Operating Rules of Course MEC-E6002
Welding Technology and Design

Master Degree in Mechanical Engineering 2023/2024

Responsible Professor: Professor Pedro Vilaça

Period V (23rd April to 6th June 2024); Credits: 5; Language: English; Evaluation: 0 to 5

Zoom link (if needed)

requires login @ https://aalto.zoom.us; **meeting ID** = 478 439 5526**; host key** = 992021

https://aalto.zoom.us/j/4784395526?pwd=eTJ5UDIwand2cXVmVlFjbkREUVphUT09

Summary of the course content:

Welding technology plays a critical role in almost every industry sector - is critical to the world's ability to cope with the continuous development demands. Whether joining the smallest bio implants or welding the world's biggest components, welding makes significant contributions to the global quality of life. Welding technologies, whether conventional or advanced, and welding engineers and operators, are thus vital elements to improved quality of life for all. In fact there is a huge demand for welders in the industry. Welding is an extremely important component to many industries in Finland and worldwide. In fact, without specialized know-how on welding, many construction projects, bridge building, vehicle manufacturing processes, computer electronics plants, plastics manufacturing and even our space program would come to a standstill.
In the present course, the fundaments of welding and joining by fusion and solid state are reviewed preparing the students for the introduction of the most relevant developments and recent innovations in the welding technology. The fundamentals on the welding metallurgy and design of welded structures will also be assessed.

In preparation to attend MEC-E6002, the participants are recommended to recollected the personal background education on fundaments of:

- "material science and engineering"
- "physics of electromagnetism"
- "mechanics of materials"
- "basics on structural design"

Learning outcomes

After the course the student can:

- Identify the main joining mechanisms within welding technology;
- Address the fundaments of physics of electric arc and metallic transference in electric arc welding;
- Implement an applicability analysis of SMAW + SAW + GTAW + PAW + GMAW + FCAW + LW + EBW + Hybrid joining techniques
- Address the fundaments of solid state welding techniques and joining techniques for advanced materials: polymers; ceramics; composites;
- Make a weldability analysis based on the welding metallurgy;
- Apply the fundaments of of design of welded structures

Course Team

Responsible Professor timetable to support the students:

- Wednesday 15h00 - 17h00, via Zoom link (provided at top of this document) and pending on email for request/confirmation;
- Email: pedro.vilaca@aalto.fi;
- Phone: +358 50 365 2110;
- Visiting address: Otakaari 4 (K1 building), Room 227b.

Contact of Welding Laboratory Teacher:

- Kalle Jalava (kalle.jalava@aalto.fi ; +358503282870); Use it to inform any details related to laboratory operation and attendance.

Contact of Course Assistant:

- Samuel Akinwamide (samuel.akinwamide@aalto.fi); Use this contact to get feedback on the evaluation of Essays and Exercise Reports.
- Maria Silva (maria.santossilva@aalto.fi); Use this contact to get feedback on the evaluation of the Laboratory Reports

References:

Main General

- [1] Principles of Welding – Processes Physics, Chemistry, and Metallurgy. Robert W. Messler, Jr. Wiley-VCH. 2004 (ISBN-13: 978-0-471-25376-1)
- [2] Welded Joint Design (3rd Edition), John Hicks. Woodhead Publishing Ltd. 1999 (ISBN-1-85573386-2).

Other

General (Welding Processes and Applications):

- [3] AWS Welding Handbook – Vol. 1 to 4 – 8th and/or 9th edition. American Welding Society.
- ASM Metals Handbook – Vol. 6 – Welding Brazing and Soldering. 1993. ASM International;

Electric Arc Physics:

- J. F. Lancaster (1986) The Physics of Welding, 2nd edition, IIW, Pergamon Press.

