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SIMULATION OF MECHANICAL COMPONENTS INTEGRATED ACCELEROMETERS
МОДЕЛЮВАННЯ МЕХАНІЧНИХ КОМПОНЕНТІВ ІНТЕГРАЛЬНИХ АКСЕЛЕРОМЕТРІВ

In the paper the model of integrated accelerometer is presented. Obtained in an analytical form solution of the differential equation describing this model.

Key words: integral accelerometer, mathematical model, differential equation, boundary conditions.

Подано моделі інтегрованого акселерометра. Отримано в аналітичному вигляді рішення диференціального рівняння, що описує цю модель.

Ключові слова: інтегральний акселерометр, математична модель, диференціальне рівняння, граничні умови.

Introduction

Accelerometer – this device, which measure acceleration or overloads that occur during testing of vehicles and their systems. Single– and multi-axle models can determine the magnitude and direction of the acceleration as a vector quantity and can therefore be used to determine the orientation, vibration and shock. They are used in many portable electronic devices.

The accelerometer measures the projection of the full acceleration. Full acceleration is the resultant of the forces of nature nehravitatsiynoyi acting on the mass, referred to the value of the mass. The accelerometer can be used both to measure the projection of the absolute linear acceleration and mediocre projection of the gravitational acceleration. The latter property is used to create inclinometers. Accelerometer is a member of inertial navigation systems that are obtained by measuring their integrated to give the inertial velocity and coordinates media.

Model of integral accelerometer

According to the analysis of existing models of accelerometers, most of the models include ordinary differential equations of second order [1]. These models are based on consolidated mikroakselerometra to design circuits with lumped parameter spring-mass-damper [2], an example of which is given on (Fig. 1). Accordingly, for such a system of differential equations for the displacement axis is a function of the external acceleration:

$$m_x \frac{d^2x}{dt^2} + B_x \frac{dx}{dt} + k_x x = F_{zovn}, \qquad (1)$$
$$F_{zovn} = ma_{zovn}$$

k_x – spring stiffness; B_x – damping coefficient; m_x – mass; a_{zovn} – applied acceleration to the inertial mass of the accelerometer; x – displacement; F_{zovn}, – external force that is applied to the inertial mass of the accelerometer;

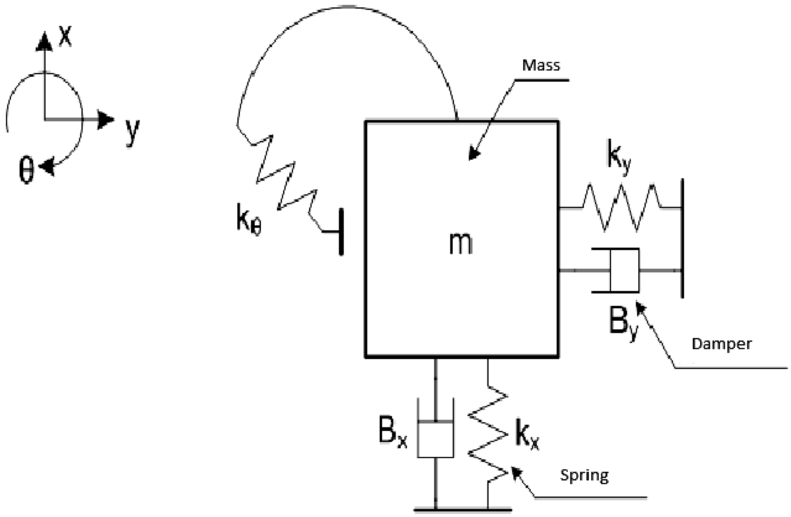

Fig. 1. Model of a spring-mass-damper for integrated accelerometer

For the general solution of differential equations of 2nd order (1) we use the method of Lagrange. Then divide the equation (1) for at for the quadratic equation (4). A common method for solving quadratic equations using discriminant (5) and look for two factors (6 and 7, respectively). The next step is using the found coefficients derive the general form of equation (9), which uses the method of variation of constant steady for finding intermediate differential equation coefficients C3 and C4, using which we find supporting characteristic equation and substitute it into the general equation (20).

