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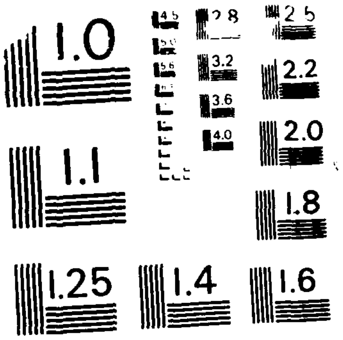

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Reports research accomplished on:

Vortex shedding from a cylinder; Development of a floating element gauge for measuring shear stress; Axisymmetric towed hydrophone housing; and Experimental study of a thick axisymmetric turbulent boundary layer.

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BODIES IN UNSTEADY FLOW

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30 December 1987

Final Report

Prepared for

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Introduction

This is the final technical report of work done under ONR contract N00014-78-C-0696, MIT OSP 87144 and 96570. The work was begun on September 1, 1978 and completed on August 31, 1985. The work accomplished is summarized in four task areas below. Publications, technical reports and theses completed under this task are indexed at the end of this report. They are referenced by author, name and date in the body of the report.

Vortex Shedding from a Cylinder

A cylindrical floating element force transducer was developed to measure the unsteady forces associated with vortex shedding from a cylinder in a cross flow. The transducer contained an integral accelerometor which served two purposes. Its output was used to compensate for the acceleration sensitivity of the floating element portion of the transducer. It also permitted simultaneous measurement of local force and cylinder motion.

This tranducer was used in the MIT Acoustics and Vibration Laboratory's Low Noise Low Turbulence Wind Tunnel to measure fluctuating forces on a cylinder undergoing in cross flow free vibration, Moeller and Leehey [1982-A].

This type of force transducer was next used in the MIT Marine Hydrodynamics Laboratory's Closed Circuit Water Tunnel to determine the forces associated with forced oscillation of cylinders in cross flow. The domain in frequency-displacement space for which the vortex shedding locks into the frequency of cylinder oscillation was determined, Moeller and Leehey [1982-B]. Extensions of this work form the basis of the doctoral dissertation of Moeller [1982]. Measurements were reported by Moeller and Leehey [1984] for both free and forced oscillations of cylinders in cross flow in the water tunnel. The hysteretic behavior of free oscillation of the cylinders was determined at the edges of lock-in boundaries in amplitude and frequency. By forming the product of force and acceleration, power flow from the fluid to the cylinder was measured. A particularly significant observation was made that there was negative power flow in a certain range for forced oscillation, i.e. that power actually flowed from the cylinder to the fluid. This is considered particularly significant as such a phenomenon could not occur under free oscillation.

Development of a Floating Element Gauge for Measuring Shear Stress

A floating element gauge was developed for measuring shear stress at the wall under a turbulent boundary layer (TBL). This gauge was developed and tested in the Acoustics and Vibration Laboratory's Wind Tunnel, Petri [1984]. The transducer was designed along the principles developed for the cylindrical force gauge discussed above. The active face of the floating element was a square 4mm on a side. The transducer was found to determine the mean wall shear stress accurately in comparison with other methods of shear stress measurement. The measurement of unsteady wall shear stress however, was severely limited by a mechanical resonance in the transducer at 63 Hz. The most significant feature of this development was the extrememly small size of the floating element and the fact that the transducer was successfully used as a passive device. It was unneccessary to employ an active force balance principle to keep the floating element centered.

Axisymmetric Towed Hydrophone Housing

A long towed sonar array has difficulty making starboard/port target discrimination without the ship turning to a new course, a time consuming maneuver. It was considered that it might be feasible to augment the towed array with a pair or more of individual towed bodies each containing a single hydrophone. These could be streamed from the downhaul cable of the towed array, to starboard and port of the main array, and thus provide the desired discrimination. We developed a towed axisymmetric body housing a hydrophone provided by the Naval Underwater Systems Center, New London. We tested this body in the MIT Close Circuit Water Tunnel. The body was first made stable by providing a torsional spring in the towing connection. Self-noise measurements of the body were carried out for towing speeds up to 16 knots over the frequency range from 0.1 - 1.0 kHz. An air chamber was necessary within the body to provide for neutral buoyancy. This chamber permitted discrimination against the background noise of the facility. The pressure-release nature of the chamber however weakened the response of the hydrophone to target signals.

A systems analysis was carried out which showed that a modest change in the hydrophone air-chamber location, involving some lengthening of the test body, would provide desired port/starboard signal discrimination for an adequate detection range at operational speeds, Kim [1984].

Experimental Study of a Thick Axisymmetric Turbulent Boundary Layer (TBL)

A long towed sonar array creates its own boundary layer which becomes many times thicker than the diameter of the array itself. In order to study the properties of this unusual boundary layer, very long cylinders were stretched the length of Low Turbulence, Low Noise Wind Tunnel and fluctuating velocity components of the boundary layer were measured using hot wires. The first task was to determine a universal law for the mean velocity profile in the flow about the cylinder. It is then possible to predict the boundary layer growth and drag characteristics of the cylinder. We found that a mixed scaling was necessary using the viscous radial coordinate from the cylinder wall and the ratio of local boundary layer thickness to the radius of the cylinder. A logarithmic region was determined. However this logarithmic region relates to a wake-like behavior of the boundary layer rather than to the overlap region associated with the convention planar boundary layer, Lueptow, Leehey,and Stellinger [1985]. This logarithmic law evolved from the assumption of a constant eddy viscosity typical of a wake. The validity of this assumption was justified by measurements of the eddy viscosity, Lupetow and Leehey [1986]. Extensive measurements of velocity dynamics were then carried out, Lueptow and Haritonides [1987]. Variable interval time averaging (VITA) and uv-quadrant techniques were used to detect the burst cycle near the wall. Flow visualization was used to observe the cross-flow eddy structures in the boundary layer of the cylinder moving through a tank of quiescent water. One of the most significant features of this investigation was the observation that large scale structures moved from the outer region on one side of the cylinder to the outer region of the opposite side of the cylinder. The behavior is, of course, impossible in a planar boundary layer. It is considered to be perhaps the most significant feature distinguishing the large axisymmetric boundary layer from the planar boundary layer.

Concluding Remark

Three Ph. D. dissertations and one M.Sc. thesis were completed in the course of this task.

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