Mhd aerodynes, with wall confined plasma, electrothermal instability annihilated and stable spiral current pattern.

J.P.Petit[1], J.C.Doré[2]

[1]Research manager, [2]Technical manager, Lambda Laboratory France

E-mail: contact@lambda-laboratory.fr

MHD propulsion has been extensively studied since the fifties. To shift from propulsion to an MHD Aerodyne, one only needs to accelerate the air externally, along its outer skin, using Lorentz forces. We present a set of successful experiments, obtained on a disk-shapped model, placed in low density air. We successfully dealt with various problems : wall confinement of two-temperature plasma obtained by inversion of the magnetic pressure gradient , annihilation of the Velikhov electrothermal instability by magnetic confinement of the streamers, establishment of a stable spiral distribution of the current, obtained by an original method. Another direction of research is devoted to the study of an MHD-controlled inlet which, coupled with a turbofan engine and implying an MHD-bypass system, would extend the flight domain to hypersonic conditions.

PACS numbers: 47.65.-d, 52.30.Cv, 52.55.-s, 52.80.Pi, 52.75.Di

1.Introduction

During the sixties it was shown that if the electrical conductivity of the gas was large enough (3,000 S/m), Lorentz forces J x B (B = 2 teslas) could deeply modify the gas parameters of a supersonic flow (M = 1.4) in a Faraday MHD converter [1]. In a constant cross section channel , when slowing down the gas (short duration argon flow, T = 10,000°K, p = 1 bar, V = 2750 m/s, delivered by a shock driven wind tunnel) when slowing down, the deceleration was strong enough to create a front shock wave, without any obstacle. Accelerating the gas, velocity gain of 4,000 m/s were obtained along a 10 cm MHD channel [1]. In supersonic flows, shock waves occur when the local slowing down is strong enough to produce self crossing of Mach lines. See figure **1**.

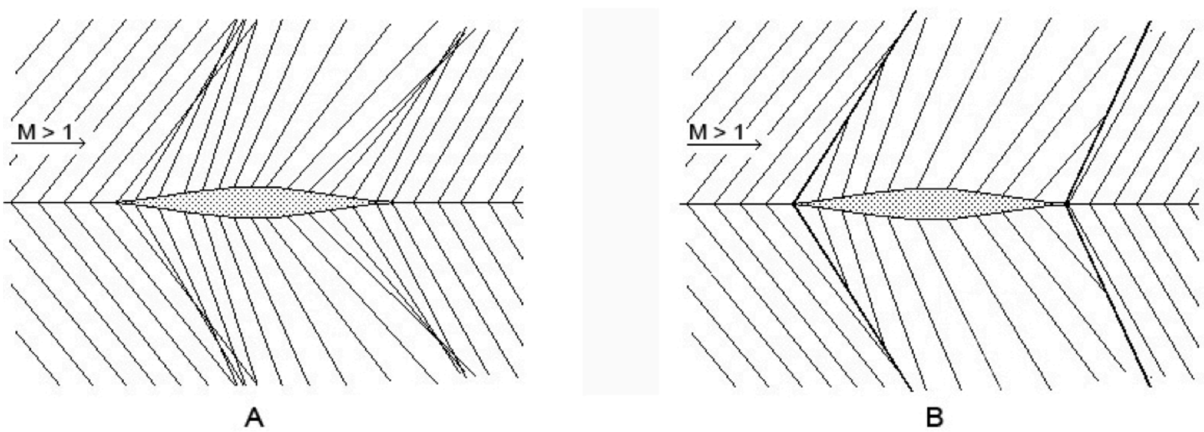

Figure 1. Two dimensional flow around a flat wing. Mach lines computed from Navier-Stockes equations. A : self crossing phenomenon. B : With shock waves system [2,3].

It was shown, based on 2d-numerical calculation and hydraulic simulation that those shock waves could be eliminated if a suitable Lorentz force was applied around the model [2-5].

