Running Multiple Cases (i.e. drag polars) with NSU3D

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Starting with version r-396, NSU3D can be set up to run multiple cases using a single additional input file. This can be used to generate complete drag polars automatically, or other types of case suites with different flow conditions.

Enabling multicase runs: MULTI_CASE optional parameter

To enable a multicase run, the optional parameter MULTI_CASE must be specified as 1.0 in the nsu3d input file.

- MULTI_CASE = 0.0 → Run single case as specified in input.nsu3d file
- MULTI_CASE = 1.0 → Run multiple cases as specified in input.multicase file
- The default value for the MULTI_CASE optional parameter is 0, therefore if this optional parameter is not specified NSU3D will run a single case

If the MULTI_CASE optional parameter is set to 1.0, NSU3D will attempt to read in the input.multicase file which specifies the different cases. If this file is not present, NSU3D will stop and output a message that the file cannot be found.

Input.multicase file

The input.multicase file is used to specify the flow conditions for each case, the restart strategy for each new case, and the stopping criteria for each case. An example of a multicase file is given below:

CASE_ID	MACH	Z-ANGLE	Y-ANGLE	RE	NCYC	FMG LEVELS	RESID_TOL	FORCE_TOL	RESTART FROM CASE
4	0.75	0.00	0.0	3000000.	500.	2.	1.e-12	0.05	CONTINUE (or NONE)
5	0.75	0.00	1.0	3000000.	500.	2.	1.e-03	1.e-6	NONE
6	0.75	0.00	2.0	3000000.	500.	1.	1.e-12	0.2	PREVIOUS
1	0.75	0.00	-1.0	3000000.	500.	1.	1.e-12	0.01	4

Definitions for input.multicase file:

CASE_ID: The cases to be run are listed in the order in which they will be run in NSU3D. Generally this order is determined by the need to have the requested restart files available from previous cases in order to restart the following case. However, the final order of the case results may be different, particularly for plotting purposes. In this example, we want to create a drag polar from angles of attack ranging from -1.0 to 2.0. However we prefer to start with the case Y-ANGLE=0.0 as the first case, which will be used to restart the following solution at Y-ANGLE=1.0, which in turn can be used to start the next

case (not done in this example). However, the final case at Y-ANGLE=-1.0 should be restarted from the case at Y-ANGLE=0, therefore it cannot be run first. In general, a drag polar might start with a nominal case in the center of the range of angles of attack, and proceed to the higher angle-of-attack cases, and then resume computing the lower-angle-of-attack cases. However, for plotting the final results, one would prefer to order the cases by increasing angle of attack. The CASE_ID enables a final labeling and ordering of the cases which is different than the order in which the cases must be run (as determined by the restart strategy employed). Note that the CASE_ID numbering does not need to be contiguous (as in this example) but the final order will include cases in ascending order of this list. This enables cases to be removed from a long list without the need for renumbering all cases.

FLOW PARAMETERS: These include MACH, Z-ANGLE, Y-ANGLE and RE, which are all the parameters which define the flow conditions for each case.

STOPPING CRITERIA: Three possible stopping criteria can be set for each case:

- **NCYC and FMG LEVELS:** For each case, the number of FMG levels can be specified. This is based on the levels set in the input.nsu3d file. Using FMG_LEVELS=1.0 means that the case will only compute on the LAST level (and NMESH setting) specified in the input.nsu3d file. FMG_LEVELS=2 will compute the case on the last 2 levels specified in the input.nsu3d file. This may be useful if preconvergence on a coarser level is required or if one wants to run multigrid cycles (NMESH>1) for a given number of iterations followed by single grid (NMESH=1). In this case, the case will start with the number of cycles, level and NMESH value set in the second to last FMG line in the input.nsu3d file, followed by the settings on the last FMG line in the input.nsu3d file. However, the value of NCYC set in the input.multicase file for each case is used on the final level in all cases as the maximum number of cycles used for this case.
- **RESID_TOL:** A residual tolerance can also be set to enable an early exit for each case. The value of RESID_TOL corresponds to the value of the density residual in NSU3D at which execution will be terminated and the code will proceed to the next case in the list. Set =0 or <0 to disable.
- **FORCE_TOL:** Alternatively (or simultaneously) a tolerance on force convergence may be used to trigger termination of each case. Currently this tolerance corresponds to the tolerance in the variation of the CL coefficient, although this can easily be upgraded to include other force coefficients if requested. Set =0 or <0 to disable. In order to measure the force tolerance, two other parameters, to be included as optional parameters in the input.nsu3d file are used:
    - **NFORCE_TOL_FREQ:** Convergence of the force coefficient (default is CL) is checked every NFORCE_TOL_FREQ iterations or cycles.
    - **NFORCE_TOL_WINDOW:** Variation of the force coefficient is measured over NFORCE_TOL_WINDOW cycles in order to check the FORCE_TOL variation for exiting.

RESTART STRATEGY: The restart strategy is set in the RESTART FROM CASE parameter. Generally, a previously computed case can be used to restart the current case. This is enabled by specifying the case number used for restart for each case in this column, as in the last line in the above example, where the Y-ANGLE=-1.0 case is to be restarted using the solution at Y-ANGLE=0.0, which corresponds to Case 4 in the input.multicase file, or the first line in the file (first case to be run). In addition to specifying the case number for restart, the following options are also available:

- **CONTINUE**: Continue with current values in memory (no file read). This is generally used for the first case in the list, which can continue running from the values produced by the settings in the original input.nsu3d file.
- **PREVIOUS**: Use the previously computed case in the input.multicase file list (previous line).
- **NONE**: No restart, reinitialize with freestream conditions.
- **ORIGINAL**: Use the original restart file listed in the input.nsu3d file (if one exists).
- Numerical Value: use this case number as described above.

At startup, NSU3D checks if the restart strategy is viable (i.e. if restart files will be available when requested), and will stop with an error message before computing any cases if the listed strategy is not viable.

OUTPUT FILES for Multicase Runs: There are two types of outputs for multicase runs.

Firstly, each case produces its own WRK.case.id directory with the restart file (for postprocessing) and convergence history files for that specific case. These directories are labeled with the case number, which may not correspond to the order in which they were run, but corresponds to the case id set in the input.multicase file. Within each WRK.case.id directory, a CASE.HEADER.txt file lists the specifics of this case in terms of flow parameters, restart and stopping criteria. The standard history files such as rplot.out and force1.out contain the convergence histories for the cycles run for this case only. The restart history files contain the full convergence history for all cases run up to this case (i.e. due to restarts). The WRK directory contains the same solution and histories as the last case run and is not needed. However, the restart history files in WRK and in the last case run can be used to examine the entire history of the muticase run, spanning all cases.

The second type of output files consists of summary data for the entire multicase run, listing force coefficients for all cases, in the specified order of cases, i.e. ordered by increasing case number. These files currently include output.force1.multicase, output.force2.multicase, output.force3.multicase, output.force4.multicase, which contain the final force values listed in the force1.out, force2.out, force3.out and force4.out files in each WRK.case.id directory. The output.force#.multicase files are written to the directory in which NSU3D is run, above the WRK directories.