Mechanical Engineering Summer Research Program 2023
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Mesh Generation for FSI Analysis of Shock Impingements in High-Speed Applications

Introduction

Shock impingements involve the interactions between objects and shockwaves resulting from objects moving at speeds exceeding the local speed of sound, causing rapid changes in pressure and temperature. These interactions significantly influence surrounding airflow and have substantial consequences for the forces experienced by the object. Research focuses on generating high-fidelity meshes for CFD (Computational Fluid Dynamics) simulations, employing the AERO-F code, to model shockwave-boundary layer interaction flows and improve the design of higher performance vehicles.

Figure 1: China's DF-ZF Hypersonic Glide Vehicle, capable of flying at speeds of between Mach 5 and Mach 10. [1]

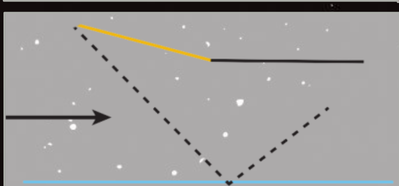
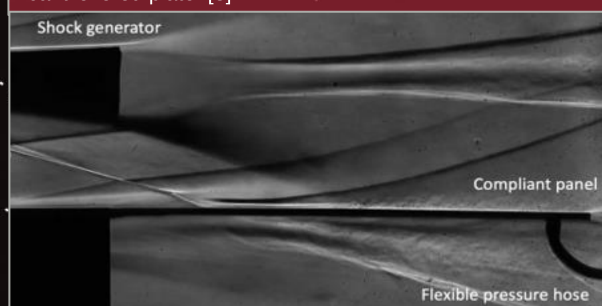


Figure 2: Shock impingement; arrow indicates incoming flow, shocks are dashed lines, gold is shock generating surface. [2]

Objectives

- Generate high-fidelity STL meshes of a cantilevered panel attached to a rigid forebody with an overhead wedge shape, having angles of 2 and 10 degrees from the surface.
- Prepare DuckUte HPC (High-Performance Computing) cluster with the necessary libraries and tools to build AERO-F.
- Conduct simulations with AERO-F that replicate real shock impingement experiments to assess any gaps in the software's accuracy.

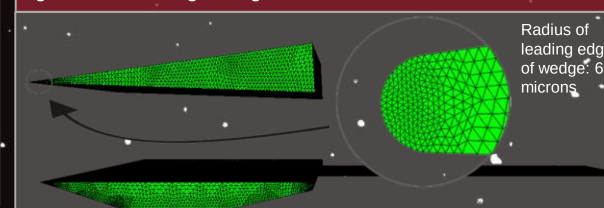
Figure 3: Schlieren image of supersonic flow going from left to right, with shock generator redirecting flow into a cantilevered plate. [3]



Methodology

- Generate high-fidelity STL meshes using Netgen
- Convert to XPOST file type using python scripts in VS Code
- Obtain access to Linux machine (ex: DuckUte HPC cluster)
    - PuTTY & WinSCP required for HPC cluster users
- Run C++ code with required Linux libraries to convert from XPOST file to EXODUS file
- Open EXODUS file in ParaView to ensure successful file creation
- Build AERO-F on Linux & run simulations

Figure 4: High-fidelity mesh of 2-degree wedge design generated through Netgen.



References

1. 果壳军事. "Chinese Hypersonic Gliding Vehicle.jpg." Wikimedia Commons, Wikimedia Foundation, 6 June 2016, https://commons.wikimedia.org/wiki/File:Chinese_Hypersonic_Gliding_Vehicle.jpg.
2. Gaitonde, Datta V., and Michael C. Adler. "Dynamics of Three-Dimensional Shock-Wave/Boundary-Layer Interactions." Annual Review of Fluid Mechanics, vol. 55, 2023, pp. 291-321. https://doi.org/10.1146/annurev-fluid-120720-022542.
3. Talluru, Krishna, et al. "Data package for HyMAX." Hypersonics Group, UNSW Canberra, https://nescacademy.nasa.gov/workshops/AePW3/public/wg/highspeed.

Future Work

Having successfully established the necessary foundations for conducting high-fidelity SWBLI FSI simulations, then next step is to replicate the real experiment within AERO-F to assess any gaps in the code.

Applications

- Hypersonic Vehicle Design
- Spacecraft Reentry and Landing
- Aerodynamic Performance of Missiles
- High-Speed Train Design

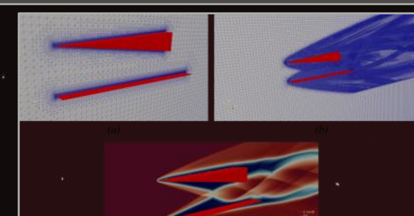


Figure 5: Preliminary CFD results using AERO-F