Numerical Simulation and Modeling on Thermal Cooling of Fuel Cell Using Water Based Al₂O₃, SiC and CuO Nanofluids

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Abstract: Simulation codes are generated and implemented on water based Al₂O₃, SiC 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 350 K, 322 K and 340 K are observed with water based Al₂O₃, SiC and CuO nanofluids, respectively. In addition, the water based SiC nanofluid extracts optimum fuel cell heat management. Because, the water based SiC nanofluid corresponds to the minimum follow-on fuel cell temperature of 322 K as well.

Index Terms: Simulation Codes, Heat Management, Fuel Cell, Al₂O₃, SiC, CuO, Nanofluids.

I. INTRODUCTION

Unquestionably, the fuel cells have got wide 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 further research in fuel cell heat management.

However, the nano fluid heat management remains incomparable. 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 texts [1-7]. Numerical assessments on heat management over rectangular field also endure within literature [8-25].

It is realized that the nano fluid heat management (rather than the natural/atmospheric heat management) evades the problems of high heat generations and hereafter, the nano fluid cooling stands as the momentous get-up-and-go of the present assessment. Here, the fuel cell heat management with water based Al₂O₃, SiC and CuO nanofluids remain accomplished numerically.

II. DEMONSTRATION OF PHYSICAL PROBLEM

Figure 2 demonstrates 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 Al₂O₃, SiC and CuO nanofluids remain accomplished numerically.

Besides, the thermophysical properties of Al₂O₃, SiC and CuO nanoparticles and model data of the computational domain remain presented in Table 1.
Table 1. Thermophysical properties and model data.

| Nanoparticle Properties | Al\(_2\)O\(_3\) | SiC | CuO |
|-------------------------|--------------|-----|-----|
| Density, \(\rho\) (Kg/m\(^3\)) | 3971         | 3161| 6316|
| Specific heat, \(C_p\) (J.Kg\(^{-1}\).K\(^{-1}\)) | 765          | 675 | 532 |
| Thermal conductivity, \(k\) (W/m-K) | 37           | 491 | 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 PROCEDURES

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/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:
\[
\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \alpha \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right)
\]  
(4)

Here, simulation codes are developed and exercised with water based Al\(_2\)O\(_3\), SiC 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

Simulation codes are generated and implemented on water based Al\(_2\)O\(_3\), SiC and CuO nanofluids. The situation visualizes on fuel cell heat management. It evaluates thermal field/contour besides fuel cell temperature.

Effect of Water-Al\(_2\)O\(_3\) Nanofluid on Fuel Cell Cooling

Figure 3. Temperature field with water-Al\(_2\)O\(_3\) nanofluid

Figure 4. Temperature contour of water-Al\(_2\)O\(_3\) nanofluid

Here, simulation codes are implemented on water based Al\(_2\)O\(_3\) 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 350 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 350 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 350 K at fuel cell edge and ambient 300 K at remotest field location.

**Effect of Water-SiC Nanofluid on Fuel Cell Cooling**

Here, simulation codes are implemented on water based SiC 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 322 K. It remains quite below the critical breakdown value of 356 K. The thermal field ranges between 322 K at fuel cell edge and ambient 300 K at remotest field location.

![Figure 5. Temperature field with water-SiC nanofluid](image)

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

Figure 6 demonstrates only the thermal contour. Here too, thermal field ranges between 322 K at fuel cell edge and ambient 300 K at remotest field location.

![Figure 6. Temperature contour for water-SiC nanofluid](image)

Figure 7. Temperature field with water-CuO nanofluid
Here, simulation 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.

Because, the water based SiC nanofluid corresponds to the minimum follow-on fuel cell temperature of 322 K as well. Table 2. Summary of Fuel cell temperatures with nanofluids.

| Nanofluid       | Fuel Cell Temperature (K) |
|-----------------|---------------------------|
| Water-Al2O3     | 350                       |
| Water-SiC       | 322                       |
| Water-CuO       | 340                       |

V. CONCLUSION

Simulation codes remain engendered and instigated on water based Al2O3, SiC 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 350 K, 322 K and 340 K are observed with water based Al2O3, SiC and CuO nanofluids, respectively. In addition, the water based SiC nanofluid extracts optimum fuel cell heat management. Because, the water based SiC nanofluid stands for the minutest ensuing fuel cell temperature of 322 K on top.

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