Design for Fractal Grid Generated Turbulence

Moira Gion
Portland State University

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**Objective**

- Design a set of passive grids with fractal geometry to be placed at the entrance of an axial tunnel, acting as an inflow condition.
- Quantities of interest are mean velocities, turbulence intensities, turbulence decay, energy dissipation rate, anisotropy/ isotropy, and the formation of vortices.

The observations obtained can contribute to the understanding of flow mixing by manipulating inflow conditions. Practical applications of this knowledge could include energy-efficient mixing, heat dissipation techniques in electronics, and ventilation.

**Background & Motivation**

Fluid flow is a dynamic system and its development is reliant on initial conditions. Turbulent flow often displays intermittency, or periodic phases, and vortices. Therefore, the Taylor microscale, $\lambda$, is calculated by:

$$\lambda = \frac{u}{\sqrt{\langle u' \rangle^2}}$$

where $u$ is the instantaneous velocity and $\langle u' \rangle^2$ is the turbulence intensity. The Taylor microscale is calculated by:

$$Re = \frac{V}{\lambda}$$

$V = \text{incoming velocity}$

$k = \text{Taylor microscale}$

$u = \text{Kinematic viscosity}$

Prior studies for fractal generated turbulence using square grids have been performed by Hurst et al. (2007), Saeed et al. (2010), and Gomes, Fernandes, and Vassilicos (2010). In these studies, they observed unusual behavior in turbulence, they found a constant ratio of integral scale to Taylor microscale as a function Reynolds number. In addition, turbulence intensities increased in the streamwise direction as the thickness ratio increased.

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**Design Process**

1. **Geometry:** Four fractal patterns were two-dimensionally sketched in AutoCAD. The open center grid was selected for the ease of design compared to the center space filled grid.

2. **Properties:** Values for length ratios, thickness ratio, and blockage ratio were chosen. The fractal dimension was determined based on the geometry of the design and describes the complexity of the shape.

$$D = \log(N)/\log(a)$$

where $N$ is the number of copies, $a$ is the ratio of the fractal dimensions, and $L$ is the ratio of the lengths.

3. **Dimension:** Based on the selected properties and the dimensions of the wind tunnel cross-section, the diameter of the circles were determined using an iterative process until all properties were met.

4. **Fabricating & Material Considerations:** Baltic birch plywood was chosen because of its stiffness and low comparable costs to other materials.

**Results**

- **Grid properties:**
  - Fractal Dimension = 2
  - Length Ratio = 4
  - Thickness Ratio = 2.5
  - Blockage Ratio = 29% ± 0.5

**Conclusion**

- Circular geometry was chosen to design five grids to study the behavior of the induced flow from a fractal grid since previous studies have been done with square and I-beam patterns that create many sharp edges.

- The fractal dimension of the circular fractal geometry was determined using the radius for the ratio of scale.

- The desired blockage ratio and thickness ratio were achieved by adjusting the inner diameters in a iterative design process.

- Material selected to build the bridge was Baltic birch plywood and the grid was fabricated using a laser cutter.

- The grid successfully showed little to no visual vibrations under desired incoming velocities.

- As the thickness ratio increases, the fractal bars will become thinner. It is recommended when doing so to look into stiffer materials in order to significant vibrations do not occur.

**Moving Forward**

Next steps that need to be taken to meet the goals of the project are:

- Create a set of fractal grids with thickness ratios of 5 & 8, while keeping blockage, length ratio, and fractal dimension constant.
- Create a center space filled grid, example reference figure 2(a).
- Collect data using Particle Image Velocimetry (PIV).

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Joe Laid - PSU MELT Team

