NSU3D Massflow Inlet Boundary Condition

May 17, 2023

Among the various power boundary conditions available in NSU3D, the IFIN boundary condition can be used in various ways to set the conditions for an engine inlet for external flow simulations. Boundary conditions at the inlet can be set in 3 ways:

- PSTATIC: Prescribed static pressure at engine inlet plane
- MACH: Prescribed Mach number at engine inlet plane
- MASS_FLOW_RATIO: Prescribed mass flow ratio at engine inlet plane

In practice, the boundary condition is controlled by a prescribed Mach number. PSTATIC and MACH specification are equivalent, in that the corresponding static pressure for a given Mach number is computed using isentropic flow relations. Similarly, the mass flow ratio is prescribed by continuously adjusting the back pressure/Mach number at the boundary face using a local Newton solver to achieve the prescribed mass flow ratio.

In previous versions, the flow was assumed to be isentopic from the freestream to the engine inlet. This precluded the possibility of properly managing cases with supersonic freestream conditions where normal or oblique shock waves may occur along streamlines entering the inlet. Additionally, total pressure losses are possible due to viscous effects and discretization errors or numerical errors. Therefore, starting in version r-398, the total pressure is first computed at the boundary face and used to set the IFIN boundary conditions.

For backward compatibility, the optional parameter USE_BCS_IFIN_OLD is provided which has the following effect:

- USE_BCS_IFIN_OLD = 1: Use old implementation. Note that the isentropic assumption may be inaccurate and results in slightly different results for subsonic flows. For supersonic flows, the MASS_FLOW_RATIO boundary condition is only available for cases with subsonic freestream conditions.
- USE_BCS_IFIN_OLD = 0: This is the DEFAULT; if the parameter is not specified this value is assumed. In this case, the new implementation that computes the total pressure at the boundary face is used.

Details for MASS_FLOW_RATIO boundary condition

The mass flow ratio boundary condition assumes that the flow is always SUBSONIC at the boundary where it is specified. This is required because a supersonic flow which crosses a boundary can not be altered by conditions at this boundary. However a supersonic inlet flow can be compressed to subsonic conditions through a converging diverging nozzle or a nozzle where internal shock waves are present. Once the flow is subsonic, the usual engine inlet conditions can be used. These in turn can alter the upstream flow to affect the flow at the supersonic inlet plane. The mas flow ratio boundary condition includes two parameters:

- MASS_FLOW_RATIO: Ratio of desired mass flow across engine inlet to mass flow computed using freestream conditions at engine inlet
- AREA_RATIO: Ratio of Area at engine inlet (i.e. where mass flow ratio is defined using freestream conditions) to area of inlet where boundary condition is prescribed (and flow is presumably subsonic). Note that often the area ratio can be unity (=1.0)

The mass flow boundary condition computes an average total pressure at the boundary where the condition is being applied. This average total pressure value is then used to set the corresponding Mach number that is adjusted during the convergence process to achieve the desired mass flow ratio. Note that the total pressure may not be constant along the engine inlet face. However, an average value of the total pressure at the face is used, since a single constant value of Mach number is determined for matching the prescribed mass flow rate over the inlet face.

For supersonic inlets, mass flow rates larger than 1 may or may not be achievable, depending on the flow pattern between the freestream and the engine inlet. A maximum mass flow rate is computed assuming isentropic flow and output to std out with a warning that this may be higher than the maximum achievable mass flow rate. When the prescribed mass flow rate cannot be achieved, the Mach number at the engine inlet boundary will grow to Mach=1.0 at which point the maximum achievable mass flow rate will be reached.

Convergence history of the mass flow rate for each individual IFIN boundary condition is output to files called massflobc.n, (in the ./WRK directory) where n denotes the number of the boundary condition specified in the bcs file. This file records the prescribed mass flow rate, the achieved or computed mass flow rate, along with the resulting Mach number, static pressure, and total pressure ratio (total pressure at face over freestream total pressure) at each iteration of the convergence process.

The user is encouraged to inspect the massflowbc.n files to ensure that the specified mass flow rates have been achieved in the computation and that the flow is not choked in any of the inlets.

An abbreviated example of a massflobc file is given below:

MASS FLOW HISTORY FOR BC INSTANCE: 3

CYCLE	PRESCRIBED MFR	COMPUTED MFR	MACH	PSTATIC	PO_Ratio
1	0.900000E+00	0.950319E+00	0.100000E+00	0.224214E+01	0.931097E+00
2	0.900000E+00	0.906625E+00	0.100000E+00	0.213886E+01	0.888207E+00
3	0.900000E+00	0.866158E+00	0.100000E+00	0.207087E+01	0.859971E+00
4	0.900000E+00	0.828747E+00	0.100000E+00	0.202569E+01	0.841211E+00
5	0.900000E+00	0.794176E+00	0.100000E+00	0.199597E+01	0.828868E+00
6	0.900000E+00	0.762144E+00	0.100000E+00	0.197709E+01	0.821029E+00
7	0.900000E+00	0.732373E+00	0.100000E+00	0.196607E+01	0.816454E+00
8	0.900000E+00	0.704634E+00	0.100000E+00	0.196086E+01	0.814288E+00
9	0.900000E+00	0.678689E+00	0.100000E+00	0.195998E+01	0.813923E+00
10	0.900000E+00	0.654374E+00	0.100000E+00	0.196241E+01	0.814930E+00
11	0.900000E+00	0.631562E+00	0.362500E+00	0.180924E+01	0.817000E+00
190	0.900000E+00	0.899519E+00	0.750990E+00	0.161660E+01	0.969065E+00
191	0.900000E+00	0.899540E+00	0.751460E+00	0.161531E+01	0.968725E+00
192	0.900000E+00	0.899563E+00	0.751907E+00	0.161406E+01	0.968381E+00
193	0.900000E+00	0.899588E+00	0.752328E+00	0.161284E+01	0.968035E+00
194	0.900000E+00	0.899616E+00	0.752723E+00	0.161166E+01	0.967687E+00
195	0.900000E+00	0.899645E+00	0.753089E+00	0.161052E+01	0.967338E+00
196	0.900000E+00	0.899675E+00	0.753423E+00	0.160943E+01	0.966988E+00
197	0.900000E+00	0.899707E+00	0.753726E+00	0.160838E+01	0.966639E+00
198	0.900000E+00	0.899740E+00	0.753995E+00	0.160739E+01	0.966291E+00
199	0.900000E+00	0.899773E+00	0.754231E+00	0.160646E+01	0.965944E+00
200	0.900000E+00	0.899805E+00	0.754433E+00	0.160558E+01	0.965599E+00