Template for entering DNS/LES data and documentation into KB Wiki

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Author : Koen Hillewaert*‡, Wolfgang Rodi†

Organisation : Cenaero*, ERCOFTAC†, and Université de Liège‡

Contact : koen.hillewaert@cenaero.be

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Preface

A separate section has been installed in the ERCOFTAC Knowledge Base (KB) Wiki for storing test-case data from high-fidelity Direct Numerical Simulations (DNS) or Large-Eddy Simulations and the accompanying documentation. These data are to provide insight into the complex turbulent phenomena and to feature as target values for calculations involving models for the turbulent motion (RANS or LES). The present document supplies the template for entering the data and documentation into this Wiki section.

The test-case set-ups in this DNS/LES section are entirely computational. While they can be inspired by experiments, they need not aim at fully reproducing these, which is mostly difficult to achieve. Important is that the set-up with all boundary conditions is completely specified. The periodic hill case (UFR 3-30) is a good example of such a fully computational test case. A second important requirement is the assessment of spatial and temporal resolution of important scales, demonstrating that this is good enough for the computation to be either a DNS or a highly resolved LES. Furthermore the statistical convergence of the averages and correlations need to be demonstrated.

The following template provides the structure and the required contents of the test case. In case several computations were undertaken, separate sections for each of the computations should be provided from section 4 onwards.

The template

1 Introduction

Give a brief overview of the test case. Describe the main characteristics of the flow. In particular, what are the underlying flow physics which must be captured by the computations ? Give reasons for this choice (e.g. poorly understood flow physics, difficulty to predict the flow with standard turbulence models, ...). Detail any case-specific data that needs to be generated.

2 Review of previous studies

Provide a brief review of related past studies, either experimental or computational. Identify the configuration chosen for the present study and position it with respect to previous studies. If the test case is geared on a certain experiment, explain what simplifications (e.g. *concerning geometry, boundary conditions) have been introduced with respect to the experiment in the computational setup to make the computations feasible and avoid uncertainty or ambiguity.*

3 Description of the test case

A detailed self-contained description should be provided. It can be kept fairly short if a link can be made to an external data base where details are given. Then only the differences should be clearly indicated.

3.1 Geometry and flow parameters

Describe the general set up of the test case and provide a sketch of the geometry, clearly identifying location and type of boundaries. Specify the non-dimensional flow parameters which define the flow regime (e.g. Reynolds number, Rayleigh number, angle of incidence etc), including the scales on which they are based. Provide a detailed geometrical description, by preference in form of a CAD, or alternatively as lists of points and a description of the interpolation.

3.2 Boundary conditions

Specify the prescribed boundary conditions, as well as the means to verify the initial flow development. In particular describe the procedure for determining the inflow conditions comprising the instantaneous (mean and fluctuating) velocity components and other quantities. Provide reference profiles for the mean flow and fluctuations at inflow - these quantities must be supplied separately as part of the statistical data as they are essential as input for turbulence-model calculations. For checking purposes, these profiles should ideally also be given downstream where transients have disappeared; the location and nature of these cuts should be specified, as well as the reference result.

4 Computational details

4.1 Computational approach

Provide an overview of the numerical method/setup used for the computation of the DNS or LES database. This includes a description of the spatial and temporal discretisation, order of accuracy; if applicable implicit iterative strategy and associated convergence criteria, . . . If available, also provide the spectral analysis curves (von Neumann analysis). In case LES is used, provide a brief description of the SubGrid Scale (SGS) *model. Avoid unnecessary detail if good references are available.*

4.2 Spatial and temporal resolution, grids

Discuss the resolution of the simulation. If possible, relate it to the spectral accuracy. Indicate the dependence of the formal accuracy of the code to the quality of the mesh. Discuss the procedure *for the a priori estimation of the grid resolution. Finally, provide the grids used for the study.*

4.3 Computation of statistical quantities

Describe how the averages and correlations are obtained from the instantaneous results and how terms in the budget equations are computed, in particular if there are differences to the proposed approach in [1].

5 Quantification of resolution

5.1 Mesh resolution

Provide wall resolution in wall coordinates, both normally ("y^+") and tangentially ("x^+", "z^+"). Evaluate typical turbulence length scales (Taylor microscale, Kolmogorov) and compare to local resolution. In case the case presents homogeneous directions, one could also provide spatial correlations between the velocity components. If possible provide computed temporal spectra at selected locations and relate to spatial resolution e.g. *by using Taylor's hypothesis.*

5.2 Solution verification

One way to verify that the DNS are properly resolved is to examine the residuals of the Reynolds-stress budget equations. These residuals are among the statistical volume data to be provided as described in section 6.1.

6 Statistical data

6.1 Volume data

All quantities of interest have been listed in the report [1], where they have been classified according to two levels:

1. *Mean quantities appearing in the Favre-averaged Navier-Stokes equations;*
2. *Terms in the Reynolds-stress equations;*

As a minimum a complete data set for level 1 has to be provided. For DNS, level 2 must be provided as well. LES results are also encouraged for most quantities of interest of level 2, but because the dissipation rate can not be computed directly, it should be determined as the residual of the Reynolds-stress equations. If available in the computation, add the distance to the wall; both actual distance as well as wall units (y^+) are of interest.

The data have to be provided using the original representation of the solution used by the code for the computation in the CGNS format; however, averaging along any homogeneous direction *is recommended. In addition to the actual terms in the Reynolds-stress equations, the residuals of these equations (*i.e. *sum of all of the terms) should be provided. A list of the quantities stored in the files is recommended, unless direct reference can be made to the tables in [1]. Indicate how the data were non-dimensionalised.*

Some plots of the distributions of the various terms and the residual along certain representative/characteristic lines in the flow field should be given in order to allow an easy check on the quality of the results. Desirable would also be plots of distributions of mean velocity components and turbulent stresses along the same lines or, even better, contour plots of these quantities in suitable planes and a brief discussion of these results. The locations of lines and cuts should be clearly indicated at least in the figure captions, but by preference in a table for a better overview.

6.2 Additional data

*Here additional statistical data should be provided such as data on solid surfaces and integral time scales as specified respectively in sections 4 and 5 of [1]. Further global quantities of interest (*e.g. *drag/lift coefficients, mass flow rates, efficiencies, ...) should be given here and if need be the procedure should be described in detail. Indicate how the data were non-dimensionalised.*

7 Instantaneous data

Time-resolved data should be provided as well in the boundary layer regions as outlined in section 6 of [1]. The spatial resolution should be that of the computation. The temporal resolution duration should be related to the boundary layer characteristics, and certainly in terms of wall time units. This does not preclude other time scales, e.g. *the time scales can also be linked to a vortex bursting frequency; these should be documented and justified.*

This section may also contain time histories at selected probe locations to illustrate time scales etc.

Indicate how the data were non-dimensionalised.

8 Storage format

Document [2] describes the mandatory storage format and guidelines to store and classify the data.

References

[1] Koen Hillewaert and Wolfgang Rodi. List of desirable and minimum quantities to be entered into the KB Wiki. Technical Report D7.1-06, HiFiTurb project, 2020.

[2] Koen Hillewaert. Rules/formats for entering the data into the KB Wiki. Technical Report D7.1-12, HiFiTurb project, 2020 (in preparation).