Appendix A

MHD lorentz force

MHD covers phenomena in electrically conducting fluids, where the velocity field V, and the magnetic field H are coupled. Any movement of a conducting material in a magnetic field generates electric currentsj, which in turn induces a magnetic field. Each unit volume of liquid having j and H experiences MHD force: $F = \mathrm{j} \times \mathrm{H}$, known as the "Lorentz force Error::0x0000 Error: 0x0000 (Figure 23 for the formation of MHD Lorentz force). For MHD flows in blanket channels, interaction of the induced electric currents with the applied plasma-confinement magnetic field results in the flow opposing Lorentz force that may lead to high MHD pressure drop, turbulence modifications, changes in heat and mass transfer and other important MHD phenomena.

Hartmann effect

The Hartmann effect is caused by the Lorentz force, which accelerates the fluid in the Hartmann layers and slows it down in the bulk. If Hartmann number M grows, the velocity profile becomes more and more flattened (Figure 24) for the velocity contour lines when $x = 0, y = -1 - 1 \mathrm{at} M = 100 - 10^5$. This effect is known as the "Hartmann effect". The thin layer near the wall where the flow velocity changes from zero to mean velocity u_m is called the "Hartmann layer" (Figure 25) for the diagram of Hartmann effect and Hartmann layer).

Hartmann effect to blanket channels

The main Hartmann effect to blanket channels is the pressure-drop of a liquid metal in the presence of a magnetic field. It is primarily due to the Lorentz force and results in a pressure drop more than an order of magnitude larger than that in the absence of the transverse magnetic field. Therefore, as a result of the large pressure-drop, large pumping power is required. Besides, there are some competing heat transfer and hydrodynamic effects. In order to explore these effects, we have to discuss the definition of Hartmann number $\mathrm{M} = \mu \mathrm{H}_0 \mathrm{a} \sqrt{\frac{\sigma}{\eta}}$ at first. In atokamak reactor, the permeability μ, the channel half width a, the conductivity σ and the fluid dynamic viscosity η are all constants. The only variable parameter is the imposed magnetic field H_0. At high Hartmann numbers, a strong magnetic field suppresses turbulence pulsation and turns the turbulent flow into laminar flow even at high Reynolds Number, and thus reduces the heat transfer. However, the heat transverse is increased as is manifested by a thinner boundary layer. On the other hand, a magnetic field stops the impurities floating, and thus extends the useful life of the blanket channels.

Relationship beteew Hartmann numbers and reference nodes

In section 4, we can get a tendency when Hartmann numbers are medium $(\mathrm{M} = 100, 500 \text{ and} 1000)$, the reference nodes of local iRBF-DQ method cost about 400 nodes, and the global nodes need about 10000 nodes. However, when Hartmann numbers are high $\left(\mathrm{M}{=}10000 \, and \; 100000\right)$, the global nodes cost about 40000-160000 nodes, but the reference nodes need only 9 modes. In this observation, when Hartmann numbers are not very high, the values of velocity near the boundary suddenly decrease to zero. In order to present the extreme boundary layer characteristic in detail, we need more reference points to support the node we approximate. However, when Hartmann numbers become very high, the values of velocity are almost zero. The variation of velocity near the boundary is not obviously. In this situation, more reference points turn to polluted data to the node we approximate. Thus only very few local reference nodes are required, as we compare to cases of the medium Hartmann numbers.