6 PÁGINAS

A MODIFIED TURBULENCE SPECTRUM BY THE DISIPATION OF THE ENERGY

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ABSTRACT

In the model of Taylor (1938) it is proposed to discuss the connection between the spectrum of turbulence, measured al fixed point, and the correlation between simultaneous values of velocity measured at two points. They are four main equations interconnected: a) the spectrum curve; b) the correlation between simultaneous values of velocity of turbulent motion at distance of propagation axis; c) the curvature (C) of the curve drawing aforementioned and distance of propagation axis; d) the equation between (C) and dissipation of energy. The aim in this paper is to deduce a spectrum curve modified using an new relationship between (C) and ours values dissipation of energy from another publications.

1. INTRODUCTION

Most of the viscous fluids have a practical interest when they are subjected to a turbulent regime. It is important to observe the effects that can produce the addition of interference factors on the regime of movement of a fluid. An example of perturbation factor would be a sound wave. In previous works the dissipation energy consequence of interaction with a sound wave was studied in a turbulent flow. Now, are analyzed the changes that take place at the turbulence spectrum comparing two alternative situations: with and without sound wave.

2. BASIC EQUATIONS IN AN INFINITE MEDIUM

Starting from the work of G. I. Taylor (1937) settles down the connection between the turbulence spectrum and the correlation among the turbulence spectrum and the correlation of simultaneous values of speeds measured in two points.

If the component of the speed of the turbulent movement () in a fixed point in the direction of the flow is discomposed in a harmonic series, the square of the mean values of the speed can be built starting from the sum of the contributions of all the frequencies. If it is the contribution of the frequencies understood among and, then. If we represent in front of the frequency the spectral curve it is obtained.

If the component of the speed of the turbulent movement (u) in a fixed point in the direction of the flow is discomposed in a harmonic series, the square of the mean values of the speed can be built starting from the sum of the contributions of all the frequencies. If $\overline{u^2}F(n)$ it is the contribution of the frequencies understood among n and $n+dn$, then $\int_0^\infty F(n)\,dn = 1$. If we represent $F(n)$ against the frequency n the spectral curve it is obtained.

When the whirls are big the correlation R_x among the simultaneous values of u at the distance x it should descend as increases x. It can be anticipated that when the curve (R_x, x) has a small slope in the coordinate x the curve $F(n)$ will extend to big values of the frequency and vice versa.

If the speed of the air current that produces the whirls is much bigger that the speed of the turbulence, it can be supposed that the sequence of changes in u in a fixed point are only due to the unaffected turbulent pattern's change of movement on the point, for example it can be supposed that,

$$u = f(t) = f\left(\frac{x}{U}\right)$$

where, U is the speed of the current in turbulent regime and x it is measured instantaneously upwind in $t = 0$ from the fixed point where u it is measured. For small values of u is defined R_x in the following way,

$$R_x = \frac{\overline{f(t)\,f\left(t+\frac{x}{U}\right)}}{\overline{u^2}}$$

The term $\overline{u^2}$ can be expressed like a sum of harmonic terms. So being $u = f(t)$ and denominating,

$$I_1 = \frac{1}{p}\int_{-\infty}^{+\infty} f(t)\cos(2p\,n\,t)\,dt$$

$$I_2 = \frac{1}{p}\int_{-\infty}^{+\infty} f(t)\,\mathrm{sen}\,(2p\,n\,t)\,dt$$

it can be demonstrated that,

$$\int_{-\infty}^{+\infty} f(t)\,f\left(t+\frac{x}{U}\right)dt = 2p^2\int_0^{\infty}\left(I_1^2+I_2^2\right)\cos\frac{2p\,nx}{U}\,dn \qquad (1)$$

On the other hand we have that the quantity,

$$2p^2 \lim_{T\to\infty}\left(\frac{I_1^2+I_2^2}{T}\right)$$

it is the contribution to $\overline{u^2}$ when it is originated starting from components of frequency among n

and $n+dn$, for example,

$$2p^2 \lim_{T\to\infty}\left(\frac{I_1^2+I_2^2}{T}\right)=F(n)$$

Consequently, substituting this result in the equation (1) it is obtained,

$$R_x=\frac{\overline{f(t)f\left(t+\frac{x}{U}\right)}}{u^2}=\int_0^\infty F(n)\cos\frac{2p\,nx}{U}dn$$

The form of this equation is similar to the integral of Fourier. If we determine the Fourier transformed of $F(n)$ it the following result is obtained,

$$F(n)=\frac{4}{U}\int_0^\infty R_x\cos\frac{2p\,nx}{U}dx \qquad (2)$$

As a consequence, R_x and $\frac{U\ F(n)}{2\sqrt{2p}}$ are mutually Fourier transformed. The advantage of this result consists on calculating R_x starting from measured values of $F(n)$, and inversely, knowing values of R_x the spectral curve $F(n)$ can be calculated,

In Taylor studies it is defined a parameter of great interest. It is the curvature (l) of the defined curve $[x, R_x]$ by the equation,

$$\frac{1}{l^2}=2Lt_{x\to 0}\left(\frac{1-R_x}{x^2}\right) \qquad (3)$$

In the case of an isotropic turbulence the parameter l can be calculated measuring the dissipation of the energy. This fact constitutes the point of union with studies about energy losses. More accurately, with the study of energy interference that produces a sound wave in their displacement through a turbulent regime.

