Engineering Faculty Document
No.: 38-26
April 14, 2025

TO: The Engineering Faculty

FROM: The Faculty of the School of Materials Engineering

RE: New graduate course – Superalloys – MSE 52100

The Faculty of the School of Materials Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM (IF ALREADY OFFERED WITH TEMPORARY NUMBER):

MSE 59700 Superalloys

Spring 2020, Spring 2022, Fall 2024 (Online Asynchronous), Spring 2025

3 total credits; 3 credit lecture

Graduate standing OR (MSE 260 (or equivalent) AND MSE 340 (or equivalent) with D- or better)

Spring 2020 – 35 (in-person) 9 (distance); Spring 2022 – 23 (in-person and distance); Fall 2024 – 8 (distance and asynchronous online); Spring 2025 – 20 (in-person) 7 (distance) 3 (asynchronous online)

TO:

MSE 52100 Superalloys

Fall and Spring Semesters online/asynchronous and Spring semesters every odd year (Spring 2027, Spring 2029, etc)

3 total credits; 3 credit lecture

Graduate standing OR MSE 260 (or equivalent) AND MSE 340 (or equivalent) with D- or better

Superalloys are Fe-, Ni-, and Co-based alloys possessing an exceptional balance of properties that typically include high-temperature strength, oxidation/corrosion resistance, toughness, and microstructure stability. These alloys are used in industries ranging from chemical processing, to nuclear power, to aerospace. This course will cover the fundamentals of the physical metallurgy, processing routes and manufacturing, high temperature deformation mechanisms, and corrosion/oxidation mechanisms related to superalloys. Basic principles of lifing and identification of failure mechanisms of superalloy components will be covered. Material design and selection strategies for practical industrial applications will be presented. Beyond superalloys, we will study emerging structural alloys that include ultra-high temperature refractory silicides and borosilicides, refractory alloys, and intermetallics.

RATIONALE:

This course will fill a critical need to introduce engineering students to superalloys – a class of high temperature nickel-based metal alloys that are ubiquitous throughout the petrochemical, aerospace, defense, and nuclear industries. The course starts by covering the basics of turbine engine operation to motivate the need for these materials, then covers in great detail the physical metallurgy of the nickel alloy systems. This part builds on prior knowledge from MSE 260 (Thermodynamics) and MSE 382 (mechanical response of materials) and delves into much greater detail, aiming to enable students to predict properties from composition and microstructure. Next, we discuss both single crystal and polycrystalline nickel based alloys – their structure and composition, processing/fabrication methods, and mechanical response, which complements existing graduate courses MSE 502 (defects in solids), MSE 505 (Modeling and simulations of materials processing), MSE 512, 536, 557 (powder, solidification, and deformation processing), and MSE 555 (deformation mechanisms in crystalline solids) – but applies them specifically to Ni-based superalloys. Specifically, we cover unique processing steps and properties are not covered in the current curriculum. Finally, we cover environment degradation (oxidation, coatings, and deposition processing) and export control considerations, which again are not covered up to this point in our curriculum as it pertains to nickel-based alloys. The course provides practical assignments that typically Bachelors levels engineers will encounter in their jobs right after graduation, but it also prepares students for further graduate studies by introducing more complex concepts, especially as it relates to crystallography and deformation mechanisms.

Bryan D. Haney

Head/Director of the School of Materials Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:33225/form

MSE 597: Superalloys – High Temperature Alloys

Course Information
Course credit hours: 3
Instructional Modality: In-person, online (asynchronous)
Course Brightspace Page: https://purdue.brightspace.com/d2l/login
Prerequisites: Graduate standing or basic phase equilibria (binary phase diagrams) and transport phenomena (heat transfer and diffusion) at the undergraduate level.

Instructor Contact Information
- Prof. Michael S. Titus
    - Office: ARMS 2309
    - Email: titus9@purdue.edu
    - Virtual office hours: TBD, in ARMS 2309 and Titus Zoom Room
    - Expectations: On-campus students should attend office hours in-person. Online For online students, the primary means of communication with the instructor should be via email. For all email messages, please put "MSE 597" in the subject line. I will do my best to respond to email and discussion questions within 24 hours.

