Fig. 3. Water flow simulation with **PSFFP** (80℃) at the anode side of DE-PEMFC (water flow rate of 12 mL/min at the inlet; environmental pressure at the outlet): (a) Pressure; (b) Velocity.

Fig. 4. Water flow simulation with PSBFFP (80℃) at the anode side of DE-PEMFC (water flow rate of 12 mL/min at the inlet; environmental pressure at the outlet): (a) Pressure; (b) Velocity.
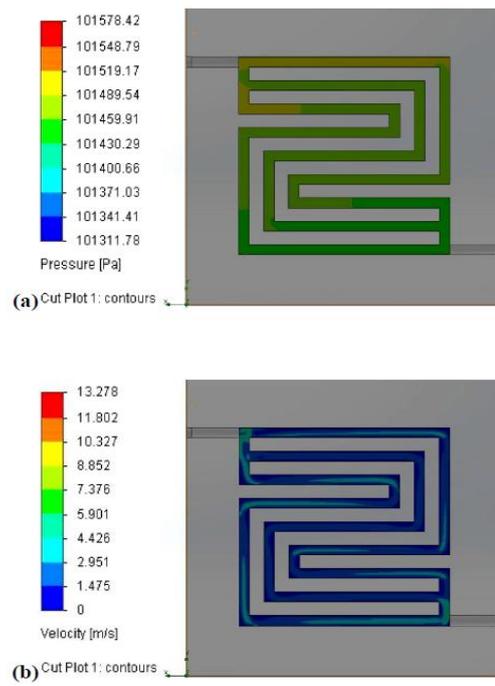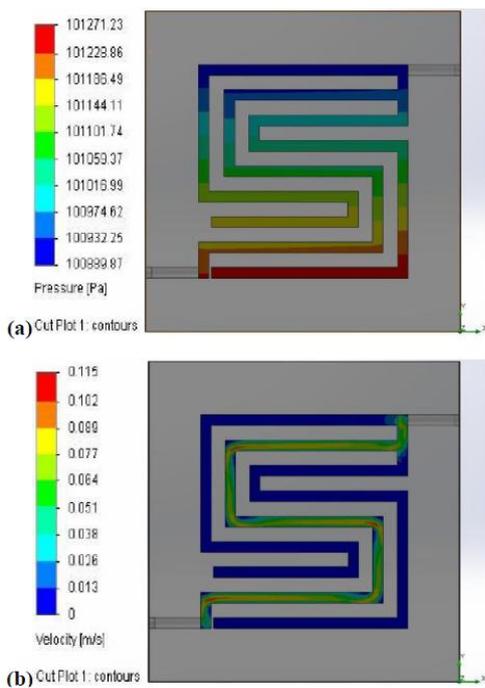

Fig. 5. Oxygen flow simulation with PSFFP (80℃) at the cathode side of DE-PEMFC (oxygen flow rate of 1 L/min at the inlet; environmental pressure at the outlet): (a) Pressure; (b) Velocity.
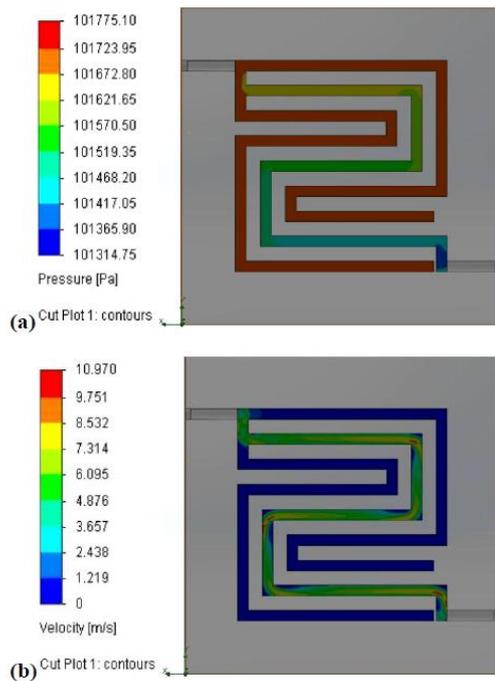

Fig. 6. Oxygen flow simulation with PSBFFP (80℃) at the cathode side of DE-PEMFC (oxygen flow rate of 1 L/min at the inlet; environmental pressure at the outlet): (a) Pressure; (b) Velocity.

