MHD Instabilities of Liquid-metal Flow Entering Strong Magnetic Fields

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ABSTRACT

This paper addresses turbulent MHD liquid-metal flow entering strong magnetic fields by means of Direct Numerical Simulations (DNS) in a circular duct. The case of a magnetohydrodynamic flow leaving a strong magnetic field has been intensively studied experimentally [1] and numerically [2] owing to its similarity to the typical parameters appearing in liquid metal blankets of nuclear fusion reactors. Current work accurately reproduces the turbulence decay of fully-developed hydrodynamic liquid-metal flow entering strong magnetic fields, for a range of parameter values that are of relevance to liquid metal blankets modules in nuclear fusion reactors. Present paper reveal new flow instabilities related to such scenarios. The study explains the phenomenological essence of such instabilities and identifies its major actors. It is well-known that the entrance of liquid-metal flow into a magnetic field generates 'M-shaped' profiles. However, accurate three-dimensional numerical simulations show additional instabilities for such configurations. Indeed, due the high intensity of the wall-normal detaching Lorentz forces generated around the inflection point of a sufficiently strong magnetic field, a 'vacuum' effect is generated in very narrow areas between the jets and the walls, viz. very low pressures take place in such locations due to 'removal' of mass flow. This fact is causing the appearance of an adverse pressure gradient, which generates back-flow. The presence of the back-flow together with the existence of a peak velocity (due to the jets) plots an instantaneous velocity profile with a inflection point very close to the wall. The stability of the flow is therefore broken, generating oscillating velocity and pressure fields. The oscillations take place in the area around the inflection point and very close to the walls. The existence of such instabilities depend on the intensity and slope of the increasing magnetic field and on the electrical conductivity of the wall. The effects of such instabilities might play an important role in the transfer properties of the blanket liquid-metal flow for nuclear fusion applications, and it is therefore also interesting from an engineering point of view.

REFERENCES

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[2] S. Molokov, C. Reed *Parametric study of the liquid metal ow in a straight insulated circular duct in a strong nonuniform magnetic field*, Fusion Sci. Technol. **43** 200216, 2003.