STUDY COURSE DESCRIPTION FORM

Name of the course **Model Order Reduction**	Code
Name of the doctoral school **Poznan University of Technology Doctoral School**	Year /Semester **....**
Specialty/Discipline **Mechanical Engineering**	Type (obligatory, elective): **elective**
No. of hours Lectures: **4** Classes: **-** Laboratories: **-** Seminars: **-**	No. of credits **1**

Cycle of study: Third-cycle studies (Polish Qualifications Framework level eight)	**Form of study:** Full-time	**Assessment:** (written exam, presentation, etc.) Report/presentation

Responsible for the course/lecturer:

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Prerequisites in terms of knowledge, skills and social competencies:

1	**Knowledge:** Basic knowledge of Mathematics, including solution of ODE (ordinary differential equations) and linear systems. Knowledge of modeling/simulation techniques in a selected field of engineering (like structural mechanics, fluid mechanics or biomechanics)
2	**Skills:** Basic engineering, mathematical and computing science skills – including understanding of mathematical formulas and numerical algorithms. Ability to use computational tools like Matlab, Octave or any programming language. Ability to perform numerical simulations, preferably in the field of mechanical engineering.
3	**Social competencies:** Ability to critically assess the knowledge and received content.

Objectives of the course: The PhD student will gain knowledge on model order reduction / reduced order modeling techniques, leading to the reduction of computational effort and memory consumption for the analysis of physical systems. Knowledge of modal decomposition techniques, like Principal Component Analysis (PCA), Dynamic Mode Decomposition and others, will allow the interpretation and better understanding of underlying phenomena. The student will get knowledge on model calibration techniques based on Artificial Intelligence (like genetic algorithms).

Educational results (Study outcomes)

Knowledge:

P8S_WG	PhD student knows and understands to the extent that enables revision of existing para-digms - global achievements, covering theoretical basis as well as general and selected specific issues, that are specific to scientific disciplines studied at the doctoral school,	**SzD_W01**
P8S_WG	PhD student knows and understands key developmental trends of science disciplines in which education takes place at the doctoral school,	**SzD_W02**
P8S_WG	PhD student knows and understands scientific research methodology in disciplines represented at the doctoral school,	**SzD_W03**

Skills:

P8S_UW	PhD student can use the knowledge from different branches of science to creatively identify, formulate and to innovatively solve complex problems or to execute research tasks in particular: - define the aim and subject of scientific research, form a research hypothesis, - develop research methods, techniques and tools and use them creatively, - draw conclusions on the basis of research results,	**SzD_U01**
P8S_UW	PhD student can critically analyze and asses scientific research results, work of experts and other creative activities together with their contribution into knowledge development,	**SzD_U02**
P8S_UK	PhD student can share results of scientific activity also in a popular form,	**SzD_U05**
P8S_UO	PhD student can plan and implement individual and team research projects, also in the international community,	**SzD_U09**

Social competencies:

P8S_KK	critically assess the achievements within a given scientific discipline,	**SzD_K01**
P8S_KK	critically evaluate their own contribution to the development of a given scientific discipline,	**SzD_K02**
P8S_KK	acknowledge the importance of knowledge in solving cognitive and practical problems,	**SzD_W03**

Compulsory literature:

1. B.R. Noack, M. Morzyński, and G. Tadmor. Reduced-order modelling for flow control. CISM Courses and Lectures 528. Springer-Verlag, 2011.
2. R. King (editor). Notes on Numerical Fluid Mechanics and Multidisciplinary Design. Volume 95: Active Flow Control. Springer, Berlin Heidelberg, 2007.
3. T. Duriez, S.L. Brunton, and B.R. Noack. Machine Learning Control - Taming Nonlinear Dynamics and Turbulence. Fluid Mechanics and Its Applications, 116. Springer-Verlag, 2016.

Additional literature:

1. C. Pozrikidis. Numerical Computation in Science and Engineering. Oxford University Press 1998
2. C.A.J. Fletcher. Computational Galerkin Methods. Springer, New York, 1984.
3. N. Aubry, P. Holmes, J. Lumley, and E. Stone. The dynamics of coherent structures in the wall region of a turbulent boundary layer. J. Fluid Mech., 192:115-173, 1988.
4. W. Stankiewicz, R. Roszak, and M. Morzyński. Genetic algorithm-based calibration of reduced order Galerkin models. Mathematical Modelling and Analysis, 16(2):233-247, 2011.
5. T. Lassila, A. Manzoni, A. Quarteroni, G. Rozza. Model Order Reduction in Fluid Dynamics: Challenges and Perspectives. Reduced Order Methods for Modeling and Computational Reduction, 235–273, 2014.

COURSE DESCRIPTION

	General issues	**Specific issues**	**No. of hours**
1	Introduction	• Computational cost of the modeling and simulation of physical systems • Applications of reduced order models	0.5

2	Modal decomposition techniques	• Theoretical fundamentals • Principal Component Analysis (PCA) / POD • Dynamic Mode Decomposition • Locally Linear Embedding • Physical modes – global stability, generalized eigenvalue problems • Applications	1
3	Model order reduction techniques	• Model requirements for real-time feedback control • White box an black box models • Galerkin projection • Galerkin approximation • Model accuracy	1
4	Robust reduced order models	• Interpolated models • Robust ROM for the changing operating/boundary conditions	0.5
5	Towards machine learning	• Model calibration using genetic algorithms • Applications of machine learning • Data preprocessing using modal decomposition	1

Assessment methods of educational results

Report/presentation on selected topics related to the issues covered by the course

STUDENT'S WORKLOAD

Activity	**Hours**
Participation in lectures	4
Contact hours with lecturers (consultations)	6
Self-study and report preparation	20
Exam	-
TOTAL	**30**
TOTAL NUMBER OF ECTS POINTS FOR THE COURSE	1