IS SUPERSONIC FLIGHT,WITHOUT SHOCK WAVE,POSSIBLE ?

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ABSTRACT: The present discussion is supported by some analogic results in hydraulics.It has been demonstrated that the Lorentz Forces could anihilate the surface waves and the turbulent wake around a moving ship(model) The question of the shock cancellation is arised.

INTRODUCTION: In previous works,see references 1 and 2,MHD acceleration was achieved in hot Argon at atmospheric pressure.Strong acceleration were obtained,and in the case of a pure discharge(no magnetic field),thermal blocking was encountered,in supersonic flows.Lorentz forces can create shocks .But is it possible to achieve shock anihilation through Lorentz forces action ?

MHD DRIVEN FLOWS: Presently,no gas experiments have been carried.Only hydraulic analogic experiments.On the figures 1 and 2 we can see the caracteristic features of supersonic flows in the vicinity of a diedra.Let us describe now the wall MHD accelerator.On figure 3 we see two coils working face to face,each against the other.In this configuration the magnetic field is reinforced at the junction of thecoils.One can associate a series of coils,with alternative polarities,which creates a corresponding alternance in the magnetic field direction.See fig.4.If this is associated to wall linear electrodes,as shown on figures 4 and 5,we get a field of Lorentz forces,all parallel to the wall,and acting in the same direction. The magnetic field is mostly concentrated in a thin layer whose width is, roughly speaking,equal to the distance between two successive electrodes or coils.We can build a close set system,such as we can operate at low voltages and directly in the boundary layer of the fluid.In the figures 6 and 7 such an accelerator has been associated to a free surface liquid flow,simulating a supersonic gas flow.In the figure 6 the fluid is slowed down and a wave occur,simulating a shoch wave.In the figure 7 the acceleration generates an expansion fan.We see that these actions are similar to the impact of the diedra geometry.Now we can combine the wall MHD accelerator with the diedra,as shown on the figures 8.a and 8.b.As a result,the MHD action can balance the compression and expansion effects due to the diedra geometry.Such as we get a MHD driven,regularized flow. In figures 9.a and 9.b we see how a succession of acceleration and sloving down can cancel the wave system due to a bump.

HYDRAULIC PARAMETERS: In these experiments the simulated Mach number was 1.3; Some acid had been added to the water,in order to get an appreciable electrical conductivity.On the figure 10.a we see the classical flow pattern around a cylinder.We call d the distance between the front wave and the body.The figure 10.b shows the location of the two acting electrodes.The magnetic field is perpendicular to the free surface of the fluid. For technical constrainst this magnetic field was generated by an external coil,not represented.But it is ovious that some internal coil could create a magnetic field in the good direction.The reader will easily rebuild the field of electric current and Lorentz forces.They are mostly important in the very vicinity of the electrodes,an suitable polarity creates an acceleration.At the stagnation point the pressure jump is $\rho V^2/2$ where V is the upstream velocity.Such as we can build a characteristic sloving down force : $\rho V^2/2d$ The interaction parameter will be:

$$S = \frac{2\,JBd}{\rho V^2}$$

If this interaction parameter is larger than unity the Lorentz force will cause an appreciable change in the wave pattern.In hydraulic experiments this simple criterion works well.We have to bound the value of the current density in order to limit the gazeous production due to electrolysis.