Solid-State Welding and Processing:

- Pedro Vilaça, João Gandra, Catarina Vidal, 2012 “Linear Friction Based Processing Technologies for Aluminum Alloys: Surfacing, Stir Welding and Stir Channeling”. Chapter 7 of book: “Aluminium Alloys-New Trends in Fabrication and Applications”. pp. 159-197. ISBN 980-953-307-512-4, Intech. Available from: doi: 10.5772/52026;
- Pedro Vilaça, Wayne Thomas, 2011 “State-of-the-art in FSW technology”. Chapter 4 of book: “Structural Connections for Lightweight Metallic Structures”. pp. 85-124. ISBN 978-3-642-18186-3, Springer. Available from doi: 10.1007/8611_2011_56.

Design of Welded Structures:

- Eurocode 3: Design of steel structures. Part 1-1 (General rules and rules for buildings) and Part 1-8 (Design of joints).

Estimated Workload Distributed over Tasks of MEC-E6002 (5 ECTS)

Event/action description	#Events or #h/event	#hours
Self-preparation of Seminars	1 h/event	15
Theory Seminars (workload factor 1:1)	12 events	35
Essays	8 events; 250 words (0.5~1 page); 1 h/100 words	22,5
		54 %
Self-preparation of Laboratory	0,5 h/event	1,5
Exercises/Laboratory (workload factor 1:2)	5 events	10
Exercises/Laboratory reporting	5 events; 500 words (1~2 page); 1 h/100 words	25
		27 %
Exam preparation / Feedback	Self-study + Discussion w/ Prof.	18.5
Exam (oral)	1 event	0.5
		19 %
	TOTAL	**135 h**

Notes:

- This is an average estimation of the workload (h), without precise, or individual character.
- 1 cr (ECTS) ≈ 27 h (26.7 h) ⇒ 5 cr ≈ 135 h

Date	Session Content	Time and Local
Theory Seminar 1 **23/04** (Tuesday)	Presentation of course contents and operation plan Introduction to welding technology: §1.1 of [1] • Technological scope • Historical development of welding processes • Nomenclature w/chapter 8 of [3] • Weldability concept w/chapter 17 of [1]	8h15-10h00 ALMA MEDIA - U356 **(Theory Essay #1)**
Theory Seminar 2 **24/04** (Wednesday)	Physics of the electric arc in welding technology: • Fundaments chapter 5 and §8.1 to 8.3 of [1] • Physics of the metal transference in electric arc chapter 9 of [1]	10h15-12h00 U261 OP - U261
Theory Seminar 3 **24/04** (Wednesday)	Physics of the electric arc in welding technology: • Physics of the metal transference in electric arc chapter 9 of [1] • Power sources in electric arc welding processes §3.3.2.2 of [1]	12h15-14h00 U261 OP - U261 **(Theory Essay #2)**
Theory Seminar 4 **29/05** (Monday)	Introduction to metallurgy of welding: chapter 13 to 16 of [1] • Fundaments • Thermal cycle in welding w/chapter 6 of [1] • Welding of steels and low alloy steels	9h15-12h00 ALMA MEDIA - U356
Theory Seminar 5 **30/04** (Tuesday)	Introduction to metallurgy of welding (cont.): chapter 13 to 16 of [1] • Welding of stainless steels • Welding of non-ferrous metals (e.g. aluminium alloys)	8h15-10h00 ALMA MEDIA - U356 **(Theory Essay #3)**
Theory Seminar 6 **06/05** (Monday)	Introduction to metallurgy of welding (cont.): chapter 13 to 16 of [1] • Welding of steels and low alloy steels • Welding of stainless steels • Welding of non-ferrous metals (e.g. aluminium alloys)	9h15-12h00 ALMA MEDIA - U356 **(Theory Essay #4)**
Theory Seminar 7 **07/05** (Tuesday)	Design of welded structures (cont.): [2] • Introduction and Principles • Stresses in Structures • Design of Welds and Joints	8h15-10h00 ALMA MEDIA - U356
Exercise Seminar 1 **13/05** (Monday)	Resolution of exercises: • Metallurgy of welding • Design of welded structures	9h15-12h00 ALMA MEDIA - U356
Theory Seminar 8 **14/05** (Tuesday)	Design of welded structures (cont.): • Residual Stress and Deformation chapter 7 of [1]	8h15-10h00 ALMA MEDIA - U356 **(Exercise Report #1)**
Theory Session 9 **20/05** (Monday)	Electric arc welding processes: §3.3.2.2 and §3.3.2.4 of [1] • Fundaments of SMAW and variants (+ arc-air cutting) • Fundaments of SAW and variants	9h15-12h00 ALMA MEDIA - U356 **(Theory Essay #5)**

