AERODYNAMICS LAB

About the Lab:

The **Aerodynamics Laboratory**, established in 2012, at Department of Aerospace Engineering at LBRCE. The laboratory provides sophisticated facilities for understanding the aerodynamic aspects of fluids flow over bodies and through the ducts/nozzles. The laboratory enables the measurement of aerodynamic forces, surface pressure distributions, flow visualization, and study compressible flows through ducts and nozzles.

List of Facilities Available:

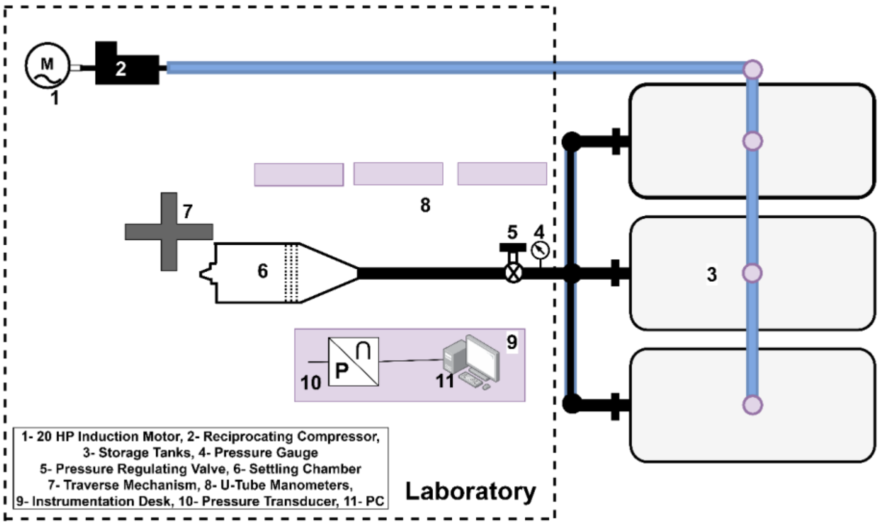
1. Open Jet Facility
2. Low-speed Wind Tunnel
3. Hele-Shaw Apparatus
4. Water Flow Channel
5. Recirculating Water Table
6. Shadowgraph System

1. Open Jet Facility

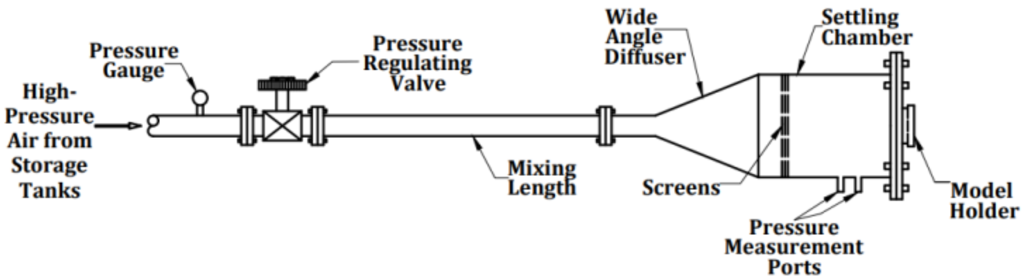
The experimental set-up includes two major parts: High-pressure air storage and Open jet test facility. The high-pressure air supply system consists of an air compressor, heavy duty pipeline and storage tanks as major components. A three-cylinder, single stage, air cooled, reciprocating air compressor, of capacity 0.33 m^3/sec, is used for compressing the air to the required pressure. A 25 HP, 3-phase induction motor is used to drive the compressor. Initially, the atmospheric air is drawn into the compressor through air filters. After compression, the air is then passed to the storage tanks through heavy-duty pipeline of capacity up to 34.47 bar. Three storage tanks are provided with a total storage capacity of 4.7 m^3. The tanks are designed to withstand pressure up to 41.36 bar, while safety valves are provided on each tank at 13.78 bar to keep the factor of safety of 3. Along with this high-pressure supply system, the laboratory is equipped with an open jet test facility, traverse mechanism, and other necessary instrumentation like manometers, pressure transducer and personal computer for data acquisition.

