Heat Transfer - Asian Research
Volume 48, Issue 5, July 2019, Pages 1857-1888

Numerical investigation of semiempirical relations representing the local Nusselt number magnitude of a pin fin heat sink (Article)

(Open Access)

Siddique, U.M.[a], Nitin, G.P.[b], Khan, S.A.[c], Taler, J.[d], Cebula, A.[d], Oclon, P.[d], Patil, R.[a]

[a]Mechanical Engineering Department, Mukesh Patel School of Technology Management & Engineering, NMIMS University, Mumbai, Maharashtra, India
[b]Mechanical Engineering Department, Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India
[c]Mechanical Engineering Department, International Islamic University of Malaysia, Kuala Lumpur, Malaysia

View additional affiliations

Abstract

View references (29)

Heat transfer augmentation study using air jet impingement has recently attained great interest toward electronic packaging systems and material processing industries. The present study aims at developing a nondimensional semiempirical relation, which represents the cooling rate (Nu) in terms of different geometric and impinging parameters. The spacing of the fin (S/d_p) and the fin heights (H/d_p) are the geometric parameters, while the impinging Reynolds number (Re) and nozzle-target spacing (Z/d) are the impinging parameters. During the plot of the Nusselt profile, three vital secondary peaks are observed due to local turbulence of air over the heat sink. To incorporate this nonlinear behavior of the Nusselt profile in developing nondimensional empirical relations, the Nusselt profiles are divided into different regions of secondary rise and fall. Four different sets of the semiempirical relation using regression analysis are proposed for $Z/d \le 6$, $H/d_p \le 4.8$ with $S/d_p \le 1.58$, $S/d_p > 1.58$ and for $Z/d > 6$, $H/d_p > 4.8$ with $S/d_p \le 1.58$, $S/d_p > 1.58$. These empirical relations benefit the evaluation of the cooling rate (Nu) without any experimentation or simulation. © 2019 Wiley Periodicals, Inc.

SciVal Topic Prominence

Topic: Fins (heat exchange) | Heat sinks | Fin arrays

Prominence percentile: 87.918

Author keywords

heat sinks | heat transfer | heat transfer enhancement | numerical simulation | Nusselt number | Reynolds number

Indexed keywords

Engineering controlled terms: Computer simulation | Cooling | Electronics packaging | Fins (heat exchange) | Heat sinks | Heat transfer | Jets | Regression analysis | Reynolds number

Engineering uncontrolled terms: Air jet impingement | Electronic Packaging | Heat transfer augmentation | Heat Transfer enhancement | Local Nusselt number | Material processing | Numerical investigations | Semiempirical relations

Engineering main heading: Nusselt number

ISSN: 10992871
CODEN: HTARF
Source Type: Journal
Original language: English
DOI: 10.1002/htj.21460
Document Type: Article
Publisher: John Wiley and Sons Inc.

References (29)

View in search results format >

All | Export | Print | E-mail | Save to PDF | Create bibliography

1 Li, H.-Y., Chao, S.-M., Tsai, G.-L.
Thermal performance measurement of heat sinks with confined impinging jet by infrared thermography
(2005) *International Journal of Heat and Mass Transfer*, 48 (25-26), pp. 5386-5394. Cited 52 times.
doi: 10.1016/j.ijheatmasstransfer.2005.07.007
View at Publisher

2 El-Sheikh, H.A., Garimella, S.V.
Heat transfer from pin-fin heat sinks under multiple impinging jets
(2000) *IEEE Transactions on Advanced Packaging*, 23 (1), pp. 113-120. Cited 37 times.
doi: 10.1109/6040.826769
View at Publisher

3 Garimella, S.V., Schroeder, V.P.
Local heat transfer distributions in confined multiple air jet impingement
(2001) *Journal of Electronic Packaging, Transactions of the ASME*, 123 (3), pp. 165-172. Cited 63 times.
doi: 10.1115/1.1371923
View at Publisher

4 Chougle, N.K., Parishwas, G.V., Sewatkar, C.M.
Numerical analysis of pin fin heat sink with a single and multi air jet impingement condition
(2012) *Int J Eng Innov Technol*, 1 (3), pp. 44-50. Cited 13 times.