(Continues in the next page…)

Date	Seminar Content	Time and Local
Theory Seminar 10 **21/05** (Tuesday)	Electric arc welding processes (cont.): §3.3.1.1 and §3.3.1.2 of [1] • Fundaments of GTAW and variants • Fundaments of PAW and variants (+ plasma cutting)	8h15-10h00 ALMA MEDIA - U356 **(Theory Essay #6)**
Theory Seminar 11 **27/05** (Monday)	Electric arc welding processes (cont.): §3.3.2.1 and §3.3.2.3 of [1] • Fundaments of conventional GMAW • Advanced GMAW-based techniques and FCAW	9h15-12h00 ALMA MEDIA - U356 **(Theory Essay #7)**
Theory Seminar 12 **28/05** (Tuesday)	High power density welding processes: §3.5.1, §8.5 and 8.6 of [1] • Fundaments of electron beam welding and variants • Fundaments of laser beam welding and variants (+ laser cutting)	8h15-10h00 ALMA MEDIA - U356 **(Theory Essay #8)**
Theory Seminar 13 **03/06** (Monday)	Fundaments and variants of resistance welding process: §3.4 of [1] • Spot, seam and projection Fundaments of joining by brazing and soldering pp.910 to 990 of [3] Fundaments of Oxyfuel welding (+ oxyfuel cutting) §3.2.1 and §8.7 of [1]	9h15-12h00 ALMA MEDIA - U356
Theory Seminar 14 **04/06** (Tuesday)	Fundaments solid-state welding processes: chapter 4 of [1] • Flash and stud welding • High frequency welding • Cold pressure welding • Diffusion welding • Explosion coating and cutting • Ultrasonic welding • Friction and friction stir based processes	8h15-10h00 ALMA MEDIA - U356
EXTRA **04/06** (Tuesday)	Preparation for oral exam	10h15-11h00 ALMA MEDIA - U356

Date	Laboratory Session Content	Time and Place
Session 1 **08/05** (Wednesday)	Safety and general information about welding laboratory facilities and procedures Demonstration and practice of electric arc welding process (1/4): • Shielded Metal Arc Welding (SMAW)	Shift A: 10h15-12h00 Shift B: 12h15-14h00 Shift C: 14h15-16h00 **K2 Welding Lab** **(Lab Report #1 to #4)**
Session 2 **15/05** (Wednesday)	Demonstration and practice of electric arc welding process (2/4): • Gas Tungsten Arc Welding (GTAW)	
Session 3 **22/05** (Wednesday)	Demonstration and practice of electric arc welding process (3/4): • Gas Metal Arc Welding (GMAW)	
Session 4 **29/05** (Wednesday)	Demonstration and practice of electric arc welding process (4/4): • Brazing, Cutting and Friction Stir Welding (FSW)	

MEC-E6002's guidelines and operative rules:

- **Summary of the course operation**: The course will be structured in **according to the chronogram** in previous pages, with emphasis for:

14 Theory Seminars, with frequent examples of engineering applications, and plan for active student interaction and discussion among them and with the professor. The expected learning outcomes for each new subject are established in the seminar slides.

1 Exercise Session with the resolution of quantitative exercises, on "Metallurgy of Welding" and "Design of Welded Structures".

4 Laboratory Sessions of 1h45 minutes each, with demonstration and practice of key welding techniques, to complement with sensorial experience, the theoretical education on the physical and chemical fundaments of welding technology.

1 Extra Session of preparation for the oral exam.

Evaluation:

Continuous evaluation of the *theory seminars*, via **8 Theory Essays** (fast answer).

