GENERAL

ansys aim tutorial compressible junction

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ANSYS AIM Tutorial: Compressible Junction Analysis

In the world of computational fluid dynamics, the ability to accurately predict flow behavior around complex geometries is essential. One common challenge is modeling a **compressible junction**, where two or more flow streams meet and interact at high speeds. Whether you're designing a turbocharger, a gas turbine inlet, or a high performance exhaust system, understanding how to set up and solve a compressible junction in ANSYS AIM is a valuable skill.

This comprehensive guide walks you through every step of the process, from geometry creation and meshing to solver configuration and post processing. By the end of this tutorial you'll be able to set up a robust compressible junction simulation, interpret the results, and refine your model to achieve accurate, reliable predictions.

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Introduction to ANSYS AIM for Compressible Junctions

ANSYS AIM (Advanced Interactive Multiphysics) is a powerful, user friendly platform that allows engineers to create, solve, and analyze multiphysics problems without writing code. Its drag and drop interface, coupled with a rich library of physics models, makes it especially popular for aerodynamic and turbomachinery applications.

A **compressible junction**is a region where two or more high speed streams converge, often at an angle. The resulting flow field is highly unsteady, with shock waves, expansion fans, and complex vortex structures. Accurately capturing these phenomena requires careful attention to mesh quality, turbulence modeling, and solver settings.

In this tutorial, we'll explore the entire workflow for a typical compressible junction case, using a simplified geometry that mimics a gas turbine inlet. The concepts and steps are directly transferable to more complex, real world designs.

Compressible Flow Fundamentals

Before diving into the software, it's important to understand the governing equations and key dimensionless parameters that influence compressible junction behavior.

Governing Equations

- Continuity: Conservation of mass.

- Momentum: Newton’s second law applied to fluid elements.
- Energy: Conservation of energy, accounting for pressure work and heat transfer.

These equations are coupled and nonlinear, making the solution process challenging, especially when shocks are present.

Mach Number

The Mach number (M) is the ratio of the local flow speed to the speed of sound. In a compressible junction, Mach numbers often exceed 1, indicating supersonic flow. The interaction of multiple supersonic streams creates shock waves that must be resolved accurately.

Turbulence Modeling

For high speed flows, turbulence is typically modeled using Reynolds Averaged Navier–Stokes (RANS) equations with models such as **k q,Pk <’ 55@**n more advanced studies, Large Eddy Simulation (LES) or Detached Eddy Simulation (DES) may be employed for unsteady, high resolution results.

Boundary Layer Considerations

Incompressible flows often rely on thin boundary layers, but in compressible flows, the boundary layer can be thicker due to high temperatures. Properly resolving the boundary layer is crucial for accurate pressure and shear predictions.

Geometry Preparation

ANSYS AIM allows you to import CAD files or create geometry directly within the platform. For this tutorial, we’ll construct a simple 2 D representation of a compressible junction using the built in geometry editor.

Step 1: Create the Junction Geometry

1. Open ANSYS AIM and select New Project.
2. Choose 2 D as the dimensionality.
3. In the Geometry tab, click Create and select Rectangle to define the inlet channel.
4. Duplicate the rectangle and rotate one copy by 30° to form the second inlet.
5. Merge the two rectangles at a common point to create the junction.
6. Define the outlet by drawing a larger rectangle that encompasses the merged region.

For more realistic studies, you can import a 3 D CAD model (e.g., a turbine inlet) and use the **Import** function.

Step 2: Assign Materials

1. Navigate to the Materials tab.
2. Assign AIR to all fluid domains.
3. If you wish to include heat transfer, add STEEL for the solid walls.

ANSYS AIM provides a library of standard materials, but you can also create custom material definitions if required.

Meshing Strategies

A high quality mesh is the backbone of any successful CFD simulation. In a compressible junction, you must capture shock waves, boundary layers, and flow separation accurately.

Mesh Type

Use a **structured mesh** for simple geometries. For more complex shapes, a hybrid mesh combining structured

patches and unstructured elements works well.

Boundary Layer Mesh

- Create a boundary layer mesh along all solid walls.
- Set the first cell height to achieve y z "H 1–5 for RANS models.
- Use a growth rate of 1.2–1.3 to smoothly transition to the interior mesh.

Shock Capturing

To resolve shocks, refine the mesh in the region where the junction is expected to produce them. Use **mesh refinement zones** or **local mesh controls** to increase element density.

Mesh Quality Checks

1. Check for skewness; aim for skewness
2. Ensure aspect ratios are below 20 in critical regions.
3. Run the Mesh Quality report to identify any problematic cells.

ANSYS AIM's automatic mesh generator often produces acceptable meshes for standard problems, but manual refinement is recommended for high speed flows.

Boundary Conditions

Correctly specifying boundary conditions is essential for a physically realistic solution. For a compressible junction, the main boundaries are the inlets, outlet, and walls.

Inlet Conditions

- Define velocity inlet or mass flow inlet for each channel.
- Set the Mach number (e.g., M = 1.2) and temperature (e.g., 300 /K).
- Specify turbulence intensity and viscosity ratio if using RANS.

Outlet Condition

- Apply a pressure outlet with ambient pressure (0 /Pa gauge).
- Set the backflow turbulence parameters to default or custom values.

Wall Conditions

- Set walls as no slip with adiabatic or isothermal conditions.
- If heat transfer is important, assign a wall temperature (e.g., 500 /K).

Symmetry/Periodic Boundaries

For a 2 D simulation of a symmetric junction, you can use a symmetry boundary to reduce computational cost.

Solver Settings

ANSYS AIM offers a range of solver options tailored for compressible flow. Selecting the right configuration can dramatically improve convergence and accuracy.

Physics Model

- Choose Compressible Flow as the physics type.
- Activate RANS with the k <' 55B GW& ulence model for a good balance between accuracy and computational effort.

Discretization Schemes

- Use a second order upwind scheme for momentum and energy equations.
- Apply a first order upwind for turbulence equations to enhance stability.

Pressure–Velocity Coupling

- Use Coupled Pressure–Velocity solver for steady state simulations.
- For transient studies, choose Explicit or Implicit time stepping depending on the Courant–Friedrichs–Lewy (CFL) condition.

Convergence Criteria

- Set residual tolerances to 1e 5 for continuity, momentum, and energy.
- Monitor global residuals and key flow variables (e.g., inlet Mach, outlet pressure).
- Use under relaxation factors of 0.7–0.9 for momentum and 0.5–0.7 for turbulence equations.

Solution Controls

1. Activate Residual Monitoring to track convergence.
2. Enable Automatic Mesh Refinement if available to adaptively improve the solution.
3. Use Solver Acceleration techniques such as Dynamic Relaxation for difficult cases.

Post Processing and Results

After the solver converges, the next step is to interpret the results. ANSYS AIM's post processing tools provide a wealth of visualization options.

Key Diagnostics

- Mach Number Contours to identify shock locations and expansion fans.
- Pressure Coefficient (Cp) plots along walls to assess pressure loads.
- Velocity Magnitude to detect separation or recirculation zones.
- Temperature Distribution to evaluate thermal effects.

Shock Wave Identification

Use the **Shock Detector**tool to locate discontinuities. Verify that the shock strength matches theoretical predictions (e.g., using the normal shock relations).

Pressure Drop Calculation

Compute the pressure drop across the junction by integrating the pressure along the inlet and outlet boundaries. This metric is critical for performance assessment.

Force and Moment Analysis

If structural coupling is of interest, export the pressure distribution to a structural solver to calculate forces and moments on the junction walls.

Exporting Data

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