NOTIZEN

Optical Studies of Plasma-Flow Interactions with Large Magnetic Fields

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Studies of shock-heated plasma-flow interactions with transverse magnetic fields have been published by several investigators [1–4]. This note reports on some interaction phenomena which have been observed for the first time by using a particularly suitable technique for visualizing the flow process.

Experiments were performed with a plasma flowing into a strong magnetic field B, applied perpendicularly to the flow (of velocity v) in a Faraday-generator-type test chamber (see Fig. 1). An induced $v \times B$ e.m.f. causes an electric current j to flow in the plasma. The current paths are closed through electrodes which are externally short-circuited. A retarding force $j \times B$ acts in opposition to the plasma flow direction, and Joule heating converts kinetic to thermal energy. These two phenomena may choke the gas so strongly that a shock is generated which then propagates upstream out of the interaction zone. The existence and the path of such a shock wave has been predicted theoretically [3, 4], but no conclusive evidence of such a shock had been given experimentally. The present study clearly confirms the theoretical predictions.

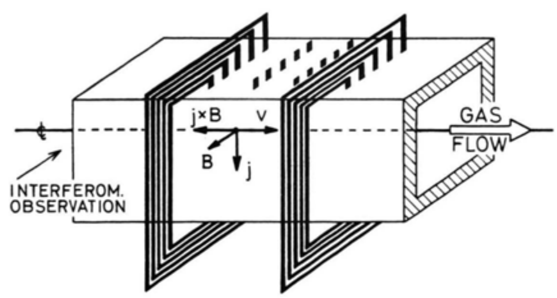

Fig. 1. Schematic representation of the Faraday-type test chamber.

The investigations were performed by means of a conventional shock tube with argon at Mach number 9.6 and initial pressure of 10 torr. A Mach-Zehnder interferometer was used to visualize the flow process. The optical axis was parallel to the magnetic field of up to 22 kG. The first streak interferograms were obtained by the conventional method of adjusting the fringes perpendicular to a slit focused onto the shock-tube axis. Although they show the reflection process, an even better visualization of the reflected shock path was obtained through an infinite fringe setting in the interferometer.

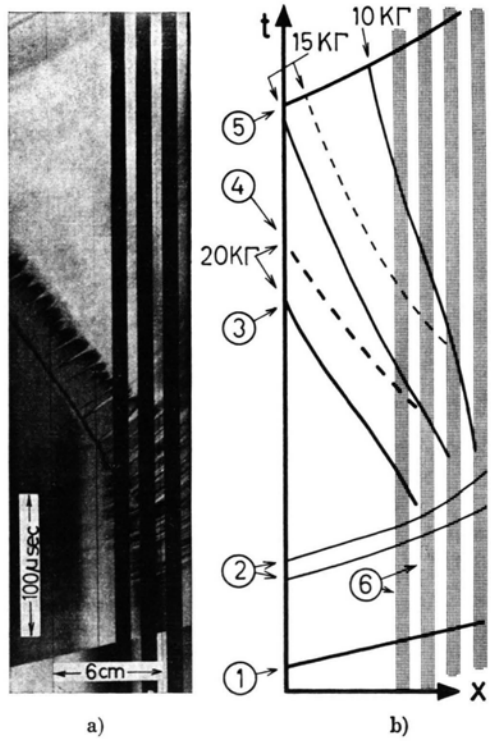

Fig. 2. Streak interferogram at 20 kG, and graphic representation of the reflected-shock-path dependence on magnetic field strength; $M_S = 9.6$, $P_0 = 10$ torr. The various lines indicate: 1) primary shock, 2) particle paths, 3) reflected shock, 4) ionization front, 5) contact front, 6) electrode short circuit bridges.

Figure 2 a shows such an interferogram. Its major lines are graphically represented in Fig. 2 b. The primary shock wave (1) runs from left to right into the interaction zone which is partially blocked out by bridges (6) connecting several rows of electrode pairs. The reflected shock (3) is seen to run upstream out of the electrode area. No ionization front is visible be-

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hind the primary shock, since only a small degree of ionization is attained in that region ($\alpha < 1\%$). The change in luminosity at some time behind the reflected shock (4), however, may be interpreted as caused by delayed ionization. Arrival of the contact front (5) forms the end of uniform plasma flow into the interaction zone. Furthermore, all streak interferograms show irregularly spaced particle paths (2) which are bent across the reflected shock towards the time axis. They are caused by inhomogeneities swept along by the flow. These may be due to contaminants or, another possible explanation, to electric arcs generated ahead of the interaction zone in an area of strong magnetic-field gradients.

In addition to the informations taken from the interferogram, the reflected shock paths and ionization fronts obtained at other magnetic field strengths are drawn into Fig. 2 b. A minimum magnetic field of about 10 kG is necessary to steepen the pressure wave to a shock front in the present configuration. This shock slowly propagates upstream out of the interaction zone. Further increase of the magnetic field causes the reflected shock to be generated at an earlier time behind the primary shock wave. Also, the reflected shock velocity increases with magnetic field strength (see shock paths at 15 and 20 kG, respectively). All reflected shock paths show an initial acceleration in the interaction zone and a deceleration further upstream. This behaviour agrees well with numerical calculations presently being made for the study of the reflection process outside as well as inside the electrode area [5].

The slowly reflected shocks obtained at 10 kG do not show visible ionization fronts. However, reflected-shock waves produced through higher magnetic fields are always followed by a relaxation zone.

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