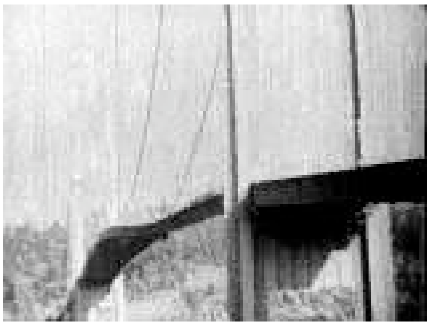
Introduction

The eBook you are reading has been written with a view to giving a good understanding of vibration, its causes and cures. In this introductory chapter, the importance of vibration will be discussed and some necessary background information given. Throughout the eBook there are links (in blue) to relevant pages/chapters.

Importance

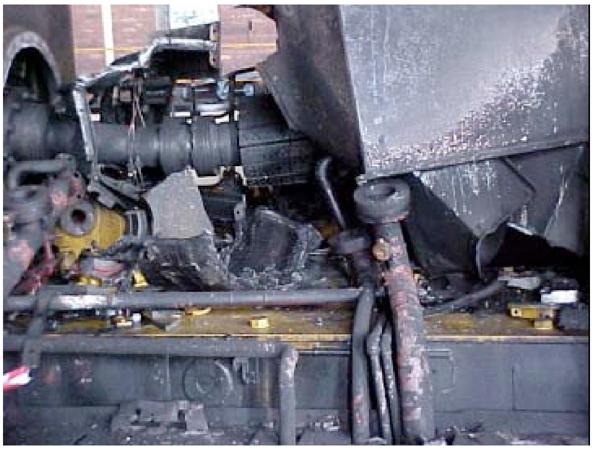
Vibration is often an important concern because of the harm that it does. There are relatively few examples of the use of vibration in a productive way. One of these would be in the use of vibratory conveyors where the vibration is used to transport materials. However, vibration is normally harmful because it causes noise, which may damage hearing, and also causes cyclic stress which may lead to fatigue. There are unfortunately many examples where this fatigue causes failure of components and indeed catastrophic failure of large engineering structures and machinery.

One of the most famous of such failures was that of the Tacoma bridge. In this case, as the wind in the area increased it caused severe vibration of the bridge, which in the end led to its failure. To see a movie of the vibration of that bridge click on the picture.



More common failures are found to occur in rotating machinery, where vibration causes components to come loose and fly off. The result of this is that the amplitude of the vibration increases and even more components may fail and fly off. The final result is a catastrophic failure of the complete machine.

The picture (above) and the two on the next page, are of a damaged 600 MW Turbine/ Generator. The incident occurred upon start-up. One of the Low Pressure Blades (2m in length) broke off while the turbine was turning at 3000 rpm. The blade crashed through the casing (10 cm solid steel), through the roof (20 meters higher up) and landed in the yard. The blade that broke took another 15 blades with it and the turbine went from 3000 rpm to standstill in a couple of seconds. The turbine/generator shaft broke clean at two different places. The ensuing fire was so hot that some of the roof's steel beams bent. The incident happened so quickly, that the vibration monitoring equipment did not even have a chance to pick anything up. Fortunately, this happened early in the morning when not many personnel were at work.

