Mass spring damper system

Next: Discrete Time/Frequency Analysis Up: Lectures Previous: Physics Review Simple Harmonic Motion Ideal Mass: Motion ideal mass does not affect friction or any other damping force. The ideal mass is perfectly firm. With Newton's Second Law: Ideal Spring: Ideal for spring is no mass or inner damping. Hooke's Law: (suitable for small, non-distortive displacements) Spring day equilibrium is determined. A positive value produces a negative restore force. Ideal mass spring system: Figure 1: ideal mass spring system. System equation: This second-order differential equation has form solutions . is the characteristic (or natural) angular frequency of the system. and are determined by initial displacement and speed. There are no losses in the system, so it will fluctuate forever. Energy in the ideal mass-spring system: the potential energy () of an ideal mass spring system is equal to the work done by stretching or compressing spring: . The ideal mass of the spring system kinetic energy () is calculated by mass movement: . The total energy of the ideal spring system is constant: at the extreme points of its displacement, the mass is at rest and has no kinetic energy. At the same time spring is maximum compressed or stretched, and thus stores all the system's mechanical energy as potential energy. When the mass is in motion and reaches the spring equilibrium position, the mechanical energy of the system is completely converted to kinetic energy. All vibration systems consist of this interaction between the energy storage component and the energy transport (mass) component. Damping Ideal mechanical resistance: The mechanical resistance or viscosity force is usually zoomed in as proportional to the speed: ideal mass spring shock absorber system: Figure 2: ideal mass spring shock absorber system. System equation: This second-order differential equation has form solutions . Figure 3: Decay sinusoids. is a decay constant and is the characteristic (or natural) angular frequency of the system. and are determined by initial displacement and speed. The natural frequency is lower than for the mass spring system (). Helmoltz Resonator Figure 4: Helmholtze Resonator and its mechanical correlate. An open pipe at low frequency is directly corathed by mechanical mass. At the low frequency limit, the cavity is direct acoustic corath with the mechanical spring. Using Newton's Second Law to simulate air mass in the tube and hook law fluids to simulate air cavity compressibility, the sinusoidal solution can be found with a natural frequency, where there is a sound velocity in the air, is the cross-sectional area of the pipe, has a pipe length, and it is the volume of the cavity. Single mass two spring system Movement (along the x axis): Figure 5: single-mass two-spring system: longitudinal movement. Net regenerative force per mass: Natural frequency of the system: transverse movement (along the y-axis): Figure 6: single-mass, two-spring system: vertical movement. If the springs are initially stretched much of their relaxed length (but not distorted), the vibration frequency is almost the same as longitudinal vibrations. If the springs are initially stretched very little of their relaxed length, the natural frequency is much lower and the vibrations are nonlinear (nonsinusoidal) for all but the smallest of the -axis displacements. Longitudinal movement of the two-mass three-per-one system (along the x axis): Figure 7: two-mass three-spring system: longitudinal movement. Natural frequencies: , where several mass systems Each additional mass adds another natural vibration mode to the axis of motion. This type of analysis is called one-off characteristics. Basic elements of the mechanical system. The basic elements of any mechanical system shall be the mass, spring and shock absorber or damper. The study of motion in mechanical systems shall correspond to the analysis of dynamic systems. In robotics, for example, the word Forward Dynamic refers to what happens to actuators when we apply certain forces and torques to them. The mass, spring and damper are the basic propulsion of the mechanical systems. Consequently, in order to control the robot, it is very necessary to know very well the nature of the movement of the mass spring shock absorber system. Moreover, this framework is set out in many areas of application and therefore the importance of its analysis. Again, in robotics, when we talk about inverse Dynamic, we talk about how to make a robot move in the desired way, what forces and torques we have to apply to actuators so that our robot moves in a certain way. Attention! I recommend the book I have written it after grouping, ordering and addressing the most common teaching books that are used in the university classes of Systems Engineering Control, Mechanics, Electronics, Mechatronics and Electromechanics, among others. If you need to acquire problem solving skills, this is a great opportunity to train and be effective in submitting exams, or have a solid foundation to start a career in this area. Take a look at the Index at the end of this article. Before performing the dynamic analysis of our spring shock absorber system, we need to obtain its mathematical model. This is the first step to be taken by anyone who wants to know the in-depth dynamics of the system, especially the behavior of its mechanical components. We will start our study with a mass spring system