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Preface

The purpose of this report is to give the reader a basic understanding into “flow induced vibrations”. This phenomenon is a relatively new aspect to engineering. Much research has been done in this field but, it is not widely known knowledge and due to the shear expanse of the subject, not many engineers have a sound understanding of it unless it directly affect them in their field of expertise.

However, this branch of engineering covers a huge array of problems and applications in the world of engineering and is therefore a subject that perhaps should be focussed on in universities and education centres.

This report is not intended to be a technical paper due to the complex nature of flow-induced vibrations. Instead, it is intended to provide the reader with an overall picture of where and how flow induced vibrations can affect engineering projects. The report will then provide information of where the reader can obtain further reading material for the particular aspect of this subject that they are interested in.

Introduction

The term “flow induced vibrations” is the term used to describe an extremely expansive engineering phenomenon. It is applicable to almost every single structure that is exposed to either wind or water flow. Structures such as bridge columns in riverbeds, skyscrapers, multiple cooling towers in close proximity and airplanes are all subject to the effects of flow-induced vibration.
It is only in the last fifty years or so when engineers have been forced to understand how flow induced vibrations work, this is because as we have become more adventurous in our engineering this phenomenon has become more of a problem.
Many people attribute the awareness of this potential problem to the development of

aviation and in particular commercial aviation. The tragic fate of the early commercial planes forced engineers to investigate these fatal failures and swiftly understand why they occurred. Such tragedies include the first Versions of the Comet Airplane that suffered from having its fuselage ripped apart from pulsating pressures that attacked its windows. This caused stress concentrations on the corners of the square windows and eventually led to a tear. This is clear example of how the flow of fluid or in this case air can develop into an oscillating action and destroy structures.
Flow induced vibrations can cause disastrous structural failures and therefore need to be considered in any design process. It is a complicated and vast subject but to design a structure that will withstand these vibrations only a few things need to be considered. These include the shape of the structure, the flow velocity and the natural frequency of the structure. With these parameters, it is possible to calculate the critical flow speed required to cause failure of the structure. However, this is not always the case and usually the problem of flow induced vibrations need to be solved using models and wind tunnels to truly understand the way the structure will react to a given flow.

Types of flow induced vibration

There are various forms of flow-induced vibration. Some can benefit us and some can cause problems for our designs. These forms include:

- **Vortex induced vibrations.** This type requires a bluff structure to be an obstacle of the flow. As the flow hits the structure, it can create vortices in various places depending on the speed of the flow and the size of the structure. We generally use the Reynolds number to predict the behaviour of these vortices. Although modelling is a more accurate way. These vortices create pressure differences around the structure and generate oscillating forces, which need to be considered for any design. Examples of where this could have an effect include bridge columns, pipes in water that run alongside the flow and cooling towers. To predict the behaviour of this scenario we need to consider the Strouhal number which, is defined as:

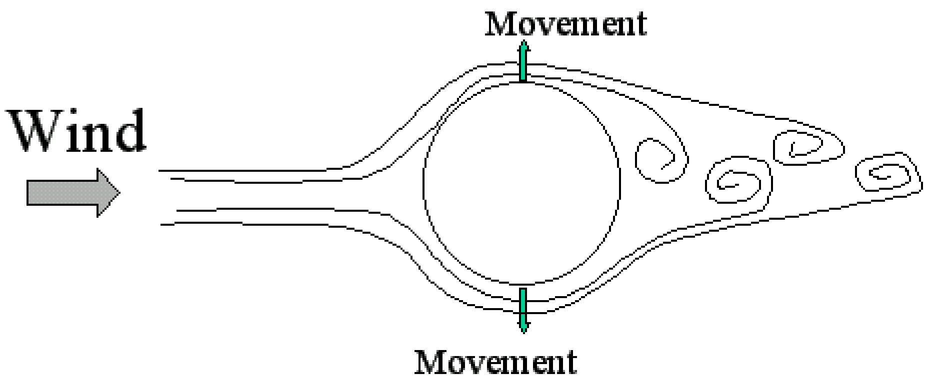
$$St = \frac{fs * D}{U}$$

Where:

St= strouhal number
Fs= predominate frequency of vortex shedding
D= cylinder width (diameter)
U= free stream velocity (1)

The Strouhal number helps to understand the behaviour of a structure in flow by assigning a value to its geometric shape and the Reynolds number relationship. The Strouhal number is a dimensionless number which, describes oscillating flow mechanisms

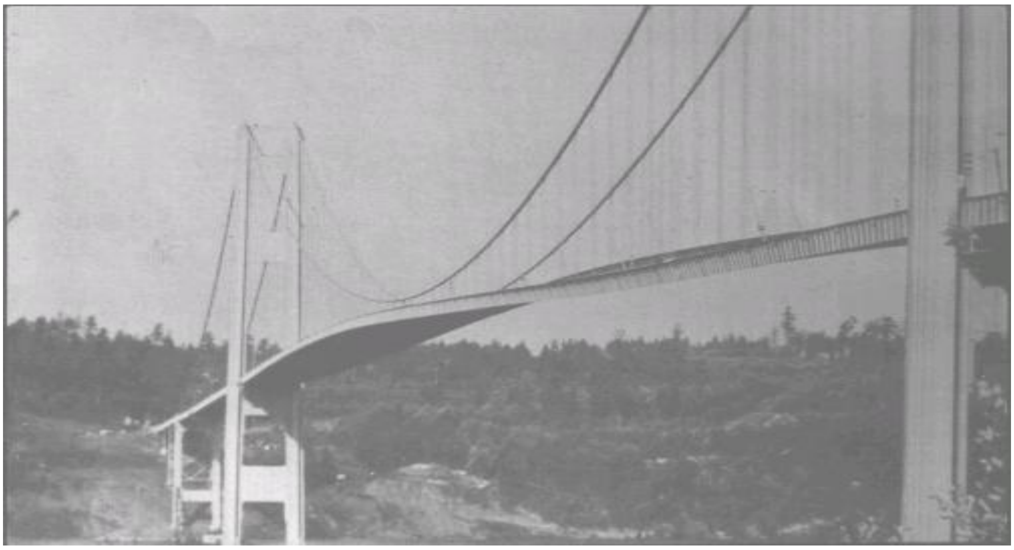
[Fig 1.0 shows possible flow scenario and the vortices it could create](2)