The compressed air from the storage tanks is supplied to the open jet test facility through a mixing length. The open jet facility consists of a settling chamber with 600 mm length and 300 mm diameter. A wide-angle diffuser connects the settling chamber with mixing length. The mixing length is connected to the storage tanks. The pressure in the storage tanks is checked by a pressure gauge. Before entering the settling chamber, the air is passed through a wire-mesh screens of three in number placed just after the wide-angle diffuser to reduce the turbulence level at the nozzle inlet.

The test model with base plate is fixed to a 100 mm diameter nipple with "O" ring sealing, placed on the other end of the settling chamber.



Layout of open jet facility



Schematic diagram of open jet test facility

Air Compressor

Storage Tanks

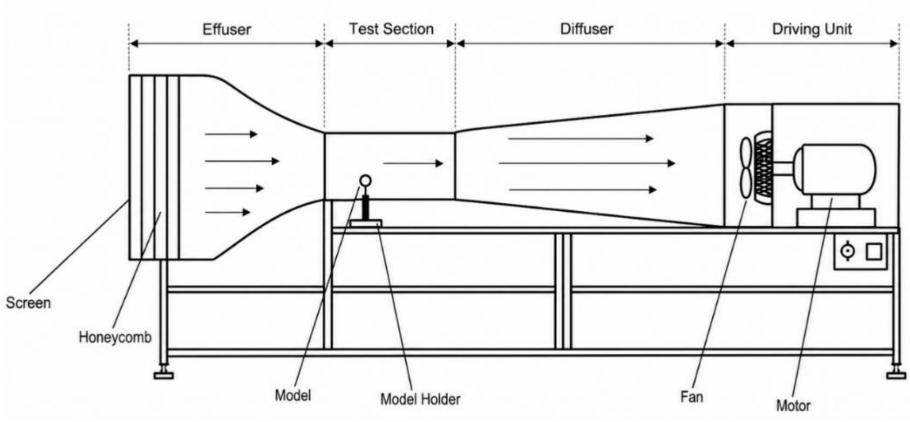
Open Jet Test Facility

Settling Chamber

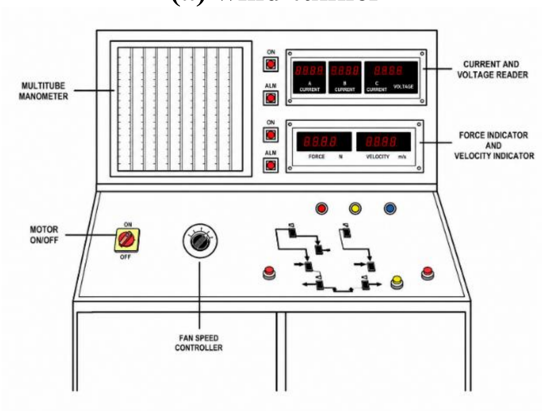
Pictorial View of Facility

2. Low-Speed Wind Tunnel

The facility consists of five major components: a convergent cone (effuser), test-section, diffuser, driving unit and control panel with each part that serves specific function. The effuser, located upstream of the test-section, is a converging section where the fluid accelerates from a very low speed to the desired conditions at the test-section. It includes screens and a honeycomb structure to minimize turbulence and ensure a uniform airflow to the test section. The model is positioned in the test-section, where the airflow exits from the effuser downstream, and necessary measurements and observations are conducted. The contraction ratio of effuser is 9:1. The wind tunnel test-section is 300 mm X 300 mm. The diffuser role is to transform the kinetic energy of the air leaving the test-section into pressure energy. The driving unit is crucial for maintaining a continuous air supply to the test-section and the most vital component for the wind tunnel operation. An axial fan driven by a DC motor serves as the driving unit in this setup, capable of delivering air at speeds up to 35 m/s. The power requirements of the driving unit are AC 3PH, 440V, 15 Amp electrical supply. The control panel includes indicators for lift, drag, and pitching moment, as well as M.C.B. Digital pressure and velocity indicators are also available on the control panel.



