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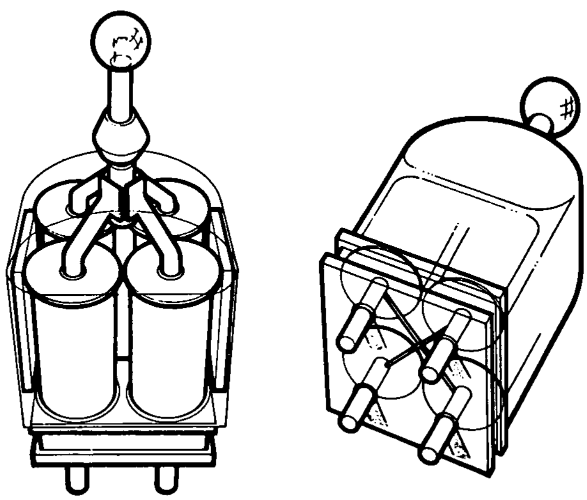
Probe for Measuring Turbulent Real-Time Shear-Stress Waves

The problem:

To measure the spectrum, magnitude, and time-average value of the turbulent shear stress in a flow of gas.



The solution:

Use a small, hollow sphere suspended in the flow to measure drag fluctuations in two 90°-directions as a function of time.

How it's done:

The probe design is based on the principle that the drag coefficient of a sphere and the cross-flow over a cylinder are constant in flows where Reynolds numbers range between 2×10^3 and 2×10^5; therefore the drag force in the sphere is directly proportional to the dynamic head ($\frac{1}{2} \rho v^2$) of the flow. As shown in the diagrams, the probe is constructed by mounting a small sphere, of a diameter suitable for the proper Reynolds number range for the flow condition, on the tip of a stereo phonograph-cartridge stylus so that the sphere can move with complete freedom in the plane of the measurements. The movements give signals resolved in two channels which represent 90° separation of the movements of any orthogonal coordinate system. A stereo cartridge has a frequency response from 8 to 33,000 Hz, and channel separation of 30 db is common.

The signals are proportional to the rate change of the drag, and thus are also separated from the constant time-averaging components. They can be amplified, integrated with time, and multiplied to give instantaneous correlated drag forces, $\rho u'v'$ drag-fluctuations, etc., independent of temperature, radiation, and chemical-reaction effects.

Total weight of the sensing elements is less than 1/10 gram; drag-force measurements up to 10 grams about the small (3.8-mm diameter) sphere is possible in a jet exhaust stream. The theoretical frequency response can be estimated as the time delay for the sphere to transmit inertial forces through a small aluminum support tube to the magnetic sensing element inside the cartridge. Since the length of the support tube is 12.7 mm and the speed of sound of aluminum is 4543 m/sec, the time delay is 2.5×10^{-6} second. Turbulent fluctuation usually has a frequency below 20,000 Hz, so the risetime of the sensing elements is more than ample to detect the signals.

Note:

Requests for further information may be directed to:

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(continued overleaf)

Patent status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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