Watch Webinar Recording Here

CFD Simulations of Supersonic Intake Ducts

10 August 2022 | Technical Topic Webinar

Vijay Kumar Veera M.Phil., M.Tech.

EIT Lecturer and Course Coordinator in Mechanical Engineering

CRICOS Provider Number: 03567C | Higher Education Provider Number: 14008 | RTO Provider Number: 51971

About EIT

We are dedicated to ensuring that you receive a world-class education and gain skills that you can immediately implement in the workforce.

Engineering Specialists

EIT is one of the only institutes in the world specializing in Engineering. We deliver professional certificates, diplomas, advanced diplomas, undergraduate and graduate certificates, bachelor's and master's degrees, and a Doctor of Engineering.

Industry Oriented Programs

Our programs are designed by industry experts, ensuring you graduate with cutting-edge skills that are valued by employers. Our program content remains current with rapidly changing technology and industry developments.

World-Class Australia Accredited Education

Our vocational programs and higher education degrees are registered and accredited by the Australian Government. We have programs that are also recognized under three international engineering accords.

Industry Experienced Lecturers

Our lecturers are highly experienced engineers and subject specialists with applied knowledge. The technologies employed by EIT, both online and on-campus, enable us to source our lecturers from a large, global pool of expertise.

Unique Delivery Model

We deliver our programs via a unique methodology that makes use of live and interactive webinars, an international pool of expert lecturers, dedicated learning support officers, and state-of-the-art technologies such as hands-on workshops, remote laboratories, and simulation software.

CRICOS Provider Number: 03567C | Higher Education Provider Number: 14008 | RTO Provider Number: 51971

Introduction - Presenter

Vijay Kumar Veera

Vijay Kumar Veera is a qualified Aerospace Engineer with over 11 years of experience in using CFD methodologies to simulate industrial and academic problems. He has obtained an M.Phil degree in Engineering from Cambridge University in UK and has M.Tech and B.Tech degrees from Indian Institute of Technology in Bombay and Madras respectively. His expertise is in capturing Fluid flow phenomena using computational methods. He has worked with major organizations in Australia and UK with Red Bull F1, Mercedes F1, Boeing, Airbus, Thales, DSTO, Fisher & Paykel some of the notable clients.

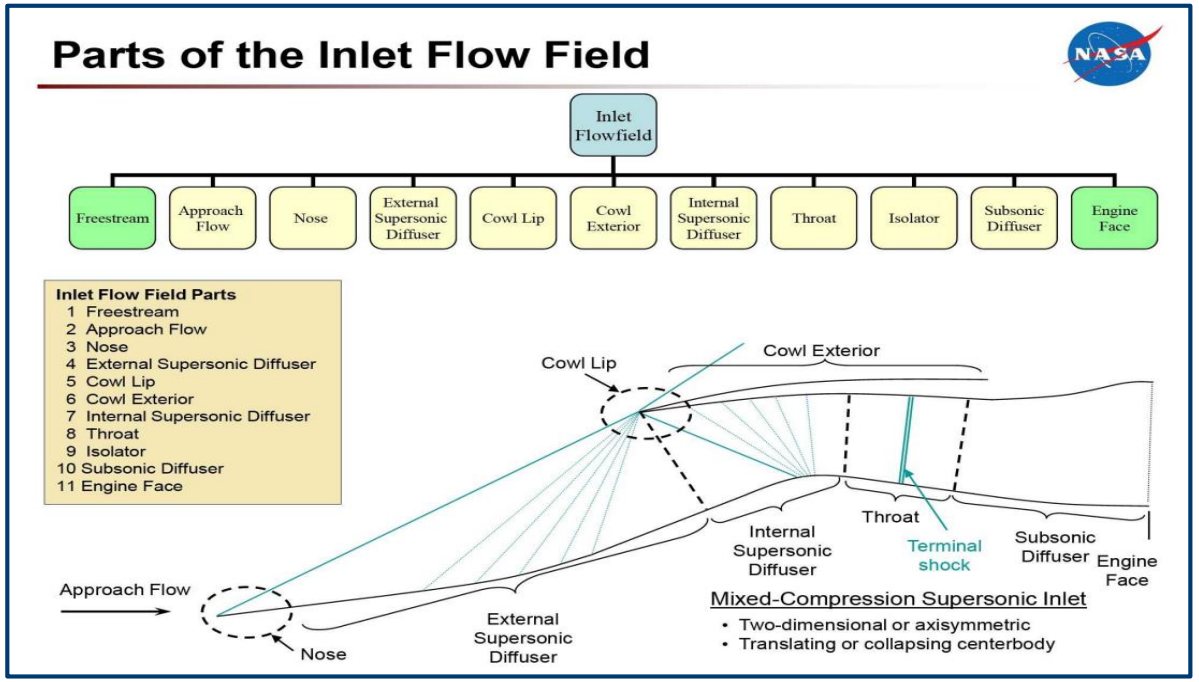
In his current role as a Unit lecturer and Course Coordinator at EIT, he has been instrumental in developing lecture materials for teaching Advanced fluid dynamics and Aerodynamics units for students pursuing Master of Mechanical Engineering. His passion is in teaching computational fluid dynamic techniques for solving real world problems, which are becoming highly popular with professional engineers wanting to advance their careers to the next level. He is a passionate educator and an advocate for using real world examples in the classroom.

Agenda

1	Welcome and Introduction
2	Supersonic Flows
3	CFD Simulation Methodology
4	Case Study
5	Contours – Density, Mach Numbers, Temperature, Static Pressure, Strain Rate, Total Pressure
6	Design Improvements
7	Conclusion and Q&A

SUPERSONIC FLOWS AND CFD

- Supersonic inlet aerodynamics involves flow compression, flow deceleration, shock waves, turbulent boundary layers, shock / boundary layer interactions, separated flow, flow control, etc...
- The goal of supersonic intake design is to maximize total pressure recovery, limit total pressure distortion, and limit inlet drag. Accurate prediction of flow patterns within the intake is essential in achieving these design objectives.
- This webinar explains how Computational Fluid Dynamic (CFD) approach is used to visualise complex flow patterns observed in supersonic flow intakes.
- The simulations are conducted using Ansys Fluent which is a widely available commercial CFD solver.



