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Energy dissipation caused by boundary layer instability at vanishing viscosity – ERRATUM

Natacha Nguyen van yen, Matthias Waidmann, Rupert Klein, Marie Farge and Kai Schneider

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Energy dissipation caused by boundary layer instability at vanishing viscosity

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A qualitative explanation for the scaling of energy dissipation by high-Reynolds-number fluid flows in contact with solid obstacles is proposed in the light of recent mathematical and numerical results. Asymptotic analysis suggests that it is governed by a fast, small-scale Rayleigh–Tollmien–Schlichting instability with an unstable range whose lower and upper bounds scale as $Re^{3/8}$ and $Re^{1/2}$, respectively. By linear superposition, the unstable modes induce a boundary vorticity flux of order Re^{1}, a key ingredient in detachment and drag generation according to a theorem of Kato. These predictions are confirmed by numerically solving the Navier–Stokes equations in a two-dimensional periodic channel discretized using compact finite differences in the wall-normal direction, and a spectral scheme in the wall-parallel direction.

Key words: boundary layer stability, vortex shedding

1. Introduction

Since the challenge laid down by Euler in 1748 for the Mathematics Prize of the Prussian Academy of Sciences in Berlin, the force exerted onto a solid by a fluid flow has been one of the central unknowns of fluid mechanics. From the vorticity transport equations he had derived, d'Alembert (1768) deduced his now famous paradox, that this force should vanish, contrary to what experimental results and even everyday observation indicate. A frictional explanation involving the viscosity of the fluid was advanced during the nineteenth century within the frame of the new theories of Navier, Saint-Venant and Stokes, but the actual amplitude of the force remained unaccounted for. Indeed, estimates based on the magnitude of the viscosity ν of the fluid, or equivalently, after non-dimensionalization, on the inverse of the Reynolds number Re, predict that friction should become negligible when $Re \gg 1$.

The group working at Göttingen University, notably Prandtl (1904) and Blasius (1908), were first to come up with a way of computing, under some hypotheses,

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