Documents

Zulkeple, M.F.M.[a], Talib, A.R.A.[a b], Harmin, M.Y.[a], Saadon, S.[a], Azami, M.H.[c], Yusaf, T.[d]

Numerical Investigation of Heat Transfer Enhancement via Dimpled Target Surface Configuration and Jet Arrangement in Impingement Cooling

(2024) *Journal of Aeronautics, Astronautics and Aviation*, 56 (1), pp. 93-106.

DOI: 10.6125/JoAAA.202403_56(1S).02

[a] Aerodynamics, Heat Transfer & Propulsion (AHTP) Research Group, Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, Selangor, Serdang, 43400, Malaysia
[b] Aerospace Malaysia Research Centre, Faculty of Engineering, Universiti Putra Malaysia, Selangor, Serdang, 43400, Malaysia
[c] Kulliyah of Engineering, International Islamic University Malaysia, P.O. Box 10, Kuala Lumpur, 50728, Malaysia
[d] School of Engineering and Technology, Central Queensland UniversityQLD, Australia

Abstract
This research employs numerical simulation to investigate the influence of dimple configurations on heat transfer. Specifically, it focuses on the 3x3 array of jets directed at a dimpled target surface. The study explores various jet pitches (P = 3Dj, 4Dj and 5Dj) and distances between jets and the dimpled surface (H = 3Dj, 4Dj and 5Dj). Additionally, dimple designs were altered while keeping their volume constant, resulting in elongated dimples. This investigation comprehensively examines flow patterns and heat transfer properties across Reynolds number (Re) range of 5,000 to 15,000. Increasing the H/Dj ratio from 4 to 5 enlarges entrainment vortices near the target surface due to reduced cross flow intensity between adjacent jets. Conversely, reducing the ratio to 3 intensifies crossflow, delaying cooling jet detachment and enhancing heat transfer. Evaluating the smallest jet-to-jet pitch (Px = 3Dj) reveals enhanced heat transfer to the target surface, driven by increased coolant mass flow rate per unit area compared to larger jet pitches (Px = 4Dj and Px = 5Dj). When altering dimple depths while maintaining constant volume, Nusselt numbers (Nu) showed improvements ranging from 10% to 16%, surpassing the 6% to 14% increase seen with hemisphere dimples.

Author Keywords
Dimple; Heat transfer; Impingement cooling; Jet arrangement; Numerical

Index Keywords
Cooling; Cross flows, Dimple, Heat Transfer enhancement, Impingement cooling, Jet arrangement, Numerical, Numerical investigations, Surface configuration, Surface jets, Target surface; Reynolds number

References

- Rafiul Alam, JA, Abu Talib, AR, Altarazi, YSM, Yusaf, T, Azami, MH, Nik Mohd, NAR
  Experimental investigation on gas turbine engine performance using alternative fuel
  (2023) *Journal of Aeronautics, Astronautics and Aviation*, 55 (3S), pp. 479-483.

- Alterazi, YSM, Abu Talib, AR, Yu, J, Gires, E, Abdul Ghafir, MF, Lucas, J, Yusaf, T
  Simulating aero-engine performance and emissions characteristics running on green diesel
  (2023) *International Journal of Green Energy*, 20 (4), pp. 372-377.

- Dawood, SDS, Harmin, MY, Harithuddin, ASM, Ciang, CC, Rafie, ASM
  Computational study of mass reduction of a conceptual microsatellite structural subassembly utilizing metal perforations
  (2021) *Journal of Aeronautics, Astronautics and Aviation*, 53 (1), pp. 57-66.

- Dawood, SDS, Harithuddin, ASM, Harmin, MY
  Modal analysis of conceptual microsatellite design employing perforated structural components for mass reduction
  (2022) *Aerospace*, 9 (1), p. 23.

- Dewan, A, Dutta, R, Srinivasan, B
  Recent trends in computation of turbulent jet impingement heat transfer

(2012) *Heat Transfer Engineering*, 33 (4-5), pp. 447-460.

- Han, B, Goldstein, RJ
Jet-impingement heat transfer in gas turbine systems
(2006) *Annals of the New York Academy of Sciences*, 934 (1), pp. 147-161.

- Ramli, MS, Abu Talib, AR, Harmin, MY, Mohd, Saiah, HR
Effect of multiple jet impingement plate configurations on Reynolds number in a pipe
(2016) *IOP Conference Series: Materials Science and Engineering*, 152, p. 012012.

- Zulkeple, MFM, Talib, ARA, Gires, E, Sultan, MH, Ramli, M
Heat transfer performance of multiple holes impingement cooling technique
(2018) *International Journal of Engineering*, 7 (4), pp. 43-52.

- Shukla, AK, Dewan, A
Flow and thermal characteristics of jet impingement: comprehensive review
(2017) *International Journal of Heat and Technology*, 35 (1), pp. 153-166.

- Culun, P, Celik, N, Pihtili, K
Effects of design parameters on a multi jet impinging heat transfer
(2018) *Alexandria Engineering Journal*, 57 (4), pp. 4255-4266.