We admit the equation proposed by Taylor that relates the parameter l with the dissipation energy,

$$l=A\sqrt{\frac{n e M}{U}} \qquad (4)$$

in which A is a constant that has a value of 2.12 ; n the dynamic viscosity of the fluid; U the speed of the current in turbulent regime; g the dissipation of the energy and M the size of the mesh that produces the turbulence.

The objective of the present study is to determine the turbulence spectrum starting from values of energy dissipation, which incorporated to the equation (4) allow to calculate the parameters l and these parameters, substituted in the equation (3) and (1) determine finally the turbulence spectra.

In the equation (4) it can be incorporated dissipation values which are obtained from certain effects, i.e. a sound wave, providing the differentiated spectrum of that interference.

It can also be included the global dissipation, which is the addition of the losses of the turbulent flow due to their intrinsic viscosity, added to the contribution of the considered effect. Later, spectra of both situations can be compared.

3. RESULTS

The turbulence spectrum is determined with the equation (2), in the one that previously the expression R_x is calculated of with the equation (3) whose integration is,

$$R_x = \frac{1}{6}\frac{(-2\,l^2 x + 3x^3 + 3\,l^2)}{l^4} + x^4 \qquad (5)$$

Finally we have equation for the turbulence spectrum $F(n)$,

$$F(n) = \frac{4}{U}\int_0^{\infty}\left[\frac{1}{6}\frac{(-2l^2 x + 3x^3 + 3l^2)}{l^4} + x^4\right]\cos\left(\frac{2p\,nx}{U}\right)dx \qquad (6a)$$

In the figures that are shown the turbulence spectrum subsequently it is represented in function of the frequency n and the distance x in address of the propagation of the turbulent current. The range of frequencies is of 0 to $4000\ Hz$ and the one of distances 0 to $0.3\,m$. It is shown in the axis of frequency multiples of $200\ Hz$, and in that of distances multiples of $0.1\,m$.

$$F(n) \approx \frac{4}{U}\sum_{x=0}^{x=3}\left[\frac{1}{6}\frac{(-2\,l^2 x + 3x^3 + 3l^2)}{l^4} + x^4\right]\cos\left(\frac{2p\,nx}{U}\right)\Delta x \qquad (6b)$$

$0 \le x \le 3\ m$, $Dx = 0.1\,m$

$0 \le n \le 4000\ Hz$, $Dn = 200\ Hz$

The spectra are shown varying the current speeds maintaining the values of the parameter l; and alternatingly fixing the speed to vary the parameter l.

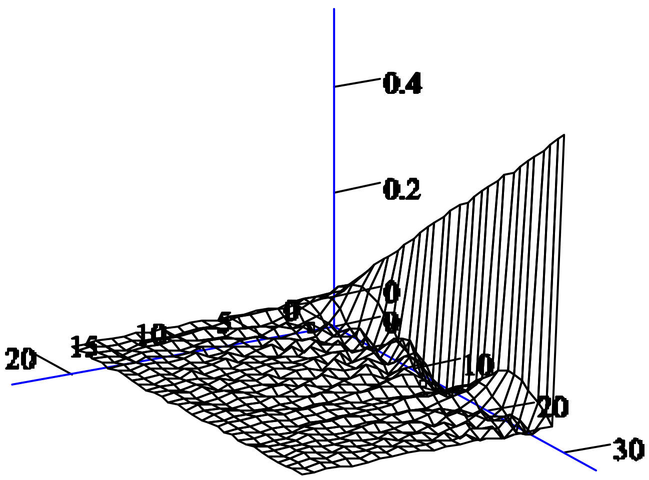

Fig. 1. Turbulence Spectrum $F(n)$ in function of the frequency in Hz and distance (in m), in sense of propagation of the current. The current speed is $20\ ms^{-1}$ and l it has in this

case a value of 0.5.

