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PROGRESS REPORT

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J. P. O'Neill, Project Supervisor

Hydrodynamics Laboratory
California Institute of Technology
Pasadena, California

THE HYDRODYNAMICS OF UNDERWATER JET PROPULSION

The work in progress on the present contract includes investigation of the action of condensable jets, of the planing of missile afterbodies, and of the drag of head shapes that produce cavities around a missile. Consultation with missile development personnel has indicated considerable interest in the condensable jet experiments. The logical continuation, however, requires a program in the High-Speed Water Tunnel and such a program was tentatively scheduled for November, 1953, pending necessary additional contract arrangements. Meanwhile, further work has been accomplished on the theoretical and experimental investigation of missile head shapes and it is expected that this work, as well as that on missile afterbodies, can be effectively continued on a reduced schedule.

Open-cavity Flow about Sharp-edged Head Forms

The theoretical calculations of a stagnation cup flow in two dimensions at zero cavitation number have been completed and numerical results obtained for various ratios of the depth to diameter. The calculations show that the drag coefficient C_D is very nearly unity for any reasonably large cup depth and, as expected, there appears to be theoretical justification for the effect of cavitation number K being given by $C_D = 1.0(1 + K)$. If, on the other hand, the cup depth is small, the drag coefficient is smaller and in fact converges on the well known result $C_D = 0.88(1 + K)$ for zero depth.

Some additional drag measurements have been made. The excellent agreement with theory obtained for the 7/8 in. diameter cup as shown in the January-March report did not hold when the cup size was reduced to 1/2 in. diameter by 3/8 in. deep. The results were about 3% low even though the two-dimensional theory indicated that this depth-diameter ratio should have given a drag coefficient that is imperceptibly lower than $1.0(1 + K)$. Further analysis and experiment is required to determine whether this is a new measurement error or a scale effect that might account for the deviation of the slope of the plot of C_D vs K for the sharper cones from the slope given by the calculations of Plesset and Shaffer.

Projectile Heads with Curved Boundaries

In the operation of high velocity underwater projectiles, it is often found that open cavities are attached to curved boundaries that do not have a definite separation point. With the theoretical and experimental work on cups, disks, and cones as a background, the more complicated problems associated with the smooth boundaries are now being investigated.

Drag measurements and photographs of the region of separation have been made for spherical head shapes in open cavity flow. In contrast to the sharp-edged nose shapes, these heads having an indefinite separation point are subject to considerable viscous effects and possibly also to surface tension effects. In the preliminary investigation, Reynolds number was varied in addition to the usual variation of cavitation parameter.

One of the photographs showing the cavity separation from the spherical surface is shown in Fig. 1. Analysis of the phenomenon of separation from curved boundaries is continuing.

Fig. 1 - Open-cavity flow about a spherical projectile head.