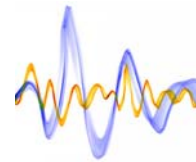


Vibrations and Acoustics

1. Vibrations : Introduction

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1



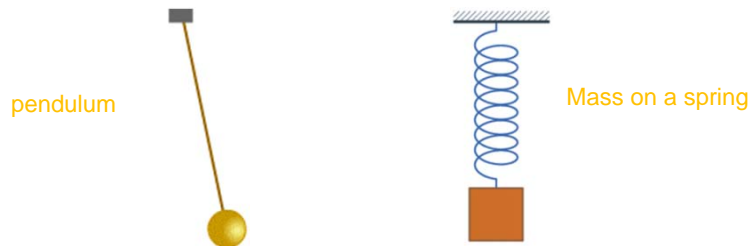
Definition and mechanism of vibrations



2

Vibrations : definition

Vibration refers to mechanical oscillations about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. (from wikipedia)



pendulum

Mass on a spring

3

Vibrations are all around us



Vibrator in cell phone



Tools



Rotating machines



Sound



Shaver



Tram

4

Mechanism of vibrations

Transfer between kinetic energy and potential energy

The diagram illustrates a mass-spring system in three stages of oscillation. A horizontal dashed line represents the equilibrium position. In the first stage, the mass 'm' is at its lowest point, the spring is stretched, and the energy is labeled 'PE max' and 'KE = 0'. In the second stage, the mass 'm' is at the equilibrium position, the spring is at its natural length, and the energy is labeled 'PE = 0' and 'KE max'. In the third stage, the mass 'm' is at its highest point, the spring is compressed, and the energy is labeled 'PE max' and 'KE = 0'. A legend at the bottom indicates 'KE Kinetic Energy' in green and 'PE Potential Energy' in red. Labels 'spring' and 'mass' with arrows point to the respective components. A small number '5' is in the bottom right corner.


Mechanism of vibrations

Transfer between kinetic energy and potential energy

The diagram illustrates a simple pendulum in three stages of oscillation. A horizontal dashed line represents the equilibrium position. In the first stage, the pendulum bob is at its highest point on the left, and the energy is labeled 'PE max' and 'KE = 0'. In the second stage, the bob is at the equilibrium position, and the energy is labeled 'PE = 0' and 'KE max'. In the third stage, the bob is at its highest point on the right, and the energy is labeled 'PE max' and 'KE = 0'. A legend at the bottom indicates 'KE Kinetic Energy' in green and 'PE Potential Energy' in red. A small number '6' is in the bottom right corner.


Sources of excitation

Free vibrations



Short initial excitation

Forced Vibrations

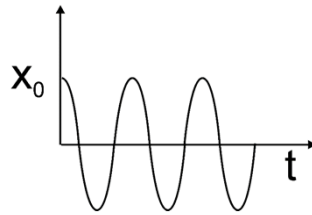
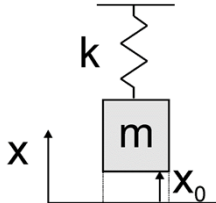


