Computational Modeling and Simulation on Thermal Management of Fuel Cell with Water Based ZnO, TiC and AlN Nanofluids

N. K. Kund

Abstract*: Simulation codes remain engendered and instigated on water based ZnO, TiC and AlN 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 330 K, 313 K and 320 K are observed with water based ZnO, TiC and AlN nanofluids, respectively. In addition, the water based TiC nanofluid extracts optimum fuel cell heat management. Because, the water based TiC nanofluid stands for the minutest ensuing fuel cell temperature of 313 K on top.

Index Terms*: Simulation Codes, Heat Management, Fuel Cell, ZnO, TiC and AlN, Nanofluids.

I. INTRODUCTION

Undeniably, the fuel cells possess extensive industrial and 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 more examination in fuel cell heat management.

Nevertheless, the nanofluid heat management stands unmatched. It is because the natural/atmospheric heat management is feeble to support the target. Also, the experimental and CFD researches on solidification remain demonstrated within literature [1-7]. Numerical assessments on heat management over rectangular field also stand within texts [8-25].

It is understood that the nanofluid heat management (instead of 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 ZnO, TiC and AlN nanofluids stay examined computationally.

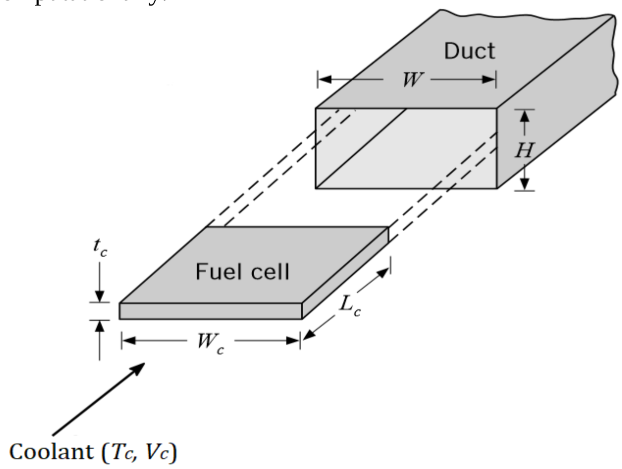

Figure 1. Fuel cell with enclosure

II. ILLUSTRATION OF PHYSICAL PROBLEM

Figure 2 illustrates 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 ZnO, TiC and AlN nanofluids stay examined computationally.

In addition, the thermophysical properties of ZnO, TiC and AlN nanoparticles and model data of the computational domain stand displayed in Table 1.

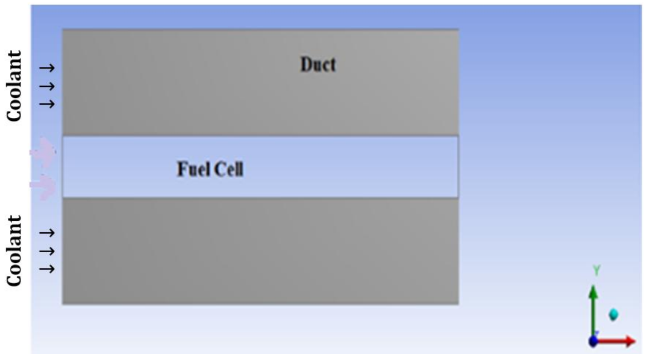

Figure 2. Computational domain

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Table 1. Thermophysical properties and model data.

Nanoparticle Properties	ZnO	TiC	AlN
Density, ρ (Kg/m^3)	5607	4931	3261
Specific heat, C_P ($J.Kg^{-1}.K^{-1}$)	668	712	741
Thermal conductivity, k (W/m-K)	14	331	286
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 TECHNIQUES

Equations of mass, momentum and energy remain presented with equalities 1-4. Linearized form of discretized equations are computed by running simulation codes. Usual steps like meshing and initialization stand chosen for running the simulation 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:

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

Simulation codes got developed and exercised with water based ZnO, TiC and AlN 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 DISCUSSION

Simulation codes got generated and implemented on water based ZnO, TiC and AlN nanofluids. The situation visualizes on fuel cell heat management. It evaluates thermal field/contour and fuel cell temperature.