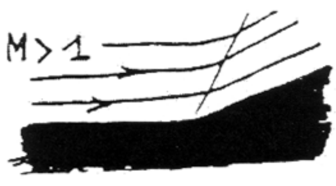


Fig. 1 Schock

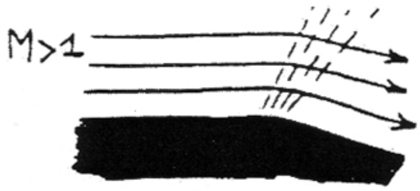


Fig. 2 Prandtl-Meyer Expansion

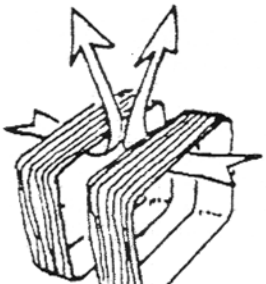


Fig. 3 Opposite coils

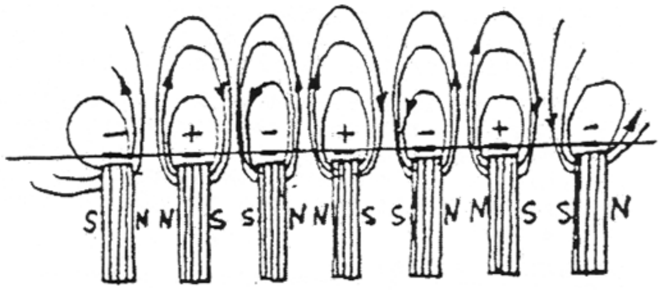


Fig. 4 alternating magnetic pattern

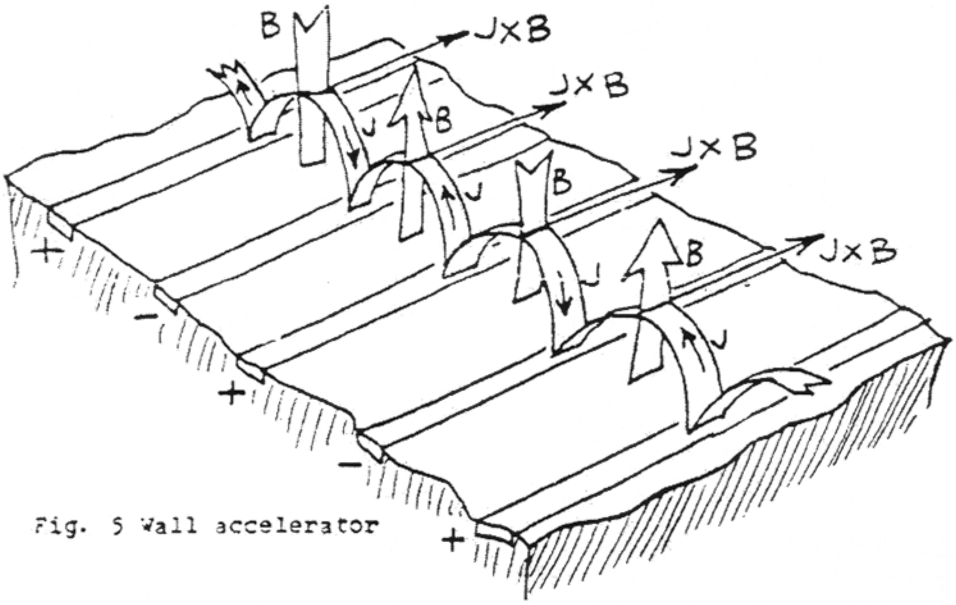
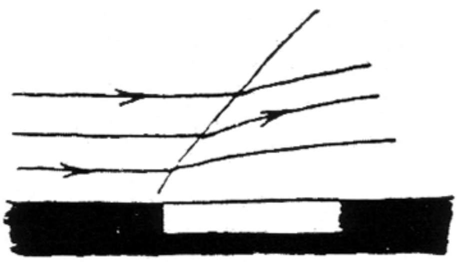


Fig. 5 Wall accelerator



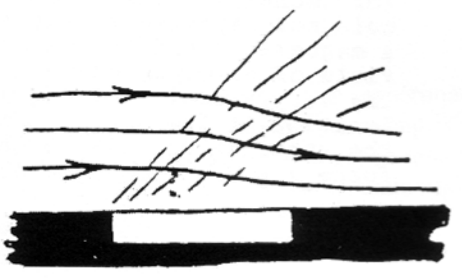
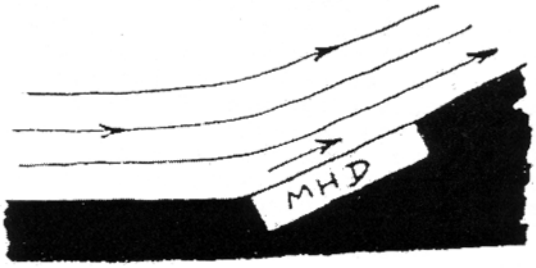


Fig. 6 Hydraulic simulation of MHD driven supersonic flow.

