README: Large-amplitude Transverse Gust Encounter Experiments

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Overview

This README described the large-amplitude transverse gust encounters dataset that is part of "A database for reduced-complexity modeling of fluid flows" [4]. Users of these data should cite the following references:

A. Towne, S. Dawson, G. A. Brès, , A. Lozano-Durán, T. Saxton-Fox, A. Parthasarthy, A. R. Jones, H. Biler, C.-A. Yeh, H. Patel, and K. Taira. A database for reduced-complexity modeling of fluid flows. *AIAA Journal*, 61:2867–2892, 2023

H. Biler, G. Sedky, A. R. Jones, M. Saritas, and O. Cetiner. Experimental investigation of transverse and vortex gust encounters at low Reynolds numbers. *AIAA Journal*, 59(3):786–799, 2021

I. Andreu-Angulo, H. Babinsky, H. Biler, G. Sedky, and A. R. Jones. Effect of transverse gust velocity profiles. *AIAA Journal*, 58(12):5123–5133, 2020

Flow conditions

This dataset corresponds to a low-Reynolds number large-amplitude sine-squared transverse gust encounters [3, 2]. The dimensionless parameters are:

- Reynolds number: $Re = U_\infty c/\nu = 20,000$
- Gust ratio: $GR = V_{\max}/U_\infty \in \{0.5, 0.75, 1, 1.5\}$
- Gust width-to-chord ratio: $w/c = 2.6$

Here, U is the freestream speed, c is the chord of the test model, and ν is the kinematic viscosity, $V_{\max}$ is the maximum gust velocity in the sine-squared gust, and w is the gust width.

Data collection

The large-amplitude transverse gust encounters are experimentally investigated in the University of Maryland free surface water towing tank. The transverse gust was created using a water jet system. The resulting gust was characterized using particle image velocimetry and found to have a streamwise sine-squared and spanwise planar velocity profile. A flat plate test model at 0° angle of attack was towed through the characterized gust and both the forces and the flowfields were obtained. The reader is referred to Ref. [3] for more details on the experimental methods used in this study.

The large-amplitude gust encounter database includes force coefficients and flowfields obtained using time-resolved high-speed planar particle image velocimetry for a flat plate wing at 0° angle of attack encountering

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gusts of various strengths ($GR = 0.5, 0.75, 1.0, 1.5$). The force and velocity datasets include data for five individual runs, as well as ensemble-averaged data for each gust ratio. The force data includes individual and ensemble-averaged normal and axial forces for the cases described above, for a time interval $-5 \leq tU_\infty/c \leq 10$, where $t = 0$ corresponds to the start of the gust encounter. The database also contains 1284 velocity fields obtained using PIV for $0 \leq tU_\infty/c \leq 6.33$, with data from eight individual runs (separate to those used for the force data) and their ensemble-average provided. The resulting field of view was 24×16 cm, and the wing was positioned in the image such that approximately 1.1 and 1.2 chords were allowed upstream and downstream of it, respectively. The final spatial resolution of the data were 0.1 mm per pixel (772 pixels per chord-length), and the temporal resolution was 202 images per convective time. Final vector spacing was 0.79 mm (96.46 vectors per chord-length). The reader is referred to Ref. [3] for further details.

Nondimensionalization

Quantities included in this database are nondimensionalized in the following manner:

$$\boldsymbol{u} = \frac{\boldsymbol{u}^*}{U_\infty^*}, \qquad \boldsymbol{x} = \frac{\boldsymbol{x}^*}{c^*}, \qquad t = \frac{t^* U_\infty^*}{c^*}, \qquad C_{L,D} = \frac{F_{L,D}^*}{0.5\rho^* {U_\infty^*}^2 c^* b^*}$$

Here, the superscript $*$ refers to the dimensional quantity. F denotes a force, with subscripts L and D corresponding to the lift and drag components, respectively. b denotes the airfoil span.

File inventory

The database contains the following files and variables:

- `gustexp_example.zip`: zip archive containing a representative subset of the following data and scripts as an entry point for users
- `gustexp_read.m`: Matlab script showing how the data can be read and manipulated
- `gustexp_parameters.h5`: hdf5 file containing flow and data parameters
  - `Re`: Reynolds number
  - `dt_field`: dimensionless timestep between successive PIV snapshots
  - `dt_force`: dimensionless timestep between successive force measurements
  - `GRs`: gust ratios included in dataset
  - `alpha`: airfoil angle of attack
  - `w2c`: ratio of gust width to airfoil chord
- `gustexp_GR###_grid.h5`: hdf5 file containing grid information
  - `x`: streamwise grid
  - `y`: stream-normal grid
  - `xa`: x locations of leading and trailing edge of airfoil
  - `ya`: y locations of leading and trailing edge of airfoil
- `gustexp_GR###.h5`: hdf5 file containing data for gust ratios `###` $\in \{050, 075, 100, 150\}$
  - `t_field`: times where velocity PIV data is collected
  - `ux`: ensemble-averaged streamwise velocity at each (`x`, `y`, `t_field`) grid point and time
  - `uy`: ensemble-averaged stream-normal velocity at each (`x`, `y`, `t_field`)) grid point and time

- `ux_allruns`: streamwise velocity at each (`x`, `y`, `t_field`,j) grid point and time, where $j \in \{1, 2, \cdots, 8\}$ is the run number
- `uy_allruns`: stream-normal velocity at each (`x`, `y`, `t_field`,j) grid point and time, where $j \in \{1, 2, \cdots, 8\}$ is the run number
- `t_force`: times where force variables are collected
- `Cl`: ensemble-averaged airfoil lift coefficient at each time `t_force`
- `Cd`: ensemble-averaged airfoil drag coefficient at each time `t_force`
- `Cl_allruns`: airfoil lift coefficient at each (`t_force`,j), where $j \in \{1, 2, 3, 4, 5\}$ is the run number
- `Cd_allruns`: airfoil drag coefficient at each (`t_force`,j), where $j \in \{1, 2, 3, 4, 5\}$ is the run number

References

[1] I. Andreu-Angulo, H. Babinsky, H. Biler, G. Sedky, and A. R. Jones. Effect of transverse gust velocity profiles. *AIAA Journal*, 58(12):5123–5133, 2020.

[2] H. Biler, G. Sedky, A. R. Jones, M. Saritas, and O. Cetiner. Experimental investigation of transverse and vortex gust encounters at low Reynolds numbers. *AIAA Journal*, 59(3):786–799, 2021.

[3] Hulya Biler. *Experimental Investigation of Force Transients during Gust Encounters*. PhD thesis, University of Maryland, College Park, 2021.

[4] A. Towne, S. Dawson, G. A. Brès, , A. Lozano-Durán, T. Saxton-Fox, A. Parthasarthy, A. R. Jones, H. Biler, C.-A. Yeh, H. Patel, and K. Taira. A database for reduced-complexity modeling of fluid flows. *AIAA Journal*, 61:2867–2892, 2023.