TEORIJA TERMOPLASTIČNOSTI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	TEORIJA TERMOPLASTIČNOSTI
Course title:	THERMOPLASTICITY
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Strojništvo, tretja stopnja, doktorski	Konstrukcijsko mehanske inženirske znanosti (smer)		Celoletni	izbirni

Univerzitetna koda predmeta/University course code:	0033442
Koda učne enote na članici/UL Member course code:	7118

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:	Miroslav Halilovič

Izvajalci predavanj:	Miroslav Halilovič
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course	Izbirni predmet /Elective course

type:	

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):**
• Definicija reprezentativnega volumna in materialne točke. Osnovni pojmi o reoloških modelih. Konstitucijske enačbe termoplastičnosti. Kriteriji plastičnega tečenja. Pristopi k modeliranju smeri plastičnega toka. • Nepovračljivost plastičnega odziva in posledice. Utrjevanje, elastična in plastična anizotropija. Ciklično obremenjevanje. • Vpliv temperature na plastični odziv. • Definicija termoplastičnega robnega problema in njegovo reševanje. Splošni teoremi in energijski izreki. • Torzija in upogib v elastoplastičnem območju. Ravninska in osnosimetrična elasto-plastična stanja. Stabilnost elastoplastičnega ravnoves¬ja. Teorija mejnih stanj. • Teorija drsnih linij in karakteristik. • Problematika eksperimentalnega določanja snovnih lastnosti elastoplastičnega odziva. • Mehanika preoblikovalnih in odrezovalnih procesov.	• Definition of a representative volume and a material point. Fundamentals of rheological models. Constitutive equations of thermoplasticity. Yield criteria. Approaches to modelling of the plastic flow direction. • Irreversibility of the plastic response and its consequences. Hardening, elastic and plastic anisotropy. Cyclic loading. • Influence of the temperature on the plastic response. • Definition of boundary value problem in thermoplasticity and its solution. General theorems in thermoplasticity, energy theorems. • Elastoplastic torsion and bending. Plane and axisymmetric elastoplastic problems. Stability of elastoplastic equilibrium. Limit stress analysis. • Slip-line theory and its characteristics. • Experimental determination of material properties during elastoplastic yielding. • Mechanics of forming and cutting technological processes.

Temeljna literatura in viri/Readings:

[1] W.F. Hosford, R.M. Caddell: Metal Forming: Mechanics and Mettallurgy, Cambridge University Press, 2007

[2] H_C.Wu: Continuum Mechanics and Plasticity, Chapman&Hall/CRC, 2005.

[3] Thermal stresses 1 (Mechanics and mathematical methods; a series of

handbooks; 1), North-Holland, 1986.

[4] A.Mendelson: Plasticity: theory and application, McMillan Comp., 1986.

[5] R.Hill: The mathematical theory of plasticity, 6th edition, The Clarendon Press, 1971.

Cilji in kompetence:	**Objectives and competences:**
Cilji: Poleg obravnave enostavnih temperaturnih in napetostno–deformacijskih stanj (enoosno napetostno in enoosno deformacijsko stanje, torzija, homogeno temperaturno polje) je cilj predmeta študentu podati moderno razumevanje splošnih pristopov v elasto-termo-plastičnosti v kontinuumu. Pri predmetu bo študent dobil predstavo, kakšno vlogo v celotnem robnem problemu imajo konstitutivni zakoni in kako je problem določitve splošnega napetostno-deformacijskega stanja v konjunkciji s temperaturno pogojenim obnašanjem materiala pogojen z rešitvijo celotnega robnega problema. Razumevanju energijskih pristopov pri določitvi pričetka plastifikacije in smeri plastičnega tečenja snovi bo pri predmetu dan poseben poudarek. **Kompetence:** Študent je s pridobljenim znanjem kompetenten za reševanje elasto-termo-plastičnih problemov, ki se pojavljajo v tehniški in znanstveni sferi. Ima podlago za razvoj naprednih elasto-termo-plastičnih modelov na osnovi meritev odziva materiala, s čemer obvladuje izračune in simulacije. Ravno tako je sposoben identificirati, katere karakteristične elasto-termo-plastične lastnosti materiala so vplivne v njegovem problemu in katere niso. Nenazadnje je študent usposobljen za vrednotenje rezultatov simulacij elasto-termo-plastičnih problemov.	**Goals:** Besides the treatment of simple temperature and stress-strain fields (uniaxial stress and uniaxial strain field, torsion, homogeneous temperature field) the aim of the course is to show a modern understanding of general approaches in elasto-thermo-plasticity. Student will gain insight of how the boundary value problem is influenced by constitutive laws, and consequently, how the stress-strain field determination in conjunction with temperature dependent material response is affected by the solution of the boundary value problem. Particular emphasis is given on the understanding of energy approaches in the determination of yielding and plastic flow direction. **Competences:** Student acquires relevant knowledge for solving elasto-thermoplastic problems, which arise in engineering practice and scientific research. Based on measurements of the material response a firm basis is given for a development of advanced elasto-thermoplastic models, which means that student is capable to perform calculations and simulations with competence. He also acquires ability to identify which elasto-thermo-plastic material properties are the most relevant in a particular problem. Finally, student is trained to properly evaluate results of the elasto-thermoplastic problem simulations.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Študent je s pridobljenim znanjem	Student acquires relevant knowledge for