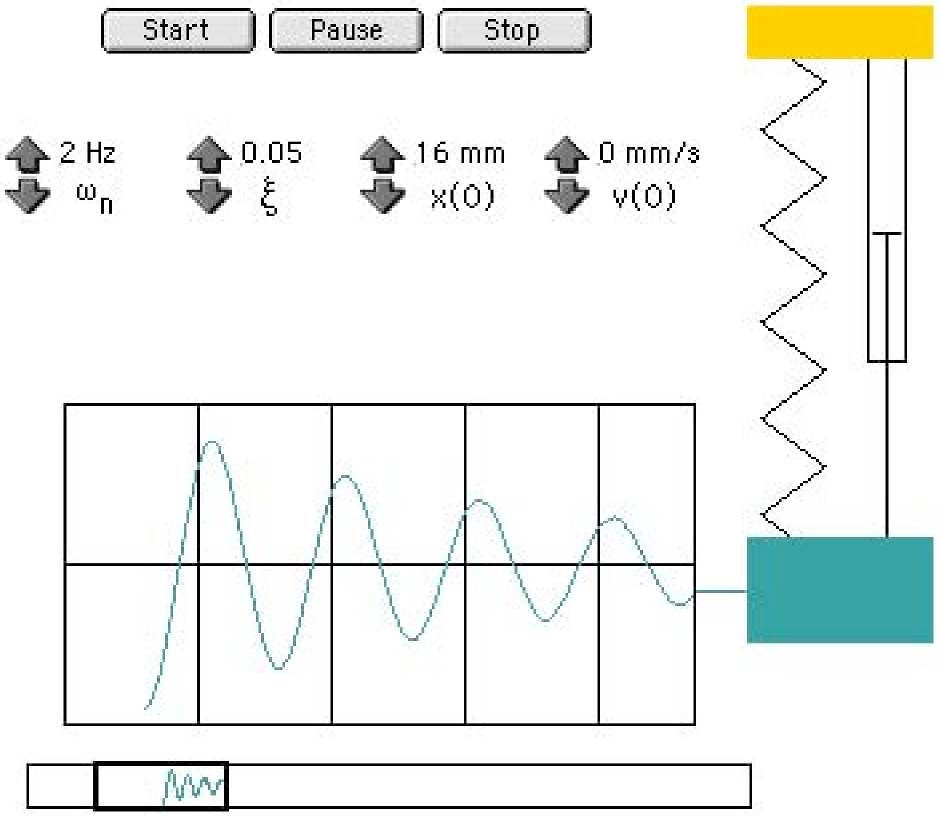


Another example of unwanted vibration is that called chatter. This is an unstable vibration that occurs in machining processes. The results are high levels of noise, an unacceptable surface finish and excessive wear on the cutting tool or grinding wheel. A separate eBook is being written on this topic. It is cross-referenced to this eBook because of the need to understand vibration theory in order to understand chatter. To hear a sample of the noise produced by chatter just click on the picture below.

Animation programs

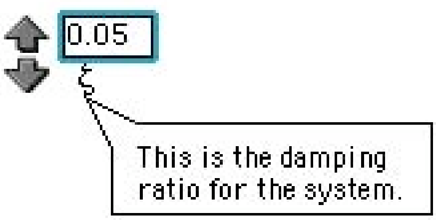
Throughout this eBook you will see the small icon shown below.

If you are connected to the WWW then when you select this icon you will be taken to an animation program. These programs are Java applets and have been written to allow you to see vibration occurring and to change variables to see the effects produced. Each of these programs has certain common features and these will be explained below. A typical program is used by way of illustration, and you may wish to run this later to check that you understand how to operate the programs. A compressed picture is shown below of what is seen when a program that illustrates damped vibration is selected.

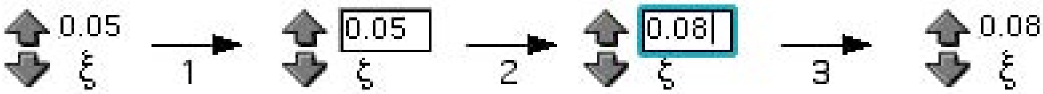


The 'Start', 'Pause' and 'Stop' buttons are self-explanatory. When the 'Start' button is selected the spring mass system vibrates and its motion is recorded on the trace that scrolls across the screen. At the same time, a thumbnail sketch of the trace is drawn and the cursor shows that part of the trace that is displayed on the scrolling trace. If the 'Pause' button is selected, the animation is stopped and it is possible to drag the cursor back to examine an earlier part of the trace. It is also possible to click on the scrolling trace and drag it. If the 'Start' button is selected the animation continues from the point where it was paused. The 'Stop' buttons finishes the animation and if the 'Start' button is then selected the motion begins from the start.

It is possible to change the values of the main parameters governing the animation. If the cursor is placed over one of these parameters an information box is opened to show what that parameter is. The up-and-down arrows allow the numerical value to be changed.



It is also possible to type in a required numerical value. If the mouse is clicked on the numerical value than a box appears around it. The numerical value may then be edited but note that the return key must be used to enter the new value. The sequence of actions is shown in the next diagram.

