https://www.proconference.org/index.php/usc/article/view/usc31-00-024
DOI: 10.30888/2709-2267.2025-31-00-024

UDC 537.3

BOKA-SCHLIPPE-KOLAR HYPOTHESIS APPLIED TO SIMULATING VIBRATIONS OF PLATE MATERIALS WITH INTERNAL ENERGY LOSSES

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Abstract. *The paper presents a modified approach to the modelling of vibrations of plates made of materials with internal energy losses, based on the Bock-Schlippe-Kolar hypothesis, which allows to increase the accuracy of prediction of the dynamic behaviour of such systems. The proposed approach combines the advantages of numerical and analytical methods and is implemented through a two-stage algorithm for solving the problem. In the first stage, a discrete-continuous model of a plate made of a material with internal energy losses is constructed. A feature of the proposed approach is the ability to find eigenvalues in any given interval of the spectrum, which increases the efficiency of the computations and allows to avoid the loss of some eigenvalues.*

Key words: *Bock-Schlippe-Kolar hypothesis, energy dissipation, internal friction*

Introduction.

The study of the vibrations of plates made of materials with internal energy losses is a topical problem in modern deformable solid mechanics, which has a wide range of practical applications in mechanical engineering, construction and aerospace. The paper proposes an improved approach to solving this problem based on the Bock-Schlippe-Kolar hypothesis, which allows for high accuracy modeling of the dynamic behaviour of plates taking into account the energy dissipation in material.

Relevance of the research

Modern structural materials are characterised by complex physical and mechanical properties, in particular the presence of internal friction and other energy dissipation mechanisms. Traditional methods for calculating plate vibrations often fail to account for these features, or only approximate them, leading to significant discrepancies between theoretical predictions and experimental data. The Bock-Schlippe-Kolar hypothesis, which has been successfully used to model independent friction, opens up new possibilities for increasing the accuracy of calculations of the dynamic behaviour of plates [1]. The integration of this hypothesis into methods for

analysing the natural oscillations of plates allows the development of more accurate models that take into account dissipative processes in the material.

Theoretical basis

The Bock-Schlippe-Kolar hypothesis is based on the concept of the independence of frictional forces from normal pressure and their dependence on the relative sliding velocity. In the context of modeling plate vibrations, this hypothesis allows us to describe the mechanisms of energy dissipation in the material by introducing complex stiffness characteristics. In this case, the equation of motion of the plate can be expressed as [1]:

$$[A]\{\ddot{u}\}+[B]\{\dot{u}\}[c]\{u\}=\{q\}$$

where [A] is the diagonal matrix of inertial differential operators, [c] is the matrix of elastic differential operators, the column matrices of displacements {u} and surface loading intensity {q}.

Internal friction is taken into account according to the Bock–Schlippe–Kolar hypothesis, and for simplicity it is considered to be the same for shear, tension and bending [1].

$$[B]=a_1[I]$$

Problem setting and problem solving

The proposed approach combines the advantages of numerical and analytical methods and is implemented through a two-stage algorithm to solve the problem. In the first stage, a discrete-continuous model of a plate made of a material with internal energy losses is constructed. In this case, the inertial properties of the plate are discretised by dividing it into separate concentric sections and concentrating the masses of these sections at certain points of a continuous inertial system [2].

In the second step, the system compliance matrix is formed taking into account the Boca-Schlippe-Kolar hypothesis. In this case, internal energy losses are taken into account by modifying the system coefficient matrix using complex stiffness parameters.

Particular attention is paid to the relationship between the model parameters and the physical properties of the material. To determine the complex stiffness parameters,

experimental data on the vibration damping of plates made of different materials are used. The relationship between the potential energy of the system and the energy dissipation parameters is established on the basis of the energy approach.

A feature of the proposed approach is the ability to find eigenvalues in any given interval of the spectrum, which increases the efficiency of calculations and allows to avoid the loss of some eigenvalues [2]. To increase the accuracy of the calculations, a combined approach is used, which allows to determine the approximate values of the eigenfrequencies in the first stage and to refine them in the second stage.

Numerical results

The effectiveness of the proposed approach has been verified on a series of test problems for plates of different geometries and with different mechanical properties.

The test calculations have shown that the consideration of internal energy losses using the Bock-Schlippe-Kolar hypothesis leads to a significant refinement of the results compared to classical approaches, especially for materials with high energy dissipation. In particular, for composite plates, the discrepancy between the experimental and calculated values of the eigenfrequencies was reduced from 12-15% to 3-5%.

An important result is also the identification of the dependence of the vibration damping parameters on the frequency, which is in agreement with the experimental data and confirms the adequacy of the use of the Bock-Schlippe-Kolar hypothesis for modelling the internal energy losses in the material.

Conclusion

1. Based on the Bock-Schlippe-Kolar hypothesis, a modified approach to modelling the vibrations of plates made of materials with internal energy losses has been developed, which allows to increase the accuracy of predicting the dynamic behaviour of such systems.

2. A two-stage numerical-analytical method has been proposed to solve the problem of natural vibrations of plates taking into account energy dissipation, combining the advantages of analytical and numerical approaches.

3. An algorithm and a software package have been developed to calculate the

frequencies and shapes of natural vibrations of plates made of materials with internal energy losses.

4. The results of test calculations have confirmed the effectiveness of the proposed approach and its superiority over classical methods, especially for materials with high energy dissipation.

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sent: 19/05/2025