AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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| Module name: | Finite Element Method in Material Engineering and Metal Forming | | |
| Academic year: | 2019/2020 | Code: ZSDA-3-0107-s | ECTS credits: 5 |
| Faculty of: | Szkoła Doktorska AGH | | |
| Field of study: | Szkoła Doktorska AGH | Specialty: | — |
| Study level: | Third-cycle studies | Form and type of study: | Full-time studies |
| Lecture language: | English | Profile of education: Academic (A) | Semester: 0 |
| Course homepage: | http://home.agh.edu.pl/~milenin/Dydaktyka/FEM.htm | | |
| Responsible teacher: | prof. dr hab. inż. Milenin Andriy (milenin@metal.agh.edu.pl) | | |

## Module summary

FEM is presented on the basis of its use in metal forming and material engineering. Examples of industrial applications, theoretical and programmatic aspects are discussed.

# Description of learning outcomes for module

| MLO code | Student after module completion has the knowledge/ knows how to/is able to | Connections with FLO | Method of learning outcomes verification (form of completion) |
|---|---|---|---|
| Skills: he can | | | |
| M_U001 | The student can use the shape functions to interpolate the parameters in the nodes in volume of the finite element. | SDA3A_U01 | |
| M_U002 | A student can write a simple program for solving with the help of FEM the problem of non-stationary heat flow. | SDA3A_U01 | |
| M_U003 | Student has the skills to apply commercial programs based on the FEM (Qform) | SDA3A_U01 | |
| Knowledge: he knows and understands | | | |
| M_W001 | Knows the basis of interpolation in FEM, definition of shape functions, the types of most commonly used finite elements. | SDA3A_W01 | |
| M_W002 | Knows the definitions of stiffness matrix and load vector, the principle of obtaining solutions in FEM. | SDA3A_W03 | |
| M_W003 | Know the basics of the solution with help of FEM the heat exchange and elasticity problems | SDA3A_W03 | |

## Number of hours for each form of classes

| Suma | Form of classes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lectures | Auditorium classes | Laboratory classes | Project classes | Conversation seminar | Seminar classes | Practical classes | Fieldwork classes | Workshops | Prace kontrolne i przejściowe | Lektorat |
| 60 | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## FLO matrix in relation to forms of classes

| MLO code | Student after module completion has the knowledge/ knows how to/is able to | Form of classes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lectures | Auditorium classes | Laboratory classes | Project classes | Conversation seminar | Seminar classes | Practical classes | Fieldwork classes | Workshops | Prace kontrolne i przejściowe | Lektorat |
| Skills: he can | | | | | | | | | | | | |
| M_U001 | The student can use the shape functions to interpolate the parameters in the nodes in volume of the finite element. | - | - | - | - | - | - | - | - | - | - | - |
| M_U002 | A student can write a simple program for solving with the help of FEM the problem of non-stationary heat flow. | - | - | - | - | - | - | - | - | - | - | - |
| M_U003 | Student has the skills to apply commercial programs based on the FEM (Qform) | - | - | - | - | - | - | - | - | - | - | - |
| Knowledge: he knows and understands | | | | | | | | | | | | |
| M_W001 | Knows the basis of interpolation in FEM, definition of shape functions, the types of most commonly used finite elements. | + | - | + | - | - | - | - | - | - | - | - |
| M_W002 | Knows the definitions of stiffness matrix and load vector, the principle of obtaining solutions in FEM. | + | - | + | - | - | - | - | - | - | - | - |
| M_W003 | Know the basics of the solution with help of FEM the heat exchange and elasticity problems | + | - | + | - | - | - | - | - | - | - | - |

## Student workload (ECTS credits balance)

| Student activity form | Student workload |
|---|---|
| Udział w zajęciach dydaktycznych/praktyka | 60 h |
| Preparation for classes | 20 h |
| przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania | 10 h |
| Realization of independently performed tasks | 20 h |
| Examination or Final test | 2 h |
| Contact hours | 5 h |
| Summary student workload | 117 h |
| Module ECTS credits | 5 ECTS |

## Additional information

## Module content

**Lectures**

Introduction to FEM

History of FEM. Usage FEM in metal forming and material engineering. Industrial exemples application of FEM. Basic conception of FEM. Interpolation in FEM, definition of shape functions. 4h.

FEM technics

Finite elements of higher order. Isoparametric transformation. Usage of local coordinat systems in FEM. Jacobi matrix. Numerical integration. 4h.

Solving the heat flow problems by FEM

Steady state and non steady state heat flow problems. Equations for stiffness matrix and load vector. Two dimensional FEM code for simulation of non steady state heat flow. 4h.

Solution of elastic problems by FEM

Basics of theory of elasticity. Variation principle of theory of elasticity. Equations for stiffness matrix and load vector. Example of two dimensional FEM code for solving plain strain problem by FEM. Usage FEM code for topology optimization. 6h

Solution of rigid plastic problems by FEM.

Theory of plasticity of non compressible materials. Variational principle. Equations for stiffness matrix and load vector. Example of FEM code for simulation of plain strain problem in flow formulation. Analogy between flow dynamic and theory of plasticity in flow formulation. 6h.

Commertional FEM code Qform for simulation of hot metal forming processes.

