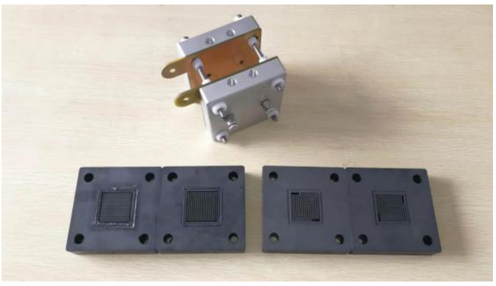
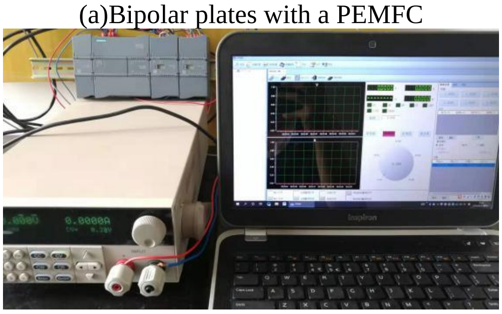
parameters (Figure 5). Obviously, the error between the simulated and experimental curves was less than 1%, which proves the reliability of our model.



(a)Bipolar plates with a PEMFC



(b)The test device

Figure 4. The test setup

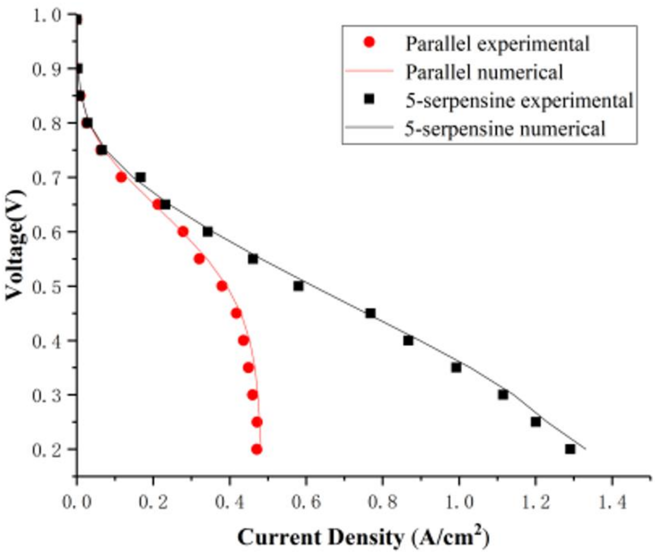
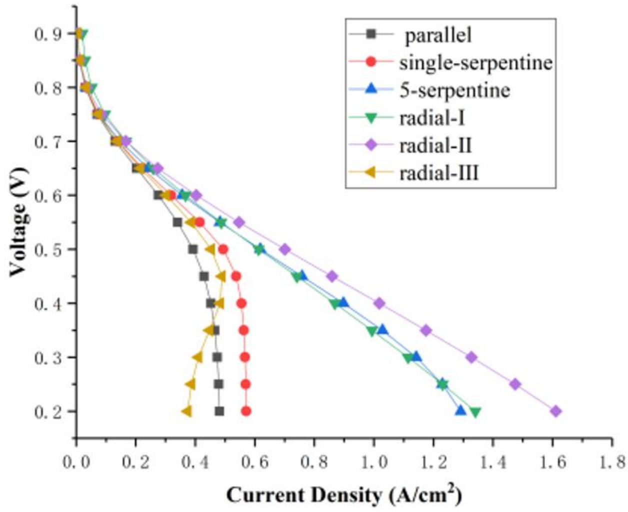


