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Computational Modeling of Fuel Cell Expending Water-Zinc Oxide Nano fluid

N. K. Kund

Abstract: ***Fuel cell cooling is highly indispensable for its real operation. Current exercise includes fuel cell in an enclosure with two openings. Water-Zinc Oxide nanofluid coolant is passed through the stated enclosure. Numerical simulations are accomplished for getting thermal performances of fuel cell to keep it within safe bound. That is why, a two dimensional computational model is actually established. The mass, momentum in addition to energy conservation equations are unraveled for forecasting the heat transfer activities. Computations are performed for envisaging thermal fields as well as thermal contours. Nature of predictions are along the expected lines. The model parameters chosen are surface heat transfer rate per unit area (of 10 W/cm^2) as well as Water-ZnO coolant velocity (of 9 m/s) at entry of enclosure. Water-ZnO coolant is observed to deliver ideal performance without any heat transfer concerns.***

Index Terms: Cooling, Numerical, Simulation, Water-ZnO, Nanofluid.

I. INTRODUCTION

Seeing their extraordinary energy conversion efficiency, zero emission possibility, low noise and prospective uses, energy cells stand selected for future purposes. Various approaches for thermal management of proton exchange membrane fuel cell systems are very nicely discussed in text [1]. The computational modeling along with the simulation practices are also described elaborately in literature [2-10]. The critical reviews about the different cooling techniques for PEM fuel cell stacks are very well described.

Energy cells generate power via electrochemical reactions by transforming chemical energy. Energy cells uphold its acceptance for resourceful power productions by considering its high energy conversion ratings. Researchers across the globe are still working.

From the abovementioned texts, to the best of author' knowhow, no such wide-ranging computational exploration on the subject of influences of Water-ZnO coolant over thermal performance of energy cells. Through this standpoint, present article make evident about computational explorations using listed nanofluid over thermal features of energy cells. Added to, computational model take account of other important issues such as torpor, viscidness and gravitational things on top of common issues vis-à-vis current somatic problem. Nevertheless, itemized model overlooks compressibility as well as viscous degeneracy influences. Computational model is back to front 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 end with, predictions of model relating to this coolant are alongside predictable lines.

II. DESCRIPTION OF PHYSICAL PROBLEM

The graphic and comprehensive representation of fuel cell with enclosure is illustrated in fig. 1. Associated somatic model demonstrated in fig. 2, pronounces about heat dissipation from energy cell. Coolant deliberated in present research is Water-ZnO. Two dimensional model is taken to reduce calculation period.

It comprises viscosity other than gravity influence on top. Flow is laminar as well as incompressible. No slip situation is indicated at solid surface. Coolant velocity in and atmospheric situations are taken at entrance of enclosure. Coolant pressure out situation is taken at vent of enclosure. At solid face, convective situation is taken for pretending whole heat variant within enclosure. Thermo-physical characteristics of nanoparticle as well as other variables, are summarized in table 1.

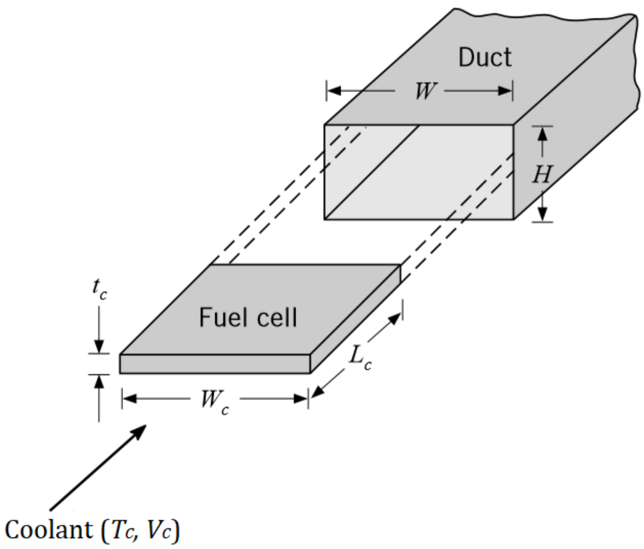

Fig. 1: Fuel cell with enclosure

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N. K. Kund, Dept. of Prod. Engg., VSS University of Technology, Burla, Sambalpur (Odisha).

