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Metals Processing

ME599 – Fall 2017

Course description

This course examines how metal components are made, highlighting the choice of processing options and parameters based on material properties and part design. We focus on metal forming plasticity theory and application: 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. We also examine other key metals processing options: casting, machining and additive manufacturing. 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 also examine material production, end-of-life options, and explore emerging paradigms in sustainable metals processing.

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, costs and environmental impacts. Using the mathematical theory of plasticity students should be able to **calculate** tool forces, **predict** part defects and **propose** solutions.
4. **Utilize** finite element software (abaqus) in order to simulate metal forming processes
5. E**xplain** current industrial and research directions in metal forming: opportunities and challenges
6. **Predict** microstructures and mechanical behavior based upon solidification theory and microstructure development through heat treatments
7. **Evaluate** proposed carbon abatement strategies (e.g., increased recycling, CCS, energy efficiency, material efficiency) using exergy analysis and considering energy and material flows.
8. **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 senior 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 may either propose their own research topic or can 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 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.

Instructional team

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