Wall Confinement Technique by Magnetic Gradient Inversion

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When a plasma is subjected to a transversal magnetic field and its Hall parameter is non-negligible, it weakens the local electric conductivity value. If an electric discharge is created near a wall and the magnetic field decreases with distance, the electric discharge will follow a path that minimises the streamer's electric resistance, which could expel it far from the wall. One solution to ensure that it remains up against the wall is by inversion of the magnetic field's gradient by arranging that field B be minimal at the wall. In the experiment we are presenting, effected in a low-density gas, in order to obtain a high value for the Hall parameter using simple permanent magnets, we will show the remarkable efficiency of this parietal confinement method and present the main lines of the programme of which this experiment forms part and whose successful realization will be the demonstration of the feasibility of the displacement of disk-shaped MHD aerodynes at supersonic speed without creating either shock waves or turbulence, an approach that we have already set out in numerous publications.

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1. Introduction

We have already set out disk-shaped MHD aerodynes of supersonic speed in numerous publications [1, 2]. We present experimental evidence of MHD wall confinement of an electric discharge, due to the inversion of the magnetic field gradient, as presented in a previous paper (Ref. [3]). The program of future experiments is evoked.

2. Experiment and discussion

As shown below, the experiment was a complete success. The basic idea was presented in a previous paper in 2008 [3]. In a plasma, when a transverse magnetic field is applied, the electrical conductivity σ follows the matrix of Eq. (1), where σ_s is the scalar conductivity and β — the Hall parameter.

$$\sigma = \sigma_\mathrm{s}\begin{bmatrix} \frac{1}{1+\beta^2} & \frac{-\beta}{1+\beta^2} \\ \frac{\beta}{1+\beta^2} & \frac{1}{1+\beta^2} \end{bmatrix}. \tag{1}$$

When the Hall parameter β is weak, the electrical conductivity σ is close to its scalar value σ_s. If not negligible the electrical discharge will tend to take place along a path that minimizes global electrical resistance of the current streamer. In order to have non-negligible Hall parameters values, with simple solid magnets, which create a B field limited to 1000 Gs, we decided to operate in low density air, in order to damp the electron-heavy species collision frequency (in future experiments the field will be created by a system of coils). With a single magnet, the magnetic field decreases at distance from the wall, so that it blows away the electric discharge, which tends to take place where the field is weak, as shown in Fig. 1.

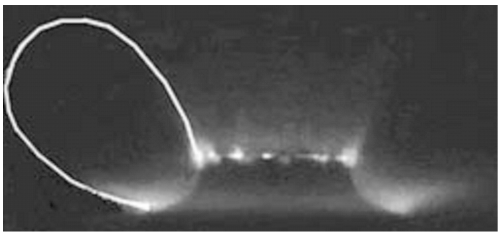

Fig. 1. The electric discharge is blown away by the magnetic field gradient.

Figure 2 shows the basic confinement system by inversion of the magnetic field gradient. Two smaller confinement coils modify the magnetic pattern.

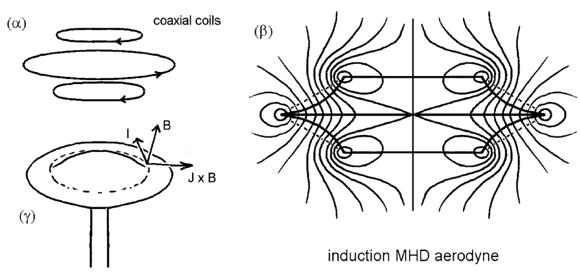

Fig. 2. Magnetic pattern with B field modified by confinement coils effect.

In this device, the magnetic field is at its minimum along a surface close to two portions of cones, containing

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the equatorial coil and the confinement coils. Figure 3A depicts a more detailed representation of the magnetic pattern. Figure 3B shows confinement effect with two magnets.

