Effect of Separators Width on the Connection in A Single HTPEMFC Among the Temperature Distributions and the Mass and Current Dense Distributions

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**Abstract:** When it comes to using a membrane with polymer electrolyte fuel cells (PEMFC), the size of the separators has a big impact on the PEMFC's size, quantity, and cost. Furthermore, distributing temperatures, or thermal control, is crucial for the PEMFC systems to function well. Nonetheless, little literature has examined the correlation between the profile of temperature and energy generation attributes, such as PEMFC electrical current density dispersion while operating at elevated temperatures (HT-PEMFC). The purpose of this work is to investigate how the wall thickness of the separators affects the HT-PEMFC's temperatures and present density profiles. In the article, the influence of separation width on the gas report phrase (H2 and O2) characteristics of HT-PEMFC was also examined via the COMSOL Multiphysics CFD programme. In the investigation, separator thicknesses of 3.0 mm, 2.5 mm, and one millimetre were used to vary the temperature at which it operated and the humidity level (RH) of the source air. According to the research, an outer diameter of 2.0 mm proved ideal for achieving better power output in HT-PEMFCs. Out of all the separators examined in this research, the one with a that measured 2.0 mm had the most thermal capacity, which led to a reduced PEM and catalytic surface drying down when contrasted with a less thick separation depth. Additionally, it was made clear that at higher temperatures and lower relative humidity, the impacts of the separator layer thickness of profiles chemicals, such as oxygen, water, and the prevailing density background, were stronger.

**Keywords:** Temperature distribution; Separator thickness; Humidity; Current density; Heat transfer.

# Introduction

According to the 2017 roadway map, the Japanese government autonomy Fresh Energies and Industries Innovation Organisation (NEDO) has declared that polymeric electrolyte membrane fuel cells (PEMFCs) should be operated at more extreme temperatures, like 364 K and 372 K, for the intended use of vehicles and paperwork, accordingly, between 2025 and 2020 [1]. However, PEMFCs that employ Nafion membranes as polymer electrolyte membranes (PEMs) often operate at temperatures lower than 352 K. The benefits of operating PEMFC at higher temperatures (HT-PEMFC) are as follows: (i) the catalyst's dynamic enhancement; additionally, (ii) the refrigeration method's downscaling impact for mobility use because of the greater temperature difference that exists between the cooling fluid and PEMFC as a stack; and (iii) a boost of carbon dioxide resilience, which permits the generation of pure H2 from gasoline like CH 4 [2]. However, there are a few problems that need to be resolved: (i) PEM deterioration due to heating and shrinking; (ii) electrode attrition; and (iii) irregular gas circulation, temperatures, pressure, voltage, and current concentration in PEMFC profiles. Furthermore, while operating at greater temperatures than typical, the PEMFC's operative lifespan and electricity output characteristics will be compromised by the uneven profile of temperatures, electric current density, H2, O2, and H2O. Nonetheless, the following drawbacks are taken into consideration with regard to the current PEMFC: (1) restricted tolerance of a catalyst, including Pt, to contaminating substances, such as carbon; (2) sluggish electrolytic dynamics; and (3) challenges with temperature and water control. Under the circumstances of a higher ambient temperature (HT-PEMFC) [3], these issues may be resolved. The authors conducted practical and computational research on the effects of PEM, gas diffusion layer (GDL), or microscopic porosity barrier (MPL) thicknesses on the interaction phenomenon of HT-PEMFC operated at 362 K and 372 K. Additionally, the impact of divider width on the mass distribution of H2, O2, H2O, and current was studied computationally, while the influence on temperature profiles on the back side of the divider has been studied empirically [4]. Earlier publications, with the exception of the authors' investigations, indicate that COMCOL Multiphysics computational fluid dynamics was used to examine the effects of the separator's interdigitated flowing field on mass transportation and chemical responses in HT-PEMFCs [12-18].

