Instabilities in electromagnetically driven flows

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The driving of an electrically conducting fluid by an electromagnetic force can yield significantly more complex behaviors than its solid equivalent, the asynchronous motor. In particular, magnetic field expulsion and hydromagnetic boundary layers can play an important role, and several questions concerning the stability of such flows remain unsolved. These questions become of primary interest in many industrial situations. For instance, Electromagnetic Linear Induction Pumps (EMPs) are largely used in secondary cooling systems of fast breeder reactor, mainly because of the absence of bearings, seals and moving parts. In these EMPs, the conducting fluid is generally driven in a cylindrical annular channel by means of an externally imposed electromagnetic wave. In such induction pumps, electrical currents are induced by the variation of the magnetic flux of the wave rather than imposed into the fluid by electrodes, as in conduction pumps [1]. However, it is known that as these pumps become large enough, a magnetohydrodynamic instability arises, yielding strong pressure pulsations and significant decrease in the developed flow rate [2,3]. To characterize this problem, we investigate numerically an MHD flow driven by a travelling electromagnetic wave in an annular channel. We show that for sufficiently large magnetic Reynolds number, or if a large enough pressure gradient is externally applied, the system undergoes an instability in which the flow rate in the channel dramatically drops from synchronism with the wave to much smaller velocities. For laminar flows, we show that this instability is similar to the stalling of an asynchronous motor, and relies on magnetic flux expulsion. For larger hydrodynamic Reynolds number, and with more realistic boundary conditions, this instability takes the form of a large axisymmetric vortex in the (r, z)-plane, in which the fluid is locally pumped in the direction opposite to the one of the magnetic wave.

Références

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