Direct Measurement of the Aerodynamic Admittance of Two-Dimensional Rectangular Cylinders in Smooth and Turbulent Flows.

R.Sankaran
Department of Civil & Systems Engineering
James Cook University of North Queensland
Townsville, Australia.

E.D.Jancauskas
Department of Mechanical Engineering
James Cook University of North Queensland
Townsville, Australia.

ummary

The aerodynamic admittance has been directly measured for a range of two-dimensional rectangular cylinders in smooth flow and grid generated turbulent flows. The present results are in good greement with those obtained using a discrete-frequency gust eneration technique. This agreement suggests a universal behaviour of [illegible]dynamic admittance.

Introduction

For the prediction of cross-wind forcing of a structure by the incident turbulence mechanism, *a priori* knowledge of the aerodynamic admittance is necessary. As stated by Jancauskas & Melbourne (1986), hereafter referred to as I, "aerodynamic dmittance is a frequency-based transfer function which relates the elocity fluctuations in a turbulent wind to the transverse (cross-wind) force fluctuations experienced by a certain structure subjected to that wind." While aerodynamic admittance can relate to either long-wind or cross-wind velocity fluctuations, only the latter case is onsidered in this paper.

There is a scarcity of detailed measurements of aerodynamic admittance primarily due to: (i) the complexity associated with its irect measurement and (ii) the uncertainty regarding the contribution rom other sources (e.g. wake excitation) to transverse force. Direct measurement of aerodynamic admittance was first reported by Kawashima & Fujimoto (1971) and subsequent studies were conducted by Konishi, Shiraishi & Matsumoto (1975) and Shiraishi & Matsumoto (1977). However, due to inherent problems with their xperimental arrangements and quality of the data, no clear trend for the behaviour of aerodynamic admittance could be identified from these studies. More recently, a detailed investigation was reported by Jancauskas (1983) for a wide range of two-dimensional structures in [illegible]ty of turbulent flow environments. These measurements were onducted using discrete-frequency cross-wind velocity fluctuations (generated by controlled circulation airfoils) superimposed on various background flows. An empirical equation was proposed to estimate the aerodynamic admittance of two-dimensional rectangular ylinders in low turbulence flow.

The present work is part of an extensive study, the long term aim of which is to develop an empirical description of the joint acceptance function and produce a workable model of the complete incident turbulence excitation mechanism. As the first stage of this study, direct measurements of the aerodynamic admittance of two-dimensional rectangular cylinders in smooth flow and grid generated turbulent flows were made and the results are presented here.

Experimental Arrangement

All the measurements were carried out in the 45kW open circuit wind tunnel at James Cook University of North Queensland. The tunnel has a test section measuring 17.5 x 2.5 x 2 m with a maximum speed of about 20 m/s. Three models of different chord-to-thickness ratio (10:1, 6:1 and 4:1) were tested. All the models were of rectangular cross-section (800 x 300 mm) and mounted within endplates which spanned the entire height of the test section. All edges were sharp.

Each model was tested in five background turbulence levels. Except for smooth flow (longitudinal turbulence intensity, I_u=1.5%), the turbulence levels (5.5%, 8%, 12.5%, 16%) were generated using biplanar grids. The grid size, geometry and location upstream of the model varied depending upon the desired level of turbulence.

The transverse force on each model was measured using two rows of 20 chordwise taps, one on the top surface of the model and the other directly below it on the bottom surface. Each row of taps was pneumatically averaged before being connected to one of two Honeywell 163 PC pressure transducers. The outputs from the two transducers were subtracted in real time to give a signal representing the fluctuating transverse force on this chordwise slice of the model.

The cross-wind velocity was measured using a TSI Model 1241-20 X-configuration hot-film probe, operated by a TSI IFA 100 constant temperature anemometer. The output signal from the anemometer was passed through a TSI Model 1072 lineariser before sampling. All the data were sampled at 100 Hz by a Data Precision 6100 waveform analyser.

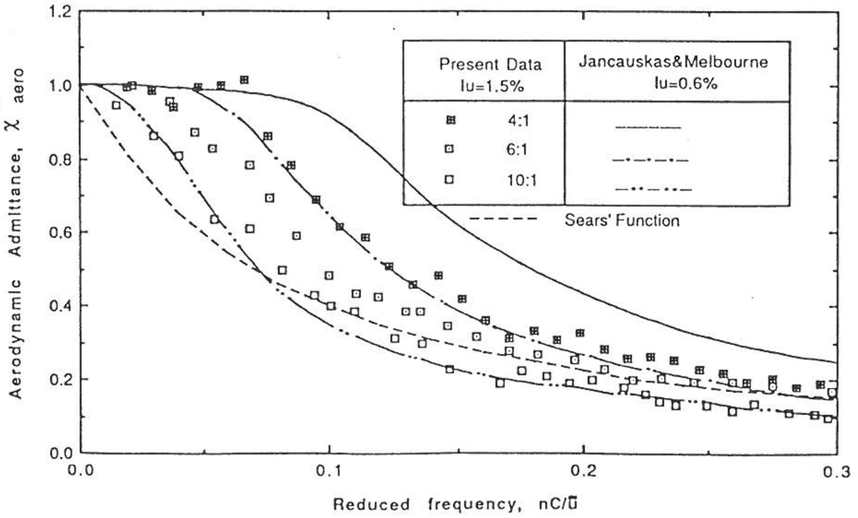

Fig. 1. Aerodynamic admittance of various two-dimensional rectangular cylinders in smooth flow. (Iu=1.5%)

Results and Discussion

The background theory, the assumptions involved and their justification will not be given here but can be found in Ref. 1 and are provided in the full paper. It suffices to say that, provided the transverse force is measured on a very thin chordwise slice of the model, it is possible to directly measure the aerodynamic admittance from the ratio of the power spectral densities of transverse force and cross-wind velocity fluctuations. To enable a direct comparison with theory, Sears' function (a theoretically derived expression for the aerodynamic admittance of a thin symmetrical aerofoil) is plotted as a dotted line in all the figures.

