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STATIC VIBRATION ANALYSIS OF LAMINATED COMPOSITE MATERIALS

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Abstract: In this paper, an improved linear radial point interpolation method is used to analyze the static and free vibration mesh of composite materials. Radial and polynomial basis functions are used to construct shape functions having the delta function property. The procedure for restoring the consistency ability and improving the convergence of the calculations was provided by the strain smoothing stabilization method for nodal integration. The analysis of the method showed its applicability to composite plates whose thickness varies in a wide range.

Key words: laminated composites, static vibration analysis, shape function construction, radial point interpolation method, nodal integration.

Static and vibration analysis of the volume of composite samples has been widely studied in experimental studies using various numerical methods. The most commonly used methods are the Ritz method [1, p. 2], the finite difference method, the finite element method [2, p. 791], and others. These methods are quite accurate and effective when solving problems with rectangular composite samples. However, the use of numerical calculations in engineering applications still faces a set of characteristic limitations.

In particular, the Ritz method is difficult to select suitable trial functions for complex problems; the finite difference method is quite flexible, but requires a set of "structured" grids, which limits its application to problems with complex geometry. To summarize, we can conclude that of the listed methods, the finite difference method is the most flexible and effective for complex geometry. However, this method also has problems associated with the grid and grid distortion.

For some complex vibration cases in non-isotropic laminated plates where analytical solutions are difficult to obtain, numerical methods such as meshless local method and collocation method [3, p. 716] are usually applied to achieve approximation results. Radial basis functions, which are widely used in analysis for function fitting and solving partial differential equations using global nodes [4, p. 1928] and collocation procedures, have been used to construct shape functions in numerical methods.

The grid-free radial point interpolation method has demonstrated its effectiveness and has been successfully applied in many engineering problems. A set of radial basis functions and polynomial functions was used to construct the parent functions. The shape functions have delta function properties, which allow imposing basic boundary conditions on laminar composite samples with parallelepiped shapes and sizes lying in a wide range. A distinctive feature of the construction of shape functions is that the interpolation approximation passes through all scattered nodes in local volumes of the composite. The possibility of using a radial basis function means that the moment matrix can always be inverted.

This paper presents an analysis of static and free vibrations of composite plates using a mesh-free radial point interpolation method. The stiffness matrix is estimated using stabilized nodal integration instead of Gaussian integration. The accuracy and stability of the present method were verified by intensive investigations for various node distributions. In addition, static deflections and free vibrations of plates with different shapes and boundary conditions were investigated.

It was assumed that the approximation function for the entire volume of the laminar composite has a set of randomly distributed points, the number of which is comparable to the number of nodes in the region. For a fixed point of the local volume, only the nodes in the local sub-region determine the value of the parent function. The influence of the nodes outside the sub-region is negligible. The corresponding local volume can be considered as a region of influence or a support region. The radius of the region of influence is proportional to the product of the scale factor and the maximum distance between neighboring nodes in the region of influence. Numerical calculations were based on matrix equations for the components of the mechanical displacement and shear tensors.

The results of static analysis of rectangular loaded composite samples were obtained using equations for energy potentials. Accordingly, the relationships for the kinetic energy of the shear components allowed us to perform an analysis of free vibrations in local volumes of laminated composites. An improved calculation method allowed us to formulate a step-by-step procedure for analyzing static and free vibrations of isotropic and composite plates using a linearly consistent radial point interpolation method. Fixed meshless shape functions were constructed by combining radial and polynomial basis functions. The special features of this method include the use of a gradient matrix deformation smoothing method. The discrete equilibrium equation and the eigen equation were solved by performing nodal integration instead of Gaussian integration.

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