

# The detailed structure of randomization process of free shear layers

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## ABSTRACT

The free shear layer is suitable for understanding the basic mechanism of randomization. Sound from a loud-speaker was used for introducing ordered velocity fluctuation in the layer. Three kinds of shear layer were tested and compared. A quantitative expression of the degree of randomness was accomplished by the elementary-wave analysis. The concept of neighbor randomness was introduced for another way of describing randomization. The randomization process of three shear layers does not show any significant difference.

Key Words: Free Shear Layers, Randomization.

### 0. Introduction

The laminar-turbulent transition is a very important problem in the fluid dynamics. The detailed structure of the transition is still not understood. The most important at present is how to express the degree of the randomness. This paper is one answer to this question.

### 1. Flow Field

Among three layers we concentrate on the separated layer. Other two layers will be compared at the end.

A 40-mesh metal screen of which width is 40 mm was placed in the test section of 25 cm x 25 cm wind tunnel. Fig 1 is the mean-velocity distribution at 30

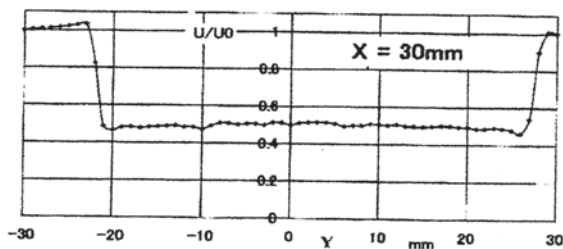


Fig 1 mean-velocity distribution of separated layer

mm from the screen. The mean-flow velocity is 4 m/s. The shear layer was excited by the sound from a loud speaker placed near the test section. The frequency of sound is 270 Hz. It is clearly shown that two separated layers are formed at two ends of the screen. The randomization is achieved before two separated layers meet downstream. Thus we are making experiment in the single separated layer.

### 2. Wave Form

The wave form of velocity fluctuation obtained by X = 100 mm Y = -25 mm

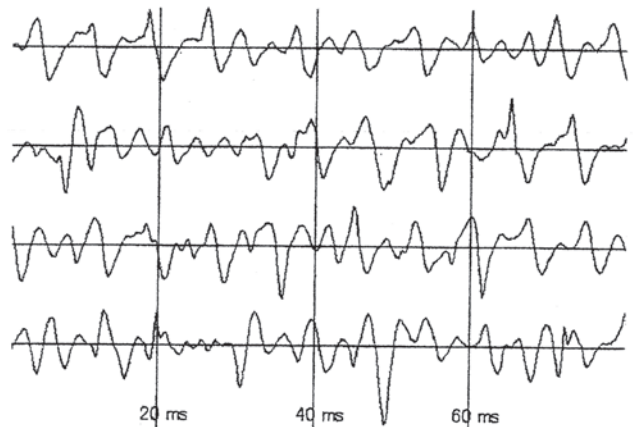


Fig 2 Wave Form

a hot-wire anemometer is shown in figs 2 and 3. The wave form in figure 2 shows some periodicity as well as random components. At  $x = 200$  mm the wave form is almost random. This means that the randomization process ends before the  $x -$  station.

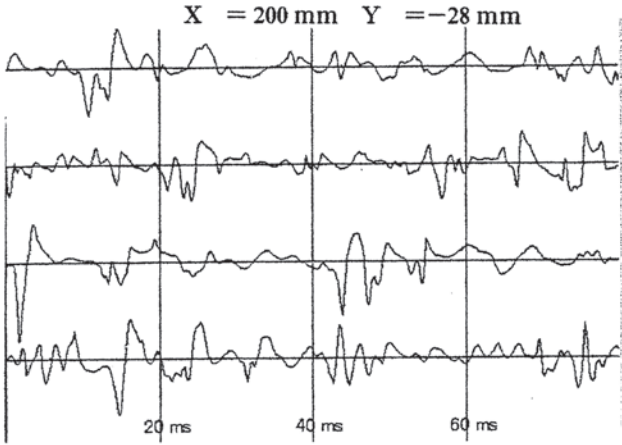


Fig 3 Wave Form

**3. spectrum**

The energy spectrum of  $u$ -fluctuation is taken by FFT process. Figures 4 and 5 are examples. Figure 4 shows some sharp peaks. It means that line components still remains.

