Engineering Faculty Document No. 45-23
December 5, 2022

To: The Engineering Faculty

From: The Faculty of the School of Materials Engineering

Re: New graduate course – MSE 52000 Steel and Aluminum Alloys: Processing, Structure and Properties

The Faculty of the School of Materials Engineering has approved the following new graduate course as of December 5, 2022 (see attached document of course description). This action is now submitted to the Engineering Faculty with recommendation for approval.

MSE 52000 Steel and Aluminum Alloys: Processing, Structure and Properties, Sem 1 or 2, Class 3, Credit 3. Prerequisite: MSE 33000 or MSE 367000 concurrently, or graduate standing.

Steel and aluminum alloy processing will be studied to provide fundamental understanding of how the final properties are influenced by processing from the extraction of metal from ore, through shaping by casting, hot-working and cold-working, and heat treatment for control of microstructure. This understanding will enable the student to go beyond comparisons of standard handbook values and recognize the fundamental metallurgical phenomena leading to differences in performance among the main alloy classifications. By examining the relationships among processing, microstructure, and properties, the course will provide the "know-how" for specifying, designing, and manufacturing with steels and aluminum alloys.

David Bahr, Head
School of Material Engineering

Proposal for New Graduate Level Course for Academic Review MSE 52000 – Steel and Aluminum Alloys: Processing, Structure and Properties

Note: The detailed course proposal is intended for academic review by the appropriate area committee of the Graduate Council. It supplements the Form 40G that is intended for administrative review of the Graduate School and Registrar.

TO: Purdue University Graduate Council

FROM: Faculty Member: Kevin Trumble
Department: School of Materials Engineering
Campus: West Lafayette

DATE: December 5, 2022

SUBJECT: Proposal for New Graduate Course

MSE 52000 Steel and Aluminum Alloys: Processing, Structure and Properties
Semester 1 or 2, Class 3, Credit 3. Prerequisites: MSE 33000 or MSE 367000 concurrently, or graduate standing.

1. Course Description

Steel and aluminum alloy processing will be studied to provide fundamental understanding of how the final properties are influenced by processing from the extraction of metal from ore, through shaping by casting, hot-working and cold-working, and heat treatment for control of microstructure. This understanding will enable the student to go beyond comparisons of standard handbook values and recognize the fundamental metallurgical phenomena leading to differences in performance among the main alloy classifications. By examining the relationships among processing, microstructure, and properties, the course will provide the "know-how" for specifying, designing, and manufacturing with steels and aluminum alloys.

2. Justification for the Course

2.1 Justification of the need for the course

Steels and aluminum alloys constitute over 97% of metallic materials in service across all application sectors. They also exhibit the full range of metallurgical phenomena, within a rich history of commercial practice. This course is designed for current and future practicing engineers across the engineering disciplines who are or will be involved in design, specification, manufacturing, and construction with metals. Originally focusing on steels, the course has been updated to encompass both steels and aluminum alloys. The course has served students from a wide range of disciplines, a large proportion of them remotely pursuing MS degrees while working in industry or as Professional MS students, as well as traditional residential graduate and undergraduate students. The course also serves as a core course in the metals stem of the Materials

Engineering curriculum and provides a foundation for more advanced study of chemical, physical and mechanical metallurgy. Enrollment over the past few years has ranged from 17 to 40.

2.2 Justification that course will be taught at a graduate level

MSE 52000 will be taught at the graduate level. After a brief introduction covering commonalities between steels and aluminum alloys, the course is divided nominally two-thirds on steels and one-third on aluminum alloys. A well-established text is used, which covers the main alloy classifications in a framework of commercial practice, including limiting properties sets and properties variability, and their origins in processing-structure relationships, leading to specifications. Several examples of advanced topics from the research literature (classical and contemporary) are incorporated and students then have an assignment to prepare an up-to-date review on a fundamental or applied steel or aluminum alloy research topic of their choosing.

Assessment will be primarily through two in-class exams and a final exam (written exams constitute 85% of final grade). The exams require intensive problem solving and reasoning from concepts covered in lecture and homework. A research review-update assignment is based on open-ended research and requires the students to synthesize the literature and assess the current state of the art in a particular area, as they would encounter a new topic in research or practice. While the final grades for the course are curved, undergraduate students are not assessed separately from the graduate students (mostly seniors) and are expected to perform at the same level.

2.3 Justification for online delivery

MSE 52000 will continue serving as one of the core MSE courses for students pursuing online Master's degrees in Engineering, including the rapidly growing Professional MS degree programs in multiple disciplines.

