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STATUS REPORT TO NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Apollo Water Impact

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Abstract

This report describes (a) the status of the cumputer program being developed to stimulate the impact of a right circular cylinder on a smooth water surface and (b) the experimental equipment and methods.

APOLLO WATER IMPACT

Experimental Work

This project was designed to determine experimentally the fluid reactions due to the impact of a rigid body. It is planned to determine the time history of the velocity distribution in the fluid and the pressure distribution on the impacting body and in the fluid by the use of high speed photography.

In developing the experimental technique, the aim is to utilize a two-dimensional verticle lattice of submerged solid or insoluable liquid particles with the same specific gravity as the fluid in which they were submerged. The particles would remain motionless in the water until acted on by the pressure wave from the impacting body. Then high speed photogrpphy would record the movement of the particles during impact. On the photographic record, streamlines will be traced by the particles. By the use of finite difference techniques, velocities and accelerations of the particles may be determined, and thus, pressure gradients may be found. By integration from a known pressure outside the influence of the impacted region, the pressure distribution within the region may be found.

The work, at present, is primarily concerned with refining the experimental technique, finding the best materials, and showing the method is workable. Initial tests have been conducted, the data analyzed, and the results are being used to better develop the experimental testing. The major problem to be encountered is accurately measuring the distance particles move between frames. The overall results of the project are highly positive.

A literature survey has been conducted which gathered reports on both theoretical and experimental methods of solution of the impact problem. Its main purpose was to find what experimental methods have been used to solve flow problems and to gather theoretical solutions with which to compare the results of experimental testing.

A four foot by four foot, 3/4 inch plexiglass tank with a depth of three and a half feet has been built for use in this project. Water was chosen as the fluid to impact into after some initial investigations of other liquids or altering the density of water by adding alcohol; however, the two do not mix well. Salt, in sufficient quantities, will raise the density of the water but also makes it murky.

In choosing the particles to use in the water, it was required that they have approximately the same specific gravity as water, be large enough to be photographed but small enough to behave as a water particle, and be of different colors so as to be distinguished from one another. Insoluable liquid particles broke under the action of the pressure wave and coated the tank. Attempts at using bubbles released from the bottom of the tank did not produce good results. A plastic particle was deemed best, and .385 inch polystyrene beads were used in the initial testing. Future testing will involve use of .375 inch and .25 inch high density polyethylene balls (specific gravity: .95).

Models thus far constructed are a seven inch plastic sphere and an eleven inch metal cylinder, two feet long. The majority of the testing to come will involve the cylinder impacting on its side, since the interest is in simulating the Apollo capsule.

A computer program has been written and checked out to evaluate data from drop experiments. A three point finite difference technique is used to evaluate velociites, accelerations, and pressure gradients of the particles in the water at each time frame. Data is analyzed using a Vanguard Film Analyzer owned by the Texas Transportation Institute.

Initial testing consisted of impacting the seven inch diameter sphere into water with two hundred .385 inch polystrene beads at approximately 20 fps. Filming was done by a team from NASA MSC using a Millican camera at four hundred frames per second. Conclusions drawn were:

(1) Smaller particles are needed in a more dense array in the impact area.

(2) A two-dimensional flow pattern must be produced. Data from the computer program was inconclusive because the sphere produced a three-dimensional flow pattern. The cylinder will give the desired pattern.

(3) Higher camera speeds are needed. The interest is in the time region from the moment of impact, t = 0, to t = .10 seconds, with the first .02 seconds the most vital. This would indicate required camera speeds approaching 1000 fps.

(4) The most pressing problem, as stated previously, is measuring the distance traveled by the particles between frames. A particle moving 30 fps will move about two and a half centimeters between frames at 400 frames per second.

The Vanguard Film Analyzer does not appear to have the accuracy required to measure the above mentioned displacements. Other means of measurement are necessary.

Future work on this project consists of another series of drop tests as soon as the particle dispensing system and drop system can be improved. A search is still being carried on for a better particle to use. Some possibilities are to use a "mush" of polystyrene or styrofoam granules to determine flow properties and plastic particles to determine pressure distribution. As soon as the experimental technique has been shown to yield good results, the method may be applied to other impacting bodies.

Theoretical Work

Results discussed in the previous progress report dated October 1969 did not allow for the discontinuity in velocity which exist on impact at the body-water interface and the effect of the air trapped between the body and the water. The computer program is being modified to allow for both these factors which are interdependant. As the body approaches the water surface the air ahead of it is compressed and the pressure builds up. This in turn starts to deflect the water surface and pushes the water down. Hence the relative velocity between the body and the water decreases until the relative velocity becomes zero and thus the discontinuity no longer exists and contact is assumed. The pressures before impact become very high and compressibility of the air must be included. Program development continues.