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Graphical Analysis Springs Dampers System on the A Freight Cars

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Abstract. In mechanical system where spring and damper are used often create unwanted vibration, due to external forces. Unwanted vibration may cause further noise and other damages such as engine break, etc. To reach system stability, we model of coupling series of freight car and analyze them using root loci and plot waves. From the result we can analyze what is the maximum stability by altering spring and damper constant. It is found when the spring and damper constant increase, the stability will be fast.

1. Introduction
Any repetitive motion in the same time interval is called periodic motion or harmonic motion. If a particle in a periodic motion moves back and forth through the same trajectory the motion is called the oscillation motion. The oscillation motion is one form of a system model with a spring-damper. This response is caused by an external force.

Mechanical systems that work with a damper-spring system often cause unwanted vibrations. Unwanted vibrations often cause problems such as noise, equipment damage and uncomfortable condition for   passengers (in a vehicle).

Therefore the model of a system needs to be built to determine the characteristics of a particular system. By knowing the characteristics of a system then we can provide solutions to control this content to fit the desired criteria. This paper discusses mechanical coupling consisting of springs and dampers which are used to hold the freight train to keep the distance between carriage 1 with another carriage when one of the carriages stops or moves.

The effect and magnitude of spring damper system will be discussed. The analysis is performed any changing the values of spring and damper to reach faster stability. All simulation were done using Simulink MATLAB structure.

2. Basic Theory
Simple harmonic oscillation is an oscillatory motion of an object that is affected by a linear restoring force and is not frictionless so that it does not experience power dissipation. Simple harmonic oscillations can also be interpreted as a vibrating system in which the restoring force is directly proportional to its negative deviation. Oscillations like this usually occur in springs that provide force or load.

If the initial length of the spring does not change, then it can be assumed that the variable x is a function of the spring configuration that is derived, the initial relation decreases to [2]:

$$f_s = -kx \tag{1}$$

where is the restoring force,   is the compression or extension distance (the change in length from the free length), and   is the spring constant, or stiffness, which is defined to be always positive. If we connect it with acceleration, it will be obtained:

$$ma = kx = m\frac{d^2x}{dt^2} \tag{2}$$

So,

$$a = \frac{d^2x}{dt^2} = -\left(\frac{k}{m}\right) \tag{3}$$

A negative sign is a restoring force or defined as a force acting in the direction of returning the mass of an object to its equilibrium position. The spring element provides an oscillating force in response to displacement. Whereas, the damping element is an element that rejects the relative velocity above it which makes the oscillation stop. Damping modeling as a linear function of relative velocity and no effect is at all the effect of damping strength, the linear damping force model as a function of the relative disadvantage of v is [4]

$$f_d = cv = c\frac{dx}{dt} \tag{4}$$

Where is the damping coefficient. The units of   are force / velocity. Damping causes the mechanical energy of the system to decrease within a certain time interval. There are 4 characteristics of the oscillation system based on the natural response:
1. Excessive damped odor (Overdamped response).
2. Low damped odor (Underdamped response).
3. Critically damped response (Critically damped response)
4. Oscillation is not muffled (Un damped Response)

The method used to solve the feedback system such as the spring damper system is bode plot method, the Nyquist method, and the root locus method [3]. In this paper the system used is analyzing bode plot method and root locus method. The bode plot consists of two graphs, the plot of the logarithm of the magnitude of the sinusoidal transfer function and the plot of the phase angle, both plotted against frequency on a logarithmic scale. The main advantage of using a bode plot is that the multiplication of magnitude produced can be added [7].

The basic factors that very frequently occur in an arbitrary transfer function G $(j\omega)$ H $(j\omega)$are [7] :
1. Gain K.
2. Derivative and Integral factors $(j\omega)^{\pm 1}$
3. First-order factors $(1 + j\omega T)^{\pm 1}$
4. Quadratic factors $(1 + \frac{2\zeta j\omega}{\omega_n} + (\frac{2\zeta j\omega}{\omega_n})^2)^{\pm 1}$

The root locus method can predict effects at the location of closed loop poles by varying the gain value or adding open loop poles and open loop zeros [7]. The root-locus method proved to be very useful in designing linear control systems, because open loop and zero poles can be modified to meet system performance response specifications [3]. The closed-loop transfer function is

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)} \tag{5}$$

Here we assume that G (s) H (s) is the polynomial ratio in s. R (s) is the input of the system and C (s) is the output of the system.

