質子交換膜燃料電池陰極流通之流場與質傳二維數學模型研究

Le,Dinh Anh、溫志湧 鄭錕燦

E-mail: 9419531@mail.dyu.edu.tw

摘 要

本文以二維之暫態數學模型，探討質子交換膜燃料電池 (PEMFC)陰極流道中反應氣體之質傳問題。此一數學模型將陰極流道中的反應氣體，在設定的電流密度下之流動情形和多成份氣體 混合物之傳輸現象同時納入考慮，之後再以有限差分法解數學問 題，藉以求得流道中氣體混合物的速度分佈及各成份之濃度分 佈。數值模擬結果顯示：陰極流道中反應氣體之化學當量比 (stoichiometry)對氧氣與水蒸氣濃度影響甚大，然而電池之電流 密度（於固定之stoichiometry 下）對氧氣與水蒸氣濃度的影響 幾乎可以忽略。此外在流道中的氧氣質傳方面，其Sherwood number 經計算結果為6.0，此一數值與利用質傳與熱傳之類比關 係所得到的結果頗為吻合。

關鍵詞 : 質子交換膜燃料電池，氣體流道，化學當量，質傳

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參考文獻

[1] Karl Kordesch, Gunter Simader, Fuel Cells and Their Application, VCH Verlagsgesellschaft GmbH, Weiheim, Federal Republic of Germany, 1996 [2] EG&G Services Parsons, Inc., Science Applications International Corporation,“ Fuel Cell Handbook Fifth Edition ”, National Energy Technology Laboratory, Oct. 2000 [3] Dawn M.Bernardi, Mark W.Verbrugge, A Mathematical Model of the Solid-Polymer-Electrolyte Fuel Cell, J.Electrochem. Soc., Vol.139, No.9 (Sep 1992) 2477-2491 [4] T.V Nguyen, J.S. Yi, An along-the-channel model for proton exchange membrane fuel cells, J. Electrochem.Soc. 145 (4) (1998) 1149-1159 [5] I-Ming Hsing, Peter Futerko, Two-dimensional simulation of water transport in polymer electrolyte fuel cells, Chemical Engineering Science 55 (2000) 4209-4218 [6] Z.H Wang, C.Y. Wang, K.S. Chen, Two-phase flow and transport in the air cathode of proton exchange membrane fuel cells, J. Power Sources 94 (2001) 40-50 [7[Linxiu You, Hongtan Liu, A two-phase flow and transport model for the cathode of PEM fuel cells, J. Power Sources 134 (2004) 185-196 [8] M. Vynnycky, E. Birgersson, Analysis of a Model for Multicomponent Mass Transfer in the Cathode of a Polymer Electrolyte Fuel Cell, Technical Reports from Royal Institute of Technology, Department of Mechanics, SE-100 44, Stockholm, Sweden, Feb 2003 [9] T. Berning, D. M. Lu, N. Djilali, J. Power Sources 106 (2002) 284-294 [7] R.B. Bird, W.E. Steward and E.N. Lightfoot, Transport phenomena, Willey, New York, 1960 [8] D.A Anderson, J.C. Tannehill, R.H Pletcher, Computational Fluid Mechanics and Heat Transfer, McGraw-Hill, New York, 1984 [9] T.V. Nguyen, Modeling two-phase flow in the porous electrodes of proton exchange membrane fuel cells using the interdigitated flow field, Electrochemical Society Proceedings, 99-14 (2000) pp 222-241 [10] Dilip Natarajan, Trung Van Nguyen, J. Power Sources 115 (2003) 66-80 [11] M. C. Potter, D. C.

Wiggert, Mechanics of Fluids, 3th Edition, Brooks/Cole, 2002.
[12] R.B. Bird, W.E. Steward and E.N. Lightfoot, Transport phenomena, Willey, New York, 1960.
[13] D.A Anderson, J.C. Tannehill, R.H Pletcher, Computational Fluid Mechanics and Heat Transfer, McGraw-Hill, New York, 1984, p. 250.
[14] A. F. Mills, Basic heat and mass transfer, IRWIN, Chicago, 1995, p. 714.
[15] A. Bejan, Convection heat transfer, Willey, New York, 1995, p. 104.
[16] Chemical Engineers Handbook, 5th edition, Mc Graw-Hill, New York, 1973, p. 14-4.
[17] K.T. Jeng, S.F. Lee, G.F. Tsai, C.H. Wang, Oxygen mass transfer in PEM fuel cell gas diffusion layers, J. of Power Source 138 (2004) 41-50
[18] Tsai Ping-Tsan, Visualization of water formation in the PEMFC and the effects of interfacial pressure on its performance, Master dissertation, Dept. of Mechanical and Automation Engineering, Da Yeh University, Changhua, Taiwan, 2005