Experimentální Analýza Napětí 2003

EXPERIMENTAL ANALYSIS OF MECHANICAL PROPERTIES OF COMPOSITES BASED ON CARBON-CARBON

EXPERIMENTÁLNÍ ANALÝZA MECHANICKÝCH VLASTNOSTÍ KOMPOZITU NA BÁZI UHLÍK-UHLÍK

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Mechanical properties of carbon-carbon (C/C) composite materials, to be used in orthopeadics in the form of intervertebral cages applied for the lumbar spine injuries treatment, were investigated. Stress analyses and materials designs were performed to achieve both physical and biocompatible properties desired. The experiments were designed to assess C/C composite mechanical characteristics and to apply them in FEM (finite element method) models of intervertebral cages. The problem was complicated due to the fact that C/C composite examined was developed aiming at matching simultaneously two important properties: i) suitable mechanical characteristics, to serve as implants, on one hand, and ii) a sufficient porosity, to enable a quality bone ingrowth, on the other hand. The C/C composite mechanical characteristics assessment was not based only on strain gauges applied, but also on displacements measured as integral deformations of the samples (machine jaws displacements). Further tests were carried out on C/C composite cores to be applied in the intervertebral cages.

Keywords

Biomaterials, Biomechanics, Orthopedics, Intervertebral Cages, Composite Materials

Introduction

C/C composite materials developed to be used as implant elements in spine surgery (aiming at the strength in bending and the modulus of elasticity approaching to those exhibited in the human bone, i.e., 150 – 200 MPa and 15 - 20 GPa, respectively) were tested. These values, especially those of the strength in bending, were attained by multiple impregnation from both liquid and gaseous phases. However, these procedures led, at the same time, to a significant decrease in the material open porosity. So, it was important to compromise between a sufficient porosity and sufficient mechanical properties.

Materials and Methods

Intervertebral cages based on C/C composite materials were designed to consist of a titanium alloy cage and a C/C core. C/C composite samples were made of plain-woven cloth (Torayca

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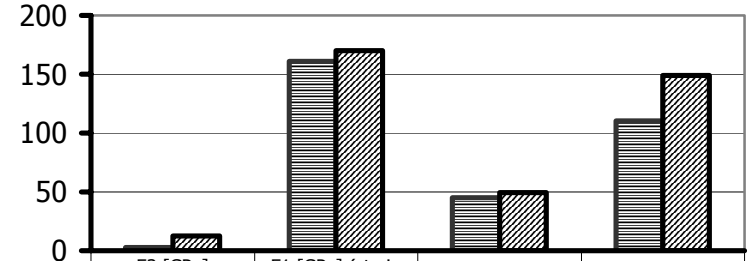
carbon fibers T 800) and phenolic resin. Experimental stress analysis consisted in testing two different kinds of the composite core having different final production technologies applied (Carbonized+3×impregnated+graphited and Carbonized+3×impregnated+graphited+PyC). Not only a composite material exhibiting high strength values was looked-for. Based on a complex analysis, a C/C composite, exhibiting a compromise between required both its mechanical properties (a relatively sufficient strength value and a low modulus of elasticity, comparable with that of the human bone), and its biological properties (a sufficient porosity), which would be favorable for the tissue and bone ingrowth, was developed.



	E3 [GPa] (perpedicular dir.)	E1 [GPa] (strain gauges)	E1 [GPa] (integral)	R1lim [MPa]
G	2,71	160,75	45,2	110,57
G+PyC	12,71	170,38	49,6	148,89

Fig. 1 Comparsion of resulting values

The C/C composite mechanical characteristics assessment was not based only on the strain gauges applied, which supplied information valid only for a local part of the sample, but also on displacements measured as integral deformations of the samples (machine jaws displacements), Fig.1. Further tests were carried out on C/C composite cores to be applied in the intervertebral cages. Nevertheless, there can be quite different interpretation of all results: the matrix is being damaged from the very loading onset and the curves measured are due to a gradual contact increase of the parallel carbon fabric layers, also three different results (strain gauges, integral deformations, deformations of the core) about the C/C core mechanical behavior were obtained. These dilemmas may be solved only after all the experiments and examinations planned have been carried out. Future mechanical tests of the whole cage consisting of two different materials having different shapes will give more information needed for its potential application in the spine surgery.

Results

Mechanical compression tests of intervertebral cages based on C/C composite materials, made by various technologies, served for choosing an optimum procedure yielding suitable mechanical characteristics for use in human lumbar spine injuries which preliminary resulted in the C/C composite infiltrated and covered with PyC. Lower porosity of samples covered with PyC (i.e., a negative feature for its integration in the bone) can be improved by covering the C/C composite with the pHEMA (2-hydroxyethyl metacrylate), which stimulates the bone ingrowth into the composite.

References

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Acknowledgments

The project is part of the GACR-funded project: Cages (for use in spine treatment) based on the carbon-carbon composite, No. 106/00/1407; and the Ministry of Education project: “Transdisciplinary research in Biomedical Engineering”, No. J04/98:210000012.