Power Spectrum of the Scalar Field

Objective and Purpose

As claimed by *Tennekes and Lumley* (pg.248), the analysis in spectrum provides us "the opportunity to think about the way in which waves, or eddies, of different sizes exchange energy with each other." The primary object this year for running this experiment is to take data on the temperature at different Taylor Reynolds Number and determine the slope of the inertial subrange in the scalar spectrum. We have an active grid running upstream of the scalar generator. A cold-wire thermometer will be taken at various downstream positions (different Taylor Reynolds Number). Essentially we want to be able to perform the experiment and collect the data on our own, compare it with the findings from Mydlarski and Warhaft 1998 and extend to higher Taylor Reynolds Numbers.

Introduction

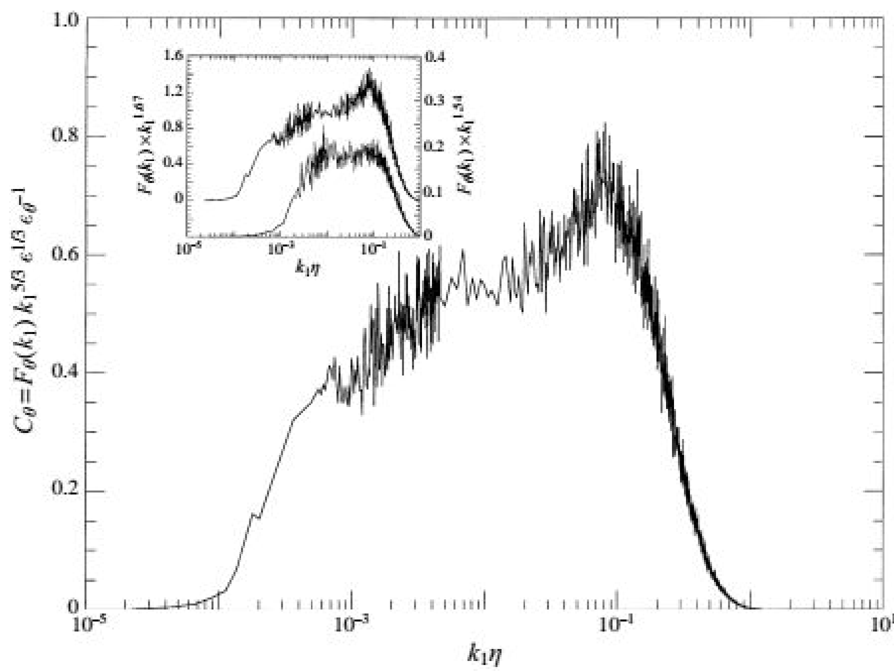

Fig. 1: a typical compensated scalar spectrum when R_λ=582 (L. Mydlarski and Z. Warhaft 1998)

Both the main curve in the figure above and upper curve of the insert show a typical compensated scalar spectrum when R_λ=582, and the lower curve of Fig. 1 shows a spectrum when R_λ=140. It indicates that, before the dissipation range, a significant bump is following around one decade of inertial range. By comparing spectrums of two R_λ, the temperature at higher reynolds number has a more obvious bump, although the bump in spectrum of lower R_λ

may slightly exist. That means the slope does not have a visible spike compared to higher Taylor Reynolds numbers. This figure is studied for two reynolds numbers. We are trying to evaluate the spectra of a wide range of reynolds numbers.

In particular, We are interested in figuring out how n_θ, the slope of the scaling range in the temperature spectrum, changes with R_λ. In *Mydlarski and Warhaft (1996)*, As Fig. 2 shown, it is a horizontal scaling region. Solid circles and squares indicating isotropic data of grid operation in random and synchronous mode, respectively. The beginning of n_θ decreases slightly from 5/3, which is around 1.5, but eventually it will stay closer to 5/3 for all R_λ. (*Mydlarski and Warhaft,* 1996)

While the insert shows the slope of the velocity spectrum, n, is a function of Taylor Reynolds Number, R_λ. At lower R_λ, the scatter is increasing, and at higher R_λ, the slope is likely to approach to 5/3 when increasing R_λ. As suggested in this article, for completeness, the equation comes to be:

$$n = 5/3 - 43.1 * R_\lambda^{-1.02}$$

Line is achieved by approaching asymptote to 1.657 when R_λ approaches infinity. (Alejandro Puga, 2014)