Continuous evaluation of the *exercise sessions*, via **1 Exercise Report**, respectively on "Metallurgy of Welding" and "Design of Welded Structures".

Continuous evaluation of the *laboratory sessions*, via **4 Laboratory Reports** on the experience and learnings arising from the action.

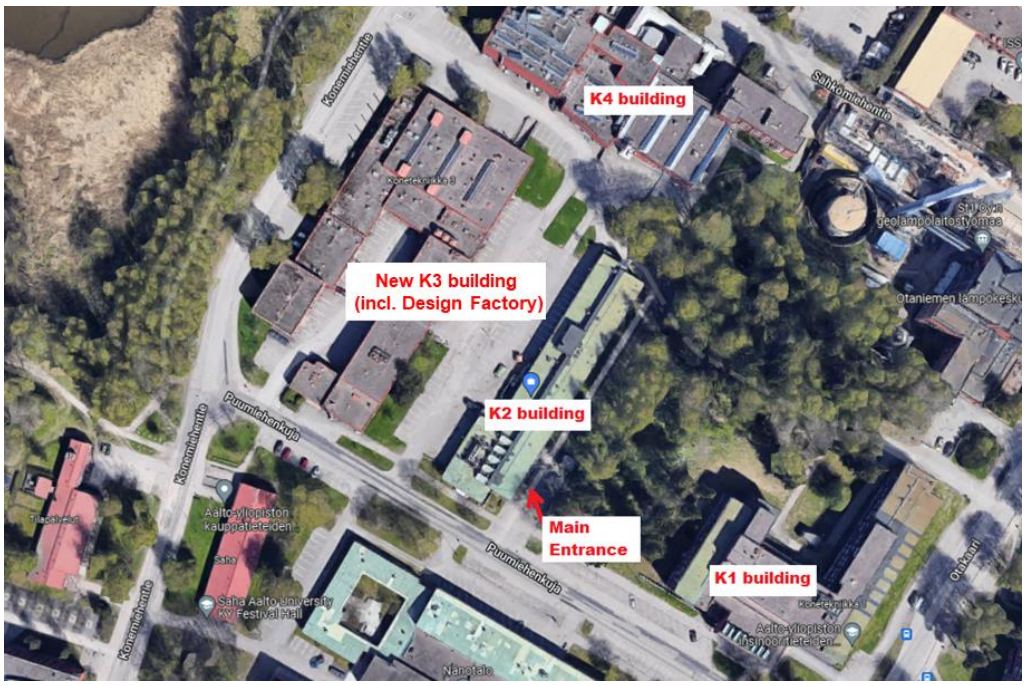
Final Exam via individual oral examination, to assess the cumulative knowledge from the course's content.

- **1 Intermediate Feedback** opportunities (confidential): @Feedback (MyCourses) open from: 20th to 24th May 2024.

- **Operationalization**:
  - **Theory Seminars**: content will be delivered (typically) in slots sessions of about **40 min** each, with about **5 min** to relax in between slot sessions**.** The **final 10 min** of each theoretical seminar, are reserved for active student's interaction and discussion with professor:
  - **Answer to the Theory seminar's Essays:**
    - ✓ The answer to the Essays is individual (each student will submit his own document) and should be submitted in *MyCourses* in the correspondent "**Assignments**" sub-section, as one document identified as: "**Firstname_Surname_Essay#.pdf**";
    - ✓ It is expected a short answer with text (e.g. about 250 words) with embedded original (e.g. hand-made) figures and/or schemes,
    - ✓ **The deadline to submit the answers is the end of Friday of the same week (23h59);**
    - ✓ The grade [0..100] is obtained from the average of the grades [0..100] from ALL of the 8 Essays = average (grade of Continuous Evaluation via **Essay #i**, $_{i=1..8}$).

