UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	NELINEARNA MEHANIKA GRADIV
Course title:	NONLINEAR MECHANICS OF MATERIALS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**
Strojništvo, tretja stopnja, doktorski	Ni členitve (študijski program)		Celoletni

Univerzitetna koda predmeta/University course code: 7008

Predavanja	**Seminar**	**Vaje**	**Klinične vaje**	**Druge oblike študija**	**Samostojno delo**	**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:	Slovenščina, Angleščina
	Vaje/Tutorial:	Slovenščina, Angleščina

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] Kunin, I.A.: Elastic Media with Microstructure. I,II, Springer, Berlin, 1982.
[2] Bhattacharya, K.: Microstructure of Martensite. Why it Forms and How it Gives Rise to the Shape-Memory Effect,

Oxford University Press, New York, 2004.
[3] Šermergor, T.D.: Teorija Uprugosti Mikroneodnorodnih Sred, Nauka,Moskva 1977.
[4] Lurje, A.I.: Nelinejnaja Teorija Uprugosti, Nauka; FML, Moskva, 1980.
[5] Navožilov, U.U., Kadaševič, J.I.: Mikro Naprjaženija v Konstrukcionih Materialah, Mašinostrojenije, Leningrad, 1990.
[6] Christian, J.W.: The Theory of Transformations in Metal and Alloys, 2nd ed.,Oxford, Pergamon, (International Series on Materials Science and Technology; Vol. 15), 1975.
[7] Mura, T.: Micromechanics of Defects in Solids, Martinus Nijhoff Publishers, 1987.

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%) • projektni seminar (50%) • ustno izpraševanje (20%)		Method (written exam, oral examination, assignments, project) • assignments (30%) • project seminar (50%) • oral examination (20%)

Reference nosilca/Lecturer's references:

doc.dr. Miha BROJAN

SITAR, Matej, KOSEL, Franc, BROJAN, Miha. Numerical and experimental analysis of elastic-plastic pure bending and springback of beams of asymmetric cross-sections. International journal of mechanical sciences, ISSN 0020-7403., Jan. 2015, vol. 90, str. 77-88, ilustr., doi: 10.1016/j.ijmecsci.2014.11.006.

BROJAN, Miha, TERWAGNE, Denis, LAGRANGE, Romain, REIS, Pedro. Wrinkling crystallography on spherical surfaces. Proceedings of the National Academy of Sciences of the United States of America, ISSN 0027-8424, Jan. 2015, vol. 112, no. 1, str. 14-19, ilustr., doi: 10.1073/pnas.1411559112.

TERWAGNE, Denis, BROJAN, Miha, REIS, Pedro. Smart morphable surfaces for aerodynamic drag control. Advanced materials, ISSN 0935-9648, Oct. 2014, vol. 26, iss. 38, str. 6608-6611, ilustr., doi: 10.1002/adma.201401403.

SITAR, Matej, KOSEL, Franc, BROJAN, Miha. Large deflections of nonlinearly elastic functionally graded composite

beams. Archives of civil and mechanical engineering, ISSN 1644-9665, Aug. 2014, vol. 14, iss.4, str. 700-709, ilustr., doi: 10.1016/j.acme.2013.11.007.
KOSEL, Franc, VIDENIČ, Tomaž, KOSEL, Tadej, BROJAN, Miha. Elasto-plastic springback of beams subjected to repeated bending/unbending histories. Journal of materials engineering and performance, ISSN 1059-9495, Aug. 2011, vol. 20, no. 6, str. 846-854, doi: 10.1007/s11665-010-9706-1.