(a) wind tunnel



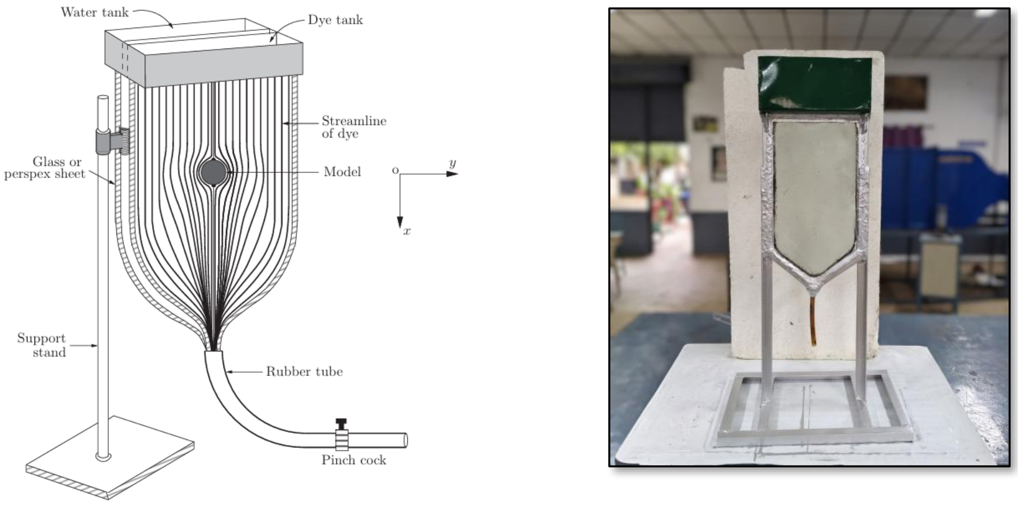
(b) control panel

Schematic diagram of wind tunnel test facility

Pictorial View of Low-Speed Wind Tunnel

3. Hele-Shaw Apparatus

The Hele-Shaw apparatus produces a flow pattern which is similar to that of potential flow. It is an analogy experiment known as Hele-Shaw analogy. The flow in the apparatus is a highly viscous flow between two parallel plates with a very small gap between them. In this flow the inertia force is negligible compared to the viscous force. Under this condition the flow equation has the same form as that of Euler's potential flow, however it does not satisfy the no-slip wall boundary condition. There is a slip at the wall. Many interesting phenomena pertaining to potential flow can be observed using this apparatus. The Hele-Shaw flow is a low Reynolds number flow which has wide application in flow visualization apparatus because of its surprising property of reproducing the streamlines of potential flows (i.e., infinite Reynolds number flows).



Schematic and Pictorial View of Hele-Shaw apparatus

This equipment basically consists of two parallel plates made of thick, trans parent (glass or plastic) plates clamped together along the edges with a narrow (about 1 mm) space in between them. The assembly of these two transparent sheets kept parallel with a uniform narrow space between them is provided with two small tanks of rectangular cross-section at the top end, as shown in Figure. The tanks are connected to the rectangular slit formed by the trans parent sheets by a set of small holes (about 1-mm diameter) arranged in a row, as shown in Figure. The holes from the two tanks are arranged to occupy alternate locations for communication. The other end of the rectangular slit is made to terminate in a circular hole, by gradually narrowing it after a specified distance from the tanks at the top. One of the tanks is filled with water and the other with dye (say potassium permanganate). Initially the circular passage at the bottom end of the apparatus is closed and the apparatus is kept vertical. Once the passage is opened, flow of water and dye takes place through the rectangular passage. Within a short duration, a flow field of water with uniform streamlines of dye in it is established in the narrow passage between the transparent plates.

