The phenomenon of periodic vortex shedding by plain circular cylinders and the associated force fluctuations on the cylinder and the radiated dipole noise centered at the vortex shedding frequency is well known. In order to suppress the wake-induced vibrations of tall chimneys, helical strakes have been successfully used.[4] A concentric perforated shroud enclosing a plain cylinder has also been found to be effective in suppressing the wake-induced vibrations.[5]

In order to understand the mechanism of suppression of the periodic vortices of a circular cylinder, Naumann et al.[6] have conducted a series of experiments. On a plain cylinder, periodic vortex shedding was found to be accompanied by a straight separation line. However, they observed that a crisscross arrangement of wires along the span of a cylinder always inhibited discrete vortex shedding and the separation line was found to be irregular. The suppression of the periodic vortex shedding was therefore attributed to the introduction of strong three-dimensional disturbances into the wake through the crisscross arrangement of wires forcing a nonlinear separation line on the cylinder.

In the present experimental arrangement, the circulation controlled cylinders are functioning as a set of stator blades by producing lift varying along the span of each cylinder. The spanwise variation of circulation on each cylinder was achieved by staggered slots as in Fig. 2. This arrangement of slots, when blown, forces the flow to separate at different angles, i.e., the separation line will be irregular. Therefore, the observed attenuation of the discrete vortex shedding noise with slot blowing is most probably due to the same mechanism of introducing strong three-dimensional disturbances into the wake, breaking up the coherent shedding of discrete vortices.

Conclusions

The present investigation demonstrates clearly that the vortex shedding and the associated noise of circular cylinders behind a ducted rotor can be attenuated by producing differential circulation along the span of the cylinders. The attenuation is probably accompanied by an irregular separation line on the axis of each cylinder. The slotted circular cylinders used as a set of stator blades in an axial flow compressor will be almost free from the discrete vortex shedding noise.

Acknowledgment

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30016

Wind-Tunnel Balance Based on Piezoelectric Quartz Force Transducers

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Introduction

THE test section of the subsonic wind tunnel at the ETH in Zurich has a cross section of 3×2.1 m, and the maximum dynamic pressure is 2300 N/m^2. It was decided to replace the mechanical compensation balances where the models were attached with wires by a new balance based on Kistler force transducers. The requirements were as follows: one balance for all kind of measurements, measurement of all six components, accuracy better than 1%, interference-free measurement of the components (cross talk below 0.1%), easy calibration at any time, and nonsteady measurements.

Drag forces to be measured down to 0.2 N. The general requirements called for a universally applicable single balance, simple mounting procedures of the models, and a direct readout data aquisition system. The whole arrangement is described in detail in Ref. 2.

Layout

Concept of Force Measurement

The requirements led to the location of the balance below the floor of the test section.

Disadvantages with the measurement of the pitch moment when a model is tested in the center of the section have to be taken into account by separate measurement at the model itself. The requirement of interference-free and nonsteady measurements led to a high stiffness of the design including force transducers, which could not be satisfied by a strain-gage balance. Furthermore, the range of a strain-gage balance would have been too small for all planned measurements.

Therefore, it was decided to use piezoelectric quartz force transducers, which offer a very wide measuring range and a high rigidity, yielding practically interference-free resolution of the components.

Arrangement and Selection of Transducers

In order to resolve six components (three forces and three moments), at least six force transducers must be arranged spatially (Fig. 1). Disposed in the x-y plane are three transducers (S_1,S_2,W) of the type Kistler 9203 (± 500 N), measuring the drag (X), lateral force (Y), and yawing moment (M_z). Arranged vertically are the transducers (A_1,A_2,A_3) of the type Kistler 9321, with the greater measuring range $\pm 10{,}000$ N. These elements measure the lift (Z) and the longitudinal and rolling moments (M_y and M_x).

The great difference of maximum loads between the two types of transducers is explained by the fact that only the 9203-type offers the high sensitivity of 48 pC/N (which is needed in the x-y plane), and the high Z loads ask for the more rigid 9321 with a sensitivity of 4 pC/N.

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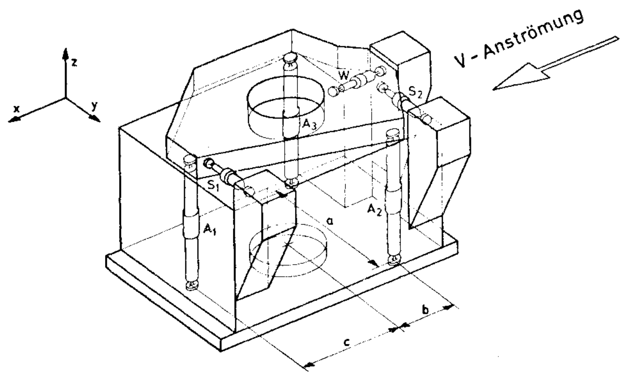

Fig. 1 Basic arrangement of the six force transducers where $a = 0.4$ m, $b = 0.15$ m, and $c = 0.25$ m.