Course Description
Superalloys are Fe-, Ni-, and Co-based alloys possessing an exceptional balance of properties that typically include high-temperature strength, oxidation/corrosion resistance, toughness, and microstructure stability. These alloys are used in industries ranging from chemical processing, to nuclear power, to aerospace. This course will cover the fundamentals of the physical metallurgy, processing routes and manufacturing, high temperature deformation mechanisms, and corrosion/oxidation mechanisms related to superalloys. Basic principles of lifing and identification of failure mechanisms of superalloy components will be covered. Material design and selection strategies for practical industrial applications will be presented. Beyond superalloys, we will study emerging structural alloys that include ultra-high temperature refractory silicides and borosilicides, refractory alloys, and intermetallics.

Course Learning Outcomes (CLOs)
By the end of the course, students will be able to:
1. **CLO1:** Identify basic components of turbine engines and their relevant operating conditions
2. **CLO2:** Predict the microstructure and properties of superalloys from material constituents
3. **CLO3:** Select industrially relevant processing steps to fabricate superalloy components
4. **CLO4:** Apply basic alloy selection and design strategies for engineering components
5. **CLO5:** Analyze experimental and computational results to predict material performance
6. **CLO6:** Identify applicable regulatory procedures for exporting superalloys

Learning Resources, Technology & Texts

Required Textbook

- ***The Superalloys – Fundamentals and Applications***, R.C. Reed, University of Cambridge press. Available via Purdue Libraries (sign in with your Purdue credentials).

Software/Web Resources

- Word Processor, Spreadsheets (e.g. MS Word, Excel), remember that MS Office is free for all students.
- Image to pdf mobile app (see Assignment instructions)
- An image data digitizer (e.g. WebPlotDigitizer)

Brightspace Learning Management System (LMS)

- Access the course via Purdue's Brightspace learning management system. Begin with the Start Here section, which offers further insight to the course and how you can be successful in it. It is strongly suggested that you explore and become familiar not only with the site navigation, but also with content and resources available for this course. See the Student Services widget on the campus homepage for resources such as Technology Help, Academic Help, Campus Resources, and Protect Purdue.

Grading & Assignments

Assessment in this course will be done using a *Specifications Grading* strategy, a unique method for evaluating your performance which clarifies exactly what is needed to earn a given letter grade, enables you to choose assignments that you find interesting, eliminates high-stakes assignments, allows you to choose your achievement level in the course, and sets clear learning outcome and expectations. Detailed guidelines about this grading system as well as a breakdown of the course assignments are available in the ***Course Essentials: Grading & Assignments*** section of the Brightspace course.

In short, you will need to complete 'bundles' of assignments, which include: self-assessments; quizzes; participation in discussion topics; two self-reflective essays; a midterm exam; analysis problems; and a final project on materials selection or a final exam. All items will include a detailed rubric and will be graded as pass/fail. Feedback will be provided. You will start with and can earn 'tokens' that can be exchanged for re-do's on assignments.

Course Schedule

*This is a comprehensive list of assessments, but you are not required to complete them all; you will decide which ones to complete based on your goals for the course (refer to the *Course Essentials: Grading & Assignments* section in Brightspace for more guidelines). Due dates for all assessments are available in Brightspace.

Modules	Suggested Dates	Suggested Reading from Reed	Assessments*
Module 1: Introduction to Turbine Engines and Materials	**1/13 – 1/19** Week 1	1.1 – 1.2	• Essay 1 • Self-Assessment 1 • Quiz 1 • Homework 1
Module 2: Why Use Nickel for Superalloys?	**1/20 – 1/26** Week 2 *MLK Day: 1/20*	1.3	• Self-Assessment 2 • Quiz 2 • Homework 2 • Discussion 1
Module 3: Physical Metallurgy of Superalloys	**1/27 – 2/9** Weeks 3-4	2.1 – 2.3	• Self-Assessment 3 • Quiz 3 • Homework 3 • Analysis Problem Set 1
Module 4: Mechanical Behavior of Superalloys	**2/10 – 2/23** Weeks 5-6	2.4	• Self-Assessment 4 • Quiz 4 • Homework 4 • Analysis Problem Set 2 • Discussion 2
Module 5: Processing of Single Crystal Alloys	**2/24 – 3/2** Lesson 1 Week 7	3.1	• Self-Assessment 5 • Quiz 5 • Homework 5
	3/3 – 3/9 Lesson 2 Week 8	3.2 – 3.3	• Self-Assessment 6 • Quiz 6 • Homework 6 • Analysis Problem Set 3
	3/10 – 3/16 Lesson 3 Week 9	3.3	• Quiz 7 • Homework 7 • Discussion 3
	Spring Break: 3/17 – 3/22		