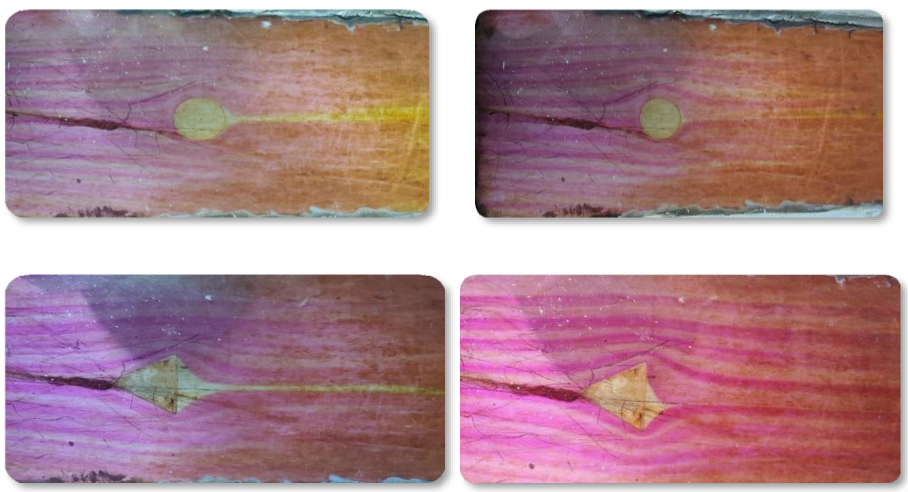


Fig. Potential Flow Patterns Over Different Objects

4. Water Flow Channel

Water flow channel is a simple duct through which water is made to flow with uniform velocity over the length of the channel. The uniform flow portion can be used to visualize flow past objects. The channel is made of Stainless-Steel sheet of 3 mm thickness, the sheet is bent into the shape as shown in Figure. The width of the test section is about 280mm, and the depth of water will be maintained at 8mm. A pictorial view of a water flow channel, of rectangular cross-section is shown in Figure. Water from the chamber spills over the inclined plate and is conditioned using an array of wire-meshes, before reaching the test-section. It is essential to ensure that the flow quality is uniform in the test section. For this a color dye may be injected at specified locations across the test-section width. If the dye streaks in the test-section are parallel and smooth, the quality of flow can be taken as good for any visualization study. The velocity of the flow may be measured using the floating-particle method technique, over the length of the test-section. The uniformity of the flow may also be checked by observing a floating body (say, a tiny bit of paper) moving from the beginning to the end of test-section of the channel. If the test-section flow is uniform, a tiny floating object will travel straight and parallel to the channel floor and sidewalls.