When comparing the execution of sequential flow fields and interdigitated stream fields, it was found that the integral flowing field's rise in current density with air equilibrium exceeded three times that of a parallel flow area's. Conversely, in the instance of an interdigitated flowing area, the polarisation curves were nearly identical with those of a single-channel sinuous flowing pattern. The link between the distribution of temperatures and energy production efficiency was not examined, despite the fact that the connection between O2, or the distribution of pressure, and energy production efficiency was studied. Three distinct kinds of cathode-enhanced mass flow fields—taped, created, and the results—were assessed in the other computational investigation that used the CFD programme COMCOL Multiphysics. Because it performed better and had less flow obstruction, the tapering flow field was the best configuration for HT-PEMFC [19-24]. The relationship between the features of power production and the spread of O2, or flow field, was examined, but the relationship among the features of electricity production and the spread of temperatures wasn't examined [5]. A number of the separation flow areas, including an altered parallel flowing area, an obstruction travel area, an altered curved wave travel area, a straight path with perplexed challenges, and a thin iron separator with an overall thickness of 0.1 mm, have been studied in relation to the broad PEMFC that worked beneath 353 K. In order to enhance mass dispersion, foam-architecture spacers made of metal or graphite have been investigated and contrasted with standard separators. As the weight proportion of the separators to the overall cells is around 80%, the porous construction of foam may enhance airflow and dispersion and decrease friction between the fluid plates and carbon paper [25-30].

# Experimental work

## Governing equation

The simulation was carried out using COMSOL Multiphysics, a multiphysics program. Complicated multiphysics interaction issues, such as transfer of charges and transfer of mass, especially radiation transfer, are present in fuel cells. Users might choose or modify several partial integrals in COMSOL before they integrate them to quickly accomplish indirect linked multi-physics field evaluation. The computational code for functions in COMSOL Multiphysics includes the Brinkman calculation, the Butler-Volmer calculation, and the temperature move calculation that takes into account the warmth produced by excessive potential, the passage of heat via every part of the cell, the conduction of heat via the conduit, and the warmth move about the gases that exit the cell to the surrounding air. In the past, multiple scientists used COMSOL Multiphysics to do a computer model for the HT-PEMFC and produced satisfactory findings for temperatures, gases, and present density profiles. Furthermore, confirmation had been carried out expertly [31-35].

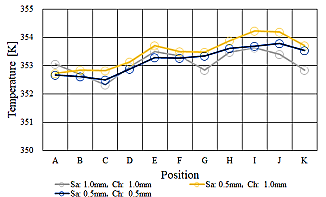
Because it provided fuel cell parameters and COMSOL's benefits, the current research used it for the computational modelling of the HT-PEMFC. The current investigation's simulation framework was created using a comparable methodology that the researchers used in their earlier investigation. The model with partition thicknesses of 2.0 mm, 1.5 mm, and 1.0 mm is shown in Figure 1. These prototypes' architectures are based on the business cell that Nishimura et al. utilised for their tests. It has five gas channels with a 1.0 mm air width for each and a sinuous flowing canal made up of all of these air streams. This cell features five air passages that correspond to the commercialised unit's configuration. The helical flow field of this separation is shown in Figure 2. The physical parameters for the model suggested in this research are shown in Table 1, which follows. Physical characteristics and operating circumstances are shown in Tables 2 and 3, respectively. The cell (Tini) is subjected to three temperature changes: 351 Report Word K, 364 K, and 372 K. In order to compare the properties acquired under typical temperature ranges with those under more extreme conditions, this research used 351 K [36-40].

# Results and discussion

In terms of model confirmation, the researchers used a comparable and similar framework from earlier research. The editors of these publications have acknowledged their findings and comments. Furthermore, a lot of earlier investigations used the business programme COMSOL, and those studies' findings were solidly confirmed. The representation was thus regarded as verified [6, 41-45].

