

FS 2024/25

MSE-422 – Advanced Metallurgy

1-Introduction

Christian Leinenbach

About myself – MER Dr. Christian Leinenbach



- My main working place: [Empa Dübendorf & Thun](#) (since 2005)
- Head Advanced Processing and Additive Manufacturing of Metals
- Education
 - MSc Materials Science and Engineering, Universities Saarbrücken (DE) and Luleå (SE)
 - PhD Materials Science and Engineering, University of Kaiserslautern (DE)
- Research focus (with ~25 years experience):
 - Design and characterization of advanced structural alloys and composites
 - Additive manufacturing: materials & process optimization
 - Advanced joining technologies
- MER/Lecturer at EPFL since 2018
 - Advanced Metallurgy (MSE-422)
 - Assembly Technologies (MSE-464, with C. Plummer)
 - Laser Materials Processing (PhD course, MSE-662, with P. Hoffmann)
 - AM of Metals and alloys (PhD course, MSE-666, with R. Logé)
- Lecturer at University of Kaiserslautern (2005-2014), Empa Academy, CCMX Winter Schools



About myself

- Contact at EPFL (on Wednesdays):
EPFL STI IMT LPMAT
christian.leinenbach@epfl.ch

- Contact at Empa (other days):
Head Advanced Processing & Additive Manufacturing of Metals
Empa-Swiss Federal Laboratories for Materials Science and Technology
Dübendorf & Thun
christian.leinenbach@empa.ch

- Topics for Internships / Master Thesis projects on metals processing and additive manufacturing at Empa available

Teaching assistants

Exercises / case studies



Jian Yang
PhD student
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Seyyed Ezzatollah Moosavi
PhD student
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Case studies



Antonios Baganis
PhD student
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Why studying the course MSE-422?

«Metallurgy is the science of the 19th century»

«Metallurgy is a workshop technology and does not belong to a university»

«We know everything about metals and there is no need for further research»

Well, really???

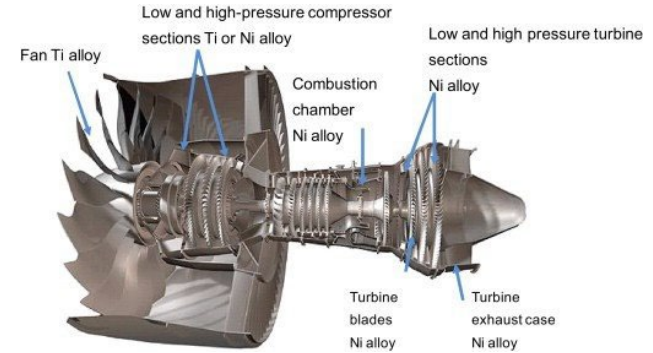
Materials in a modern aero-engine



[/www.airbus.com/](http://www.airbus.com/), [/www.geae.com/](http://www.geae.com/)



[/www.volvo.com/](http://www.volvo.com/)



A closer look at a turbine blade

■ Ni superalloy CM247LC – directionally solidified

	C	Si	Mn	Cr	Mo	Ni	Ta	Ti	W	Co	Fe	Al	Hf	V	Zr
CM 247	0.074	< 0.03	< 0.03	8.16	0.43	Bal.	3.21	0.68	9.55	9.364	0.03	5.63	1.42	< 0.03	0.015
	Cu	B	P	S	Pb	Ag	Bi	Te	Tl	Sb	Sn	Zn	Cd		
	< 0.03	0.0155	< 0.005	6 ppm	< 2 ppm	< 2 ppm	< 0.3 ppm	< 1 ppm	< 1 ppm	< 3 ppm	< 3 ppm	< 2 ppm	< 0.5 ppm		

Typical chemical composition in wt.%

- Why Ni as base material?
- Why so many alloying elements and what do they do?
- Why this particular composition?
- Why this special grain structure?
- How do we produce such a turbine blade?
- What are the properties of the turbine blade?



