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MODELING METHOD FOR MECHANICAL MICROSYSTEMS ELEMENTS

The application of diacoptic method during design of complicated mechanical systems on the stage of dynamic analysis are examined. The method of forming and solving of equalizations describing dynamic processes in the complicated mechanical systems is developed.

Key words: diacoptic method, dynamic processes.

Розглянуто застосування діаскопічного методу під час проектування складних механічних систем на стадії динамічного аналізу. Розроблено метод формування та розв'язання тотожностей, що описує динамічні процеси у складних механічних системах.

Ключові слова: діаскопічний метод, динамічні процеси.

Introduction

System approach to the computer-aided design of an object with a given set of properties requires the construction of a mathematical model, which reflects the influence of several significant factors (including their relationship and subordination) on forming the initial characteristics of the device.

One of the important aspect of simulation is the need to consider a set of different physical processes occurring in the system. Among them are mechanical processes that significantly affect the operation of MEMS.

Furthermore, the use of traditional methods makes it difficult to apply evolutionary approach to the design process, which is the basis of object-oriented design (OOD), and does not allow to fully consume the benefits of object-oriented design that is the use of expressive object-oriented programming languages, to support reusage of separate software components, to create more open systems.

Development of modeling method

From a mechanical standpoint components of modern MEMS should be presented in the form of systems with distributed parameters. Mechanical processes in them are described with a system of differential equations in partial derivatives that bind displacement, strain and elasticity (1):

- the relationship between strains and generalized displacements

$$e_1 = \frac{\partial U_1}{\partial x}, \quad e_2 = \frac{\partial U_2}{\partial x}, \quad e_{12} = \frac{\partial U_2}{\partial x} + \frac{\partial U_1}{\partial y},$$

$$e_{13} = g_1 + \frac{\partial w}{\partial x}, \quad e_{23} = g_2 + \frac{\partial w}{\partial y}, \tag{1}$$

$$H_1 = \frac{\partial g_1}{\partial x}, \quad H_2 = \frac{\partial g_2}{\partial y}, \quad 2H_{12} = \frac{\partial g_2}{\partial x} + \frac{\partial g_1}{\partial y};$$

- equilibrium equation

$$\frac{\partial N_1}{\partial x} + \frac{\partial S_{12}}{\partial y} + q_1 = 0, \quad \frac{\partial N_2}{\partial y} + \frac{\partial S_{12}}{\partial x} + q_2 = 0,$$

$$\frac{\partial Q_1}{\partial x} + \frac{\partial Q_2}{\partial y} - q_n = 0, \tag{2}$$

$$\frac{\partial M_1}{\partial x} + \frac{\partial H_{12}}{\partial y} - Q_1 + m_1 = 0, \quad \frac{\partial M_2}{\partial y} + \frac{\partial H_{12}}{\partial x} - Q_2 + m_2 = 0,$$

- the ratio of elasticity

$$N_1 = B(e_1 + ne_2), \quad N_2 = B(e_2 + ne_1), \quad S_{12} = \frac{B(1-n)}{2}e_{12},$$
$$Q_1 = 2K'G'he_{13}, \quad Q_2 = 2K'G'he_{23}, \quad M_1 = D(H_1 + nH_2) \tag{3}$$
$$M_2 = D(H_2 + nH_1), \quad H_{12} = \frac{D(1-n)}{2}2H_{12}$$

Considering the cases of kinematic excitation, we obtain a system of differential equations from (1) – (3):