Module 6: Processing of Polycrystalline Alloys	**3/24 – 3/30** Lesson 1 Week 10	4.1	• Self-Assessment 7 • Quiz 8 • Homework 8 • Analysis Problem Set 4
	3/31 – 4/13 Lesson 2 Weeks 11-12	4.2 – 4.3	• Quiz 9 • Homework 9 • Analysis Problem Set 5 • Discussion 4
Module 7: Environmental Degradation of Superalloys	**4/14 – 4/27** Weeks 13-14	5.1 – 5.5	• Self-Assessment 8 • Quiz 10 • Homework 10 • Essay 2
Module 8: Legal and Export Control Considerations	**4/28 – 5/3** Week 15		• Quiz 11
Standalone Assessments (Not associated with a module)			• Midterm Exam (Week 9) • Material Selection Project (Week 15) • Final Exam (Week 16)

Responsible Use of Artificial Intelligence (AI) Tools in Completing Coursework

Advancements in AI provide students with unparalleled access to information and problem-solving capabilities. However, with these advantages come the responsibilities of ethical use and academic integrity. Students should ensure that assignments submitted are original and based on their understanding. While AI can assist in research or provide general guidance, it should not produce work on behalf of the student. Any content, ideas, or assistance obtained through AI tools must be appropriately cited, similar to any other reference or source. AI should not be used to complete assignments. As AI tools become increasingly embedded in existing technologies, students will enter gray areas. If a student is unsure of whether and how much of a submission has been AI-generated, or whether they are in violation of a certain policy, they should reach out to the instructor and ask for guidance.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace under *University Policies and Statements*.

Netiquette

We want to foster a safe online learning environment. All opinions and experiences, no matter how different or controversial they may be perceived, must be respected in the tolerant spirit of academic discourse. You are encouraged to comment, question, or critique an idea, but you may not attack an individual. Our differences, some of which are outlined in the University's nondiscrimination statement below, will add richness to this learning experience. Please consider that sarcasm and humor can be misconstrued in online interactions and generate unintended disruptions. Working as a community of learners, we can build a polite and respectful course ambiance. Please read the Netiquette rules for this course:

- Monitor how much space/time you are taking up in any discussion. Give other students the opportunity to join in the discussion.
- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could lead to misinterpretation.
- Keep an “open mind” and be willing to express even your minority opinion.
- Think and edit before you push the “Send” button.
- Seek and take in feedback from others; learning from other people is an important life skill.

Copyright

See the *University Policies and Statements* section of Brightspace for guidance on Use of Copyrighted Materials. Effective learning environments provide opportunities for students to reflect, explore new ideas, post opinions openly, and have the freedom to change those opinions over time. Students and instructors are the authors of the works they create in the learning environment. As authors, they own the copyright in their works subject only to the university's right to use those works for educational purposes Students may not copy, reproduce, or post to any other outlet (e.g., YouTube, Facebook, or other open media sources or websites) any work in which they are not the sole or joint author or have not obtained the permission of the author(s).

Nondiscrimination Statement

Purdue University is committed to maintaining a community that 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 potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under *University Policies and Statements*.

Accessibility

Purdue University is committed to making learning experiences accessible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try Therapy Assistance Online (TAO), a web and app-based mental health resource available courtesy of Purdue Counseling and Psychological Services (CAPS). TAO is available to all students at any time by creating an account on the TAO Connect website, or downloading the app from the App Store or Google Play. It offers free, confidential well-being resources through a self-guided program informed by psychotherapy research and strategies that may aid in overcoming anxiety, depression and other concerns. It provides accessible and effective resources including short videos, brief exercises, and self-reflection tools.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 a.m.- 5 p.m.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions in West Lafayette with a Purdue

Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect. Students in Indianapolis will find support services curated on the Vice Provost for Student Life website.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS offices in West Lafayette or Indianapolis.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday.

Emergency Preparation

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 beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Disclaimer

This syllabus is subject to change. You will be notified of any changes as far in advance as possible via an announcement on Brightspace. Monitor your Purdue email daily for updates.

