Aeroacoustics Training Track for OpenFOAM

1 Brief of the course

The module will start with a short introduction to computational aeroacoustics, examples, acoustic analogies and Fast Fourier Transform algorithm to perform transfer data from time to frequency domain. We will do an examination of prepared source code -library with a simple acoustic analogy (Curle's analogy), FFTW code and mechanism of functionObject API in OpenFOAM. We have an option to run the "tandem cylinders" or "cylinder at Re 90 000" tutorial. The "cylinder at Re 90 000" is preferable due to relatively low computational time and simplicity. We shall do analysis of results (pressure fluctuations for an observer, frequency, Strouhal number, SPL). The attention will be paid on a choice of numerical schemes, turbulence model and grid's resolution. As a result of developing of the Curle analogy, one should see the limitations and problems of the simulation non-stationary turbulent flows in comparison with experimental and computational results obtained by other research group.

The attendees will require good knowledge of setting up cases, running/modifying tutorial cases as well as a basic understanding of programming/compiling source code. This module will be hands - on. The attendees will require a laptop with a current OpenFOAM installation or - preferably - be able to boot the conference USB stick.

2 Directory structure

Location of the course - https://github.com/unicfdlab/TrainingTracks /

Folder libAcoustics-OF3.0.0 for OpenFOAM 3.0.0 version of the course

The folder contains next sub-directories:

No.	Name	Description
1.	**cases/**	Cases that will be used to demonstrate developed functionObject's created during the track. The selected cases could be transformed into validation cases.
1.1	cylinder2D	Simple case for calculation of the single cylinder SPL levels. Experiment was conducted by Revell et all, several calculations for SST turbulence using aeroacoustic analogy were obtained by Brentner et all.
1.2	tandem-65k-1	NASA tandem cylinders case for aeroacoustical validation of Curle analogy. Coarse mesh.
1.3	tandem-274k-1	NASA tandem cylinders case for aeroacoustical validation of Curle analogy. Refined mesh.
2.	**lib**	Contains libAcoustics library
3.	**test**	Source code functionObject classes, considered in this track.

3.1	SimpleFoamFunctionObject	Test functionObject, used to demonstrate process of creating custom functionObject from standard OpenFOAM class.
3.2	SimpleFoamLibrary	Test library code that is used during track.
4.	**data**	Source code functionObject classes, considered in this track.
3.1	BrentnerSST-one-cyl-SPL.dat	The scanned [2] Brentner et all simulation data obtained using CFD code with SST turbulence model
3.2	Revell-one-cyl-SPL.dat	The scanned [2] Revell et all experimental data St vs SPL for one cylinder at Re = 90 000

3 Case definitions

3.1 Cylinder at Re = 90 000

This case was selected from experiment series [1]. Dimensionless, geometry and physical parameters has next values:

$$\mathrm{Re} = 90000$$
$$\mathrm{D} = 0.019$$
$$\mathrm{M} = 0.2$$
$$\mathrm{Tu} = 0.2-0.4\%$$
$$k-\omega\, SST\ \ turbulent\ \ model$$
$$pisoFoam\ \ solver$$

The experimental and simulation results by Brentner (scanned from CAA Workshop [2]) is presented in files BrentnerSST-one-cyl-SPL.dat Revell-one-cyl-SPL.dat in “data” sub-directory.

3.2 Tandem cylinders

The case is well described in the article [3] that accumulate data of the two similar experiments obtained at different NASA facilities. The flow parameters and chosen models has following values:

$$\mathrm{Re} = 1.6\times10^5$$
$$\mathrm{St} = 0.01-1.0$$
$$\mathrm{M} = 0.12$$
$$k-\omega\, SST\ \ turbulent\ \ model$$
or
$$SpalartAllmaras\ \ turbulent\ \ model$$
$$pisoFoam\ \ solver$$

Mesh was generated using SALOME v. 6.6.0 and saved in I-DEAS UNV format. Boundary conditions:

- inlet — fixedValue for velocity and turbulent variables,
- zeroGradient for pressure;

- outlet — fixedValue for pressure, zeroGradient for other;
- free — slip for all variables;
- cyl-1 and cyl-2 — no-slip for velocity, impermeability for pressure and wall functions for turbulent variables

Table 1. Tandem cylinder case results

Num.	Source	Cx, 1st	Cx, 2nd
1	Mehdi R. Khorrami and others, simulation	0.71	0.32
2	Luther N. Jenkins and others, experiment	0.62	0.32
3	**Luther N. Jenkins and others, experiment, 1 cylinder**	**0.7**	
4	Markus Weinmann, simulation	0.4-0.6	0.35-0.42
5	Con J. Doolan, experiment by link	0.49-0.52	0.24-0.35
6	Con J. Doolan, simulation	0.338	0.245
7	**Giancarlo Bruschi, experiment, 1 cylinder**	**1.2**	

4 References

[1] James D. Revell, Roland A. Prydz, and Anthony P. Hays. "Experimental Study of Aerodynamic Noise vs Drag Relationships for Circular Cylinders", AIAA Journal, Vol. 16, No. 9 (1978), pp. 889-897.

[2] Second Computational Aeroacoustics (CAA) Workshop on Benchmark Problems; (NASA-CP-3352); (SEE 19970029036 through 19970029065)

[3] David Lockard: Summary of the Tandem Cylinder Solutions from the Benchmark problems for Airframe Noise Computations-I Workshop. 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition Orlando, Florida, DOI: 10.2514/6.2011-353