Turbulent transition of helical vortices

Yuji Hattori*, Ivan Delbende†, Maurice Rossi†

Helical vortices form around rotating blades of helicopter rotors, ship propellers and many other engineering applications. The dynamical properties of the helical vortices should be understood in detail since they affect the flow and the performance of the devices. The helical vortices are subjected not only to long-wave instability but also to short-wave instabilities (the elliptic instability and the curvature instability). We study nonlinear dynamics of helical vortices destabilized by the short-wave instabilities. How the core of a helical vortex becomes turbulent is of particular interest.

There are three possible scenarios: (i) the disturbance energy saturates when the vortex core grows due to viscous diffusion so that the instability condition is lost (viscous saturation); (ii) the disturbance energy saturates due to weakly nonlinear effects (weakly nonlinear saturation); and (iii) the disturbance keeps growing until the vortex core becomes turbulent (turbulent transition). Direct numerical simulation of a helical vortex disturbed by an elliptic instability has been performed. Figure 1a shows the viscous saturation for $Re_\Gamma = 5000$ and the turbulent transition for $Re_\Gamma = 15700$; small-scale vortical structures develop after the transition (figure 1b). Which of the scenarios occurs depends on the parameters characterizing the base helical vortex and the instability mode.

In order to predict which scenario occurs, we evaluate the saturation amplitudes for the viscous saturation and the weakly nonlinear saturation, while a critical amplitude for transition is estimated for the turbulent transition. The scenario of the smallest amplitude is expected to occur. Preliminary results show that the above criterion gives reasonably accurate prediction. The details will be present in the talk.

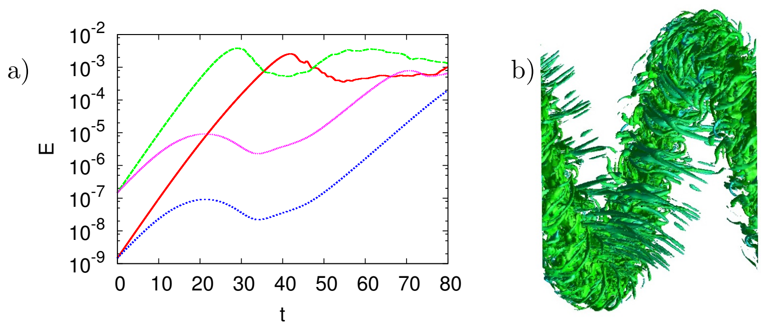

Figure 1: (a) Disturbance energy as a function of time for $Re_\Gamma = 5000, 15700$ and $A_0 = 10^{-4}, 10^{-3}$. (b) Iso-surface of magnitude of vorticity after turbulent transition.

*IFS, Tohoku University, Katahira 2-1-1, Aoba, Sendai, 980-8577, Japan
†Sorbonne Université, Institut Jean le Rond d'Alembert 4 place Jussieu, 75005 Paris, France