Mass Spring Damper System Modelling and MATLAB Simulation

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***Abstract* — The main goal of our work is to explore the relative motion and the behavior of the system corresponding to an external, constant load that attaches to the system at time t = 0. This will explore strictly the longitudinal motion of the system. Therefore, it neglects all the other influences of the gravitational pull, aerodynamic drag, other influences as well as no form of lateral displacement and spinning will be taken place during the experiment. In effect, the attention will be based on the relative motion caused by stiffness and damping of the spring.To get the equations of motion of this system, the approach of Newtonian mechanics can be utilized. According to Newtonian mechanics, the mass of each mass in the system is considered. Then by using Newton's second law of motion, the second-order differential equations can be developed that can explain the relationships between the position, velocity, acceleration, spring force, and damping force.To analyze the system's behavior over time, a simulation framework is created in MATLAB and Simulink. While MATLAB m-files set up the system matrices and perform time domain analysis, Simulink allows to observe the interconnections of the mechanical jigsaw and monitor the evolution of the system states over time.**

***Index Terms* — Mechanical system modeling, mass-spring-damper system, Newtonian mechanics, state-space representation, MATLAB simulation, Simulink modeling, system dynamics, vibration analysis, transient response, dynamic system simulation, multi-degree-of-freedom system, control systems, damping and stiffness, system response analysis, engineering mechanics.**

INTRODUCTION

The engineering field is common in the field of automatic suspension systems. This is due to the availability of masses, springs, and dampers in the engineering field. The modelling and simulation of these kinds of mechanics help us to predict the efficiency and the effectiveness of these kinds of systems when used in different conditions. The expectations of the systems can also be determined after simulating the system. This study focuses on the determination of a mechanical system consisting of several masses connected by springs and dampers. This will involve the simulation, modeling and mathematical analysis of the system.The primary focus of this analysis will be the system's dynamic response to a sudden and constant vertical load applied at the same instant in time at t = 0. It will also be assumed that all forces, other than the applied load, are negligible. The analysis will only consider strictly vertical motion, neglecting any lateral movement or the effects of gravity and air resistance in order to simplify the problem.Formulating the equations of motion for each mass involves applying Newton's second law by using Newtonian mechanics. The system equations of spring stiffness and damping forces are then used to combine the equations to form a completed mathematical model of the mechanical system.

In this study, the computational and simulation is structured using MATLAB and Simulink. This is through the use of MATLAB scripts to implement the system parameters and the state-space model, as well as analyze the time-domain results. The real-time interaction between the masses, springs, and dampers is simulated using Simulink, where the simulation allows the observation of time response such as displacement and velocity of each mass. This enables the evaluation of the damping effectiveness, the oscillatory motion, and the stability of the system.

I. Mass Spring Damper System

The Mass-Spring-Damper system is a very important mechanical system that is used to study vibrations, damping, and oscillatory systems. The system comprises of one or more masses connected through a spring and a damper. The purpose of this system is to model actual mechanical systems. These systems are widely used in the design of control systems, suspension systems, automotive engineering, robotics, structural analysis, etc.

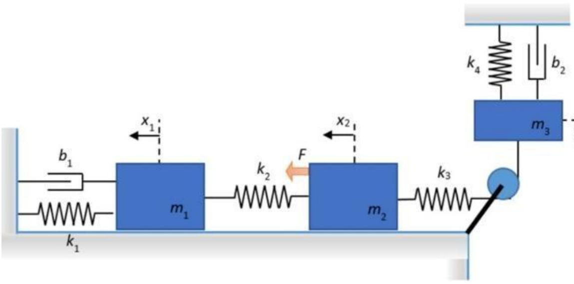

Fig1.**Diagram Of the Specified Mechanical System**

Purpose of Modeling

Modeling such systems helps:

i. Understand dynamic behavior under various inputs.

ii. Analyze the response to forces, displacements, or disturbances.

iii. Design controllers or damping mechanisms for stability and performance.

Types of Systems

i. Single-Degree-of-Freedom (SDOF): A single mass is connected to a spring and damper. The purpose is to explain the basic concepts of harmonic motion.

ii. Multi-Degree-of-Freedom (MDOF): In Multi-Degree-of-Freedom (MDOF) systems, there are several interconnected masses in the system.

Mathematical Approach

The system is simulated with the help of a programmed computer. Newton's laws or Lagrange equations are used to derive differential equations of motion. These equations are differential second-order equations for which the second differential equation is linear, and hence it can be converted to state equations.

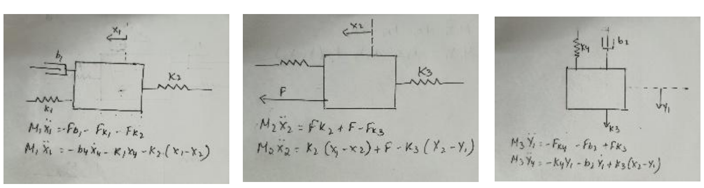

Fig3. Free-Body Diagram and Motion Equations

Simulation and Analysis

By using the software tools like Simulink, the response of the system to a variety of forces such as step, impulse and more can be observed. Some of them are:

i. Displacement and velocity of each mass.

ii. Effect of damping on oscillations.

iii. System stability and resonance behavior.