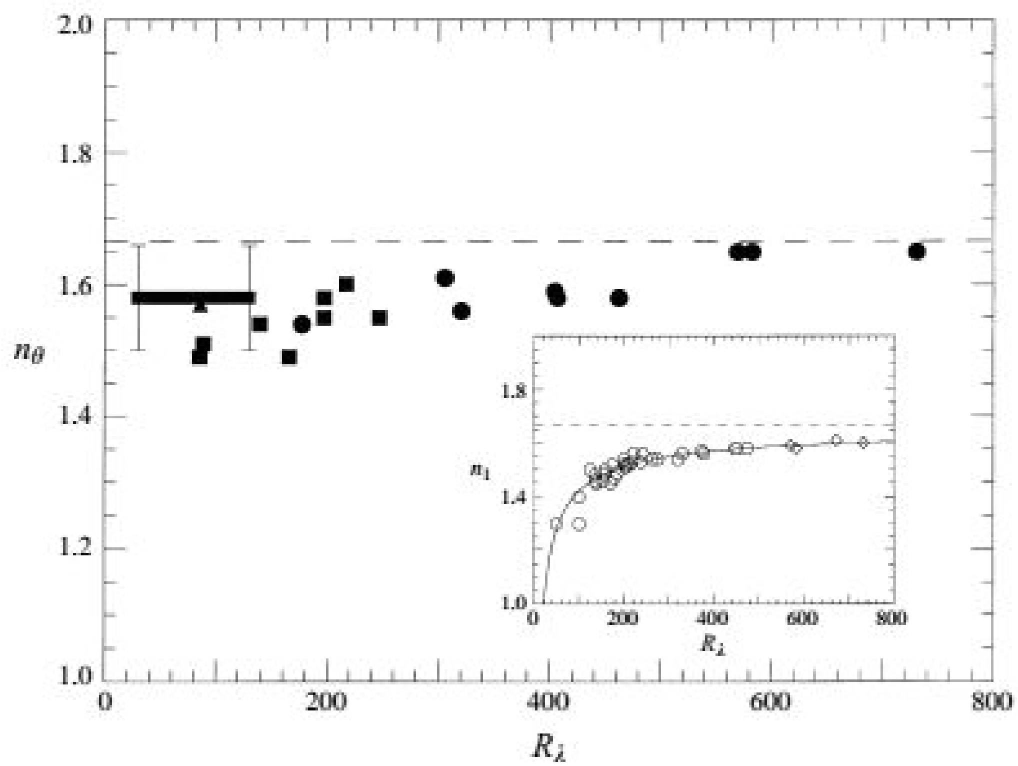

Fig 2: the slope n_θ, of temperature spectrum as a function of R_λ (*Mydlarski and Warhaft,* 1996)

In fact, it is expected that at lower Reynolds numbers, scalar field keeps the characteristics of strong turbulence than the velocity field does. (*Mydlarski and Warhaft,* 1996)
Furthermore, we will extend our study to much higher Taylor Reynold numbers. In the part of higher R_λ of Fig 2. It seems that the scale is going to be a horizontal line when the R_λ increases. In this case, doing more research by using much higher R_λ is quite necessary, therefore, we can check how close that scale can approach 5/3.

Approach

During the experiment, an active grid, consisting of diamond shaped flaps mounted on vertical and horizontal rods, is placed in the upstream section of a wind tunnel and able to rotate, in order to produce turbulent flows that are nearly isotropic and homogeneous. The passive scalar for this experiment is temperature, and the heat is produced by galvanized wires in horizontal and vertical direction. These wires are such thin that we can neglect their influence in the turbulence of incoming flows.
To obtain the scalar power spectrum, a cold-wire thermometer is needed.

