VIBRATION RESPONSE TO WIND OF TWO IN-LINE CIRCULAR CYLINDERS FOR VARIOUS WIND APPROACH ANGLES AND SPEEDS.

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Introduction

Reference 1. contains a comprehensive review of the available literature on the fluctuating response of cylinders in small groups in traverse fluid flow. Many of the studies on two, tandem, flexible circular cylinders apply to values of reduced velocity V_R in the range 1 to 10, spacings up to about 5D and in-line test conditions. There are relatively few studies for $V_R > 10$, spacings > 5D and wind approach angles (incidence α) of 10^o to 20^o. The present paper contains some experimental data for these last conditions.

Design of the Experiments

In that much of the existing data applies to V_R values close to 5 when vortex shedding responses could be expected to predominate it was decided to investigate values of $V_R > 10$ when wake buffeting effects might be more significant. Since wake flutter requires coupling between in-line and cross-flow modes (with each mode being stable in isolation) this was precluded by only allowing cross-flow vibrations. Wake galloping may occur but this is only likely at larger spacings (> 10D).

It is known that dynamic response to vortex shedding and to other flow excited phenomena decreases as the non-dimensional mass-damping parameter k ($=2m\delta/\rho D^2$) increases (Ref. 2) so ideally k should be a variable. This was intended but in the event a constant, high value ($\simeq 30$) was used. Spacings up to 14D and incidence angles of 10^o and 20^o were catered for in the design of the rig.

Experimental Set-up

The tests were carried out in the L.U.T. open jet type wind tunnel at speeds in the range 6 - 16 m/sec.

The test cylinders were made from extruded perspex with dimensions of outside diameter -40mm, wall thickness -3 mm, length -680mm as seen on Fig. 1. The models were effectively rigid and the flexure of the strain gauged leaf spring occurred in the cross-flow direction only. Each cylinder was calibrated to give net transverse load at the mid-point of the cylinder and tip transverse deflection for the range of strain gauge outputs measured.

A standard method was used to measure the logarithmic decrement of each cylinder from a decaying oscillation in still air with it hung vertically from its rigid supporting framework above the tunnel working section. With the two cylinders mounted in their correct relative positions the wind speed was increased in five steps as shown below:

CASE	Vm/sec	fHz	V_R
A	6.3	32	11
B	9.5	49	17
C	11.6	60	20
D	13.6	70	24
E	15.5	81	28

Data Recording and Analysis

A four channel Bruel and Kjaer tape recorder was used to record the strain gauge outputs; an oscilloscope was used to monitor the signals and the Sanborn pen recorder was used to obtain immediate hard copies of the signals. The tape recorder voice channel was used to record the test conditions and to time each test run of 15 secs. after stable conditions had been reached. The tapes were replayed through a Nicolet Scientific Ubiquitous UA-500 Real Time Frequency Analyser (RTFA) coupled to a Farnwell X-Y Plotter and oscilloscope.

The frequency spectrum scan was selected in general from 0 - 100 H_z and set to cover 3 spectrum analyses for each 15 second run.

Discussion of the Results

The logarithmic decrement of the two cylinders was $\delta_u = 0.069$ and $\delta_d = 0.078$ and the corresponding values of k are $k_u = 29$ and $k_d = 33$. Such high values are considered sufficient to suppress the normal vortex shedding response of a single cylinder at $V_R \doteq 5$.

The natural frequencies were measured as $n_u = 14.4$ H_z and $n_d = 14.8$ H_z using the Sanborn pen recorder. These values are slightly higher (0.6 H_z) than were measured in the response spectra. This may be due to a slight error in the running speed of the Sanborn.

It is apparent that the lowest frequency f for the shedding of vortices from alternate sides of the cylinder at 32 H_z for Case A is almost 2¼ times the natural frequency ($\doteq$14 H_z) of the cylinders. Typical spectra for the responses of the two cylinders for specific cases are shown in Fig. 2. Similar spectra were derived for the downstream cylinder in all 14 of its test positions and for the upstream cylinder at the first four of these.

