ZIBELINE INTERNATIONAL PUBLISHING
ISSN: 1024-1752
CODEN : JERDFO

Journal of Mechanical Engineering Research and Developments (JMERD)
DOI : http://doi.org/10.26480/jmerd.03.2018.93.98

CrossMark

EXPLORATORY INVESTIGATION OF VIBRATIONAL CHARACTERISTICS OF THE UN-DAMPED AND DAMPED SPRING MASS SYSTEMS

Seretse O.M[1], Agarwal A[1], Letsatsi M. T[2]

[1] Department of Mechanical Engineering, University of Botswana, Gaborone, Botswana
[2]Department of Industrial design and technology, University of Botswana, Gaborone, Botswana.
**Corresponding Author email: seretseom@mopipi.ub.bw*

ARTICLE DETAILS

Article History:

Received 23 May 2018
Accepted 24 September 2018
Available online 27 September 2018

ABSTRACT

The essential goal of this investigation was to break down the free oscillatory motion of dynamic systems and the powers related with the motion. This is the investigation of a free vibration of two states of a spring mass system that is un-damped and damped. Free vibration happens when a mechanical system is set in motion with an underlying info and permitted to vibrate unreservedly. Cases of this kind of vibration are pulling a kid back on a swing and lifting up or hitting a tuning fork and giving it a chance to ring. The mechanical system vibrates at least one of its regular frequencies and damps down to motionlessness. A definitive objective in the investigation of vibration is to decide its impact on the execution and security of the system concerned. Subsequently the investigation of oscillatory motions is an imperative advance towards this objective. The investigation demonstrates that damping proportion (ζ) is directly proportional to current. The lighter the current, the lighter the damping ratio, and the more grounded the damping power.

KEYWORDS

Dynamic system, spring-mass system, vibrational parameters, frequency, cycle.

1. INTRODUCTION

Mechanical vibration manages the connection between powers following up on the mechanical system and the oscillatory movement of mechanical system about a point inside the system. Vibration is the investigation of oscillatory movements of dynamic systems [1]. Vibrations are mechanical motions around a balance position. There are situations when vibrations are attractive, for example, in specific kinds of machine apparatuses or generation lines. Mechanical vibrations and stun are dynamic marvels, — i.e. their force fluctuates with time. Both the most extreme force and the rate of progress in power with time, spread over wide estimation ranges and frequently require very specific gear for their exact assurance. Ground movements caused by a long shot off seismic tremors (or blasts) may, for example, be scarcely noticeable while vibrations caused by expansive burning motors can cause serious mechanical weariness harm [2].

More often than not the vibration of mechanical systems is unwanted as it squanders vitality, diminishes proficiency causes noise and might be hurtful or even hazardous. For instance, traveller ride comfort in air ship or vehicles is enormously influenced by the vibrations caused by outside unsettling influences, for example, air turbulence or rough road conditions. In different cases, eliminating vibrations may spare human lives, a great illustration is the vibration control of structures in a quake situation. It is a mechanical marvel whereby motions happen about balance point. It is notable in basic progression that an undamped examination is the preparation of a damped investigation. When all is said and done, the dynamic reaction investigation of a damped system can be completed based on the free vibration examination of the undamped system. Looking through the literature, no single paper was found to examine the free vibration qualities of a plate joined by persistently disseminated spring-mass. A few papers contemplated the free vibration of rectangular plates with flexible/inflexible point-bolsters, in light of the vitality technique, utilizing distinctive methodologies, for example, spline limited strip strategy [3].

The conduct of oscillating systems is regularly of enthusiasm for a different scope of orders that incorporate control building, mechanical designing, basic building, and electrical designing. In spite of the fact that by and large mechanical stuns and vibrations are undesired side-effects of generally helpful procedures, and incredible endeavours are spent to reduce their presence, a few vibrations are delivered intentionally. Normal illustrations are the vibrations created by passing on and screening machines, mechanical mallets, ultrasonic cleaning showers, and so forth., while alluring stun impacts are incorporated with riveting sledges and heap drivers [4].

