Experiment Name / No.: 07

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Date 19/02/2021

Experiment No:-> 07/08.

1) Aim:-> To determine the damping coefficient and damped and undamped natural frequency of an under-damped single degree of freedom system from its response to an initial displacement.

2) Apparatus:-> Spring-Mass-Damper System at bottom i.e. spring and damper are grounded and they support a mass, different masses.

Here in our experiment, we are provided with a simulator at which we'll perform the experiment with above mentioned experimental setup.

3) Theory:->

* In a usual spring mass damper arrangement, the spring and damper are joined together and connected to a ground and the rigid mass of M kg is hanged to the string in a vertical direction

Friday

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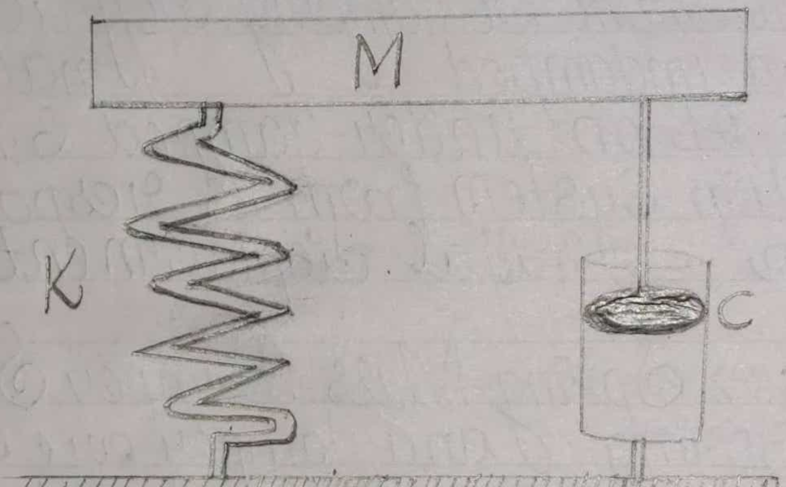

(fig:i)

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★) Let the Spring constant be 'K' N/m and its coefficient of Damping is 'C' Ns/m.

★) Since there is only one mass and one probable direction of motion (vertical direction) the system is a single degree of freedom system.

★) The damping will be assumed to be viscous i.e. resistance of the motion is proportional to velocity of mass of system.

• Damped and Undamped vibrations: Because of resistance to motion, energy is continuously dissipated and free vibrations of such systems come to halt after some time. This is called damped vibration and such systems are called damped systems.

★) When the resistance is offered by a damping element proportional to velocity of mass of system, it is termed as viscous ~~dragging~~ damping.

★) System without damping elements are undamped systems and undamped vibrations.

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Let this type of SDOF system be acted upon by a harmonic force i.e. value of force varies wrt time following the equation,

- $f = F_0 \sin \omega t$ or $f = F_0 \cos \omega t$, when frequency of such harmonic force acting on system equals natural frequency of system, the amplitude of motion of mass of system is large and resonance is said to occur.

- Amplitude of forced vibration tends to be large when difference between frequency of harmonic force acting on vibratory system and natural frequency of system is small.

- Value of amplitude at and near resonance depends on the amount of damping present in system. damping factor is a measure of amount of damping.

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4) Formula Used

1) $\omega n = \sqrt{\frac{K}{M}}$; wn is natural frequency in radians per second.

2) $\omega n = \frac{\sqrt{4\pi^2+\delta^2}}{T}$

3) Damping natural frequency = $(\omega d) = \frac{\omega n}{\sqrt{1-\xi^2}}$

4) Damping factor = $(\xi) = \frac{C}{C_c}$ or $\frac{C}{2\sqrt{KM}}$

5) Time Period = $\frac{2\pi}{\omega d} = (T)$

6) Logarithmic decrement (δ) =

$$\log_e\left(\frac{\text{Amplitude of one cycle}}{\text{Amplitude of Consequenty next cycle}}\right)$$

7) For Underdamped i.e. $\xi << 1$;

$$\xi \approx \partial / \sqrt{4\pi^2+\delta^2}$$

OBSERVATION TABLE

Observed values

S.No	X_0 (mm)	Mass M (kg)	Spring constant (K)	C_c	C (NS/m)	Time (t) in second	ω_d	ω_n
1	8	8	200	80	10	7	4.96078	5
2	8	8	100	56.568	10	7	3.4798	3.5355
3	8	6	150	60	10	10	4.9301	5

$$\text{Average } C_{(obs)} = \frac{10+10+10}{3} = 10\,Ns/m$$

$$\text{Average } \omega_{n(obs)} = \frac{5+3.5355+5}{3} = 4.51183\,rad/sec$$

$$\text{Average } \omega_{d(obs)} = \frac{4.9608+3.4798+4.9301}{3} = 4.4569\,rad/sec$$

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Calculations.