New Graduate Course Checklist

GENERAL INFORMATION

1. Originating Campus
   c. West Lafayette/Indianapolis
2. College/School and Department
   College of Engineering, School of Materials Engineering
3. Proposed Course Number
   a. I am requesting a specific course number (subject to availability):
      MSE 52100
4. Proposed Subject Code and Course Number
   Short Title – Superalloys
5. Long Title – Superalloys And High Temperature Alloys
6. Is this course Variable Title?
   a. No (most common)
7. Is this course equivalent to any other Purdue course?
   a. No
8. If yes, what is the equivalent course? Please indicate if the equivalent course currently exists or is also newly proposed.
9. A syllabus is required for all new courses. There will be a place to upload in Curriculog.
10. Justify Course Level.

This course primarily draws from Prof. Roger Reed's book: The Superalloys: Fundamentals and Applications which requires a baseline knowledge of materials science related topics. The course covers
Beyond quizzes, ungraded homeworks, and in-depth analysis problems, this course utilizes two essays and a final project to evaluate student's capacity for research and original work. In the first essays, students are given a material microstructure and composition and are asked to predict the performance of the material. Undoubtedly, students cannot adequately answer this question because they haven't been exposed to the course material yet and instead are graded on how they incorporate prior course topics into answering question. The second essay is given at the end of course and is largely the same prompt. Students at this point can use all of the course material to predict not only the material performance, but also which engineering components would be applicable for the material, which coating systems can be used, and how the material can be fabricated. Similarly, the final project is a 1200-word technical report that asks the students to start from the opposite viewpoint: given an engineering component, which material would be best suited for this application, how can one make it, what coatings are required? Students are then asked to identify limitations to their proposed material system and propose alternative novel solutions, not covered in class – requiring students to perform their own research. Thus, beyond the challenging analysis problems, this course requires independent creativity and research as demonstrated through these three (major) assignments.

11. Justify Course Need

This course will fill a critical need to introduce engineering students to superalloys – a class of high temperature nickel-based metal alloys that are ubiquitous throughout the petrochemical, aerospace, defense, and nuclear industries. The course starts by covering the basics of turbine engine operation to motivate the need for these materials, then covers in great detail the physical metallurgy of the nickel alloy systems. This part builds on prior knowledge from MSE 260 (Thermodynamics) and MSE 382 (mechanical response of materials) and delves into much greater detail, aiming to enable students to predict properties from composition and microstructure. Next, we discuss both single crystal and polycrystalline nickel based alloys – their structure and composition, processing/fabrication methods, and mechanical response, which complements existing graduate courses MSE 502 (defects in solids), MSE 505 (Modeling and simulations of materials processing), MSE 512, 536, 557 (powder, solidification, and deformation processing), and MSE 555 (deformation mechanisms in crystalline solids) – but applies them specifically to Ni-based superalloys. Specifically, we cover unique processing steps and properties are not covered in the current curriculum. Finally, we cover environment degradation (oxidation, coatings, and deposition processing) and export control considerations, which again are not covered up to this point in our curriculum as it pertains to nickel-based alloys. The course provides practical assignments that typically Bachelors levels engineers will encounter in their jobs right after graduation, but it also prepares students for further graduate studies by introducing more complex concepts, especially as it relates to crystallography and deformation mechanisms.

COURSE INFORMATION (STUDENT LEARNING DETAILS)