The physical quantity that is oscillating varies greatly and could be the swaying of a tall building due to the wind, or due to the speed of an electric motor. A dynamic system is a combination of matter which possesses mass and whose parts are capable of relative motion. All bodies possessing mass and elasticity are capable of vibrating. The mass is inherent of the body and the elasticity is due to the relative motion of the parts of the body. A system is said to experience free vibration when it wavers just under an underlying unsettling influence with no outer powers acting after the initial disturbance [5]. A spring mass system in horizontal position is shown in figure 1 below.

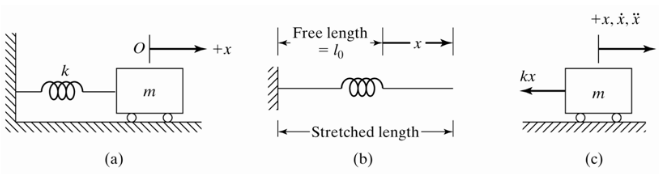

Figure 1: A spring mass system in horizontal position

2. TYPES OF DAMPED SYSTEMS

The particular manners by which energy is disseminated in vibration are needy upon the physical systems dynamic in the structure. The movement of a mechanical system subjected to outside powers is usually named the reaction of the system to the specific powers being referred to. So also, the outer powers following up on the system are named the energizing powers, or just the excitation [6]. These physical mechanisms are complicated physical processes that are not fully understood. The kinds of damping that are available in the structure will rely upon which components prevail in the given circumstance [7].

2.1 Underdamped systems

In an underdamped system the damping ratio is between zero and one (0<ζ<1). This is the most common case and the only one that yields oscillation. The underdamped system gives an oscillation response with an exponential decay. Most of the natural systems vibrate in this fashion. Underdamped oscillation has its own frequency of oscillation called the damping frequency. Response of an underdamped system is shown in figure 2.

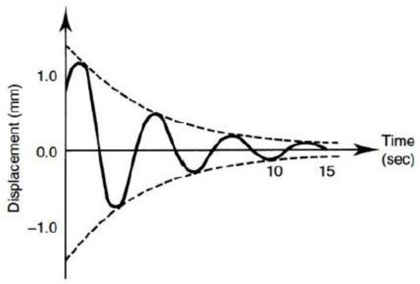

Figure 2: Response of an underdamped system [8]

2.2 Over-damped systems

In an over damped system the damping ratio is greater than 1 (δ>1). An over damped system doesn't oscillate, and it returns to its rest position exponentially. It is also slower to respond than a critically damped system as shown in figure 3 [3].

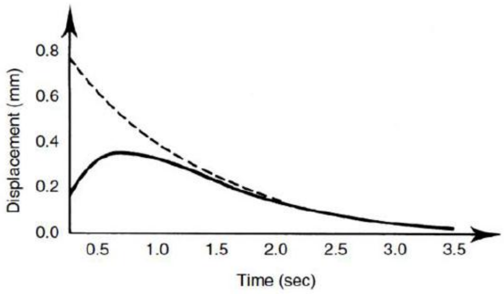

Figure 3: Response of an over-damped system [9]

2.3 Critically Damped systems

For a critically damped system the value of the damping ratio is equal to 1 (ζ=1). In a critically damped system no oscillation occurs. It has the value of damping that provides the fastest return to time zero without oscillation [3]. The property of critical damping is used in many practical applications. For example, large guns have dashpots with critical damping value, so that they return to their original position after recoil in the minimum time without vibrating as shown in figure 4. If the damping provided were more than the critical value, some delay would be caused before the next firing [10].

