多孔性介質應用於平板噴射的熱傳性能數值分析

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摘 要

衝擊噴射在工業界是一個很重要的冷卻熱傳技術，如工業乾燥、金屬與玻璃退火、鑄鐵時的二次冷卻、雷射冷卻與電漿切割冷卻、氣渦輪葉片冷卻、微電子散熱。衝擊噴射的熱傳增強技術，目前在學術界是正在積極探討的問題。　　本研究採用數值模擬方法，探討衝擊冷卻目標平板上加裝多孔材料在無挖中心孔與有挖中心孔時，與平板噴射基本情形比較的熱傳增強效果，並探討多孔介質重要物理幾何參數對熱傳之影響。本研究先參考相關數值與實驗文獻，選擇最適切的數學模式，之後再套入本研究不同物理幾何的數值模型中，進行模擬。　　模擬結果顯示加裝有中心孔的多孔介質可有效提升衝擊冷卻之熱傳效果，加裝無中心孔的多孔介質對熱傳增強反而有反效果。此外，多孔介質挖孔幾何與滲透率對熱傳性能有決定性的影響，最佳的中心孔幾何是讓流體可有效的穿入多介質進行熱傳。當孔隙率高時，滲透率越小越好；當孔隙率低時，滲透率則是越大越好。

關鍵詞 : 衝擊噴射，熱傳增強，多孔介質，中心孔，孔隙率，滲透率

目錄

參考文獻

【1】Beitelmal, A.H., Saad, M.A.,Patel, C.D., 2000," The effect of -inclination on the heat transfer between a flate surface and an -impinging two-dimensional air jet," Inter national Journal of -Heat and Fluid Flow, Vol.21, pp. 156-163 【2】張中興，「多孔介質流之流場與熱傳性質之分析(Investigatim of -Flow and Thermal Properties of Porous Medium Flow)」，中興 大學機械工程研究所碩士論文(1996) 【3】Jiang, P.X., Ren, Z.P., Wang, B.X., 1999," Numerical simulation -of forced convection heat transfer in porous plate channels -using thermal equilibrium and nonthermal equilibrium models," -Numerical Heat Transfer,Vol. 35, pp. 99-113 【4】Lee, D.Y., Vafai, K., 1999," Comparative analysis of jet -impingement and microchochannel cooling for high heat flux -applica tions," International Journal of Heat and Mass Transfer, -Vol. 42, pp. 1555-1568 【5】黃新鉗,「加裝多孔凸塊以增強熱傳效率之研究（A Study of -Thermal Enhancement by Adding Porous Block Under -Impinging Jet）」,交通大學機械工程研究所博士論文(1997) 【6】San, J.Y., Huang, C.H., Shu, M.H., 1997," Impingement cooling -of a confined circular air jet," International Journal of Heat and -Mass Transfer, Vol. 40, pp. 1355-1364 【7】Voke ,P.R., Gao, S., 1997," Numerical study of heat transfer from -an impinging jet," International Journal of Heat and Mass -Transfer, Vol. 41, pp. 671 680 【8】Shu, J.J., Wilks, G.., 1996," Heat transfer in the flow of a Cold , -two-dimensional vertical liquid jet against a hot,horizontal -plate," International Journal of Heat and Mass Transfer, Vol. 39, -pp. 3367-3379 【9】Francis, N.D., Wepfer, W.J., 1996," Jet impingement drying of a -moist porous solid," International Journal of Heat and Mass -Transfer, Vol. 39, pp. 1911-1923 【10】謝文政,「具上限制板之紊流三維五噴射撞擊流場數值模擬 分析（Numerical Simulation and Analysis of Three-Dimension -Turbulent Impinging Flow Field from Confined Five Jets）」, 逢 甲大學機械工程研究所碩士論文(1999) 【11】陳宗榮,「具橫向流之三維紊流雙噴射撞擊平板流場數值模 擬與分析」中原大學機械工程研究所碩士論文(1997) 【12】Jiang, P.X., Ren, Z.P., 2001," Numerical investigation of -forced convection heat transfer in porous media using a -thermal non-equilibrium model," International Journal of Heat -and Fluid Flow, Vol. 22, pp. 102-110 【13】Lee, D.Y., Vafai, K., 1999," Analytical