Influence of Water-ZnO Nanofluid on Fuel Cell Cooling

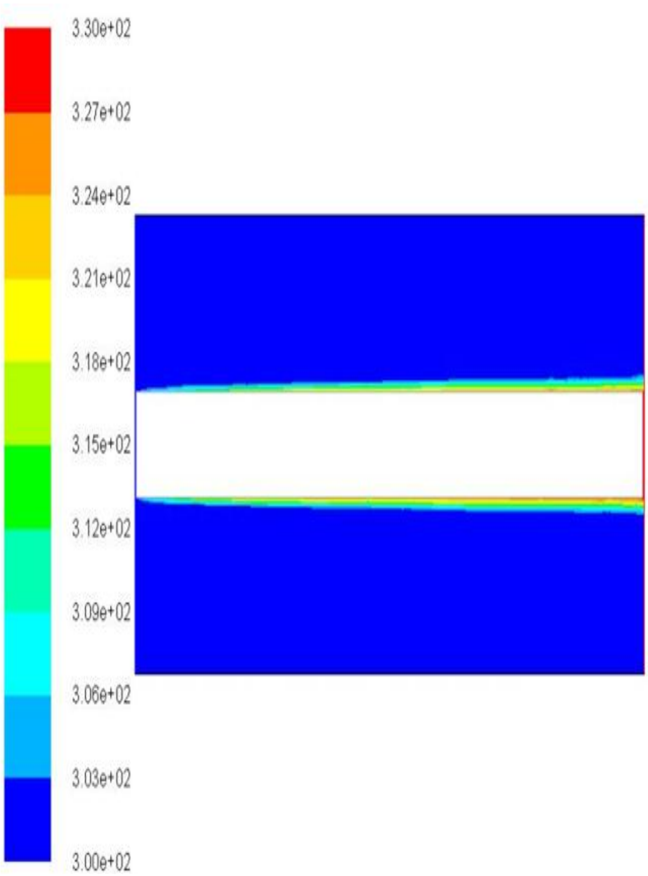

Figure 3. Temperature field with water-ZnO nanofluid

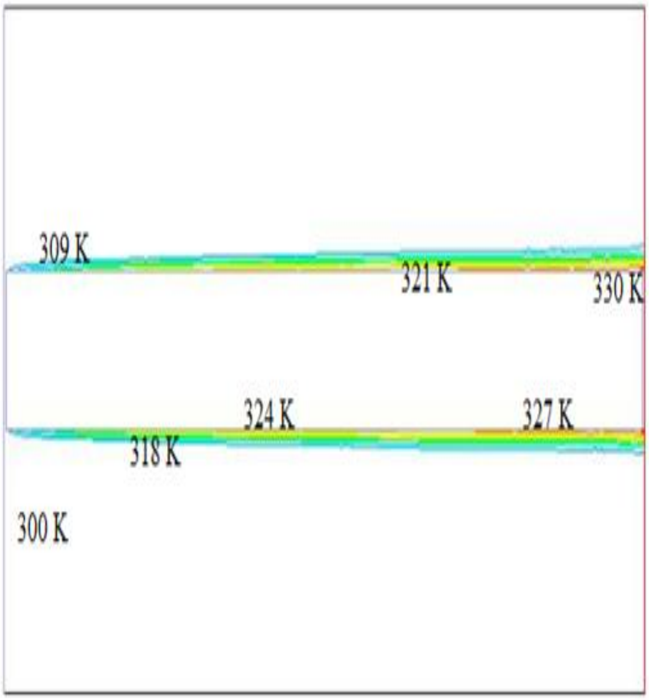

Figure 4. Temperature contour of water-ZnO nanofluid

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Simulation codes are implemented on water based ZnO 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. The follow-on fuel cell temperature is 330 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 330 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 330 K at fuel cell edge and ambient 300 K at remotest field location.

Influence of Water-TiC Nanofluid on Fuel Cell Cooling

Simulation codes are implemented on water based TiC 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 313 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 313 K at fuel cell edge and ambient 300 K at remotest field location.