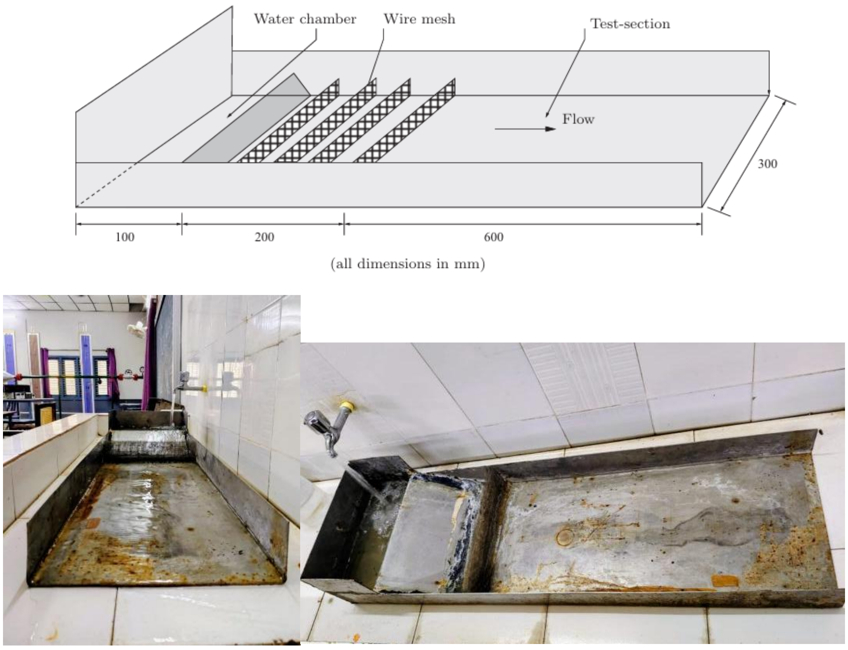


Fig. Schematic and Pictorial View of Water Flow Channel

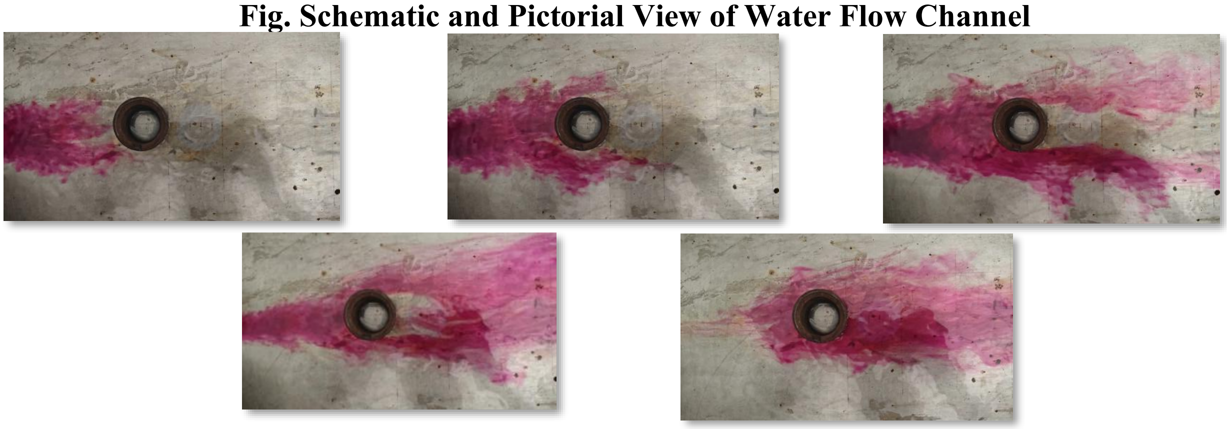


Fig. Flow Visualization Over a Circular Cylinder

5. Water Table

The **Water Table** is a low-speed flow visualization facility used to study the flow of water over different objects and geometries. It enables students to observe **streamline patterns, flow separation, wake formation, and vortex structures** around test models. The facility provides a simple and effective means of visualizing fluid-flow behavior and relating experimental observations to fundamental concepts of fluid mechanics and aerodynamics