5 Yamane, Y., Ichikawa, Y., Yamamoto, M., Honami, S.
Effect of injection parameters on jet array impingement heat transfer
(2012) *International Journal of Gas Turbine, Propulsion and Power Systems*, 4 (1), pp. 27-34. Cited 15 times.
http://www.gtsj.org/english/jgpp/v04n01tp04.pdf

6 Brignoni, L.A., Garimella, S.V.
Experimental optimization of confined air jet impingement on a pin fin heat sink
(1999) *IEEE Transactions on Components and Packaging Technologies*, 22 (3), pp. 399-404. Cited 85 times.
doi: 10.1109/6144.796542
View at Publisher

7 Issa, J.S., Ortega, A.
Experimental measurements of the flow and heat transfer of a square jet impinging on an array of square pin fins
(2006) *Journal of Electronic Packaging, Transactions of the ASME*, 128 (1), pp. 61-70. Cited 36 times.
doi: 10.1115/1.2160513
View at Publisher

8 Maveety, J.G., Hendricks, J.F.
A heat sink performance study considering material, geometry, nozzle placement, and reynolds number with air impingement
(1999) *Journal of Electronic Packaging, Transactions of the ASME*, 121 (3), pp. 156-161. Cited 30 times.
doi: 10.1115/1.2792678
View at Publisher

9 Huang, C.-H., Chen, Y.-H., Li, H.-Y.
An impingement heat sink module design problem in determining optimal non-uniform fin widths

(2013) *International Journal of Heat and Mass Transfer*, 67, pp. 992-1006. Cited 14 times.
doi: 10.1016/j.ijheatmasstransfer.2013.08.103

View at Publisher

10 Huang, C., Chen, Y.
An optimal design problem in determining non uniform fin heights and widths for an impingement heat sink module
(2014) *Int J Heat Mass Transf*, 63, pp. 482-494. Cited 2 times.

11 Yang, Y.-T., Peng, H.-S.
Numerical study of pin-fin heat sink with un-uniform fin height design

(2008) *International Journal of Heat and Mass Transfer*, 51 (19-20), pp. 4788-4796. Cited 64 times.
doi: 10.1016/j.ijheatmasstransfer.2008.02.017

View at Publisher

12 Kobus, C.J., Oshio, T.
Development of a theoretical model for predicting the thermal performance characteristics of a vertical pin-fin array heat sink ur

(2005) *International Journal of Heat and Mass Transfer*, 48 (6), pp. 1053-1063. Cited 60 times.
doi: 10.1016/j.ijheatmasstransfer.2004.09.042

View at Publisher

13 Katti, V., Prabhu, S.V.
Experimental study and theoretical analysis of local heat transfer distribution between smooth flat surface and impinging air jet

(2008) *International Journal of Heat and Mass Transfer*, 51 (17-18), pp. 4480-4495. Cited 186 times.
doi: 10.1016/j.ijheatmasstransfer.2007.12.024

View at Publisher

14 Hikkimath, G.K., Chappar, S.S.
Numerical investigation of L/D ratio of nozzle on heat transfer characteristic of a circular jet on flat plate
(2014) *Global J Eng Sci Res*. Cited 3 times.

15 Huang, J., Jang, J.
Numerical study of a confined axis symmetric jet impingement heat transfer with nanofluids
(2013) *Sci Res*, 5, pp. 69-74. Cited 11 times.

16 Gorji, S., Seddighi, M., Ariyaratne, C., Vardy, A.E., O'Donoghue, T., Pokrajac, D., He, S.
A comparative study of turbulence models in a transient channel flow (Open Access)

(2014) *Computers and Fluids*, 89, pp. 111-123. Cited 30 times.
doi: 10.1016/j.compfluid.2013.10.037

View at Publisher

17 Langtry, R.B., Menter, F.R.
Correlation-based transition modeling for unstructured parallelized computational fluid dynamics codes

(2009) *AIAA Journal*, 47 (12), pp. 2894-2906. Cited 662 times.
http://pdf.aiaa.org/getfile.cfm?
urlX=%2D%3CWI%277D%2FQKS%2B%2FRPKOWP%20%20%0A&urla=%26%2A%22L%20%23%20%2AC%0A&urlb=%21%2A%20%20%20%0A&urlc=%21%
doi: 10.2514/1.42362

