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Numerical Simulations of Magnetohydrodynamic Flows in a Misaligned Duct

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Extended Abstract

Nowadays, Magnetohydrodynamic (MHD) duct flow (the flow of an electrically conducting fluid under an external magnetic field) has a wide range of application in many engineering field and its importance keeps growing. These applications consist of electromagnetic pumps, liquid-metal cooling of nuclear reactors, MHD flowmeters and electromagnetic casting, which have great relevance to the development of fusion reactor. MHD effect, caused by the motion of liquid-metal (LM) under a strong magnetic field, is one of the key issues in the design of an optimal LM blanket. Therefore, it has a dramatic impact on velocity distribution, pressure drop, heat transfer characteristics, and pumping powers required for the cooling systems. The liquid metal Pb-17Li can serve as both breeder materials and coolant. However, there are some problems in the application of liquid metal Pb-17Li in terms of a large pressure drop due to a strong magnetic field and degraded heat transfer due to suppressed turbulence. As shown by Morley et al. (2000) and Hunt et al. (1971), many works have been performed experimentally and mathematically to examine the features of LM MHD flow.

In this paper, three-dimensional liquid-metal (LM) magnetohydrodynamic (MHD) flows in a misaligned duct under a uniform magnetic field applied in the z-directional B_0 = 0.8027 T with Hartmann number 1000 are numerically investigated. The duct includes two misaligned x-directional channels (one inflow channel and one outflow channel) and one central y-directional channel (the height of the y-directional channel is 0.36 m). At the inlet, a uniform velocity u_0 = 0.01 m/s is given; at the outlet, the variables (exclude the pressure) of main flow direction do not change. Computational fluid dynamics simulations are performed to predict the behaviour of the MHD flows by using the commercial code CFX. In the current study, a structured grid system (around 4,000,000 cells) is used. The electromagnetic features of LM MHD flows are elucidated to examine the interdependency of the flow velocity, current density, electric potential, pressure drop and Lorentz force.

The flow design for the fusion blanket may consider liquid metal channels in different shapes, so the investigations of MHD flows in diverse ducts can be very significant. Though various experimental, mathematical and numerical studies on MHD flows have been performed, detailed features of LM MHD in a misaligned duct are not reported too much. The results show that the pressure gradually decreases along the main flow direction, apart from the region around the edge of the second right angle segment. The pressure gradient here in the outer region is obviously higher than that in the other region. Related with the direction of the EMCC, higher electric potential can be induced in the outer duct wall and lower electric potential is seen in the inner duct wall. The highest electric potential is observed in the fluid recirculation area which is between the fluid-outer wall interface and the crescent of higher velocity. The lowest electric potential is also seen in the fluid recirculation area which is between the fluid-inner wall interface and the crescent of higher velocity.

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