Slater, J.W. and Folk, T.C., 2009, September. Design and Analysis Tools for Supersonic Inlets; In Fundamental Aeronautics 2009; Technical Conference: Supersonic Program

CFD SIMULATION METHODOLOGY

Engineering Institute of Technology.

Repeat the process if necessary

GEOMETRY CREATION

- Identify the fluid domain to capture necessary physics

MESH GENERATION

- Generate a mesh that captures regions of high gradients with sufficient resolution

CASE SETUP

- Choose the appropriate models to represent flow physics
- Specify the correct boundary conditions
- Choose the solver settings necessary to run the solver.

RUN SOLVER

- Solve the governing equations iteratively until the residuals drop to low values.

POST PROCESS

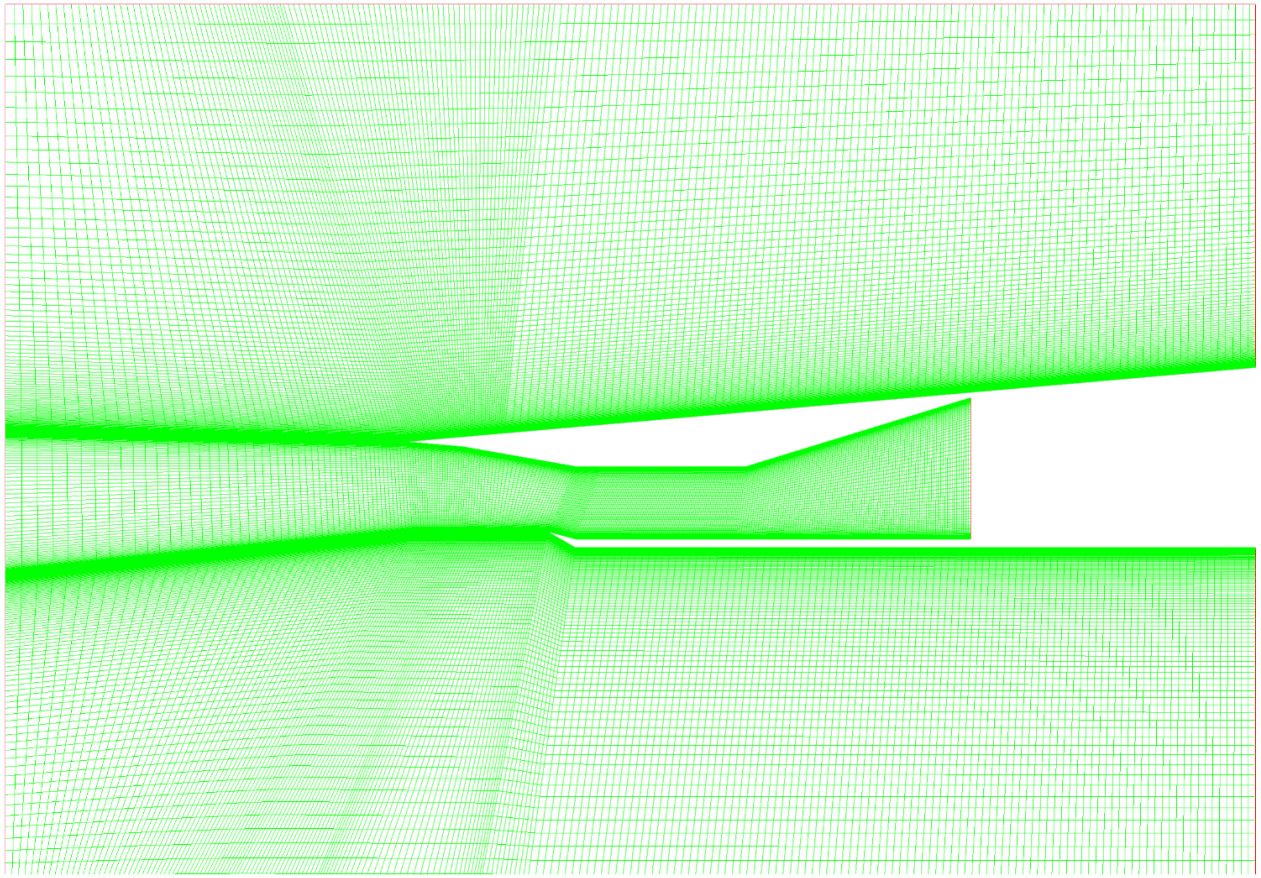
- Visualise the flow field by plotting contours, vectors, streamlines and animations.

VALIDATE RESULTS

- Compare with available experimental data to evaluate the efficacy of the CFD model.

