Study of turbulence development by induced oscillatory modes

P. Buchhave[a], R. Schlander[b], M. Dotti[c], M. Ren[d] and C. M. Velte[e]

The study of the dynamic development of turbulent velocity structures in the Fourier domain, often called triad interactions, provides a very instructive view of the workings of turbulence. In the following, we give examples of experiments where one or two oscillations have been injected into a jet flow. We measure the velocity and compute the power spectrum at stations downstream along the jet axis. We interpret the development of the flow as the result of repeated actions of the Navier Stokes Equation on a fluid parcel convected with the flow. We also use a computer program to simulate the developing flow. By repeated iterations of the Navier Stokes Equation acting on a measured velocity record, we compute the expected development of the triad interactions and power spectra. In each case, we get very good agreement between the measured and computed velocity power spectra. The computation in addition allows us to show exactly which Fourier components participate in the development of the flow, when the interactions take place and whether the Fourier components contribute with a positive or a negative sign to the spectrum.
In the first example, we inject an oscillation into a highly turbulent flow at 10D, 20D or 30D, where D is the diameter of the jet aperture, by means of a flapping air foil. We then measure the axial velocity at stations from 1D to 50D along the jet centerline and display the power spectrum.
In a second series of experiments, we inject oscillations in a low turbulence jet by vortex shedding from one rectangular rod or from two parallel rectangular rods suspended across the 100 mm diameter jet exit. We measure the velocity and compute the measured power spectrum at six stations along the centerline from 10 mm to 60 mm. In further two-dimensional plots, see Figure 1 below, we display the computed Fourier components at wave numbers, k_1 and k_2 entering into the creation of the resulting power spectrum at $k=k_1+k_2$

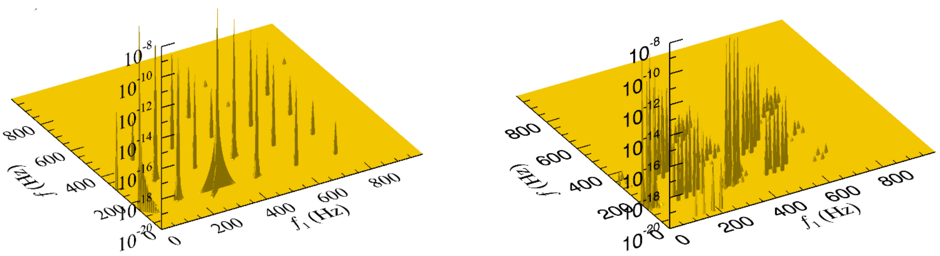

Figure 1. Examples of mode interactions. Left: Single rod. Right: Two parallel rods.

a Intarsia Optics, Sønderskovvej 3, 3460 Birkerød, Denmark
b Imperial College, London, UK
c Dep. Chemical and Biochemical Eng., Technical University of Denmark
d Dep. Aeronautics and Astronautics, Kyushu University, Fukuoka 819-0395, Japan
e Dep. Civil and Mechanical Engineering, Technical University of Denmark