International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

Numerical Modeling and Simulation on Fuel Cell Thermal Cooling with Water Based TiO_2, AlN and CuO Nanofluids

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Abstract: ***Computer codes are developed and applied on water based TiO_2, AlN and CuO nanofluids. The situation visualizes on fuel cell heat management. It evaluates thermal field/contour besides fuel cell temperature. Ultimately, for all the quoted nanofluids, the fuel cells temperatures remain quite below the critical breakdown value of 356 K. Furthermore, for all the quoted nanofluids, the thermal fields/contours range between fuel cells edges and ambient values. Despite the resemblances in thermal fields/contours, the dissimilarities are in consequence of the deviances in thermophysical properties of enumerated nanomaterials. Besides, fuel cell temperatures of 353 K, 320 K and 340 K are observed with water based TiO_2, AlN and CuO nanofluids, respectively. In addition, the water based AlN nanofluid extracts optimum fuel cell heat management. Because, the water based AlN nanofluid also corresponds to the lowest stimulating fuel cell temperature of 320 K.***

Index Terms: ***Computer Codes, Heat Management, Fuel Cell, TiO_2, AlN and CuO, Nanofluids.***

I. INTRODUCTION

Definitely, the fuel cells are having widespread industrial/domestic applications. However, the fuel cell heat management still remains the toughest ever challenge. A typical fuel cell is demonstrated in figure 1. The natural/atmospheric heat management remains inapt for tremendously high heat generation circumstances. Nevertheless, in the last few decades the abnormal method of heat management or heat removal has compelled the investigators for further exploration in fuel cell heat management. Nonetheless, the nanofluid heat management remains unparalleled. It is because the natural/atmospheric heat management is feeble to support the target. Also, the experimental and CFD researches on solidification remain demonstrated in literature [1-7]. Numerical assessments on heat management over rectangular field also remain exist in texts [8-25]. It is comprehended that the nanofluid heat management (as opposed to the natural/atmospheric heat management) evades the problems of high heat generations and hereafter, the nanofluid cooling stands as the momentous get-up-and-go of the present assessment. Here, the fuel cell heat management with water based TiO_2, AlN and CuO nanofluids are researched numerically.

II. DESCRIPTION OF PHYSICAL PROBLEM

Figure 2 establishes the computational domain of fuel cell where top and bottom faces represent heat evolution. Remaining faces represent the ambient conditions. Here, the fuel cell heat management with water based TiO_2, AlN and CuO nanofluids are researched numerically.

Additionally, the thermophysical properties of TiO_2, AlN and CuO nanoparticles and model data of the computational domain are presented in Table 1.

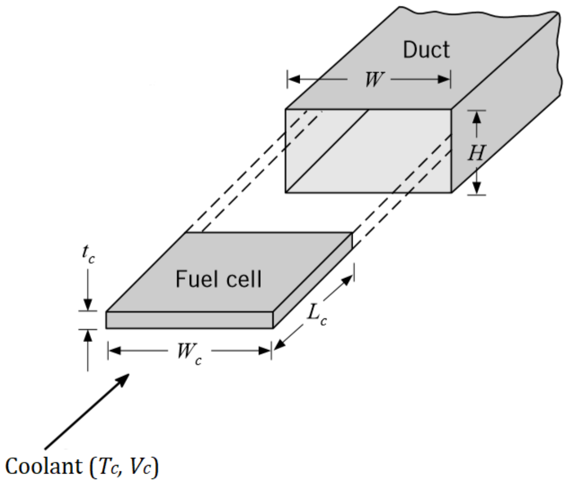

Figure 1. Fuel cell with enclosure

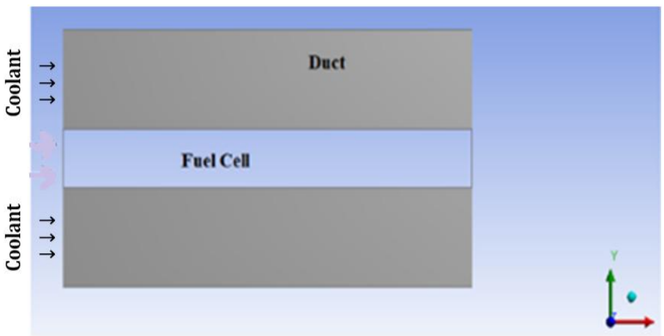

Figure 2. Computational domain

Revised Manuscript Received on October 30, 2019.
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Table 1. Thermophysical properties and model data.

