Turbulent/non-turbulent interfaces bounding regions of equilibrium and non-equilibrium turbulence

M. Zecchetto,* T. Watanabe,† K. Nagata‡ and C. B. da Silva*

The statistics of turbulent/non-turbulent interfaces (TNTI), which divide the turbulent core region from the surrounding irrotational region, are evaluated using direct numerical simulations (DNS) of turbulent planar wakes and planar jets, where the turbulent core region is under non-equilibrium (unbalanced) configuration. The evolution of the non-dimensional dissipation rate ($C_\varepsilon = \langle \varepsilon \rangle L_{11}/u'^3$) with time and with respect to the turbulent Reynolds number (Re_λ) is used to evaluate the non-equilibrium state of the flow[1], and the results show that the non-dimensional dissipation displays the power law $C_\varepsilon \sim Re_\lambda^{-1.2}$, characteristic of non-equilibrium turbulence (figure 1a).

The key quantity when analysing a TNTI is the vorticity (or enstrophy) since its magnitude increases abruptly from virtually zero in the irrotational region into the value of the turbulent core region[2]. Figure 1(b) depicts the time evolution of the conditional enstrophy profiles obtained with the origin ($y_I = 0$) at the irrotational boundary separating the irrotational ($y_I < 0$) and turbulent ($y_I > 0$) flow regions. It is clearly shown that in the first instants the 'classical' shape of the profile is not present and it is recovered only successively. The normalisation of the conditional enstrophy profiles using Kolmogorov velocity and time scales, as described in Zecchetto and da Silva[3] shows that during the times corresponding to equilibrium turbulence, the same form is regained, but not for the first instants when the turbulence inside the turbulent core region is out of equilibrium. This shows that the interface's primary characteristics have not altered, in particular, the mean thickness of the TNTI scales with the Kolmogorov micro-scale as previously reported at high Reynolds numbers.

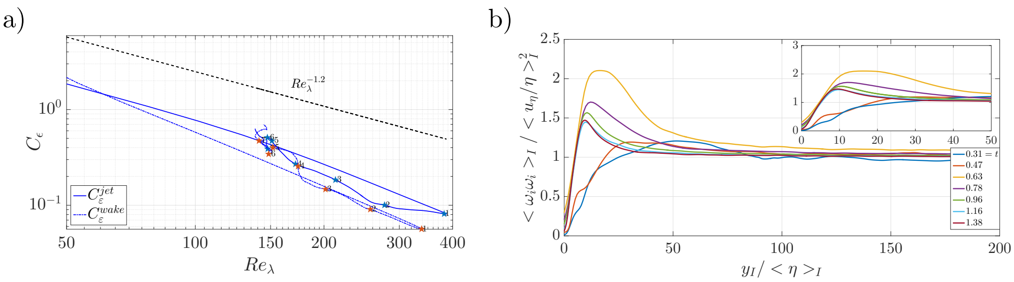

Figure 1: (a) Non-dimensional dissipation C_ε as a function of the Reynolds number and, (b) Conditional mean enstrophy profiles for the DNS of the wake for several instants.

*LASEF, IDMEC, Instituto Superior Tcnico, Universidade de Lisboa, Av. Rovisco Pais, 1, Lisboa 1049-001, Portugal

†Education and Research Center for Flight Engineering, Nagoya University, Nagoya, 464-8603 Japan

‡Department of Mechanical Engineering and Science, Kyoto University, Kyoto, 615-8540 Japan

[1] Zheng et al., *J. Fluid Mech.* **956**, A20 (2023).

[2] da Silva et al., *Annu. Rev. Fluid Mech.* **46**,567-590 (2014).

[3] Zecchetto and da Silva, *J. Fluid Mech.* **916**, A9 (2021)