ECE 533 Final Project

Decomposing non-stationary turbulent velocity in open channel flow

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1 Introduction

In natural environment, the flow of a fluid can be categorized as laminar or turbulent flow. Observing that water run through a pipe, we can inject neutral dye to investigate the flow characteristics (see the Figure 1 below). For "small enough flowrates", the dye streak will remain as a well-defined line as it flows along, with only slight blurring due to molecular diffusion of the dye into the surrounding water. For a somewhat "intermediate flowrates", the dye streak fluctuates in time and space, and intermittent bursts of irregular behaviors appear along the streak. On the other hand, for "large enough flowrates" the dye streak almost immediately becomes blurred and spread across the entire pipe in a random fashion. These three characteristics are denoted as laminar, transitional, and turbulent flow, respectively.

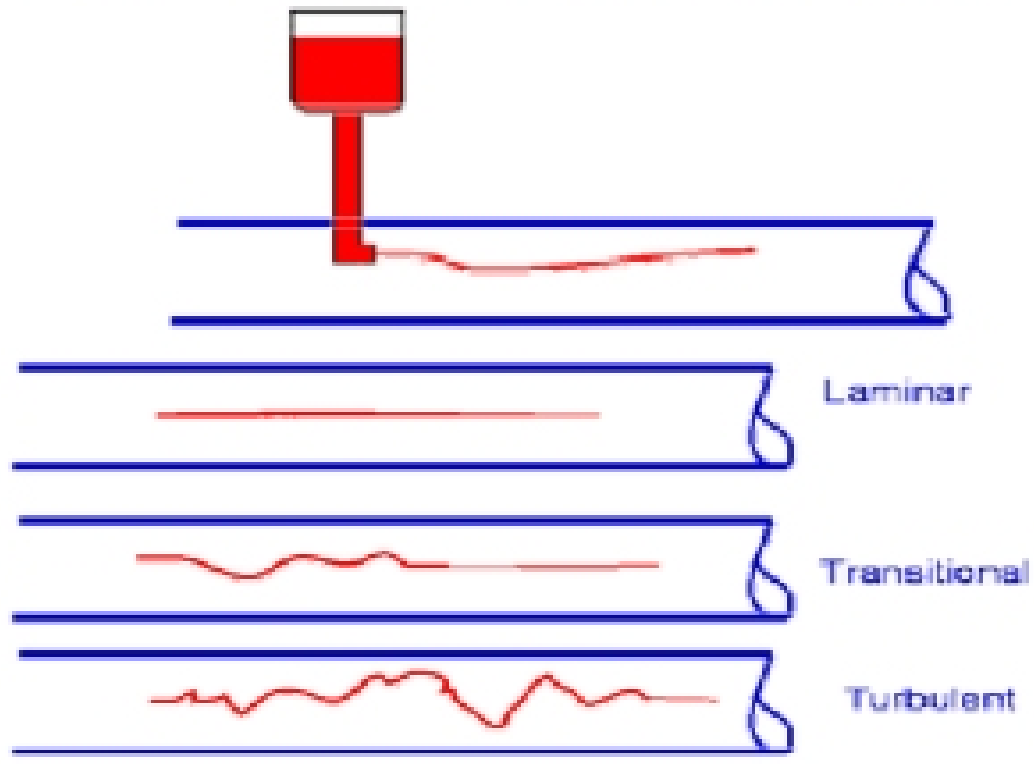

Figure 1 Experiment to illustrate type flow and dye streaks

Suppose that we place a velocimetry probe at one point of the pipe, for laminar flow, there is only one component for velocity; however, for turbulent flow the predominant component of velocity is also along the pipe, but it is accompanied by random components normal to the pipe axis. Slow motion pictures of the flow can more clearly reveal the irregular, random, turbulent nature of the flow.

