Warsaw University of Technology

COURSE OFFERED IN THE DOCTORAL SCHOOL

Code of the course	4606-ES-0000EHI-0108	Name of the course	Polish	**Modelowanie spalania turbulentnego**
			English	**Modelling of turbulent combustion**
Type of the course	speciality subject			
Course coordinator	Prof.dr hab.inż. Andrzej Teodorczyk			
Implementing unit	Faculty of Power and Aeronautical Engineering	Scientific discipline / disciplines*	Mechanical Engineering / Environmental Engineering Mining and Power Engineering / Chemical Engineering	

Level of education	doctoral	Semester	summer		
Language of the course	English				
Type of assessment:	Passing with the grade	Number of hours in a semester	30	ECTS credits	2
Minimum number of participants	12	Maximum number of participants	50	Available for students (MSc)	Yes/~~No~~

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week	2				
	in a semester	30				

* does not apply to the Researcher's Workshop

1. Prerequisites

Thermodynamics, combustion, fluid mechanics and numerical methods

2. Course objectives

knowledge and skills in the field of theoretical and numerical modeling of laminar, turbulent and detonative combustion

3. Course content (separate for each type of classes)

Lecture

1. Introduction – 1h

1. Fundamentals of turbulent flow – 3h

2.1. Definition of turbulence

2.2. Turbulence formation

2.3. Statistical concepts of turbulence

2.4. 3D spectrum of turbulence

2.5. Dynamics of vorticity and energy cascade

2.6. Influence of density changes on vorticity and turbulence

2.7. Transport processes in turbulent flow

2. Conservation equations for reacting flows – 2h

3.1. General forms

3.2. Simplified forms

1. Laminar premixed flames – 3 h

4.1. Conservation equations and numerical solutions

4.2. Steady 1D flames

4.3. Theoretical solutions

4.4. Flame thickness

4.5. Flame stretch

4.6. Flame speeds

4.7. Instabilities of laminar flame fronts

2. Laminar diffusion flames – 3h
   5.1. Theoretical tools
   5.2. Flame structure for infinitely fast chemistry
   5.3. Full solutions for infinitely fast chemistry
   5.4. Real diffusion flames
3. Introduction to turbulent combustion – 4h
   6.1. Interaction between flames and turbulence
   6.2. Computational approaches to turbulent combustion
   6.3. RANS simulations
   6.4. DNS simulations
   6.5. LES simulations
   6.6. Chemistry for turbulent combustion
4. Turbulent premixed flames – 4h
   7.1. Turbulent premixed flames regimes
   7.2. RANS of turbulent premixed flames
   7.3. LES of turbulent premixed flames
   7.4. DNS of turbulent premixed flames
8. Turbulent non-premixed flames – 4h
   8.1. Turbulent non-premixed flames regimes
   8.2. RANS of turbulent non-premixed flames
   8.3. LES of turbulent non-premixed flames
   8.4. DNS of turbulent non-premixed flames
9. Flame/wall interactions – 2h
10. Flame/acoustics interactions -2h
11. Detonative combustion – 2h

Laboratory

4. Learning outcomes			
	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
Knowledge			
K01	Conservation equations for multicomponent flows with combustion and their simplification	SD_W2 SD_W3	Written colloquium
K02	Numerical methods of laminar premixed combustion	SD_W2 SD_W3	Written colloquium
K03	Numerical methods of laminar diffusion combustion	SD_W2 SD_W3	Written colloquium
K04	Basic concepts of turbulent combustion modelling	SD_W2 SD_W3	Written colloquium
K05	Models of turbulent premixed flames	SD_W2 SD_W3	Written colloquium

K06	Models of turbulent diffusion flames	SD_W2 SD_W3	Written colloquium
K07	Models of the interaction of flames with walls	SD_W2 SD_W3	Written colloquium
K08	Models of combustion couplings with acoustics	SD_W2 SD_W3	Written colloquium
K09	Detonative combustion	SD_W2 SD_W3	Written colloquium
Skills			
S01	Creating a mathematical model of the combustion process	SD_U1, SD_U2, SD_U4, SD_U6	Project evaluation
S02	Using numerical simulations to analyze the combustion process	SD_U1, SD_U2, SD_U4, SD_U6	Project evaluation
S03	Interpreting the results of numerical simulations of combustion	SD_U1, SD_U2, SD_U4, SD_U6	Project evaluation
Social competences			
SC01		SD_K1	

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria

The final grade is the result of the evaluation from colloquia and the evaluation of the project (results, report)

6. Literature

Basic literature:

1. T.Poinsot, D.Veynante: Theoretical and Numerical Combustion, Third Edition by authors, 2011
2. Turbulent Combustion Modeling, Advances, New Trends and Perspectives, T.Echekki and E.Mastorakos Eds., Springer 2011
3. R.S.Cant, E.Mastorakos: An Introduction to Turbulent Reacting Flows, Imperial College Press, London, UK (2008)

Supplementary literature:

1. R.O.Fox: Computational Models for Turbulent Reacting Flows, Cambridge University Press, Cambridge, UK (2003)
2. N.Peters: Turbulent Combustion, Cambridge University Press, 2001
3. E.S.Oran, J.P.Boris: Numerical simulation of reactive flow, Cambridge University Press, 2001
4. R.Borghi: Turbulent combustion modeling, Prog. Energy Comb. Sci., 14(4) 1998
5. J.Janicka, A.Sadiki: Large Eddy simulation for turbulent combustion, Proc. Combust. Inst. 30: 537-547, 2004
6. H.Pitsch: Large eddy simulation of turbulent combustion, Ann.Rev.Fluid Mech., 38:453-482, 2006
7. S.B.Pope: Pdf methods for reactive flows, Prog.Energy Combust.Sci., 19(11), 1985

D.Veynante, L.Vervisch: Turbulent combustiom modeling, Prog.Energy Combust. Sci. 28:196-266, 2002

7. PhD student’s workload necessary to achieve the learning outcomes**

No.	Description	Number of hours

1	Hours of scheduled instruction given by the academic teacher in the classroom	30
2	Hours of consultations with the academic teacher, exams, tests, etc.	10
3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	10
4	Amount of time devoted to the preparation for exams, test, assessments	10
	Total number of hours	**60**
	ECTS credits	**2**

** 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)