Figure 5. Comparison between simulated and experimental polarization curves

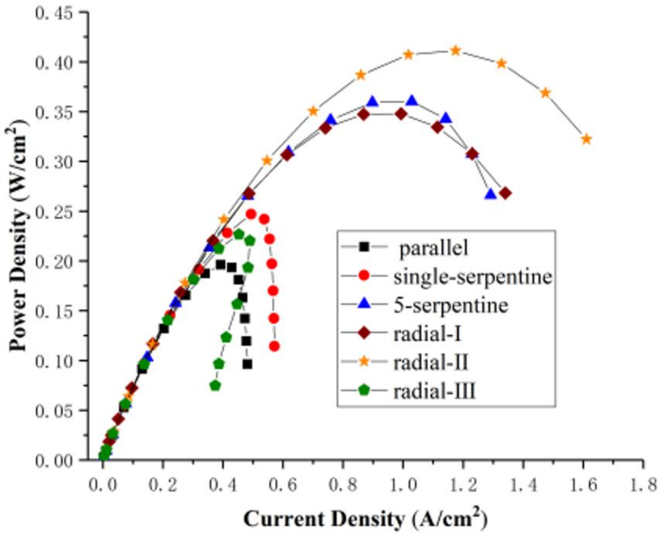
4. RESULTS AND DISCUSSION

4.1 Polarization curves

In the PEMFC, the voltage loss mainly occurs in activation polarization, ohmic polarization and concentration polarization [26, 27]. Figure 6 presents the polarization and power density curves of Radial-I, Radial-II, Radial-III, parallel, single serpentine and 5-serpentine flow fields. Obviously, the radial flow fields were similar to the traditional flow fields in the activation polarization region (low current density), but differed greatly from the latter in the ohmic polarization region and concentration polarization region (high current density). Radial-I and Radial-II had higher limit current density and power density than the flow fields with other channel structures. The advantage of Radial-II was particularly obvious. Moreover, the 5-serpentine flow field had a similar curve between power density and current density as Radial-I, which is lower than that of Radial-II. In addition, Radial-I, Radial-II and Radial-III reached the peak power density at the working voltage of 0.4V. Thus, this voltage was set as the working voltage of radial flow fields.



(a) Polarization curves



(b) Power density curves

Figure 6. Comparison of flow fields with different structures

4.2 Effects of flow field structure

This subsection analyzes the effects of channel depth, channel width and rib width on the performance of radial flow fields. Taking the Radial-I as an example, the PEMFC performances were measured at the channel depths of 0.5 mm, 0.75 mm, 1 mm, 1.25 mm, 1.5mm and 2mm (Figure 7). It can be seen that the polarization curves of Radial-I were almost the same at different channel depths. This means the channel depth has little effect on the performance of radial flow fields

Water discharge is a thorny issue in the design of channel structure [28]. The water produced at the cathode catalysis layer is normally collected in the diffusion layer and discharged through the channel. If not discharged in time, the water will block the cathode channel, hinder the mass transfer of oxygen, and affect the PEMFC performance [29].