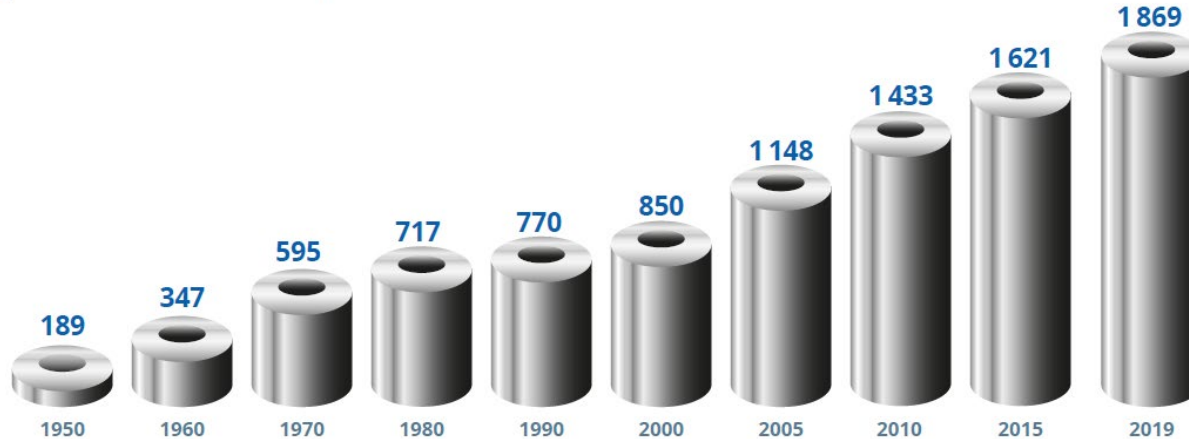
Materials in a modern car body structure



- Why do we still use that much steel for a car body and not e.g. Al or Mg?
- What requirements do we have for steels to be used in a car body structure?
- Car bodies consist of different types of steels: Dual Phase (DP), Complex-Phase (CP), Ferritic-Bainitic (FB), Martensitic (MS), Transformation-Induced Plasticity (TRIP), and Twinning-Induced Plasticity (TWIP). What do all these terms mean?
- How are these steels made?

The problems with steel making

World crude steel production 1950 to 2019 (million tonnes)



/www.worldsteel.org/

- Every ton of steel produced in 2018 emitted on average 1.85 tons of carbon dioxide, equating to about 8 percent of global carbon dioxide emissions.
- Are there ways for a more sustainable steel production?
- What is the picture for other metals?

Course structure

- 4 ECTS point
 - 2/4h lectures per week (Wednesday 11-13 and 14-16)
 - 2h exercises every second week
- The exercises will include
 - Problems/calculations
 - Case studies and examples from ongoing research
 - Software demonstration (Thermo-Calc) and hands-on software training
- Assessment
 - A larger case study for groups of 3-4 students during the semester including (50%)
 - Literature review
 - A Thermo-Calc case study
 - Summary of results in a paper and a poster presentation at the end of the course
 - Final written exam 90 mins (50%)

- As the course name “Advanced Metallurgy” implies, the students are expected to have some basic background in metallurgy.
- What is considered as already known is based on the syllabus of what B.S. students in Materials Science at EPFL have seen in their courses on Metals and Alloys, Phase Transformations, Deformation of Materials...
 - I will give a short reminder of the most important points, but it is up to you to make yourself familiar with these fundamentals!
- For those coming from other universities or those having a B.S. in another subject, either from EPFL or another university, additional work in personal reading might be necessary.
 - Ask your course mates from EPFL for their old course material!
- If you are interested in a semester projects or PDM on advanced metallurgy and metals processing, come and see me

Course outline

- Introduction
- Reminder
 - Thermodynamics and phase diagrams
 - Kinetics and phase transformations
 - Mechanical properties (quasistatic, cyclic, creep); strengthening mechanisms in alloys for RT and HT

- Modern high performance metallic materials
 - in each chapter I will talk about compositions & microstructures, properties, main fabrication/processing technologies and fields of application.
 - Advanced steels: austenitic steels, HT resistant steels, AHSS
 - Ni (and Co) alloys
 - Al and Mg alloys
 - Ti alloys
 - Structural intermetallics (TiAl, NiAl, silicides)
 - High entropy alloys and bulk metallic glasses
 - Precious metals (Au, Pt alloys)

- Introduction into alloy design
 - how can we design multi-component alloys with specific properties?
 - integrated computational materials engineering
 - Thermodynamic/kinetic modeling using [Thermo-Calc](#)
 - Case studies and alloy development cycle
- "Green" (sustainable) metallurgy and metals recycling
 - Energy consumption and CO₂ emission due to metals processing
 - Supply vs. demand of main metallic materials now and in the future; recyclability of the main alloy classes
 - Microstructure optimization vs. chemical variation to avoid "over-alloying"
 - Novel manufacturing/processing technologies