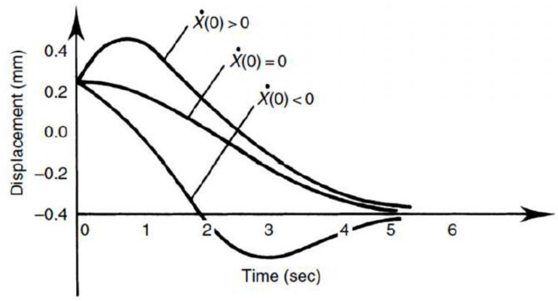

Figure 4: Response of a critically damped system

2.4 Unforced Damped Systems

The behavior of the spring-mass system in this case is strongly dependent on the types of roots the characteristic equation has. An unforced damped system consists of the equation of motion equal to zero.

3. OBJECTIVES AND FOCUS OF EXPERIMENTAL EVOLUTION

The chart for a damped system relies upon the estimation of the damping proportion which influences the damping coefficient. This paper discusses one of the many analysis of oscillatory motions performed to investigate the following:

- The effects of varying the mass on constant spring stiffness.
- The effects of a constant mass on a variety of spring's stiffness.
- The effects of damping a spring mass system; as shown in in figure 5 (a) and 5 (b).

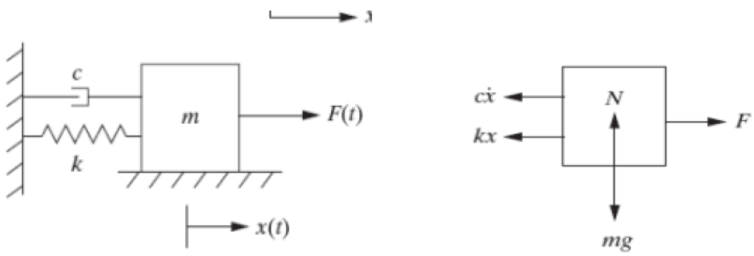

Figure 5: (a) spring system, (b) Free body diagram of spring system

4. RESULTS AND DISCUSSIONS

The vibration of a system includes the exchange of its potential energy to dynamic energy and of motor energy to potential energy. On the off chance that the system is damped, some energy is disseminated in each cycle of vibration and must be supplanted by an outer source if a condition of consistent vibration is to be kept [10]. The examination was performed utilizing the accompanying equipment: a progression of masses and springs of different stiffness's, Horizontal spring mass system with eddy current damper and a displacement transducer and recorder.

4.1 Analysis A – Un-damped Vibrations

A spring of 260 N/m stiffness was loaded with a variety of masses. The time in seconds was recorded against ten bounces (cycles) of the spring mass system, each time the mass is changed. Table 1 shows the tabulated parameters from the analysis and Figure 6 shows a curve of Logarithm of mass (log m) plotted against a Logarithm of frequency (log f).

Table 1: Results for a spring of 260 N/m stiffness with a variety of mass.

Spring Stiffness k (N/m)	Force (N)	Mass (kg)	Log m	Frequency F (Hz)	Log F	Time	Cycles
260	68.67	7	0.845	0.9091	-0.0414	11	10
260	58.86	6	0.778	1.0000	0.0000	10	10
260	49.05	5	0.699	1.1111	0.0458	9	10
260	39.24	4	0.602	1.4286	0.1549	7	10
260	29.43	3	0.477	1.6667	0.2218	6	10

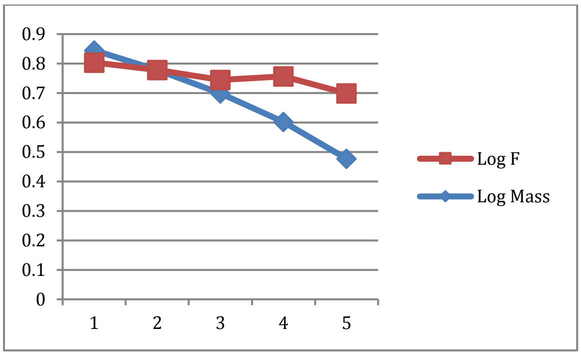

Figure 6: Logarithmic relationship between mass and frequency of oscillation.

