

**AGH**AGH UNIVERSITY OF SCIENCE  
AND TECHNOLOGY

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 examples 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 coordinate 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. Variational 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.

##### Commercial 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 analytical 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 transfer, 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, thermal stresses. Data, needed for simulation. Flow stress models. Elasticity parameters of material. Boundary conditions – friction, heat transfer, 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 sylabusem 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 knowledge 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