$$\frac{\partial N_1}{\partial x} + \frac{\partial S_{12}}{\partial y} = -rS\frac{\partial^2 U_1}{\partial t^2}$$
$$\frac{\partial N_2}{\partial y} + \frac{\partial S_{12}}{\partial x} = -rS\frac{\partial^2 U_2}{\partial t^2}$$
$$\frac{\partial Q_1}{\partial x} + \frac{\partial Q_2}{\partial y} = +rS\frac{\partial^2 w_1}{\partial t^2}$$
$$\frac{\partial M_1}{\partial x} + \frac{\partial H_{12}}{\partial y} - Q_1 = -rS\frac{\partial^2 U_1}{\partial t^2} \tag{4}$$
$$\frac{\partial M_2}{\partial y} + \frac{\partial H_{12}}{\partial x} - Q_2 = -rS\frac{\partial^2 U_2}{\partial t^2}$$
$$B\left(\frac{\partial U_1}{\partial x} + n\frac{\partial U_1}{\partial y}\right) = N_1$$
$$B\left(\frac{\partial U_2}{\partial y} + n\frac{\partial U_1}{\partial x}\right) = N_2$$
$$\frac{B(1-n)}{2}\left(\frac{\partial U_2}{\partial x} + \frac{\partial U_1}{\partial y}\right) = S_{12}$$
$$\Lambda\left(g_1 + \frac{\partial w}{\partial x}\right) = Q_1$$
$$\Lambda\left(g_2 + \frac{\partial w}{\partial y}\right) = Q_2$$
$$D\left(\frac{\partial g_1}{\partial x} + n\frac{\partial g_2}{\partial y}\right) = M_1$$
$$D\left(\frac{\partial g_2}{\partial y} + n\frac{\partial g_1}{\partial x}\right) = M_2$$
$$H = \frac{D(1-n)}{2}\left[\frac{\partial g_2}{\partial x} + \frac{\partial g_1}{\partial y}\right],$$

where r – material density; S – thickness, G' – displacements modulus in the platform, which is perpendicular to the middle surface.

Existing methods of analytical solutions of differential equations in partial derivatives do not allow to receive a universal equation that take into account variety of load conditions and heterogeneity.

To solve the system of differential equations we use the method of finite differences with five-pointed template that allows to replace differential equations with finite-difference ones, which leads to a system of linear algebraic equations relatively to unknown discrete values of the unknown function at the nodal points of the grid area, approximating a given one.

At the next stage the diacoptical approach is used. Technology of system simulation in parts (principle of diacoptics) is a mathematical technique that allows parallelize the process of simulation of complex systems and thus increase the speed of simulation [2-4]. Principle of diacoptics provides system representation as a set of functional blocks connected to each other in the N nodes.

For similar functional blocks a system of equations forms that represents the computational pattern in the form of generalized multipole (multi-port network that is a basic element), the model is described by a system of equations that associate the generalized displacement Si (linear and angular) of components with the generalized force factors Ri (reactions and moments) in these nodes.

$$\begin{Vmatrix} S_1 \\ \dots \\ S_5 \end{Vmatrix} = F\left[\begin{Vmatrix} R_1 \\ \dots \\ R_5 \end{Vmatrix}\right] \quad (5)$$

In this approach, the generalized displacement components associated with generalized responses in the relevant functional dependence which can be described for each consistency functional unit, by creating a library of models.

For each functional block the analysis and search for solutions are conducted. The general solution is obtained by combining the partial solutions for specific functional blocks.

When simulating a system by part the following steps are performed [5]:

1. Instead of forming a "large system matrix" the so-called " crosslinking matrix " is formed the rank of whick does not exceed N. Using the crosslinking matrix, we consider a way of communication functional blocks between themselves and their influence on each other.

2. The system of linear algebraic equations of the functional blocks are solved by any known methods, concurrently to each other on the set of values of vectors b on the right side.

3. With the solutions obtained on the previous step, we form the right side of crosslinking matrix and solve it. In forming the right side of crosslinking matrix of the vectors of solutions of linear algebraic equations blocks is only a small portion of samples, ie processors for 2 – 3 and 3-4 steps exchanging small amounts of data.

4. Then again, concurrently to each other we solve the system of linear algebraic equations blocks, but with regard to the solution obtained on the previous step.

This approach allows to make the transition from a system with distributed parameters to the system with lumped parameters, considering diverse, and combined boundary conditions, to reduce computing costs by introducing a unified basic elements and concurrent simulation process using the principles of object-oriented approach.

Conclusions

The combination of finite-difference approximation and diacoptical approach makes it possible to simulate mechanical systems with distributed parameters the effective application of modern information technology of design.

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