航空学报 » 1985, Vol. 6 » Issue (1) :38-48 DOI:

湍流的耗散及弥散相互作用理论

高歌

北京航空学院

A THEORY OF INTERACTION BETWEEN DISSIPATION AND DISPERSION FOR TURBULENCE

Gao Ge

Beijing Institute of Aeronautics and Astronautics

摘要 湍流具有涡团散裂、耗散和弥散的特性。根据Prigogine倡导的耗散结构理论,推导了表征耗散与弥散相互作用的新的湍流控制方程组。其特点是:用稳定性分析得到湍流动能产生项,再根据广义熵增原理推出并列存在的,分别适用于强弱涡量的二个湍流动量方程。运用该理论已成功地计算了一些典型的湍流问题:湍流边界层中的马蹄涡拟序结构、钝体涡尾区的湍流能量逆转、湍流涡团散裂弛豫及各向异性分布。文中给出了部分算例。

关键词:

Abstract: A theory of interaction between dissipation and dispersion for turbulence and a pair of new momentum equations are presented. The deduction of the theory is based upon the following ideas:a) Turbulent flows possess the properties of vortex decay, dissipation and soliton dispersion. Since the dissipation means entropy rise and forbids inversion, the fact of turbulent energy inversion shows that the turbulence theory considering only dissipation as dominant has neglected another important aspect of turbulent flow, i. e. dispersion. b) Whatever form the 2nd partial derivative takes in the momentum equation its corresponding term in the energy equation must be positive. In fact, this is a concrete application of the generalized theory of entropy rise.Based on the stability analysis of turbulent flow, the relation between the destabilizing factors and the turbulent energy production is established （Eqn 10）. A moving coordinate system along a temporal mean streamline is adopted. The coordinate system is radically different from either the Eular or the Lagrange coordinates. The loss of stability does not mean the TMSL is destroyed but means eddies are displaced off the track of the TMSL or bursted away. Actually, this is the energy exchange between the collective temporal mean flow and the discretized turbulent eddies. In order to keep the viscous dissipative terms in the turbulent energy production rate （Eqn 10） positive, two coexiting momentum equations of turbulent flow have been derived: one for strong vorticity （Eqn 11） and the other for weak vorticity （Eqn 12）. Most models of turbulence in the published literature may be included in the domain of Equation 12. In previous investigation forms like Equation 11 were absent. A lot of difficult turbulence problems, such as the coherent patterns, the energy inversion, the decay or halt in cascading down of turbulent energy through the energy spectrum and the anisotropy, can be solved by Equation 11.The physical meaning of turbulent energy inversion is that turbulent eddies possess the duality of wave and particle, and can be rectified to be the unidirectional flow by Corriolis force in the particular region. The 2nd partial derivative of vorticity in the region has large value that signifies strong negative dispersion. The new energy equation of turbulent flow （Eqn 22） contains both dissipation functionφand dispersion function （?）. φ is always positive. But（?） may be positive or negative and allows energy inversion.Successful numerical computations of typical turbulence problems have been obtained. The calculations of the coherent patterns in buondary layers and the energy inversion within a complex vortex tail are provided. The theoretical analyses and the numerical calculations have revealed that the theory possesses good generality and gives a reasonable explanation of the physical meaning of turbulence.

Keywords:

Received 1984-06-12;

引用本文:

高歌. 湍流的耗散及弥散相互作用理论[J]. 航空学报, 1985, 6(1): 38-48.

Gao Ge. A THEORY OF INTERACTION BETWEEN DISSIPATION AND DISPERSION FOR TURBULENCE[J]. Acta Aeronautica et Astronautica Sinica, 1985, 6(1): 38-48.