The characteristic frequencies of oscillation ranged from 13.6 to 14.2 H_z. Other peaks clearly seen in Fig. 2 correspond to integer multiples of the natural frequency. Three presumably spurious frequencies also appear frequently in most spectra viz 36.4, 50 and 68.6 H_z.

Fig. 3 shows the dimensionless amplitude Y/D for the upstream cylinder for four downstream cylinder positions, and for the downstream cylinder for all 14 positions. The vibration of the upstream cylinder is clearly influenced significantly by the position of the downstream cylinder. It is almost suppressed for position 1 and is over 4 times as great for positions 2 and 3. The vibration of the downstream cylinder is a maximum in position 3 and with due consideration of its value of k this maximum (Y/D = 0.44) indicates a very strong exciting force.

Conclusions

Comparison of the data obtained with that summarised in Ref. 1 confirms that at a given V_R the maximum response of both cylinders occurs with a spacing of 3 - 5 diameters and at incidence angles of between 10° - 20°. For spacings of less than 2D the responses may be lower than those for isolated cylinders. There is a dramatic increase in response as α increases from 0 to 10° at the higher values of V_R considered in this study.

References

1. ANON 1979. Engineering Sciences Data Unit. Item No.79025 Fluctuating response of circular cylinders in small groups in fluid flows - discussion and guide to data available.

2. R. D. BLEVINS, 1977. Van Nostrand Reinhold Co. Flow-Induced Vibrations.

Notation

D	Diameter
f	Strouhal Frequency
k	$2m\delta/\rho D^2$
m	mass per unit length
n	natural frequency
V	wind velocity
V_R	V/nD
Y	tip deflection
α	incidence
δ	log decrement
ρ	air density

suffices:

d	downstream
u	upstream

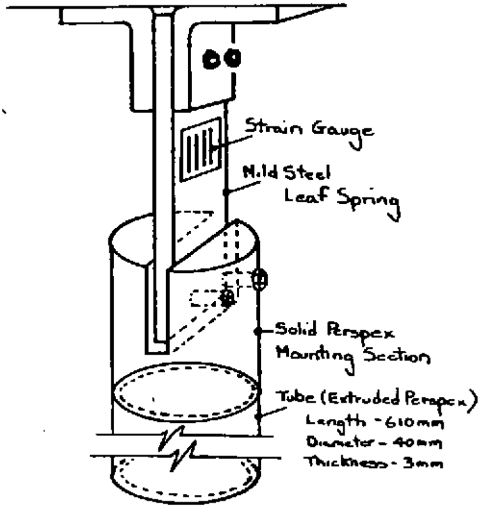

FIG. 1 Mounting of Cylinder

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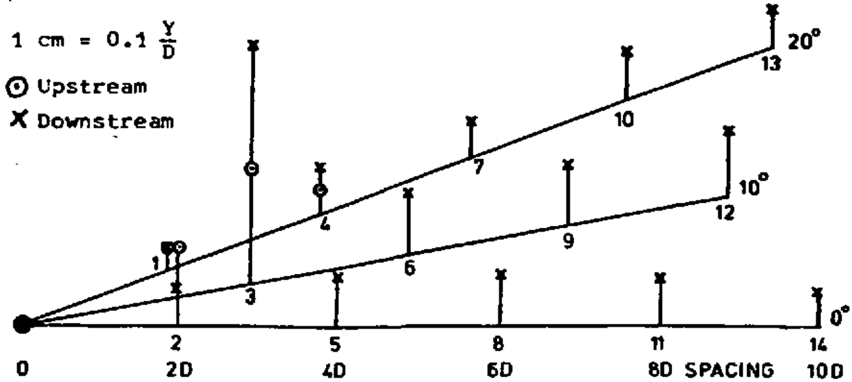

FIG. 3 Dimensionless Amplitudes for two cylinders at V_R = 28

FIG. 2 Typical Response Spectra - Position 3.