3. Research Methods
Script structure which is the result of review and study of theory or concept written as follows:

3.1. Identification of errors
   Identification of errors concerning the damping of the system with springs and dampers obtained from the results of the joint discussion. Damping system using springs and dampers is rarely used whereas spring and damper systems are the most dominant mechanical systems. For example: engine failure due to excessive vibration and in the long run.

3.2. Implementation of the design
Implementation of the design of the damp with spring and damper is done by system identification and modeled into mathematical equations. Then converted by Laplace transform into transfer function so that it can be modeled with MATLAB program precisely Simulink. New process of system analysis done. After that varied values of existing parameters. From that process, a comparison of the results was obtained.

4. Modeling System
Here is a real picture of the coupling system of a number of freight cars.

Figure 1. Coupling system of series of freight cars. [8]

   The above figure is a mechanical coupling commonly used to hold the freight cars in the following picture. This system can be modeled as two masses, a spring, a damper, and thrust and pull forces on each mass. And here is a clutch system model of a series of freight cars.
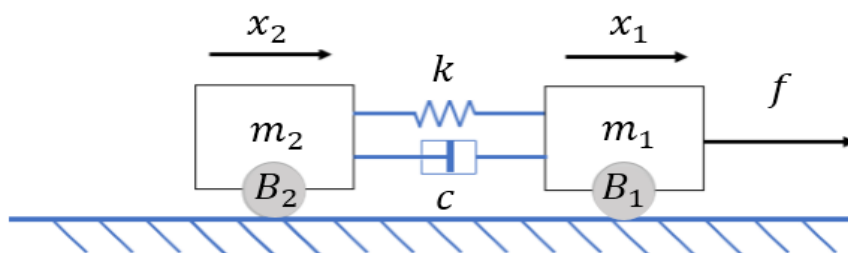
Figure 2. Model spring-damper coupling series of freight cars.

where:
    f = Input force of freight cars (N)
    m_1 = Mass of freight cars (kg)
    m_2 = Mass of the car being coupled (kg)
    B_1 = Friction of freight car (N s/m)
    B_2 = Friction of the car being coupled (Ns/m)
    x_1 = Freight car distance (output) (m)
    x_2 = Car being coupled distance (output) (m)
    c = Constant of damper (Ns/m)
    k = Constant of spring (N/m)

Completion of a system with many orders is more complicated than a system that is modeled with two orders, but the completion of a system with many orders can be solved using the concept of two orders [1]. From the spring-damper system model is made Mathematical equations as follows:

The equation of m_1 :
$$f(t) = m_1 \frac{d^2 x_1(t)}{dt^2} + B_1 \frac{dx_1(t)}{dt} + c\left(\frac{dx_1(t)}{dt} - \frac{dx_2(t)}{dt}\right) + k(x_1(t) - x_2(t)) \tag{6}$$

The equation of m_2:
$$c\left(\frac{dx_1(t)}{dt} - \frac{dx_2(t)}{dt}\right) + k(x_1(t) - x_2(t)) = m_2 \frac{d^2 x_2(t)}{dt^2} + B_2 \frac{dx_2(t)}{dt} \tag{7}$$

Apply the Laplace transform to this equation, using zero initial condition, to obtain transfer function. Substituting equation 1 and equation 2 to obtain $\frac{X_1(s)}{F(s)}$ and $\frac{X_2(s)}{F(s)}$ and if $V_1 = \frac{X_1(s)}{s}$ and $V_2 = \frac{X_2(s)}{s}$, so the equation as follows:

$$\frac{V_1(s)}{F(s)} = \frac{(m_1 s^3 + (B_2 + c)s^2 + ks)}{(m_1 s^3 + (c + B_1)s^2 + k)^2 - (cs + k)^2} \tag{8}$$

$$\frac{V_2(s)}{F(s)} = \frac{(cs^2 + ks)}{(m_2 s^3 + (c + B_1)s^2 + k)^2 - (cs + k)^2} \tag{9}$$

5. Result and Discussion

The mass spring damper system is used to design coupling system of series of freight train. In table 1 used several parameters to be simulated using MATLAB so it can be known the influence of springs and dampers on of the freight train. And the result of the graph also can be used to analyze about stability, damping ratio, and others.

