CS2 - Spanwise periodic DNS/LES of the transitional flow in T106 LP turbine cascades

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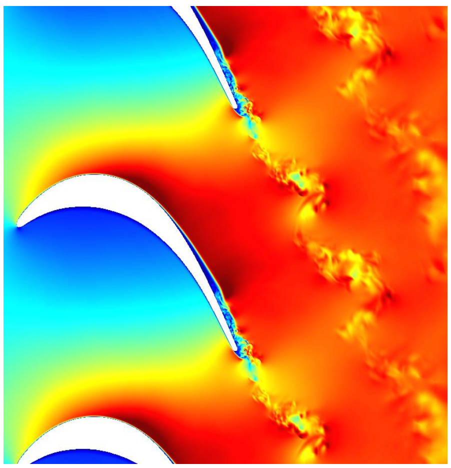
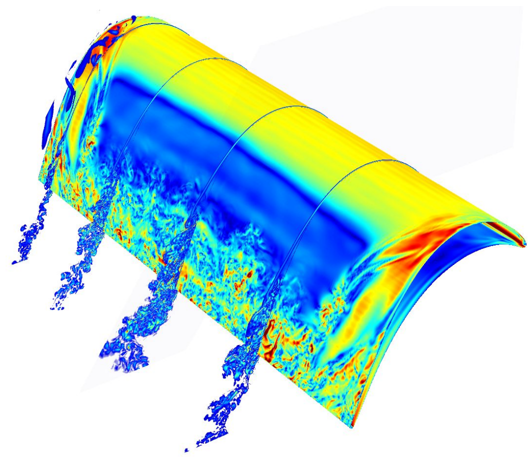




General description

This test case concerns the DNS or LES of the transitional and separated flow on the T106A and T106C high-lift subsonic turbine cascades. This cascade is a well-known test case for assessing transition models for Reynolds numbers of 50.000 and beyond. The Reynolds numbers of 60.000 and 80.000 are chosen for this workshop. As the inlet turbulence is very low, both flows feature laminar separation and a relatively slow natural transition.

The T106A cascade has already been run with success by several authors, and has therefore a sound reference solution.

Blade pressure distribution and wake total pressure loss profiles for the T106C have been measured at the von Karman institute (VKI) in the framework of the European research projects UTAT and TATMO. These data, as well as the geometry are made available by Prof. T. Arts of the von Karman institute. The T106C test case was also present in the 2nd workshop on high order CFD methods, where it was discovered that the leading edge blade loading was different from the experiments, but similar for all simulations; similar discrepancies were found in literature. Since the reason for this discrepancy was not elucidated and probably corresponds to 3D effects, the main aim here is to demonstrate (rapid) grid convergence for a number of key quantities, and to verify coherence of results between different simulation strategies.

Required computations - spanwise periodic computations

The main objective is to demonstrate grid and statistical convergence on a sequence of successively refined meshes for the T106A case (mandatory) and optionally for the T106C case.

The following data should be provided for

- Quantitative assessment
  - averaged isentropic Mach number and skin friction distributions on the blade
  - time averages of total and static pressure, total and static temperature, as well as velocity across the wake;
- Qualitative assessment
  - velocity auto and cross-correlations as well as rms of pressure and density across the wake.
  - on the periodic plane
    - instantaneous & averaged Mach number, vorticity and total pressure
    - averaged turbulent kinetic energy, RMS of density and pressure and temporal velocity component correlations
- Statistical convergence :
  - time evolution of the blade forces and the mass flow;
  - for the time-averaged data, we expect to get two results for two different averaging windows
- Grid resolution in wall units, corrected for order (DG, FR, … -> use h/p)
  - non-dimensional wall normal cell height y+
  - Chordwise resolution c+
  - Spanwise resolution s+ (if different from c+)

Statistical data (averages, rms, correlations, spectra) are obtained by averaging in time as well as in the spanwise direction. Both auto- and cross-correlations between the three components of the velocity are required. The provided data needs to be non-dimensionalized using the upstream total pressure p_{t1} and temperature T_{t1} for thermodynamic quantities, and $\sqrt{RT_{t1}}$ for the speeds. For the T106A and T106C computations, the wake profiles should be respectively taken at an axial distance of $0.4c_x$ and $0.465c_x$ from the trailing edge, where c_x denotes the axial-chord[1].