model. It is convenient for the following reason. All mechanical systems have the nature of their movements, which drives them fluctuating, as when the object hangs from the thread to and by hand we push it. Or shoes on the platform with springs. It is good to know which mathematical function best describes this movement. But it turns out that the fluctuations in our examples are not endless. There is a frictional force that reduces movement. In the case of an object hanging from the thread is air, liquid. So, studying the case of the perfect mass of the spring system, without dampening, we will take into account this frictional force and add a function already found a new factor that describes the decay movement. Mass spring system. Figure 5 The dynamics of the system are first represented by a mathematical model consisting of differential equations. For the mass spring system, said the equation is this: This equation is known as the equation for motion in a simple harmonic Oscillator. Let's see where it is derived from. If our intention is to get a formula that describes the power created by spring against movement that stretches or shrinks, the best way is to visualize the potential energy that is injected into the spring when we try to stretch it or shrink. This graph describes how this energy works as a horizontal displacement function. , the value corresponding to the maximum spring extension or compression. The mathematical equation that best describes in practice this form of the curve, including a constant k for the physical property of the material, which increases or decreases the slope of that curve, is as follows: the force is related to the potential energy as follows: Therefore: It is appropriate to see that F (x) is inversely proportional to the mass m displacement. Because it is clear that if we stretch in the spring, or shrink it, this force opposes this action, trying to return to spring in its relaxed or natural state. For this reason, it is called restitution. The above equation is known in the Academy as Hooke's Law, or the Power of The Law Springs. The following is a representative diagram of that force, for energy, as it was mentioned, without interference by frictional forces (damping), and therefore it is known as the Simple Harmonic Oscillator. It is important to emphasize the proportional relationship between displacement and force, but with a negative inclination, and that in practice it is more complex than linear. Source: Física. Robert Resnick For an animated analysis of spring, short, simple but forceful, I recommend watching the following video: Potential energy in spring, restore strength of spring AND STAGE: SECOND ORDER II (Mathlets) Amplitude-and-Phase-2nd-Order-II Returning to Figure 5: We're going to Newton's Second Law: This equation tells us that the vector amount of all forces that operate on body weight m is equal to the product value of that mass due to its acceleration obtained due to that force. Given that our spring mass system, ΣF=-kx, and remembering that acceleration is the second derivative of relocation, by applying Newton's Second Law we get the following equation: Fixing things a bit, we get the equation we wanted to get from the beginning: This equation is the dynamics of the ideal Mass-Spring System. Apart from Picture 5, another common way to represent this system is through the following configuration: In this case, we must take into account the effect of weight on the amount of force acting on the body m. Weight P is determined by the equation P = m.g, where g is the value of body acceleration in free fall. If the mass is pulled down and then released, the rejuvenating force of spring works, causing acceleration ÿ body weight m. We acquire the following relationship by applying Newton: If we implicitly consider the static deviation, that is, if we take measurements of the equilibrium level of mass hanging from spring without moving, then we can ignore and discard the effects of weight P equation. If we y =x, we take this equation again: Mass-spring-damr system If there is no friction effect, a simple harmonic oscillator fluctuates indefinitely. In fact, the amplitude of fluctuations gradually decreases, a process known as damping, which is graphically described as follows: the displacement of the start-up movement is depicted against time, and its amplitude is represented by a sinusoidal function, which is reduced by the decrease in exponential factor in the graph in the form of an envelope. The friction effect of Fv running amortized Harmonic movement is proportional to the speed of V in most cases of scientific interest. This force is the form Fv = bV, where b is a positive constant, which depends on the properties of the fluid that causes friction. This friction, also known as Viscose friction, is depicted in a diagram consisting of a piston and a cylinder filled with oil: The most popular way to represent the mass spring shock absorber system is through a series of compounds such as: Figura 6 As follows: In both cases, the same result is obtained by applying our method of analysis. Taking into account Figure 6, we can observe that it is the same configuration as shown in Figure 5, but with the addition of shock absorber effects. Applying Newton's second law to this new system, we acquire the following relationship: This equation reflects the dynamics of the Mass-Spring-Damper System. Laplace transform The system