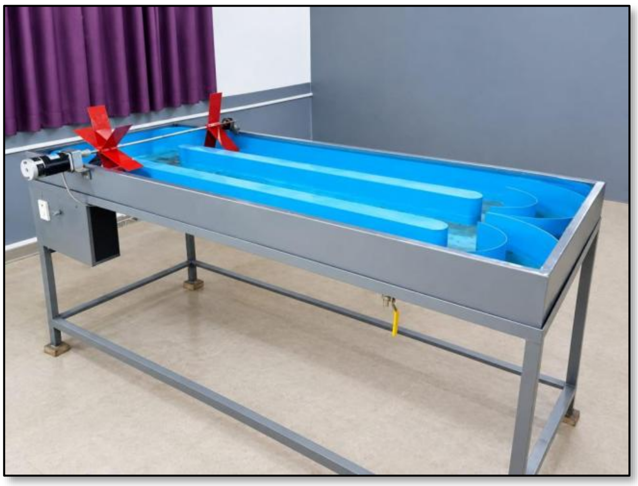


Fig. Pictorial View of Water Table

6. Shadowgraph System

The schematic of shadowgraph system used in the present investigation is shown in Fig. 3.5. Though the shadowgraph system is simple to use, it demands high precision and high-quality optical components along with a high-speed camera to obtain quality visualization images. The major components of a shadowgraph system include a light source, reflector/mirror, a screen and a high-speed camera. The light rays emitted from the light source, a halogen light source of capacity 15 V and 150 W, are directed onto the parabolic mirror. The mirror used in the present study is of parabolic type with a diameter of 150 mm having a focal length of 1200 mm and a surface finish quality of $\lambda/12$. Then from the surface of the mirror the light rays are reflected towards the flow field after making them normal to the flow field. When the light rays are passed through the flow field, the light rays experience difference in the refractive index because of changes in density gradient. If the density gradient is the same everywhere in the flow field, the light rays will be deflected by an equal amount and no changes in the illumination is observed on the screen. If there are changes in the density gradient, which represent the presence of shock waves, the light rays tend to converge or diverge there by forming dark and bright patches on the screen. The bright patches represent the zone where there is abrupt change in the density and vice versa. These bright and dark patches visually represent the fluid flow-field. The flow-field that is present on the screen is captured by a high-speed camera in the form of videography and the same will be processed to obtain a picture that better represents the flow field. The process will be repeated to capture the flow-field at various operating conditions.

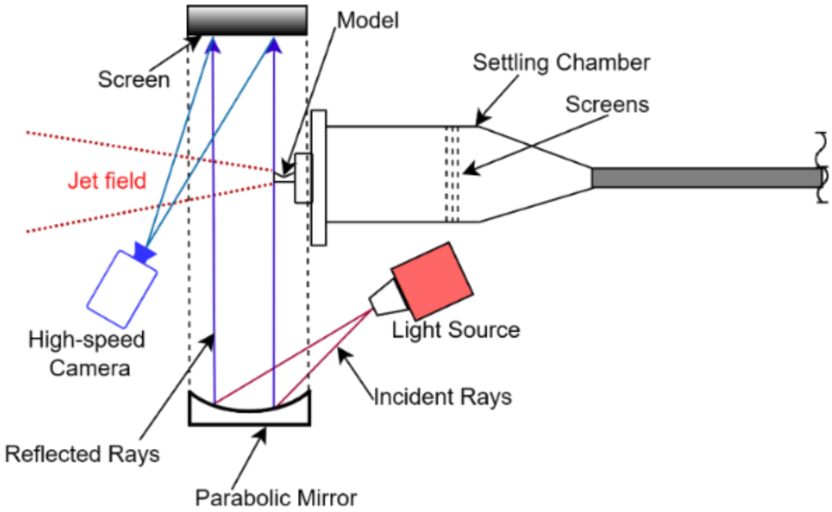


Fig. Schematic of Shadowgraph System

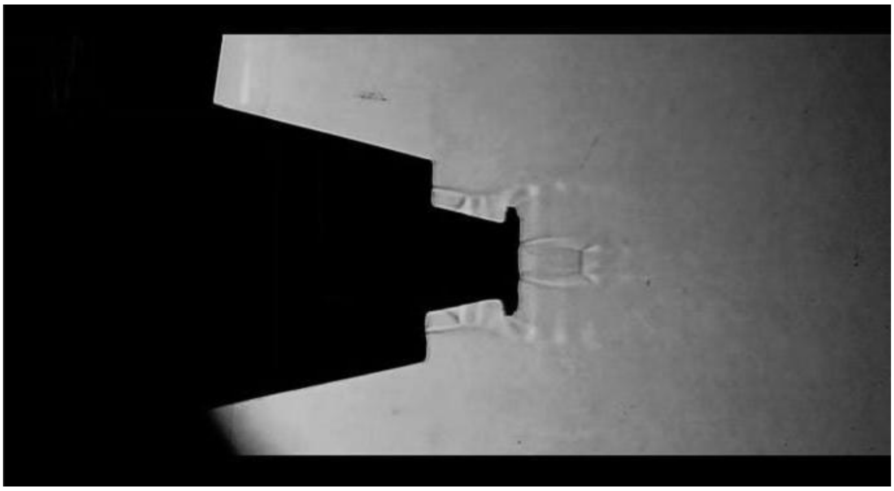


Fig. Schematic of Underexpanded Jet Emanating from a Co-flow Nozzle

Equipment Inventory & Capital Expenditure:

