India.

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II. SOMATIC PROBLEM DEFINITION

Explicit and broad depiction of fuel cell having enclosure is illustrated in fig. 1. Accompanying physical model is demonstrated in fig. 2, speaks about heat dissipation from fuel cell. Coolant pondered in current exploration is water-copper nanofluid. Two dimensional model is in use for reducing calculation time.

This covers viscosity plus gravity influences with the upper hand. Flow is laminar plus incompressible. No slip state is pointed to solid face. Coolant velocity input and atmospheric circumstances are in use at entry of enclosure. Coolant pressure out circumstance is in use at opening of enclosure. At solid face, convective state is in use to pretend entire heat variation inside enclosure. Thermo-physical features of nanoparticle as well as supplementary parameters, are briefed in table 1.

III. NUMERICAL FORMULATION

In effect the topic is set on by present computational skills vis-à-vis both modeling as well as simulation. Allied continuity, momentum as well as energy balances in x-y plane are noticeable in equivalences from (1) to (3), respectively. Compressibility plus viscous dissipation impacts are passed over at current state.

Continuity:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

X-momentum:

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

Y-momentum:

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\rho g \tag{2b}$$

Energy:

$$\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \tag{3}$$

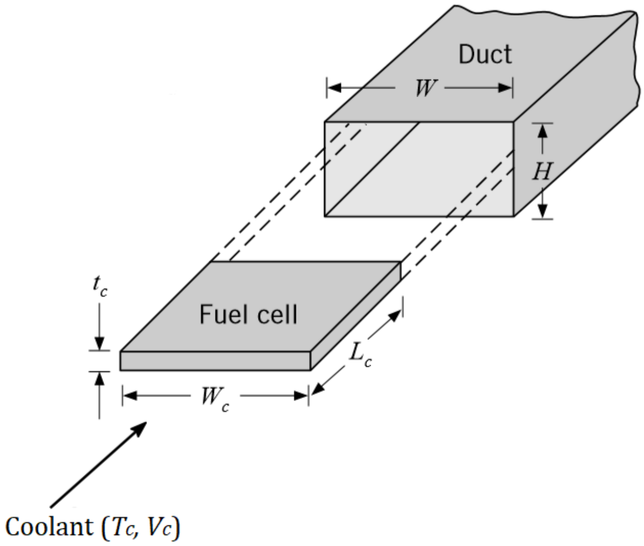

Fig. 1: Fuel cell and enclosure

Fig. 2: X-Y plane computational domain

Table 1. Thermophysical properties of nanoparticle and model data

Nanoparticle Properties	**Cu**
Density, ρ (Kg/m^3)	8941
Specific heat, C_P (J.Kg^{-1}.K^{-1})	384
Thermal conductivity, k (W/m-K)	402
Model Data	**Values**
Enclosure height (H)	25 mm
Fuel cell length (L_c)	51 mm
Thickness of fuel cell (t_c)	5 mm
Fuel cell thickness (W_c)	51 mm
Enclosure width (W)	51 mm
Atmospheric temperature	300 K
Fuel cell heat flux	10 W/cm^2
Coolant velocity	8 m/s

IV. NUMERICAL TECHNIQUES

A. Computational Scheme as well as Algorithm

The said fundamental equivalences are adapted into all-inclusive recipe as beneath.

$$\frac{\partial}{\partial t}(\rho\varphi)+\nabla.(\rho\mathbf{u}\varphi)=\nabla.(\Gamma\nabla u)+S \qquad (4)$$

Adapted fundamental equivalences are discretized with upwind technique expending pressure involved FVM using SIMPLER algorithm, whereas, symbols carry standard meanings.

B. Grid, Interval as well as Convergence Trials

Conclusion of grid independence test divulges 50 × 20 matching grids for crucial computation. Equivalent interval meant for computation is 10^{-4} s. Into the bargain, more finer grid assembly certainly not improved results evocatively. Equally, more finer grid embroils greater computation time. Convergence is inveterate after $\left|\frac{\varphi-\varphi_{old}}{\varphi_{max}}\right| \leq 10^{-4}$ is achieved for every parameter, whereas, symbols carry standard meanings.

V. RESULT AND DISCUSSIONS

Computations are run and conducted for observing sway of water-copper nanofluid on thermal behaviors of fuel cell. It implicates temperature contour and field in addition exterior temperature of fuel cell. At the start, enclosure height, fuel cell thickness and length are preferred as 25, 5 and 51 mm, respectively. Likewise, heat transfer rate/area of fuel cell is chosen as 10 W/cm^2 above and beyond coolant velocity at enclosure entry is 8 m/s.

Water-Copper nanofluid coolant

Computations are executed and run by means of existent model in conjunction with thermophysical properties of water-cgpper nanofluid coolant.

