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A METHOD FOR DETERMINING THE TRAJECTORIES OF PARTICLES IN SUSPENSION IN A FLUID

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(Procédé pour déterminer les trajectoires de corpuscles en suspension dans un fluide
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Investigators who use smoke to visualize steady fluid flows assert that the trajectories of the particles which constitute the smoke patterns coincide with the flow lines. Indeed, such an approximation is justified only in the case of very small particles, low velocities, and moderate curvatures.

In general, particles in suspension in a fluid with a nonuniform motion have trajectories distinct from the streams of fluid if their specific mass is different from that of the fluid. The mathematical, graphical, and experimental study of these trajectories is developed in the technical report No. 15 of the G. R. A. by M. Vasseur and the present authors. We wish to supplement here the experimental study included in the above report by a description of a procedure suitable for tracing conveniently the trajectories of particles when the flow is plane or possesses axial symmetry.

I. Principle

1) Let us imagine at first that all particles have identical shape and dimensions. In the plan of the flow being considered the stream tube crosses the trajectory of particles at an angle at point P (Fig. 1).

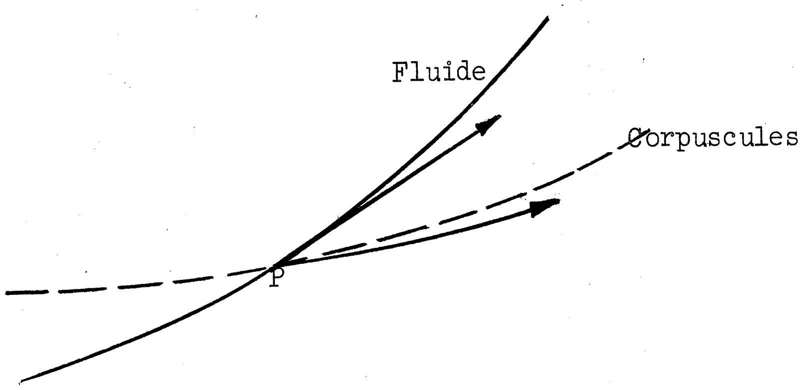

Fig. 1

We then place a circular cylinder in such a manner that its axis, perpendicular to the plane of the flow, intersects this plane at point P (Fig. 2). We assume the diameter of this cylinder to be very small compared to the radii of curvature of the trajectories and of the streams. The fluid curves around the cylinder while a beam of trajectories of particles (which we suppose to be adhesive) hit it, and the corresponding particles adhere to it.

We can assume that, in view of the smallness of the diameter of the cylinder, the deposit of particles is symmetrical with respect to the tangent to the trajectory of particles at point P.

If, in several points, P, P', P''..., of the plane of flow, we place cylinders of revolution similar to the one above, we shall obtain by this method the tangents to the trajectories at these points.

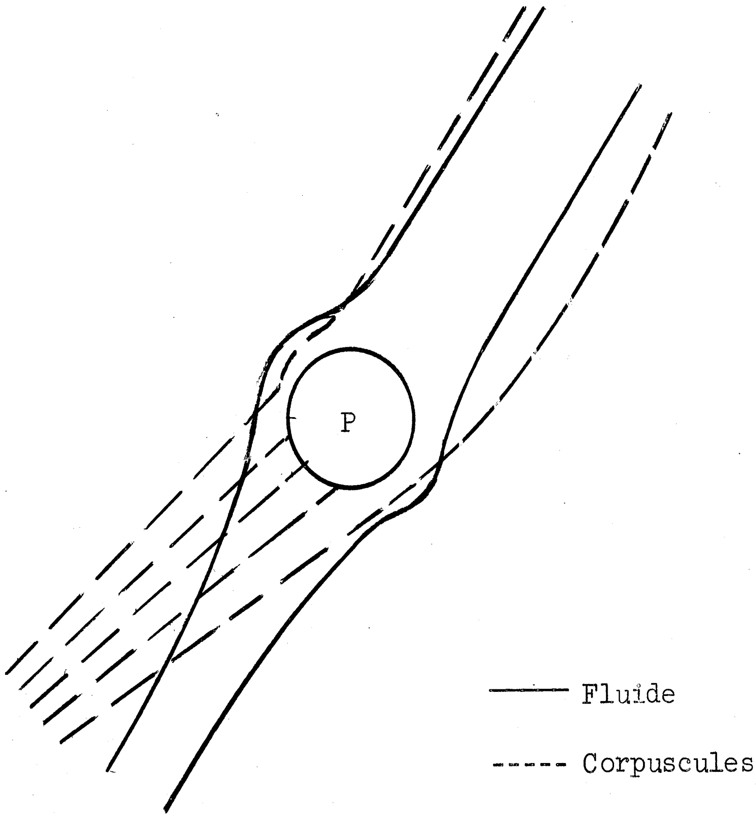

Fig. 2

2) Let us assume now that the particles are all spherical, but of different diameters. To each diameter there corresponds, at point P, a trajectory and thus a certain type of deposit on the cylinder. It is natural to assume that the resultant deposit is the superposition of the deposits with respect to each diameter. It follows that the shape of the gross deposit will

be influenced mainly by the deposit of particles, the diameter of which corresponds to the maximum of the distribution curve of the mass of all particles of the same diameter as a function of this diameter.

