PRESSURE DISTRIBUTION IN A MHD FLOW OVER A SPHERE

Yu. M. Kolesnikov, A.B. Tsinober, A.G. Shtern, and E.V. Shcherbinin

Magnitnaya Gidrodinamika, Vol. 3, No. 4, pp. 148–149, 1967

UDC 538.4

1. The measurements were made in a rotating annular channel [1] using two slightly different schemes. Both versions of the experiment employed a two-liquid differential manometer, but in the first the static pressure was sampled directly from the annular channel, and in the second from a separate vessel containing mercury. As the experiments showed, the two systems are equivalent in the absence of a magnetic field and make it possible to eliminate ambient temperature and pressure fluctuations. However, extended operation with the electromagnet switched on led to perceptible heating of the mercury in the channel and as a result of its expansion an uncontrollable systematic measuring error was introduced. This error was eliminated by using the first scheme, shown in Fig. 1.

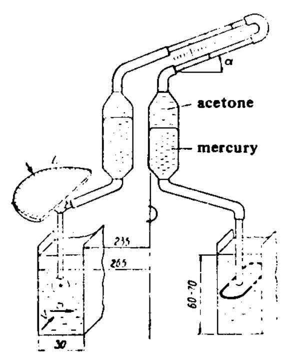

Fig. 1. Measuring setup.

The experiments were performed with a plastic sphere 10 mm in diameter attached to a holder 2 mm in diameter. The total pressure orifice in the surface of the sphere was 0.45 mm in a diameter, which led to averaging of the pressure over a solid angle of about $6.37 \cdot 10^{-3}$ steradian. When the sphere was rotated about a vertical axis, the center of the orifice remained in the equatorial plane parallel to the vectors of the oncoming flow velocity **V** and the magnetic field induction **B**. The angle of rotation was measured by means of quadrant L correct to ±0.5°. The static pressure was sampled (in the first version of the experiment) from the lower surface of a plate also parallel to the vectors **V** and **B**. This orientation of the plate relative to the magnetic field made it possible to eliminate any effect that the latter might have on the pressure distribution at its surface, since, apart from fringe effects, a magnetic field oriented along the surface of a plate has no effect on the flow in the boundary layer [2]. The orifice was located at the center of the plate 16.5 mm from the sharp leading edge at a plate thickness of 1 mm.

In order to measure the velocity of the oncoming flow we used a special probe employed previously in [3] to measure the velocity in the boundary layer (this probe is not shown in Fig. 1, a description may be found in [3]). The use of such a probe is necessary to check the lag of the mercury in the channel and the effect of the magnetic field on this lag. As the experiments showed, at B = 0 the velocities determined by the probe corresponded correct to 2% with the values calculated from the pressure drop.

All three elements—sphere, plate, and velocity probe—were arranged around the periphery of a channel 157 cm long, roughly the same distance apart.

2. The curves in Fig. 2 represent the pressure distribution around the equator of the sphere. The solid curve corresponds to the Hartmann number, calculated from the diameter of the sphere, Ha = 0, the dashed curve to the Hartmann number Ha = 75, both curves being obtained for Re $= 9.6 \cdot 10^3$. The curves show that, as for a cylinder [4], the

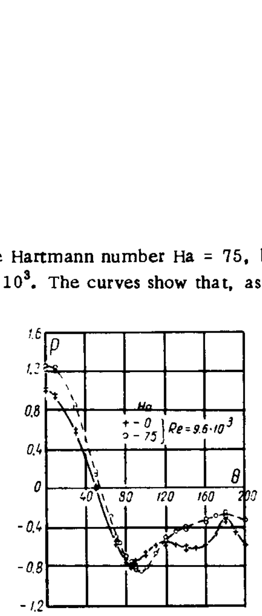

Fig. 2. Distribution of pressure $p = 2\Delta p/\rho V^2$ around the equator of the sphere.

pressure increases in front of the sphere, while the point of minimum pressure is displaced downstream. However, at the back of the sphere the picture differs from that for a cylinder. At Ha = 0 at the back of the sphere in the range $160° \leq \theta \leq 180°$ there is a region of rapid recovery. The existence of this region is apparently due to the three-dimensional turbulence behind the sphere which results in a stronger influx of fluid into that region. The data obtained in the presence of a magnetic field indicate that the field has an important influence on this motion. Unfortunately, the lack of experimental data makes it still impossible to determine the precise effect of the field on the three-dimensional flow behind a sphere.

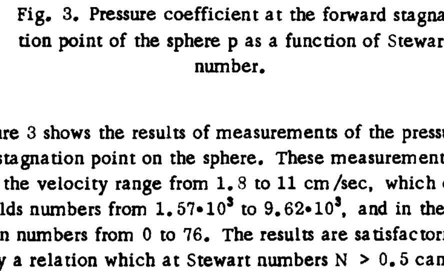

Fig. 3. Pressure coefficient at the forward stagnation point of the sphere p as a function of Stewart number.

Figure 3 shows the results of measurements of the pressure at the forward stagnation point on the sphere. These measurements were made in the velocity range from 1.8 to 11 cm/sec, which corresponds to Reynolds numbers from $1.57 \cdot 10^3$ to $9.62 \cdot 10^3$, and in the range of Hartmann numbers from 0 to 76. The results are satisfactorily generalized by a relation which at Stewart numbers $N > 0.5$ can be written in the form

$$p = 2\Delta p/\rho V^2 = 0.8 + 0.6 N^{2/3}. \tag{1}$$

The results are in agreement with the conclusions of a theoretical analysis made in [5]. As assumed in [5], the slope of the straight line (1) is less than in the case of plane flow over a cylinder [6].

The circles in Fig. 3 denote measurements made in the first version of the experiment, the crosses measurements made in the second version. Clearly, the latter measurements give a much greater scatter about the curve than the former.

REFERENCES

1. G. G. Branover, O. A. Lielausis, and I. M. Kirko, Trudy In-ta fiziki AN LatvSSR, Riga, **12**, 167, 1961.

2. K. Gotoh, J. Phys. Soc., Japan, **15**, 4, 696, 1960.

3. B. Ya. Gurevich, R. L. Miller, A. B. Tsinober, and A. G. Shtern, Magnitnaya gidrodinamika [Magnetohydrodynamics], 4, 69, 1965.

4. A. B. Tsinober, A. G. Shtern, and E. V. Shcherbinin, Izv. AN LatvSSR, ser. fiz.-tekh. nauk, 4, 61, 1964.

5. G. G. Branover, Yu. M. Gel'fgat, A. B. Tsinober, A. G. Shtern, and E. V. Shcherbinin, Magnitnaya gidrodinamika [Magnetohydrodynamics], 1, 98, 1966.

6. Kh. E. Kalis, A. B. Tsinober, A. G. Shtern, and E. V. Shcherbinin, Magnitnaya gidrodinamika [Magnetohydrodynamics], 1, 18, 1965.

8 June 1967