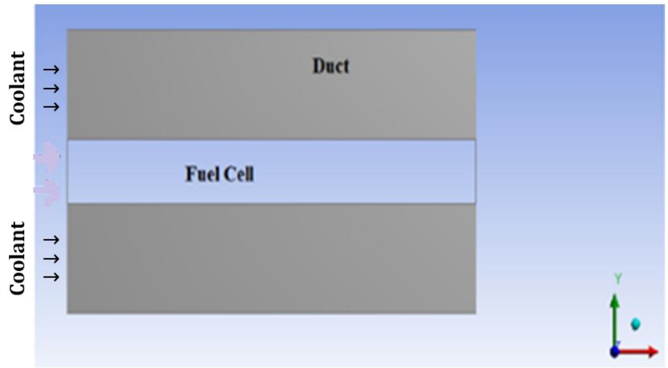

Fig. 2: Two dimensional computational domain

Table 1. Thermophysical properties of nanoparticle and model data

Nanoparticle Properties	**ZnO**
Density, ρ (Kg/m^3)	5605
Specific heat, C_P (J.Kg^{-1}.K^{-1})	668
Thermal conductivity, k (W/m-K)	12.8
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

III. MATHEMATICAL FORMULATION

Existing issue is resolved by present numerical techniques concerning both modeling and simulation. The related continuity, momentum and energy balances in two dimensions are pronounced in equalities from (1) to (3), one-to-one. Compressibility in addition to viscous dissipation influences are ignored at present 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:

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

IV. NUMERICAL PROCEDURES

A. Computational Scheme with Algorithm

Aforesaid prevailing equalities are converted into comprehensive formula as underneath.

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

Converted prevailing equalities are discretized through upwind method by pressure centered FVM by means of SIMPLER algorithm, where, symbols have usual meanings.

B. Grid, Interval with Convergence Measures

Result of grid independence test reveals 50 × 20 identical grids for ultimate simulation. Equivalent interval used for simulation is 10^{-4} s. In addition, further finer grid structure never changed outcomes meaningfully. Moreover, further finer grid involves higher simulation time. Convergence is confirmed once $\left|\frac{\varphi-\varphi_{old}}{\varphi_{max}}\right|\leq 10^{-4}$ is fulfilled for each variable, where, symbols have usual meanings.

V. RESULT AND DISCUSSION

Computations are performed for exploring influence of water-zinc oxide nanofluid on thermal features of fuel cell. It involves temperature contour, temperature field besides external temperature of fuel cell. In the beginning, enclosure height, fuel cell thickness and fuel cell length are taken as 25 mm, 5 mm and 51 mm, one-to-one. Furthermore, heat transfer rate per unit area of fuel cell is 10 W/cm^2 besides coolant velocity at enclosure entrance is 9 m/s.

Water-Zinc Oxide nanofluid coolant

Computations are accomplished with present model together with thermophysical characteristics of current nanofluid coolant.

Fig. 3 elucidates computational predictions of temperature field coupled with vertical colored gauge ruler. It presents temperature quantity expressed in K. These are acquired at listed model situations bearing in mind Water- ZnO nanofluid coolant. Solid face temperature of fuel cell is observed as 330 K. It falls below safe bound of 356 K temperature. It is wanted with the purpose of circumventing thermal letdown of fuel cell. Unsurprisingly, temperature of Water- ZnO nanofluid coolant is higher close to neighborhood of fuel cell. In addition, temperature of Water-ZnO nanofluid coolant progressively declines with rise in remoteness from fuel cell. This turns out to be ambient temperature in far field regime. Related temperature contour is illustrated in fig. 4 as well.

At this juncture too, nature of outcomes are alongside predictable lines.