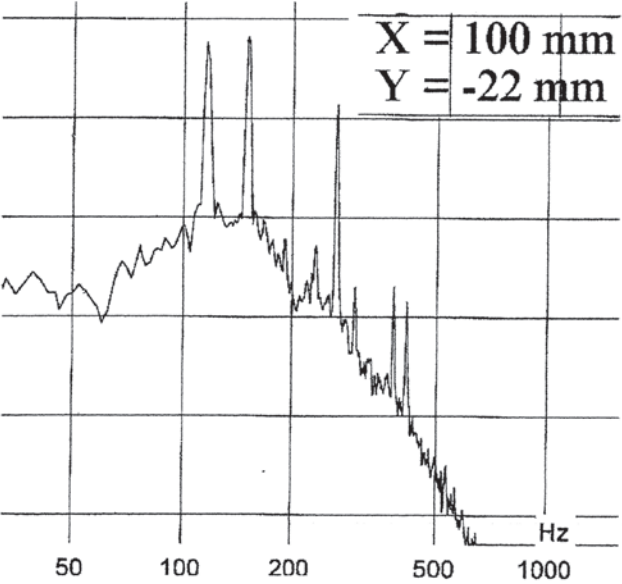


Fig 4 Spectrum

At  $X=200$  mm the spectrum is smooth and continuous. It means that a turbulent separated layer is formed here.

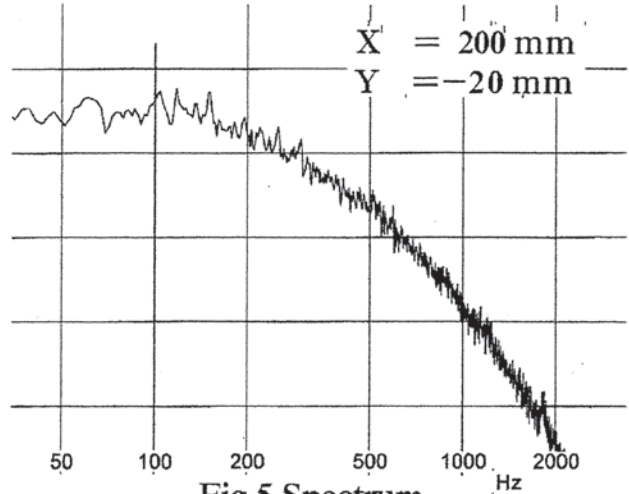


Fig 5 Spectrum

**4 . elementary-wave analysis**

The energy spectrum is useful for detecting the end of randomization process but it does not give any quantitative information of the randomness.

We here propose a new method of analyzing the wave form directly. It is called elementary-wave analysis. The wave form is analyzed piece by piece as shown in fig 6. The wave length and amplitude of each wave is obtained by a small computer, and registered into the memory. Each wave length and amplitude was normalized by the average and expressed on the wave length and amplitude axis by small circles as shown in fig 7.

The wave form at  $x = 75$  mm is close to sinusoidal

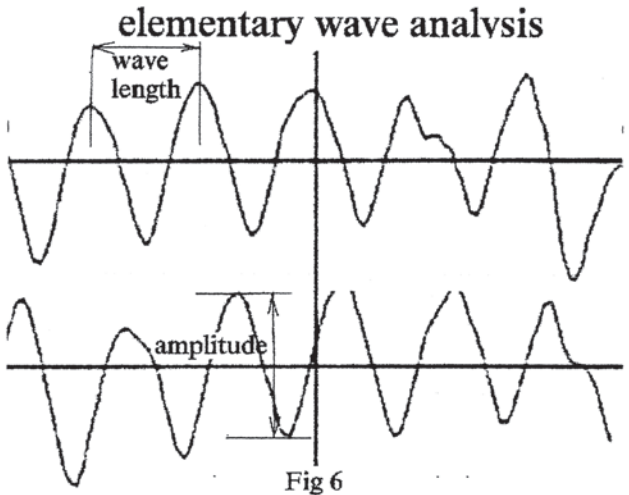


Fig 6

Therefore small circles gather around (1,1) point. The average distance from (1,1) is multiplied by

