The Success and trends of hydrodynamic instability research

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The well-known O. Reynold's experiment of flows in a circular pipe in 1883 proposed three challenging issues: (1) Why and when a laminar flow turns to turbulent state; (2) How does the transitional process look like; (3) How do you understand and calculate turbulent flows. These puzzles drove scientists to strive to resolve them for more than 100 years.

C.C. Lin was among a few great masters who laid the foundation in answering the first question, the bottleneck of which was how to solve the Orr-Sommerfeld equation of linear hydrodynamic instability. When WKB method was extended to the fourth order with turning point and analyzed the behaviors of comparative equations, a set of asymptotic solutions were given to find neutral curve of instability for a two dimensional channel flow. The same approach was then applied to boundary layer flows. Both of them were later verified by wind tunnel and water flume experiments.

To answer the second question, it is inevitable to consider nonlinear effects of finite amplitude. Different routes and pattern during transition were identified. Very likely, the pass-by process can be responsible for the eventual transition of linearly stable circular flow to turbulence. So far, interfacial instability, stability of oscillating and compressible flows are still of great concern in scientific community.

In regard to the 3rd question, people have revealed statistical and structural behaviors of completely developed turbulent flows. Numerous turbulent modeling were successfully applied in airliner design. However, Large Eddy Simulation of complex turbulent wall flow still need decades' efforts, in particular, depending on robust sub-grid model and efficient computational strategy.