CANCELLATION OF THE VELIKHOV INSTABILITY BY MAGNETIC CONFINMENT

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ABSTRACT:

In high Hall parameter regimes, a non homogeneous magnetic field creates a non homogeneous electrical conductivity, which tends to guide the electric current. In some non equilibrium and a priori unstable configurations, it is shown that magnetic confinment may cancel the Velikhov instability and control strongly the current density pattern.
Furthermore, this guidance appears to be stronger than the Hall effect itself, such as it can almost suppress the transverse electric current.

INTRODUCTION: In 1965, in Paris, Velikhov and Golubev presented some experimental work, done in a MHD disk convertor, in a non equilibrium regime. They revealed how fast the ionization instability could grow, and that was the begining of a lot of trouble for closed cycles.
The ionization instability created strong electron density and temperature inhomogeneities, which appeared clearly with the fast camera pictures. The electric current tended naturally to follow these highly conducting pathes.
Now, instead of suffering inhomogeneities, why don't we create and use it ?
In a strong Hall regime, the direct abd transverse conductivities are:

$$\sigma_{\parallel} \simeq \sigma_s / \beta^2 \qquad \sigma_{\perp} \simeq \sigma_s / \beta \qquad (\beta \gg 1)$$

EXPERIMENTS IN A DISK SHAPE MACHINE:

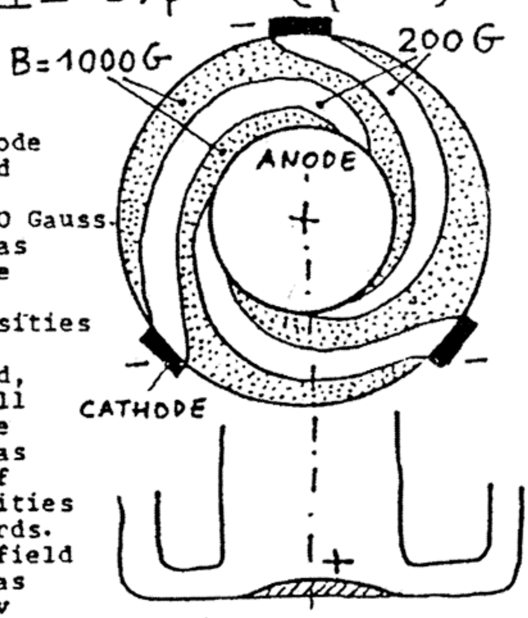

Figure 1. Disk accelerator

In 1977 we did some experiments in a disk accelerator, with a central anode and three cathodes. This was operated in low pressure air (0.8 Torr).
The "general" magnetic field was 1000 Gauss. And, along spiral alleys, this field was attenuated down to 200 Gauss, i.e. the magnetic pressure contrast was 25.
For moderate electric current densities (0.02 to 0.1 A/cm^2) a good spiral electric current pattern was obtained, corresponding to some "appearent" Hall parameter up to 5. The diameter of the converter was 7 cm, and the voltage was about one KV. They were no evidence of inhomogeneities. For low current densities the streamers appeared like thin chords.
At the contrary, when the magnetic field was homogeneous, the spiral pattern was strongly altered, like in the Velikhov experiments. In This last condition, the ionization instability was evident, creating inhomogeneities among the spiral streamers, where the spiral angle, according to the theory, remained close to unity.
The impact, of magnetic confinment on the instability was interesting, and we decided to study different magnetic patterns. It appeared possible to control the current pattern, and a surprise was to see that, if desired, one could even reverse the spiral angle, through confinment effect. See figures 2 and 3.

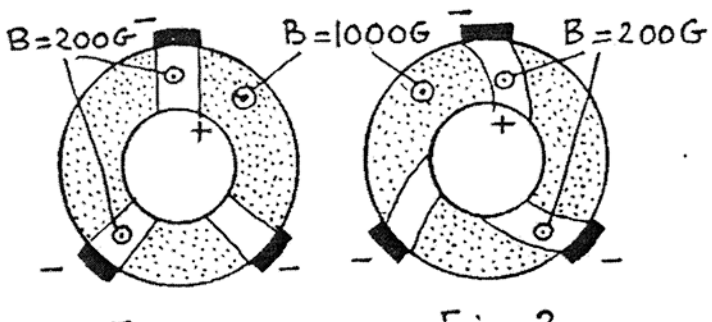

Fig. 2 Fig. 3

reverse current spiral due to magnetic confinment.

It was clear that the magnetic confinment could act in a stronger way than the Hall effect itself.

