Characterisation of confined Alfvén waves at low magnetic Reynolds number

S. Lalloz[*,†], A. Pothérat[*], L. Davoust[†] and F. Debray[‡]

MHD Turbulent flows at low magnetic Reynolds number (Rm) have been extensively studied over the last 60 years and are understood to be governed by a pseudo-diffusive process of momentum caused by Lorentz forces. Sommeria and Moreau[1] provide quantitative interpretation of this process by introducing a bidimensionalization time characterizing this pseudo-diffusive process. However, it has never been clear whether the dominance of the diffusive effects of the Lorentz force necessarily implies that propagative effects in low-MHD are absent. In other words, can Alfvén wave still exist and if, so what is their dynamics. So far, this question has received limited attention for the simple reason that, at low Rm, it is technically difficult to observe the propagation of Alfvén waves in laboratory conditions. Thus, since their theorization in 1942,[2] only few studies paid attention to their characterization at low Rm.[3,4,5,6] Here, we overcome these technical limitations by forcing Alfvén waves electrically in a liquid metal at much higher magnetic fields than available for the early studies.

To this end, a revisited version of the Flowcube apparatus, which was initially designed to study MHD turbulence in detail,[7,8] is used to investigate Alfvén waves. The device is a cubic container placed in a vertical, static and homogeneous magnetic field of up to 10T. Wave forcing is performed by injecting an AC current through an array of electrodes located at the vessel bottom wall, so that the forcing intensity, the wave frequency and the transverse forcing scale to the magnetic field can be electrically controlled. Waves are tracked by means of two arrays of potential probes positioned in mirror symmetry to each other and placed at opposite walls fo the cube. This measurement technique makes it possible to characterise wave propagation (attenuation, velocity, patterns) along the directions parallel and orthogonal to the magnetic field. Experimental results are interpreted in the light of an analytical model of forced Alfvén waves in a bounded geometry and at low Rm.

Through this study, we confirm that Alfvén waves indeed propagate at low Rm, in line with historical experimental studies. Interestingly, we found non-homogeneous propagation of Alfvén waves, especially near the point where the forcing current is injected into the fluid point. It appears that Alfven wave propagation is strongly influenced by the geometry of the system, an important effect that is not captured by the classical theory of homogeneous Alfvén waves.

[*]Center for Fluids and Complex Systems, Coventry University, Priory Street, Coventry CV1, UK
[†]SIMAP EPM, 1130 rue de la Piscine, Saint Martin d'Hères, France
[‡]National Laboratory for High Magnetic Fields, 25 avenue des Martyrs, 38000 Grenoble France

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