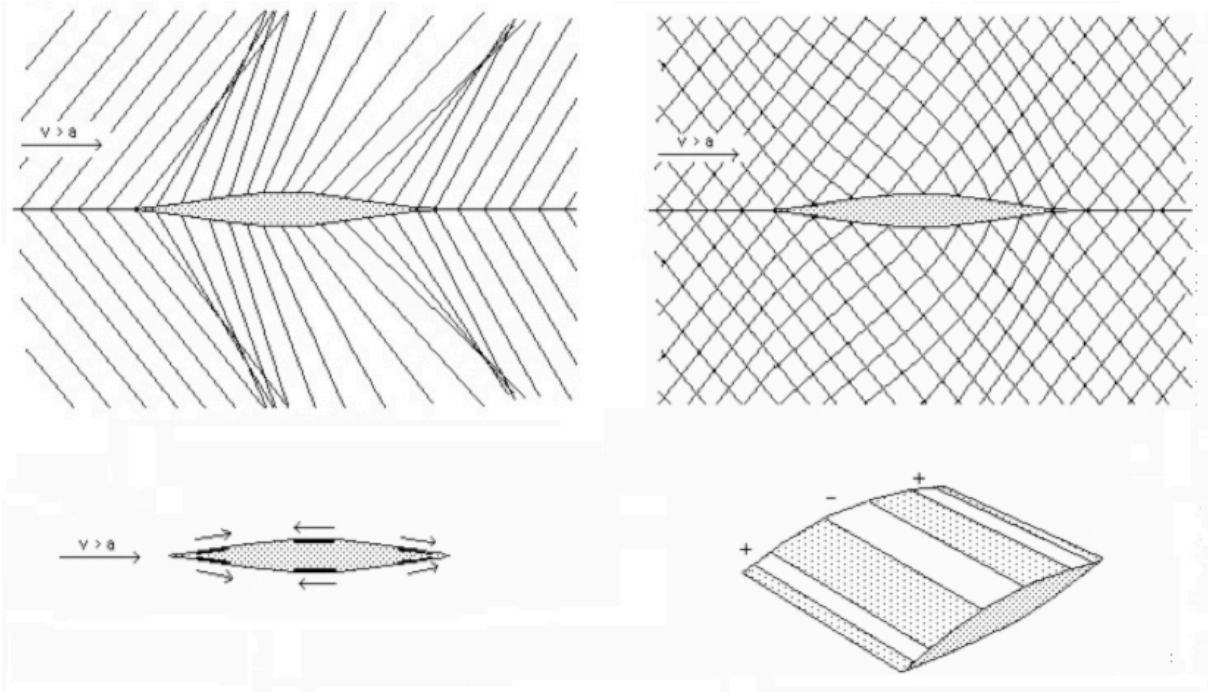

Figure 2. Elimination of shocks around a flat wing by convenient Lorentz force field.

The gas must be accelerated around the leading edge and the bottom, and slowed down between the two to prevent the expansion fan. By the way, this introduced the concept of MHD bypass. In the eighties it was planned to use a shock tube as a supersonic, high electrical conductivity gas flow generator, to operate this key-experiment. But, due to the connexion to UFO phenomenon (supersonic silent flight, as reported by witnesses) this was no longer possible in institutional structures. Years after, the Lambda Laboratory was created (2007) with private funding. The use of a shock tube was too complex and expansive, so that the team shifted to experiments in low pressure hypersonic wind tunnel, providing natural high electrical conductivity. Then disk shaped MHD aerodynes, as described in references [6] and [7] are more suitable, due to the high Hall parameter conditions. This arises specific difficulties, such a the tendancy of the discharge to be blown away, due to the magnetic field gradient. This was rapidly solved, by wall confinement through inversion of magnetic gradient.

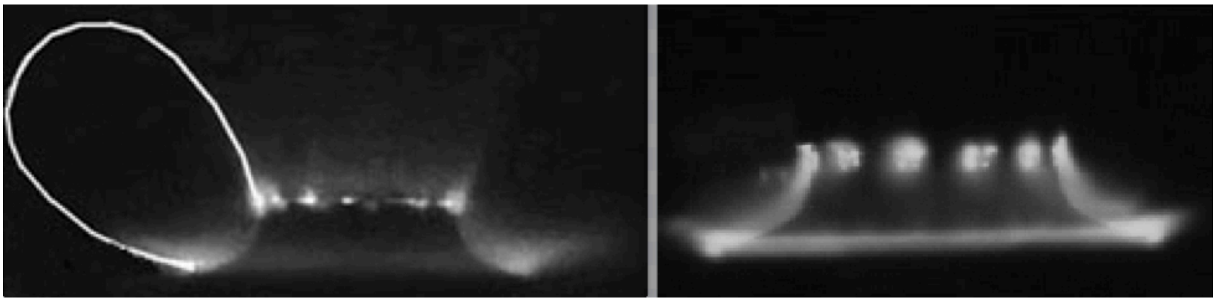

Figure 3. Left, the discharge is blown away by the magnetic gradient. Right : wall confinment by inversion of this magnetic gradient [9].