Registration in Laboratory Sessions:

- ✓ Shifts available are:
  - **Shift A:** Wednesday 10h15 to 12h00.
  - **Shift B:** Wednesday 12h15 to 14h00.
  - **Shift C:** Wednesday 14h15 to 16h00
- ✓ All the students should register at MyCourses, in the section: “Selection of Welding Laboratory Shift”.
- ✓ The 1st laboratory sessions is on Wednesday 8th May, and students can only attend the laboratory sessions in the shift where they are registered.
- ✓ The **deadline to register is Friday 3th May** (23h59).
- ✓ Number maximum of students per shift is 10.
- ✓ The welding laboratory is located @ K2 building ground floor. Access to the laboratory is made from the main door of the K2 building:



Submission of the 4 Laboratory Reports:

- ✓ The reports are individual (each student will submit his own document).
- ✓ Only the students present during laboratory sessions are entitled to submit the Laboratory Reports.
- ✓ Instructions and guidance information for the report of the laboratory activities will be available in a separated document in *MyCourses* in the “Materials” sub-section.
- ✓ Laboratory Reports cannot be larger than 4 pages.
- ✓ Reports should be submitted in *MyCourses* in the “**Assignments**” sub-section, as one document identified as: “**Firstname_Surname_LabReport#.pdf**”.
- ✓ **The deadline to submit the reports is the end of the Sunday immediately after of the exercise or laboratory session (23h59).**
- ✓ The grade [0..100] is obtained from the average of the grades [0..100] from ALL of the 4 Laboratory Reports = average (grade of Continuous Evaluation via Laboratory Report #$j_{,\ j=1..4}$).

↳ **Submission of the 1 Exercise Report:**

- ✓ The report is individual (each student will submit his own document).
- ✓ All students can submit the Exercise Report.
- ✓ Size of Exercise Report is not limited.
- ✓ Reports should be submitted in *MyCourses* in the "**Assignments**" sub-section, as one document identified as: "**Firstname_Surname_ExerciseReport.pdf**".
- ✓ **The deadline to submit the Exercise Report is the end of the Sunday immediately after of the exercise or laboratory session (23h59).**

Evaluation:

Grade [0..100] = 0.5 X max [grade of **Exam** 1st phase; grade of **Exam** 2nd phase] +
+ 0.2 X average grade of Continuous Evaluation via **Essay #i**, $_{i=1..8}$
+ 0.1 X average grade of Continuous Evaluation via **Exercise Report #1**
+ 0.2 X average grade of Continuous Evaluation via **Laboratory Report #j**, $_{j=1..4}$

Grade [0..5] = (Grade [0..100] - 23)/14:
0 (insufficient); 1 (sufficient); 2 (satisfactory); 3 (good); 4 (very good); 5 (excellent)

- All **Exams**, **Essays, Exercise Reports** and **Laboratory Reports** are evaluated in a scale of [0..100];
- **min (grade of Exam 1st phase; grade of Exam 2nd phase) ≥ 30 %**, i.e.:
  - ↳ if min [grade of **Exam** 1st phase; grade of **Exam** 2nd phase] < 30 %
    then Final Grade [0..5] = 0 else Final Grade [0..5] = Final Grade [0..5];
- **Exams**:
  - ↳ **All exams are individual oral exams** of 25 min max.
  - ↳ 1st phase **Oral Exam**:
    - Thursday, 6th June, 2024; 30min slots 1 to 8 from 8h00 to 12h00
    - Thursday, 6th June, 2024; 30min slots 9 to 18 from 13h00 to 18h00
    - Friday, 7th June, 2024; 30min slots 19 to 26 from 8h00 to 12h00
    - Friday, 7th June, 2024; 30min slots 27 to 30 from 13h00 to 15h00
    - Place: Meeting room 236c K1 building
      - ✓ Oral examination is meant to be in F2F, but in exceptional circumstances it can be done using the Zoom link at top of this document.
    - **Guidelines and instructions for the oral exam will be provided** in MyCourses (Section "Documents…"). Namely, a set of possible case-studies and typical questions will be supplied beforehand. Other questions are also possible.
  - ↳ 2nd phase **Exam** (room and date to be defined).