We note that, in the case of icing of an airplane, the most dangerous droplets of water are those which cause the largest deposits. This procedure leads directly to the determination of the trajectories of the most dangerous droplets.

II. An Application

We have applied the described method to the study of the tracing of the trajectories of the droplets of a mist in the neighborhood of an airplane windshield.

The model of this windshield, placed between two panels, constitutes a cylindrical obstacle the generators of which are perpendicular to the velocity at some distance.

We place, on one of the boards and perpendicular to it, numerous thin headless pins, thus covering with a grid the region where we want to find the trajectories of the spray-droplets (Fig. 3). The length of the pins increases in the downstream direction so that the deposit on the extremity of one pin is little affected by the wake caused by the preceding pins since the wind encounters pins of increasing heights.

We then subject the model to icing. For this purpose the model is installed in a wind tunnel that is cooled down below 0°C and in which the supercooled water spray circulates. The water droplets are iced in hitting the pins. When the deposit of ice on each pin is sufficient to permit the determination of its axis of symmetry, the experiment is stopped, the apparatus is taken apart, and a picture of the board is made (Fig. 4). On this photograph the directions of the deposits are determined; thus, in each point marked with a pin, we know the tangent to the trajectory of the droplets which pass over it (Fig. 5). By continuity it is then possible to trace approximately the net of trajectories (Fig. 6).

We have used the tracing of trajectories of spray-droplets to determine the shape of vanes which, placed at the base of the windshield, intercept the trajectories of the droplets below the tangential trajectory shown in the broken line in Fig. 6.

The unprotected winshield and the one equipped with vanes have then been subjected to icings of the same intensity. Figures 7 and 8 enable us to compare the results obtained and at the same time show the effectiveness of the protecting vanes.