$$m_x \frac{d^2x}{dt^2} + B_x \frac{dx}{dt} + k_x x = m_x a / m_x \quad (2)$$

$$\frac{d^2x}{dt^2} + \frac{B_x}{m_x}\frac{dx}{dt} + \frac{k_x}{m_x} x = a \quad (3)$$

$$k^2 + \frac{B_x}{m_x} k + \frac{k_x}{m_x} = 0 \quad (4)$$

$$D = (\frac{B_x}{m_x})^2 - 4\frac{k_x}{m_x} \quad (5)$$

$$k_1 = \frac{-\frac{B_x}{m_x} + \sqrt{D}}{2} \quad (6)$$

$$k_1 = \frac{-\frac{B_x}{m_x} - \sqrt{D}}{2} \quad (7)$$

$$y = y^{-} + y* \quad (8)$$

$$y = C_1 e^{k_1 x} + C_2 e^{k_2 x} \quad (9)$$

$$C_3'(x) e^{k_1 x} + C_4'(x) e^{k_2 x} = 0 \quad (10)$$

$$C_3'(x) k_1 e^{k_1 x} + C_4'(x) k_2 e^{k_2 x} = a \quad (11)$$

$$\Delta = \begin{vmatrix} e^{k_1 x} & e^{k_2 x} \\ k_1 e^{k1x} & k_2 e^{k_2 x} \end{vmatrix} = k_2 e^{(k_2+k_1)x} - k_1 e^{(k_2+k_1)x} = e^{(k_2+k_1)x}(k_2 - k_1) \quad (12)$$

$$\Delta C_3'(x) = \begin{vmatrix} 0 & e^{k_2 x} \\ a & k_2 e^{k_2 x} \end{vmatrix} = -a e^{k_2 x} \quad (13)$$

$$\Delta C_4'(x) = \begin{vmatrix} e^{k1x} & 0 \\ k_1 e^{k_1 x} & a \end{vmatrix} = ae^{k_1 x} \qquad (14)$$

$$C_3'(x) = \frac{\Delta C_3'(x)}{\Delta} = \frac{-ae^{k_2 x}}{e^{(k_1+k_2)x}(k_2 - k_1)} = \frac{-ae^{k_1 x}}{k_2 - k_1} \qquad (15)$$

$$C_4'(x) = \frac{\Delta C_4'(x)}{\Delta} = \frac{ae^{k_1 x}}{e^{(k_1+k_2)x}(k_2 - k_1)} = \frac{ae^{-k_2 x}}{k_2 - k_1} \qquad (16)$$

$$C_3(x) = \int \frac{-ae^{-k_1 x}}{k_2 - k_1} dx = \frac{ae^{-k_1 x}}{k_1(k_2 - k_1)} \qquad (17)$$

$$C_4(x) = \int \frac{ae^{-k_2 x}}{k_2 - k_1} dx = -\frac{ae^{-k_2 x}}{k_2(k_2 - k_1)} \qquad (18)$$

$$y^- = C_3(x)e^{k_1 x} + C_4(x)e^{k_2 x} = \frac{a}{k_1(k_2 - k_1)} - \frac{a}{k_2(k_2 - k_1)} = \frac{a(k_2 - k_1)}{k_2 k_1 (k_2 - k_1)} = \frac{a}{k_2 k_1} \qquad (19)$$

$$y = C_1 e^{k_1 x} + C_2 e^{k_2 x} + \frac{a}{k_2 k_1} \qquad (20)$$

$$k_2 k_1 = \frac{k_x}{m_x} \qquad (21)$$

Next, we introduce boundary conditions and substitute them into the equation solving them. We find two equations resulting permutations and use them to determine the coefficients of differential equations C1 and C2 (32 and 33 respectively) by the same constant variations constants.

