EXPERIMENT NO: P-1

MODELING OF DYNAMICAL SYSTEMS

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Introduction

This report introduces the mathematical phenomenon, practical applications and our practical of the vibration. Vibration is an oscillation of a rigid body from a position of equilibrium. The oscillation can be periodic (e.g. – motion of a pendulum) or random (e.g. – motion of a vehicle tire on a rutty road). There are mainly two kinds of vibration,

1. Free vibration

   When the system oscillates without the action of external forces. Examples of this type of vibration is hitting a tuning fork and letting it ring. On this case system vibrates at one or more its natural frequencies.

2. Forced vibration

   When the system oscillates under the excitation of external forces. The system is forced to vibrate at the excitation frequency of the external force. Vibration due to earthquake, rotation of unbalanced masses are some examples of forced vibrations.

In this report I explained about five applications of mechanical vibration. Such applications are mobile phones' vibration, vibratory plate compactor, vibrations of musical instruments, vibrating screens and uses of vibration in medical field. After that I described the basic vibration in an automobile travelling on a wavy road is due to forced vibrations, dumping, resonance and natural frequency. The nature of the practical session also proven using mathematics. Finally identified the practical issues and errors encountered during the practical and discuss the possible remedies to overcome the practical issues encountered.

In our practical session we fixed a mass with two springs and vibrate it using the frequency generator in a laboratory. First we have to find the resonance frequency by looking at the maximum amplitude. It helps to get our readings more accurately. Then we are increased frequency from zero and get the readings of amplitude of vibrating mass. We did the same procedure for different masses and found total stiffness of the two springs by using graphs. Calculation part is described on this report also.

Discussion

Engineering applications of mechanical vibrations

1. Mobile Phones

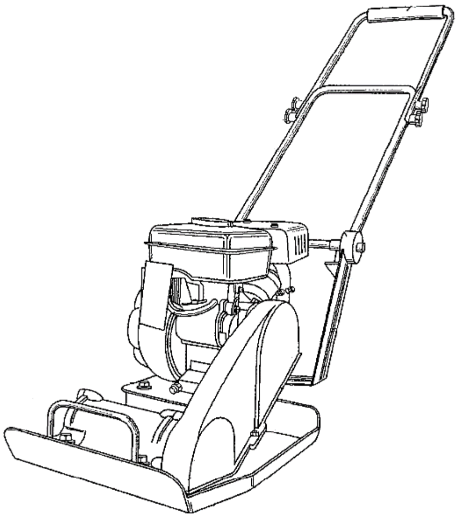
Mobile phone is an electronic device that uses vibration to indicate calls, messages and other notifications. Vibration mechanism of phone based on small motor. A mass of improper (offset or non-symmetric) weight distribution is attached to the motor's axis. When we get a call, electronic chip that inside the phone creates a signal to power on this motor. So when the motor rotates, the irregular weight causes the phone to vibrate. The mass at the left in the picture beside, is the off-balanced weight and the cylindrical part contains the motor.

Motor that causes vibration in phones

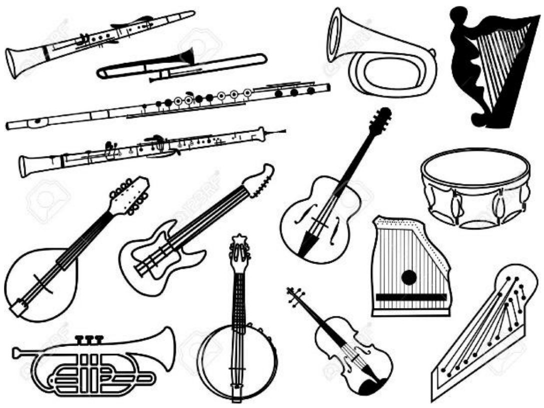
This is a forced vibration. When the motor rotates it creates the centripetal non-symmetric force on the offset mass. Because of that it results net centrifugal force, this causes the displacement of the motor. The strength of vibration affected by the mass of the improper weight, the distance between improper mass and motor shaft and the speed of rotation (Input voltage effects the rotation speed). Different vibration patterns are created by changing the input voltage in mobile phones.

