

Experimental Investigation of Heat Transfer Enhancement of Jet Impingement on a Plate Attached by a Porous Medium with a

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ABSTRACT

Jet impinging is an important cooling heat transfer technique in the industries, such as industrial drying, metal and glass annealing, secondary cooling in iron casting, laser cooling, plasma cutting cooling, gas turbine blade cooling, and cooling of microelectronics. Nowadays, enhancement techniques for jet impingement heat transfer are still under intense investigation by academic researchers. In this study, the jet impingement heat transfer on a target plate covered with porous medium with or without a center hole is experimentally investigated using the transient liquid crystal technique. Based on the results from jet impingement on a bare flat plate, the enhancement in heat transfer due to the addition of porous material is evaluated. The validity of the experimental system constructed for this research was confirmed first by comparing the experimental data of impingement on a flat plate at similar conditions in the literature. The system and the data reduction procedure were then applied to the experimental cases with the flat plate covered with a thick layer of porous medium. Experimental results show that the addition of the porous material with a center hole can effectively enhance the jet impingement heat transfer over a flat plate. The addition of the thick porous layer without a center hole, however, gave rise to adverse effect in jet impingement heat transfer. In addition, the geometry of the center hole of the porous layer has deterministic influence on heat transfer performance. An optimal center-hole geometry will allow fluid to effectively penetrate into the porous medium for heat exchange.

Keywords : jet impingement heat transfer, heat transfer enhancement, porous Material, center hole

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REFERENCES

- 【1】張中興, 1996, "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。【2】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. 【3】Lee, D.Y., Vafai, K., 1999, "Comparative analysis of jet impingement and microchannel cooling for high heat flux applications," International Journal of Heat and Mass Transfer, Vol. 42, pp. 1555-1568. 【4】Beitelmal, A.H., Saad, M A., and Patel, C.D., 2000, "The Effect of Inclination on The Heat Transfer Between a Flat Surface and an Impinging Two-dimensional Air Jet," International Journal of Heat Transfer, Vol. 21, pp. 156-163. 【5】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 Transfer, Vol. 45, pp. 223-227. 【6】Lytel, D., and Webb, B.W., 1994, "Air Jet Impingement Heat Transfer at Low Nozzle-plate Spacings," International Journal of Heat Transfer, Vol. 37, no. 12, pp. 1687-1697. 【7】Baughn, J.W., and Shimizu, S., 1989, "Heat Transfer Measurements from a Surface with Uniform Heat Flux and an Impinging Jet," Journal of Heat Transfer Transactions of ASME, Vol. 111, pp. 1096-1098. 【8】Jungho, Lee, and Sang-Joon, Lee, 2000, "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. 【9】Meola, C., Luca, L.d., and Carlomagno, G.M., 1996, "Influence of Shear Layer Dynamics on Impingement Heat Transfer," Experimental Thermal and Fluid Science. Vol. 13, pp. 29-37. 【10】Seyed-Yagoobi, J., Narayanan, V., and Page, R.H., 1998, "Comparison of Heat Transfer Characteristics of Radial Jet Reattachment Nozzle to In-line Impinging Jet Nozzle," Journal of Heat Transfer, Vol. 120, pp. 335-341. 【11】Beitelmal, A.H., Saad, M.A., Patel, C.D., 2000, "The effect of inclination on the heat transfer between a flat surface and an impinging two-dimensional air jet," International Journal of Heat and Fluid Flow, Vol. 21, pp. 156-163. 【12】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. 【13】Peper F., Leiner W., and Fiebig M., 1997, "Impinging Radial and Inline Jets: A Comparison with Regard to Heat Transfer, Wall Tressure Distribution, and Pressure Loss," Experimental Thermal and Fluid Science, Vol. 14, pp. 194-204. 【14】J. Seyed-Yagoobi, Narayanan V., and Page R.H., 1998, "Comparison of Heat Transfer Characteristics of Radial Jet Reattachment Nozzle to In-line Impinging Jet Nozzle," Journal of Heat Transfer, Vol. 120, pp. 335-341. 【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】Gau C., Shen 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. 【17】Liu T., and Sullivan J. P., 1996, "Heat transfer and flow structures in an excited circular impinging jet," International Journal of Heat Mass Transfer, Vol. 39, no. 17, pp. 3695- 3706. 【18】Hartnett J. P., and Minkowycz W. J., 2000, "Effect of Surface roughness on The Average Heat Transfer of an Impinging Air Jet," Int. comm. Heat Mass Transfer, Vol. 27, no. 1, pp. 1-12. 【19】Meola C., Luca L. d., and Carlomagno G. M., 1996, "Influence of Shear Layer Dynamics on Impingement Heat Transfer," Experimental Thermal and Fluid Science. Vol. 13, pp. 29-37. 【20】Narayanan V., J. S. Y., and Page R. H., 2004, "An Experimental Study of Fluid Mechanics and Heat Transfer in an Impinging Slot Jet Flow," International Journal of Heat and Mass Transfer, Vol. 47, pp. 1827-1845. 【21】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, no. 6, pp. 1355-1364. 【22】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. 【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】Chen, C.Y., Wang, L., and Kurosaki, Y., 2001, "Numerical Simulations of Heat Transfer in Porous Media with Effect of Heterogeneities," International Journal Heat and Mass Transfer, Vol. 40, pp. 850-872. 【25】Fu, W.S., and Huang, H.C., 1999, "Effect of a Rondon Porosity Model on Heat Transfer Performance of Porous Media," International Journal Heat and Mass Transfer, Vol. 42, pp. 13-25. 【26】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. 【27】Ould-Amer, Y., Chikh, S., Bouhadeh, K., Lauriat, G., 1998, "Forced convection cooling enhancement by use of porous materials," International Journal of Heat and Fluid Flow, Vol. 19, pp. 251-258. 【28】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. 【29】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. 【30】Coppage J. E., and London A. L., 1956, "Heat Transfer and Flow Friction Characteristics of Porous Media," Chemical Engineering Progress, Vol. 52, no. 2, 57-63. 【31】李文鈞, 2001, "金屬濾網堆積床之壓降與熱傳特性測定," 中正大學機械工程研究所。【32】吳俊源, 2001, "多孔性電子散熱器應用於微處理器之散熱特性研究," 中正大學機械工程研究所。【33】邱偉誠, 2002, "電子多孔性散熱器熱傳特性之研究," 中正大學機械工程研究所。【34】黃新鈞,

1997, "加裝多孔凸塊以增強熱傳效率之研究," 交通大學機械工程研究所博士文。【35】鄭豐嘉, 2004, "多孔性應用於平板噴射的熱傳性能數值分析," 大葉大學機械工程研究所。【36】吳佩學, 1998, "應用液晶技術之熱傳實驗系統的建立," 台灣電力公司結案報告。