University of Craiova
Faculty of Mechanics
Doctoral School „Acad. Radu Voinea”

SUMMARY of
Engineering PhD Thesis (field - mechanical engineering)
with title

“CONTRIBUTIONS TO THE STUDY OF STATIC AND DYNAMIC BEHAVIOR OF THE BARS AND PLATES BUILT FROM COMPOSITE MATERIALS”

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Thesis structure

The work consists of "Thesis topic news" and ten chapters, each of which is divided into numerous sections. End of each chapter is marked by relevant bibliographical references.

Thesis Content

THESIS TOPIC NEWS

Knowing the elastic characteristics is very important for dynamic studies of materials.

It should be noted that theoretical results for composites with random distribution of reinforcement, were not obtained, were obtained only semi-empirical results, following statistical analysis.

It is therefore important to determine a theoretical method, which define the elastic characteristics in a general case, for some types of composite materials.

1. MECHANICAL BEHAVIOUR OF COMPOSITE MATERIALS

Are reviewed, ways in which metallic materials, from composition of various mechanical structures may be replaced by composite materials. It showed how they should be chosen so that their properties to be tailored to the needs imposed by the mechanical structure, which is made of composite material.

It is necessary to design, simultaneously, both product and material, the result is a system that includes nature, texture and form of reinforced fabric, the nature of resin, hardener and the percentage of its mass, geometry of the parts to be obtained, and the process used to achieve them.

2. CHARACTERISTICS OF SECTION, FROM COMPOSITE BAR

In engineering design, are made, precise calculus, both static requests, which have particular regard to ensuring the structural strength, and dynamic requests, which aimed at avoiding duplication of requests pulsations outer structure over their pulses, and thus avoid resonance phenomenon.

3. THE EXPERIMENTAL VALIDATION OF THE ANALYTICAL MODEL, USED TO STUDY THE DYNAMIC BEHAVIOUR OF A MULTILAYER COMPOSITE STRUCTURE

In this chapter is presented an analytical model, which makes the similitude between the DTMM theory of composite multilayer bars and the FSDT theory used in the study of composite bars and plates in a dynamic regime. The authors proposed a numerical application of the model, for two different bars made from glass-epoxy reinforced composite. The experimental validation of theoretical results was made on a composite bar as a component of a quadrilateral mechanism, whereon the leading element describes a rotation motion with the constant angular speed.

4. STUDY CONCERNING SOME ELASTICITY CHARACTERISTICS DETERMINATION OF COMPOSITE BARS

In this chapter we propose a new method to determine the properties of a composite material made from two different components: fiber glass cloth and resin. On the separation surface between the two materials it is assumed that the continuity conditions concerning the tensors of stresses and strains between these two components are totally satisfied. The constitutive equations were determined for each material as functions of these components with respect to a local system of reference. Medium stresses and strains were defined in order to establish the properties of the material as a whole. Considering the interdependence existing at the level of those properties the constitutive equations of the composite have been found. Mathematical expressions for elastic modulus and Poisson’s ratio have been also determined. A loading with forces applied on a longitudinal as well on a perpendicular direction face to the fibers direction of the composite is considered. We find out that the elastic properties along the fibers of the composite are closer to the properties of the reinforcing fibers and the elastic properties perpendicular to the fibers of the composite are closer to the matrix properties.

We also make an overall assessment of the characteristics of elasticity tensor, taking into account the interdependencies that arise between stress and strain.

Elasticity modulus form is new.

5. THE RESISTANCE TO FRACTURE DETERMINATION FOR COMPOSITE PLATES WITH RANDOM DISTRIBUTION OF REINFORCEMENT

In this chapter we introduce a formula for the calculus of resistance to fracture for the composite plates with a random reinforcement's distribution. Also, we give a formula for the calculus of upper limit of resistance to fracture for the composite plates, described as depending on the volumetric proportion of reinforcement. As applications, we give the variation of resistance to fracture depending on the volumetric proportion for two types of composite materials and, in addition, we determine the characteristic curves and the resistance to fracture for a traction test considering the two composite materials.

