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Experimental and Numerical Study of a Turbulent Water Flow Mixing Induced by a Fractal Grid

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Mixing is a physical phenomenon that manifests in diverse contexts. In nature, it plays a role in preventing erosion along coastlines and occurs within the atmosphere, influencing weather patterns. An example of mixing is when a sugar cube is placed in a cup of coffee. Diffusion acts as the driving force for its dissolution. However, using a spoon enhances the mixing of sugar into the coffee. In fluid mechanics, turbulence has a similar effect to the spoon: it improves the mixing of a physical quantity, such as temperature or concentration.

Turbulence can be enhanced using a grid because of the creation of turbulent structure of the size of the grid mesh. A laminar flow can become turbulent, and a turbulent flow can become even more intense. Grids, therefore, promote mixing. To evaluate the mixing process, the Turbulent Kinetic Energy (TKE) serves as a good first approximation. For classical grids, the TKE follows a *power-law decay* which is the highest just downstream of the grid and decreases with distance.

In 2007, Hurst and Vassilicos [1] developed a *fractal* grid. The mesh of this grid is non-uniform, which results in the generation of multiscale turbulence. A key consequence of this multiscale turbulence is the behaviour of the turbulent kinetic energy (TKE): it exhibits a peak at a specific distance x_{peak} from the grid. At this location, the mixing effect reaches its maximum. One interpretation of this phenomenon is that the turbulent structures at all scales converge at the distance x_{peak}. Furthermore, the homogeneity and isotropy of fractal grid turbulence are comparable to those observed in classical grid turbulence.

Most studies on fractal grids have been conducted in wind tunnels. However, experiments on fractal grid-generated turbulence in water are rare. Nevertheless, water flows generate more shear than air flows due to the higher dynamic viscosity of water ($\frac{\mu_{water}}{\mu_{air}} = 50$ at 298K). As a result, velocity gradients are higher, leading to increased turbulence.

This study investigates the velocity characteristics of mixing in a turbulent confined water flow. For the experimental aspect, an hydraulic loop was developed, where four isothermal water flows are blended using a fractal grid (cf. Figure 1). The mixing process, which is amplified by the confinement, was observed using stereo-PIV in several planes within the mixing region (cf. Figure 2). On the numerical side, a Large Eddy Simulation (LES) was carried out to compare with the experimental results. Additionally, all the data were compared with literature.

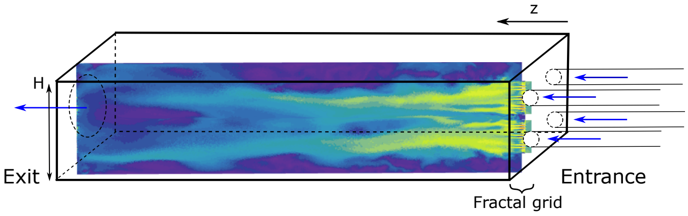

Figure 1: Experimental configuration with an instantaneous longitudinal velocity field from LES.

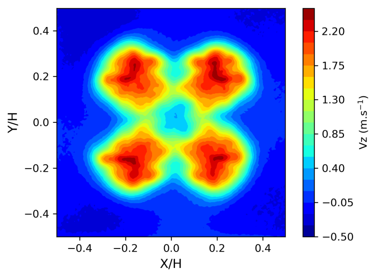

Figure 2: Example of mean velocity fields with turbulent water flow using a fractal grid at z/H=0.05.

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[1] Hurst and Vassilicos, *Physics of Fluids* **19**, 035103 (2007)