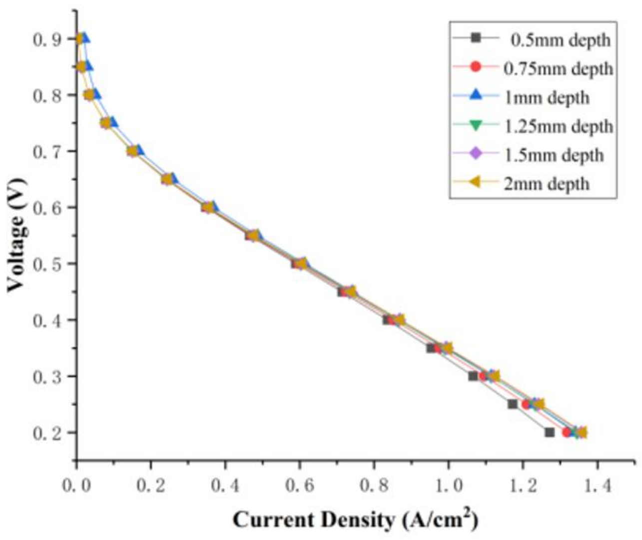


Figure 7. Polarization curves of Radial-I at different channel depths

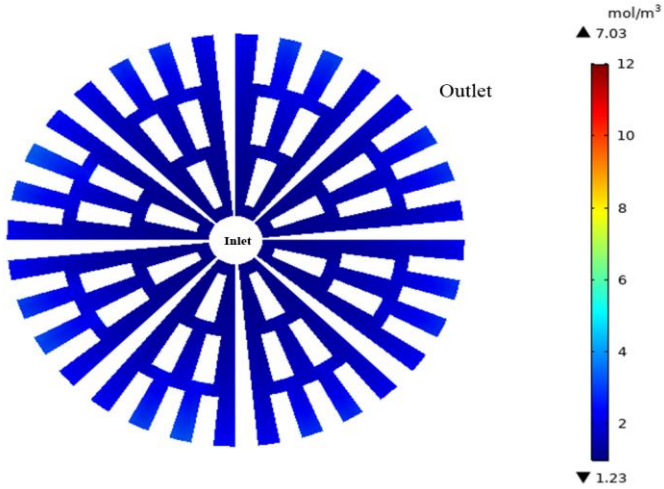
With the channel depth of 1mm, the effects of channel and rib widths on the performance of the radial flow field was analyzed based on the water content distribution in the cathode channel of Radial-I, Radial-II and Radial-III. As shown in Figure 8, Radial-I and Radial-II had lower but more uniformly distributed water content than Radial-III, and the water content in Radial-III increased gradually from 1.05mol/m^3 at the inlet to 11.9mol/m^3 near the outlet. This is attributable to the following facts: as the reaction proceeds, the generated water gradually accumulates, pushing up the water content along the direction of the gas flow. Compared with Radial-I and Radial-II, Radial-III is very likely to face flooding, which affects the transport of cathode gas.

The channel with a high pressure drop needs a huge pumping power to transport reactive gas. This inevitably brings a great parasitic energy loss and reduces cell efficiency. Therefore, the pressure drop is another consideration in channel design.

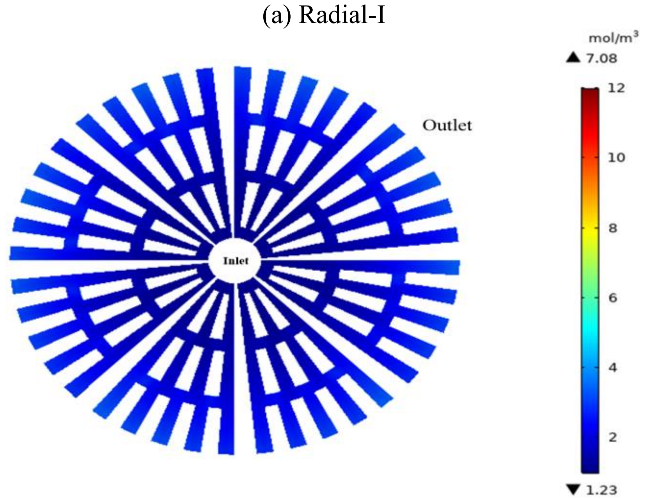
Figure 9 compares the pressure drop in cathodic channel between Radial-I, Radial-II, Radial-III, parallel, single serpentine and 5-channel serpentine flow fields. It can be seen that the pressure drops of parallel, single serpentine and 5 serpentine flow fields were 41.6Pa, 1,017.9Pa and 292Pa, respectively. The pressure drops of Radial-I, Radial-II and Radial-III were 27.3Pa, 40Pa and 130Pa, respectively. The numerical results show the significant correlation between pressure drop with channel structure. In general, Radial-I and Radial-II had equal or smaller pressure drops than the parallel flow field, and lagged Radial-III in pressure drop. The relatively high pressure drop in Radial-III is resulted from the suppression effect of reaction generated water over oxygen transport. Hence, Radial-I and Radial-II are more rational than Radial-III in channel structure.

Since the flow of the reaction medium is constant, the channel flow velocity normally has a negative correlation with the cross-section area of the flow passage, and the mass of the reaction medium on the catalyst layer tends to increase with time. Therefore, the smaller the cross-section area of the flow passage, the stronger the current density and power density.