A mass of 5 kg was loaded into a variety of springs having different stiffness. Table 2 shows the parameters from the analysis while Figure 7 shows a curve obtained after plotting the logarithm of stiffness (log k) against the logarithm of frequency (log F).

Table 2: Values of different parameters from the analysis.

Spring Stiffness k (N/m)	Log k	Force (N)	Mass (kg)	Frequency F (Hz)	Log F	Time	Cycles
260	2.415	49.05	5	1.1111	0.04575	9	10
225	2.352	49.05	5	1.1111	0.04575	9	10
150	2.176	49.05	5	0.9091	-0.0414	11	10
125	2.097	49.05	5	0.7143	-0.1461	14	10
67	1.826	49.05	5	0.5882	-0.2304	17	10

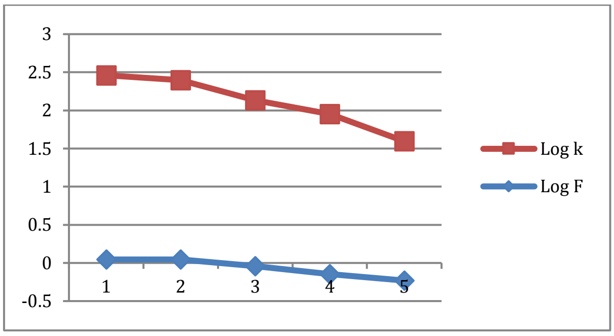

Figure 7: curve obtained after plotting the (log k) |& (log F).

4.2 Results for analysis A

Relationship: $f \alpha m^{a}$ (1)

δst = Static Spring deflection
f_n = frequency in Hz, ω_n = frequency in rad/s
m = mass, F = force, T =period

F = k . x (2)

Also F = mg (3)

m.g = k. x (4)

$F_n \times 2\pi = \omega_n$ (5)

$\omega_n = \sqrt{\frac{k}{m}}$ (6)

$f_n \times 2\pi = \sqrt{\frac{k}{m}}$ (7)

$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (8)

$f_n = \frac{1}{2\pi}\sqrt{\frac{260}{m}}$ (9)

4.3 Analysis B – Damped Vibrations

With the eddy-current set at zero a mass was displaced at a convenient distance and released suddenly as shown on the graph of the pen recorder. Figure 8 shows the response of the displacement against time when the eddy-current is set at 0 amps.

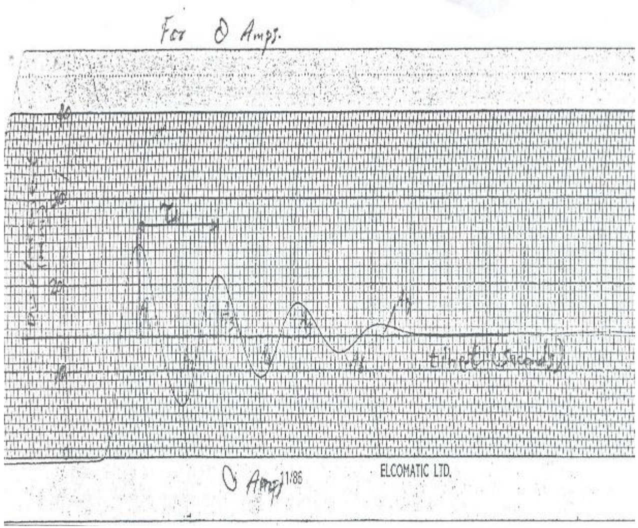

Figure 8: Response of the displacement against time

The above procedure was repeated, but this time with the current on the eddy-current damper set at 1 amp, 2 amps and 2.5 amps respectively for each displacement. The graphs of the pen recorder for each displacement are as shown in figures. Initial displacements are shown on the graph and table of results. Figure 9 shows the response of the displacement against time when the eddy-current is set at 1 amp while Figure 10 shows the response of the displacement against time when the eddy-current is set at 2 amps. Figure 11 shows the response of the displacement against time when the eddy-current is set at 2.5 amps.