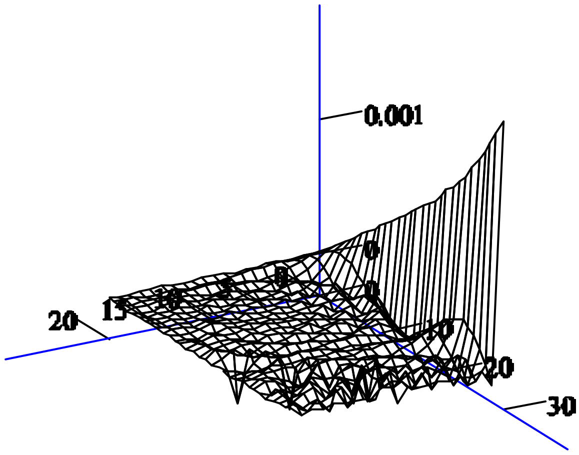

Fig. 2. Turbulence spectrum $F(n)$ in function of the frequency in Hz and distance (in m), in sense of propagation of the current. The current speed is $20\ ms^{-1}$ and it l has in this case a value of 10.

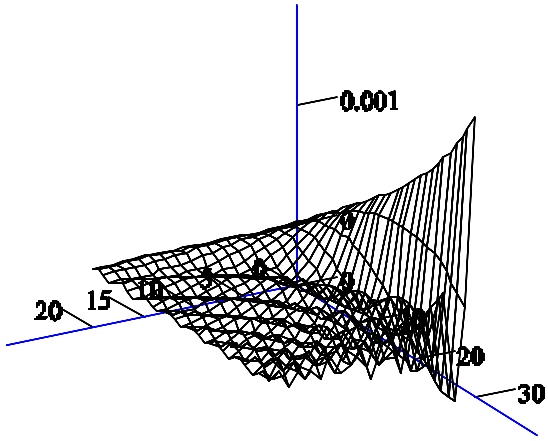

Fig. 3. Turbulence spectrum $F(n)$ in function of the frequency in Hz and distance (in m), in sense of propagation of the current. The current speed is $80\ ms^{-1}$ and it l has in this case a value of 0.5.

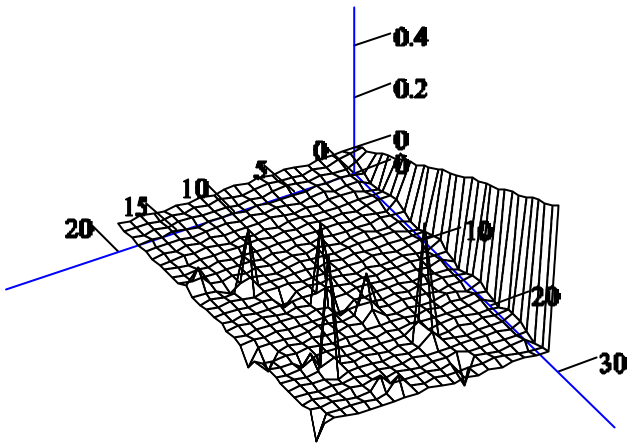

Fig. 4. Turbulence spectrum $F(n)$ in function of the frequency in Hz and distance (in m), in sense of propagation of the current. The current speed is $6\,ms^{-1}$ and it l has in this case a value of 0.5.

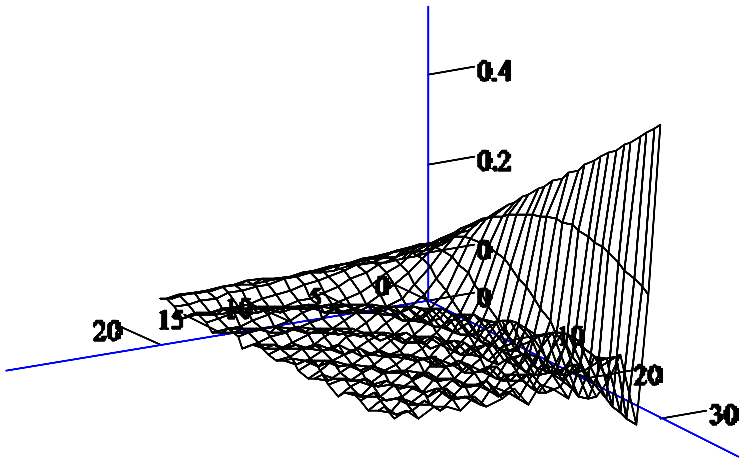

Fig. 5. Turbulence spectrum $F(n)$ in function of the frequency in Hz and distance (in m), in sense of propagation of the current. The current speed is $80\,ms^{-1}$ and it l has in this case a value of 10.

5. CONCLUSIONS

At high speeds the spectrum presents a wavy concentric mesh around the point of $2000\,Hz$ and $1.5\,m$; as the parameter l increases the repetitions of the wavy mesh they are increased.

At a slow speed the spectrum presents marked picks indicating spectral instability and same time it is more intense as the parameter l increases. In the order of $20\,ms^{-1}$ the concentric wavy mesh is observed also displaced toward the origin.

The interferences due to an increment of the parameter l cause alterations from the spectrum to big distances and high frequencies. The increasing of the parameter owes to the contribution i.e. of a sound wave in displacement through a fluid in turbulent regime.

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