§34. Quantum Vortex Simulation in Cooling Process of Superconducting Magnet

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The purpose of this stud is to understand the heat transfer mechanism in the cooling of superconducting magnet by Helium liquid. Helium liquid behaves like no viscosity fluid called super fluid He II smaller than 1.9K. Therefore, it may be useful to understand the interaction of small-scale vortex and the solid wall, which transfer the heat and momentum. In classical turbulence, small-scale vortex plays also a significant contribution to the momentum and heat transfer in high Reynolds number. In this year, we simulate the Navier-stokes turbulence and visualize the small vortexes near the solid surface.

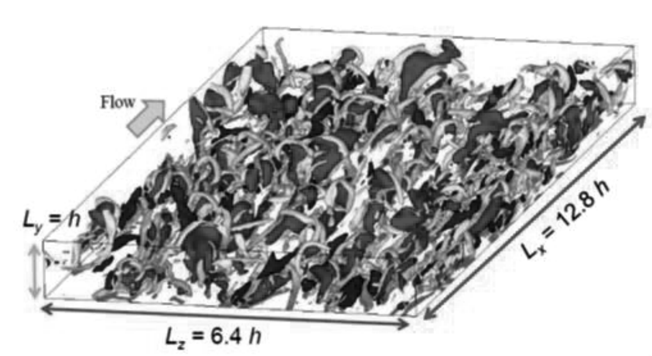
Direct numerical simulation of the fully developed turbulent channel flows have been carried out at the Reynolds number based on the friction velocity and the channel half width, 2000. A hybrid 10th order accurate finite difference scheme in the stream and span-wise directions, and a second-order scheme in the wall-normal direction is adapted as the spatial discretization method. We observed the plateaupro files in the indicator function corresponded to the von Karman constant. Furthermore, second peak of stream-wise pre-multiplied spectra were appeared in the same wall normal height, $300 < y+< 600$, in case of Re= 4000.Nevertheless, the effects of the lager than the channel half-height scale on the stream-wise turbulent intensity are fixed contributions without dependence on Reynolds number. These results suggested that the new stream-wise vortexes are formed between buffer layer and outer layer with increasing of Reynolds number.

The target flow is an incompressible turbulent flow. The flow is assumed to be a fully developed turbulent channel flow driven by the constant mean pressure gradient in the stream-wise direction. To solve the above turbulent fields numerically, we used two-types DNS codes of a turbulent channel flow. One is a hybrid Fourier spectral and the second-order central differencing method(PSM). The other is a hybrid 10th order accurate finite differencing and the second-order method (FDM).In both codes, second-order central differencing method was adapted for the wall-normal discretization method.

It was found that the contribution of the span-wise wave-lengths is larger than the channel half height (h) on the stream-wise turbulent intensity. In the overlap region, these contributions are not increased but constant with increasing of Re. In contrast, the span-wise wave-lengths less than the channel half-height were increased with increasing of Re under the inner layer, $y/h< 0.2$. These are indicated that turbulent energy transfer from the large-scale structures to the buffer layer ($y+=15$) structures is not conducted directly but indirectly.

Vortexes scaled by the inner layer height ($y/h= 0.2$) are observed. These results suggested that the new stream-wise vortexes are formed between buffer layer and outer layer in high-Re, and these vortexes are played the roles to energy transfer from outer layer to the vicinity.

Figure 1 shows the visualization of small vortexes (yellow region). They are visualized by the criteria based on the eigenvalues of velocity-gradient tensor. Blue and red regions correspond to the ejection and sweep processes respectively, which generate the positive Reynolds shear stress. Therefore, the small-scale vortexes relate to the momentum transfer process. It may be assumed that the quantum vortex has similar role near the wall. We are now undergoing the simulation of quantum fluid turbulence.



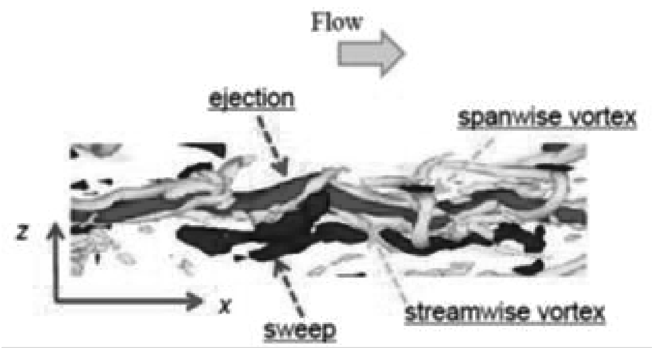


Fig.1 Small scale vortex structures near the wall are visualized by eigenvalues of velocity gradient tensor indicated by the yellow regions. Red and blue ones are ejections and sweep process.