As we used a two temperature plasma (Te > Tg) in unstable conditions, with respect to electrothermal (Velikhov) instability, we operated successfully an instability concellation method by streamers confinement by magnetic pressure gradient control [8-10].

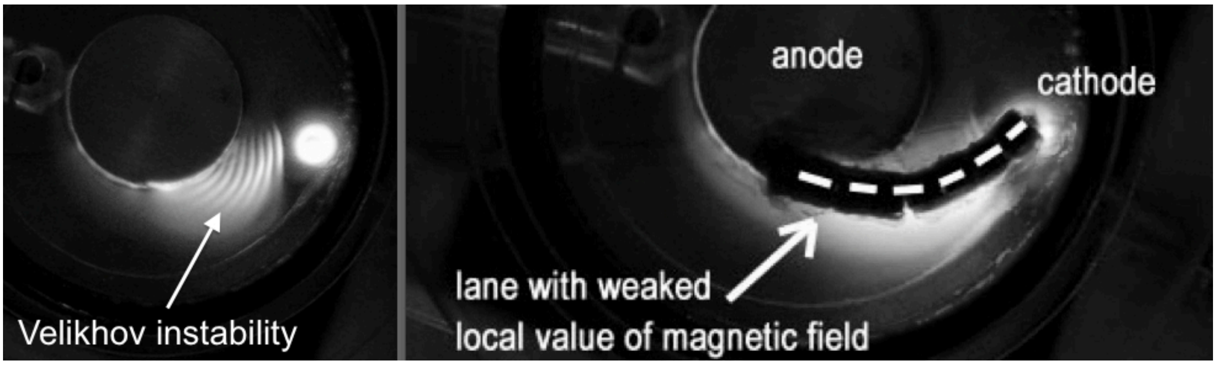

Figure 4. Annihilation of the electrothermal instability [10].

The MHD aerodyne concept is a set of many formulae, described in reference [11], including induction systems with pulsed wall controlled ionization by microwaves or micro wall ionizers. In figure 5, the schema of the MHD aerodyne working with spiral currents.

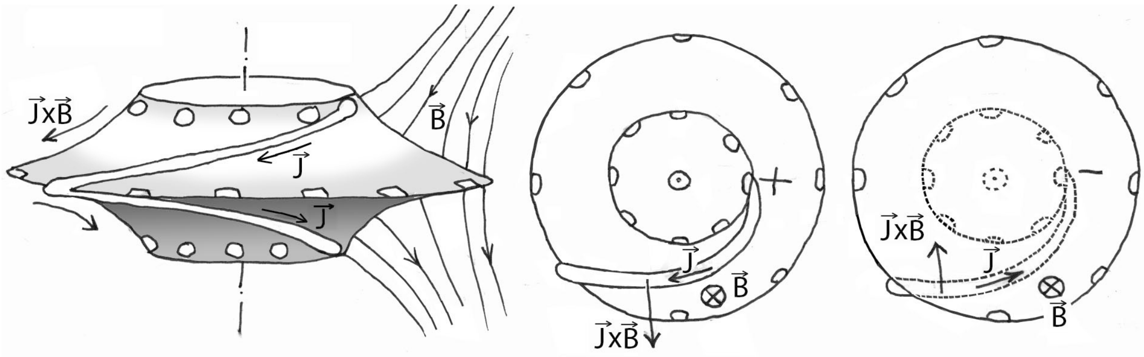

Figure 5. MHD aerodyne with spiral current

2. Recent work.

The team works on this system, which implies spiral current pattern. If one tries to obtain such pattern with all couples of electrodes simultaneously feeded, the result is poor (figure 6 left). Using a sequential feeding we got good looking spiral pattern (figure 6 right), the criterium being the following : in order to control the flow, the commutation periode must be small with respect to the transit time of the gas around the disk shaped machine.