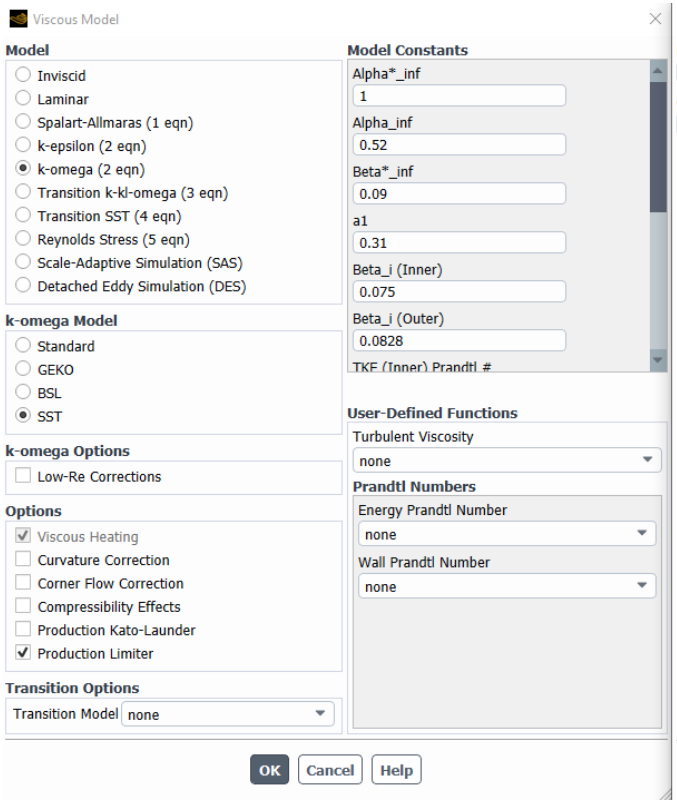
Geometry Creation & Mesh Generation

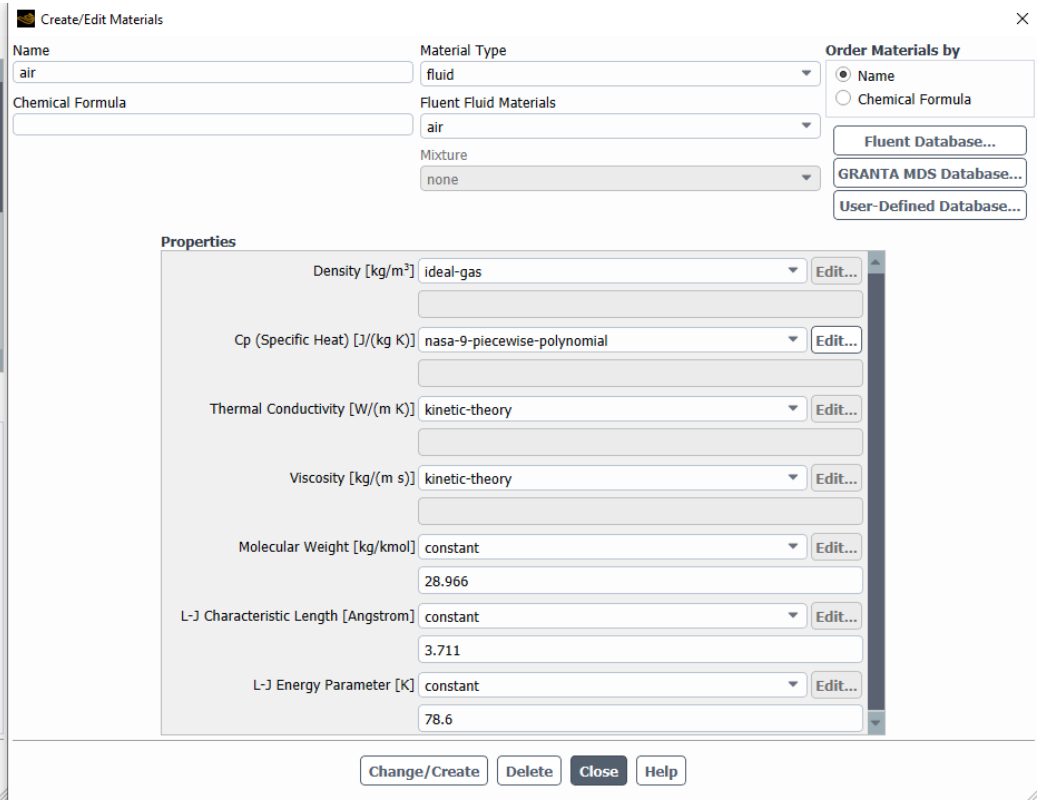
- Create a model of the computational domain in ANSYS SpaceClaim.
- Sub-divide the geometry into “blocks”.
- Mesh each block using cartesian mesh, ensuring smooth transition of mesh sizing between the blocks.
- Specify necessary boundary conditions.