Theoretical basics of Qform FEM program. Structure and interface of Qform. Simulation of forging, shape rolling and extrusion in Qform. Implementation of advanced material models in Qform. Lua scripts in Qform. Implementation of flow stress and fracture models in Qform. Examples of industrial applications of Qform for design of metal forming technologies. 4h

Summary of course.
Industrial examples of usage FEM in research for metal forming and material engineering. 2h

**Laboratory classes**

Development of a program for modeling non-stationary heat flow.
Presentation of main modules of FEM program for simulation of heat flow problems, equations for stiffness matrix and load vector. Usage of Paraview program for visualisation of results. Numerical experiments: influence of FEM grid density to results of simulation.  (6).

Development of a program for modeling of elasticity problem.
Presentation of main modules of FEM program for simulation of elasticity, equations for stiffness matrix and load vector. Usage of Paraview program for visualisation of results. Numerical experiments: influence of FEM grid density to results of simulation. Comparison of numerical results with analitical solution. (6).

Usage of Qform program for simulation of rigid-plastic problems
Motivation for simulation of metal forming processes using rigid-plastic approach. Data, needed for simulation. Flow stress models. Boundary conditions – friction, heat transfear, geometry. Numerical parameters of simulation. (4)

Topology optimisation
Modification of FEM code for topology optimisation (generative design). Numerical example: optimization of beam shape (2)

Usage Qform for simulation of elastic-plastic deformation.
Motivation for simulation of metal forming processes using elastic-plastic approach. Problems of residual stresses, springback, termal stresses. Data, needed for simulation. Flow stress models. Elasticity parameters of material. Boundary conditions – friction, heat transfear, geometry. Numerical parameters of simulation. Example – simulation of flow forming processes (6)

Programming in Qform program.
Usage of LUA scripts for simulation of flow stress, ductility, microstructure. Debug of • .lua module. (6)

## Teaching methods and techniques:

Lectures: Treści prezentowane na wykładzie są przekazywane w formie prezentacji multimedialnej w połączeniu z klasycznym wykładem tablicowym wzbogaconymi o pokazy odnoszące się do prezentowanych zagadnień.
Laboratory classes: W trakcie zajęć laboratoryjnych studenci samodzielnie rozwiązują zadany problem praktyczny, dobierając odpowiednie narzędzia. Prowadzący stymuluje grupę do refleksji nad problemem, tak by otrzymane wyniki miały wysoką wartość merytoryczną.

## Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:

Presented by a teacher at the first lecture of the semester

## Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:

Lectures:
– Attendance is mandatory: Yes

– Participation rules in classes: Studenci uczestniczą w zajęciach poznając kolejne treści nauczania zgodnie z syllabusem przedmiotu. Studenci winni na bieżąco zadawać pytania i wyjaśniać wątpliwości. Rejestracja audiowizualna wykładu wymaga zgody prowadzącego.
Laboratory classes:
– Attendance is mandatory: Yes
– Participation rules in classes: Studenci wykonują ćwiczenia laboratoryjne zgodnie z materiałami udostępnionymi przez prowadzącego. Student jest zobowiązany do przygotowania się w przedmiocie wykonywanego ćwiczenia, co może zostać zweryfikowane kolokwium w formie ustnej lub pisemnej. Zaliczenie zajęć odbywa się na podstawie zaprezentowania rozwiązania postawionego problemu. Zaliczenie modułu jest możliwe po zaliczeniu wszystkich zajęć laboratoryjnych.

## Method of calculating the final grade
Final grade = 0.6 Evaluation on the exam + 0.4 Evaluation in the practical classes.

## Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:
Presented by a teacher at the first lecture of the semester

## Prerequisites and additional requirements
Programming in C++ or Fortran.
Numerical methods.
Basic knowlege in metal forming, mechanics, material engineering.

## Recommended literature and teaching resources
1. Milenin A. Basics of FEM. Thermomechanical problems // AGH, 2010 (in Polish).
2. O.C.Zienkiewicz, R.L.Taylor The Finite Element Method // Butterworth Heinemann, 3 vol, 5-th Edition, London, 2000
3. K.J. Bathe, Finite Element Procedures in Engineering Analysis, Prentice Hall Inc.
4. Segerlind L. J., Applied Finite Element Analysis // J. Wiley & Sons, New York, 1976, 1984, 1987, 427 pp. ISBN 0-471-80662-5.

## Scientific publications of module course instructors related to the topic of the module
1. Andrij Milenin, Piotr Kustra, Tsuyoshi Furushima, Peihua Du, Jiří Němeček Design of the laser dieless drawing process of tubes from magnesium alloy using FEM model // Journal of Materials Processing Technology, 2018, 262, 65-74
2. A. MILENIN, P. KUSTRA, D. BYRSKA-WÓJCIK FEM-BEM code for the multiscale modeling and computer aided design of wire drawing technology for magnesium alloys // Advanced Engineering Materials ; ISSN 1438-1656. — 2014 vol. 16 iss. 2, p. 202–210.
3. A Milenin, P Kustra, D Byrska-Wójcik, M Pietrzyk Numerical prediction of fracture during manufacturing of thick wall tubes from low ductility steels in flow forming process, 2015,Computer Methods in Materials Science 15 (4), 469-480
4. A. MILENIN, M. KOPERNIK Multiscale FEM model of artificial heart chamber composed of nanocoatings // Acta of Bioengineering and Biomechanics ; 2009 vol. 11 no. 2, p. 13–20

## Additional information
None