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Experimental investigation on the flow mixing and core length of a supersonic multiple jet configuration using cross-wire as vortex generators

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Abstract
Many Engineering applications use multi-jet systems, such as aircraft propulsion units and spacecraft. A complex aerodynamic flow field occurs when multiple jets are close to each other. This study experimentally examines the supersonic jets' mean flow field and mixing characteristics from one, two, and three different converging-diverging nozzles placed in close vicinity. The cross-wire is used as a passive control technique to investigate the impact of the control on the flow field and the core length. The nozzle is designed for Mach number M = 1.5, with an inter-nozzle positioning equal to twofold the nozzle exit diameter. The typical contact procedure and the triple jet's growth are discussed using cross-sectional contour patterns and transverse pressure profiles. The effect of leading parallel jets on local flow field features, comprising shock wave structure, supersonic core, and jet spread, is observed by measuring pressure beside the jet axes. Similarly, the flow spread rate declines when the quantity of jet flow increases- this is mainly owed to a decrease in attuning; subsequently, the jet decays more slowly, and the core length decreases. Schlieren's pictures of triple, twin, and single jets reveal that the core of the supersonic jet varies in triple and twin jets compared to single jets. © 2025 Elsevier Masson SAS

Author Keywords
Crosswire; Experimental study; Mean flow; Multiple-jets; Passive control; Vortex-generators

Index Keywords
Aerodynamic configurations, Flow fields, Rocket nozzles, Supersonic aerodynamics, Supersonic aircraft, Surface discharges; Cross-wire, Experimental study, Flow-mixing, Mean flow, Multiple jets, Passive control, Supersonic jets, Triple-jets, Twin-jets, Vortex generators; Vortex flow

References

- Berndt, D.E.
(1984), "Dynamic pressure fluctuations in the Internozzle region of a twin-jet nacelle,".
- Seiner, J.M., Manning, J.C., Ponton, M.K.
Dynamic pressure loads associated with twin supersonic plume resonance
(1988) *AIAA J.*, 26 (8), pp. 954-960.
- Kuo, C.W., Cluts, J., Samimy, M.
Exploring physics and control of twin supersonic circular jets
(2017) *AIAA J.*, 55 (1), pp. 68-85.
- Dimotakis, P.E., Brown, G.L.
The mixing layer at high reynolds number: large-structure dynamics and entrainment
(1976) *J. Fluid Mech.*, 78 (3), pp. 535-560.
- Barre, S., Quine, C., Dussauge, J.P.
Compressibility effects on the structure of supersonic mixing layers : experimental

results
(1994) *J. Fluid Mech.*, 259, pp. 47-78.

- Bradbury, L.J.S., Khadem, A.H.
The distortion of a jet by tabs
(1975) *J. Fluid Mech.*, 70 (4), pp. 801-813.
Aug

- Zaman, K.B.M.Q., Reeder, M.F., Samimy, M.
Supersonic jet mixing enhancement by Delta tabs
(1992) *28th Jt. Propuls. Conf. Exhib. cosponsored by AIAA, SAE, ASME, ASEE Nashville, Tennessee*, p. 3548.
July 6-8, 1992

- Ahuja, K.K., Brown, W.H.

"Shear flow control by mechanical tabs," 1989

- Liepmann, D., Gharib, M.
The role of streamwise vorticity in the nearfield entrainment of round jets
(1992) *J. Fluid Mech.*, 245, pp. 643-668.

- Zaman, K.B.M.Q.

"Streamwise vorticity generation and mixing enhancement in free jets by 'Delta-Tabs,'" 1993

- Arun Kumar, P., Aileni, M., Rathakrishnan, E.
Impact of tab location relative to the nozzle exit on the shock structure of a supersonic jet
(2019) *Phys. Fluids*, 31 (7).
Jul

- Zaman, K.B.M.Q., Reeder, M.F., Samimy, M.
Control of an axisymmetric jet using vortex generators
(1994) *Phys. Fluids*, 6 (2), pp. 778-793.

- Khan, A., Kumar, R.
Experimental study and passive control of overexpanded plug nozzle jet
(2018) *J. Spacecr. Rockets*, 55 (3), pp. 776-782.

- Gretta, W.J., Smith, C.R.
The flow structure and statistics of a passive mixing tab
(1993) *J. Fluids Eng.*, 115 (255).
[Online]. Available

- Reeder, M.F., Samimy, M.
The evolution of a jet with vortex-generating tabs: real-time visualization and quantitative measurements
(1996) *J. Fluid Mech.*, 311, pp. 73-118.