2. Vibratory plate compactor

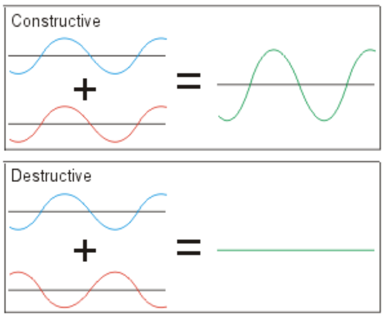
A compactor is a machine used to reduce the size of materials. It is powered by an engine that fixed to the plate through a strong spring. Generally these compactors are run with 3-4 horse power engines. The engine base is fixed on vibrating plate by shock absorbing rubber. The lower part is made up vibrating plate and vibrator unit that has an eccentric rotary shaft built in. Vibrator pulley rotates eccentric rotor shaft that is contained in vibrator case. The vibration that creates from eccentric rotor is transferred to compacting plate. Machine forward also causes because of vibration of the vibrating plate. This vibrates with the engine give harder push to the ground. This is also a forced vibration. These compactors weighs around 150-200lbs and the frequency of this steel plate is around 50-70Hz.



3. Vibration of musical instruments

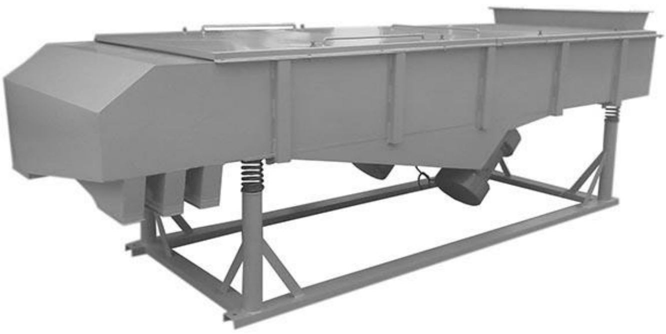


Sound is produced when something vibrates. When we vibrate something, the vibrate body causes the medium (air, water, etc.) around it to vibrate. It creates sound waves. They are travelling longitudinal waves. The longest wave that suits for a particular vibrating body is the fundamental and others are overtones. These overtones are multiple of the fundamentals. Sound creates because of the compressions (High pressure) and rarefactions (low pressure) of the media. When two waves meet there can be two kinds of interference methods. They are constructive and destructive. When two peaks or troughs meet, it will generate new wave that has louder sound. It is the constructive method. Trough and peak will meet in destructive method. It will create lower sound. This is how the sound is created because of the vibration.



4. Vibrating screens

Vibrating screen machine are used to spate different kind of materials such as sands, gravels and etc. This is made with a screening surface vibrated mechanically at high speed and used mainly for screening ore, coal or other fine dry materials. To process of vibration it uses mainly hydraulic or electric vibrators. These electrical vibrates can be either electric motors or solenoids.



The efficiency of vibration machine depends on mainly area of the screen, angle of inclination and equipment capacity. When the inclined angle and flow rate increases, efficiency will reduce. The frequency of the screen is mainly depend on electromagnetic vibrator which is mounted above and directly connected to the screen surface. These high frequency screen vibrators operates in 1500-7200 rpm and low amplitude (1.2-2.0 mm).

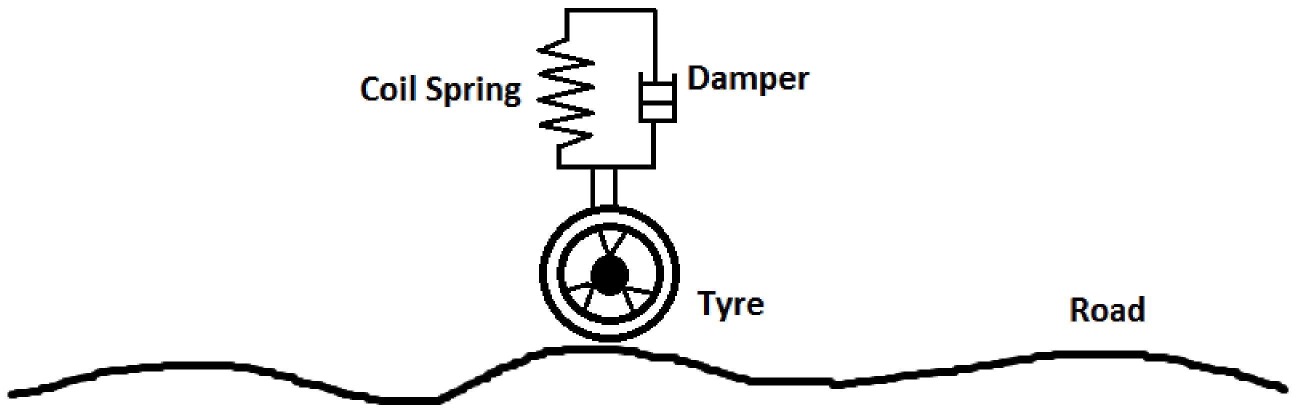
5. Uses of vibrations in medical field

In modern world uses ultra sound high energy waves to break kidney stones. In this scenario, when the high frequency wave is given, it creates energy inside the kidney stone by increasing the internal temperature of the stone. Temperature increases because of the vibration of stone particles. Vibration gives by the high frequency waves. Because of this procedure kidney stone will blast into small pieces.