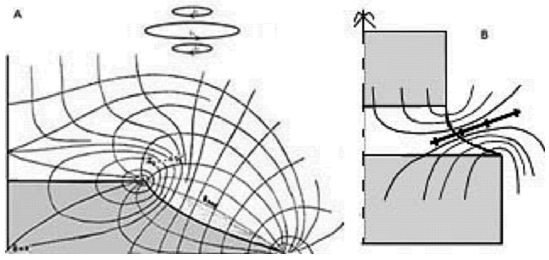

Fig. 3. (A) The magnetic field produced by a system of coils, (B) by two magnets.

The left diagram of Fig. 4 shows the value of the magnetic field along a straight line, visible in Fig. 3. On the right there is the square of the magnetic field. The ratio between the maximum value, at distance of the wall, and the value at the wall is 1.4.

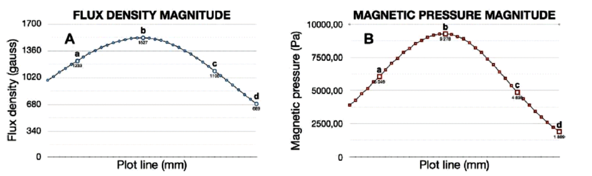

Fig. 4. Evolution of B and B^2, along the line in Fig. 3.

Figure 5 shows the experimental apparatus. At the top of the 40 cm diameter cylindrical chamber, an actuator moves a confinement magnet vertically and makes possible its entering into contact with the cap of the model, equipped with segmented electrodes (in order to obtain an axi-symetrical discharge). The pressure inside the bell is of the order of 20 mbar.

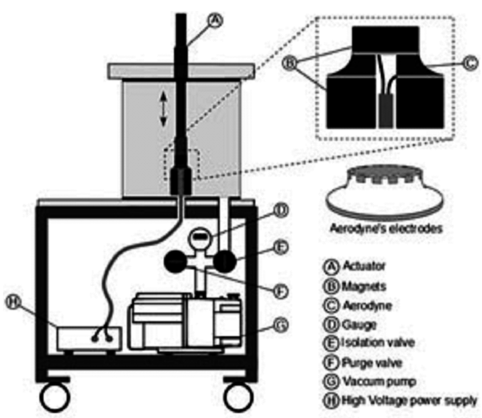

Fig. 5. Experimental device for low pressure MHD experiments.

Figure 6 depicts the apparatus. When the confinement magnet is lowered, this modifies the magnetic pattern and, subsequently, the electric discharge pattern. At the end of the course, the latter takes place at the wall of the model as shown in Fig. 7.

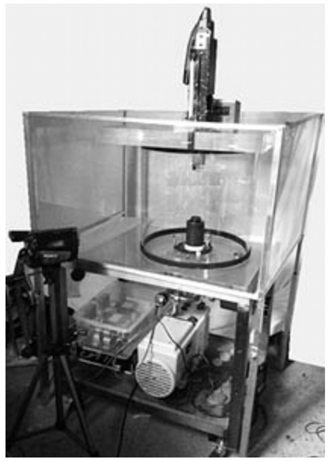

Fig. 6. Low pressure experimental device.

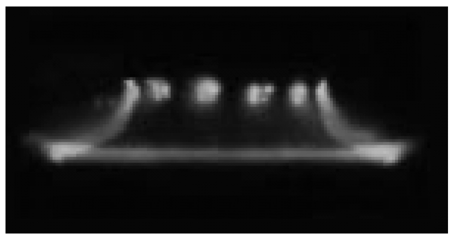

Fig. 7. Magnetic confinement of the electric discharge at the wall.

3. Conclusion

This is the first step of our experimental program, using this low density MHD apparatus. In the next experiments we will deal with the Velikhov instability cancellation, by magnetic gradient, as presented in Ref. [13]. Then we will build up a ionization control system, located at the wall of a disk-shaped model, as mentioned in Refs. [15] and [16]. With time-variable ionization and B-field we will try to operate a disk-shaped MHD accelerator, and to illustrate the induced flow in low density experiments. Finally we will shift to atmospheric pressure experiments, with time-variable ionization, produced by 3 GHz microwaves coupled to a synchronized time variable B-field. An attempt will be made to show, in a short duration supersonic wind tunnel, that such disk-shaped MHD aerodyne may fly in air without shock wave system and turbulence [7–12], which would avoid subsequent energy loss, due to the wave and frictional drag.

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