6. EXPERIMENTAL RESEARCHES REFERENCED TO PROPERTIES OF COMPOSITE MATERIALS WITH RANDOM DISTRIBUTION OF REINFORCEMENT

In this chapter we present the result of the experiments on which we accomplished them, in order to obtain the characteristics curves for five composite materials with random distribution of reinforcement. From these curves we determined the elasticity modulus and the resistance to fracture. Using the modal identification method we determined the first eight eigenmodes for two bars from composite materials (Bar 1 – phenolic fireproof resin reinforced with fiberglass; Bar 2 – ortophtalic polyesteric resin reinforced with fiberglass), embedded at one end and free at the other. We determined the eigenpulsations for the modes considered and we used the first four modes for the calculus of elasticity modulus. The results obtained by traction testing compare with the one from modal identification method certify the utilization of modal analysis in the determination of properties of composite structures.

7. THE UTILIZATION OF SPECTRAL DECOMPOSITION OF ELASTICITY MATRIX, FOR THE CALCULUS OF ELASTIC PROPERTIES, IN THE CASE OF A BAR FROM COMPOSITE MATERIALS

In this chapter we present the spectral decomposition of the matrices of elasticity, for homogeneous and isotropic materials, and for materials with transversal isotropy. A bar from composite material reinforced with long fibers, is conceived as a material with transversal isotropy, and constituents are considered as homogeneous and isotropic materials. We determine the eigenvalues of the matrix of elasticity, for the bar from composite material, depending on elastic properties and volumetric proportion, of constituents. For composite bar, which has the matrix from epoxy resin reinforced with fibers of glass, we present the variations of eigenvalues depending on the volumetric proportion of reinforcement.

8. THE DETERMINATION OF THE RESISTANCE TO FRACTURE AND THE ELASTICITY MODULUS FOR POLYESTER RESIN PLATES REINFORCED WITH RANDOMLY DISPOSED FIBREGLASS

Using the linearity of the term $\sqrt{\sigma_l \sigma_t}$ we will deduce a new formula for the calculus of the resistance to fracture for composites with randomly distributed reinforcement. This formula will depend on the volumetric proportion of reinforcement. Using the medium values for longitudinal and/or transversal elasticity modulus, to the reference system turning, we will obtain an original relation for the calculation of the elasticity modulus for composite plates with randomly disposed reinforcement. We preferred to write this relation in a similar manner to the one used for the resistance to rapture, using the linearity related to $\sqrt{E_l E_t}$. Experimental determinations were made for three sets of samples obtained from plates with various mass proportions of reinforcement, which confirm the theoretical results that we obtained.

9. EXPERIMENTAL RESEARCH RELATED TO THE MECHANIC PROPERTIES OF COMPOSITE MATERIALS REINFORCED WITH WOVEN POLYPROPYLENE

In this chapter we obtained the characteristic curves for polyester and epoxy resins used in the process of making composites, and determined their elastic and resistance properties. We determined the characteristic curves on two directions for the epoxy and polyester resin composites, reinforced with woven polypropylene. We established the flow strain and two coefficients from the calculus relation for the plastic potential. We determined the equation of nonlinear dependency between strain and deformation in the plastic field using a fourth degree polynomial relation which indicates the specific elongation and resistance to fracture.

10. THE NONLINEAR MECHANICAL BEHAVIOR OF COMPOSITE MATERIALS REINFORCED WITH CARBON FIBER WEAVES

This chapter proposes an elastic displacements field for a composite bar made of two constituents (phases). The deformation hypothesis described by this field is built in full respect of all the conditions of compatibility concerning deformation status and strain-stress status of any kind. More else, the conditions of continuity concerning the surface separating the two constituents are also fully satisfied. Using this new displacements field we show that the tangent to each and every point of the characteristic curve built for this composite material depends only on the size of external charge (loading) and the longitudinal deformation of the composite bar. Based on these facts we also show that the constitutive equation of this composite material is a non-linear one: in fact it is a concave curve the way that the slope of the tangent to each and every point of the characteristic curve is decreasing as the deformation increases. We have released three sample groups with different arrangements of reinforcing fibers from one group to any other one and we have established the characteristic curve for each and every sample group. Using these curves we have obtained the longitudinal elasticity modulus, the tension at break, the elongation at break as well as the slope and the ordinate at the origin for the tangent to the breaking point of the characteristic curve. The characteristic curves have the shape (allure) suggested by the theoretically obtained results. We have shown that a certain parameter characterizing the non-linear behavior of the composite material is given by the ratio between the longitudinal elasticity modulus and the value of the slope of the tangent to the breaking point of the composite material's characteristic curve.