BULL. AUSTRAL. MATH. SOC. 76D30
VOL. 12 (1975), 315-316.

Abstracts of Australasian PhD theses

Low-Reynolds-number flows: The application of fundamental singularities

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There are relatively few exact solutions of the partial differential equations associated with a continuum-mechanics description of a newtonian fluid. However low-Reynolds-number approximations are available for some problems. In many cases these approximate solutions consist of expressions which are singular at various points in the region of consideration. Two such important singularities are point sources of mass and point sources of momentum which may be either steady or time dependent. These fundamental singularities are analysed in this thesis since their regions of dominant influence are where the action occurs.

A mass source, two-dimensional or three-dimensional, situated on a wall is investigated first. The flow field solution is made uniformly valid by taking account of the finite width of the gap through which the fluid flows. Applications of the theory are given for both porous media flow and a possible method of low-Reynolds-number propulsion; while extensions of the theory are possible for the case of an unsteady source on a wall (de Mestre and Guiney [2]).

Steady point sources of momentum (stokeslets or point forces) are next considered. These are continuously distributed over a finite line segment to yield drag coefficients for slender circular cylinders falling near a single plane wall or between two parallel plane walls. This extends the result of Batchelor [1] and enables slender-body theory to be tested

Received 22 July 1974. Thesis submitted to the University of New South Wales, Faculty of Military Studies, July 1974. Degree approved, December 1974. Supervisor: Professor J.C. Burns.

experimentally. Reasonably consistent results are obtained for two series of experiments but a third series produces a significant discrepancy.

Finally an unsteady point source of momentum is considered. When it is given a strength which oscillates it becomes a basic singularity in oscillatory viscous flows, particularly with regard to the diffusion of vorticity from an oscillating body. An approach similar to that advocated by Riley [3] is pursued to obtain detailed results about acoustic streaming plus a uniformly valid description of the flow field caused by an oscillating cylinder in a steady uniform stream.

References

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[3] N. Riley, "Oscillatory viscous flows. Review and extension", *J. Inst. Math. Appl.* 3 (1967), 419-434.