ANNEX 17

Jet Stability in the Presence of an Electromagnetic Field

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FORMULATION AND NUMERICAL SOLUTION

The trajectory of a jet was studied, that travels inside an electromagnetic field. The motion is assumed to remain with a plane that is perpendicular to the magnetic field $\vec{B} = B\vec{e}_x$ and that is defined by the external electric field, $\vec{\nabla}\phi = \frac{d\phi}{dz}\vec{e}_z = a\vec{e}_z$, and the original jet speed $\vec{u}_0 = -u_0\vec{e}_z$; z is also the direction of gravity. The effect of Lorentz forces, gravity and pressure drop are accounted for in a unidirectional model that assumes a small jet radius in comparison with the trajectory length. At steady state the pressure drop is determined by the relative importance of capillary and electric stresses at the jet/plasma interface.

The jet is progressively accelerated due to the action of the electric potential gradient part of the Lorentz force $-\sigma\vec{\nabla}\phi \times \vec{B}$ along the y direction, *Fig. 1*; the flow arrangement examined aims at simulating the experiments at ISSTOK, *Fig.* 2, [1]. The simulations performed were simple Runge-Kutta time integrations on a parameter range determined by the conditions of the above experiment.

As a result the pressure drops due to the action of electric stresses and the jet is accelerated along its trajectory while its thickness is reduced in order to conserve mass. The above pattern curves the jet trajectory towards the y direction with a deflection that increases as the magnetic field intensity increases, (*Fig. 3*). This effect will continue until the jet radius becomes very small while the jet trajectory is more or less aligned with the y direction in which case deceleration will take place. However, most likely, instability will prevail long before this stage leading to drop formation. *Fig. 4* shows the jet trajectory when a small jet velocity is imposed along the z direction at t=0.

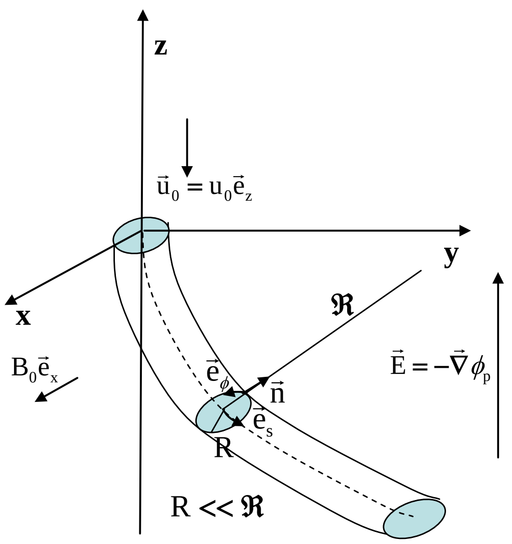

Fig. 1: Schematic diagram of the flow arrangement

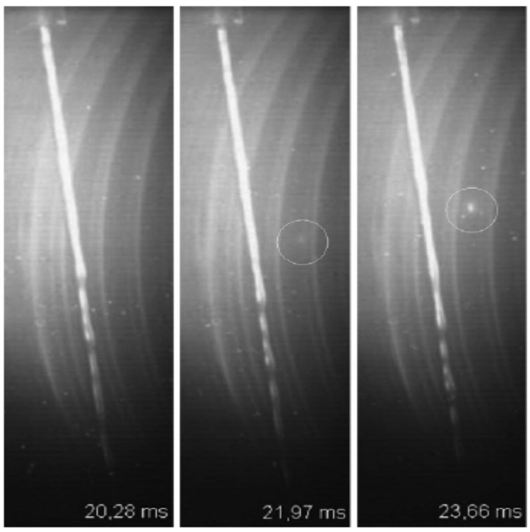

Fig. 2: Jet deflection measured at the ISSTOK experiment (Gomes et al. Fus. Eng . Des 2008)

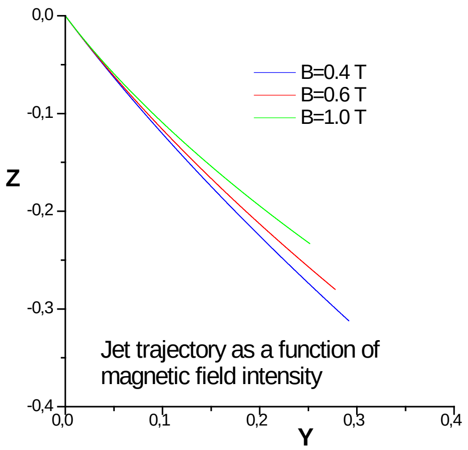

Fig. 3: Jet trajectory as a function of magnetic field intensity for a jet with an initial 35^o angle with the negative z axis

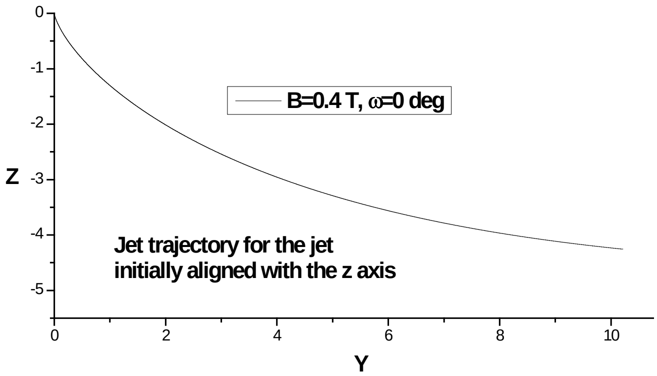

Fig. 4: Jet trajectory for a jet that is initially aligned with the negative z axis

CONCLUSIONS AND GENERAL PERSPECTIVES

Based on the preliminary one-dimensional analysis that was carried out, the effect of external electric potential gradients on jet deflection was ascertained, Lorentz force or $\vec{j}\times\vec{B}$ effect, in conjunction with the importance of electric stresses in accelerating the jet and reducing its radius. As a result it is anticipated that the jet will be susceptible to an interfacial instability, equivalent to the Rayleigh instability but now due to the interfacial electric stresses, that will generate drops. Stability analysis is required in order to identify the parameter range for which electric stresses will overcome capillarity and pinch–off droplets [2,3]. The trajectory of the emerging droplets will subsequently be determined by a similar force balance as for the jet where, however, their smaller size in combination with a possible reduction of the electric potential gradient, depending on the positioning of the initial jet, may attenuate their deflection.

REFERENCES

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