The flow simulations of oxygen behaviour in the cathode side equipped with either PSFFP or PSBFFP are shown in Figures 5 and 6, respectively. At the cathode side, the flow field design had an influence on oxygen pressure distribution. The pressure loss increased from the inlet (101,578 Pa) to the outlet (101,312 Pa) in the cathode fitted with PSFFP, as noted by other researchers. The fluid velocity was at a maximum value of 13,278 m/s close to the inlet and outlet, and homogeneously distributed throughout the three channels.

The oxygen gas acquired complete velocity and pressure loss stability in the cathode with PSBFFP. In the baffle channels, the gas velocity was null and the pressure was maximum (101,775 Pa). On the other hand, in the serpentine channels, the gas pressure loss increased from the inlet (101.775 Pa) to the outlet (101.315 Pa), and the oxygen reached the maximum velocity of 10.970 m/s. In particular, the flow field geometry has an important effect on the mass transport rates of reactants and

products and on the pressure drop of the reactants across the cell.

The experimental curves of voltage and power versus current for the four combinations of PSBFFP and PSFFP are shown in Figure 7. The DE-PEMFC unit performance in the current range of 0 to 0.6 A varied according to the plates' combination at the anode and cathode. Above 0.1 A, the cell fitted with PSFFP in the anode and PSBFFP in the cathode (red curve) presented the best performance among the four combinations. Using the plates combination PSFFP/PSBFFP, the cell reached a maximum power of 0.16 W, which is twice the maximum power (0.075 W) reached by the cell equipped with the inverse combination (PSBFFP/PSFFP). For the cells equipped with PSFFP/PSFFP or PSBFFP/PSBFFP, the maximum power achieved was 0.07 W and 0.05 W, respectively, and the current values were not higher than 0.4 A.
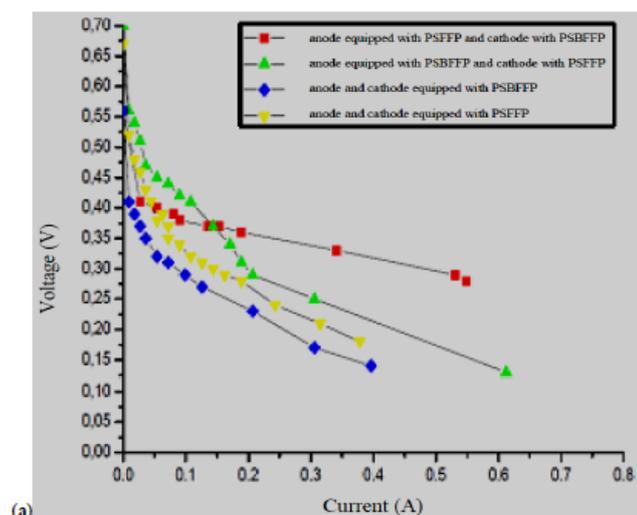
(a)
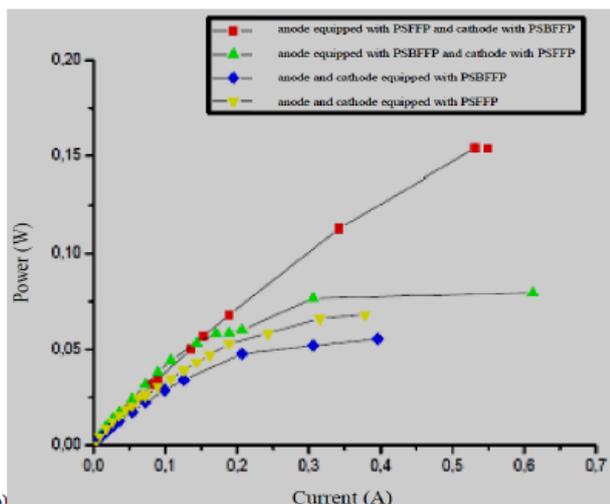
(b)

Fig. 7. Curves of (a) current-voltage and (b) current-power obtained in the DE-PEMFC prototype for the four combinations of flow field plates in the anode/cathode.

