Effect of nozzle geometry and attached porous layer on jet impingement heat transfer of a flat plate

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ABSTRACT

Jet impingement is an important heat transfer technique in industries, such as metal and glass annealing, laser cooling, gas turbine blade cooling, and cooling of microelectronics. Nowadays, enhancement techniques for jet impingement heat transfer are still under intensive investigation by academic researchers. In this study, the enhancement of impingement heat transfer on a flat plate covered with a thick layer of porous medium with or without a center hole was numerically investigated. The renormalization group (RNG) turbulence model is selected for the fluid region while Forchheimer extended Darcy’s model is used for porous region. The numerical modeling was justified by comparisons with available experimental data. A modification to the existing model which shows drawbacks for high Reynolds number applications is also suggested in this study. Computational results show that an attached porous medium having a sufficiently deep center hole can effectively enhance jet impingement heat transfer while an attached thick porous layer without a center hole, or having a center hole with insufficient depth, has detrimental effect. The physics of these results are supported and well explained by the detailed flow patterns. Under the condition of fixed porosity and permeability, the influential parameters for the investigated heat transfer problem include the jet Reynolds number, nozzle geometry (including nozzle length and jet-to-hole diameter ratio), jet-to-plate distance, and the center hole depth. A good hole geometry should well trap the jet and direct the coolant along the heated plate. The heat transfer performance is the best when the jet-to-hole diameter ratio equals one. To give better heat transfer performance, the nozzle should be shorter, resulting in more uniform flow at the exit, at low Reynolds numbers, and it should be long enough at high Reynolds numbers so that the exit flow is fully developed. Finally, corre3lations of Nusselt number versus Reynolds number are proposed for the investigated problem. It is hoped that the correlations are helpful to the designers who will use an attached porous layer in an impingement cooling design.

Keywords : jet impingement、porous medium、center hole、numerical modeling、center hole depth、Reynolds number

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