Numerical Investigation of Micronozzle Performance for Various Nozzle Geometries

P. A. Haris[1], T. Ramesh[1]

[1]National Institute of Technology Tiruchirappalli, Tiruchirappalli, Tamil Nadu, India

Abstract

Design and manufacture of thrusters for producing very low thrust force in the range of milli or micro newtons using micronozzles has been actively developed in the last decade. The nature of propellant flow in such micronozzles differs from that of macro nozzles. In micronozzles, viscous effect dominates; hence the flow is always in laminar regime with high viscous losses. Objective of this paper is to address these issues in micronozzle flow of vapor and also to compare the performance of two different micronozzle geometries. A numerical study has been carried out on the flow of water as propellant in vapor phase inside a 3D micronozzle. The study involved solving the Navier-Stokes equation with no slip boundary condition and equation of energy conservation. The computational model is validated with available experimental data in the literature. The computations are performed for different mass flow rates with inlet vapor temperature kept constant at 600K. Different output parameters of both nozzle geometries are compared and the boundary layer effects are also quantified.

Reference

[1] J. Mueller, W.C. Tang, A.P. Wallace, W. Li., D. Bame, I. Chakraborty, R. Lawton, Design analysis and fabrication of a vapourizing liquid microthruster, AIAA Paper 97-3054, Seattle, WA, USA, July 1997.
[2] D.K. Maurya, S. Das, S.K. Lahiri, An analytical model of a silicon MEMS vapourizing liquid microthruster and some experimental studies, Sensors and Actuators A 122 (2005) 159–166.

[3] E.V. Mukerjee, A.P. Wallace, K.Y. Yan, et al., Vapourizing liquid microthruster, Sensors and Actuators A 83 (2000) 231–236.
[4] X.Y. Ye, F. Tang, H.Q. Ding, Z.Y. Zhou, Study of a vapourizing water micro-thruster, Sensors and Actuators A 89 (2001) 159–165.

[5] C.C. Chen, C.W. Liu, H.C. Kana, et al., Simulation and experiment research on vapourizing liquid micro-thruster, Sensors and Actuators A 157 (2010) 140–149.

[6] Pijus Kundu, Tarun Kanti Bhattacharyya, Soumen Das, Design, fabrication and performance evaluation of a vapourizing liquid microthruster, J. Micromech. Microeng.22(2012) 025016 (15pp)

[7] K. Karthikeyan, S.K. Chou, L.E. Khoong, Y.M. Tan, C.W. Lu, W.M. Yang, Low temperature co-fired ceramic vapourizing liquid microthruster for microspacecraft applications, Applied Energy 97 (2012) 577–583
[8] J.W. Cen, J.L. Xu, Performance evaluation and flow visualization of a MEMS based vapourizing liquid micro-thruster, Acta Astronautica 67 (2010) 468–482
[9] Chia-Chin Chen, Heng-Chuan Kan, Ming-Hsiao Lee, Chein-Wei Liu, Computational Study on Vapourizing Liquid Micro-Thruster, International Microsystems, packaging Assembly and Circuits Technology Conference.
[10] K.H.Cheah, J.K.Chin, Performance improvement on MEMS Micropropulsion system through a novel two-depth micronozzle design, Acta Astronautica 69(2011)59-70

[11] Gibbon D, Coxhill I, Nicolini D, Correi R
and Page J 2004 The design, development and in-flight operation of a water resistojet micropropulsion system 40th AIAA/ASME/SAE/ASEE Joint Propulsion Conf. and Exhibit (FortLauderdale, FL) AIAA 2004-3798