100 and defined as the random number. Figure 7 indicates that the average is 22.76. This number is an indication of randomness. This value is small and far

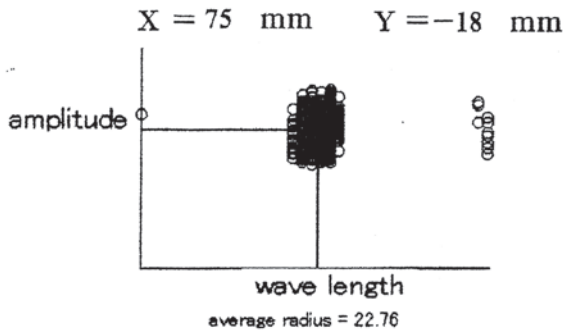


Fig 7

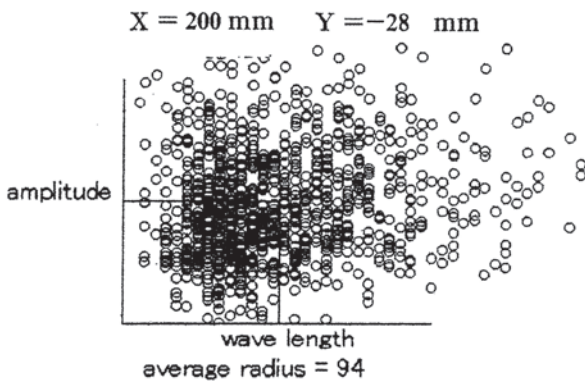


Fig 8

from being random.

Figure 8 shows at X = 200 mm. It is clear that small circles scatter in a wide space and average radius is 94 which indicates a turbulent layer is formed. There is no positive reasoning about the border of being turbulent. This fact is essential to the randomization process. No body can clearly distinguish the border between turbulent and non-turbulent region.

Fig 9 shows the streamwise variation of randomness number. If we assume the border of randomization as 90, it is accomplished between x = 150 and 200.

The Y-distribution of randomness number is not uniform. It seems that the randomization is late near the center line. It should be emphasized here that the results of randomization is poorly reproducible. It seems convincing that the randomization takes place randomly. If it is not so, the process is self

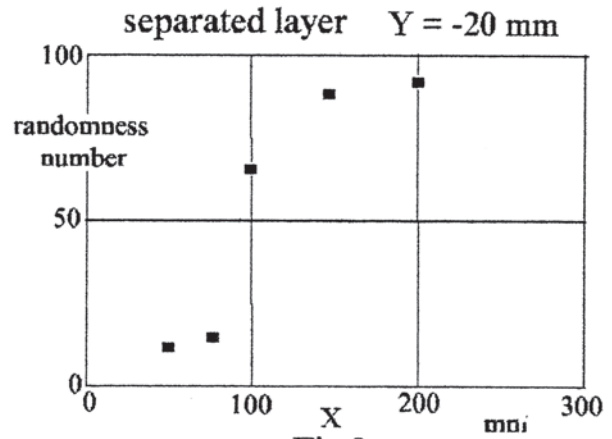


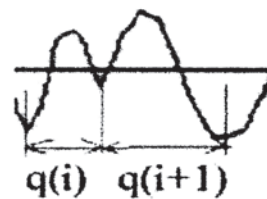
Fig 9

contradictory.

### 5 . Neighbor Randomness

Other feature of randomization is the permutation problem. It is to seek the way of appearance. The random number or dice casting is one of randomness. Each trial is independent and one can easily calculate the probability. This is one of randomness. The turbulent flow is governed by the continuity relation and equation of motion. The appearance of next number can not be independent of the preceding wave.