Machine that uses to give high frequency waves for kidney stones

And also vibration with high frequency (20-80 kHz) and low amplitude are used to remove dental plaque. In neuropathy, uses vibrations to test a patient’s response to varying levels of touch and by using that, it will able to find damage areas. Also vibrating motors can use for message therapies. It will reduce the tension of mussels in pain areas.

Vibration Analysis



This system mostly similar to the suspension system of the vehicle. This system is subjected to a forced vibration. To minimize this vibration vehicle uses suspension system which contains basically coil springs and dampers. Without damper the system is similar to practical that we have done in laboratory. So without damper as we saw in our practical the mass on the higher position is vibrated. In this case mass of the higher position is the vehicle body and we don't want to vibrate the vehicle body because it is uncomfortable to passengers. In case of reduce that vibration of vehicle body, damping mechanism uses in suspension systems.

Damping mechanism

This is a shock absorption method. It reduces the amplitude of oscillations with the time by dissipates the energy of the shock. Generally any real vibration has damping effect because of friction and other resistance. In damper there are hydraulic gates and valves to absorb the shock and it reduces the amplitude of vibration. In modern vehicle damping has been controlled by either increasing or reducing the resistance to the fluid flow in the shock absorber.

Mathematical approach of the practical

When we consider an equation for the displacement of the tyre on a vehicle => $y = A\sin(Pt)$

Where,

y = Displacement of the tyre

A = Amplitude of the ground

P = Excitation frequency

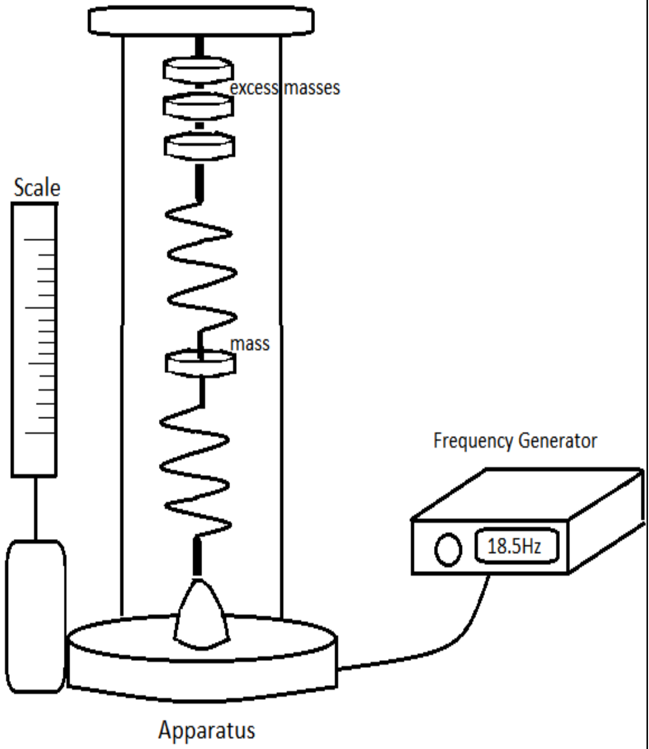
t = Time

In our practical we fixed the 'A' value to 1mm and measure the 'B' value (i.e. Amplitude of the upper mass / in this case it similar to body of the vehicle).

We didn't add a damping mechanism, but the friction of vibration acts as a damping system to this practical.

This is the apparatus that we used to measure the amplitude of second mass.

- First we loaded the 41.0g mass for the apparatus by raising other excess mass to up.
- Adjust the position of zero in scale to bottom line of the mass.
- Then set the frequency to the zero and increase frequency by 1Hz or 0.5Hz.
- When the frequency was increasing we observed the maximum amplitude of the mass. (resonance frequency)
- Then took four amplitude (B) readings from below and above of that frequency. (Now we have all nine readings)
- Repeat the above steps to 58.5g, 76.0g, 93.5g and 111.0g.