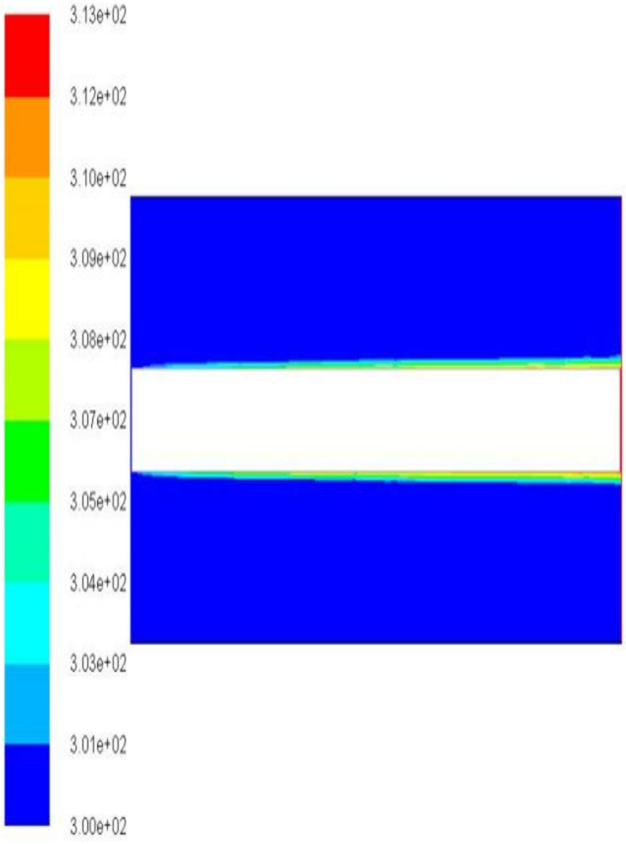

Figure 5. Temperature field with water-TiC nanofluid

Figure 6 demonstrates only the thermal contour. Here too, thermal field ranges between 313 K at fuel cell edge and ambient 300 K at remotest field location.