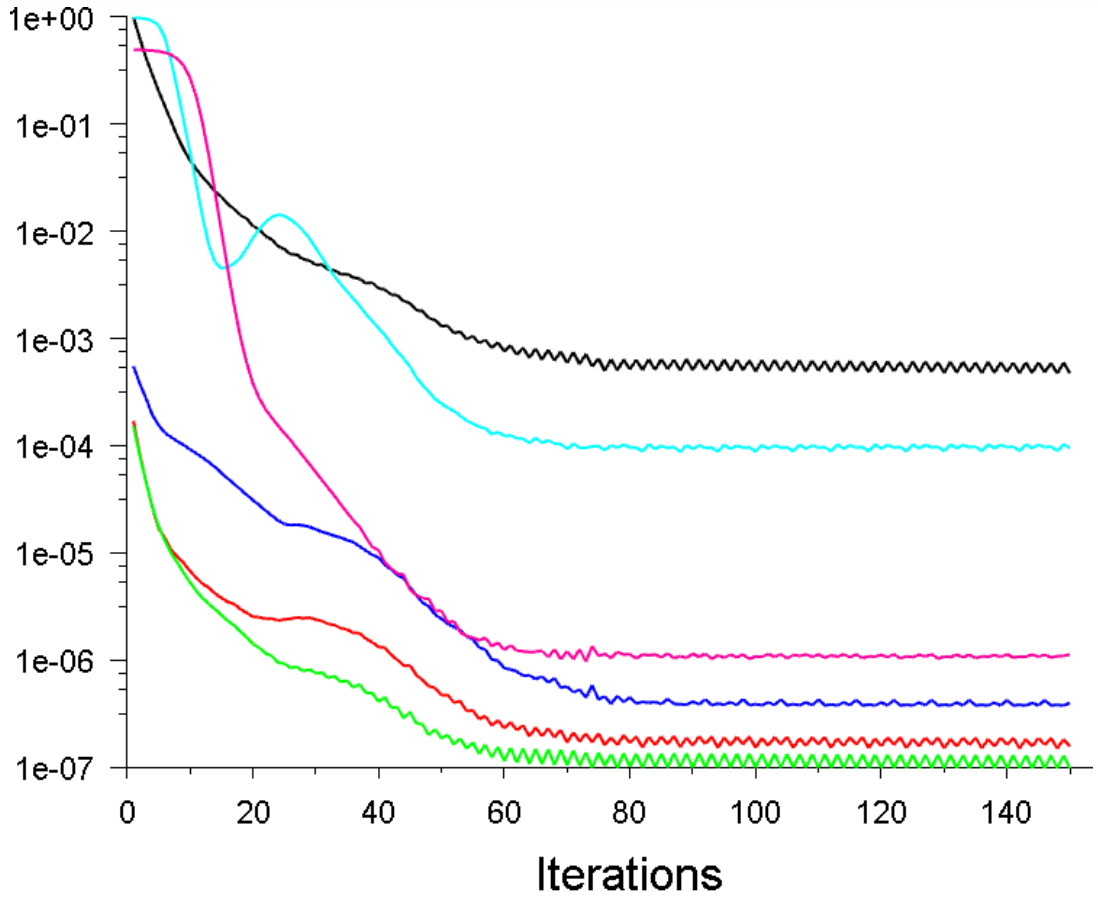
Case Setup & Solver Settings

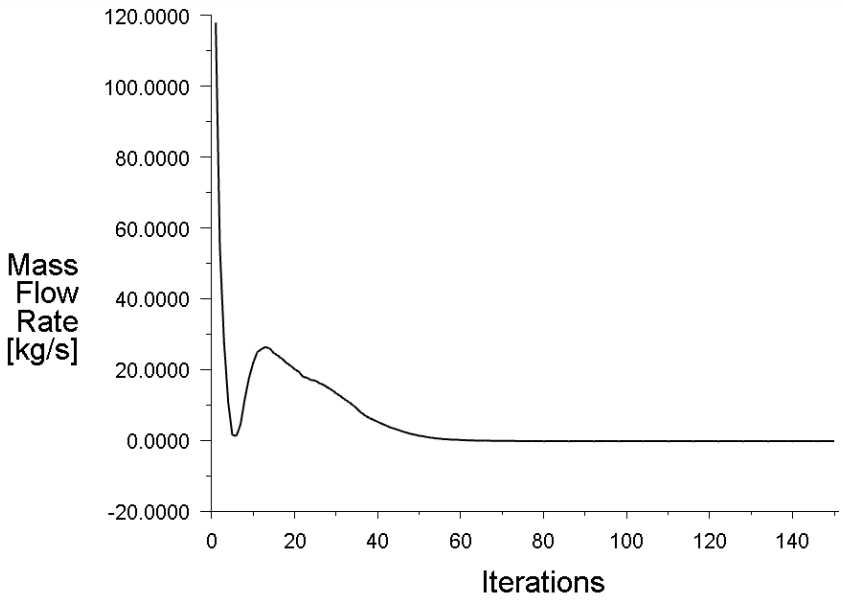
- K-ω turbulence model (Industry best-practice).
- Model air as ideal gas.
- Specify inlet Mach number and direction at inlet
- Zero pressure condition at outlet.
- Adiabatic no-slip condition at wall boundaries.
- Choose pressure-based coupled solver.
- Solve the flow equations with second order discretization.