$$y(0) = 0; y'(T) = X : boundary - conditions \qquad (22)$$

$$y(0) = C_1 e^{k_1 * 0} + C_2 e^{k_2 * 0} + \frac{a}{k_x m_x} = C_1 + C_2 + \frac{m_x a}{k_x} \qquad (23)$$

$$C_1 + C_2 + \frac{m_x a}{k_x} = 0 \qquad (24)$$

$$y'(T) = C_1 k_1 e^{k_1 * T} + C_2 k_2 e^{k_2 * T} \qquad (25)$$

$$C_1 k_1 e^{k_1 * T} + C_2 k_2 e^{k_2 * T} = X \qquad (26)$$

$$C_1 + C_2 + \frac{m_x a}{k_x} = 0 \qquad (27)$$

$$C_1 k_1 e^{k_1 * T} + C_2 k_2 e^{k_2 * T} = X \qquad (28)$$

$$\Delta = \begin{vmatrix} 1 & 1 \\ k_1 e^{k1T} & k_2 e^{k_2 T} \end{vmatrix} = k_2 e^{k_2 T} - k_1 e^{k_1 T} \qquad (29)$$

$$\Delta C_1 = \begin{vmatrix} -\frac{m_x a}{k_x} & 1 \\ X & k_2 e^{k_2 T} \end{vmatrix} = -\frac{m_x a}{k_x} k_2 e^{k_2 T} - X \qquad (30)$$

$$\Delta C_2 = \begin{vmatrix} 1 & -\frac{m_x a}{k_x} \\ k_1 e^{k_1 x} & X \end{vmatrix} = X + \frac{m_x a}{k_x} k_1 e^{k_1 x} \qquad (31)$$

$$C_1 = \frac{\Delta C_1}{\Delta} = \frac{-\frac{m_x a}{k_x} k_2 e^{k_2 T} - X}{k_2 e^{k_2 T} - k_1 e^{k_1 T}} \qquad (32)$$

$$C_2 = \frac{\Delta C_2}{\Delta} = \frac{\frac{m_x a}{k_x} k_1 e^{k_1 T} + X}{k_2 e^{k_2 T} - k_1 e^{k_1 T}} \qquad (33)$$

Substitute the above characteristics are found in the final solution (34) to find the general solution of the equation.

$$y = C_1 e^{k_1 x} + C_2 e^{k_2 x} + \frac{m_x a}{k_x} \quad (34)$$

Thus obtained in an analytical form solution of the differential equation describing the model is integrated accelerometer.

Conclusion

The developed model is implemented in the educational system simulation of MEMS sensors, which includes a monitor system, a database, subsystem modeling, visualization subsystem and subsystem analysis of simulation results. Comparison of simulation results with experimental data confirm the feasibility of its use for structural design of integrated accelerometers.

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EFFECT OF IMPACT VELOCITY IN THE ROADBLOCK ON THE SPATIAL ARRANGEMENT OF ACCELERATION OF THE VEHICLE BODY

ВПЛИВ ШВИДКОСТІ УДАРУ В КОНТРОЛЬНО-ПРОПУСКНОМУ ПУНКТІ НА ПРОСТОРОВОМУ РОЗТАШУВАННІ ПРИСКОРЕННЯ КУЗОВА ТРАНСПОРТНОГО ЗАСОБУ

The article presents the results of experimental studies of the process of intense acceleration, passing through the barrier and the vehicle brakes adapted for the transport of persons using two speed ranges passing through the barrier. Tests were conducted on dry roads made of cobblestones. Performed experimental studies, which aim was to determine the acceleration in each axis while passing through the obstacle.

Key words: barrier, impulse of force, tire, suspension, acceleration.

Подано результати експериментальних досліджень процесу інтенсивного прискорення, що проходять через бар'єр і транспортний засіб, гальма пристосовані для перевезення осіб з використанням двох діапазонів швидкостей, проходячи через бар'єр. Випробування проводилися на сухих дорогах з бруківки. Виконані експериментальні дослідження, мета яких – визначити прискорення в кожній осі при проходженні через перешкоди.

Ключові слова: бар'єр, імпульс сили, шини, підвіска, прискорення.

Introduction

Land transport of goods and services is a strategic sector of the economy. Transport routes often cross, which leads to the need to ensure the safety of different vehicles. This is the example. Intersections of road transport and rail. The present infrastructure crossings and track tram, which may constitute