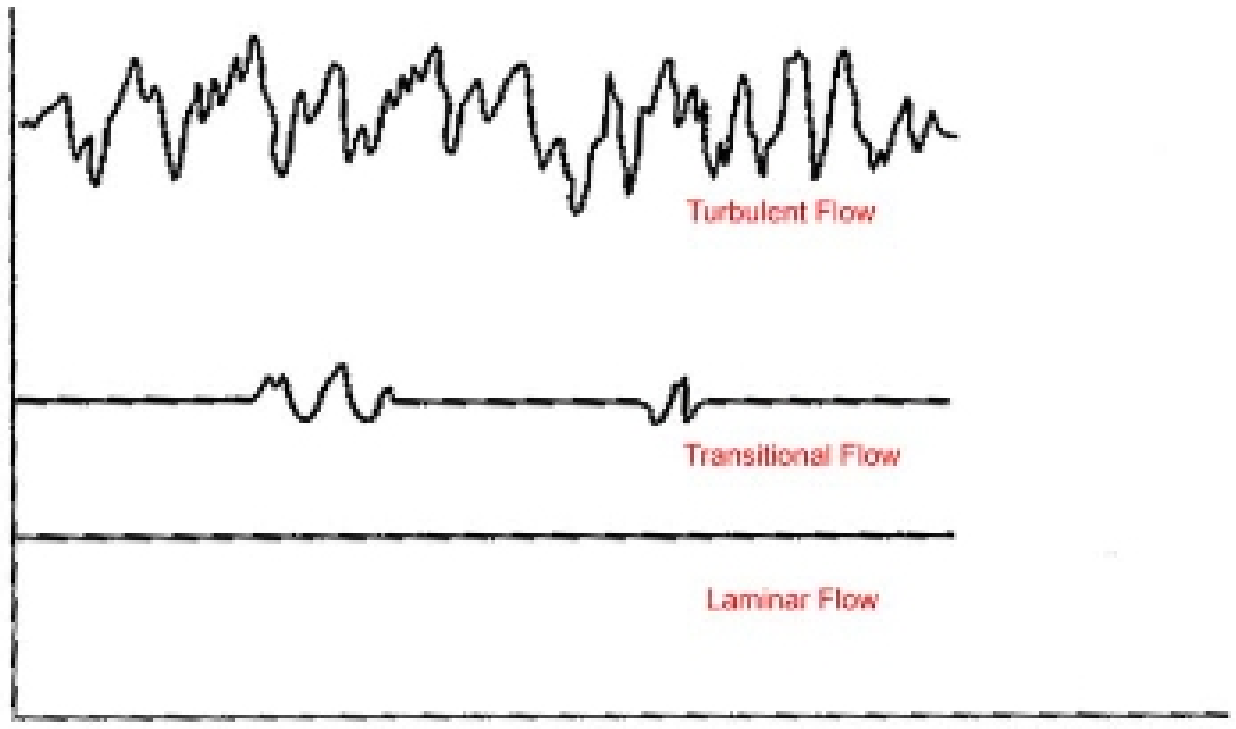

Figure 2 Time independent of fluid velocity at a point

Turbulent flows are beneficial to our daily life. Mixing processes and heat and mass transfer processes are considerably enhanced in turbulent flow compared to laminar flow. For example, to transfer the required heat between a solid and an adjacent fluid (such as in the cooling coils of an air conditioner or a boiler of a power plant) would require an enormously large heat exchanger if the flow were laminar. Furthermore, it is considerably easier to mix cream into a cup of coffee (turbulent flow) than to thoroughly mix two colors of a viscous paint (laminar flow). In order to deal with turbulent flow, previous researcher represented the turbulent velocity as the sum of time mean value, $\bar{u}$ and the fluctuating part of the velocity, u', that is:

$$u = \bar{u} + u' \tag{1}$$

Where $\bar{u} = \frac{1}{T}\int_{t_0}^{t_0+T} u(t)dt$, the time interval, T, is considerable longer than the period of the longest fluctuations, but considerably shorter than any unsteadiness of the