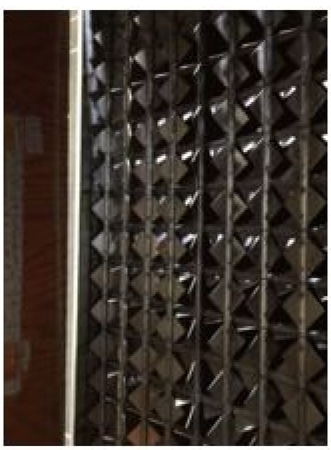

Fig: active grid in the wind tunnel

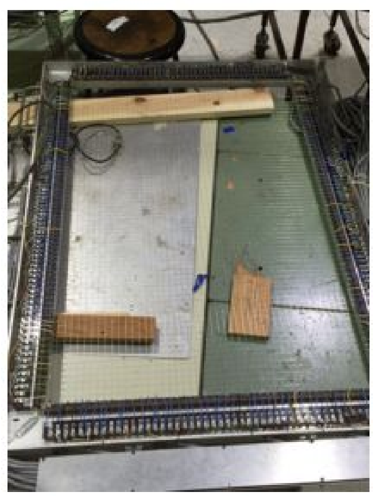

Fig: galvanized wires placed horizontally and vertically

The cold-wire thermometer will be run at low but continuous current, the purpose is to heat it up just a tad above ambient temperature, so it will be sensitive to temperature fluctuations instead of velocity fluctuations.
We will have the thermometer at various distance and set height somewhere downstream from the scalar generator, and we will take the data on temperature at those locations.

The thermometer will be far enough downstream to make sure that the temperature is homogeneous; and that the scalar field is homogeneous as well.
After obtaining the datas we will construct them in excel and analyze it to see if it matches up to the past experiments and their results.

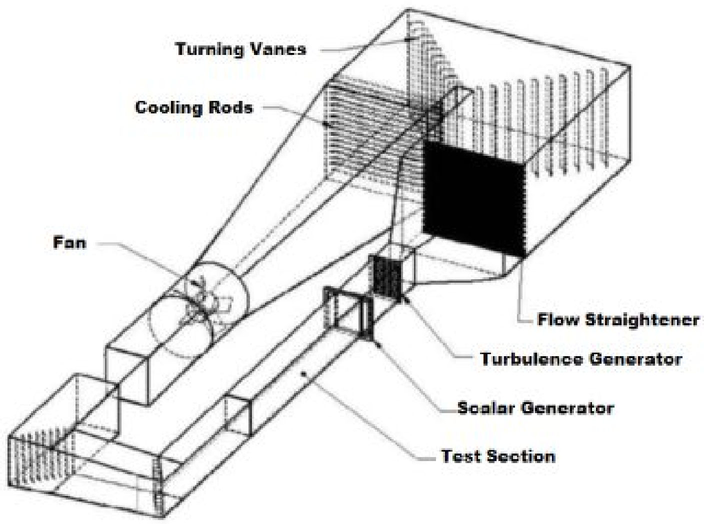

Fig: wind tunnel diagram

Responsibilities

Our responsibilities will be to construct and maintain a passive, power scalar generator and collect data with the cold wire sensor at different distances from the active grid. The generator will consist of criss-crossing, galvanized wires that are attached to the frame by solder. These thin wires must be able to withstand the force by the turbulent flow and the heat generated from the external power source. Additionally, we will be responsible for conducting accurate tests and calibrating the cold wire sensors daily. We will operate the data collection software, the traverse control, and the data analyzing software. Also, we will need to adjust the active grid to produce turbulent flows that are nearly isotropic and homogeneous. This can include altering the software that operates the grid or possibly machining the parts necessary to attain these conditions. After collecting all the data we will input the data into excel and analyze it.

Timeline

Fabrication of the Passive Grid	1 week
Maintaining and Testing of All Components	3 weeks
Data Collection with Passive Grid	2 weeks
Data Analysis	2 weeks
Symposium Preparation	2 weeks

Budget

Item Description	Quantity	Estimated Cost
Wollaston Wire	2	$1200
X-Wire	1	$600
17MD-Stepping Motor	2	$170
Soldering Irons	2	$76
Chromel P Wire	2	$48
Indium Wire Solder	1	$25
Terminal Block	2	$12
Total		$2131

Reference

Tennekes, H. & Lumley, J.L., 1972. A First Course in Turbulence, MIT Press.

Mydlarski, L. & Warhaft, Z., 1998. Passive scalar statistics in high-Péclet-number grid turbulence. Journal of Fluid Mechanics.

Mydlarski, L. & Warhaft, Z., 1996. On the onset of high-Reynolds-number grid generated wind tunnel turbulence. Journal of Fluid Mechanics.

Alejandro Puga, 2014. Characteristics of the velocity and temperature power spectrum as a function of Taylor Reynolds number. UNIVERSITY OF CALIFORNIA, IRVINE