HEXAGON | Cradle

Case study

Indian Institute of Science (IISc)

Computational study of flow behaviour of highly under expanded jets

The Computational Mechanics Lab (CML) is a part of the Department of Aerospace engineering at the Indian Institute of Science (IISc), Bangalore. It provides a platform to study fluid dynamics using in-house and commercially available CFD tools. The lab works closely with several Indian defence laboratories on collaborative projects. For instance, it worked with the Defence Research and Development Laboratory on supersonic flow computation for a missile configuration, which entailed the development of Three-Dimensional time marching inviscid code based on Kinetic Flux vector splitting (KFVS). CML also regularly works to develop algorithms and applications in areas such as aerospace CFD, high-speed flows, shock waves applications, cardiovascular fluid dynamics, and Parallel computing

Challenge

In this instance, the endeavour was to numerically study the flow behaviour of highly under-expanded jets. The team wanted to study this behaviour at a nozzle exit pressure ratio of 5.60 through a circular nozzle. These jets find several applications especially in areas such as jet propulsion. However, there is a limited understanding of this flow field even among experts. The gas formation in the plume is not uniform in structure, velocity or composition. It contains several flow regimes and supersonic shockwaves. The overall plume flow field can be divided into three regions:

- Plume nearfield – In this region, there is an inviscid inner core and a relatively thin outer mixing layer
- Transition region – Here, the mixing layers engulf the entire plume and wave strengths diminish due to turbulent dissipation

• Plume farfield – In this region, we find that wave processes have totally diminished in constant pressure (Almost equal to ambient pressure).

The team was using commercially available software for grid generation and flow simulation. There were certain challenges associated with this. The grid generation was a highly time-consuming process, which required several man-hours. Also, the project required a density-based high-speed compressible flow with higher shock resolutions. Since it is a function of density and temperature, it required intense flow monitors.

During the flow computation, pressure fluctuation is determined by the equation of state along with the script (journal file) as an external file to keep the CFL ramping in control, resulting in a large number of iterations to solve the physics, making the approach computationally very expensive.

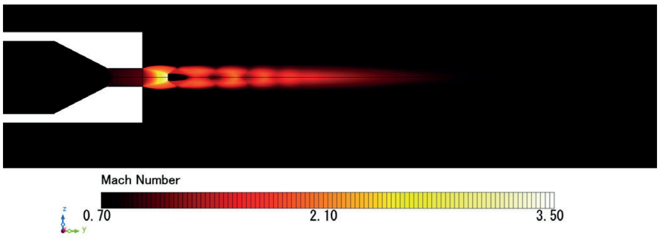
Solution

The team decided to model the complete computational methodology using Cradle (scFLOW) from MSC Software. scFLOW significantly simplified the effort of generating the grid. Most approaches such as creating a density box (to define the finer elements), defining the global element sizes, and calculating the first layer height were automated. The software also ensured smooth computation ramping with variable divergence control.

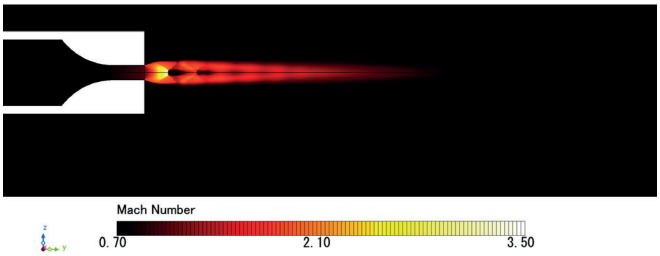
MSC Software worked with the team, providing timely guidance and support with respect to understanding the tool and setting up the problem, which helped throughout the research process.

Benefits

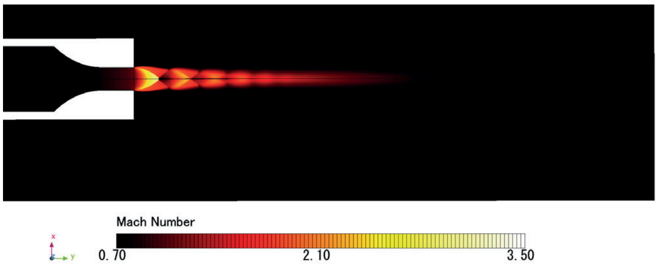
Overall scFLOW proved to be computationally in-expensive and high fidelity CFD tool for the research team. In addition, the scFLOW (Polyhedral) meshing approach saved up to 50-60 percent of the time. Also, the team was able to achieve a smaller overall grid size. The results were achieved in fewer cycles for the same RANS simulation. The team also benefited from a good post-processing experience, which was part of the package within MSC Software's scFLOW offering.



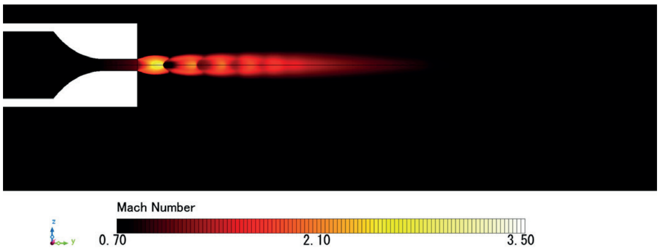
Mach contour of circular nozzle



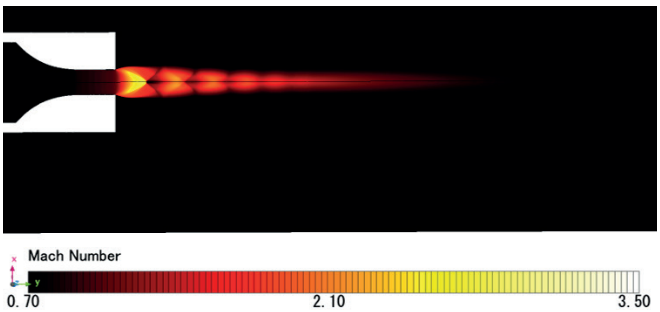
Mach contour of square nozzle



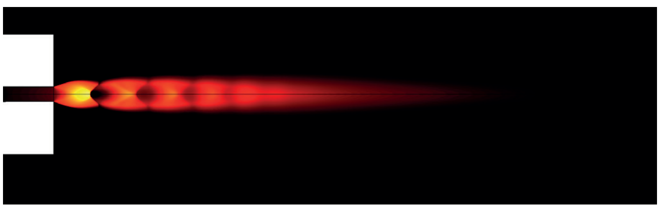
Mach contour of elliptical nozzle (Major axis)



Mach contour of elliptical nozzle (Minor axis)



Mach contour of rectanguler nozzle (Major axis)



Mach contour of rectanguler nozzle (Minor axis)

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Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

Software Cradle, part of Hexagon's Manufacturing Intelligence division, provides highly reliable, multiphysics-focused computational fluid dynamics (CFD), thermal dynamics software and integrated simulation tools that enhance customers' product quality and creativity. Learn more at cradle-cfd.com. Hexagon's Manufacturing Intelligence division provides solutions that utilise data from design and engineering, production and metrology to make manufacturing smarter.

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