Instabilities in a Conducting Liquid Column

Taj Sobral[1] & Jovan Nedić[1] & Andrew J. Higgins[1]
1 Department of Mechanical Engineering, McGill University, Montreal, Quebec, CANADA

The study of magnetohydrodynamic instabilities in dense fluids has been a subject of interest since the early 1950s, in particular for their application to thermonuclear fusion. Indeed, the compression of dense plasmas with different magnetic configurations was quickly identified to be an inherently unstable process. The early Z-pinch method of compression, in which a large current is run through a plasma column that is then compressed by the induced azimuthal field, is known to be particularly sensitive to m = 0 mode instability, also known as pinch instability. Although many theoretical, numerical, and some experimental studies have been focused on the study of these instabilities in plasmas, few studies have looked at the unstable behaviour in liquids. In the present work, we present experimental results showing the growth of magnetohydrodynamic instabilities in liquid metal columns. The liquid metal used is a eutectic alloy of Bismuth-Lead-Tin-Cadmium with a melting temperature of 70°C. It is continuously heated and pumped using a peristaltic pump. The liquid metal flows through a nozzle and falls vertically down to create a smooth column with a diameter ranging between 1-3 mm and a length between 5-15 mm. A high current (300-700 A) is then passed through the column, generating an azimuthal magnetic field that compresses the column, leading to the growth of instabilities. A high-speed camera captures the rapid growth of the magnetohydrodynamic instability as the current flows through the column, and the experiment ends when the instability leads to the column pinching itself completely, thus cutting the flow of current. The growth rate of instability is quantified for different current amplitudes as well as column dimensions, and the results are compared to theoretical values. Some experiments are also run with an imposed axial magnetic field aligned with the column, which stabilizes the m = 0 mode instability, thus leading to m = 1 and m = 2 mode instabilities, also known as kink instabilities. The results obtained using liquid metal can be useful in some industrial applications as well as serving as a useful surrogate for plasma, as experiments with high-temperature plasmas can be very costly and complicated to run.

Email address for correspondence: *taj.sobral@mail.mcgill.ca*