Figure 1 shows smooth flow (I_u = 1.5%) aerodynamic admittances for the 10:1 (300 x 30 mm), 6:1 (300 x 50 mm) and 4:1 (300 x 75 mm) rectangular sections. The data of I for the same rectangular sections are also plotted in Figure 1 as solid lines. Two general features emerge from this figure. Firstly, the "flattening" trend of the aerodynamic admittance as the reduced frequency approaches zero (referred to as a "quasi-steady plateau", in I) can be clearly seen for all three cases. Secondly, as the chord-to-thickness ratio increases, the extent of this flattening decreases. These trends are in good agreement with the data of I. However, a direct quantitative comparison between the present results and I cannot be made as there is a relatively large difference in the turbulence intensity between the two experiments.

The 5.5% turbulent flow aerodynamic admittances for the 10:1 (300 x 30 mm), 6:1 (300 x 50 mm) and 4:1 (300 x 75 mm) rectangular sections are shown in Figure 2. The data of Jancauskas (1983), for a turbulence intensity of 5%, is also plotted as solid lines. As can be seen, there is good agreement between these two sets of measurements. It is clear that, for I_u = 5.5%, Sears' function still significantly underestimates the aerodynamic admittance for the 4:1 section, but for the more slender 6:1 and 10:1 sections the prediction is good. Further measurements indicate that, for $I_u \approx 16\%$, Sears' function adequately predicts the aerodynamic admittance of the 4:1 rectangular section.

The good agreement between the present results and those of Jancauskas (1983), for various rectangular sections under a number of background turbulence configurations, suggests a universal behaviour of the aerodynamic admittance of two-dimensional rectangular cylinders.

Conclusions

1. The behaviour of aerodynamic admittance, directly measured in smooth flow and grid generated turbulent flow, is qualitatively similar to that measured previously by Jancauskas (1983) by superimposing discrete-frequency cross-wind velocity fluctuations on the background flow. This suggests a universal behaviour of the aerodynamic admittance of two-dimensional rectangular cylinders.

2. The present results confirm the suggestion that, for smooth flow, Sears' function can substantially underestimate the aerodynamic admittance of two-dimensional rectangular cylinders. The extent of this under estimation increases with decreasing chord-to-thickness ratio.
3. As the turbulence intensity of the flow increases, the aerodynamic admittance of two-dimensional rectangular sections converges to Sears' function.

Acknowledgements

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References

1. E.D. Jancauskas, The cross-wind excitation of bluff structures and the incident turbulence mechanism, Ph.D. Thesis, Monash University, 1983.
2. E.D. Jancauskas and W.H. Melbourne, The aerodynamic admittance of two-dimensional rectangular section cylinders in smooth flow, J. Wind Eng. & Ind.Aero., 23 (1986) 395-408.
3. S. Kawashima and N. Fujimoto, An investigation of the sinusoidal gust loads, Paper IV 39, Proc. 3rd Int. Conf. on Wind Effects on Buildings and Structures, Saikon Co., Tokyo, 1971.
4. I. Konishi, N. Shiraishi and M. Matsumoto, Aerodynamic response characteristics of bridge structures, Proc. 4th Int. Conf. on Wind Effects on Buildings and Structures, Cambridge University Press, London, 1975.
5. N. Shiraishi and M. Matsumoto, Aerodynamic response of bridge structures subjected to strong winds, Symp. on Engineering for Natural Hazards, Manilla, 1977.

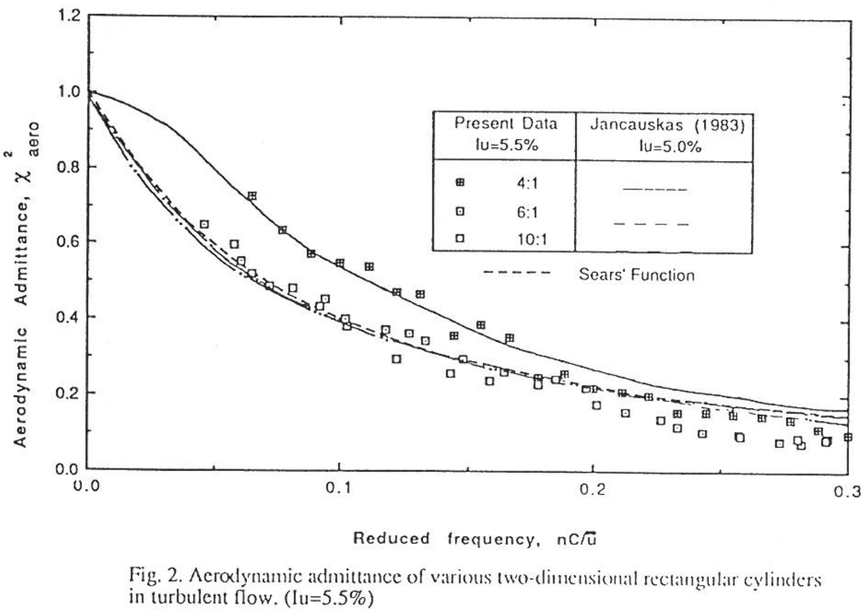

Fig. 2. Aerodynamic admittance of various two-dimensional rectangular cylinders in turbulent flow. (Iu=5.5%)