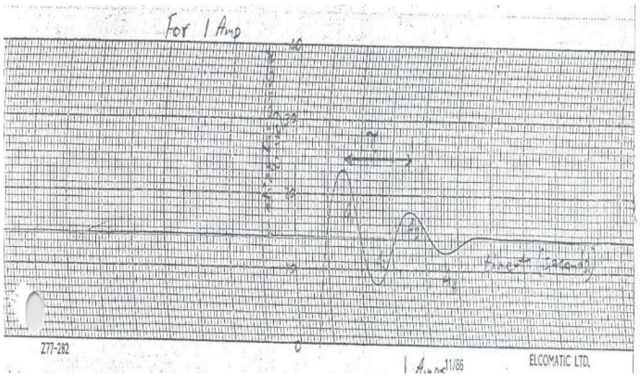

Figure 9: at 1 amp

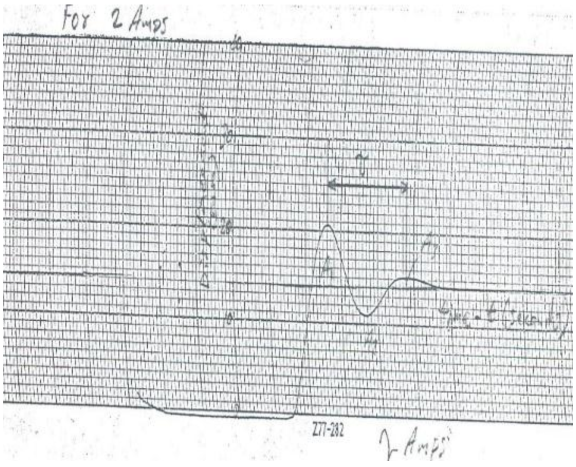

Figure 10: at 2 amps

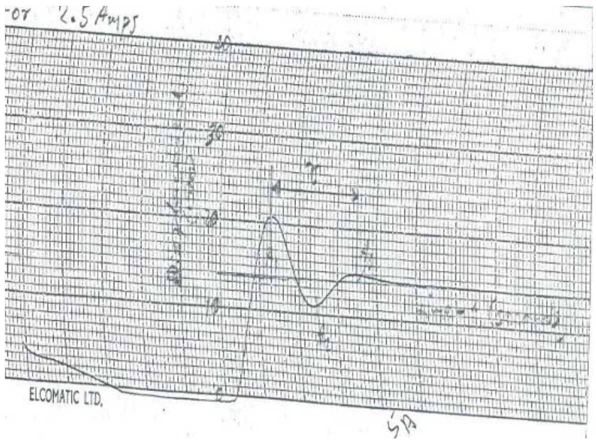

Figure 11: at 2.5 amp

4.4 Results – Analysis B

The equation of the vibrations of a damped system is given by: mx + δ.x + k.x = 0 (10)

Where: x = instantaneous displacement of mass, m = mass

δ= vicious damping coefficient

Let one small square on the pen recorder graph resemble 1 mm vertically and 1 second horizontally.

Logarithmic decrement: $\delta = \ln\left(\frac{A1}{A3}\right)$ (11)

Damping ratio: $\varsigma = \frac{\delta}{\sqrt{(2\pi)^2+\delta^2}}$ (12)

$\frac{A1}{A2} = \frac{A2}{A3} = \frac{A3}{A4} = \frac{An}{An+1}$ (13)

Logarithm decrements (δ) and damping ratios (ξ) of different currents are as follows:

For 0 Amps: $\delta n = \ln\left(\frac{A1}{A3}\right) = \ln\left(\frac{11}{7}\right) = 0.4520$

Damping Ratio: $\varsigma = \frac{\delta}{\sqrt{(2\pi)^2+\delta^2}} = \frac{0.4520}{\sqrt{(2\pi)^2+0.4520^2}} = 0.07175$

For 1 amp: $\delta = \ln\left(\frac{A1}{A3}\right) = \ln\left(\frac{9}{4}\right) = 0.8109$

