TURBULENCE – FULL CYCLE

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Turbulence in the boundary layer of a viscous gas is a cyclical process of the emergence and decay of vortex tubes. The full cycle of turbulence includes the following stages: amplification of low-frequency disturbances, the emergence of Tollmin-Schlichting waves, the emergence of vortex tubes, deformation and stretching of vortex tubes, the decay of vortex tubes, accompanied by an explosive, asymptotic growth of pressure pulsations, propagation of pressure disturbances along the vortex tubes with the formation of turbulent Emmons spots, the emergence of speed pulsations of various frequencies and intensities. Each of the stages is described by its own equation or formula. Some of the above stages may be absent in certain conditions.

Key words: turbulence, cyclic process, full cycle of turbulence, vortex tube, boundary layer, viscous gas.

Turbulence in the boundary layer of a viscous gas is a cyclical process of the emergence and decay of vortex tubes.

A full cycle of turbulence includes the following stages [1]:

1. Amplification of low-frequency disturbances.
2. The emergence of Tollmin-Schlichting waves.
3. The emergence of vortex tubes.
4. Deformation and stretching of vortex tubes.
5. Decay of vortex tubes, accompanied by explosive, asymptotic growth of pressure pulsation.
6. Propagation of pressure disturbances through vortex tubes with the formation of Emmons turbulent spots.
7. The emergence of velocity pulsations of various frequencies and intensities, preparing the conditions for a new cycle of turbulence generation.

Each of the stages is described by its own equation or formula. We present these equations in the form of a table.

Table

№ stage	Equations
1.	$\Delta p = 2(k-1)\mu \frac{u_\infty u'_m}{\omega\delta^2}\sin\omega t.$
2.	$\frac{\partial^2 \mathbf{V}}{\partial t^2} = (a_s^2 + \frac{4}{3}(k-1)\nu \operatorname{div}\mathbf{V})\operatorname{grad}\operatorname{div}\mathbf{V}.$

3.	$\frac{\partial^2 \boldsymbol{\omega}}{\partial t^2} = 0.$
4.	$\frac{d\boldsymbol{\omega}}{dt} = \boldsymbol{\omega}\dot{S} - \boldsymbol{\omega}\mathrm{div}\mathbf{V}$ – is the Friedmann equation.
5.	$\Delta p = \frac{4(k-1)}{9}\mu\frac{\omega_0^4 t_0^3}{(1-\tau)^3}.$
6.	$\frac{\partial^2 p}{\partial t^2} = (a_s^2 + \frac{4}{3}(k-1)\nu\mathrm{div}\mathbf{V})\mathrm{divgrad}p.$
7.	$\frac{d\mathbf{V}}{dt} = -\frac{1}{\rho}\mathrm{grad}p + \nu\nabla^2\mathbf{V} + \frac{\nu}{3}\mathrm{graddiv}\mathbf{V}$ – is the Navier-Stokes equation.

The designations of the variables are given in [1].

Some of the above stages may be absent in certain conditions. Stage 2 of the emergence of Tollmin-Schlichting waves occurs, as a rule, on the leading edge of the plate at low initial turbulence and is absent in a developed turbulent flow. Stage 6, with uniform stretching of the vortex tube along its entire length, can also be absent.

The results obtained in this work for a perfect gas are easily generalized to Van der Waals gas and liquids, as was done in [2].

Conclusions:

1. Turbulence in the boundary layer of a viscous gas is a cyclical process of the emergence and decay of vortex tubes. Equations are given that describe the full cycle of turbulence, which includes various stages. Some of the above stages may be absent in certain conditions.
2. The results obtained in this work for a perfect gas are easily generalized to Van der Waals gas and liquids.

References

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