## Comparison of temperature profile

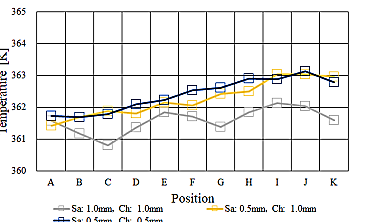
The thermal distribution determined by a 3D computer simulation framework at Tini = 351 K, 364 K, and 372 K, respectively, is shown in Figures 4-6 [7]. The terms Sa and Ch represent the saddle width and canal elevation accordingly in the above diagrams. Considered is the impact of divider width on heat gradient [8]. Additionally, the supply gases' RH varies. Figures 4-6 show that, regardless of the source of gas's relative humidity, the temperature rise at the cathode-side interface of the PEM and catalytic layers decreases as Tina increases between the cells input and output. It is widely recognised that the saturation level of H2O grows dramatically with temperature, making PEM drying simple at above-normal temperatures [9]. Specifically, due to significant ohmic loss, it might be simple to lower the conductivity of protons in PEM at elevated temperatures, which results in a drop in electrical power generation capability. Consequently, less heat is produced. Since the intake gas flow rate is assumed to be greater than s.r. = 1.0, the produced heat is collected alongside the flow of gases through the air conduit. As a result, from a cell's intake to its output, temperatures go up at the anode end of contact with the PEM and catalytic layers [10, 46-50]. With respect to the influence of separator depth, the Celsius variability along the path of gases at Tini = 354 K and 364 K is made up of a bind width of 1.0 mm and a channel height of 1.0 mm [11]. The dehydrating effect of PEM and the catalyst coating would take place less than with a thinner separation thickness since the 2.0 mm separator had the largest thermal production of all the separators examined in the present study. As a result, it is believed that increasing the separation element thickness enhances power production capacity. The subsequent parts address the rationale for temperature drop at locations C, G, and K as separator depth and the supplied gases RH rise [12, 51-54].



**Figure 1.** An analysis comparing the temperature profiles of various separator thicknesses

## Comparison of O2 distribution

Oxygen concentrations computed using a 3D numeric simulation structure at Tini = 351 K, 364 K, and 375 K, respectively, are shown in Figures 7–9. Figures 7–9 show that, regardless of the separator's thickness, the reduction in the molecular weight of the unreported molecule of O2 (carbon dioxide) from a cell's intake to its exit, or the absorbed amount of O2, decreases as Tini increases and the incoming gas's relative humidity drops. A gas route is used to carry through the oxygen-reducing process [12]. It is widely recognised that, as previously said, the pressure that is saturated with H2O grows linearly with temperature, making PEM dry at greater temperatures than typical simple [13]. Because PEM becomes dehydrated at temperatures that are higher and lower relative humidity levels, its protons permeability decreases [14]. The electromagnetic overpotential rises as a consequence. However, a major problem for the cathode portion of the O2 decrease reaction efficiency is that the ionomer in catalysis 11 layers on the electrode end is difficult to humidify by H2O migrated via PEM from the anode half onto the copper half. Hydroxide and electrical opposition create a huge electromagnetic overpotential. Hydroxide impedance and PEM resistance are connected, as they form the ionomer of the catalytic layer. Consequently, with a rise in Tini and a reduction in RH in the supply air owing to reduced humidity, the drop in the molecular amount of O2 between a cell's input and its output is less pronounced [15].



**Figure 2.** An analysis comparing the O2 profile of various separator thicknesses

# Conclusion

In this position, a numerical model utilising CFD software COMSOL Multiphysics was used to explore the effect of divider depth on the link among the temperature distribution and not just the present density profiles but additionally the characteristics of chemicals, such as O2 and water. The research compared the features of an HT-PEMFC with those of a regular PEMFC by setting its temperature of operation at 351 K, 364 K, and 372 K, respectively. The study's results include the ones that follow: In comparison to other divider sizes, the mean temperature shift from a cell's input to output in the instances of Tina = 351 K or 364 K was greater compared to a divider thickness of 2.0 mm. With the rise in Tini and the reduction in RH that supplied gases, accordingly, there was a lesser rise in the molecular amount of water and a drop in the molecular percentage of oxygen from the cell's intake to its exit. Regardless of separation depth, the current densities dropped as the Tini and RH of the source gas increased. Out of the three separator widths that were studied, 2.0 mm was the optimum size to provide better power output. The thickness of the separation might be reduced if one could create an element of separation that would efficiently extract the excessive heat that was produced.

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