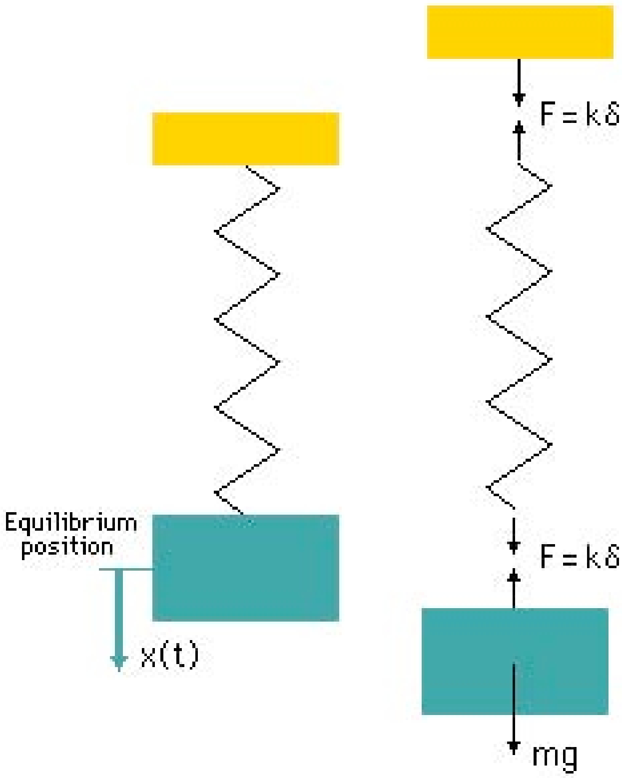


You may wish to run this program now by selecting the icon.

Equilibrium position

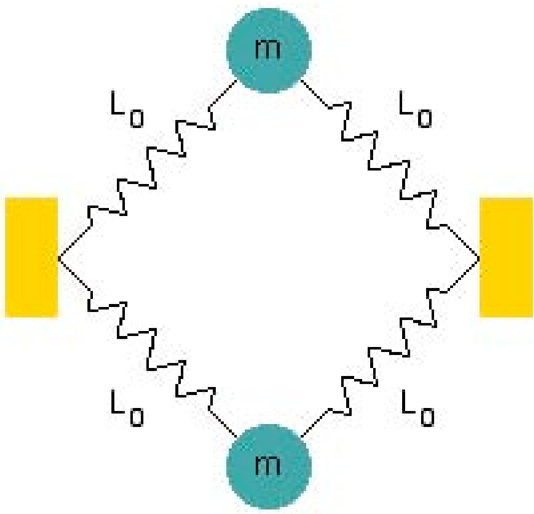
In the following chapters, vibration will be considered about the equilibrium position. The equilibrium position is the 'at rest' position for the system when there is no external disturbance. For example, consider the spring mass system shown with gravity acting downwards. In the equilibrium position the spring will be stretched by the amount (δ) necessary to provide an upward force equal to the gravitational force(mg) acting downwards.

Thus $mg = k\delta$



If the mass is displaced from this position then it will vibrate up and down. For the sample program discussed above this initial displacement is called X(0) and it is also possible to have an initial velocity.

In passing, it is important to note that some systems may have more than one equilibrium position. For small disturbances, they will then vibrate about the equilibrium position they are currently in. An example of a system with two equilibrium positions is shown below.



Contents

As shown the system is lying in a horizontal plane. If the system was in a vertical plane the two equilibrium positions would be moved downwards. You may wish to run an animation program written to illustrate this. This program includes the effects of gravity and sometimes there is only one equilibrium position.

<u>Maths</u>

There are many different approaches to the analysis of vibration and it rarely happens that two individuals will be familiar with the same notation never mind the same perspective. This situation has arisen mainly because there is no universal approach to vibration problems rather different problem areas are more amenable to solution using particular techniques.

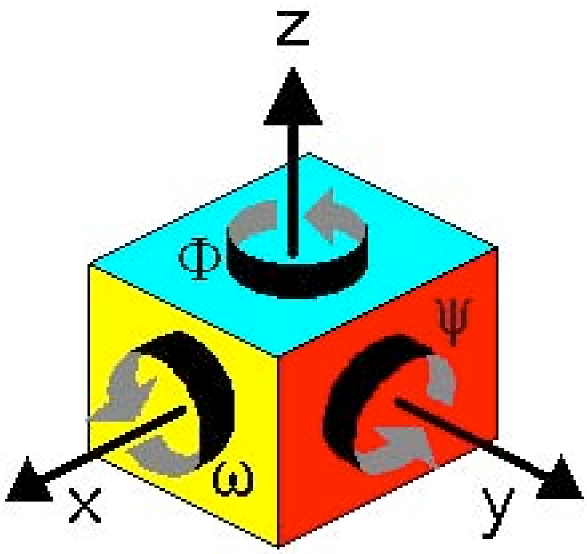
It has been said of vibration theory that a great deal of mathematics is required with little reward. As a result it is the aim in these notes to give a good understanding of a particular topic and to that end the most appropriate/simple mathematics will be used.