Nanoparticle Properties	**TiO_2**	**AlN**	**CuO**
Density, ρ (Kg/m^3)	4176	3261	6316
Specific heat, C_P ($J.Kg^{-1}.K^{-1}$)	693	741	532
Thermal conductivity, k (W/m-K)	9	286	34
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 width (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. NUMERICAL METHODS

Equations of mass, momentum and energy remain presented with equalities 1-4. Linearized form of discretized equations are computed by running computer codes. Usual steps like meshing and initialization stand chosen for running the computer codes. It is intended for getting thermal fields/countours within computational domain presented previously in figure 2.

Continuity:

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

X-momentum:

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

Y-momentum:

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

Energy:

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

Here, computer codes are developed and exercised with water based TiO_2, AlN and CuO nanofluids. The situation visualizes on fuel cell heat management. Equations of mass, momentum and energy remain computed for the same. Time step chosen in the present computation is 0.0001 s.

IV. RESULTS AND DISCUSSIONS

Computer codes are generated and implemented on water based TiO_2, AlN and CuO nanofluids. The situation visualizes on fuel cell heat management. It evaluates thermal field/contour besides fuel cell temperature.

Influence of Water-TiO_2 Nanofluid on Fuel Cell Cooling

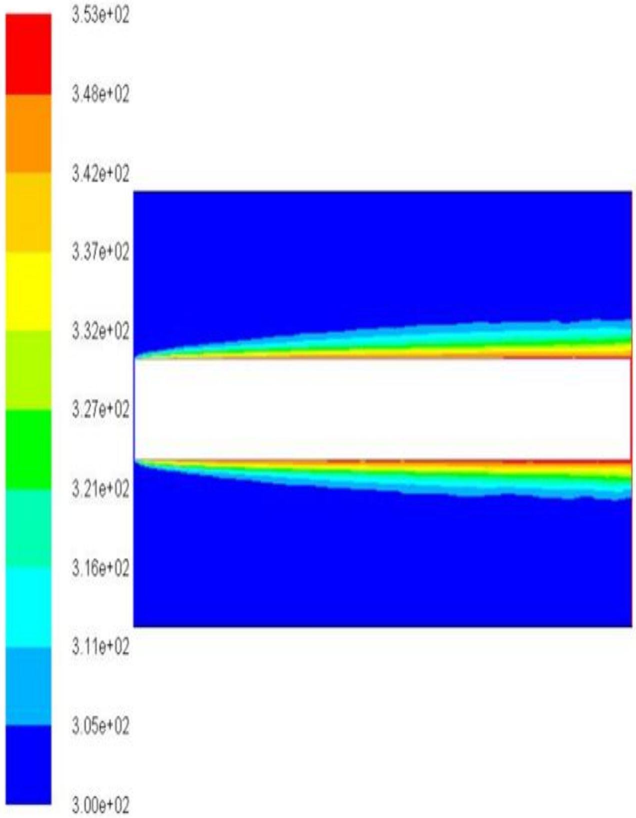

Figure 3. Temperature field with water-TiO_2 nanofluid

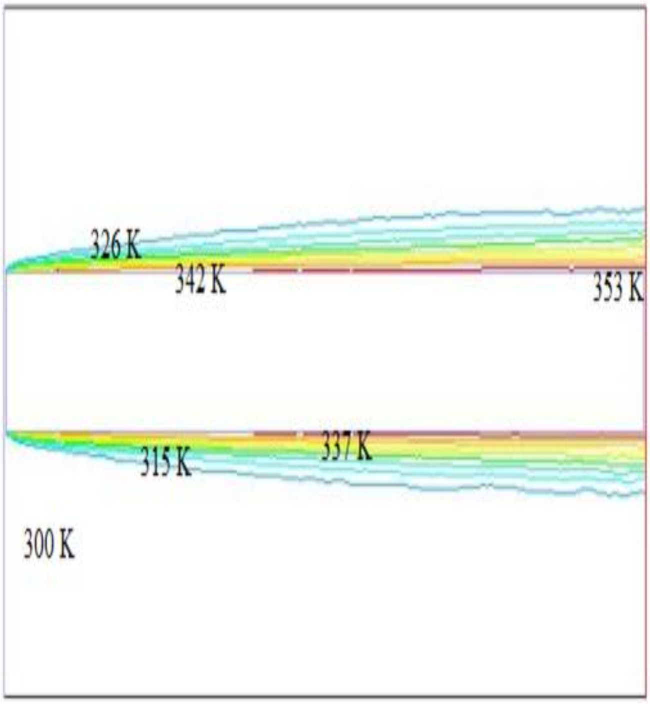

Figure 4. Temperature contour of water-TiO_2 nanofluid

Here, computer codes are implemented on water based TiO_2 nanofluid. The site visualizes on fuel cell heat management. This evaluates thermal field/contour and fuel cell temperature. Figure 3 demonstrates the thermal field only.

ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

The follow-on fuel cell temperature is 353 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 353 K at fuel cell edge and ambient 300 K at remotest field location.

Figure 4 demonstrates only the thermal contour. Here too, thermal field ranges between 353 K at fuel cell edge and ambient 300 K at remotest field location.

Influence of Water-AlN Nanofluid on Fuel Cell Cooling

Here, computer codes are implemented on water based AlN nanofluid. The site visualizes on fuel cell heat management. This evaluates thermal field/contour and fuel cell temperature. Figure 5 demonstrates the thermal field only. The follow-on fuel cell temperature is 320 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 320 K at fuel cell edge and ambient 300 K at remotest field location.

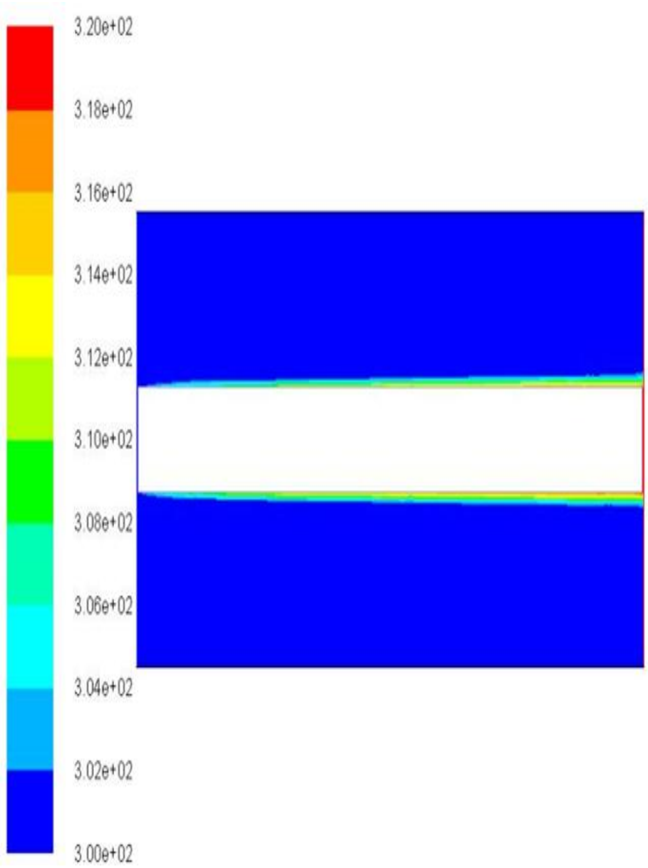

Figure 5. Temperature field with water-AlN nanofluid

Figure 6 demonstrates only the thermal contour. Here too, thermal field ranges between 320 K at fuel cell edge and ambient 300 K at remotest field location.

