NELINEARNA MEHANIKA GRADIV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	NELINEARNA MEHANIKA GRADIV
Course title:	NONLINEAR MECHANICS OF MATERIALS
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo, tretja stopnja, doktorski	Ni členitve (študijski program)	1. letnik, 2. letnik	Celoletni	izbirni

Univerzitetna koda predmeta/University course code:	0033416
Koda učne enote na članici/UL Member course code:	7008

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
90					160	10

Nosilec predmeta/Lecturer:	Miha Brojan

Izvajalci predavanj:	Miha Brojan
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni predmet /Elective course

Jeziki/Languages:		
	Predavanja/Lectures:	Angleščina, Slovenščina
	Vaje/Tutorial:	Angleščina, Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Veljajo splošni pogoji za doktorski študij.	General prerequisites for the third level studies.

Vsebina:	**Content (Syllabus outline):**
Gradient deformacije. Elementi loka, površine in volumna. Materialne in prostorske koordinate. Enačbe gibanja kontinuuma. Konstitutivne enačbe. Materialne simetrije in njihov vpliv. Reologija gradiv z oblikovnim spominom. Reologija večfaznih gradiv. Uvod v mehaniko kompozitnih gradiv. Strukturno-fenomenološki model. Mehanske lastnosti makroskopskega modela kompozita. Analiza reoloških lastnosti gradiv z uporabo teorije dislokacij. Robni problemi termoplastičnosti v gradivu s periodično strukturo. Stohastični model napetostno-deformacijskega stanja v gradivih s slučajno strukturo. Ocena nosilnosti elementov in konstrukcij iz kompozitnih gradiv. Kompoziti z mikrostrukturo.	Deformation gradient. Line, area and volume elements. Material and spatial coordinates. Motion equations of a continuum. Constitutive equations. Material symmetries and their influence. Rheology of shape memory materials. Rheology of multi-phase materials. Introduction to mechanics of composites. Structural-phenomenological model. Mechanical properties of the macroscopical model of composite material. Analysis of rheological properties of materials using theory of dislocations. Boundary value problems in thermoplasticity of materials with periodical structure. Stochastic model of stress-strain state in materials with chaotic structure. Load carrying capacity of elements and structures made of composites. Particle reinforced composites.

Temeljna literatura in viri/Readings:

[1] R.W. Ogden: Nonlinear elasticity : theory and applications, Cambridge University Press, 2001 (COBISS.SI-ID – 10664537) e-knjiga
[2] Bhattacharya, K.: Microstructure of Martensite. Why it Forms and How it Gives Rise to the Shape-Memory Effect, Oxford University Press, New York, 2003 (COBISS.SI-ID - 8739867).
[3] Mura, T.: Micromechanics of Defects in Solids, Martinus Nijhoff Publishers, 1987 (COBISS.SI-ID - 575977)
[4] M.T. Shaw: Introduction to polymer rheology, Wiley, 2012 (COBISS.SI-ID – 127146755)
[5] M. Negahban: The mechanical and thermodynamical theory of plasticity, CRC Press, 2012 (COBISS.SI-ID – 36778501)

Cilji in kompetence:	Objectives and competences:
Cilji: Študentu prikazati vlogo in pomen nelinearne mehanike pri obravnavi kompleksnih inženirskih problemov. Predstavljene so osnovne zveze, ki nastopajo v nelinearni mehaniki gradiv. Podrobneje se obravnava termomehansko obnašanje večfaznih gradiv, s posebnim poudarkom na materiale z oblikovnim spominom in modeliranje njihovega obnašanja. Poleg tega se obravnava tudi mehansko obnašanje kompozitnih gradiv, kjer pri opisu mehanskega stanja izhajamo iz mikrostrukture gradiva. Študent se tako seznani s teorijo dislokacij in mikromehaniko in tako spozna njun vpliv na makroskopsko obnašanje kompozitnih gradiv. **Kompetence:** Študent osvoji ustrezno znanje, ki je potrebno za določanje mehanskega odziva različnih konstrukcijskih elementov iz večfaznih gradiv ter iz kompozitnih gradiv.	**Goals:** The principal goal of this course is to demonstrate the significance of nonlinear mechanics in treating complex engineering problems. Basic relations of nonlinear mechanics of materials are presented. Thermomechanical behaviour of multi-phase materials is treated, with emphasis on modeling of shape memory materials. In addition microstructural approach to mechanical behaviour of composites is studied. The student is familiarized with micromechanics and theory of dislocations and their influence on macroscopical behaviour of composites. **Competences:** The student acquires knowledge necessary to determine mechanical behaviour of various structural elements made of multi-phase materials and/or composites.

Predvideni študijski rezultati:	Intended learning outcomes:
Študent osvoji ustrezno znanje, ki je potrebno za določanje mehanskega odziva različnih konstrukcijskih elementov iz večfaznih gradiv ter iz kompozitnih gradiv.	The student acquires knowledge necessary to determine mechanical behaviour of various structural elements made of multi-phase materials and/or composites.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezujoče se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.	Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as possible, to the student's doctoral research field. Study on a recommended literature basis.

Načini ocenjevanja:	Delež/Weight	Assessment:
Način (pisni izpit, ustno izpraševanje, naloge, projekt) • naloge (30%)		Method (written exam, oral examination, assignments, project) •

• projektni seminar (50%) • ustno izpraševanje (20%)		assignments (30%) • project seminar (50%) • oral examination (20%)

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

izr. prof. dr. Miha BROJAN

AHČIN, Žiga, DALL'OLIO, Stefano, ŽEROVNIK, Andrej, ŽVAR BAŠKOVIČ, Urban, PORENTA, Luka, KABIRIFAR, Parham, CERAR, Jan, ZUPAN, Samo, BROJAN, Miha, KLEMENC, Jernej, TUŠEK, Jaka. *High-performance cooling and heat pumping based on fatigue-resistant elastocaloric effect in compression*. Joule. 2022, vol. 6, nr. 10, str. 2338-2357, ISSN 2542-4351. DOI: 10.1016/j.joule.2022.08.011. [COBISS.SI-ID 122510851]

SARKAR, S., ČEBRON, Matjaž, BROJAN, Miha, KOŠMRLJ, Andrej. *Elastic multipole method for describing deformation of infinite two-dimensional solids with circular inclusions*. Physical review. E. 2021, vol. 103, iss. 5, str. 1-25, ISSN 2470-0053. DOI: 10.1103/PhysRevE.103.053003. [COBISS.SI-ID 64663811]

LOLIĆ, Damjan, ZUPAN, Dejan, BROJAN, Miha. *A consistent finite element formulation for laminated composites with nonlinear interlaminar constitutive law*. Composite structures. 2020, letn. 247, št. 112445, str. 1-13, ISSN 1879-1085. DOI: 10.1016/j.compstruct.2020.112445. [COBISS.SI-ID 19031811]

RAHMANI, Ramin, ANTONOV, Maksim, BROJAN, Miha. *Lightweight 3D printed Ti6Al4V-AlSi10Mg hybrid composite for impact resistance and armor piercing shielding*. Journal of Materials Research and Technology. 2020, vol. 9, iss. 6, str. 13842-13854, ISSN 2238-7854.DOI: 10.1016/j.jmrt.2020.09.108. [COBISS.SI-ID 33580803]