The fuel cell fitted with PSBFFP/PSFFP (green curve) has showed better performance at currents below 0.1 A, where activation overpotential occur. The activation overpotential is directly related to reaction kinetics, and the electrochemical reactions propagate under a rate demanded by a specific load. As reported in literature [3], the oxygen reduction kinetic by a Pt electrocatalyst is excellent compared to that of ethanol electro-oxidation by a Pt-based electrocatalyst. Thus, it is assumed that the activation overpotential at the cathode is less significant compared to that at the anode. Beyond this low-current region associated with activation overpotential, there is a strong interference of ethanol crossover and the fuel cell fitted with PSFFP/PSBFFP showed the best performance. The maximum power density reached by the DE-PEMFC prototype fitted with the four different combinations of flow field plates in the anode and cathode is shown in Figure 8. The DE-PEMFC prototype fitted at the anode with PSFFP and at the cathode with PSBFFP reached the highest maximum power, which was 92% and 165% higher, respectively, of the maximum power obtained when the cell was fitted with PSBFFP/PSFFP and only with PSBFFP. The maximum power difference when the fuel cell was fitted only with PSFFP was 120%. The results show that the use of the baffle plate PSBFFP is strategic if a better fuel cell performance is sought.
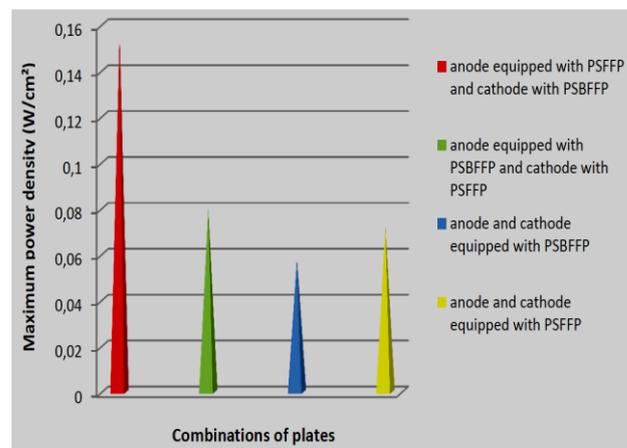

Fig. 8. Maximum power density vs. combination type of cell.

Nguyen [4] has showed in the study of a gas distributor design for PEMFC that an interdigitated flow field plate pushes the reagents more strongly through the diffusion layer. By the fluid dynamic simulation tests was seen that through the two interdigitated channels of PSBFFP, there was a much higher oxygen pressure on the MEA at the cathode side compared to the pressure exerted by the alcohol on the same MEA at the anode side. The results here discussed are in accordance with that presented by Nguyen since the PSBFFP has changed the fuel cell performance considerably depending on which plate is fitted in the fuel cell sides. Computations showed that the pressure loss relative to the unique serpentine channel on the PSBFFP at the cathode was at a maximum throughout the cell ($\Delta p \approx$ -460 Pa). However, the increase in pressure loss within this channel promoted convective or under-rib flow. This flow favoured elimination of the residual water in the cathode side and increased the overall efficiency of the electrochemical reaction, and a maximum current density was obtained.

5. Conclusion

In the present research, a perfect balance between decreasing the ethanol crossover and efficient removal of the water produced at the cathode of a DE-PEMFC was achieved without the use of peripherals, by combining different flow field plates, a PSFFP at the anode and a PSBFFP at the cathode. For the best fuel cell performance obtained, the major behavioural difference between the anode equipped with PSFFP and the cathode equipped with PSBFFP was due to the pressure of the reagent within the channels of each plate. The reagents were pushed more intensely against the diffusion layer in the two discontinuous flow channels of the PSBFFP visualized through the fluid simulation tests. In the PSBFFP channels, the pressure exerted by oxygen on the MEA at the cathode is greater than that exerted by the alcohol on the same MEA at the anode. We conclude that a higher oxygen pressure at the cathode related to the alcohol pressure at the anode can decrease ethanol crossover in a DA-PEMFC. However, decreasing ethanol crossover is not a guarantee of improvement in the overall fuel cell performance; this must be combined with efficient removal of the water produced by redox reaction in the cathode.

Acknowledgement

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