SPREADING OF A LIQUID METAL COATING IN THE PRESENCE OF ADHESION AND LORENTZ FORCES

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ABSTRACT

We study the flow of a liquid lithium layer through a pore of a capillary porous system (CPS) and investigate the stability of the spreading process along the pore walls, in the presence of an azimuthal magnetic field. Complete wetting is assumed on the wall and the interplay with Lorentz forces is investigated when electric current enters the layer from the surrounding plasma, Fig. 1a. We initially assume isothermal conditions, small magnetic Reynolds and neglect plasma density. The Navier-Stokes equations coupled with the Lorentz forces are solved for the flow and induced magnetic fields, using the finite element method and the spine or elliptic mesh generation techniques. A thin film is formed along the wall, where the intermolecular forces between the film and the substrate are described via the disjoining pressure. We consider two types of interaction: a long range attractive-short range repulsive (LRA-SRR) and a purely repulsive[1]. Lithium is pumped out of a reservoir by an imposed overpressure with respect to plasma pressure or by the magnetic pressure generated by the irrotational part of the Lorentz force. In both cases there is a pressure threshold under which static equilibrium is reached. Dynamic simulations above this threshold show the formation of a film that assumes a dynamic contact angle that, roughly, conforms with an algebraic law, O($Ca^{1/3}$), of spreading. When an equivalent magnetic pressure above the threshold value is applied, Rayleigh-Taylor instabilities are captured[2] leading to drop formation, Fig. 1b, in the form of a finite time singularity. In both cases, the spreading velocity increases/decreases as the strength of the repulsive/LRA-SRR potential increases. In the latter case, the value of the critical magnetic pressure for instability and drop ejection is inversely proportional to the pore radius while it increases with the square root of surface tension and strength of interaction potential. Upon relaxing the isothermal condition excessive evaporation tends to suppress drop ejection. Repercussions pertaining to the use of liquid metals as alternative plasma facing components in fusion reactors[3] are discussed, in an effort to mitigate JxB effects that may lead to drop ejection and plasma contamination during off-normal events[4].

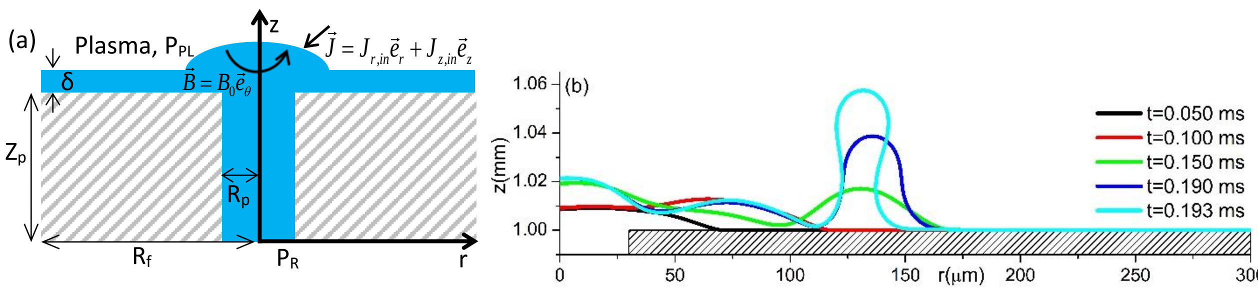

Figure 1: Spreading, (a) Schematic diagram of the flow arrangement, (b) magnetic pressure Bo_m=5.4. LRA-SRR-W_0=10^{-4} N/m.

KEYWORDS: CPS, Adhesion, Lorentz force, MHD, FEM

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