**Table** 1. Variations Input Parameters Of Spring And Damper Constants

No	Parameter	$m_1 = m_2$ (kg)	k	$B_1 = B_2 = c$ (N.s/m)
1	Parameter 1 (P1)	1×10^4	20×10^3	30×10^3
2	Parameter 2 (P2)	1×10^4	30×10^3	40×10^3
3	Parameter 3 (P3)	1×10^4	40×10^3	50×10^3

The following is a simulation of the equation result so that the speed graph is obtained when driving, when there is braking and the distance between mass 1 with mass 2 with parameters already given.
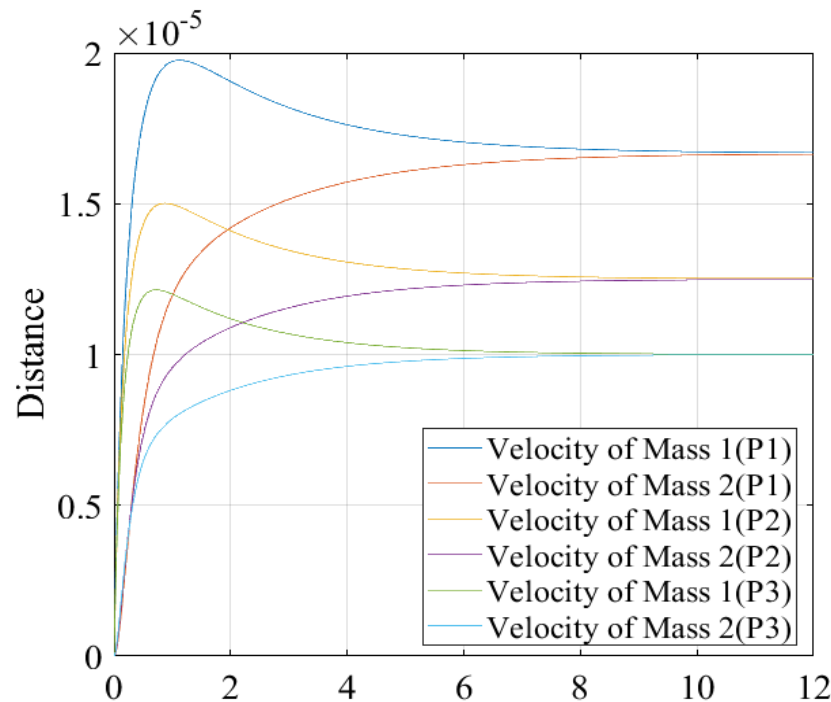
Figure 3. Graph of speed simulation with three different parameters.

From Figure 3 we see the output of mass velocity 1 and mass 2. Although in the initial conditions the speeds of m_1 and m_2 are different, but in steady state the two masses have the same speed. From Figure 3 it can also be seen that by using large dumper and spring constant values, the time needed to reach steady state is faster.
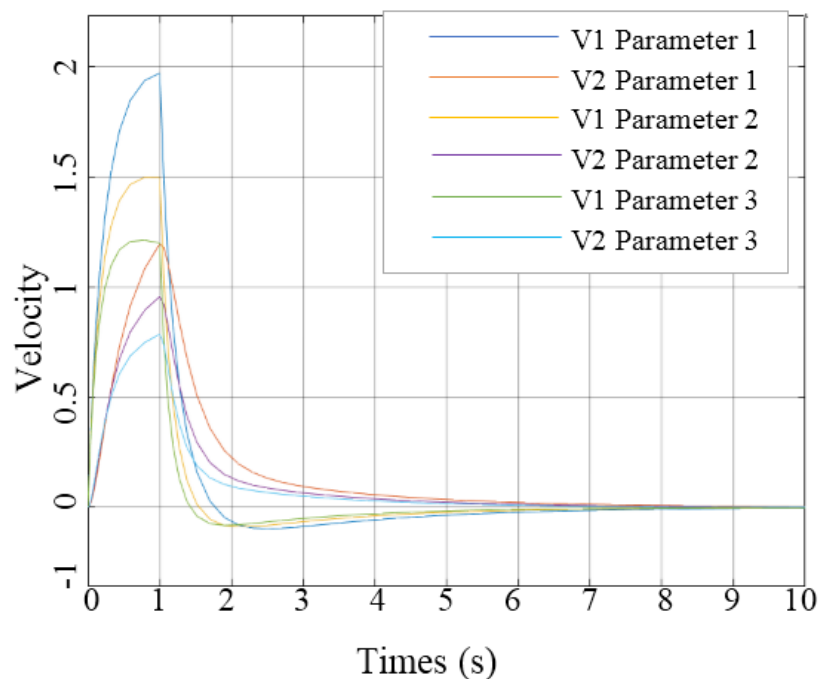

Figure 4. Graph of speed comparison simulation when Braking Occurs with three different parameters.

