Experimental investigation of transition to turbulence in a magnetic obstacle

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EXPERIMENTAL INVESTIGATION OF TRANSITION TO TURBULENCE IN A MAGNETIC OBSTACLE

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1 Abstract

We present an experimental study about the structure of the flow in the movement of an electrically conducting fluid past a localized magnetic field,which has been called magnetic obstacle. We studied the sequences of vortex generation and the structure of bifurcations in the flow of eutectic alloy GaInSn. The flow is shown to undergo really complicated phenomena. Here we will try to introduce these phenomena.

2 Introduction

In practical applications we always deal with the nonideal, i.e. confined and nonhomogenous magnetic fields. There are many applications in which we combine such a magnetic field with the liquid metal flow and benefits from the interaction force which is called Lorentz force. This force can be used as an active force to drive the fluid flow, in a pump or stirrer, or as a passive force in measurement devices. The liquid metal flows under the influence of confined non-homogeneous magnetic fields, so called magnetic obstacle [1] is hardly understood. There are some literatures who try to discover the secrets of the magnetic obstacle [1]– [4] but they all suffer from the lack of experimental evidences and the transition to turbulence is still obscure. In the obove references the authors demonstrated that the flow pattern in a magnetic obstacle is really more complex than in the wake behind an ordinary hydrodynamical body. Votyakov et al. [1] showed that The flow will undergo two bifurcations (rather than one) and will involve up to six (rather than just two) vortices. The fluid flow is predicted to be stable and free of vortices at high velocities. By decreasing the flow rate, inner vortices and later on the six-vortex pattern will appear. This is in contrast to what we know from ordinary hydrodynamics in which vortex generation will be amplified by increasing flow rate. They also predicted the appearence of two bifurcation and related them to the appearence of the vortices, see figure 1. In this letter we will present the experimental results of the transition to turbulence in a magnetic obstacle.

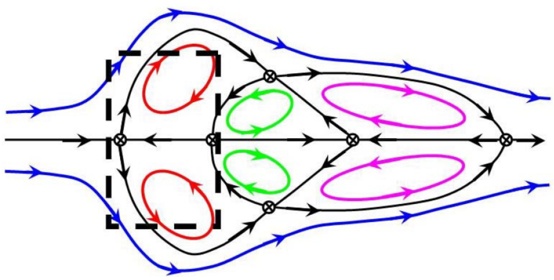

Figure 1: Topology of the predicted fluid flow as mentioned in [1].

3 Experimental set up

A 1200mm long channel with a rectangular 100mm $\times$ 25mm cross section made of Plexiglas is used in this experiment. The channel is filled up with 10mm GaInSn and has one Hartmann wall, one free surface and two side walls.The maximum intensity of the magnetic field in the Hartmann wall and in the free surface will be 0.4T and 0.2T accordingly and the related Hartmann number will be Ha $= 110.6$. The 20mm $\times$ 30mm $\times$ 40mm permanent magnet is installed on a moving rail beneath the channel which has the course of 850mm (figure 2). The distance between the magnet and the Hartmann wall is 8 mm. The experimental set up enables us to move the magnet with constant velocities varying from 5mm.s^{-1} to 80mm.s^{-1}, i.e. Re $= 125 - 2000$. The streamlines has been illuminated using gas bubbles generated due to the reaction of the acid HCl and GaInSn oxide on the free surface. A camera which moves with the magnet has been used to record the vortex generation sequences.

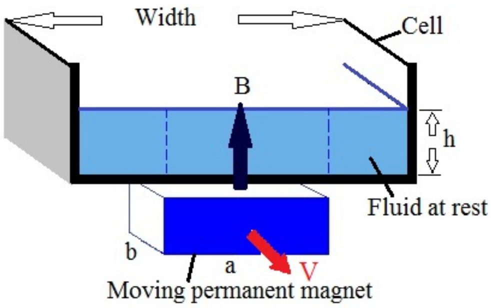

Figure 2: Sketch of channel and permanent magnet arrangement for this experiment.

4 Result and discussion

As the velocity and hence the Re Number changed, we observed different behaviours inside the magnetic field region and in downstream. These includes formation of bifurcations or their suppression, vortex shedding behind the magnet, symmetry breakdown, dupplication of vortices and also a behaviour that looks like intermittency. Two of the pictures taken during this investigation is shown in figures 3 and 4. In this figures a magnet indicatior shows the end position of the magnet. Notice that all the pictures do not have the same scale.

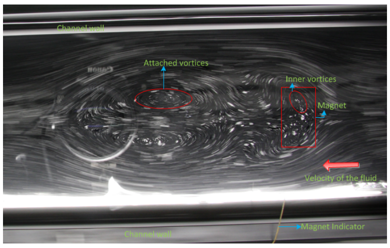

Figure 3: Transient 6 vortex structure at Re = 1000

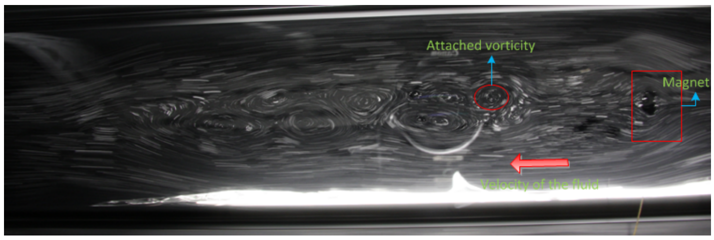

Figure 4: A street of vortices at Re = 1500

5 Conclusion

A new complicated phenomena that shows the features of the turbulent flow has been discovered. The vast number of turbulent phenomana that are visible in the fluid flow past a magnetic obstacle make it worth investigating in order to achieve a better understanding of magnetic obstacle or even turbulence.

6 Acknowledgment

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