Damping Ratio: $\varsigma = \frac{\delta}{\sqrt{(2\pi)^2+\delta^2}}$ $\varsigma = \frac{0.8109}{\sqrt{(2\pi)^2+0.8109^2}} = 0.1280$

For 2 amps: $\delta = \ln\left(\frac{A1}{A3}\right) = \ln\left(\frac{7}{1}\right) = 1.9459$

Damping Ratio: $\varsigma = \frac{\delta}{\sqrt{(2\pi)^2+\delta^2}} = \frac{1.9459}{\sqrt{(2\pi)^2+1.9459^2}} = 0.2958$

For 2 amps: $\delta = \ln\left(\frac{A1}{A3}\right) = \ln\left(\frac{7}{1}\right) = 1.9459$

Damping Ratio: $\varsigma = \frac{\delta}{(9\sqrt{(2\pi)^2+\delta^2}} = \frac{1.9459}{\sqrt{(2\pi)^2+1.9459^2}} = 0.2958$

Table 3 gives the overview of results for Analysis B.

Table 3: Results for Analysis B – Damped Vibration

Current (amps)	Initial Displacement A1	A2	A3	Logarithmic Decrement (δ)	Damping Ratio (ς)	Periodic Time (seconds)	Damped frequency (ω_n)
0	11	8	7	0.4520	0.07175	20	0.314
1	9	6	4	0.8109	0.1280	21	0.299
2	7	3	1	1.9459	0.2958	22	0.285
2.5	7	3	1	1.9459	0.2958	22	0.285

5. CONCLUSION

One of the motivations for the present paper is to survey a portion of the properties of real damping components and to depict a portion of the scientific studies that are utilized to present to these systems. The estimation procedure is demonstrated using the masses and springs of different stiffness's with eddy current damper. A dynamic system is a mix of issue which has mass and whose parts are fit for relative movement. The mass is characteristic of the body and the versatility is because of the relative movement of the parts of the body. In shock absorbers this phenomenon is used to optimise damping and hence a smoother ride compared to the conventional suspension. The transformation additionally includes control with the immediate outcomes to correct identification functionality. Further, as a typical approach to use a mathematical software tool, for example Matlab to simulate and validate the different responses of a system can be utilized.

REFERENCES

[1] Mannan, F.A. 2017. Mechanical Vibration. https://www.slideshare.net. Bahr Alyafei, pp. 1–10.

[2] Broch, J.T. 2009. Mechanical Vibration and Shock Measurements. Mechanical Vibration and Shock Analysis: Second Edition, 4, 1–436.

[3] Inman, D.J. 2014. Engineering Vibration. Pearson Education Inc. 4th edition.

[4] Dalenbring, M. 1999. Damping function estimation based on measured vibration frequency responses and finite-element displacement modes. Mechanical Systems and Signal Processing, 13 (4), 547–569.

[5] Sulaiman, R. 2014. Free vibration of single degree of freedom (SDOF). https://www.slideshare.net/. p. 1.

[6] Crandall, S.H. 1991. The Hysteretic Damping Model in Vibration Theory. Proceedings of the Institution of Mechanical Engineers, Part C, 205 (1), 23–28.

[7] Adhikari, S. 2000. Damping models for structural vibration. Department of Engineering, p. 228.

[8] Blake, R.E. 2010. Basic vibration theory. Harris' Shock Vib. Handb., p. 2.1-2.32.

[9] Lecture, N. Introduction to Damping in Free and Forced Vibrations. nptel.ac.in. NPTEL.

[10] Rao, S.S. 2011. Mechanical Vibrations, 5th ed. Prentice Hall.

Cite The Article: Seretse O.M, Agarwal A, Letsatsi M. T (2018). Exploratory Investigation Of Vibrational Characteristics Of T he Un-Damped And Damped Spring Mass Systems . *Journal of Mechanical Engineering Research and Developments*, 41(3) : 55-58.