<u>Degrees of Freedom</u>

It is important to appreciate the concept of "degrees of freedom" as this will be a recurring theme in this eBook. The number of "degrees of freedom" that a vibrating system has will greatly affect how it vibrates. Chapter 1 deals with a 'One degree-of-freedom' system, Chapter 2 with 'Two degrees-of-freedom'. Chapter 5 covers 'Multi degree-of-freedom' systems and Chapter 6 continuous systems which have an infinite number of degrees-of-freedom.

A simple definition of "degrees of freedom" is - the number of coordinates that it takes to uniquely specify the position of a system.

Consider a rigid block that is free to move in 3 dimensional space. As shown in the diagram it may move without rotation in each of the three directions x, y and z. These are called the three degrees of translation. The block may also rotate about each of the axes, these are called the three degrees of rotation. Thus to uniquely define the position of the block in space we need to define six coordinates, three translation and three rotation. It should be noted that each of the



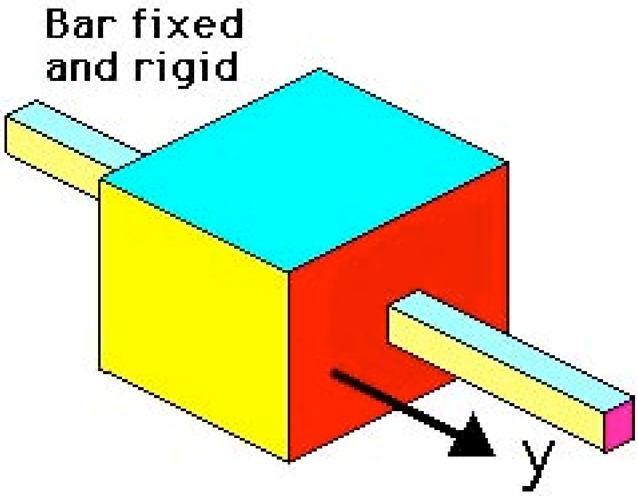
coordinates would be defined with respect to some fixed reference. The origin of the x, y and z axes would be a fixed position with respect to earth and the directions of the 3 axes would also be fixed. It is possible to reduce the number of degrees of freedom of such a rigid block by introducing constraints.

Contents

One degree of freedom.

In this first case we have constrained the block to have only one degree of freedom by,

Using a rigid rod which is fixed to earth (not shown for clarity) Thus the block may move along the rod in the y direction only. Also because the rod has a square section the block cannot rotate about the axis of the rod.

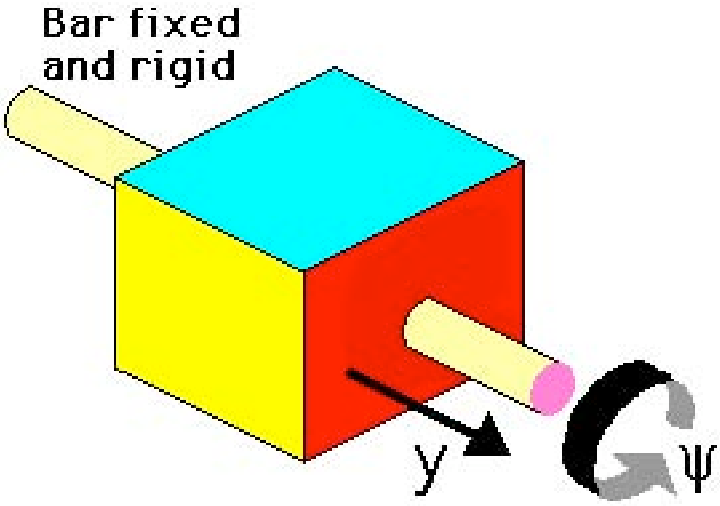


There is therefore only one degree of freedom. Knowing the position of the fixed and rigid rod we only need one coordinate - in this case the y coordinate - to uniquely specify the position of the block.

Two degrees of freedom.

In this second case we have allowed the block a second degree of freedom by giving the rigid rod a circular section. This means that the block may rotate about the axis of the rod.

To uniquely define the position of the block now requires that we specify the position along the rod (the y coordinate) and also the rotation of the block about the rod (the y coordinate). The block thus has two degrees of freedom.



Next chapter

Contents