University of Zagreb

University of Zagreb FACULTY OF MINING, GEOLOGY AND PETROLEUM ENGINEERING

INTER RGN

Projekt je sufinancirala Europska unija iz Europskog socijalnog fonda.

1. GENERAL INFORMATION				
1.1. Course teacher	Associate Professor Domagoj Vulin, PhD		1.6. Year of the study	II.
1.2. Name of the course	Enhanced recovery methods		1.7. ECTS credits	5
1.3. Associate teachers	-		1.8. Type of instruction (number of hours L + E + S + e-learning)	18L+0E+30S+12e-učenja
1.4. Study programme (undergraduate, graduate, integrated)	graduate		1.9. Expected enrolment in the course	15
1.5. Status of the course	☐ mandatory	☒ elective	1.10. Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	level 3, 20% online
2. COUSE DESCRIPTION				
2.1. Course objectives	By taking the exam, the student will be able to apply the criteria for selecting the method of enhancing the reservoir performance and know the evaluation procedures, including the physical, technological and economic aspects of each method.			
2.2. Enrolment requirements and/or entry competences required for the course	-			
2.3. Learning outcomes at the level of the programme to which the course contributes	Independently solve complex engineering problems in petroleum engineering and geoenergy engineering; Analyse reservoir rock and reservoir fluids properties; Plan hydrocarbon and geothermal reservoir management; Predict reservoir behaviour and the behaviour of hydrocarbon and geothermal water production system; Optimize hydrocarbon and geothermal water production; Compare specific procedures and processes in petroleum engineering and geoenergy engineering; Appraise process and facility's efficiency in petroleum engineering and geoenergy engineering; Assess the environmental impact of petroleum engineering and geoenergy engineering; Appraise projects in petroleum engineering and geoenergy engineering.			
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	Explain the mechanisms of enhanced recovery methods; Select candidate fields to apply enhanced recovery methods to increase recovery; Make simulation models of injection of gases, steam, polymer solutions and surfactants; Compare the cost-effectiveness of different WAG ratios; Show the examples of chemical and thermal methods, as well as gas injection under miscible and non-miscible conditions; Describe the specifics of unconventional reservoirs; Compare and show the differences of the scenarios of primary, secondary and tertiary oil production; Evaluate the techno-economic perspective of the application of different strategies of increasing the recovery.			