View at Publisher

18 Malan, P., Suluksna, K., Juntasaro, E.
Calibrating the γ-Re_θ transition model for commercial CFD

(2009) *47th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition*, art. no. 2009-1142. Cited 69 times.
ISBN: 978-156347969-4

19 Angioletti, M., Nino, E., Ruocco, G.
CFD turbulent modelling of jet impingement and its validation by particle image velocimetry and mass transfer measurements

(2005) *International Journal of Thermal Sciences*, 44 (4), pp. 349-356. Cited 62 times.
doi: 10.1016/j.ijthermalsci.2004.11.010

View at Publisher

20 Alenezi, A., Teixeria, J., Addali, A.
Numerical Analysis of Heat Transfer Characteristics of an Orthogonal and Obliquely Impinging Air Jet on a Flat Plate."
(2015) *Proceedings of the World Congress on Engineering*, 2. Cited 4 times.

21 Khameneh, P.M., Mirzaie, I., Pourmahmoud, N., Rahimi, M., Majidyfar, S.
A numerical study of single-phase forced convective heat transfer in tube in tube heat exchangers
(2010) *World Acad Sci Eng Technol*, 4 (10), pp. 958-963. Cited 4 times.

22 Sundaram, M.S., Venkatesan, M.
Heat transfer study of perforated fin under forced convection

(2015) *International Journal of Engineering, Transactions A: Basics*, 28 (10), pp. 1156-1163. Cited 4 times.
http://www.ije.ir/Vol28/No10/A/7.pdf

23 Khoshravan, E., Soleimani, G.
A numerical study of natural convection and radiation interaction in vertical circular pin
(1997) *Int J Eng*, 10 (3), p. 163. Cited 5 times.

24 Rostamzadeh, A., Jafarpur, K., Goshtasbirad, E., Doroodmand, M.M.
Experimental investigation of mixed convection heat transfer in vertical tubes by nanofluid: Effects of reynolds number and fluid

(2014) *International Journal of Engineering, Transactions B: Applications*, 27 (8), pp. 1251-1258. Cited 9 times.
http://www.ije.ir/Vol27/No8/B/11.pdf
doi: 10.5829/idosi.ije.2014.27.08b.11

View at Publisher

25 Alimohammadi, S., Murray, D.B., Persoons, T.
Experimental validation of a computational fluid dynamics methodology for transitional flow heat transfer characteristics of a ste

(2014) *Journal of Heat Transfer*, 136 (9), art. no. 091703. Cited 19 times.
http://asmedl.aip.org/HeatTransfer
doi: 10.1115/1.4027840

View at Publisher

26 Umair, S.M., Gulhane, N.P.
On Numerical Investigation of Heat Transfer Augmentation through Pin Fin Heat Sink by Laterally Impinging Air Jet (Open Acces

(2016) *Procedia Engineering*, 157, pp. 89-97. Cited 3 times.
http://www.sciencedirect.com/science/journal/18777058
doi: 10.1016/j.proeng.2016.08.342

View at Publisher

27 Mohd Umair, S., Gulhane, N.P.
On numerical investigation of non-dimensional constant representing the occurrence of secondary peaks in the nusselt distribution curves
Int J Eng, 29 (10), pp. 1453-1461.

28 Umair, S.M., Kolawale, A.R., Bhise, G.A., Gulhane, N.P.
On numerical heat transfer characteristic study of flat surface subjected to variation in geometric thickness
(2017) *Int J Comput Mat Sci Eng*, 6 (2), p. 1750010. Cited 2 times.

29 Umair, S.M., Gulhane, N.P.
On numerical investigation of nonuniformity in cooling characteristic for different materials of target surfaces being exposed to

(2017) *International Journal of Modeling, Simulation, and Scientific Computing*, 8 (3), art. no. 1750024. Cited 3 times.
http://www.worldscinet.com/ijmssc/
doi: 10.1142/S1793962317500246

View at Publisher

Siddique, U.M.; Mechanical Engineering Department, Mukesh Patel School of Technology Management & Engineering, NMIMS University, Mumbai, Maharashtra, India; email:umair.siddique@nmims.edu