### neighbor randomness



$$= \sum_{i=1}^N \frac{|q(i+1) - q(i)|}{q(i+1) + q(i)} \cdot \frac{100}{N}$$

Fig 10

Fig 10 is the definition of neighbor randomness. It is nothing but summing up of difference of two

neighboring waves. It is clear that for sinusoidal wave the randomness is zero. As moving downstream the randomness increases and eventually it may reach 100.

Fig 11 shows calculated neighbor randomness at

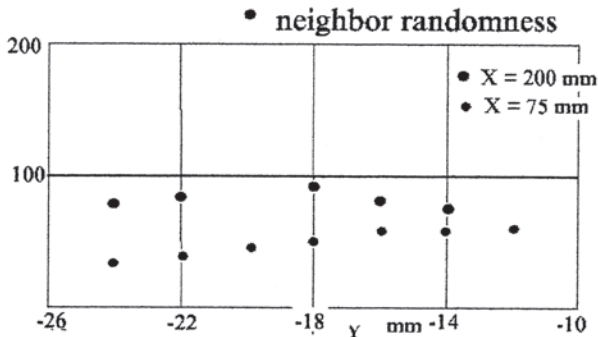


Fig 11

two x-stations. The neighbor randomness is small at small  $x$  and reach around 40 at  $x = 200$  mm. This is obviously another expression of randomness.

## 6 . primary- wave analysis spectrum

It is possible to make some statistics based on the primary analysis. It is number of waves accumulated according to the wave length. The vertical scale is in logarithmic.

$X = 50$  mm  $Y = -23$  mm

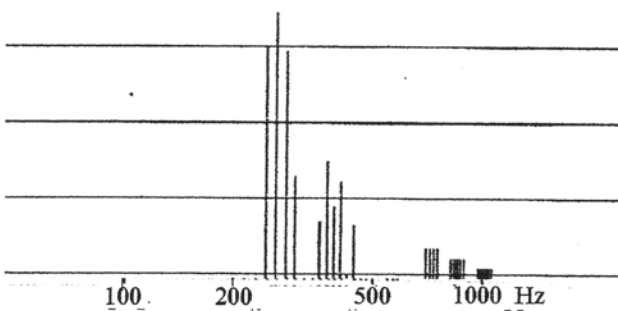


Fig 12

Fig 12 shows an example of the spectrum at relatively upstream position. The concentration of spectrum is clearly observed between 200 and 500 Hz.

Fig 13 shows spectrum at larger  $x$ . Many spectral components are formed in lower as well as higher frequency range. It is similar to the energy spectrum.

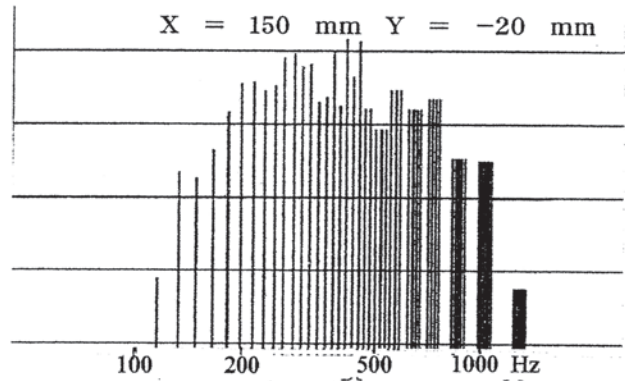


Fig 13

## 7 . Comparison with other shear flows

Experiments were made with a narrow screen, width being 4 mm. In this case two separated layer meets before they are randomized. the randomization process is more complicated. Accordingly, the randomization is a little slower than the separated layer. Another flow is the wake of a flat plate placed parallel to the flow. In this case there is no separation and a symmetrical laminar wake is formed at the trailing edge. This wake seems to be slow in the randomization process.

Generally speaking, there is no essential difference among these three shear flows. The turbulent wakes also show no significant differences.

## 8 . conclusion

The following conclusions were obtained

1. The quantitative description of the degree of randomness became possible by the introduction of the primary -wave analysis.
2. The poor reproducibility of randomization process was clearly observed.
3. The turbulent flows made in three different free shear layers are more or less similar.
4. The primary-wave spectrum is another indication of randomness. It shows similar nature as energy spectrum.