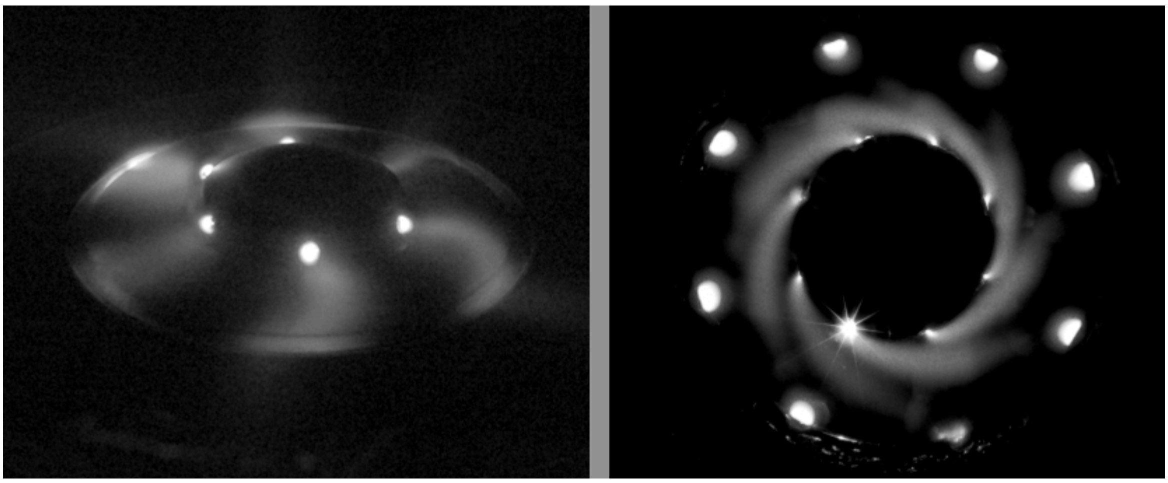

Figure 6. Spiral current pattern

References

[1] Forestier B., Fontaine B., Bournot P., and Parraud P. 1970 Study of the variations in the aerodynamic flow parameters of ionized argon subjected to Laplacian accelerating forces. *CRAS*, Paris, French Academy of Sciences, B series, No. 271

[2] Lebrun B. 1987 Theoretical study of shock wave annihilation around a flat wing in hot supersonic argon flow with Lorentz forces. *Engineer-Doctor thesis*, Aix-Marseille University; & *Journal of Mechanics*, France.

[3] Petit J.P., Lebrun B. 1989 Shock wave annihilation by MHD action in supersonic flow. Quasi one dimensional steady analysis and thermal blockage. *European Journal of Mechanics B/Fluids*, Vol. 8, No. 2 pp. 163-178.

[4] Petit J.P. 1983 Is supersonic flight, without shock wave, possible? *International Conference on MHD Electrical PowerGeneration*, 8th, Moscow, Russia, Proceedings Vol. 2.

[5] Petit J.P., Lebrun B. 1986 Shock wave cancellation in gas by Lorentz force action *International Conference on MHD Electrical Power Generation*, 9th, Tsukuba, Japan. Proceedings Vol. 3 pp. 1359-1368.

[6] Petit J.P. 1975 New MHD converters *CRAS*, Paris, French Academy of Sciences Vol. 11 No. 281 pp. 157-160.

[7] Petit J.P., Viton M. 1977 New MHD converters: induction machines. *CRAS* Paris French Academy of Sciences No. 284 pp. 167-179.

[8] Petit J.P., Geffray J. 2009 Non equilibrium plasma instabilities. 2nd Euro-Asian Pulsed Power Conference (EAPPC2008), Vilnius, Lithuania, *Acta Physica Polonica A* Vol. 115 No. 6 pp.1170-1173.

[9] Petit J.P., Doré J.C. 2012 Wall confinement technique by magnetic gradient inversion. . 3rd Euro-Asian Pulsed Power Conference (EAPPC2010), JeJu, Korea, *Acta Physica Polonica A* Vol. 121 No. 3 page 611

[10] Petit J.P., Doré J.C. 2013 Velikhov Electrothermal Instability Cancellation by Modification of Electrical Conductivity Value in a Streamer by Magnetic Confinement. 25th Symposium on Plasma Physics and Technology,Prague, Czech Republic, *Acta Polytechnica* Vol. 53 No. 2 page 219-222

[11] Petit J. P., Geffray J. 2009 Wall confinement technique by magnetic gradient inversion. Accelerators combining induction effect and pulsed ionization. Applications. 2nd Euro-Asian Pulsed Power Conference (EAPPC2008), Vilnius, Lithuania, *Acta Physica Polonica A* Vol. 115 No. 6 pp. 1162-1163.