- Lou, H., Alvi, F.S., Shih, C.
Active and passive control of supersonic impinging jets
(2006) *AIAA J.*, 44 (1), pp. 58-66.
Jan

- Samimy, M., Zaman, K.B.M.Q., Reeder, M.F.
Effect of tabs on the flow and noise field of an axisymmetric jet
(1993) *AIAA J.*, 31 (4), pp. 609-619.

- Akram, S., Rathakrishnan, E.
  Corrugated tabs for enhanced mixing of supersonic elliptic jet
  (2019) *J. Aerosp. Eng.*, 32 (1).
  Jan

- Akram, S., Rathakrishnan, E.
  Control of supersonic elliptic jet with ventilated tabs
  (2020) *Int. J. Turbo Jet Engines*, 37 (3), pp. 267-283.
  Aug

- Shaw, L.
  Twin-jet screech suppression
  (1990) *J. Aircr.*, 27 (8), pp. 708-715.

- André, B., Castelain, T., Bailly, C.
  Broadband shock-associated noise in screeching and non-screeching underexpanded supersonic jets
  (2013) *AIAA J.*, 51 (3), pp. 665-673.

- Sinha, A., Alkandry, H., Kearney-Fischer, M., Samimy, M.

  "The impulse response of a high-speed jet forced with localized arc filament plasma actuators," 2012

- Mitchell, D.M., Honnery, D.R., Soria, J.
  Nearfield structure of under-expanded elliptic jets
  (2013) *Exp. Fluids*, 54 (7).
  Jul

- Husain, H.S., Hussain, F.
  Elliptic jets. Part 3. Dynamics of preferred mode coherent structure
  (1994) *J. Fluid Mech.*, 248, p. 41.

- Rathakrishnan, E.
  Experimental studies on the limiting tab
  (2009) *AIAA J.*, 47 (10), pp. 2475-2485.
  Oct

- Khan, A., Kumar, R., Verma, S.B., Manisankar, C.
  Effect of cross wire tab orientation on twin jet mixing characteristics
  (2018) *Exp. Therm. Fluid Sci.*, 99, pp. 344-356.
  Dec

- Faheem, M., Khan, A., Kumar, R., Khan, S.A., Asrar, W., Sapardi, M.A.M.
  Experimental study of midplane jet evolution in multiple jets at Mac 2.0
  (2021) *Mater. Today Proc.*, 46, pp. 2677-2681.

- Khan, A., Akram, S., Kumar, R.
  Experimental study on enhancement of supersonic twin-jet mixing by vortex generators
  (2020) *Aerosp. Sci. Technol.*, 96.

- Faheem, M., Khan, A., Kumar, R., Khan, S.A.
  Experimental study of supersonic multiple jet flow field
  (2019) *Proc. of the 32nd International Symposiumon ShockWaves(ISSW32)*, pp. 2509-2516.
  no. December

- Krothapalli, A., McDaniel, J., Baganoff, D.
  Effect of slotting on the noise of an axisymmetric supersonic jet
  (1990) *AIAA J.*, 28 (12), pp. 2136-2138.

- Arun Kumar, P., Rathakrishnan, E.
Triangular tabs for supersonic jet mixing enhancement
(2014) *Aeronaut. J.*, 118 (1209), pp. 1245-1278.
Nov

- Goparaju, K., Gaitonde, D.V.
Dynamics of closely spaced supersonic jets
(2018) *J. Propuls. Power*, 34 (2), pp. 327-339.
Mar

- Katanoda, H., Miyazato, Y., Masuda, M., Matsuo, K.
Pitot pressures of correctly-expanded and underexpanded free jets from axisymmetric supersonic nozzles
(2000) *Shock Waves*, 10 (2), pp. 95-101.

- Faheem, M., Khan, A., Kumar, R., Afghan Khan, S., Asrar, W., Sapardi, A.M.
Experimental study on the mean flow characteristics of a supersonic multiple jet configuration
(2021) *Aerosp. Sci. Technol.*, 108, pp. 1-13.
Jan 106377

- Heeb, N., Gutmark, E., Kailasanath, K.
An experimental investigation of the flow dynamics of streamwise vortices of various strengths interacting with a supersonic jet
(2014) *Phys. Fluids*, 26 (8).
Aug

- Rathakrishnan, E.
Applied Gas Dynamics
(2010), 2nd ed. WILEY

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