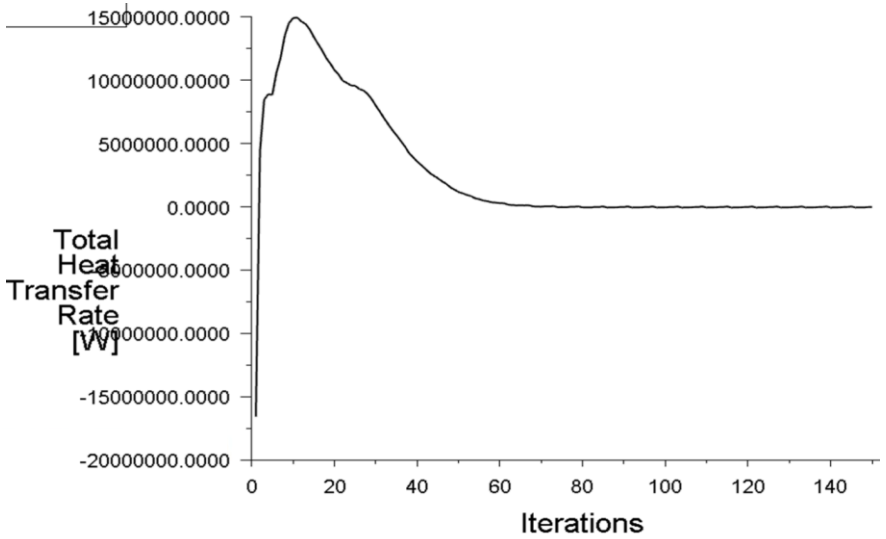




Simulation Postprocessing



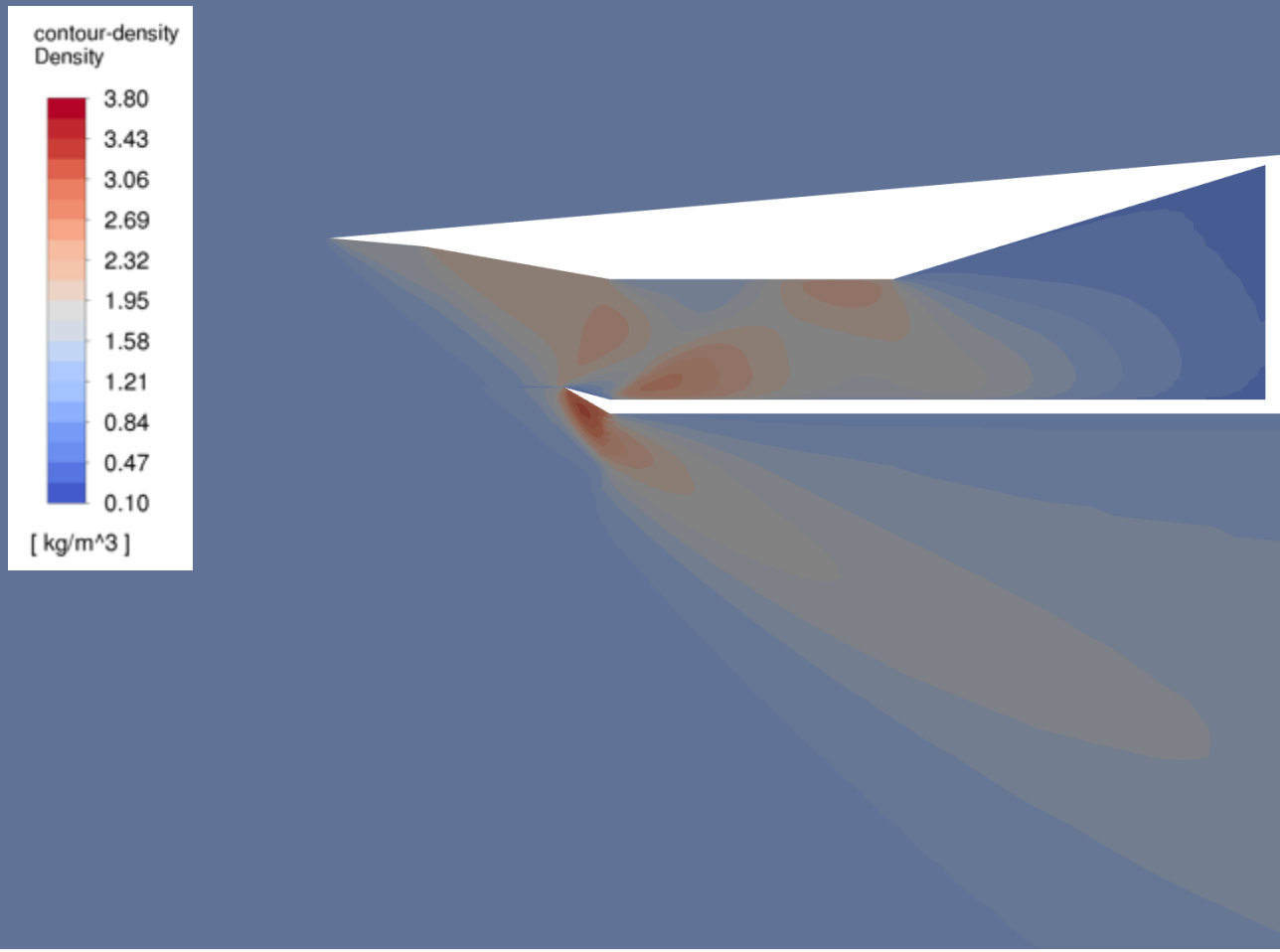




- Track the progress of residuals. Ideally drop by three orders of magnitude.
- Create report definitions for mass imbalance and heat transfer imbalance. Run simulation till they flatline at zero.

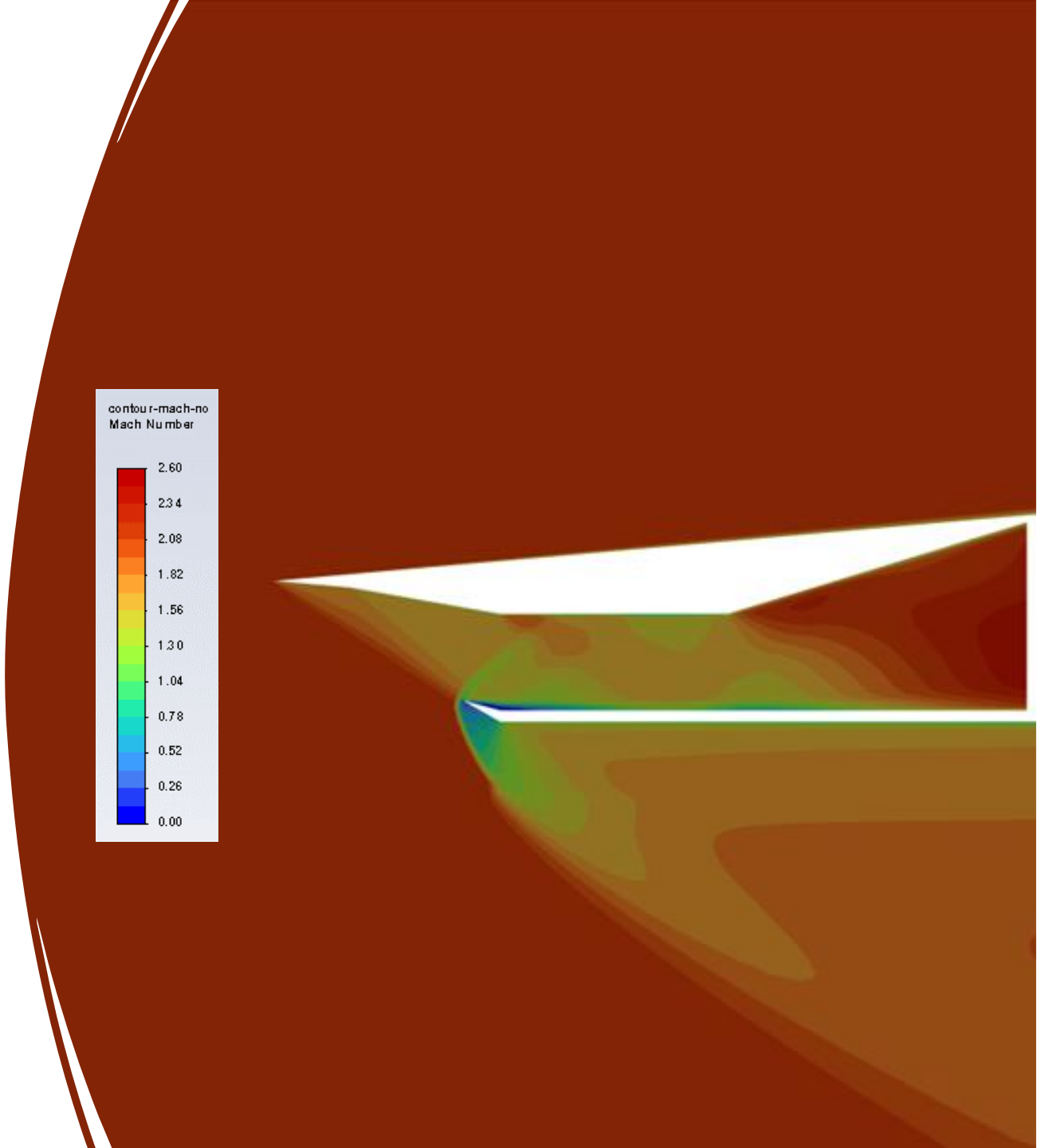
Density contours

- Regions of high density highlight regions of flow compression due to formation of shock waves.
- Shocks get reflected between top and bottom walls of the intake.
- Shock position greatly affects mass flow into the intake.