characterization and -conceptual assessment of solid and fluid temperature -differentials in porous media," International Journal of Heat -and Mass Transfer, Vol.42, pp. 423-435 【14】Ould-Amer, Y., Chikh, S., Bouhadef, K., Lauriat, G., 1998," -Forced convection cooling enhancement by use of porous -materials," Internation al Journal of Heat and Fluid Flow, Vol. -19, pp. 251-258 【15】Chen, Y.C., Chung, J.N., Wu, Y.F., 2000," Non-Darcy mixed convection in a vertical channel filled with a porous medium," -International Journal of Heat and Mass Transfer, Vol. 43, pp. -2421-2429 【16】Jiang, P.X., Wang, Z., Ren, Z.P., Wang, B.X., 1999," -Experimental research of fluid flow and convection heat -transfer in plate channels filled with glass or metallic -particles," Experimental Thermal and Fluid Science 20, pp. -45-54 【17】Jiang, P.X., Fan, M.H., Si, G.S., Ren, Z.P., 2001," -Thermal-hydraufic performance of small scale micro-channel -and porous media heat-exchangers," International Journal of -Heat and Mass Transfer, Vol. 44, pp. 1039-1051 【18】Bhattacharya, A., Calmidi, V.V., Mahajan, R.L., 2002," -Thermophysical properties of high porosity metal foams," -International Journal of Heat and Mass Transfer, Vol. 45, pp. -1017-1031 【19】Yang, J.H.,and Lee, S.L., 1999," Effect of anisotropy on -transport phenomna in anisotropic porous media," -International Journal of Heat and Mass Transfer, Vol. 42, pp. -2673-2681 【20】Lee, S.L.,and Yang, J.H., 1997," Modelling of effective thermal -conductivity for a nonhomogeneous anisotropic porous -medium," International Journal of Heat and Mass Transfer, -Vol. 41, pp. 931-937 【21】Chen, C.Y., Wang, L., Kurosaki, Y., 2001," Numerical -simulations of heat transfer in porous media with effect of -heterogeneities," 【22】Kim, S.J.,and Jang, S.P.,2002," Effects of Darcy number, the -Prandtl number, and the Reynolds number on local thermal -non-equilibrium," International Journal of Heat and Mass Transfer, Vol. 45, pp. 3885-3896 【23】Fu, W.S.,and Huang, H.C., 1999," Effect of a random porosity -model on heat transfer performance of porous media," -International Journal of Heat and Mass Transfer, Vol. 42, pp. -13-25 【24】Hansen, L.G.,and Webb, B.W., 1993," Air jet impingement heat -transfer from modified surfaces", International Journal of -Heat and Mass Transfer, Vol. 36, pp. 989-997 【25】Merci, B., Dick, E., 2002," Heat transfer predictions with a cubic -k- ε model for axisymmetric turbulent jets impinging onto a -flat plate," International Journal of Heat and Mass Transfer, -Vol. 46, pp. 469-480 【26】Behnia, M., Durbin, S., and Durbin, P. A., 1998," Prediction of -heat transfer in an axisymmetric turbulent jet impinging on a -flatplate," International Journal of Heat and Mass Transfer, -Vol. 41,pp. 1845-1855 【27】Prakash, M., Turan, O.F., Li, Y., Mahoney, J.,and Thorpe, G. -R.,2001," Impinging round jet studies in a cylindrical -enclosure with and without a porous layer : Part I-Flow -visualizations and simulations," Chemical Engineering -Science, Vol. 56,pp. 3855-3875 【28】Shu, J. J., Wilks, G., 1996," Heat transfer in the flow of a cold, -two-dimensional vertical liquid jet against a hot, horizontal -plate," International Journal of Heat and Mass Transfer, Vol. -39, pp. 3367-3379 【29】Shi, Y., Ray, M.B., and Mujumdar, A. S., 2002," Effects of -prandtl number on impinging jet heat transfer under a -semi-confined turbulent slot jet," International Comm. of Heat -and Mass Transfer, Vol. 29, pp. 929-938 【30】Shi, Y.L., Ray, M.B., and Mujumdar, A.S., 2003," Effects of -prandtl number on impinging jet heat transfer under a -semi-confined laminar slot jet," International Comm. of Heat -and Mass Transfer, Vol. 30, pp. 455-464 【31】Shuja, S.Z., Yilbas, B.S., and Budair M. O., 2001," Local -entropy generation in an impinging jet : minimum entropy -concep evaluating various turbulence models," Comput. -Methods Appl. Mech. Engrg., Vol. 190, pp. 3623-3644 【32】Chiriac, V. A., Ortega, A., 2002," A numerical study of the -unsteady flow and heat transfer in a transitional confined slot -jet impinging on an isothermal surface," International Journal -of Heat and Mass Transfer, Vol. 45, pp. 1237-1248 【33】Chen, C.H., 1998," Mixed convection heat transfer from a -horizontal plate with variable surface heat flux in a porous -medium," Heat and Mass Transfer, Vol. 34, pp. 1-7 【34】Fu, W.S., Huang, H.C., 1997," Thermal performances of -different shape porous blocks under an impinging jet," -International Journal of Heat and Mass Transfer, Vol. 40, pp. -2261-2272 【35】Chalupa, C., Chen, M., Modi, V.,and West, A., 2001," High -Schmidt mass transfer in a turbulent impinging slot-jet flow," -International Journal of Heat and Mass Transfer, Vol. 44, pp. -3775-3785 【36】Lee, D. H., Won, S. Y., Kim, Y. T., and Chung Y. S., 2002," -Turbulent heat transfer from a flat surface to a swirling round -impinging jet," International Journal of Heat and Mass -Transfer, Vol. 45, pp. 223-227 【37】Meola, C., Luca, L., and Carlomagno, G. M., 1996," Influence of -shear layer dynamics on impingement heat transfer," -Experimental Thermal and Fluid Science, Vol. 13, pp. 29-37 【38】Gau, C., Sheu, W. Y., and Shen, C. H., 1997," Impingement -cooling flow and heat transfer under acoustic excitations," -Journal of Heat Transfer, Vol. 119, pp. 810-817 【39】Lee, J., Lee, S. J., 1999," The effect of nozzle aspect ratio on -stagnation region heat transfer characteristics of elliptic -impinging jet," International Journal of Heat and Mass -Transfer, Vol. 43, pp. 555-575 【40】Liu, T., Sullivan, J. P., 1996," Heat transfer and flow structures in -an excited circular impinging jet," International Journal of -Heat and Mass Transfer, Vol. 39, pp. 3695-3706 【41】Fitzgerald, J., Garimella, S. V., 1998," A study of the flow field -of a confined and submerged impinging jet," International -Journal of Heat and Mass Transfer, Vol. 41, pp. 1025-1034 【42】Fitzgerald, J. A., Garimella, S. V., 1997," Flow field effects on -heat transfer in confined jet impingement," Journal of Heat -Transfer, Vol. 119, pp. 630-632 【43 】Sheriff, H. S., Zumbrunnen, D. A., 1994," Effect of flow -pulsations on the cooling effectiveness of an impinging jet," -Journal of Heat Transfer, Vol. 116, pp. 886-895 【44】Seyed-Yagoobi, J., Narayanan, V., and Page, R. H., 1998," -Comparision of heat transfer characteristics of radial jet -reattachment nozzle to in-line impinging jet nozzle," Journal -of Heat Transfer, Vol. 120, pp. 335-341 【45】Baughn, J. W., Hechanova, A. E.,and Yan, X., 1985," An -Experimental study of entrainment effects on the heat transfer -from a flat surface to a heated circular impinging jet," Journal -of Heat Transfer, Vol. 113, pp. 1023-1025 【46】Bizzak, D. J.,and Chyu, M. K., 1995,"Use of laser-induced -fluorescence thermal imaging system for local jet impingement --heat transfer measurement," International Journal of Heat and -Mass Transfer, Vol. 38, pp. 267-274 【47】-Breugem, W. P., Boersma, B. J., 2002,"The turbulent flow over a -permeable wall," Center for Turbulence Research Proceedings -of the Summer Program 【48】Chikh, S., Boumedien A., Bouhadef, K., and Lauriat, G., -1998,"Analysis of fluid flow and heat transfer in a channel with -intermittent heated porous blocks," Heat and Mass Transfer, -Vol. 33, pp. 405-413 【49】Jiang, P. X., Ren, Z. P., 2001,"Numerical investigation of forced -convection heat transfer in porous media using a thermal -non-equilibrium model," International Journal of Heat and