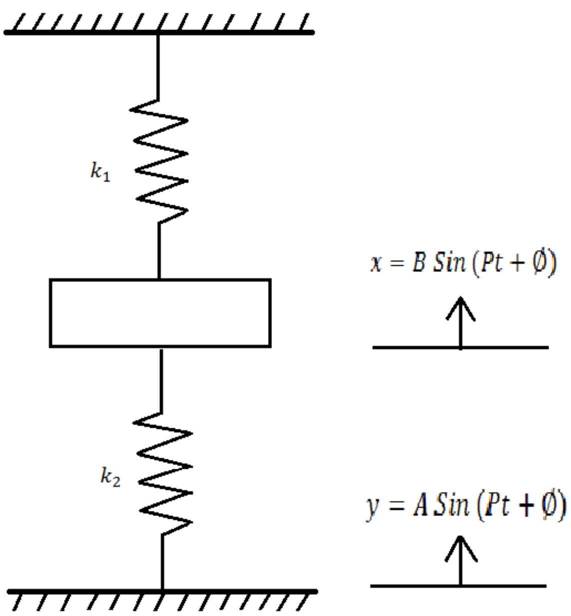
Calculation part,

k_1 *and* k_2 = Stiffness of spring

$\emptyset$ = Phase angle

B = Amplitude of the mass

ω_n = Natural frequency ($\omega_n = 2\pi f_n$)



For an equilibrium position,

$\uparrow F = ma$

$m\ddot{x} + k_1 x + k_2(x - y) = 0$

$m\ddot{x} + (k_1 + k_2)x - k_{2y} = 0$

$m\ddot{x} + kx - k_2 y = 0$ -----------(1) ($k = k_1 + k_2$)

By substituting values for { $x = B\ Sin\ (\emptyset + Pt)$ }, when t = 0 and x = 0,

$0 = B\ Sin(\emptyset + 0)$

$\therefore\ \emptyset = 0\ (Since\ B \neq 0)$

x= $B\ Sin\ (Pt)\ => \dot{x} = Bp\,\mathrm{Cos}(Pt)\ \ => \ddot{x} = -Bp^2\,\mathrm{Sin}(Pt)$-------------(2)

By (1) and (2),

$m(-Bp^2\,\mathrm{Sin}(Pt)) + k(B\ \ \mathrm{Sin}(Pt)) - k_2(A\,\mathrm{Sin}(Pt)) = 0$

$mBP^2 + Ak_2 - kB = 0$

$$\frac{B}{A}mP^2 + k_2 - \frac{B}{A}k = 0$$

$$\frac{B}{A} = \frac{k_2}{k - mP^2}$$

Now, $\omega_n = \sqrt{\frac{k}{m}}$

$$\frac{B}{A} = \frac{k_2/m}{\omega_n^2 - P^2}$$

Conclusion

When increasing the frequency of the mass we saw that amplitude of the mass increases and after a certain frequency amplitude decreases. B/A values (Actually it is the B value. Because on the beginning we set A as 1mm) vs. frequencies curved graphs are symmetrical at the middle (At the resonance point frequency). After that we plotted ω_n^2 vs. 1/m graph. It is almost linear. By calculating the gradient of the graph we got the total stiffness of the spring.

Practical errors and issues encountered during the practical

- Main practical error occurs when we get the amplitude of the mass. It is very hard to get the correct value on naked eye. Since it was a small reading the error was high. It may be vary from person to person.
- The reading depends on the place where your eye is, we can't exactly take the eye perpendicular to the scale. Therefore parallax errors occur.
- Also there are some instrumental errors. The apparatus is calibrated to A as 1mm, but by the time it can be slight changes of that value. And there can be errors occurred on frequency generator.
- When we are vibrating the mass for a long time, due to the friction springs get heated. Because of that stiffness of springs are changing slightly through the practical. So we calculated the average value of spring stiffness.
- After the practical we draw some graphs using the readings which took in the practical. When we are plotting these graphs there can be issues on drawings. As we saw it would not exact symmetrical and not crossed the all points.
- We did not consider air resistance and the energy dissipation to the external environment in our practical.

Possible remedies to overcome the practical issues encountered

When measuring amplitude of the mass we have to place our eye perpendicular to the scale and we can use ruler to take readings (Place ruler perpendicular to the scale and corner of the mass) as well as we can keep a white paper behind the vibrating mass and the scale, it helps to focus on the scale. By increasing efficiency (By reducing least count) of the scale, we can minimize the errors. We can take two readings and use the average of it to plot the graphs. If we can calibrate the 'A' value again in the beginning of the practical it will reduce the errors also. In order to reduce air resistance, we can use closed room to do the practical. After taking some readings we can switch of the apparatus to get it to room temperature. It helps to keep spring constants in one value. When we are plotting the graphs, we can neglect points that deviated from the symmetric shape.