3. Learning Outcomes and Methods of Assessment

3.1 Learning Outcomes

All Students will be able to:

A. Describe current practice of steel and aluminum production in terms of the thermochemical unit processes.
B. Understand the differences between the main classes of commercial metal shaping processes and their intrinsic effects on microstructure.
C. Relate alloy microstructure to properties as measured in standard mechanical testing.
D. Interpret standards and specifications for processing and properties of different steel and aluminum alloy classifications.

Most Students will be able to:

A. Identify processing defects and predict their effect on material performance.
B. Specify alloy and processing route to achieve desired properties sets for particular applications.
C. Explain properties variability in terms commercial practice constraints.
D. Analyze critically the state of research on a particular current topic in steel or aluminum metallurgy.

3.2 Assessment Methods

Assessments will be achieved through three exams (two midterms and a final exam). Each exam will require complex problem solving and reasoning. These exams will be designed to assess students' knowledge of metallurgical processing and resulting microstructure development in the main classes of steel and aluminum alloys, and their skills in assessing the corresponding mechanical properties for structural applications.

Several homework sets will be assigned throughout the term to reinforce the information covered during lecture. The homework will be nominally graded and solutions to the more difficult problems will be covered in detail in class and during review sessions held prior to the exams.

3.3 Final Grading Criteria

Grading is based on the following weighting: two mid-term exams (25% each), final exam (35%), current topics research review (10%), and (5-6) homework sets (5%). Graduate and undergraduate students will be evaluated together and a single curve will be applied to the final grade assignments if necessary. The final grading scale will be based on overall class performance, with grade divisions no higher than 85% -A, 70% -B, 60% -C, 50% -D.

3.4 Methods of Instruction

The primary method of instruction will be through lectures, discussion and feedback on homework exercises, to help the students achieve the learning outcomes. These include analyses of basic principles of concepts covered during lectures and their application in practice.

3.5 Prerequisites

Completed or concurrently MSE 33000 or MSE 36700, or graduate standing

4. Course Instructor

Kevin Trumble, Professor, MSE, member of the Graduate Faculty:

Prof. Trumble has extensive experience teaching materials engineering at Purdue. He has developed and taught an array of undergraduate and graduate courses, mainly in the materials processing area, including MSE 512 Powder Processing, MSE 536 Solidification Processing, and MSE 548 Deposition Processing. He recently developed another new course in the materials processing series, also at the 500 level, Additive Manufacturing of Materials.

5. Course Outline:

1. Properties and applications of steels and aluminum alloys
2. Iron and steel making processes
    a. Blast Furnace and Direct Reduced Iron
    b. Basic Oxygen Process and Electric Arc Furnace
    c. Ladle refining and continuous casting
3. Hot- and cold-working and annealing

4. Mechanical properties
    a. Hardness, tensile, impact and fracture toughness testing
    b. Strengthening mechanisms (microstructural origins)
5. Low-carbon sheet steels and their forming
6. Ferrite-Pearlite steels
7. Alloy steels and their heat treatment
    a. Bainite and Martensite structures
    b. Hardenability and process specifications
8. High-alloy steels
    a. Stainless steels
    b. Tool steels
    c. Cast irons and cast steels
9. Aluminum production
    a. Bayer refining and Hall-Heroult smelting processes
    b. Liquid aluminum conditioning and direct-chill casting
10. Non-heat-treatable Al alloys
    a. Solid-solution strengthened, strain-hardening, and annealing
    b. Sheet forming of aluminum alloys
11. Heat-treatable Al alloys
    a. Precipitation-hardening
    b. Heat-treatment systems and processes
    c. Residual stresses
12. Casting and welding aluminum alloys

6. Reading List

(Required text)

WF Smith, Structure and Properties of Engineering Alloys, 2nd Edition, McGraw-Hill, 1993. Paperback (International Edition, 2014) ISBN: 9339205294.

The course also utilizes the ASM Handbooks, for commercial practices and resulting alloy properties, and the ASTM Compass database for specifications; both are available electronically through the Purdue Library Online.

(Advanced references)

G Krauss, Steels: Processing, Structure, and Performance, ASM International, 2nd Edition, 2015. ISBN: 978-1627080835.

DG Altenpohl, Aluminum: Technology, Applications and Environment, Wiley and Sons, 6th Edition, 1998. ISBN: 0873394062.

IJ Polmear, D StJohn, J-F Nie and M Qian, Light Alloys, Butterworth-Heinemann, 5th edition, 2017. ISBN: 0080994318.