Figure 4 shown the output of mass velocity 1 and mass 2 when braking occurs. It is apparent that the mass velocity of 1 is decreased faster than mass velocity 2 but in steady state the two masses have the same velocity. From Figure 4 it can also be seen that by using large values, the time required to get to steady state is faster.
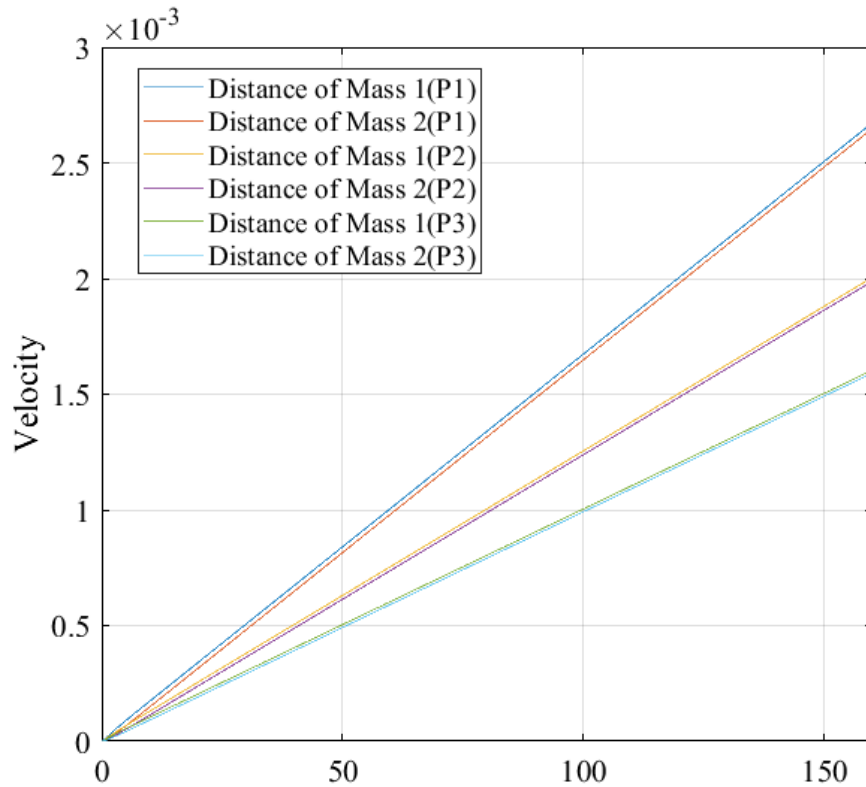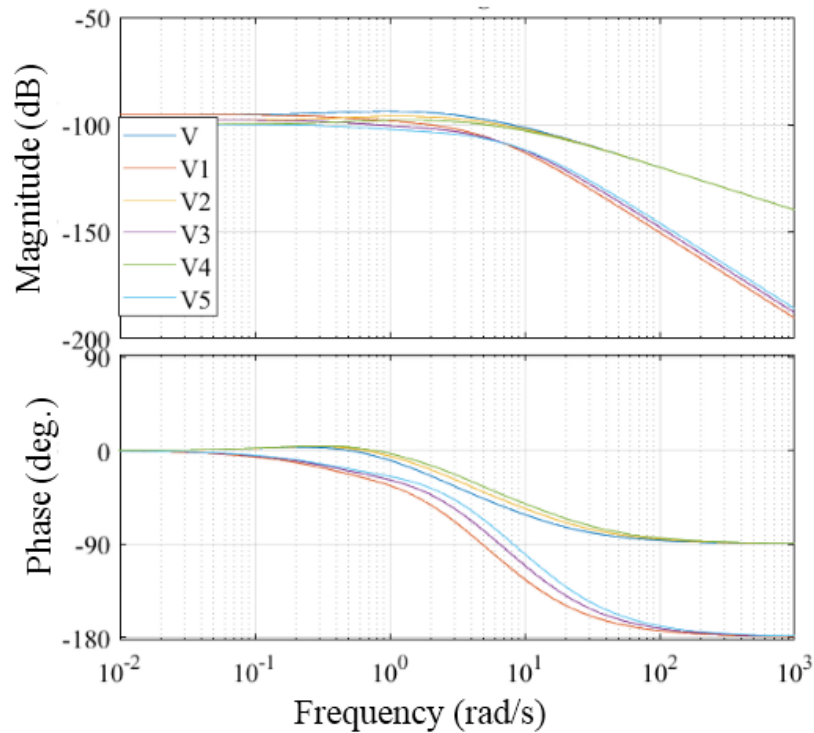

Figure 5. Graph of the distance between mass 1 and mass 2.