- Florschuetz, L, Metzger, D, Takeuchi, D, Berry, R
(1980) *Multiple jet impingement heat transfer characteristics - experimental investigation of inline and staggered arrays with crossflow*,
NASA-CR-3217, Tempe, USA

- Azad, GS, Huang, Y, Han, JC
Impingement heat transfer on dimpled surfaces using a transient liquid crystal technique
(2000) *Journal of Thermophysics and Heat Transfer*, 14 (2), pp. 186-193.

- Ekkad, SV, Kontrovitz, D
Jet impingement heat transfer on dimpled target surfaces
(2002) *International Journal of Heat and Fluid Flow*, 23 (1), pp. 22-28.

- Kanokjaruvijit, K, Martinez-Botas, RF
An experimental investigation of the heat transfer due to multiple jets impinging normally on a dimpled surface
(2004) *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 218 (1), pp. 1337-1347.

- Kanokjaruvijit, K, Martinez-Botas, RF
Jet impingement on a dimpled surface with different crossflow schemes
(2005) *International Journal of Heat and Mass Transfer*, 48 (1), pp. 161-170.

- Kanokjaruvijit, K, Martinez-Botas, RF
Parametric effects on heat transfer of impingement on dimpled surface
(2005) *Journal of Turbimachinery*, 127 (2), pp. 287-296.

- Kanokjaruvijit, K, Martinez-Botas, RF
Heat transfer and pressure investigation of dimple impingement
(2008) *Journal of Turbomachinery*, 130 (1), p. 011003.

- Kanokjaruvijit, K, Martinez-Botas, RF
Heat transfer correlations of perpendicularly impinging jets on a hemispherical-dimpled surface
(2010) *International Journal of Heat and Mass Transfer*, 53 (15-16), pp. 3045-3056.

- Xing, Y, Weigand, B
Experimental investigation of impingement heat transfer on a flat and dimpled plate

with different crossflow schemes
(2010) *International Journal of Heat and Mass Transfer*, 53 (19-20), pp. 3874-3886.

- Kim, SM, Kim, KY
Evaluation of cooling performance of impinging jet array over various dimpled surfaces
(2016) *Heat and Mass Transfer*, 52 (4), pp. 845-854.

- Xie, Y, Li, P, Lan, J, Zhang, D
Flow and heat transfer characteristics of single jet impinging on dimpled surface
(2013) *Journal of Heat Transfer*, 135 (5), p. 052201.

- Luo, L, Wang, C, Wang, L, Sunden, BA, Wang, S
A numerical investigation of dimple effects on internal heat transfer enhancement of a double wall cooling structure with jet impingement
(2016) *International Journal of Numerical Methods for Heat and Fluid Flow*, 26 (7), pp. 2175-2197.

- Schukin, AV, Kozlov, AP, Agachev, RS
Study and application of hemispheric cavities for surface heat transfer augmentation
(2015) *Proceedings of International Gas Turbine and Aeroengine Congress and Exposition*,

- Chang, SW, Jan, YJ, Chang, SF
Heat transfer of impinging jet-array over convex-dimpled surface
(2006) *International Journal of Heat and Mass Transfer*, 49, pp. 3045-3059.

- Chang, SW, Liou, HF
Heat transfer of impinging jet-array onto concave- and convex-dimpled surfaces with effusion
(2009) *International Journal of Heat and Mass Transfer*, 52, pp. 4484-4499.

- Huang, X, Yang, W, Ming, T, Shen, W, Yu, X
Heat transfer enhancement on a microchannel heat sink with impinging jets and dimples
(2017) *International Journal of Heat and Mass Transfer*, 112, pp. 113-124.

- Singh, P, Ekkad, SV
Detailed heat transfer measurements of jet impingement on dimpled target surface under rotation
(2018) *Journal of Thermal Science and Engineering Applications*, 10 (3), p. 031006.

- Vinze, R, Khade, A, Kuntikana, P, Ravitej, M, Suresh, B, Kesavan, V, Prabhu, S
Effect of dimple pitch and depth on jet impingement heat transfer over dimpled surface impinged by multiple jets
(2019) *International Journal of Thermal Sciences*, 145, p. 105974.

- Menter, FR
Two-equation eddy-viscosity turbulence models for engineering applications
(1994) *AIAA Journal*, 32, pp. 1598-1605.

- Jing, Q, Zhang, D, Xie, Y
Numerical investigations of impingement cooling performance on flat and non-flat targets with dimple/protrusion and triangular rib
(2018) *International Journal of Heat and Mass Transfer*, 126, pp. 169-190.

Correspondence Address
Talib A.R.A.; Aerodynamics, Selangor, Malaysia; email: abdrahim@upm.edu.my

Publisher: The Aeronautical and Astronautical Society of the Republic of China

ISSN: 19907710

Language of Original Document: English
Abbreviated Source Title: J. Aero. Astron. Aviat.
2-s2.0-85187552862
Document Type: Article
Publication Stage: Final
Source: Scopus