7. Course Syllabus

Purdue University

School of Materials Engineering

MSE 597 Steel and Aluminum: Process, Structure and Properties **Fall 2022**

Lecture: MWF 8:30-9:20 WANG 2579
Instructor: Prof. Kevin Trumble, ARMS 2333, 765-494-4114, driscol@purdue.edu
Teaching Assistant: Xuanyu Sheng, sheng18@purdue.edu
Website: *Brightspace*
Regular Office Hours: Prof. Trumble will hold live office hours, initially 9:30-10:20 Wednesdays via Webex at: https://purdue.webex.com/meet/driscol. Day(s)/time(s) may change depending on student input. Session(s) may be added or canceled depending on demand.
Individual (or small group) consultation: can always be arranged by e-mail.

Objectives: To apply chemical, physical and mechanical metallurgy principles to engineering specifications for the main classes of steel and aluminum alloys, including design, manufacturing and service.

Description: Steel and aluminum alloy processing will be studied to provide fundamental understanding of how the final properties are influenced by the sequence of processes from the extraction of metal from ore, through shape processing of cast, wrought and powder forms, to heat treatment for control of microstructure and properties. This understanding will enable the student to go beyond comparisons of standard handbook values and to recognize and understand how the fundamental metallurgical phenomena lead to differences in performance among the main alloy classifications. By examining the relationships among processes, microstructure, and properties, the course will provide the "know-how" for better design, manufacturing and specification with steel and aluminum alloys, as well as competing materials. This approach will be broadly applicable to industrial metallurgical practice.

Brief outline: Steel production and processing will include the blast furnace and basic oxygen converter, direct reduction processes, electric arc furnace, and refining; continuous casting and deformation processing; shape casting and powder routes; and heat treatments. Phase diagrams and phase transformation kinetics will be studied in order to understand the variety of microstructures that are obtained by thermal processing. Plain-carbon, low-alloy, alloy, stainless and tool steels; cast steel; cast iron; and powder alloy specifications will be included. Aluminum alloy production and processing will include Bayer refining and Hall-Heroult smelting processes; direct-chill casting and deformation processing; shape casting and powder routes; and heat treatments. The different Al alloy systems will be studied to understand the distinctions and applications of heat treated vs. non-heat treated Al alloys. The framework will be structural applications, but key specialty applications based on electrical and magnetic properties will also be covered. A week-by-week topic outline is provided on page 4.

Prerequisites: Introductory undergraduate courses in materials science, chemistry and physics.

Textbooks
Required: WF Smith, Structure and Properties of Engineering Alloys, 2nd Edition, McGraw-Hill, 1993. Paperback (International Edition, 2014) ISBN: 9339205294; Hardcover ISBN: 0070591725 (out of print).

Recommended: Depending on your background, a refresh may be useful on some introductory MSE concepts, e.g., crystallography, diffusion, phase diagrams, and basic structure-properties relationships. Many part of the course will build from these foundational MSE topics. Thus, an introductory MSE textbook, e.g., WD Callister et al., *Materials Science and Engineering* or *Fundamentals of Materials Science and Engineering*, Wiley, is recommended. If you don't already have one, back editions of these and others (Ashby, Flinn and Trojan, etc.) can be obtained for next to nothing from online sellers. Their fundamental content does not go out of date; you don't need to invest in the latest edition. These books can also be readily borrowed from libraries.

Also recommended is *CES EduPack*, Granta Design, which is available through the Purdue library; requires download of Citrix Receiver. This source is an interactive software platform for materials properties and processing visualization and design analysis. It also contains "drill down" links that connect to narratives on basic topics from the Ashby introductory textbooks.

An annotated list of other reference sources on the course topics will be provided.

Lecture access

The course is running in a hybrid in-person/online mode in Fall 2022 through Purdue Online, College of Engineering. Lectures will be recorded with an in-person (on-campus) class in WANG 2579 and posted to *Brightspace* usually in the same day. Once posted, the lecture recordings will be available to both off-campus and on-campus students any time.

Lecture format

The lectures will be presented using partially completed template slides that can be downloaded from the website and used to follow along as the instructor fills them in on the document camera. This system accomplishes some of the feel of a chalkboard lecture and avoids "death by powerpoint," i.e, listening to the reading of a deck of slides, which you might as well just read yourself.

Exams

Two hour-exams covering the steel portion (~25 lectures) of the course will be given in-class, same day for off-campus students (September 23 and October 28) and the final exam period (December 12-17, TBA) will cover the aluminum portion of the course (~15 lectures).

Homework

Homework sets (6) will be turned in electronically on *Brightspace* and nominally graded as follows: ✓+ (100) / ✓(75) / ✓– (50). Solutions will be discussed in class.

