§ 7. Study on Thermo-Fluid System Design and Database Construction for a Helical Reactor

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The main feature of FFHR is force-free-like configuration of helical coils, which makes it possible to simplify the coil supporting structure and to use high magnetic field. The other feature is the selection of molten-salt Flibe as a self-cooling tritium breeder. In fusion application, Flibe was once put aside due to lack of databases, but still has attractive merits on safety aspects: low tritium inventory, low reactivity with air and water, low pressure operation, and low MHD resistance compatible with the high magnetic field design in FFHR. In general, a high Prandtl number ($Pr=\nu/a$, here ν is viscosity and a is thermal diffusivity) fluid like Flibe (Pr=~30) has less heat transport capability than liquid metal (Pr=~0.03 for Li), because of very low thermal diffusivity and low thermal mixing due to thinner thermal boundary layer at an interfacial region. Therefore, in particular, the design feasibility of the first wall for Flibe blanket is one of key issues.

In the present study, in order to investigate the fluid flow and heat transfer characteristics of a laminar swirl flow in a pipe, we carried out the numerical simulation of this flow. The pipe was divided by a thin metal twisted tape and transferred the heat through the tape, i.e., a conjugate heat transfer problem. Figure 1 shows the computational domain and grid arrangement: (a) configuration, (b) cross-section and (c) outlook. The computational conditions are tabulated in Table. Figure 2 shows the temperature and axial velocity distributions in the pipe. The thermal boundary layer vicinity of the wall is always removed by a swirling flow along the twisted surface at $\phi=0$ and π. Resulting of the computation, we found the heat transfer enhancement of the pipe due to the swirl flow. Moreover we found the heat removal from the wall boundary layer is enhanced by the momentum exchange between high and low temperature fluids.

We also investigated the acoustic vibrated liquid film flow for the first wall cooling by means of a direct numerical simulation. We can simulate a three-dimensional falling film flow: natural transition mode as shown in Fig.3.

Dimensions of tube and fluid properties: inside diameter of tube=14mm, wall thickness=0.5 mm, tube length L=100 mm, density = 1909 kg/m^3, viscosity = 1.97 mPa·s, Pr = 4.7
Thermal conductivity of the wall = 27.0 W/(m·K), Condition for temperature: T_U = 900K, T_L = 400 K, T_{fin} = 500 K

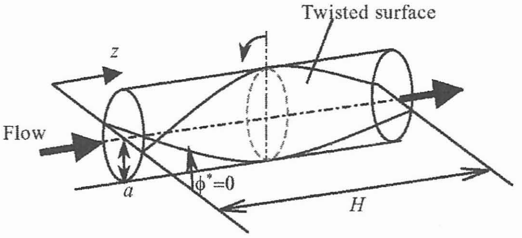

Fig. 1 (a) Configuration of a part of swirl tube

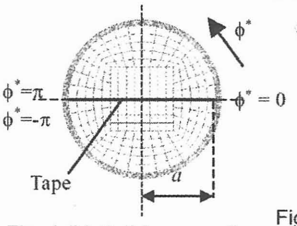

Fig. 1 (b) Cell faces on the tube cross-section

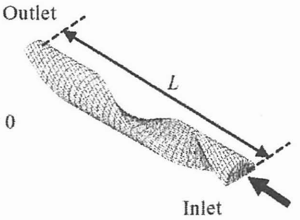

Fig. 1 (c) Outlook of the half fluid domain divided by twisted-surface

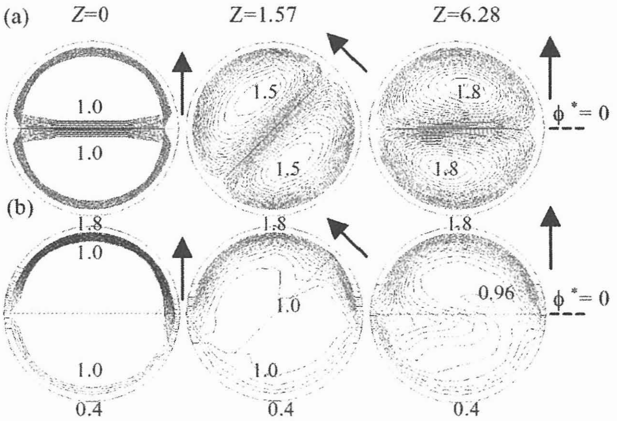

Fig. 2 (a) Contours of axial velocity, (b) Isothermal map

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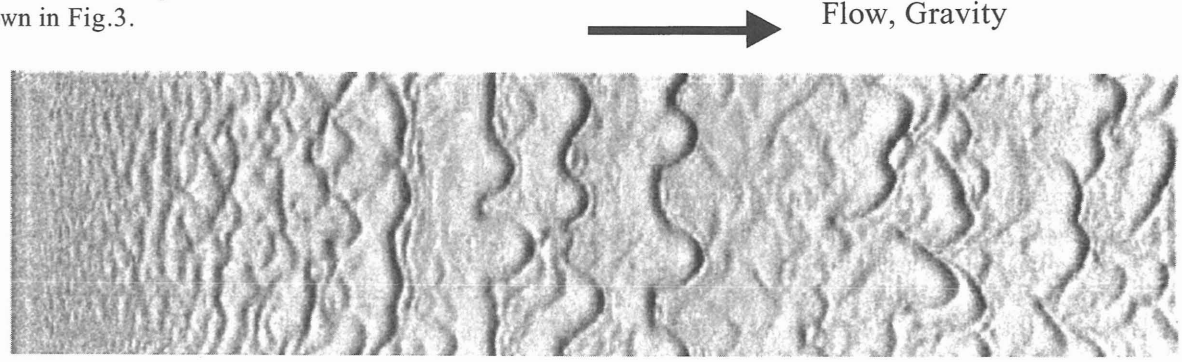

Fig.3 Instantaneous three-dimensional falling film flow (Natural transition)