The University of Texas at Austin
Aerospace Engineering
and Engineering Mechanics
Cockrell School of Engineering

ASE 162M High-Speed Aerodynamics
Section 14275

Tuesday: 4:00 - 6:00 pm

Final Exam

Andrew Doty
Due Date: December 14, 2024

Contents

1 Paper 1: Visualization of Supersonic Free and Confined Jet using Planar Laser Mie Scattering Technique

1.1 Paper Information

Title: Visualization of Supersonic Free and Confined Jet using Planar Laser Mie Scattering Technique
Authors: S.K. Karthick, G. Jagadeesh and K.P.J. Reddy
Publication: Journal of the Indian Institute of Science
Publication Date: January-March 2016

1.2 Citation (Chicago Format)

Karthick, S.K., G. Jagadeesh, and K.P.J. Reddy. "Visualization of Supersonic Free and Confined Jet using Planar Laser Mie Scattering Technique." Journal of the Indian Institute of Science 96, no. 1 (2016): 29-45.

1.3 Experimental Technique

The experimental technique used is Planar Laser Mie Scattering (PLMS), which is an optical flow visualization method.

1.4 Methodology

PLMS works by illuminating particles in the flow field with a laser sheet and capturing the scattered light. The technique involves:

- Using a high-power laser converted into a sheet (thickness 0.5 mm).
- Seeding the flow with particles (DOP or TiO2).
- Capturing scattered light using high-speed cameras.
- Processing images to extract flow features.

1.5 Experimental Apparatus

The setup included:

- A Mach 2.0 supersonic wind tunnel with optical access.
- Nd-YAG laser (532 nm, 500 mJ) for free jet studies.
- Nd-YLF laser (527 nm, 24 mJ) for confined jet studies.
- Phantom Miro 110 high-speed camera.
- An in-house designed seeder unit with a modified Laskin nozzle.
- Optical glass windows for flow visualization.

1.6 Flow Application

The technique was applied to:

- Supersonic axisymmetric free jet (Mach 1.37-2.5).
- Supersonic rectangular confined jet (Mach 2.0).

The authors chose PLMS because it provides:

- Instantaneous flow field visualization.
- The ability to capture both large-scale structures and fine details.

- Non-intrusive measurement capability.

1.7 Key Conclusions

1. PLMS successfully captured important flow features, including the Mach disc, shear layer instability, and shock cells in supersonic jets.
2. The shock cell spacing increases with increasing Mach number ratio.
3. Particle lag significantly affects the magnitude of Reynolds stresses in supersonic flow measurements.

1.8 Suggested Improvements

1. Implement advanced particle tracking algorithms to better quantify particle lag effects.
2. Develop improved seeding methods for near-wall regions.
3. Extend the technique to higher Mach numbers with better temperature control to prevent window fogging.

1.9 Insights Gained

1. Particle selection and seeding methodology are crucial for accurate flow visualization in supersonic flows.
2. The semi-local scaling shows better agreement with incompressible flows than conventional Morkovin's scaling.
3. Proper image processing techniques are essential for extracting meaningful flow features from raw PLMS data.

2 Paper 2: Particle Lag in Supersonic Turbulent Boundary Layers

2.1 Paper Information

Title: The Effect of Particle Lag on Supersonic Turbulent Boundary Layer Statistics
Authors: K. Todd Lowe, Gwibo Byun and Roger L. Simpson
Publication: AIAA SciTech Forum
Publication Date: January 2014

2.2 Citation (Chicago Format)

Lowe, K. Todd, Gwibo Byun, and Roger L. Simpson. "The Effect of Particle Lag on Supersonic Turbulent Boundary Layer Statistics." In 52nd Aerospace Sciences Meeting, AIAA SciTech Forum. 2014.

2.3 Experimental Technique

The study uses Laser Doppler Velocimetry (LDV) combined with particle lag analysis to study supersonic turbulent boundary layers.

2.4 Methodology

The technique involves:

- Three-component laser Doppler velocimetry measurements.
- Analysis of particle response to turbulent fluctuations.
- Application of a linear first-order lag correction scheme.

- Use of Reynolds stress spectral functions for corrections.

2.5 Experimental Apparatus

Key components included:

- Mach 2.0 supersonic wind tunnel with optical access.
- Small supersonic LDV system with 3 measurement volumes.
- Diode-pumped solid state laser (532 nm, 1.5 W).
- Argon ion laser (514.5 nm and 488 nm, 1.9 W).
- High-quality optical glass window for LDV measurements.
- DOP seeding system with modified Laskin nozzle.

2.6 Flow Application

The technique was applied to:

- Mach 2.0 supersonic smooth wall turbulent boundary layer.
- Reynolds number based on momentum thickness of approximately 15,582.

The authors chose this technique because:

- It provides detailed turbulence statistics.
- It allows for quantification of particle lag effects.
- It enables correction of Reynolds stress measurements.

2.7 Key Conclusions

1. Particle lag significantly affects the magnitude of turbulence quantities in high-speed flows.
2. Normal-to-wall stress is most susceptible to frequency filtering effects due to particle lag.
3. Semi-local scaling shows better agreement with incompressible flows than conventional Morkovin's scaling.

2.8 Suggested Improvements

1. Develop direct measurement techniques for Reynolds stress spectra in supersonic flows.
2. Implement advanced particle tracking methods for better lag quantification.
3. Extend the study to higher Mach numbers and different flow configurations.

3 Conclusion

1. Both studies highlight the critical importance of particle behavior in supersonic flow measurements and the importance of having a good reference mask, accurate particle tracking, and a high-quality camera.
2. The complementary nature of PLMS and LDV techniques provides comprehensive flow field information when both are used together.
3. Particle lag effects must be carefully considered in both visualization and quantitative measurements.