Abstract: In this article we present direct comparisons of experimental results on transition in wall-bounded flows obtained by flow visualizations, hot-film measurement, and particle-image velocimetry (PIV), along with a brief mention of relevant theoretical progresses, based on a critical review of about 120 selected publications. Despite somewhat different initial disturbance conditions used in experiments, the flow structures were found to be practically the same. The following observed flow structures are considered to be of fundamental importance in understanding transitional wall-bounded flows: The three-dimensional nonlinear wave packets called solitons-like coherent structures (SCS) in boundary layer and pipe flows; the $A$-vortex; the secondary vortex loops; and the chain of ring vortices.

The dynamic processes of the formation of these structures and transition as newly discovered by recent experiments include, among others:

1. The sequential interaction processes between the $A$-vortex and the secondary vortex loops, which controls the manner by which the chain of ring vortices is periodically introduced from the wall region into the outer region of the boundary layer;

2. The generation of high-frequency vortices, which is one of the key issues for understanding both transitional and developed turbulent boundary layers (as well as other flows), of which several explanations have been proposed but a particularly clear interpretation can be provided by the experimental discovery of secondary vortex loops. The ignorance of secondary vortex loops would make the dynamic processes and flow structures in a transitional boundary layer inconsistent with previous discoveries; and

3. The dominant role of SCS in all turbulent bursting, which is considered as the key mechanism of turbulent production in a low Reynolds-number turbulent boundary layer. Of direct relevance to bursting is the low-speed streaks, whose formation mechanism and link to the flow structures in wall-bounded flows can be answered more clearly than before in terms of the SCS dynamics.

We combine these newly observed structures and processes to those well-known ones to form a more integrated physical picture of the transitional dynamics. This not only enables revisiting the classic story of wall-bounded flow transition, but also opens a new avenue to reconstruct the possible universal scenario for wall bounded flow transition.

Outline: In Russia and Japan, Professors Y. S. Kachanov and M. Asai believed that the establishment of a universal scenario for the turbulent production in wall-bounded flows is about to come. Some obvious progress has been made in China. The paper is focused on discussing the possibilities to establish a universal turbulent production mechanism in wall-bounded flows, based on the experimental facts recently found in EU, Russia, Japan, and mainly in China.
The aim of this paper is to describe the recent advances in the physical understanding of wall-bounded flow transition. In the last ten years, significant progresses of wall-bounded flow transition have been made in Russia, Japan, EU, USA, as well as in China. Comprised with the remarkable theoretical and numerical works, experimental investigations show its special characteristics in the original observations of the detailed dynamic processes.

The present paper presents direct comparisons of related visualizations, hot-film measurement, and PIV studies of the nonlinear, late stages of transition in wall-bounded flows. Despite somewhat different initial disturbance conditions used in experiments, the flow structures were found to be practically the same. The three-dimensional wave packets called soliton-like coherent structures (SCS) and the nonlinear traveling wave in pipe flows, the $\Lambda$-vortex, the secondary vortex loop and the chain of ring vortices are postulated to be the basic flow structures of the transitional-wall bounded flows.

The experimental results show new dynamic processes in a transitional boundary layer and in pipe flows. For example, the sequential process describing the interaction between the $\Lambda$-vortex and the secondary vortex loop controls the manner in which the chain of ring vortices is periodically introduced from the wall region into the outer region of the boundary layer. There are several proposals to explain the generation of the high-frequency vortices, which is one of the key problems for understanding both transitional and developed turbulent boundary layers as well as other flows. The experimental discovery of secondary vortex loop provides a physical interpretation of the formation of high-frequency vortices”. If secondary vortex loops were ignored, the dynamic processes and flow structures in a transitional boundary layer would be very different from those discussed in previous studies.

It is well-known that turbulent bursting is the dominant mechanism of turbulent production in a low Reynolds-number turbulent boundary layer. The low-speed streaks are directly related to the turbulent bursting. What is the mechanism for the formation of low-speed streak structure? The recent experimental evidence shows that this question can be answered more clearly than before. And, how to link the turbulent bursting to the flow structures in wall-bounded flows? The experimental evidence shows that the nonlinear traveling wave dominates all the turbulent bursting process (give the foot to the turbulent bursting).

The observed nonlinear traveling waves and secondary vortex loops not only enable us to revisit the classic story of wall bounded flow transition but also give us an opportunity to rebuild the universal scenario for wall bounded flow transition (Lee & Wu 2008).


Biographical Sketch
Professor Cunbiao Lee received his first degree from the Nanjing University of Aeronautics & Astronautics in 1984. He obtained his master degree in Institute of Mechanics, Chinese Academy of Sciences in 1990 and his Ph.D from the Beijing University of Aeronautics & Astronautics in 1995. He was employed in Chinese Institute of Aeronautics in 1984 and started his post doctor fellowship in Institute of Atmospheric Physics, Chinese Academy of Sciences in 1995. He joined the Tsinghua University as associated professor in 1998. He moved to the State Key Laboratory for Turbulence Research and promoted to full professor at Peking University in 2001. He has published over 50 technical reviewed papers and present over 30 invited lectures/Seminars. He was awarded the National Outstanding Young Scientist in 2005. He is a vice director of State Key Laboratory for Turbulence Research. He is now an Editorial Advisory Board of Experiments in Fluids. His current research interests include boundary layer transition, hypersonic turbulent boundary layer and nonlinear wave interaction.