Numerical Modeling and Simulation on Fuel Cell Thermal Cooling with Water Based TiO₂, AlN and CuO Nanofluids

N. K. Kund

Abstract: Computer codes are developed and applied on water based TiO₂, 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 deviations in thermophysical properties of enumerated nanomaterials. Besides, fuel cell temperatures of 353 K, 320 K and 340 K are observed with water based TiO₂, 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.


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 TiO₂, 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 TiO₂, AlN and CuO nanofluids are researched numerically.

Additionally, the thermophysical properties of TiO₂, AlN and CuO nanoparticles and model data of the computational domain are presented in Table 1.
Numerical Modeling and Simulation on Fuel Cell Thermal Cooling with Water Based TiO$_2$, AlN and CuO Nanofluids

Table 1. Thermophysical properties and model data.

<table>
<thead>
<tr>
<th>Nanoparticle Properties</th>
<th>TiO$_2$</th>
<th>AlN</th>
<th>CuO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, $\rho$ (Kg/m$^3$)</td>
<td>4176</td>
<td>3261</td>
<td>6316</td>
</tr>
<tr>
<td>Specific heat, $C_p$ (J.Kg$^{-1}$.K$^{-1}$)</td>
<td>693</td>
<td>741</td>
<td>532</td>
</tr>
<tr>
<td>Thermal conductivity, $k$ (W/m-K)</td>
<td>9</td>
<td>286</td>
<td>34</td>
</tr>
</tbody>
</table>

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/contours within computational domain presented previously in figure 2.

Continuity:

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

(1)

X-momentum:

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

(2)

Y-momentum:

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

(3)

Energy:

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

(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. 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 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.

**Influence of Water-CuO Nanofluid on Fuel Cell Cooling**

Figure 7 demonstrates the 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 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.

<table>
<thead>
<tr>
<th>Nanofluid</th>
<th>Fuel Cell Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-TiO₂</td>
<td>353</td>
</tr>
<tr>
<td>Water-AlN</td>
<td>320</td>
</tr>
<tr>
<td>Water-CuO</td>
<td>340</td>
</tr>
</tbody>
</table>

V. CONCLUSION

Computer codes stand built and practiced on water based TiO₂, 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 TiO₂, 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.

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REFERENCES


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