Załącznik nr 6 do ZW 121/2020

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| FACULTY OF MECHANICAL AND POWER ENGINEERING | |
| **SUBJECT CARD** | |
| Name in Polish | Zaawansowane modelowanie numeryczne w środowisku OpenFOAM |
| Name in English | **ADVANCED NUMERICAL MODELLING USING OPENFOAM** |
| Main field of study | |
| Specialization | CAE |
| Level and form of studies | 2nd level, full-time |
| Kind of subject | obligatory |
| Subject code | W09ENG-SM0058 |
| Group of courses | No |

| | Lecture | Classes | Laboratory | Project | Seminar |
|---|---|---|---|---|---|
| Number of hours of organized classes in university (ZZU) | 30 | | 30 | | |
| Number of hours of total student workload (CNPS) | 60 | | 60 | | |
| Form of crediting | Crediting with grade | | crediting with grade | | |
| For group of courses mark (X) final course | | | | | |
| Number of ECTS points | 2 | | 3 | | |
| including number of ECTS points for practical (P) classes | | | 2 | | |
| including number of ECTS points for direct teacher-student contact (BK) classes | 1 | | 2 | | |

**PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES**

Preliminary knowledge related to numerical modelling including basic discretization schemes.

**SUBJECT OBJECTIVES**

C1 Introduction to the OpenFoam numerical toolbox and OpenFoam programming.
C2 Introduction to basic and advanced numerical models implemented in OpenFoam.
C3 Developing abilities to define new numerical models and their implementation in OpenFoam.

| SUBJECT EDUCATIONAL EFFECTS |
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| **relating to knowledge:** |
| PEK_W01 – knows and understands basics of finite volume discretization and its specifics in the Computational Fluid Dynamics |
| PEK_W02 – knows and understands the structure of OpenFoam numerical toolbox and basics of OpenFoam programming. |
| PEK_W03 – knows and understands advanced numerical models including: conjugate heat transfer, flow with mixing and reactions |
| PEK_W04 – knows and understands dynamics mesh concepts including Arbitrary Mesh Interface |
| PEK_W05 – knows and understands basic and more complex boundary conditions |
| **relating to skills:** |
| PEK_U01 – is able to: use the basic and advanced numerical models offered by the OpenFOAM |
| PEK_U02 – is able to: use the basic and advanced preprocessing and postprocessing utilities offered by the OpenFOAM |
| PEK_U03 – is able to: use the ParaView software to visualise the numerical data |
| PEK_U04 – is able to: implement new equations and to develop the exiting OpenFoam solvers |
| PEK_U05 – is able to: implement new numerical models in the OpenFoam |
| PEK_U06 – is able to: define numerical models with dynamic mesh |
| PEK_U07 – is able to: define numerical multiphase numerical models |

| PROGRAMME CONTENT | | |
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| **Form of classes - lecture** | | **Number of hours** |
| Lec1 | Summary of conservation equations and their representation by partial differential equations. Introduction to OpenFoam software. | 2 |
| Lec2 | Introduction to OpenFoam software including: the OpenFoam structure, available numerical models and basic pre- and post-processing utilities. | 2 |
| Lec3 | Thermodynamic and transport models available in OpenFoam. Introduction to conjugate heat transfer modelling and detailed presentation of a corresponding flow example. | 2 |
| Lec4 | Introduction to modelling of flow with multiple spices and flow with chemical reactions. Detailed presentation of a corresponding numerical example based on lecturer own research. | 2 |
| Lec5 | Introduction to Finite Volume Method and basic methods of discretization used in CFD. | 2 |
| Lec6 | Introduction to OpenFoam programming #1: implementation of Burgers equation. Discussion of consequences of non-linear nature of the Burgers equation. | 2 |
| Lec7 | OpenFoam programming #2: adding a new PDE equation to an existing solver, compilation and usage. | 2 |
| Lec8 | OpenFoam programming #3: implementation of variable viscosity in an existing model, explanation of definition of new numerical model with the implemented viscosity model. Discussion of influence of the new model on the flow. | 2 |
| Lec9 | Introduction to complex boundary condition. | 2 |
| Lec10 | OpenFoam programming #4: creation of a new numerical library by definition and implementation of Casson viscosity model. Presentation of its usage and consequences in the flow. | 2 |
| Lec11 | Introduction to turbulence and turbulence modelling: RANS equations, Eddy viscosuty. | 2 |
| Lec12 | Introduction to the concept of wall functions and basics of their implementation. | 2 |
| Lec13 | Modelling of wind power plant: linear and angular momentum theory. | 2 |