From Figure 5 that the distance difference between the two masses tends to be stable or in other words there is still a distance between mass 1 and mass 2.
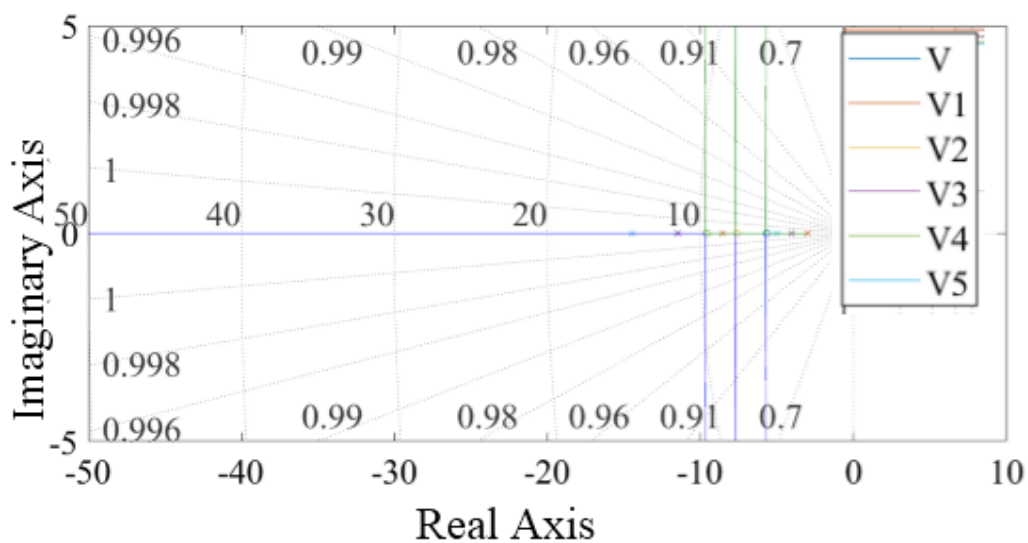
Figure 6. Root Locus with variation damping coefficient

Figure 7. Bode Plot with variation damping coefficient

From Figure 6 and Figure 7, by looking at the location of the roots of the characteristic equation and the bode plot. It is seen that in mass 1 by looking at the position of the roots having a complex root value, the system will tend to be underdamped (overshoot) and at mass 2 with the corresponding spring and damper values of the parameters get the over damped system response. The results can also be seen that the response of the system tends to be more stable because it has a pole and zero value on the left. As well as the frequency response analysis using a bode plot. The greater the damping coefficient and the spring then the system will tend to be more quickly stable.

6. Conclusion
From the results of the graph analysis can be concluded that the damped oscillations are influenced by the spring constants and the steady constants. From the graph also, we can know that with the constant increase of constant spring and damper the higher attenuation is proved by the decreasing graph value in graph 3 we also know the effect of damper counter to steady state time faster.

Acknowledgments

References
[1] Benaroya, Haym Han, Nagurka, Mark L., "Mechanical vibration: analysis, uncertainties, and control," CRC Press 2018
[2] Jorge Angeles, "Dynamic Response of Linear Mechanical Systems_ Modeling, Analysis and Simulation-Springer," US, 2012

[3] To, Cho W. S, "Introduction to Dynamics and Control in Mechanical Engineering Systems," Wiley-ASME, 2016

[4] William Palm III "System Dynamics," McGraw-Hill Education. 2013

[5]   C. Mei, "On Teaching the Simplification of Block Diagrams," *Int. J. Engng Ed. Vol. 18, No. 6, pp. 697-703, 2002*

[6] P. Flores, J. Ambro sio, J.C.P. Claro, H.M. Lankarani, C.S. Koshy, "A study on dynamics of mechanical systems including joints," *Sience Direct*, Mechanism and Machine Theory 41, pp 247–261, 2006.

[7] Katsuhiko Ogata, "Modern Control Engineering," ,Prentice Hal, 2010

[8] Mobil Truk Besar Gandeng Luar Negri | Mobil Truk. (n.d.). Retrieved November 27, 2018, from http://trukaz.com/326/mobil-truk-besar-gandeng-penting-diketahui.html/mobil-truk-besar-gandeng-luar-negri