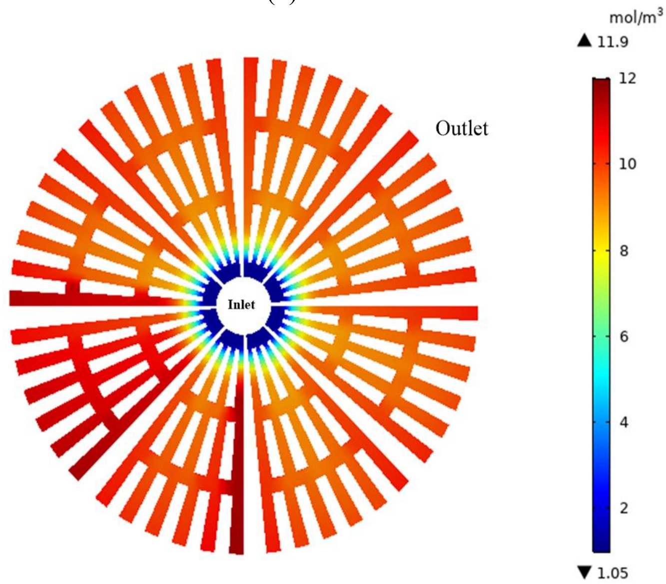
However, Radial-III has an extremely small limit current density and maximum power density, although it has a smaller cross-sectional area than Radial-I and Radial-II. The possible reason is that the cross-section area of Radial-III is too small. The channel is easily blocked by water, making it difficult to transport oxygen. This further confirms the importance of channel and rib widths to PEMFC performance and in channel design.



(a) Radial-I



(b) Radial-II



(c) Radial-III

Figure 8. Water content distribution in cathode channel

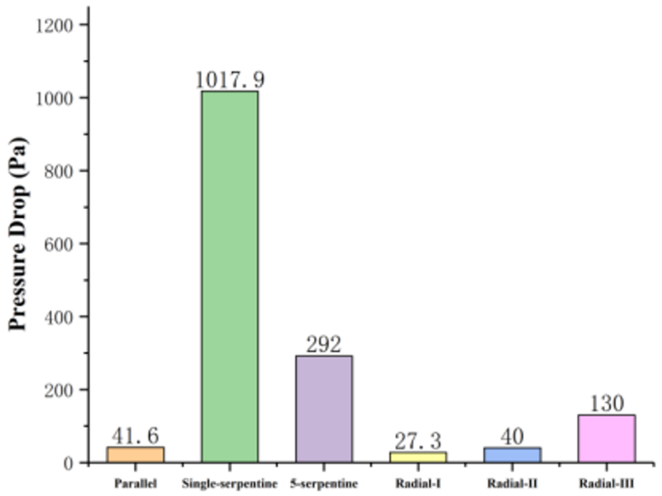


Figure 9. Pressure drops of flow fields with different channel structures

5. CONCLUSIONS

The radial flow fields were compared with traditional flow fields in terms of polarization curves and pressure drop. The comparison shows that the radial flow fields with reasonable structure has the higher limit current density and maximum power density. Among the traditional flow fields, the 5-serpentine flow field has very high limit current density and maximum power density. However, the pressure drop of this flow field is much larger than that of the radial flow fields. The large pressure drop requires a huge pumping power to transport reactive gas, which induces a very large parasitic energy loss.

The channels of Radial-I, Radial-II and Radial-III were contrasted in water content distribution, pressure drop and polarization curves. The results show that the channel depth has a negligible impact on the performance of radial flow fields, while the channel and rib widths directly affect the performance of radial flow fields. Radial-II enjoys the best limit current density and maximum power density among all channel designs, and Radial-Ⅲ has equal or even lower limit current density and maximum power density than the parallel flow field. This fully demonstrates the importance of channel structure to radial flow fields. Among the three radial flow fields, Radial-II has the best channel structure, which provides an acceptable current density, a low pressure drop and a compact flow field to the PEMFC. Our research shows the broad prospects of radial flow field in the PEMFC.

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