Case 1.> $T = \frac{t_2 - t_1}{1} = \frac{2.5 - 1.3}{1} = \underline{1.2 \text{ seconds}}$

$$\partial = \log_e\left(\frac{A_0}{A_1}\right) = \log_e\left(\frac{3.58}{1.62}\right) = \underline{0.79293665}$$

$$\xi = \frac{\partial}{\sqrt{4\pi^2 + \partial^2}} = \frac{0.79293665}{\sqrt{4 \times (3.1415926)^2 + (0.79293665)^2}} = \underline{0.12520668}$$

$$w_n = \frac{\sqrt{4\pi^2 + \partial^2}}{\partial T} = \frac{\sqrt{4(3.141592634 2)^2 + (0.79293665)^2}}{1.2} = \underline{5.277518234} \text{ rad/s}$$

$$w_d = w_n\sqrt{1 - \xi^2} = 5.2277518234 \times 0.99213068$$
$$= \underline{5.235987757}$$

$$C = 2\xi\sqrt{KM}$$

$$C = 2 \times 0.12520668 \times \sqrt{8 \times 200} \quad (K = 200, M = 8)$$

$$C = \underline{10.0165344 \text{ Ns/m}}$$

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Case 2.

$$T = \frac{t_2 - t_1}{1} = \frac{3.6 - 1.8}{1} = \underline{1.8 \text{ seconds}}$$

$$\delta = \log_e\left(\frac{A_0}{A_1}\right) = \log_e\left[\frac{2.59}{0.84}\right] = \underline{1.126011263}$$

$$\xi = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}} = 0.\underline{176399985}$$

$$C = 2\xi\sqrt{KM}$$

$$C = 2 \times 0.176399985\sqrt{100 \times 8} = \underline{9.978690058} \text{ Ns/m}$$

$$W_n = \frac{\sqrt{4\pi^2 + \delta^2}}{T} = \frac{\sqrt{4 \times (3.1415926)^2 + (1.126011263)^2}}{1.8} = \underline{3.546269078} \text{ rad/s}$$

$$W_d = W_n\sqrt{1 - \xi^2} = 3.546269078 \times 0.984318565$$

$$\underline{W_d = 3.490658504 \text{ rad/s}}$$

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Case 3:

$$T = \frac{t_2 - t_1}{1} = \frac{2.5 - 1.3}{1} = 1.2 \text{ seconds}$$

$$\delta = \log_e\left(\frac{A_1}{A_0}\right) = \log_e\left(\frac{2.74}{0.93}\right) = 1.080528613$$

$$\xi = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}} = \frac{1.080528613}{\sqrt{4 \times (3.141592654)^2 + (1.080528613)^2}} = 0.169483561$$

$$\omega_n = \frac{\sqrt{4\pi^2 + \delta^2}}{T} = \frac{\sqrt{4 \times (3.141592654)^2 + (1.080528613)^2}}{1.2} = 5.312848661 \text{ rad/s}$$

$$\omega_d = \omega_n \sqrt{1 - \xi^2} = 5.312848661 \times \sqrt{1 - (0.169483561)^2}$$

$$\omega_d = 5.235987756 \text{ rad/s}$$

$C = 2\xi\sqrt{KM}$ where $K = 150, M = 6$

$$C = 2 \times 0.169483561 \times \sqrt{150 \times 6}$$

$$C = 10.16901367 \text{ Ns/m}$$

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Experimental Averages

$$C_{mean} = \frac{10.0165344 + 9.978690058 + 10.16901367}{3} = \underline{\underline{10.05474604\ Ns/m}}$$

$$(\omega_n)_{mean} = \frac{5.277518234 + 3.546269078 + 5.312848661}{3} = \underline{\underline{4.71221191\ rad/s}}$$

$$(\omega_d)_{mean} = \frac{5.235987757 + 3.490658504 + 5.235987756}{3} = \underline{\underline{4.65421139\ rad/s}}$$

Percentage error :->

	Observed Values	Experimental Values	% Error
C	10 Ns/m	10.05474604 Ns/m	0.5474604 %
ω_n	4.5118 rad/s	4.71221191 rad/s	4.441950219 %
ω_d	4.4569 rad/s	4.65421139 rad/s	4.427099329 %

$$\%\ error = \frac{|\text{Observed value} - \text{Experimental value}|}{|\text{Observed value}|} \times 100\ \%$$

$$C\%\ error = \left(\frac{10.05474604 - 10}{10}\right) \times 100\%$$

$$C\%\ error = 0.5474604\%$$

$$\omega_n\%\ error = \left(\frac{4.71221191 - 4.5118}{4.5118}\right) \times 100\%$$

$$\omega_n\%\ error = 4.441950219\%$$

$$\omega_d\%\ error = \left(\frac{4.65421139 - 4.4569}{4.4569}\right) \times 100\%$$

$$\omega_d\%\ error = 4.427099329\%$$

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5.) Percentage Error:->

$$\%\ error = \frac{|\text{Observed value} - \text{Experimental value}|}{|\text{Observed Value}|} \times 100$$

Damping Coefficient (C)

$$= \left(\frac{10.05474604 - 10}{10}\right) \times 100\% \Rightarrow 0.5474604\%$$

ω_n (Natural frequency)

$$= \frac{(4.71221191 - 4.5118)}{4.5118} \times 100\% \Rightarrow 4.441950219\%$$

ω_d (Damping frequency)

$$= \left[\frac{4.65421139 - 4.4569}{4.4569}\right] \times 100\%$$

$$= 4.427099329\%$$

Teacher's Signature:

Result :->

Damping Coefficient (C) = 10.05474604 Nm/s

% error in C = 0.5474604 %

Natural frequency (ω_n) = 4.711721191 rad/s

% error in ω_n = 4.441950219 %

Damped frequency (ω_d) = 4.65421139 rad/s

% error in ω_d = 4.427099329 % Ans

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6.) Result :->

i) Damping Coefficient (C) = 10.05474604 Ns/m

% error in C = 0.5474604%

ii) Natural frequency (ω_n) = 4.71221191 rad/s

% error in ω_n = 4.441950219%

iii) Damped frequency (ω_d) = 4.65421139 rad/s

% error in ω_d = 4.42 7099329% Ans

7) Precautions & Sources of error

1) Spring may be old or have different value of K.

2) Calculation error

3) Value of C should be taken less than Cc

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