ENGINEERING

Effect of Polymer Additives on Boundary Layer Separation and Drag of Submerged Bodies

THIS communication describes a simple experiment which demonstrates that in some circumstances the use of polymer additives can increase drag owing to a change in the position of boundary layer separation which results in a change of wake size and thus form drag.

Recently, there has been considerable interest in the turbulence damping properties of certain long chain polymers when dissolved in water. It has been found that very small traces in solution can reduce turbulent friction by a very significant amount and drag reductions of more than 50 per cent are possible by the addition of just a few parts per million by weight of the polymer[1,2].

The large drag reduction produced by these visco-elastic polymer solutions is being considered for practical application in many fields. The effect has already been made use of in certain aspects of oil field technology and experiments are at present being carried out with the view of using it in marine technology[3] in the testing of ship models[4].

If we consider flow around a submerged surface, flow separation is likely in a region of adverse pressure gradient and the point of separation will depend on whether the boundary layer is laminar or turbulent—the separation point being nearer to the leading edge with a laminar boundary layer.

For this experiment a concrete sphere 7·75 in. in diameter was dropped into a 'Perspex' sided tank which contained either water or dilute poly (ethylene oxide) solution ('Polyox' *W.S.R.* 301), and the wake pattern was recorded by high speed ciné photography. A comparison of the drag coefficients has also been obtained by analysis of the film record.

The sphere was first made hydrodynamically smooth by careful rubbing down and painting and was then dropped into water from a suitable height so that the average Reynolds number was just below the critical value ($\rho Vd/\mu < 2 \times 10^5$). The wake is shown in Fig. 1, which indicates a laminar boundary layer with characteristic early separation.

The front of the sphere was then roughened by glueing on a patch of sand, and the sphere was again dropped into the water from the same height. Fig. 2 shows the wake pattern from this test which exhibits a much later separation point caused by the turbulent boundary layer. The drag coefficient was about half the value found from the previous test. These results are well known and are described in any standard fluid dynamics text[5].

For the third test the roughened sphere was dropped into a solution of 'Polyox' (60 parts per million by weight). Fig. 3 shows that the polymer additive has suppressed turbulence in the boundary layer and caused the separation point to move forward again with a resulting increase in form drag. The drag coefficient was about the same as for the first test.

It is therefore seen from this rather basic experiment that although polymer addition can significantly reduce skin friction, the effect can in certain circumstances be more than offset by an increase in form drag caused by a change in the separation point and wake size.

The effect was anticipated by Gadd[6] and could lead to difficulties with tests of ship models in polymer solution.

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Particle Migration in Cone-plate Viscometry of Suspensions

VISCOMETERS with a cone and plate configuration are often used for viscosity measurements on non-Newtonian fluids, and for suspensions provided that a particle cone truncated near its open end is used. In the latter case it has been assumed that radial motion of particles occurs too slowly to affect the accuracy of the measurements involved.

Recently, however, while investigating the behaviour of suspensions of spherical particles in certain non-Newtonian fluids using a cone and plate viscometer, rapid radial migration of the suspended solids was observed at low cone speeds (up to 40 r.p.m. corresponding to a shear rate of 184 sec^{-1}). Significant migration was observed after shearing for only 5 min whereas centrifugal

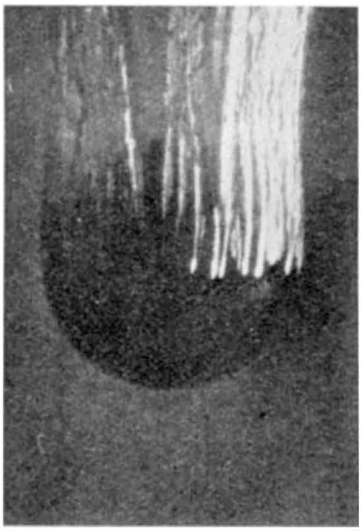

Fig. 1.

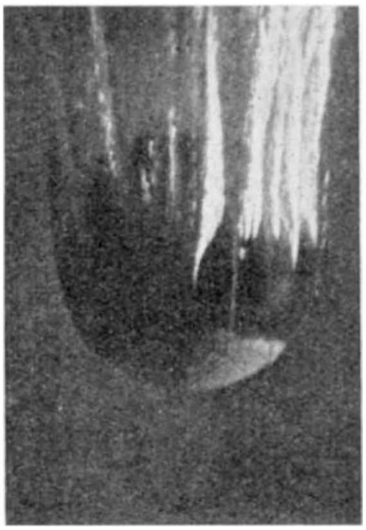

Fig. 2.

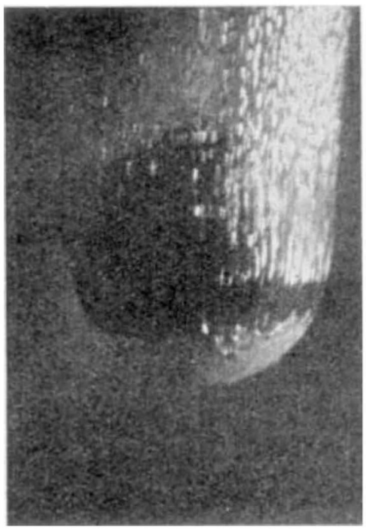

Fig. 3.