Fig. 6 Fig. 7



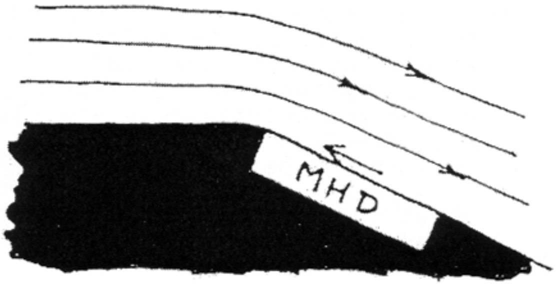
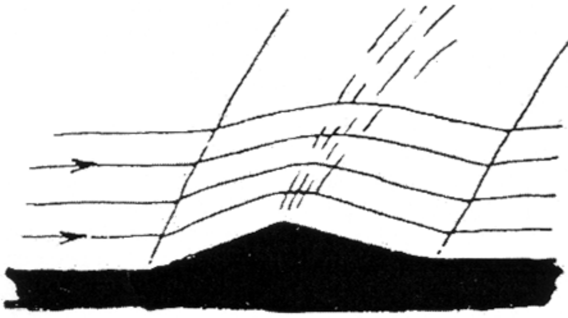


Fig.7   Fig.8 a   Fig. 8 b

Hydraulic simulation of MHD supersonic driven flows.



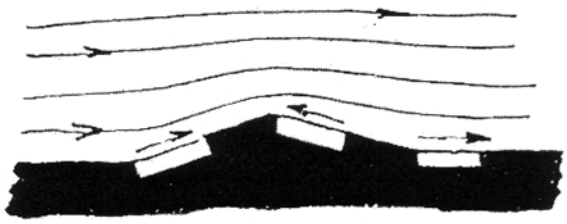
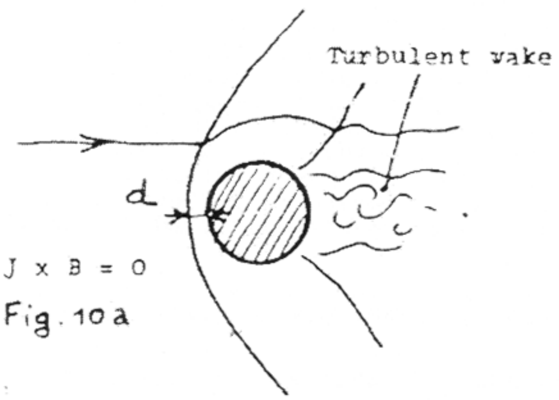


Fig.9a classical flow
(Hydraulic simulations).

Fig. 9b MHD driven flow



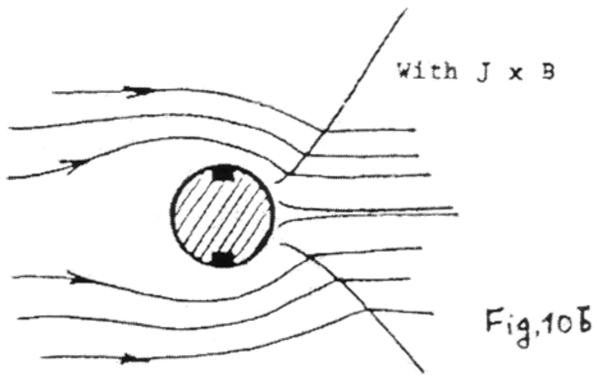
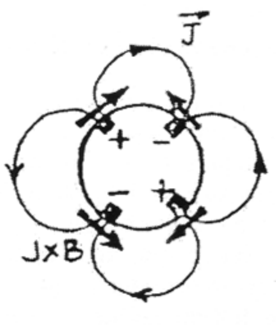


Fig.10 Hydraulic simulation of front wave cancellation.