solution for equation (37) is shown below: the equation (38) clearly shows what was previously observed. The example of Matlab can be simulated by the following procedure: the shape of the displacement curve in the mass spring absorber system represents a sinusoid, which is determined by a decreasing exponential factor. It is important to understand that in the previous case the system does not apply force, so the behavior of this system can be classified as a natural behavior (also called a homogeneous reaction). Later, we will set an example by applying force to the system (one step), which creates coercive behavior that affects the system's ultimate behavior, which will be the result of both the addition of behavior (natural + forced). Note: If the system is pressed, the right side of the equation (37) is no longer equal to zero and the equation is no longer homogeneous. The solution of the above equation (37) can be obtained by the traditional method to solve the differential equations. However, this method is impractical when we are faced with more complex systems, such as the following, which also applies the force f(t) : Figura 7 The need arises for a more practical method to find system dynamics and facilitate further analysis of their behaviour through computer simulation. Laplace Transform allows you to achieve this goal quickly and firmly. It is not easy to clear x(t) in the equation (37), which in this case is the output and percentage function. The differential equation cannot be represented as a flowchart, which is the language most used by engineers to model systems, transforming something complex into a visual object more easily understandable and analysable. The first step is to clearly separate the output function x(t), the input function f(t) and the system function (also called transfer functions) reaching the following representation: r(t) = f(t), c(t) = x (t) Transform consists of changing the function of interest from time to domain using the following equation: The main advantage of these changes is that it transforms derivatives into addition and subtraction , then through associations we can clarify the function of interests by applying simple algebra rules. In addition, it is not necessary to apply the equation (2.1) to all the functions f(t) we find when tables are available that already indicate a function conversion that occurs at high frequency in all phenomena, such as sinusoids (mass system power, spring and shock absorber) or stepway function (input reflecting sudden changes). As for our basic elements of the mechanical system, ie: mass, spring and damper, we have the following table: That is, we apply a force diagram for each mass unit of the system, we the frequency equivalent of each force in a timely basis (called resistance in the table by analogy between mechanical systems and electrical systems) and the superposition property is applied (each movement shall be examined separately and then added to the result). Figure 2.15 shows the site transformation of the mass spring shock absorber system, the dynamics of which are described by a single differential equation: the 7th figure system allows to describe a fairly practical general method of finding a laplace transformation for systems with multiple differential equations. First, a force chart is applied to each mass unit: in Figure 7, we are interested in finding out the transfer function G(s)=X2(s)/F(s). By arranging the matrix in the form of equation movements we acquire as follows: Equations (2118a) and (2118b) show a pattern that is always true and can be applied to any mass-spring shock absorber system: The immediate effect of the previous method is that it greatly facilitates the production of equations of motion mass in the spring shock absorber system, unlike what happens to differential equations. In addition, we can quickly achieve the necessary solution. In our example case: Where: These are the results of the application of the linear Algebra rules, which give great computing power to the Laplace Transform method. Examples of applications ... under construction, example 1. Exercise B318, Modern_Control_Engineering, Ogata 4t p 149 (162), Answer Link: Ejemplo 1 – Función Transferencia de Sistema masa-resorte-amortiguador Example 2. Control Systems Engineering, Nise, p 101 Answer Link: Ejemplo 2 – Función Transferencia de sistema masa-resorte-amortiguador Rotary case So far, only the translation case has been considered. In case the displacement is rotating, the following table summarizes the application of the Laplace transform in this case: Example: The following figures show how to make a force chart in this case: Therefore: Being: We see that again it is true that: Bibliography: Robert Resnick, Tomo1 Dinamica_de_Sistemas, Katsuhiko Ogata Control Systems Engineering, Norman Nise Sistemas de Control Automatico, Benjamin Kuo Ingenieria de Control Moderna, 3° ED. I recommend the book I have written it after grouping, ordering and addressing the most common teaching books that are used in the university classes of Systems Engineering Control, Mechanics, Electronics, Mechatronics and Electromechanics, among others. If you need to acquire problem solving skills, this is a great opportunity to train and be effective in submitting exams, or have a solid foundation to start a career in this area. INDEX Ii introduction (iii)

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