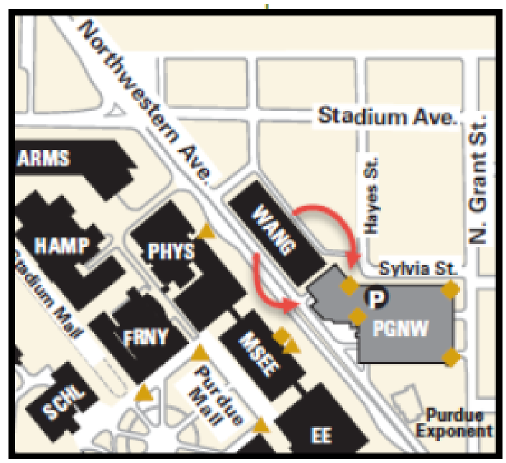
Presentation Assignment

A communication assignment (due after the second exam) will involve preparing a 5-slide/5-minute recorded presentation (Voice-over-Powerpoint) giving an update of the latest status on a particular topic of your own interest in commercial steel and aluminum metallurgy.

Assessments and Grading (percentage of final grade)

Homework problem sets throughout the semester (5%); update presentation (10%); two exams on steel (25% each); one exam (during finals period) on aluminum alloys (35%). Final grades will include "+" and "-" divisions; divided evenly by score within each letter grade range.

Emergency Procedures
Fire, weather, and civil emergency procedures specific to the WANG 2579 will be reviewed in class. Information on emergency preparedness at Purdue is available on the Purdue homepage and at http://www.purdue.edu/emergency_preparedness/.



For a shelter-in-place siren (tornado, hazardous material release, civil disturbance) stay in WANG 2555 and wait for further instructions. In case of a fire alarm, exit WANG via the stairway and assemble in the Northwestern Avenue parking garage.

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. These changes would be posted on the course website on *Brightspace*. In case of an extended disruption in which classes on campus are suspended the course will continue via *Brightspace*.

Covid-19 Protocols and Contingencies
See the Protect Purdue website for the latest information: https://protect.purdue.edu/. If you feel sick or at all symptomatic, do not come to class; follow the Protect Purdue guidelines. If in-person meetings become restricted, the lectures will still be available in the recorded format and the exams will be administered online through *Gradescope*. If you anticipate an extended absence from the course for any reason please inform Prof. Trumble as soon as possible, to discuss how you can make up any missed work.

Remote Examinations
In the event that increased pandemic restrictions at Purdue preclude in-person exams, the exams will be administered online through *Gradescope* via *Brightspace* using the following procedure:

A pdf exam file identical to an in-class exam paper will be downloaded and worked (written out) by the student, either electronically on a tablet or printed and worked on paper and then scanned or photographed, and uploaded as a single electronic file to *Gradescope*. Extra time will be allowed for downloading and uploading exams. Students are on their honor to work the exam by themselves and without any internet resources.

Mental Health Resources
If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765) 494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Students with Disabilities
If you anticipate or experience physical or academic barriers based on disability, you are welcome to discuss options with Prof. Trumble. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247; https://www.purdue.edu/drc/.

Diversity and Inclusion
Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. Purdue's nondiscrimination policy can be found at the following website: http://www.purdue.edu/purdue/ea_eou_statement.html. If you see, hear or experience discrimination in any form you are always welcome to discuss it with Prof. Trumble. The College of Engineering also has a website that provides extensive resources for diversity at: https://engineering.purdue.edu/Engr/AboutUs/Diversity/DiversityResources.

Academic Dishonesty Policy
Purdue University Regulations, Part 5, Section III-B-2-a describes the formal policies governing academic dishonesty. A guide providing specific examples, tips, and consequences is available at http://www.purdue.edu/odos/osrr/academic-integrity/index.html. You are encouraged to study together and discuss coursework, but any work you turn in for grading is expected to be your own original work. Notes presented in the lectures are subject to copyright. Students in the course are granted permission to copy and exchange these notes with other students in the course, but they cannot be sold, bartered or posted on any website.

Week-by-Week Topic Outline (approximate)
1. Introduction, Overview, Iron and aluminum production and properties
2. Steel making, casting and working
3. Mechanical properties review, pure iron and sheet steels
4. Low-carbon steels (mostly sheet)
5. Ferrite-Pearlite steels and Exam 1 (through low-carbon sheet steels)
6. Pearlitic steels and Alloy steels
7. Alloy steels and heat treatment
8. OCTOBER BREAK, Alloy steels
9. Stainless steels and tool steels
10. Cast steels and cast irons and Exam 2 (through cast steels)
11. Aluminum production overview and properties
12. Aluminum alloy systems, Non-heat-treatable alloys (solution- and strain-hardening)
13. Non-heat-treatable Al alloys, THANKSGIVING BREAK
14. Non-heat-treatable Al alloys, Heat-treatable Al alloys
15. Heat treatable Al alloys (precipitation hardening)
16. Aluminum alloys advanced topics and summary
17. Final Exam (2-h), covers only Al alloys