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| | Introduction to usage of additional source therms in modelling. | |
| Lec14 | Introduction to Blade Element Method and its implementation and usage in OpenFoam | 2 |
| Lec15 | Final test of the lecture | 2 |
| | Total hours | **30** |
| **Form of classes - laboratory** | | **Number of hours** |
| Lab1 | Introduction to the OpenFoam, discussion of its structure and installation. First Example: Lid-driven cavity flow and flow in a channel. | 2 |
| Lab2 | Usage of complex boundary conditions (derived from basic Bcs) based on T-junction example. | 2 |
| Lab3 | Usage and definition of conjugate heat transfer model. Running calculation in parallel mode. | 2 |
| Lab4 | OpenFoam programming #1: adding a new PDE equation to existing solver, compilation and usage. | 2 |
| Lab5 | OpenFoam programming #2: step-by-step implementation of a variable viscosity in an existing solver. Exercise: modelling of a flow of two miscible fluids with different viscosities. | 2 |
| Lab6 | Definition of a numerical model with dynamic mesh based on a sloshing tank example and a rigid body motion. | 2 |
| Lab7 | Dynamic mesh motion using Arbitrary Mesh Interface | 2 |
| Lab 8 | OpenFoam programming #3: step-by-step implementation of a new viscosity model (Casson model). | 2 |
| Lab 9 | Usage of the new viscosity model implemented during Lab 8 in a flow in channel and comparison of the results with different viscosity models. | 2 |
| Lab 10 | Definition and running of numerical model of a flow of reacting mixture including: combustion, reactions and mixing. | 2 |
| Lab 11 | Adapting the reactingFoam for a passive gases mixing. | 2 |
| Lab 12 | Definition of a numerical model of helium discharge and its propagation in a tunnel. | 2 |
| Lab 13 | Adding new physical models as source therms (using fvOptions). Modelling of wind turbine as Actuation Disc Source. | 2 |
| Lab 14 | Adding new physical models as source therms (using fvOptions). Modelling of porosity. | 2 |
| Lab 15 | Presentation of individual student's projects. | |
| | Total hours | **30** |

| **TEACHING TOOLS USED** |
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| N1. Traditional lecture with a use of slides |
| N2. Laboratories – computational exercises |
| N3. Laboratories - individual problem solving using OpenFoam |
| N4. Consultation |
| N5. Self-reliant work – individual studies and preparation of home works and final project. |

**EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT- lecture**

| **Evaluation** (F– forming (during semester), C– concluding (at semester end) | Educational effect number | Way of evaluating educational effect achievement |
|---|---|---|
| C | PEK_W01 ÷ PEK_W05; PEK_U01 ÷ PEK_U07 | Final test. |

**EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT- laboratory**

| **Evaluation** (F– forming (during semester), C– concluding (at semester end) | Educational effect number | Way of evaluating educational effect achievement |
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| F1 | PEK_U01 ÷ PEK_U02; | Report |
| F2 | PEK_U03 ÷ PEK_U04; | Report |
| F3 | PEK_U05 ÷ PEK_U07; | Report |
| P=(F1+F2+F3)/3 | | |

## PRIMARY AND SECONDARY LITERATURE


PRIMARY LITERATURE :

[1] F Moukalled, L Mangani, M Darwish, The Finite Volume Method in Computational Fluid Dynamics An Advanced Introduction with OpenFOAM® .

[2] User Guide, Tutorial Guide, Programmers Guide, https://www.openfoam.com/documentation/

[3] OpenFOAM wiki: http://openfoamwiki.net/index.php/Main_Page

SECONDARY LITERATURE:

[1] JH Ferziger, M Perić, RL Street, Computational Methods for Fluid Dynamics, Springer.


## SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)


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