-Fluid Flow, Vol. 22, pp. 102-110 【50】Fu, W. S., Huang, H. C., 1999,"Effects of random porosity model -on heat transfer performance of porous media," International -Journal of Heat and Mass Transfer, Vol. 42, pp. 13-25 【51】Angirasa, D., Peterson, G. P., 1999,"Forced convection heat -transfer augmentation in a channel with a localized heat source -using fibrous materials," ASME J. Electronic packaging, Vol. -121, No.1, pp. 1-7 【52】Prakash, M., Turan, O. F., Li, Y., Mahoney, J., and Thorpe, G. R., -2001," Impinging round jet studies in a cylindrical enclosure -with and with and without a porous layer: Part I—Fiow -visualization and simulations", Chemical Engineering Science, -Vol. 56, pp. 3855-3878 【53】Jiang, P. X., Fan, M. H., Si, Z. P., and Ren, Z. P., 2001,"Thermal -—hydraulic performance of small scale micro-channel and -porous-media heat-exchangers," International Journal of Heat -and jass Transfer, Vol. 44, pp. 1039-1051 【54】Jiang, P. X., Wang, Z., Ren, Z. P., and Wang B. X., 1-999,"Experimental research of fluid and convection heat -transfer in plate channel filled with glass or metallic particles," -Experimental Thermal and Fluid Science, Vol. 20, pp. 45-54 【55】Bhattacharya, A.,Calmidi, V. V., and Mahajan, R. L., -2002,"Thermophsical properties of high porosity metal -foams," International Journal of Heat and Mass Transfer, Vol. -45, pp. 1017-1031 【56】FLUENT 6 User's Guide Volume 1-4,Tutorial Guide Volume 1-2 始用手冊