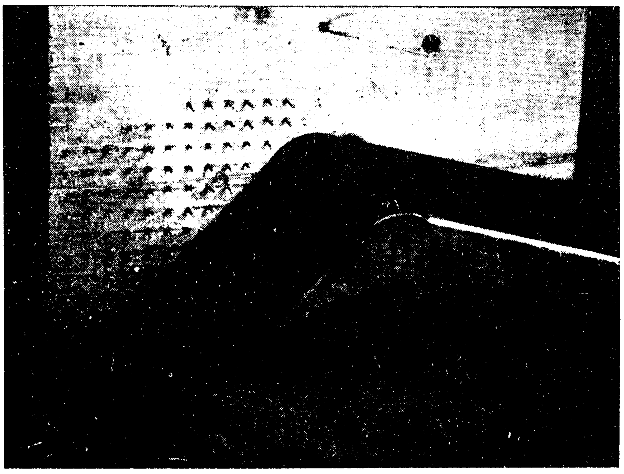

Fig. 3

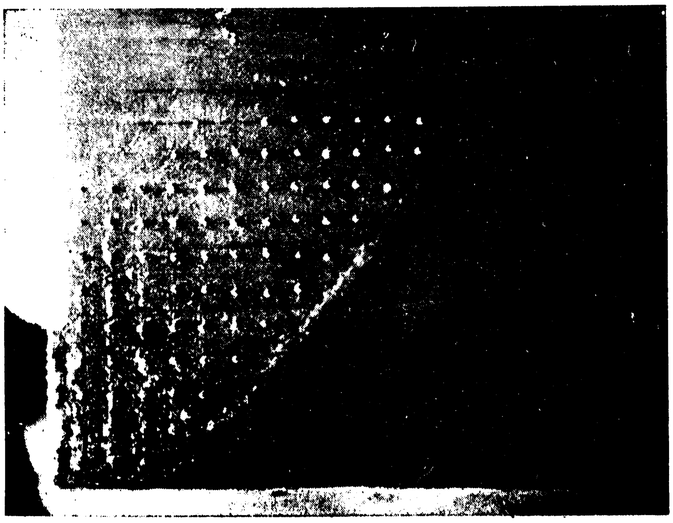

Fig. 4

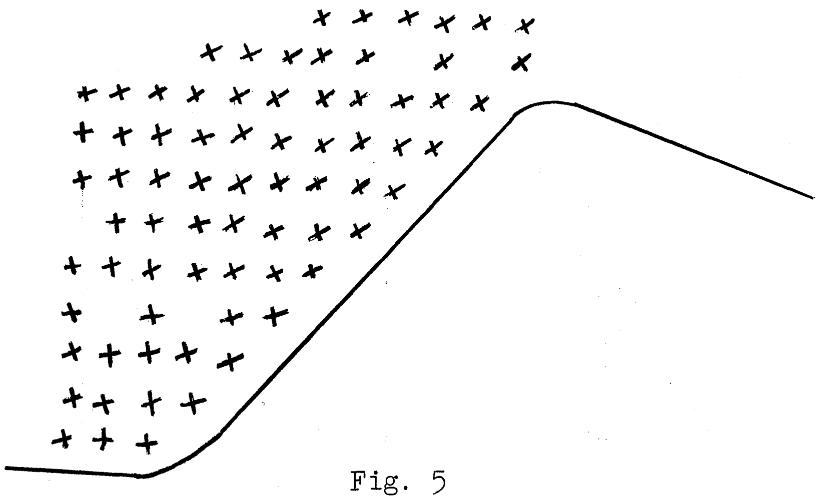

Fig. 5

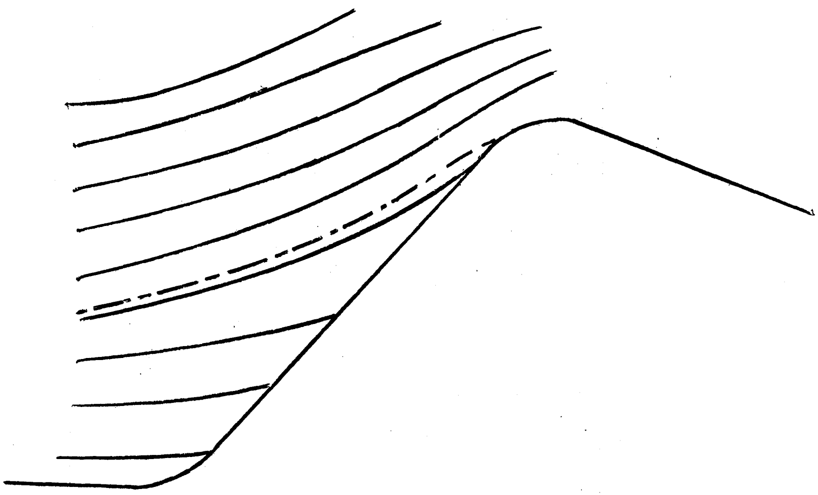

Fig. 6

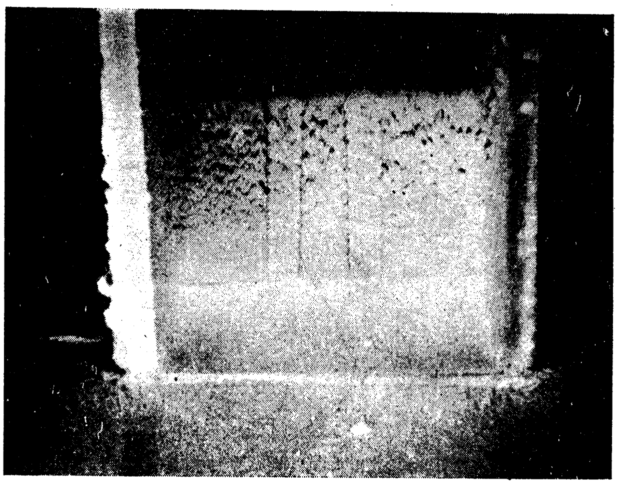

Fig. 7

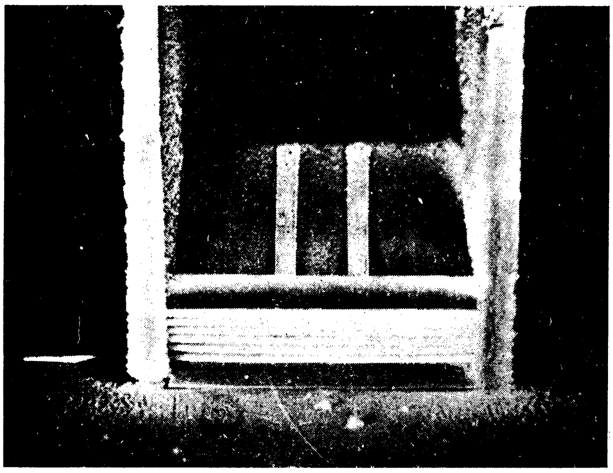

Fig. 8

The method of determination of trajectories of spray-droplets applies generally to any obstacle in a plane flow or in a flow with axial symmetry. It is adequate to place a plate mounted with pins in the vicinity of the obstacles in the icing windstream. As we have just seen in the above case, the knowledge of these trajectories is very useful in the design of devices for protection against ice or other particles.