Laboratory for Turbulence Research in Aerospace and Combustion

LTRAC datset of the large-eddy simulations of under-expanded supersonic impinging jets

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by
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Summary

The datasets of large-eddy simulation of under-expanded supersonic impinging jets funded by the Australian Research Council are summarised in this document.

The interested reader is referred to the listed publication for further detail of the datasets and analysis performed to the date.

The datasets are available for collaboration based projects. Please contact either Dr Shahram Karami or Professor Julio Soria for further discussion.

Contents

Publication

1. KARAMI, S., Edgington-Mitchell, D., A., Theofilis, V. and Soria, J. "Characteristics of acoustic and hydrodynamic waves in under-expanded supersonic impinging jet", Journal of Fluid Mechanics, 905, p. A34 (2020), doi:10.1017/jfm.2020.740.

2. KARAMI, S., Stegeman, P., Ooi, A., Theofilis, V. and Soria, J. "Receptivity characteristics of supersonic under-expanded impinging jets", Journal of Fluid Mechanics (Journal Front Cover), 889, p. A27 (2020).

3. KARAMI, S., Stegeman, P., Ooi, A. and Soria, J. "High-order accurate Large Eddy Simulation of compressible viscous flow in cylindrical coordinate", Computers Fluids, 191: p. 104241(2019), doi:10.1016/j.compfluid.2019.104241.

4. KARAMI, S., Soria, J. "Analysis of Coherent Structures in an Under-Expanded Supersonic Impinging Jet Using Spectral Proper Orthogonal Decomposition (SPOD)", Aerospace, 5(3), 73 (2018), doi:10.3390/aerospace5030073.

5. KARAMI, S., Stegeman, P., Theofilis, V., Schmid, P., Soria, J. "Linearised dynamics and non-modal instability analysis of an impinging under-expanded supersonic jet", Journal of Physics Conference Series, 1001(1):012019 (2018), doi:10.1088/1742-6596/1001/1/012019.

1 Computational details

A parallel C++ code, named ECNSS (Explicit Compressible Navier Stokes Solver), solves for density, momentum and total energy in cylindrical coordinates with a hybrid solver employing a sixth-order central finite difference scheme for the smooth regions and a fifth-order weighted essentially non-oscillatory (WENO) scheme with local Lax-Friedrichs flux splitting in the discontinuous regions. Temporal integration is performed using a fourth-order five-step Runge-Kutta scheme. When operated as an LES code, the subgrid scale terms are computed using Germano's dynamic model. Further details of the numerical method and validation can be found in Ref [PUB-3].

2 Configurations and available datasets

Table 1 summarises the six cases used in the publications outlined in previous section.

Table 1: Datset of the large-eddy simulations of under-expanded supersonic impinging jets.

Case ID	A	B	C	D	E	F
Computational domain ($L_x \times L_r \times L_\theta$)	$5d \times 12d \times 2\pi$			$2d \times 12d \times 2\pi$	$2d \times 12d \times 2\pi$ & $0.6d \times 11.48d \times 2\pi$	
Computational grids ($N_x \times N_r \times N_\theta$)	$608 \times 632 \times 96$			$480 \times 432 \times 96$	$480 \times 432 \times 96$ & $192 \times 368 \times 96$	
Nozzle-to-wall distance (h/d)	$5d$			$2d$		
Nozzle pressure ratio (NPR)	2.6	3.4	4.2	3.4		
Reynolds number (Re_d)	50,000					
Nozzle thickness (t/d) (t/d)	12 (Infinite)	12	12	12	0.016 & upper	0.016 & sponge
Total time period (T/t_{ref})	200	400	200	200	200	200
Total dataset size (TB)	8.0	21.0	8.0	5.0	5.0	5.0

The simulations are run for 204.8 acoustic time units ($t_{ref} = ta_o/d$, where t is time, and a_o is the speed of sound) following the transient period. The transient period is approximately 50 acoustic time units during which the initial conditions are translated out of the computational domain. Subsequently, the three-dimensional flow fields are stored every 0.05 acoustic time units, which yields 4096 three-dimensional snapshots. It should be noted that the equations and all dependent and independent variables are non-dimensionalised with respect to the nozzle diameter (d), the speed of sound (a_o) and the reference viscosity which is taken to be at atmospheric conditions.

Flow visualisation of these datasets are available either on YouTube Channel of LTRAC or YouTube Channel of Dr Shahram Karami

3 Structure and format of the datasets

The datasets are archived on Monash University Research Data Storage.

The datasets are organised in different folders based on the parameters of the LES with a name format of:

Data_LES_NPRXX_hYY_tZZZ

where 'XX' is the NPR times 10, 'YY' is the nozzle to wall distance times 10 and 'WW' is the lip thickness times 1000 with '000' refers to infinite lipped ($t/d = 12$) nozzle cases. The three-dimensional fields of density, density weighted velocity vector and total energy are written using parallel HDF5 libraries in files named 'Block.***.h5' and located in Output sub-directory in each of the cases' main directory. A Python script to read output '*.h5' files are also provided on the main directory of the datasets.

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