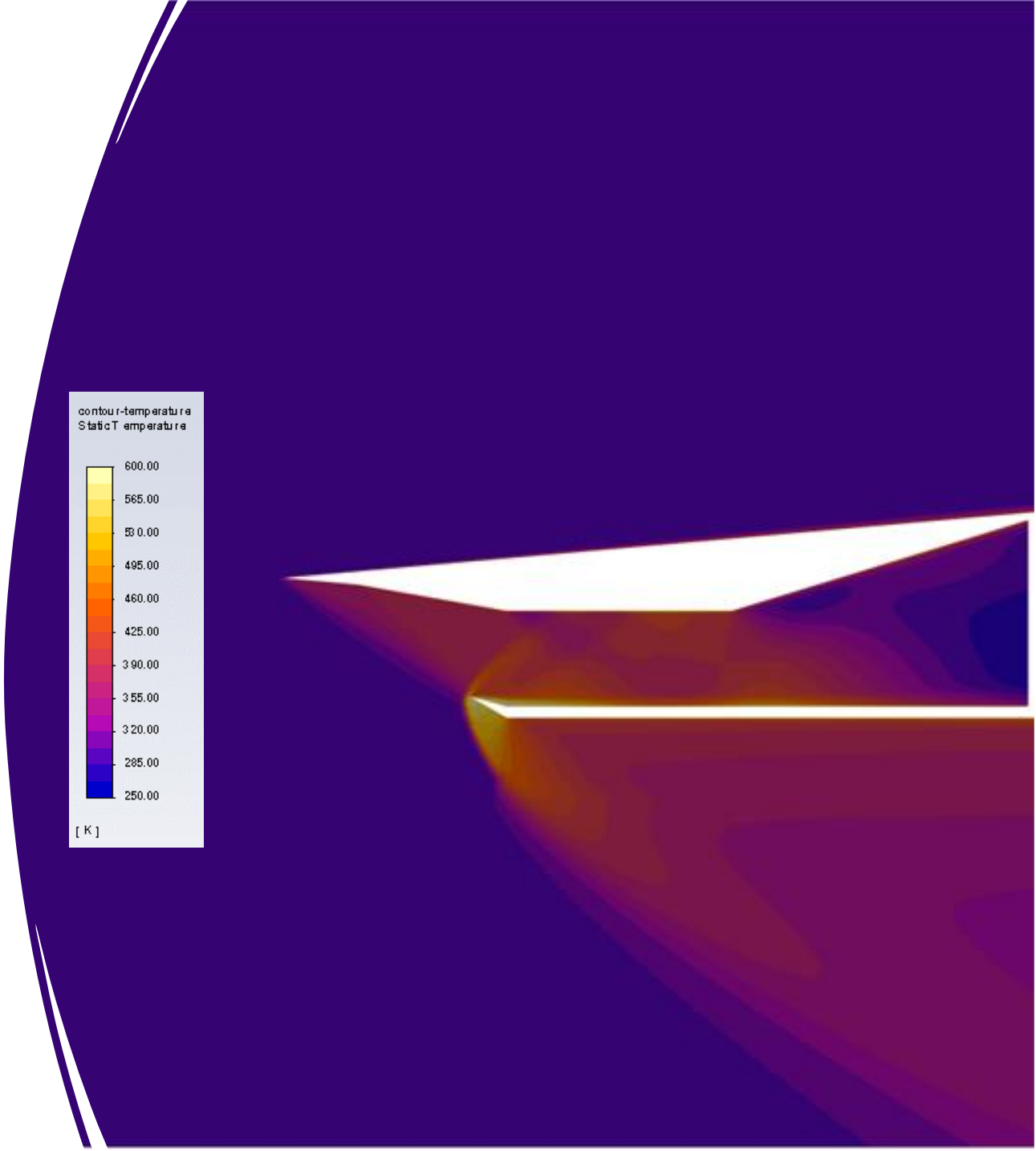
Mach Number contours

- Mach number contours clearly highlight regions of high-speed flow and low-speed flow.
- Inlet flow at M=2.2 decelerates to about M=1.3 in the intake before accelerating back to M=2.5