The diagram above shows that as the vortices are created, the structure experiences low pressure at certain places that excites movement. If this movement is, more than the structure can cope with then failure will occur.

- **Galloping vibrations and stall flutter.** This occurs when structures vibrate in a steady flow. Suspension bridges are a good example of this type of flow-induced vibration. "If the oscillating aerodynamic force tends to diminish the vibrations of the structure, then the structure is said to be aerodynamically stable. If the oscillating aerodynamic force tends to increase the vibrations of the structure, the structure is said to be aerodynamically unstable" (3). In other words, if the structure can absorb the extra vibrations caused by the flow then it is safe. If it cannot then it will increasingly vibrate until structural failure occurs. This was seen in the great Tacoma narrows bridge failure in America. In this instance, the bridge suffered from vertical displacement as well as torsion movement on a huge scale. Displacements of 25ft were recorded just before the collapse (4). This also happened in Brighton. The Brighton chain pier collapsed in the same way. Both of these bridges suffered this fate because of their initial design. The Tacoma narrows bridge required more torsion stability. This could have been solved by having a thicker road deck. Recent opinions state that the most likely cause was vortex shedding. Vortices are created by the bridges interruption of the wind, which causes aero elastic flutter. If the vortices have a natural frequency equalling the natural frequency of the bridge then this would cause the gyration effect. Because wind is not a constant velocity then this is not the same as resonant frequencies but this phenomenon does behave similarly.(5)

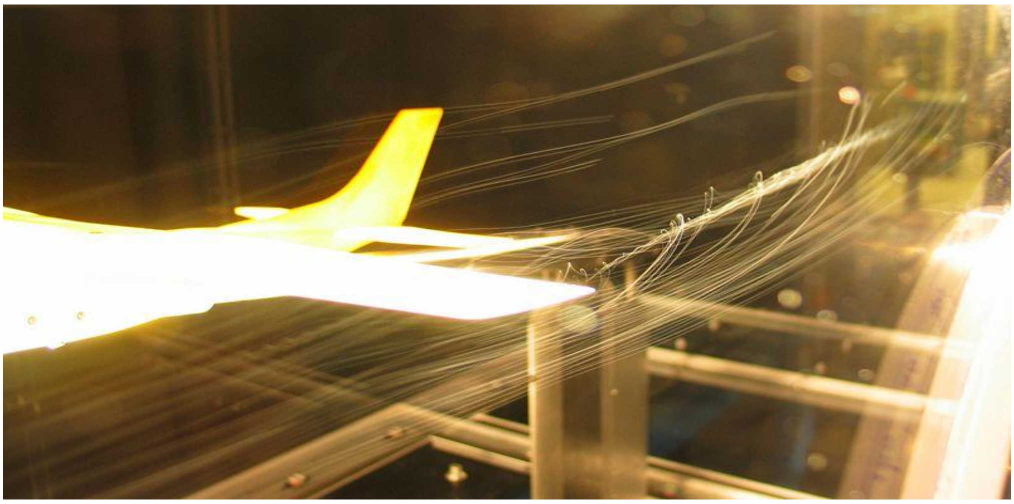
[Fig 1.1 shows the Tacoma Narrows Bridge before the collapse](6)



Modelling to predict behaviour

To predict structures behaviour requires a lot of complicated mathematics and principles and therefore it is usually decided to use a scale model to observe structures behaviour and its ability to withstand any potential problems caused by vortices or flow induced vibrations. This approach eliminates any fluctuations that may not be taken into account when calculating behaviour. Wind is not a constant function and its velocity and direction are always constantly changing. Because of this applying, a model is a favoured approach. The model can be placed at any angle of attack and be subject to extreme wind or flow velocities and generally gives a much more precise view of how the structure will act.

[Fig 1.2 shows an airplane in a wind tunnel] (7)



In the picture above, it can clearly be seen that the air is spiralling and trailing from the wing tip. This could create problems to the runway on take off by sucking up debris into the engine or affect the planes stability on landing.

Conclusions

This report is only a glimpse at the expansive subject of flow-induced vibrations. A subject that can be seen in many different forms but one that can have dramatic effects on our structures and designs. As we design our structures to be increasingly slender and try to use less materials it will be vital that we can apply the theories of flow-induced vibrations to ensure we can engineer to a fine degree but also remain safe. The use of wind tunnels is vital in this role as the calculations can become extremely complicated and may not take into account the varying complexities of the way our planet works and its constantly changing natural weather conditions. By creating a model, it is possible to take the design to its extreme natural limits and observe exactly how the structure behaves. This approach has been adopted on bridge design and some designers are adopting aerodynamics more and more in their designs in an attempt to reduce material usage and minimise bridge deck displacements.

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