# COURSE DESCRIPTION CARD - SYLLABUS

Course name
MODEL ORDER REDUCTION

## Course

Proposed by Discipline
Mechanical Engineering

Year/Semester
II/4, III/6

Type of studies
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

## Number of hours

| Lecture | Tutorials | Projects/seminars |
|---|---|---|
| 4 | | |

## Number of credit points

1

## Lecturers

Responsible for the course/lecturer:
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Responsible for the course/lecturer:

## Prerequisites

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).

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.

Social competencies: ability to critically assess the knowledge and received content.

## Course objective

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).

## Course-related learning outcomes

### Knowledge

A PhD student who graduated from doctoral school knows and understands:

1) global achievements, covering theoretical basis as well as general and selected specific issues, that are specific to scientific disciplines studied at the doctoral school, to the extent that enables revision of existing paradigms, [P8S_WG/SzD_W01]

2) key developmental trends of science disciplines in which education takes place at the doctoral school, [P8S_WG/SzD_W02]

3) scientific research methodology in disciplines represented at the doctoral school. [P8S_WG/SzD_W03]

### Skills

A PhD student who graduated from doctoral school can:

1) 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, [P8S_UW/SzD_U01]

2) critically analyze and asses scientific research results, work of experts and other creative activities together with their contribution into knowledge development, [P8S_UW/SzD_U02]

3) share results of scientific activity also in a popular form, [P8S_UK/SzD_U05]

4) plan and implement individual and team research projects, also in the international community. [P8S_UO/SzD_U09]

### Social competences

A PhD student who graduated from doctoral school is ready to:

1) critically assess the achievements within a given scientific discipline, [P8S_KK/SzD_K01]

2) critically evaluate their own contribution to the development of a given scientific discipline, [P8S_KK/SzD_K02]

3) acknowledge the importance of knowledge in solving cognitive and practical problems. [P8S_KK/SzD_K03]

### Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

| PQF code | Methods for verification of learning outcomes | Assessment criteria |
|---|---|---|
| W01, W02, W03 | Report/presentation on selected topics related to the issues covered by the course | Knowing and understanding methods of model order reduction |
| U01, U02, U05, U09 | Report/presentation on selected topics related to the issues covered by the course | Ability to create reduced order model of a given physical phenomenon |
| K01, K02, K03 | Discussion, report/presentation | Ability to critically evaluate the applicatioins and limitations of presented and currently developed methods |

### Programme content

1. Introduction (computational cost of the modeling and simulation of physical systems, applications of reduced order models).
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).
3. Model order reduction techniques (model requirements for real-time feedback control, white box and black box models, Galerkin projection, Galerkin approximation. model accuracy).
4. Robust reduced order models (interpolated models, robust ROM for the changing operating/boundary conditions).
5. Towards machine learning (model calibration using genetic algorithms, applications of machine learning, data preprocessing using modal decomposition).

### Teaching methods

Lecture: multimedia presentation including illustrations and examples.

## Bibliography

Basic

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

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.

## Breakdown of average student's workload

| | Hours | ECTS |
|---|---|---|
| Total workload | 30 | 1.0 |
| Classes requiring direct contact with the teacher | 10 | 0.5 |
| Student's own work (literature studies, preparation for tutorials, project preparation) [1] | 20 | 0.5 |

[1] delete or add other activities as appropriate