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2.5. Course content (syllabus)	Changing the ratio of mobility, wettability or viscosity of fluid in a reservoir; Analysis of fields that are suitable candidates for a particular EOR method - analysis of the given reservoir and production parameters and screening by the Taber method; Criteria for selecting the supplementary extraction method (EOR). Review and analysis of activities and performance of world-famous EOR studies and projects; Chemical methods: Elements of the study of increasing the recovery by chemical methods - injection of surfactants, polymers, alkalis + infrastructure required for the application of supplementary methods; Case Study - Injection of polymers, analysis of prices of products (polymers) available on the market and the price of injection; Analysis, ie interpretation of laboratory analysis of rheological properties of different types of polymers (determination of the ratio of shear stress and viscosity of polymers); Analysis and selection of the optimal solution (ie concentration) of polymers - interpretation by modified Buckley - Leverett method, determination of "retardation factor", "oil banking"; Matching of laboratory coreflood measurement data + polymer injection with the analytical model and confirmation by the simulation coreflood model; Case study: Analysis of polymer injectivity into the reservoir and the efficiency of flooding with the use of polymers, analytical and simulation models, the impact of heterogeneity; Thermal methods: Elements of the study of steam injection and cyclic steam injection (huff & puff) - thermal concepts (parameters), heat losses, well spacing, gravity drainage with the help of steam; Case study - Thermal EOR, consideration of high utilization of thermal energy of produced fluid and use of solar energy to help heat water; Balancing energy sources for hydrocarbon production by steam injection; Losses, ie ratios of heat losses during injection into wells of different configurations (different conductivities and temperatures of surrounding rocks, different well diameters, different injection speeds); Simulation of thermal efficiency by thermal simulator (Eclipse) - Steam assisted gravity drainage; Gas injection in miscible and immiscible conditions: Elements of the study of gas injection in miscible conditions - estimation of recovery based on measurement of minimum mixing pressures and slim-tube test of extraction; Case Study - CO_2 EOR (required analyses, well tests, pilot, parameters for evaluating the success of CO_2 EOR methods); PVT analysis of CO_2 injection EOR - interpretation of swelling tests and principles of PVT simulation of CO_2-oil system, triangular diagram. Compositional simulation of slimtube test, harmonization with laboratory data; Case sensitivity analysis of cost-effectiveness of different WAG ratios when CO_2 is injected into the reservoir - analysis of technological parameters (injectivity, corrosion under different conditions, minimum fracture pressure); Analysis of CO_2 retention in the reservoir based on a simulation model and possible benefits with a smaller recovery, but large retention; Microbiological methods of increasing recovery; Techno-economic conditions for the application of EOR methods; Features of simulation models for each EOR method; Criteria for the selection of formation and candidate wells for hydraulic fracturing; Reservoir engineering characteristics of unconventional reservoirs; Estimation of gas and gas condensate productivity from low-permeability reservoirs (influence of capillary forces on flow and non-Darcy flow in the near-wellbore zone); Case study: determination of the production regimes of reservoirs with low-permeability zones (eg blockage of gas flow due to condensate formation).		
2.6. Format of instruction:	☒ lectures ☒ seminars and workshops ☒ exercises ☐ online in entirety ☒ partial e-learning	☒ independent assignments ☒ multimedia and the internet ☐ laboratory ☒ work with mentor	2.7. Comments: -

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	☒ field work	☒ work in teams with evaluation of team generic skills	
2.8. Student responsibilities	The student should submit project in the prescribed seminar format, making clear the difference between individual work and teamwork.		

2.9. Monitoring student work	Class attendance	YES		Research		NO	Oral exam	YES	
	Experimental work		NO	Report		NO			
	Essay		NO	Seminar paper	YES				
	Preliminary exam	YES		Practical work	YES				
	Project	YES		Written exam		NO	ECTS credits (total)	5	

	Title	Number of copies in the library	Availability via other media
2.10. Required literature (available in the library and/or via other media)	Sheng, J. (2010.): *Modern chemical enhanced oil recovery: theory and practice*, Gulf Professional Publishing.	YES	YES
	Ramirez, W. F. (1987.): *Application of optimal control theory to enhanced oil recovery* (Vol. 21), Elsevier.	NO	YES

2.11. Optional literature	Manrique, E.J., Izadi, M., Kitchen, C.D., Alvarado, V. (2009.): *Effective EOR decision strategies with limited data: Field cases demonstration*. SPE Reservoir Evaluation & Engineering, *12(04)*, 551-561.
	Zhao, D.F., Liao, X. W., Yin, D. D. (2014.): *Evaluation of CO_2 enhanced oil recovery and sequestration potential in low permeability reservoirs, Yanchang Oilfield, China*, Journal of the Energy Institute, 87(4), 306-313.
	Verma, M.K. (2015.): *Fundamentals of carbon dioxide-enhanced oil recovery (CO_2-EOR)*: A supporting document of the assessment methodology for hydrocarbon recovery using CO_2-EOR associated with carbon sequestration. Washington, DC: US Department of the Interior, US Geological Survey.
2.12. Other (as the proposer wishes to add)	The course is held through an overview of enhanced oil and gas recovery methods, each accompanied by an explanation of the goal of the study as the terms of reference for project problem to be solved in groups ("case study"). As experts in this field must work in teams, special attention will be paid to each new selection of groups for the next project task, which will be carried out for each student through an evaluation of the qualities needed for teamwork (individuality / teamwork, occasional initiative / continuous work, organization, creativity).

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