SOME COMMENTS: A complete and correct analysis of this phenomenon is rather difficult. At first, this is quite different from the classical magnetic confinment un fusion machines. But we can try some qualitative description. When the voltage is applied, the electrical conductivity is a priori very different inside and outside the magnetic alleys, in which the field has been attenuated. Such as the current tends naturally to flow along these alleys. In a non equilibrium situation, and in the weak magnetic field areas, the electron density and temperature are increased. Probably the plasma becomes Coulomb dominated inside the alleys. Such as the local Hall parameter is decreased, and this is a first cause of stabilization. Furthermore, the dissipative process due to high local values of the electric parameters tends to stabilize to. This is definitively a non linear process, but, now, instead suffering it, we USE it.

The method has its own limits. We can try to build up a criterium for the magnetic confinment. For an example, like in fusion machines, we can compare the electron pressure $p_e = n_e k T_e$ to the magnetic pressure.

It looks to fit. And as low is the electron pressure, as thin is the plasma chord. At the opposite, if the current density is increased enough, the spiral pattern may be altered, and disruptions occur.

APPLICATION TO A LINEAR GEOMETRY: Let us consider a Faraday convertor operating with a high Hall parameter. It looks to be a contradiction. In effect this is the worse machine one can imagine. But now introduce a non homogeneous magnetic field, as shown on the figure 4 :

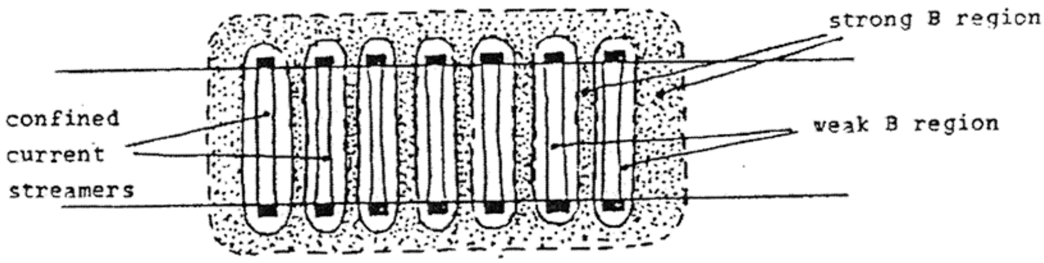

Figure 4. Faraday convertor with non homogeneous magnetic field.

The magnetic field has been attenuated along linear pathes. The experiment has been again carried in low pressure air. Thin, distinct electric streamers have been obtained, without evidence of ionization instability. While local Hall parameter remains larger than unity, this machine operates like a Faraday convertor.

FURTHER COMMENTS: Starting from these experimental facts, would the closed cycle problem be reconsidered ?

Of course, these experiments have been carried out with a very modest plant. Extension to hi h pressure conditions would be desirable. We would like to reconsider some experiments done in France in 1966-67 in helium argon mixtures, and in a shock tube generator. See reference 1 . A 30 % argon, 70 % helium is a Penning mixture, and provides a fast ionization process, as it was presented in the international meeting of Warsaw in 1967. We would like to reconsider such an approach, with non homogeneous magnetic field. Shock tubes are very reliable for gas temperature exploration. This is what we plan to do in France.

Both linear and disk geometries can be considered. This method including the magnetic control of the streamers is a source of a lot of new geometric configurations. For an example, consider a disk generator:

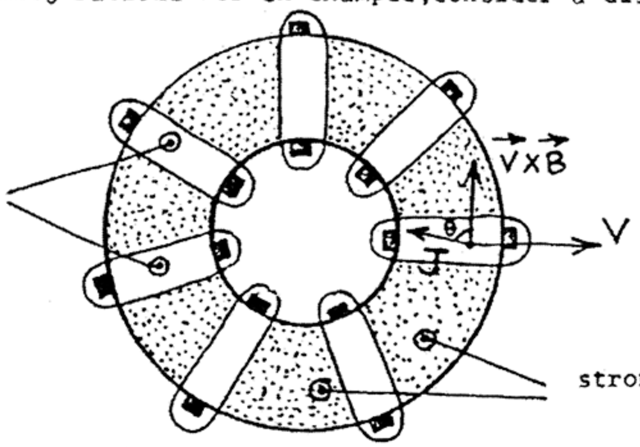

Figure 5. Disk generator

The velocity is radial, and the induced electric field azimutal. With some high parameter value, the desirable current would flow almost radially, if the ioni ation instability would not occur. We can try to drive the current along radial pathes, joining face to face electrodes. Along these linear alleys, the magnetic field would be weaker. The magnetic field tends to confine the currents. But this can be reenforced if some seed can be emitted at the wall, increasing the conductivity contrast, in the weak field areas.

CONCLUSION : During years, non linear instability process has been a problem for closed cycles. As a result, all the MHD French program collapsed in 1972. We are going to build a new action according to these new ideas.

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