Fig. 3 illuminates computational forecasts of temperature field attached to vertical colored measurement ruler. This exhibits temperature magnitude articulated in K. These are assimilated at enumerated model states given that water-copper nanofluid coolant. Outside face temperature of fuel cell is detected as 310 K. This falls lower than safety boundary of 356 K temperature. This is required with drive for sidestepping thermal anticlimax of fuel cell. As you would have thought, temperature of water-cgpper nanofluid coolant is very near to neighborhood of fuel cell. Into the bargain, temperature of water- copper nanofluid coolant gradually declines with rise in distance from fuel cell. This becomes equal to ambient temperature in distant field regime. Interrelated temperature contour is exemplified in fig. 4 on top. At this moment, nature of outcomes are alongside expectable lines as well.

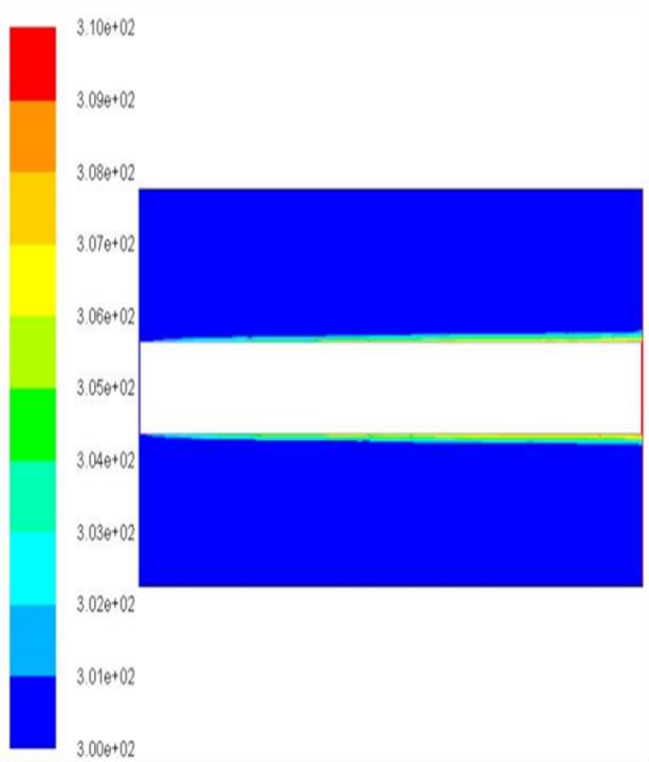

Fig. 3: Temperature field using water-copper nanofluid

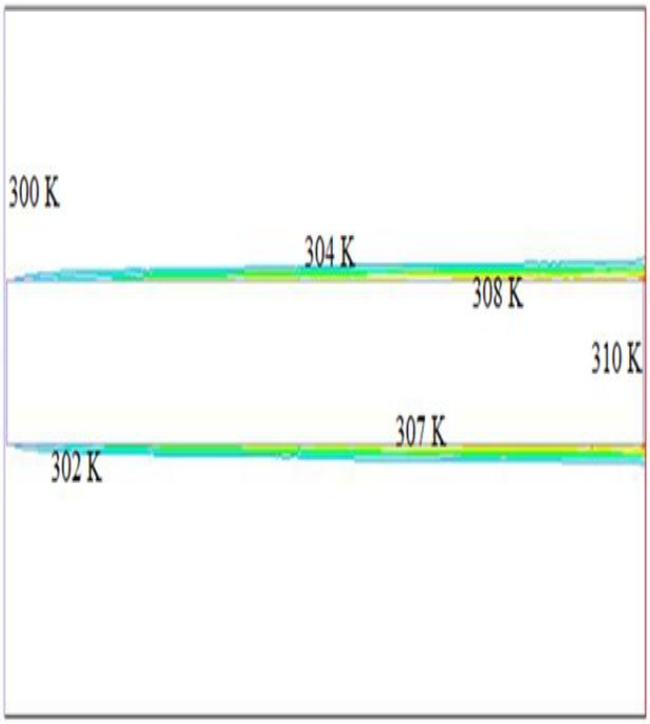

Fig. 4: Temperature contour by water-copper nanofluid

VI. CONCLUSION

Fuel cell thermal supervision is exceptionally vivacious for suave exercise. Current trial clinches fuell cell inside an enclosure with both ends open. Water-copper nanofluid is brought to the enumerated enclosure. Simulations are run to obtain thermal performances of fuel cell to shield under safety limit. Afterwards, x-y computational model is principally developed. Model factors designated are 10 W/cm^2 of heat transfer/area plus 8 m/s of water-copper nanofluid velocity at entry of enclosure. Continuity, momentum and energy equivalences are computed to foretell thermal whereabouts. Computations are run for visualizing thermal fields plus contours. Trends of aftermaths follow the foreseeable lines. Water-copper nanofluid is noticed to offer pivotal concert with no thermal catastrophe.

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AUTHORS PROFILE

Dr. N. K. Kund has got both M.Tech. & Ph.D. in Mech. Engg. from IISc Bangalore. In addition, he has done B.Tech.(Hons) in Mech. Engg. from IGIT Sarang, Utkal University Bhubaneswar. He has published several research papers in international journals and having two decades of teaching/ research experience. He is currently working as Associate Professor in the Dept. of Prod. Engg., VSS University of Technology Burla (A Government Technical University)