Continuous excitation

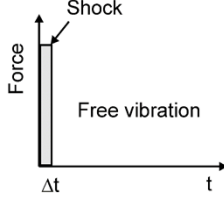

7

Free vibrations

Initial displacement



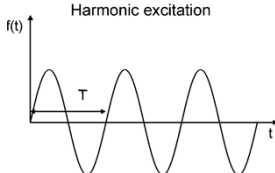
Shock



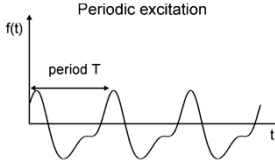
8

Forced vibrations : types of input forces

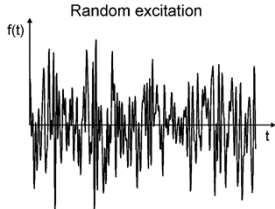
Harmonic force signal



Periodic force signal



Random force signal

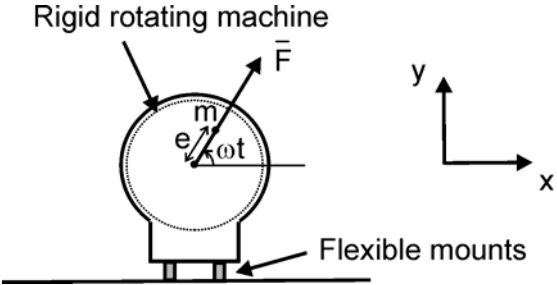


9

Harmonic excitation


The signal is in the form of a sine or/and cosine function

Rigid rotating machine



Flexible mounts

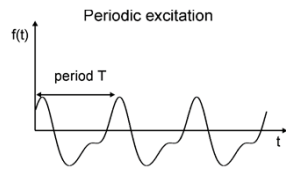
$$F_x = me\omega^2 \cos(\omega t)$$

$$F_y = me\omega^2 \sin(\omega t)$$


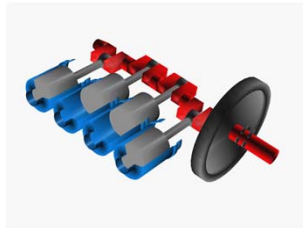
Mobile phone vibrator 10

Periodic excitation

The signal repeats itself



Power generator



11

Random excitation

No structure in the signal

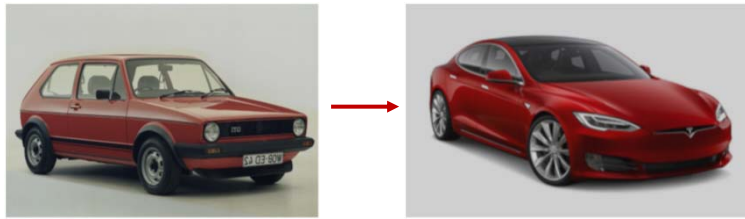
- Wind
- Tire on a road
- Waves
- Earthquakes



12

Vibrations in mechanical engineering structures

- Vibration sources are increasing
- Comfort demands are increasing
- Health issues are appearing
- In some cases, high precision technologies require very low vibration levels
- New designs make some structures more susceptible to vibrations



Reduction of weight for optimal use of material results in higher levels of vibrations

13

Vibrations in structures

A first example : the Millenium bridge in London



Tate modern museum of Art



14

Vibrations in structures

Opening June 10, 2000



15

Vibrations in structures

A second example : aeroelastic flutter in aircrafts



16

Vibrations in structures

A third (catastrophic) example: Takoma Narrows bridge, USA, 1940



17

Vibrations in civil engineering structures



18

Undesirable effects of vibrations

Fatigue

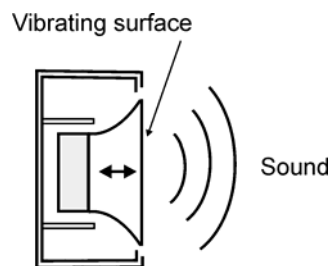
- Noise
- Comfort
- Health
- Performances
- ...
- (collapse)



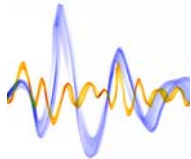
19

Positive effects of vibrations

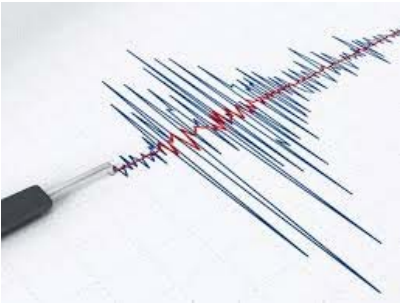
- High frequency vibrations to decrease friction in engines (formula 1)
- Electric tooth brush, sander
- Musical instrument
- Loudspeaker



20




Case studies



21

A test-case based learning of vibrations in mechanical engineering

Case study 1 : Payload comfort in space launchers



- Source of excitation
- Effects
- Design methodology
- Remedial measures

22

A test-case based learning of vibrations in mechanical engineering

Case study 2 : Passenger comfort in cars (suspension)



- Source of excitation
- Effects
- Design methodology
- Remedial measures

23

A test-case based learning of vibrations in mechanical engineering

Case study 3 : Passenger comfort in cars (engine vibration)



- Source of excitation
- Effects
- Design methodology
- Remedial measures

24

A test-case based learning of vibrations in mechanical engineering

Case study 4 : Aircraft tail vibration



- Source of excitation
- Effects
- Design methodology
- Remedial measures

25

A test-case based learning of vibrations in mechanical engineering

Case study 5 : Fatigue analysis of wind turbines



- Source of excitation
- Effects
- Design methodology
- Remedial measures

26