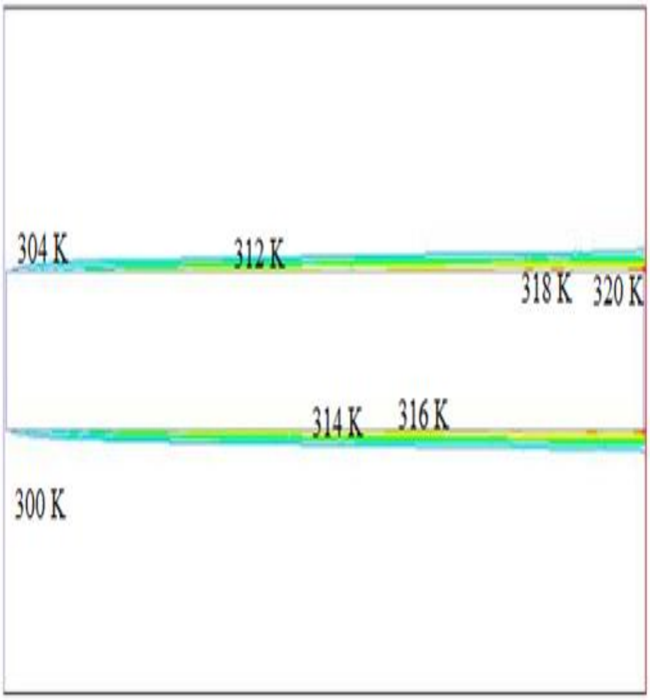

Figure 6. Temperature contour for water-AlN nanofluid

Influence of Water-CuO Nanofluid on Fuel Cell Cooling

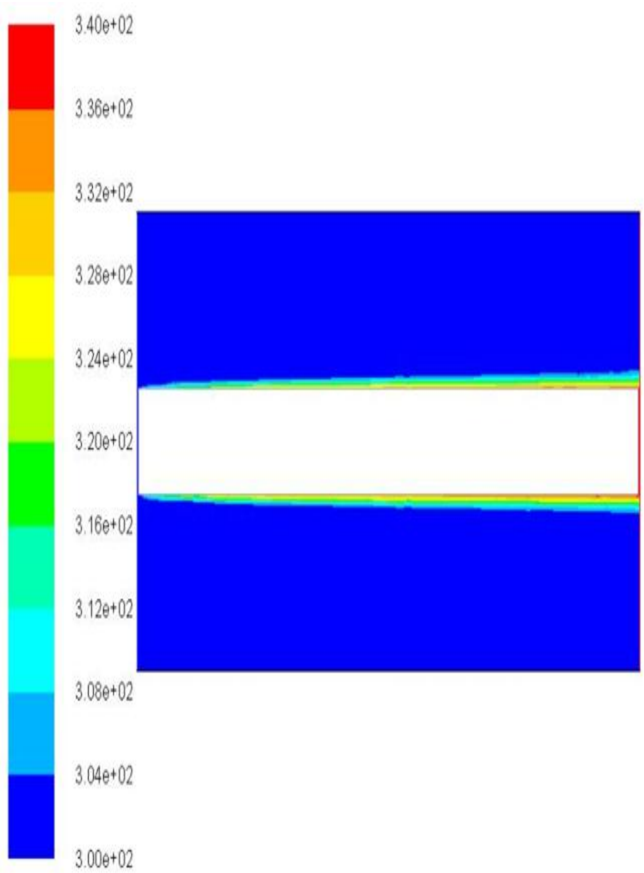

Figure 7. Temperature field with water-CuO nanofluid

Here, computer codes are implemented on water based CuO nanofluid. The site visualizes on fuel cell heat management. This evaluates thermal field/contour and fuel cell temperature. Figure 7 demonstrates the thermal field only. The follow-on fuel cell temperature is 340 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 340 K at fuel cell edge and ambient 300 K at remotest field location.

Figure 8 demonstrates only the thermal contour. Here too, thermal field ranges between 340 K at fuel cell edge and ambient 300 K at remotest field location.