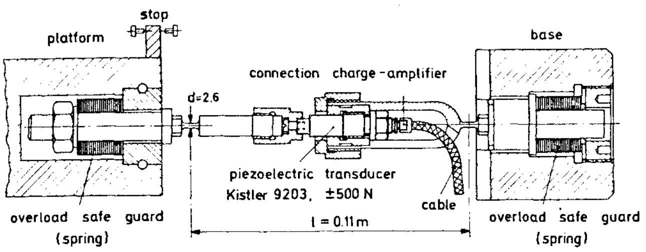

Fig. 2 Longitudinal section of the elements W, S_1, and S_2 arranged in the x-y plane.

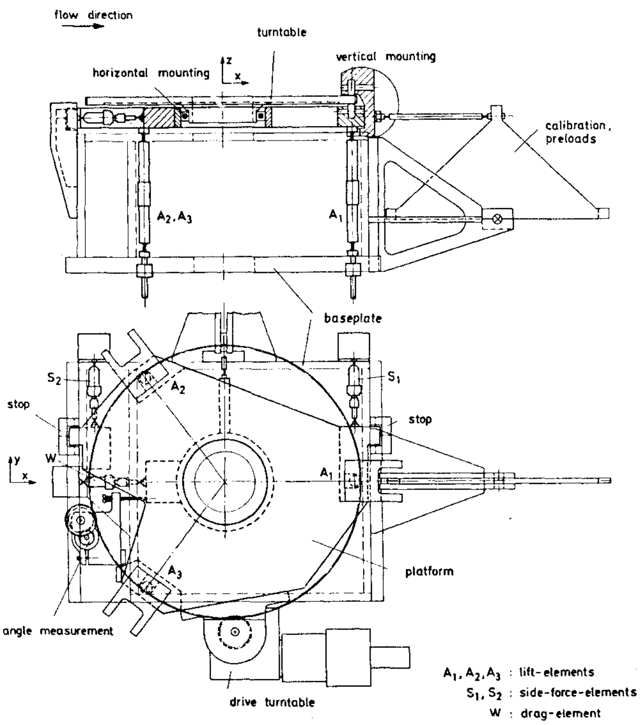

Fig. 3 View of the balance with turntable and calibration equipment.

Additional Equipment

The capabilities of the balance were extended by the following equipment:

1) Overload safeguards for the transducer elements W, S_1, and S_2 in the x-y plane (preloaded spring washers, Fig. 2). These prevent damage due to severe overloads (including nonsteady ones).

2) Permanent calibration devices for all force directions, allowing calibration for checking purposes at every measurement. The same devices in x and y directions allow to

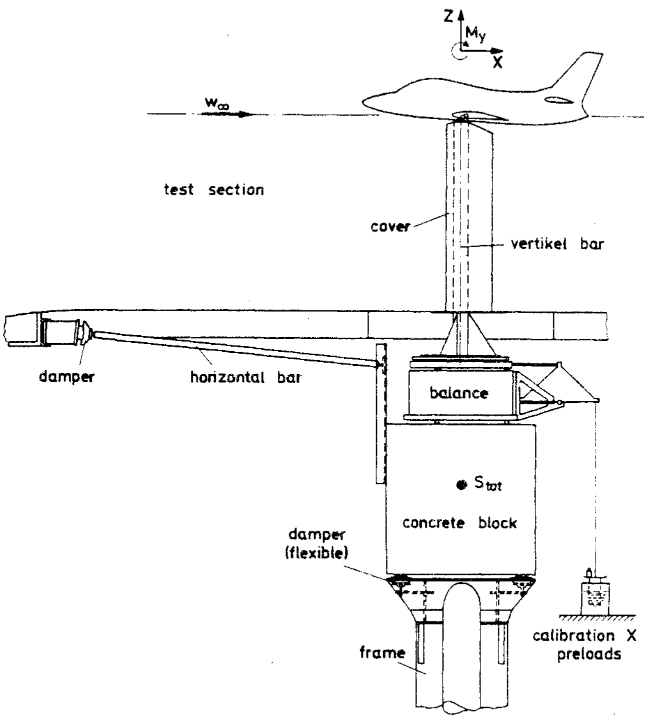

Fig. 4 Arrangement of the balance below the wind-tunnel test section.

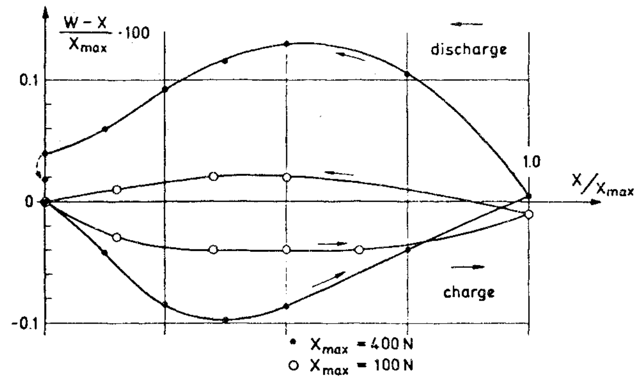

Fig. 5 Linearity of the element W. X = applied load; W = indicated load.

apply a preload on the W—respectively, S_1 and S_2—elements, thus doubling their measuring range.