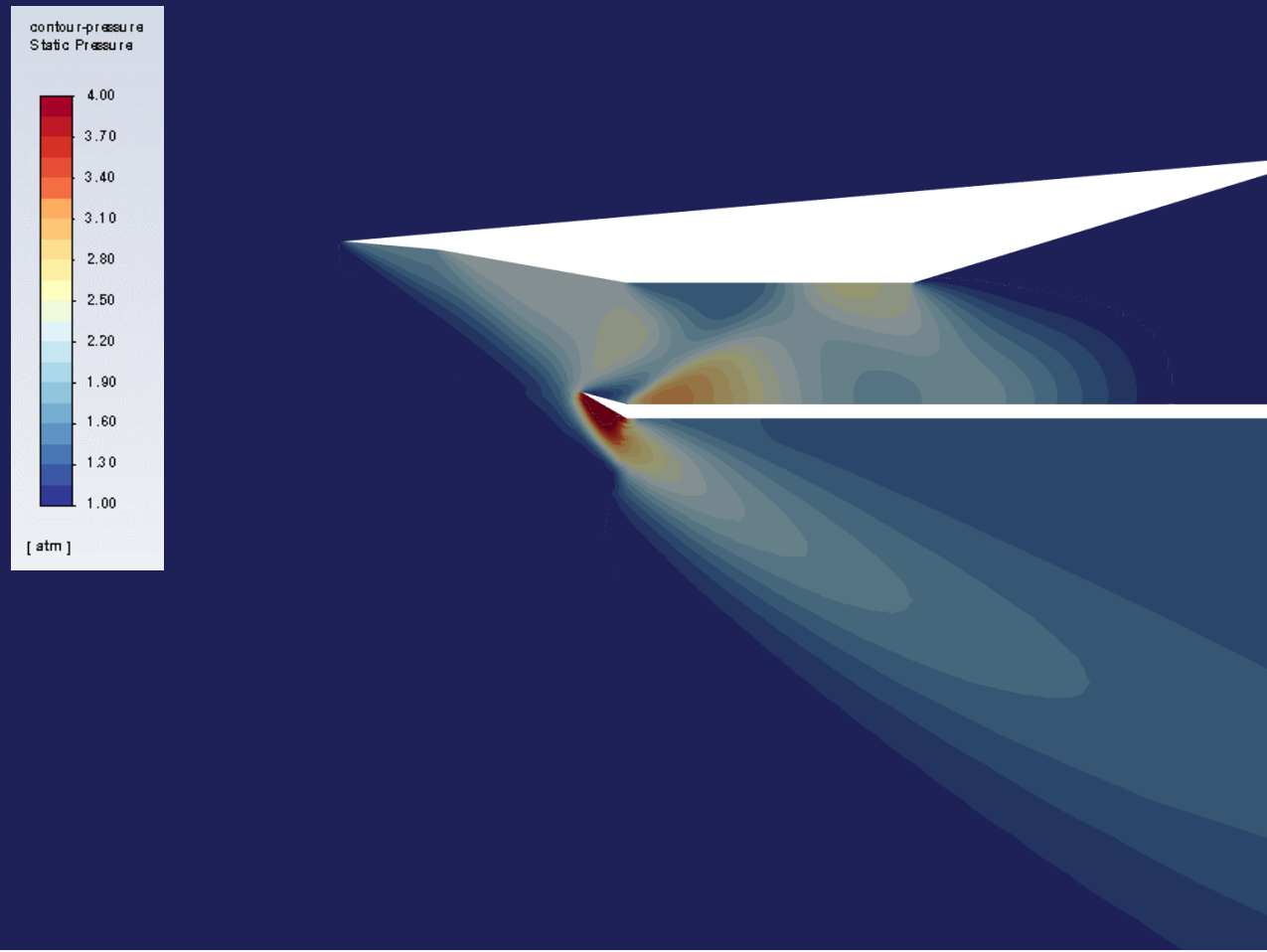
Temperature contours

- Temperature contours differentiate regions of hot and cold flow.
- Shocks generated in supersonic flow cause transfer of kinetic energy into heat energy.
- Strong shocks cause flow temperature to increase from 300 K to about 550K. Weaker shocks case more moderate increase of temperature to 450 K.
- Weaker shocks better from a design perspective.



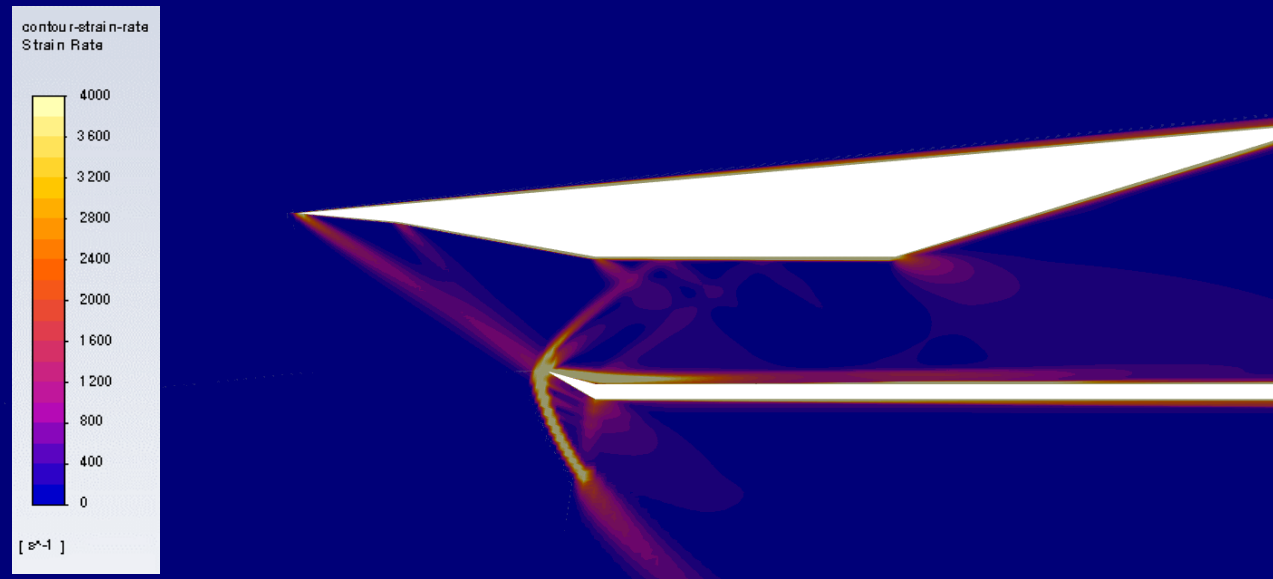
Static Pressure contours

- Strong shocks create regions of highly pressurized flow while weaker shocks have more moderate pressure rise.
- Design criteria is to have weaker shocks within the intake to preserve total pressure.



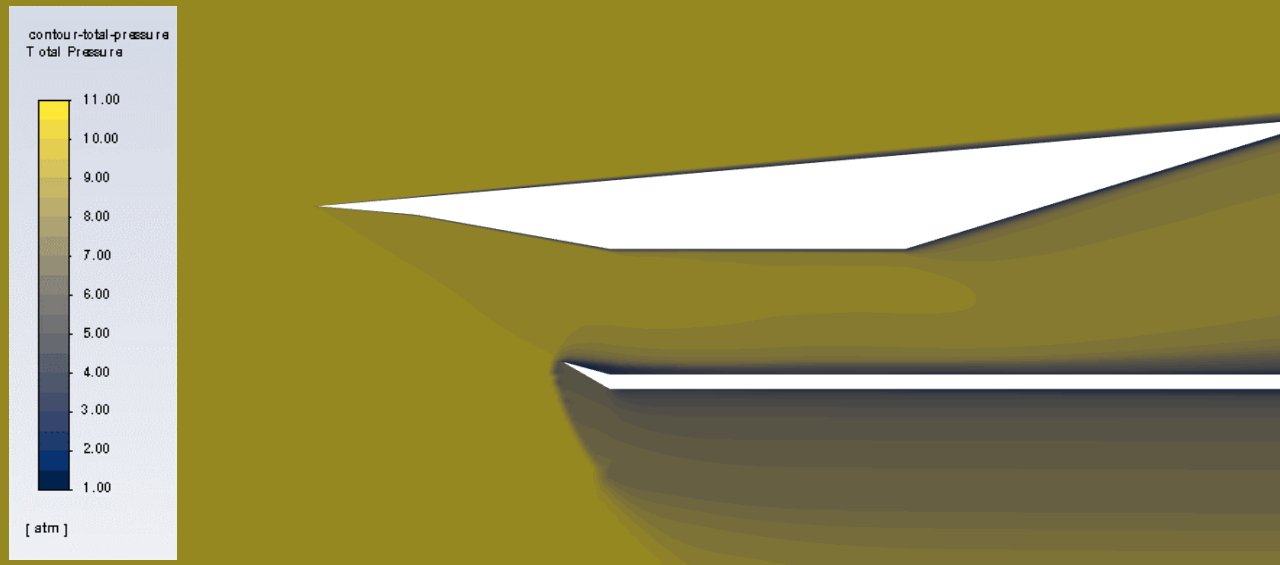
Strain Rate contours

- Strain rate measures flow acceleration or deceleration. Regions of high strain rate correspond to strong shocks.
- Allows visualization of shock impingement locations.
- Useful for design improvements.