S.No.	Name of the Equipment	Quantity	Cost
1	Air Compressor (700 CFM)	1	2,86,471/-
2	Open jet Facility (Pressure vessels 2 No's, Settling Chamber, Heavy Duty Pipeline)	1	3,84,492/-
3	Traverse Mechanism	1	1,42,155/-
4	Low-speed Wind Tunnel	1	4,86,625/-
5	Recirculating Water Table	1	80,000/-
6	Pressure Vessel 2.5 m3Volume	1	1,04,365/-
7	Digital 16 Channel Pressure Scanner (16-Pressure Sensors (0 to 200 psi), Data Acquisition System with NI card)	1	2,58,066/-
8	Parabolic Mirror (6’’ F8D = 153 mm/ F= 1200 mm)	2	29,169/-
9	Parabolic Mirror (6’’ F8D = 153 mm/ F= 1200 mm)	1	8,400/-
10	Open Channel	2	In house Fabrication
11	Hele-Shaw Apparatus	2	In house Fabrication
12	Multi Tube Manometer	1	In house Fabrication
Total Cost			**17,79,743/-**

People:

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Lab In-charge

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Present Ph.D Scholars

Mr. V. Mani Kumar	Mr. K. B. V. Satya Prakash	Mr. Kedarnath Mahapathro	Mr. I. Dakshina Murthy	Mr. Nazumuddin Shaik
Assistant Professor Dept. of ME, UCE, JNTUK, Kakinada, Andhra Pradesh	Assistant Professor Dept. of ME, Andhra Layola Institute of Engg. & Technology, Vijayawada	Assistant Professor Dept. of ME, Godavari Global University, Rajahmundry, Andhra Pradesh	Sr. Assistant Professor Dept. of Aerospace Engg., LBRCE, Mylavaram, Andhra Pradesh	Sr. Assistant Professor Dept. of Aerospace Engg., LBRCE, Mylavaram, Andhra Pradesh

Past Ph.D Scholars

Dr. T. Srinivasa Rao

Professor & HoD

Dept. of ME,

VVIT University, Guntur, Andhra Pradesh

Supporting Staff

Mr. D. Seetarami Reddy

Lab Technician

Research Areas:

- **Experimental Aerodynamics**
- **Compressible and High-Speed Flows through Nozzles and Ducts**
- **Supersonic Jets and Jet Flow Control**
- **Fluidic Injection and Thrust Vectoring**
- **Flow Visualization**
- **Experimental Fluid Mechanics**

Sponsored Research:

Project Title: Flow Characteristics of High-Speed Co-flow Jets Funding

PI: Mr. I. Dakshina Murthy

Agency: University Grants Commission (UGC) – Minor Research

Project Scheme Reference No: MRP-7049/16 (SERO/UGC)

Fund Received: INR 4,30,000 (USD 6600)

Project Duration: 2 Years (Mar 2018 to Mar 2020)

Research Publications (Selected):

Peer Reviewed Journals:

[1] Murthy, I.D., Lovaraju, P. & Raju, V.R. Flow Field Characteristics of Single Expansion Nozzle. Russ. Aeronaut. 69, 263272 (2026). https://doi.org/10.3103/S1068799826010277

[2] Prakash, K.B., Lovaraju, P. & Rathakrishnan, E. Effect of Spacing and Canting on Twinjet Characteristics. *Fluid Dyn* **60**, 145 (2025). https://doi.org/10.1134/S0015462825603134