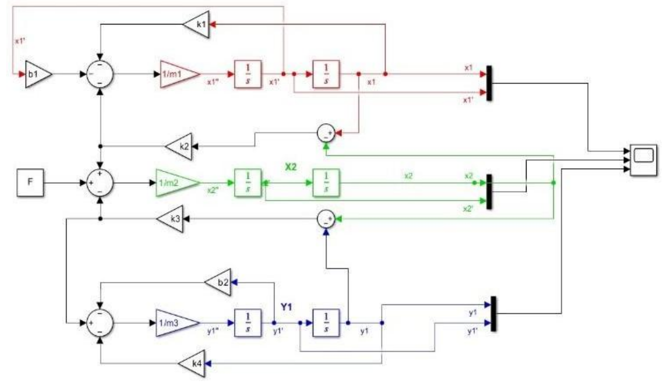

Fig3 . **Si**mulink Block Diagram

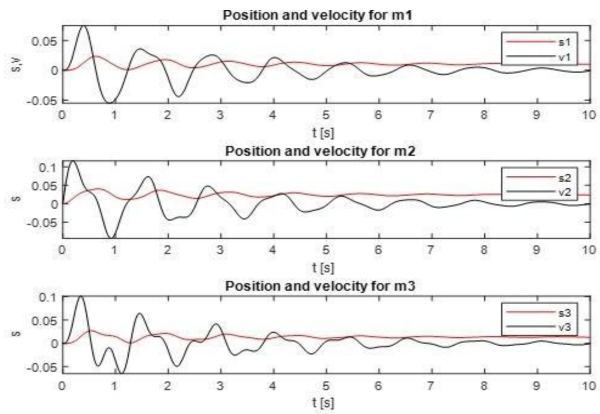

Fig4. Graphical Output of Simulink Block Diagram

II. Methodology

The objective of this work is to model, analyze, and simulate a multi-degree-of-freedom (MDOF) mechanical system consisting of masses, springs, and dampers. The methodology is a systematic approach with mechanical modeling based on Newtonian mechanics and simulation and analysis done in MATLAB and Simulink. Emotions are not always discrete; they exist on a spectrum and can be influenced by multiple factors, leading to classification errors. Current SER models struggle with accurately distinguishing between similar emotions (e.g., anger vs. frustration, happiness vs. excitement). Hybrid emotion classification models incorporating continuous emotion dimensions (valence, arousal) could be explored.

1. System Analysis and Assumptions.

The mechanical system consists of three masses:

i. M1=0.2kg

ii. M2=0.15kg

iii. M3=0.1kg

Springs k1 to k4 and dampers b1,b2 are used to connect the masses. An external F=0.15N is applied to mass m2.

Assumptions:

- The system is idealized.
- Gravity, air resistance, and lateral deflection are neglected.
- Only longitudinal (1D) motion is considered:

a. $x1(t)$: displacement of m1 (horizontal)
b. $x2(t)$: displacement of m2 (horizontal)
c. $y1(t)$: displacement of m3 (vertical)

2. Free-Body Diagram and Equation Derivation
Using Newton's Second Law, the equations of motion are derived as follows:
For mass M1:

$$M1x1= -k1x1-b1x1+k2(x2-x1)$$

For mass M2:

$$M2x2= -k2(x2-x1)-k3(x2-y1) + F$$

For mass m3:

$$M3y1= -k4y1-b2y1+k3(x2-y1)$$

These are the three coupled second order differential equations defining the system dynamics.

3. Conversion to State- Space Representation
Each second-order equation is rewritten as two first-order differential equations. Define the state vector:

$$X= \begin{pmatrix} x1 \\ \overline{x}1 \\ x2 \\ \overline{x}2 \\ y1 \\ \overline{y}1 \end{pmatrix}$$

The system is expressed in standard state-space form:

$$X=AX + Bu$$
$$Y=CX + Du$$

4. MATLAB and Simulink Implementation.
The model is implemented in MATLAB using numerical solvers such as ode45 or ode23s.
A Simulink model is also built with the following components:
i. **Integrator blocks**: to represent displacement and velocity.
ii. **Gain blocks**: for spring constants and damping coefficients.
iii. **Sum blocks**: to compute net forces.
iv. **Step input block**: to simulate external force F(t) applied at t=0.

5. **Simulation and Response Analysis**
i. Simulation is performed for a time range of 0 to 10 seconds.
ii. The displacements of all three masses are plotted over time.
iii. Oscillation decay due to damping.
iv. Coupling effects between horizontal and vertical movements.
v. The influence of different spring stiffness and damping coefficients on the dynamic response.

6. Coupling effects between horizontal and vertical movements.
The influence of different spring stiffness and damping coefficients on the dynamic response.

iii. The following behaviours are observed and analysed :

iii. CONCLUSION

This modeled and simulated an external force excited multi-mass spring-damper system with analytical techniques, state-space modeling, and implementation using matlab & simulink. The outcome provides a robust basis for the investigation of complex control methods for vibration and motion control and design parameter optimization of complex mechanical systems. this research fills the gap between theoretical analysis and simulation application, which provides a pathway towards future development in mechanical engineering.

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