OPTIMAL FIBERS ARRAGEMENT IN SINGLE- AND MULTILAYERED COMPOSITE MATERIALS

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1. Introduction

The present paper constitutes the results of further investigation in the area of designing structural components made of fibre-reinforced composite materials (cf. Ref.[1-3]).

To fulfil the assumed properties of a composite structure one can modify some its structural parameters, such as mechanical properties of a matrix and fibres, fibre density, shape and arrangement of fibres etc. However, as shown in previous research, the full advantages of composite materials are obtained when the reinforcing fibres are optimally distributed and oriented or shaped in the matrix with respect to assumed objective behavioural measure under actual loading conditions of the structure. It is important particularly when the unique or important from behavioural point of view structures are considered.

The stiffness and stress optimization of fibre-reinforced composite materials is performed with the aid a hybrid evolution-gradient oriented algorithm. Such algorithm can serve as an alternative technique to classic methods applied in the optimal design of a structure made of fibre-reinforced single- or multilayered composite materials.

2. Object of analysis

A thin, two-dimensional and linearly elastic disk, made of multilayered composite material, is supported on the boundary portion S_U with prescribed displacement $\mathbf{u}^0$ and loaded by body forces $\mathbf{f}^0$ within domain its A and by external traction $\mathbf{T}^0$ acting along the boundary portion S_T , cf. Fig.1.

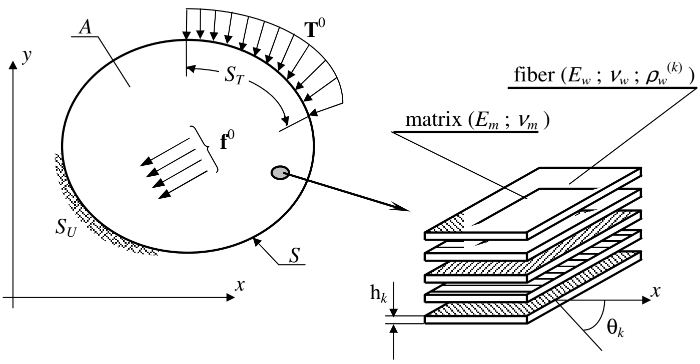

Figure 1: Two-dimensional composite disk subjected to service loading

The material of each layer is a composite made of a matrix reinforced with a ply of long and arbitrary shaped unidirectional fibres of assumed cross-section. The mechanical properties of the matrix and the fibres in k-th layer are E_{mk}, ν_{mk} and E_{wk}, ν_{wk}, respectively. The fibres are regularly spaced and perfectly aligned in the matrix with constant density ρ_{wk}, and their orientation at any point of the composite material is denoted by θ_k with respect to the global co-ordinate system x-y (see Fig. 1).

The microscopically non-homogeneous composite material is next modelled by a macroscopically homogeneous, orthotropic and linearly elastic material in the analysis step of composite structure behaviour. The purpose of this modelling process is to determine the extensional stiffness matrix **D** for the model of the composite in the global co-ordinate system *x*-*y* and to express its components in terms of the mechanical properties of the reinforcing fibres and the matrix, fibre density as well as fibre orientation, namely

$$D_{ij} = D_{ij}\left(E_{wk}, \nu_{wk}, E_{mk}, \nu_{mk}, \rho_{wk}, \theta_k\right) \tag{1}$$

Each of these parameters influences the mechanical properties of the composite disk and then it can be treated either as constant parameter or as the design variable during the optimal design of a composite structure.

3. Optimization procedure

Let us assume that the mechanical properties of fibres and matrix as well as fibre density are given in advance, whereas orientation of rectilinear fibres or parameters defining the shape of curvilinear ones will be selected as the design variables during optimization procedure of composite layout. To describe the layout of reinforcing fibres in this last case, a polynomial, spline or Bezier function will be used.

The optimal design of fibre orientation or layout in a composite material will be discussed either for the case of the mean stiffness design for a disk subjected to service loading or for the case of stress design. Thus, in the first case, the problem can be formulated as a minimization of work done by external forces acting on structural element with the constraint imposed on total cost of composite structure and other behavioural constraints, while in the second case the objective functional will be expressed using the Tsai-Wu stress criterion.

4. Hybrid optimization system

The optimisation procedure defined in previous section will be performed with the aid of a hybrid, evolution-gradient oriented optimization system composed from two main modules.

The first module is the module of initial optimization performed using the evolution algorithm starting from randomly selecting initial solution, while the second module performs the final optimization using the gradient-oriented algorithm starting from the last, best solution generated by evolution algorithm. The finite element method is applied in both modules in order to perform the analysis step of structural behavior. In addition, this method is also used in final optimization module for performing the sensitivity analysis of state fields in order to obtain the gradient information for objective functional and behavioral constraints.

5. Acknowledgment

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6. References

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