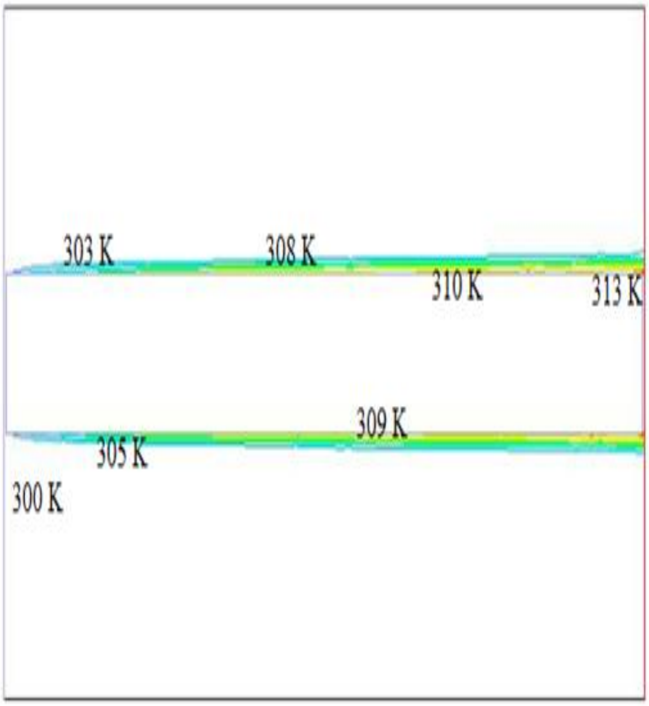

Figure 6. Temperature contour for water-TiC nanofluid

Influence of Water-AlN Nanofluid on Fuel Cell Cooling

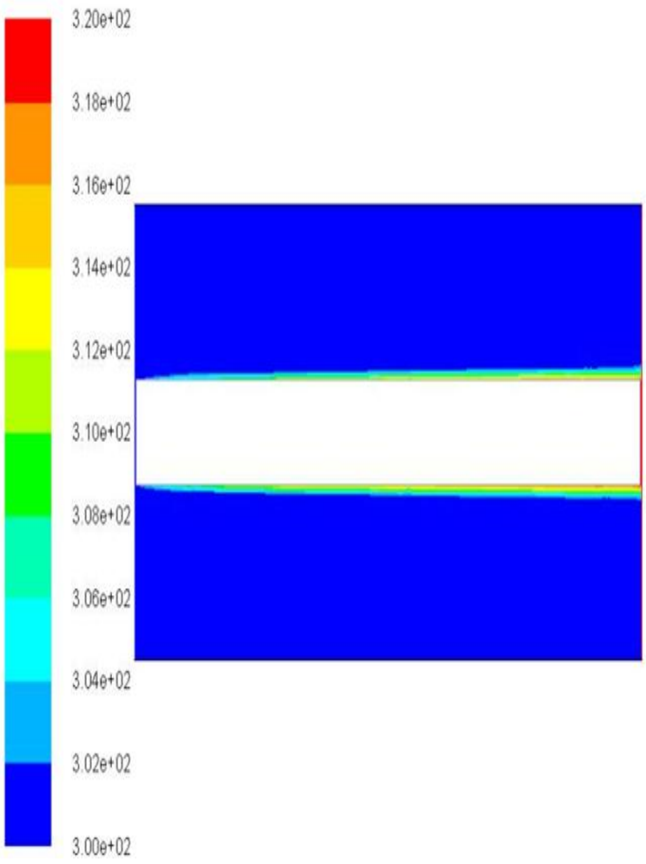

Figure 7. Temperature field with water-AlN nanofluid

Simulation 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 7 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 8 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.

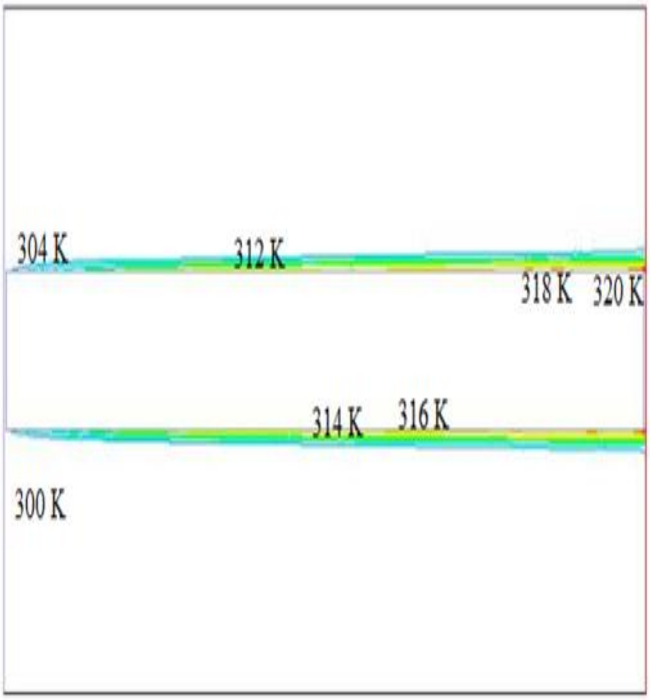

Figure 8. Temperature contour for water-AlN nanofluid

Table 2 retells the follow-on fuel cells temperatures of water based ZnO, TiC and AlN 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.

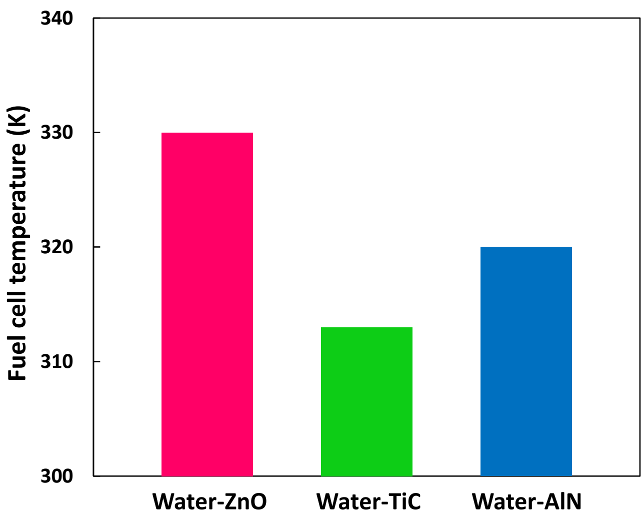

Figure 9. Fuel cell temperature vs. nanofluid

Figure 9 also presents the histogram of fuel cell temperature alongside nanofluid. Further, the water based TiC nanofluid extracts optimum fuel cell heat management. Because, the water based TiC nanofluid corresponds to the minimum follow-on fuel cell temperature of 313 K as well.

Table 2. Summary of Fuel cell temperatures with nanofluids.

Nanofluid	Fuel Cell Temperature (K)
Water-ZnO	330
Water-TiC	313
Water-AlN	320

V. CONCLUSION

Simulation codes are generated and implemented on water based ZnO, TiC and AlN 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 330 K, 313 K and 320 K are observed with water based ZnO, TiC and AlN nanofluids, respectively. In addition, the water based TiC nanofluid extracts optimum fuel cell heat management. Because, the water based TiC nanofluid corresponds to the minimum follow-on fuel cell temperature of 313 K as well.

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