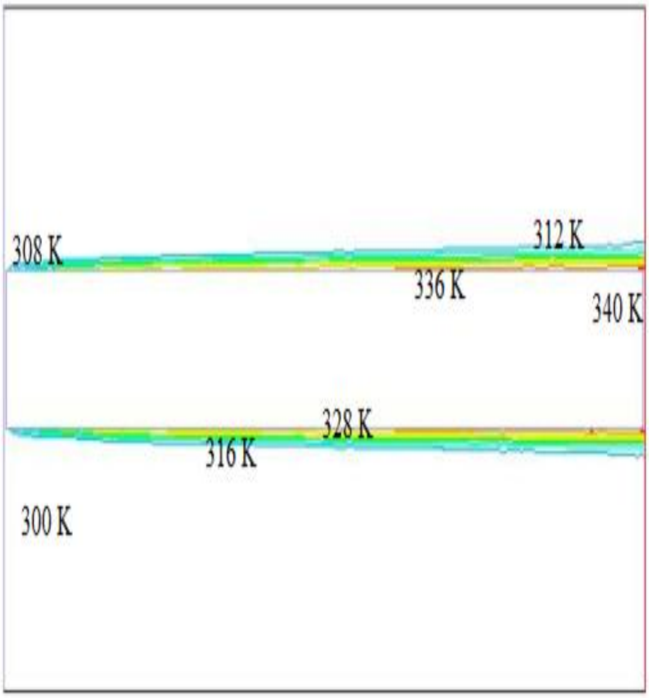

Figure 8. Temperature contour for water-CuO nanofluid

Table 2 retells the follow-on fuel cells temperatures of water based TiO_2, AlN and CuO nanofluids. Despite the resemblances in thermal fields/contours, the dissimilarities are in consequence of the deviances in thermophysical properties of nanomaterials enumerated in table 1.

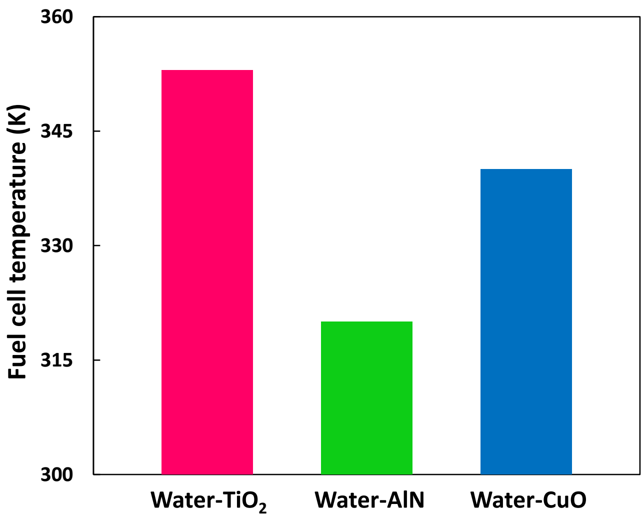

Figure 9. Fuel cell temperature vs. nanofluid

Figure 9 also presents the histogram of fuel cell temperature alongside nanofluid. Further, the water based AlN nanofluid extracts optimum fuel cell heat management. Because, the water based AlN nanofluid corresponds to the minimum follow-on fuel cell temperature of 320 K as well.

Table 2. Summary of Fuel cell temperatures with nanofluids.

Nanofluid	Fuel Cell Temperature (K)
Water-TiO_2	353
Water-AlN	320
Water-CuO	340

V. CONCLUSION

Computer codes stand built and practiced on water based TiO_2, AlN and CuO nanofluids. The situation visualizes on fuel cell heat management. It evaluates thermal field/contour besides fuel cell temperature. Ultimately, for all the quoted nanofluids, the fuel cells temperatures remain quite below the critical breakdown value of 356 K. Furthermore, for all the quoted nanofluids, the thermal fields/contours range between fuel cells edges and ambient values. Despite the resemblances in thermal fields/contours, the dissimilarities are in consequence of the deviances in thermophysical properties of enumerated nanomaterials. Besides, fuel cell temperatures of 353 K, 320 K and 340 K are observed with water based TiO_2, AlN and CuO nanofluids, respectively. In addition, the water based AlN nanofluid extracts optimum fuel cell heat management. Because, the water based AlN nanofluid also remains with the smallest resulting fuel cell temperature of 320 K.

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.

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