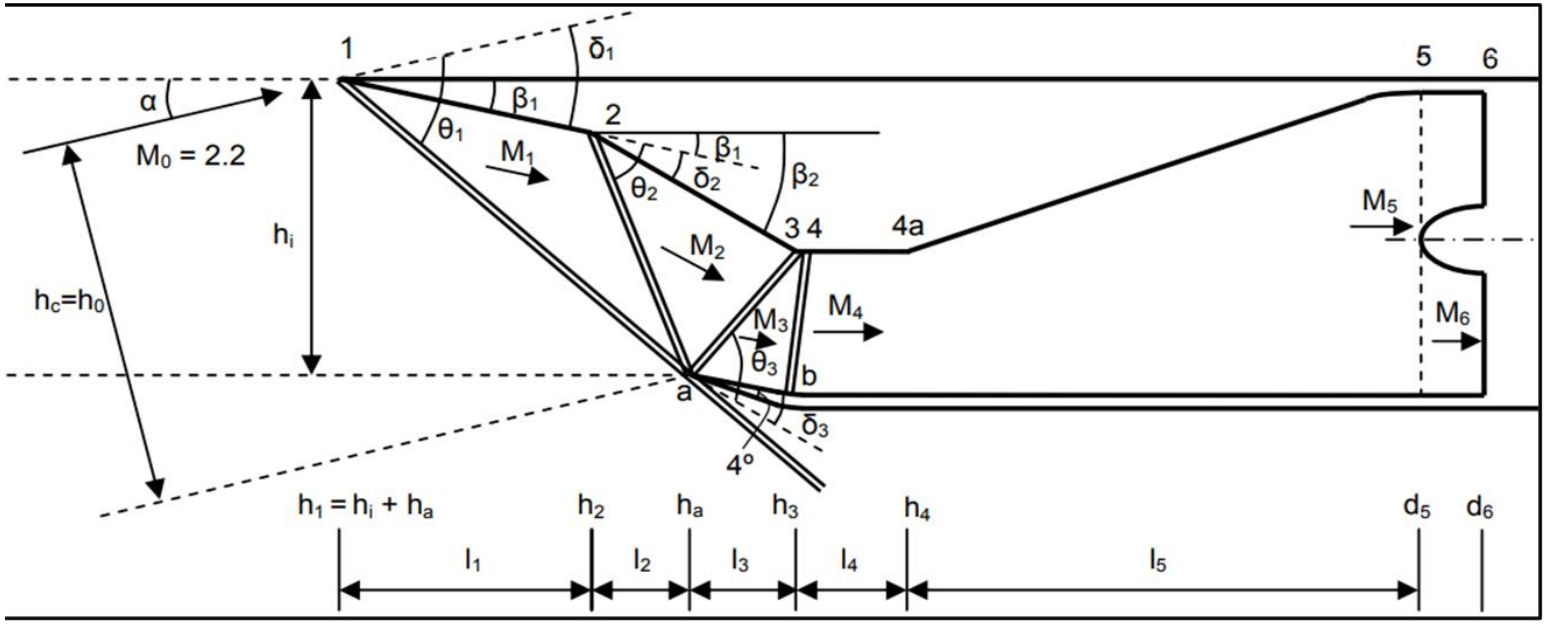
Total Pressure contours

- Total pressure is measure of useful work that can be done by flow.
- Main objective of the design is to minimize total pressure losses.
- CFD analysis indicates regions with highest loss in total pressure are outside the air intake.



DESIGN IMPROVEMENTS

- Parameterise the intake geometry.
- Conduct multiple CFD simulations to identify parametric combination that gives highest average total pressure at exit plane.
- Virtually simulate flow patterns within a flight envelope.



Hongjun, R. and Dimitri, M., 2005. Preliminary Design of a 2D Supersonic Inlet to Maximize Total Pressure Recovery; In AIAA 5th ATIO and16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences pp. 3-5.

SUMMARY AND CONCLUSIONS

- Brief introduction to analysis of supersonic flows through CFD.
- Visualised flow patterns in a typical supersonic intake through CFD.
- Understood how this information can be used to improve the design.
- More cost-effective than conducting experimental analysis.

Hongjun, R. and Dimitri, M., 2005. Preliminary Design of a 2D Supersonic Inlet to Maximize Total Pressure Recovery; In AIAA 5th ATIO and16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences pp. 3-5.

Upcoming Webinars

Upcoming webinars: www.eit.edu.au/news-events/events/

Upcoming EIT Courses

We have a range of courses in Civil, Electrical, Mechanical and Industrial Automation Engineering.

Course Type	Intakes/start date
Professional Certificate of Competency courses (short courses)	Throughout the year
Diploma & Advanced Diploma courses	Throughout the year
Undergraduate Certificates	13 February 2023
Bachelor of Science degrees	13 February 2023
Graduate Certificates	2 January 2023
Master of Engineering degrees	2 January 2023
Doctor of Engineering	13 February 2023
On Campus Bachelor's, Master's and Doctor of Engineering programs	20 February 2023

See our full course schedule here: www.eit.edu.au/schedule/

Certificate of Attendance

To receive your digital certificate of attendance for participating in this webinar, please fill out the form and survey here (or scan the QR Code):

qrco.de/bdEI5A

Please note that Certificate of Attendances will be sent out in the next 1-2 business days.

SCAN ME

Q&A

Engineering Institute of Technology.

Thank you for attending.

Contact Us:

Website
www.eit.edu.au

Head Office
1031 Wellington Street West Perth
Perth, WA 6005

Phone
Inside Australia: 1300 138 522
Outside Australia: +61 8 9321 1702

Email
webinars@eit.edu.au

Courses
https://www.eit.edu.au/schedule/