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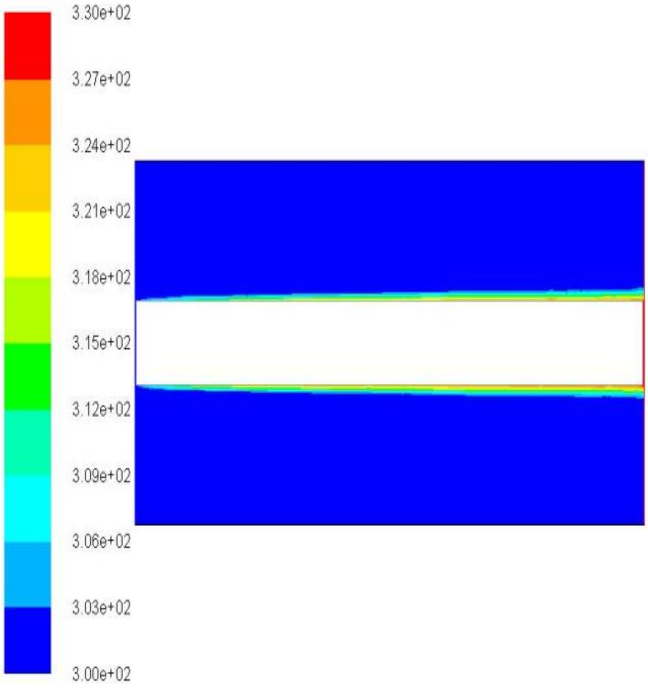

Fig. 3: Temperature field using water-zinc oxide nanofluid coolant

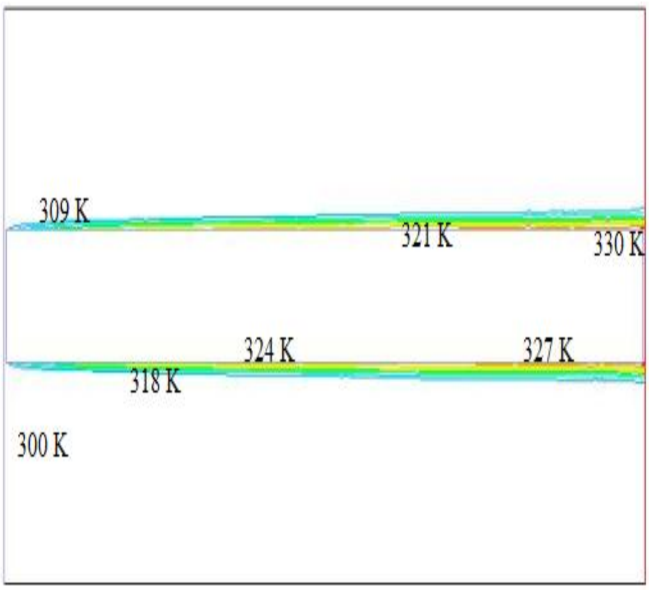

Fig. 4: Temperature contour using water-zinc oxide nanofluid coolant

VI. CONCLUSION

Energy cell thermal management is exceedingly vital for its smooth maneuver. Present workout embraces energy cell in an enclosure with openings at left and right. Water-ZnO nanofluid coolant is delivered to the listed enclosure. The Computations are executed to receive thermal recitals of energy cell for protecting it below safe bound. Subsequently, a two dimensional computational model is essentially established. Model parameters selected are 10 W/cm^2 of heat transfer rate per unit area in addition to 9 m/s of Water-ZnO coolant velocity at entrance of enclosure. The mass, momentum over and above energy conservation equalities are

solved to predict thermal actions. Simulations are accomplished for picturing thermal fields in addition to thermal contours. Nature of outcomes are alongside the predictable lines. Water-Zinc Oxide nanofluid coolant is witnessed to provide ultimate performance without any thermal failure.

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AUTHORS PROFILE

Dr. N. K. Kund has completed Ph.D. in Mechanical Engineering from Indian Institute of Science Bangalore. He has also obtained M.Tech. in Mech. Engg. from IISc Bangalore. Furthermore, he has obtained B.Tech.(Hons) in Mechanical Engineering from IGIT Sarang, Utkal University Bhubaneswar. He has published several research papers in international journals and also having above 20 yrs of both academic and research practice. He is currently working as Associate Professor in the Dept. of Prod. Engg., VSS University of Technology Burla (A Government Technical University).