Version 02, Updated 04/22/2019

Metals Manufacturing

ME599-004 – Fall 2019

Course description

This course examines how metal components are made, highlighting the choice of processing options and parameters based on material properties, design requirements, and metrics of cost, quality, time, and environmental impacts. We initially examine supply chain risks and impacts for traditional and emerging alloys, and the development process and challenges associated with using new materials in mass production. We then focus on metal forming plasticity theory and application to solve process design problems: elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations; and the effects of hardening and friction, temperature, strain rate, and anisotropy. Multiple lectures are also dedicated to examining other key metals processing options: casting, machining and additive manufacturing. The additive manufacturing lectures focus on the basic physics of the process, capabilities and potential defects, market opportunities and barriers. Students will analyze processes using some of the key equations governing product quality (e.g., dimensional accuracy), process rate, and manufacturing energy intensity. Metals processing is a significant contributor to global energy demand and greenhouse gas emissions; we will explore emerging paradigms in sustainable manufacturing: energy and material efficiency in material production and along the supply chain, and end-of-life options including recycling opportunities and challenges.

Course goals

By the finish of this course students should be able to:

1. **Describe** global supply chains (processing steps, locations etc.) and key industrial sectors and products relevant to the metals industries
2. Describe the main processing steps in the production of some key metals, **calculate** the minimum energy requirements for materials separation and refining using exergy analysis, and **identify** suitable reducing agents using Gibbs free energy (Ellingham diagrams).
3. **Describe** different metal shaping processes and **compare** processing capabilities (e.g. achievable tolerances), production rates, quality, costs and environmental impacts.
4. **Select** different manufacturing processes based upon material, shape, mechanical properties, and number to be produced.
5. Using the mathematical theory of plasticity students should be able to **calculate** tool forces, **predict** part defects and **propose** solutions.
6. **Utilize** finite element software (Abaqus) in order to simulate basic metal forming processes [Students are only given a brief introduction to Abaqus in this class]
7. E**xplain** current industrial and research directions in metal forming: opportunities and challenges
8. **Predict** microstructures and mechanical behavior based upon solidification theory and microstructure development through heat treatments
9. **Evaluate** proposed carbon abatement strategies (e.g., increased recycling, CCS, energy efficiency, material efficiency) using exergy analysis and considering energy and material flows.
10. **Develop key research skills** during the class project where, in teams, students ascertain the state of the art when addressing a particular problem, propose a research plan, and evaluate preliminary experimental or theoretical results.

Audience

Graduate students. The class is also open to undergraduate students – please check with the instructor.

Course topics

- Global supply chains, key processes, sectors and products
- Material production, exergy analysis and the use of Ellingham diagrams
- Casting and heat treatments: processes, solidification theory, microstructure of casting, and microstructure development in wrought alloy processing
- Plasticity theory: yield criteria and flow rules, upper and lower bound theories and slip line fields, hardening laws, effect of friction, temperature, strain rate, anisotropy. Introduction to physical origins of plasticity (crystal plasticity)
- Application of plasticity theory to key metal shaping processes: sheet metal forming, forging, extrusion, machining
- Research challenges in metal forming: new materials and flexible forming processes
- Introduction to additive manufacturing of metals and comparison to more traditional approaches: processes, current capabilities, research opportunities and challenges
- Sustainable metals processing: material production and end of life options, energy and material efficiency

Grading

Homework assignments	20 %	
Exam 1	25 %	
Exam 2	25 %	
Class participation	5 % (attendance **and** active participation)	
Class project	25 %	
• Report		15 %
• Presentation		10 %

Class project

During the course, student teams (2-3 people) will perform research projects on current challenges in metals processing. Students either propose their own research topic or choose from a range of potential projects proposed by the instructor. At the end of the semester, teams must write a group report and present to the class on their project. The aim of the research project is to encourage both a deeper level of understanding than possible with class materials alone and to help students develop their research and exposition skills. Students are expected to determine the state of the art relating to the problem at hand, suggest a research plan in order to produce transferable knowledge, present some preliminary theoretical and/or experimental results, and draw conclusions from the preliminary work.

Absence policy

Please contact the instructor as early as possible if you need to miss a class. No more than two absences are deemed acceptable without prior agreement with the instructor.

Instructional team

Dr. Dan Cooper, Instructor drcooper@umich.edu	Office: 2458 GGB Office hours: 3:15-4:15pm Mondays & Wednesdays