3) Turntable for rotating the model about its z axis. The angles can be preselected and adjusted automatically (Fig. 3).

4) Electronic data acquisition, which calculates the forces and moments from the measured transducer values. It includes analog-elements (additions, multiplications, etc.), filters and mean-value calculators (eliminating oscillations in static measurements), digital panelmeters, and signal exits (permitting direct plotting of the measurements).

5) The support of the balance consists of a concrete block which isolates, in combination with shock absorbers, from external vibrations (Fig. 4). The balance with block and frame can be moved rearwards to give access to the space below the test section for other measurements.

Test of Balance

Behavior with Static Loads

Most important for static measurements are the various drift errors of the piezoelectric system. Preliminary tests, above all with the type 9203 element, confirmed that the total drift of the piezo-measuring system lies within the stipulated

Table 1 Range required for the tests

	Component	X, N	Y, N	Z, N	M_x, Nm	M_y, Nm	M_z, Nm
Range required	Model in center of test section	+1000	±200	+2000	±200	+1200	±100
	Half-model	+1000	±2000	–	±1000	+500	±20
	Drag measurement	+1000	–	–	–	+500	–
	Actual range of the balance	2×500[a]	2×1000[a]	30000			

[a] See the section "Additional Equipment."

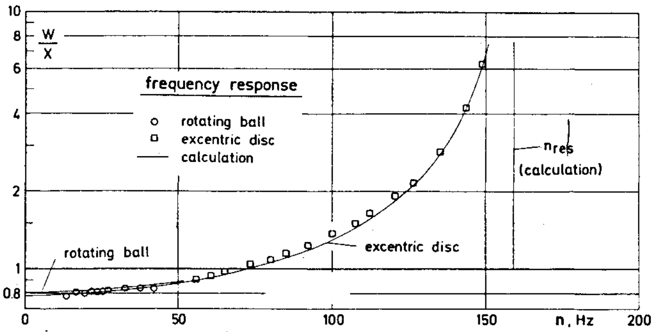

Fig. 6 Frequency response of the measuring platform in x-direction, balance hanging on ropes. X = applied load; W = indicated load.

tolerances where, during a typical measuring time of 5 min and for typical loads (e.g., $X = 10$ N), no corrections have to be made (errors $<0.5\%$ of X). Temperature variations raised no problems, as the elements are protected against air currents and are connected to a large mass which results in small temperature changes. For very accurate measurements, the drift (the rate of which remains practically constant during the measuring period) can be determined after the measurement and taken into account by correction of the error linear with time. So far, this has never proved necessary with the 9203 elements and, for the vertical transducers, only at low forces.

The linearity of the transducers, including charge amplifier, has been measured in a special program. In most cases, linearity of the elements shown in Fig. 2 remains within the boundary of 0.1% (see Fig. 5). The interferences were measured on a special turntable offering a precision of ± 0.001 deg. Calculation of the interferences predicted errors in the order of 0.01/0.05%. The tests therefore were merely checking the precision of the workmanship. If the balance is loaded strictly in one axis, the transducers not involved in the load measurement are showing signals in any case below 0.05% of the test load. The errors can be neglected in all cases. Experience showed an overall accuracy of the balance down to 10% of the required load (see Table 1) of ±0.3% of the load applied. With the analog data acquisition system, the corresponding figure is ±0.8%. Relatively high loads, however, offer an accuracy in the order of ±0.15%.

Behavior with Dynamic Loads

The dynamic response has been calculated for two conditions: 1) balance hanging on elastic nylon ropes (external forces can be neglected), turntable removed, no model; 2) balance mounted on the concrete block.

Figure 6 shows the frequency response of the balance in X-direction. The sinusoidal loads are generated by a compressed air-driven eccentric disk or steel ball. The balance shows a very low logarithmic decrement of $\bar{\delta} = 0.0178$ at 160 Hz.

The frequency response of the balance mounted on the block shows a 10% lower resonance frequency. The frequency response usually has to be measured separately for each dynamic configuration in order to detect resonances with the model and its support. This enables the measured loads to be corrected to the real aerodynamic loads up to frequencies of 100 Hz for drag and considerably higher for lift.

Conclusions

The concept of a floor-mounted six-component balance with piezoelectric force transducers has been confirmed. It offers good accuracy in a wide range of static loads, permits dynamic measurements, and enables interference-free readout of the components.

Acknowledgment

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C80-064

Use of an Apex Drogue as a Means for Controlling Parachute Inflation

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Introduction

THE aerodynamic recovery of payloads from high speeds and high dynamic pressures usually involves the application of parachutes. It is well known that these parachutes are stressed to withstand the forces that are imposed during the relatively short, parachute inflation sequence. Immediately after the inflation, the loads imposed upon the system reduce by one or two orders of magnitude when compared to the loads during the inflation stage.

From an aeroelastic viewpoint, the mechanics of the inflation sequence are not well understood. There is generally much uncertainty in calculating the unsteady pressures and stresses in the parachute structure during this critical inflation sequence.

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