kompetenten za reševanje elasto-termo-plastičnih problemov, ki se pojavljajo v tehniški in znanstveni sferi. Ima podlago za razvoj naprednih elasto-termo-plastičnih modelov na osnovi meritev odziva materiala, s čemer obvladuje izračune in simulacije. Ravno tako je sposoben identificirati, katere karakteristične elasto-termo-plastične lastnosti materiala so vplivne v njegovem problemu in katere niso. Nenazadnje je študent usposobljen za vrednotenje rezultatov simulacij elasto-termo-plastičnih problemov.	solving elasto-thermoplastic problems, which arise in engineering practice and scientific research. Based on measurements of the material response a firm basis is given for a development of advanced elasto-thermoplastic models, which means that student is capable to perform calculations and simulations with competence. He also acquires ability to identify which elasto-thermo-plastic material properties are the most relevant in a particular problem. Finally, student is trained to properly evaluate results of the elasto-thermoplastic problem simulations.

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:**
Ustni izpit, poročilo o seminarskem delu. Pogoj za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo. • projekt (seminarsko delo) (70%) • ustno izpraševanje (30%)		Oral exam, report on seminar work. The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade. • project (seminar assignment) (70%) • oral examination (30%)

Reference nosilca/Lecturer's references:

doc.dr. Miroslav HALILOVIČ

HALILOVIČ, Miroslav. Analiza tehnoloških parametrov pri procesu kontinuiranega litja z vidika njihovega vpliva na mehanski odziv = [Technology parameter analysis in the continuous casting process regarding to their influence on the mechanical response] : magistrsko delo, (Fakulteta za strojništvo, Ljubljana, Magistrska dela, 1104). Ljubljana: [M. Halilovič], 2000. 101, [16] str., graf. prikazi.

HALILOVIČ, Miroslav, ISSA, Sally, WALLIN, Mathias, HALLBERG, Håkan, RISTINMAA, Matti. Prediction of the residual state in 304 austenitic steel after laser shock peening : effects of plastic deformation and martensitic phase transformation. International journal of mechanical sciences, ISSN 0020-7403.

[Print ed.], Jun. 2016, vol. 111/112, str. 24-34, ilustr., doi: 10.1016/j.ijmecsci.2016.03.022.

HALILOVIČ, Miroslav, VRH, Marko, ŠTOK, Boris. A general method for implementation of elasto-plastic constitutive models into FEM programs. V: 6th International Congress of Croatian Society of Mechanics, Dubrovnik, Croatia, September 30 - October 2, 2009. SMOJVER, Ivica (ur.), SORIĆ, Jurica (ur.). Book of abstract. Zagreb: Croatian Society of Mechanics, cop. 2009, str. 147.

VRH, Marko, HALILOVIČ, Miroslav, STARMAN, Bojan, ŠTOK, Boris, COMSA, Dan-Sorin, BANABIC, Dorel. Capability of the BBC2008 yield criterion in predicting the earingprofile in cup deep drawing simulations. European journal of mechanics. A, Solids, ISSN 0997-7538. [Print ed.], May/Jun. 2014, vol. 45, str. 59-74, ilustr., doi: 10.1016/j.euromechsol.2013.11.013.

STARMAN, Bojan, HALILOVIČ, Miroslav, VRH, Marko, ŠTOK, Boris. Consistent tangent operator for cutting-plane algorithm of elasto-plasticity. Computer Methods in Applied Mechanics and Engineering, ISSN 0045-7825. [Print ed.], Apr. 2014, vol. 272, str. 214-232, ilustr., doi: 10.1016/j.cma.2013.12.012.

VRH, Marko, HALILOVIČ, Miroslav, ŠTOK, Boris. Mechanical behaviour characterization of sheet metal at large plastic strains. V: 7th International Congress of Croatian Society of Mechanics, Zadar, Croatia, 22 - 25 May 2012. VIRAG, Zdravko (ur.), KOZMAR, Hrvoje (ur.), SMOJVER, Ivica (ur.). Book of abstracts : [organized by] Croatian Society of Mechanics. Zagreb: STUDIO HRG, 2012, str. 185-186, ilustr.