[3] Pinnam, Lovaraju, Kurapati, Ruby, Inturi, Dakshina Murthy and Rathakrishnan, Ethirajan. "Flow field characteristics of isolator with fluidic injection" International Journal of Turbo & Jet-Engines, vol. 43, no. 1, 2026, pp. 215222. https://doi.org/10.1515/tjj-2025-0075

[4] Inturi DM, Pinnam L, Vegesna RR. Characterization of jets emanating from single expansion nozzles. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering. 2025;239(13):1591-1609. doi:10.1177/09544100251331688

[5] Inturi Dakshina Murthy, Pinnam Lovaraju, Vegesna Ramachandra Raju and Ethirajan Rathakrishnan Effect of secondary fluid injection on flow through supersonic nozzle. Journal of Visualization, 27, 1049–1058 (2024). https://doi.org/10.1007/s12650-024-01013-w

[6] Inturi, Dakshina Murthy, Pinnam, Lovaraju and Vegesna, Ramachandra Raju. "Effect of free boundary on the performance of single expansion nozzle" International Journal of Turbo & Jet-Engines, vol. 41, no. 2, 2024, pp. 253265. https://doi.org/10.1515/tjj-2023-0034

[7] Inturi, D.M., Lovaraju, P., Tanneeru, S.R. et al. Effect of Eccentricity on Co-flow Jet Characteristics. Iran J Sci Technol Trans Mech Eng 46, 407–420 (2022). https://doi.org/10.1007/s40997-021-00444-2

[8] E. Sri Ramya P. Lovaraju, I. Dakshina Murthy, S. Thanigaiarasu, Ethirajan Rathakrishnan "Experimental and Computational Investigations on Flow Characteristics of Supersonic Ejector", International Review of Aerospace Engineering, Volume 13, Issue 1, Feb 2020. DOI: https://doi.org/10.15866/irease.v13i1.18108

[9] Srinivasarao, T., Murthy, I. Dakshina, Lovaraju, P. and Rathakrishnan, E.. "Effect of Inner Nozzle Lip Thickness on Co-flow Jet Characteristics" *International Journal of Turbo & Jet-Engines*, vol. 34, no. 3, 2017, pp. 287-293. https://doi.org/10.1515/tjj-2016-0004

Peer reviewed Conferences:

[1] Inturi, D.M., Lovaraju, P., Pasupuleti, R.K. (2025). Effect of Truncation and Axial Location of Plug Geometry on the Performance of Aerospike Nozzle. In: Kothadia, H., Arun, K.R., Rajesh, G., Arakeri, J.H. (eds) Proceedings of Fluid Mechanics and Fluid Power (FMFP) 2023, Vol. 2. FMFP 2023. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-97-6783-0_19

[2] Inturi, DM, Pinnam, L, &Vegesna, RR. "Experimental and Computational Studies on Flow Characteristics of Single Expansion Nozzle." Proceedings of the ASME 2021 Fluids Engineering Division Summer Meeting. Volume 3: Fluid Mechanics; Micro and Nano Fluid Dynamics; Multiphase Flow. Virtual, online. August 10–12, 2021. V003T05A024. ASME. https://doi.org/10.1115/FEDSM2021-66275

[3] I Dakshina Murthy, V Ramachandra Raju, P Lovaraju "Experimental and Computational Studies on Half-ConvergentDivergent Rectangular Nozzle" Proceedings of Southeast Asia Workshop on Aerospace Engineering (SAWAE-2019) 29-30 Aug 2019, Organized by University of Putra and University of Technology Malaysia, Kuala Lumpur, Malaysia

[4] K Sai Sarath, I Dakshina Murthy, R Subbarao and Ravi Gujjula "Influence of Heat Treatment on Mechanical and Micro Structural Properties of Titanium Alloys for Enhanced Applications" ICAAMM 26-28 June 2016, Organized by MLRIT, Hyderabad, India. Published in Materials Today Proceedings https://doi.org/10.1016/j.matpr.2017.07.151