Governing Equations and models

[1] $c_x = \cos(30.71)c \approx 0.7610c$

The compressible Navier-Stokes equations should be used, with heat capacity ratio $\gamma=Cp/Cv=1.4$ and Prandtl number $Pr=0.71$.

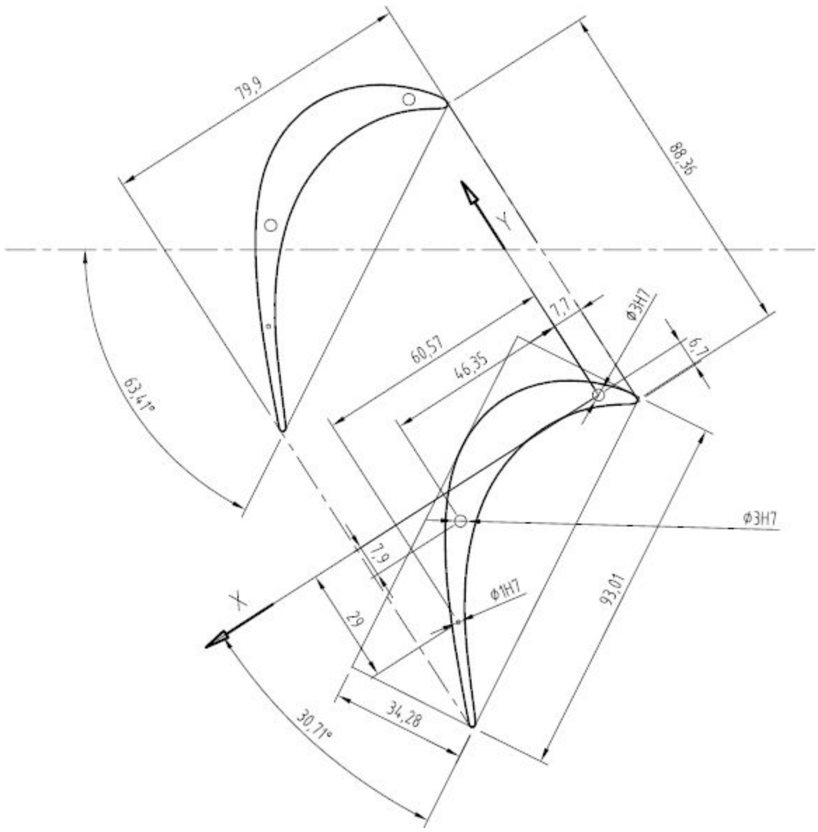
The test cases should be run with at least a wall-resolved large eddy simulation (LES) approach, up to direct numerical simulations (DNS). Participants are obviously free concerning the choice of models, but are expected to provide details on the model itself as well as the specificities of the implementation in relation to the discretisation method. Participants are allowed to complete the results with wall-modeled LES (WMLES) or other hybrids of LES.

Flow and boundary conditions

At the inlet, total pressure and temperature, as well as flow direction are imposed, whereas static pressure is imposed at the outlet. The total to static pressure ratio over the cascade, the inlet total temperature and the flow viscosity need to be chosen such that the isentropic exit Mach M_{2s} and Reynolds number Re_{2s}, based upon the velocity obtained by an isentropic expansion and the chord, correspond to the specifications in the table below. The inlet is furthermore supposed to be clean, and therefore no inlet turbulence needs to be specified.

Geometry	T106A	T106C
$Re_{2,s}$	60.000	80.000
$M_{2,s}$	0.405	0.65
α_1	45.5	32.7

Geometry and grids



The geometry of the T106C cascade is shown above.The blade description is available as IGES/step CAD file constructed from the coordinates provided by R.Stieger[2]. A single blade is to be computed, assuming pitchwise and spanwise periodicity, corresponding to 10% of the axial chord for the latter.

A basic Gmsh geometry and meshing description is available for both cascades. Meshes suitable for fourth-order (P3) schemes are also provided. The blade dimensions are scaled to retrieve a unit chord.

Block-structured meshes can be provided on request in ijk format (CGNS), each containing 4 multigrid levels. For DG, FR and SD these meshes should be coarsened to keep the degree of freedom count approximately constant with respect to the baseline resolution. This operation can be performed by Gmsh. Alternatively computations can be run on spanwise extruded 2D unstructured meshes. Participants are expected to run at least one unstructured mesh computation if the method allows it.

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[2] R. Stieger,*The effects of wakes on separating boundary layers in low pressure turbines.* Ph.D. Thesis, Cambridge, 2002.