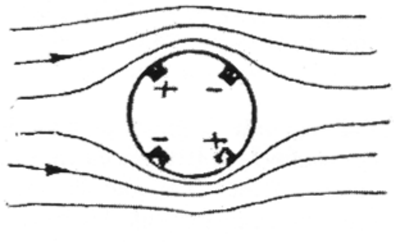


Fig.11 Hydraulic simulation of the regularization of a supersonic flow by lorentz forces.

The diameter of the model was 7 mm and the upstream velocity 8 cm/s. With a one ampere per cm^2 current density level, the magnetic field to be applied was 1.5 tesla. As a result, the front wave was immediatly sucked and anihilated, while the bottom wave was reinforced. But notice the effective reduction of the turbulent wake (Fig. 10.b). For large interaction parameter value (10) the water was depressed at the stagnation poiht, and a net thrust was found. A more sophisticated model is shown on figure 11, in which both acceleration and slowing down process occur. At a given regime, suitable voltages give a complete wave anihilation.

POSSIBLE EXTENSION TO GAS EXPERIMENTS: The main problem is the thermal blocking. In effect, air at normal conditions is a poor conductor. Such as large electric current densities would be required, in order to create a non equilibrium ionzation. The Joule effect rises the gas pressure and pressure gradient may be stronger that the Lorentz force. Call L the interaction lenght. We can take the width of the electrodes. To get a possible action on the wave pattern, we need at first an interaction parameter larger than unity, which scales the JB value. The gas, carrying its own enthalpy, gains the thermal energy $J^2L/\sigma V$ while the Lorentz force work is JBL. We have a chance to avoid thermal blocking if:

$$\frac{\sigma \rho V^3}{2LJ^2} \gtrsim 1$$

That means moderate currents and large electrical conductivity. The last could be increased by seed emission, through a porous wall. Microwaves can help to. We intend to begin with shock tube experiments, in hot Argon provided by a shock tube. Then we can operate with the natural electrical conductivity of the fluid, up to 3000 mhos/m. The impact on the wave pattern would be observed through laser interferometry.

LARGE HALL PARAMETER AERODYNES: In such experiments, all the tools of the plasma physics can be used. And we get a fascinating question : is supersonic flight, with no shock wave, possible ? Computational evaluation shows that such flying machines could be competitive at large Mach numbers, while the would require a technology and some electric generator that do not already exist ! However the efficiency grows with the magnetic field intensity. In the air at standard conditions, when the magnetic field goes up to, say, four teslas, the Hall effect becomes important. Various low Hall parameters aerodynes can be designed, including spherical objects. But with a large Hall parameter value, it is obvious that they don't fit anylonger. Somebody who knows a bit about MHD accelerator will rapidly see that the large Hall parameter aerodynes muts be disk shaped. And their electric current pattern must be a spiral. The reader will find in my other paper some experimental results about spiral currents making.

REFERENCES:

(1) B.FORESTIER B.FONTAINE J.VALENSI: IUTAM Intern. Symp. on dynamics of ionized gases, Tokyo 1971.

(2) B.FORESTIER B.FONTAINE P.PARRAUD J.VALENSI 2nd Intern. Symp. on gas dynamics of explosions. Novosibirsk 1969 and Astronautica Acta 15 (1970)

(3) J.P.PETIT: accélérateurs MHD d'un genre nouveau. CR. Acad. Sc. Paris t. 281 série B p. 157

(4) J.P.PETIT: Accélérateurs MHD. Revue Pour la Science (french edition of the Scientific American) May 1980.

(5) J.P.PETIT : Perspectives en Magnétohydrodynamique. Rapport de conjoncture CNRS 1980.