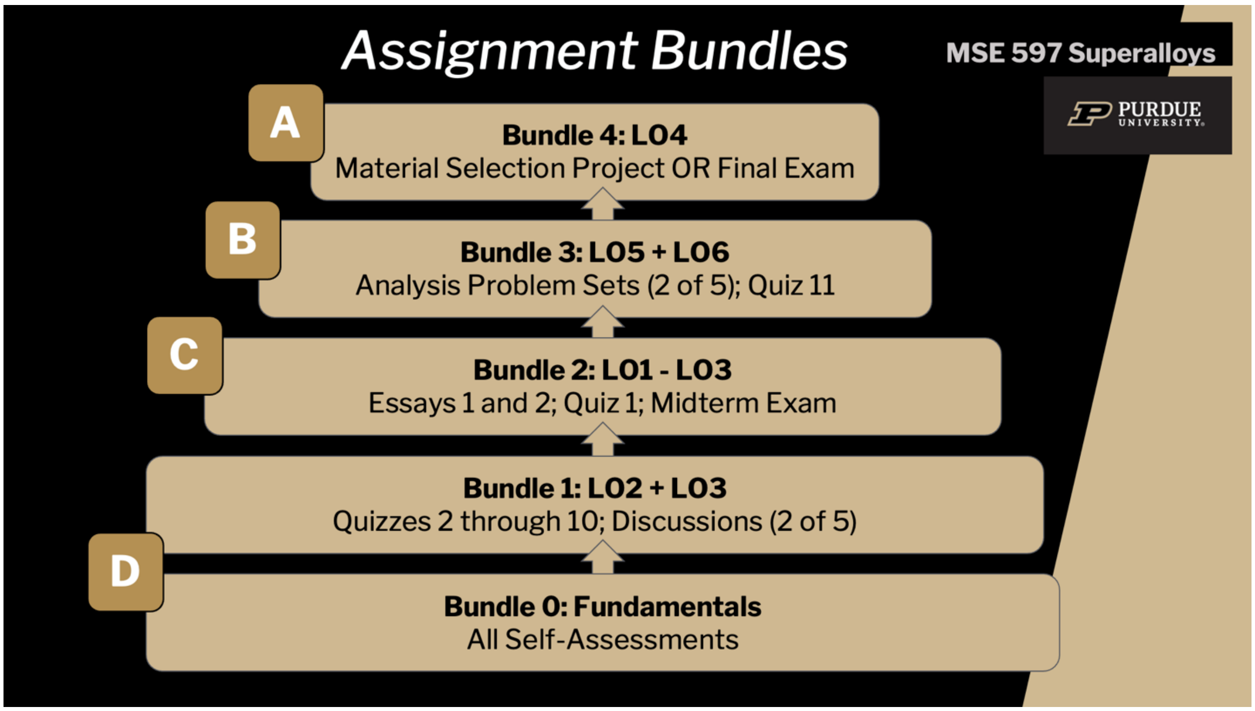
12. Course Description

Superalloys are Fe-, Ni-, and Co-based alloys possessing an exceptional balance of properties that typically include high-temperature strength, oxidation/corrosion resistance, toughness, and microstructure stability. These alloys are used in industries ranging from chemical processing, to nuclear power, to aerospace. This course will cover the

fundamentals of the physical metallurgy, processing routes and manufacturing, high temperature deformation mechanisms, and corrosion/oxidation mechanisms related to superalloys. Basic principles of lifing and identification of failure mechanisms of superalloy components will be covered. Material design and selection strategies for practical industrial applications will be presented. Beyond superalloys, we will study emerging structural alloys that include ultra-high temperature refractory silicides and borosilicides, refractory alloys, and intermetallics.
13. Course Outcomes
By the end of the course, students will be able to:

1. CLO1: Identify basic components of turbine engines and their relevant operating conditions
2. CLO2: Predict the microstructure and properties of superalloys from material constituents
3. CLO3: Select industrially relevant processing steps to fabricate superalloy components
4. CLO4: Apply basic alloy selection and design strategies for engineering components
5. CLO5: Analyze experimental and computational results to predict material performance
6. CLO6: Identify applicable regulatory procedures for exporting superalloys14. Assessment Methods

Final grading criteria includes the use of specifications grading. Briefly, students must complete bundles of assignments to earn their desired grade. See image below.



15. Should any special grade modes be added? All courses include Regular Grade, Audit, and Pass/No Pass.
    a. No other grade modes (most common)
16. Are the current library resources sufficient to support this course?
    a. Yes – The primary textbook is available online to all Purdue students.

COURSE OFFERING DETAILS
17. Is this a fixed or variable credit course?
    a. Fixed (always the same credit)
18. Credit(s)
    3.00
19. Maximum Credits (variable only)
20. Can this course be repeated for credit?
    b. No; non-repeatable (most common)
21. If Repeatable, what is the maximum number of credits a student can earn and apply towards their program?
22. Maximum repeatable credit

23. Please select all appropriate schedule types for the course.
Distance Education
Lecture
24. Instructional Time
MWF for 50-minute lectures, or TR for 75-minute lectures
25. What is the proposed weekly schedule for this course?
MWF for 50-minute lectures, or TR for 75-minute lectures
26. For independent study courses, is this Internship or Cooperative Experience?

STUDENT ENROLLMENT INFORMATION

27. Requisites
Graduate standing or basic phase equilibria (binary phase diagrams, e.g. MSE 260) and transport phenomena (heat transfer and diffusion, e.g. MSE 340) at the undergraduate level.
28. Type of Requisite(s)
c. Pre-Requisite (must be taken before)
29. Requisite Course(s)
Graduate standing, OR
MSE 260 (or equivalent) AND MSE 340 (or equivalent) with D- or better
30. Registration Restrictions
Graduate standing in engineering, or
Undergraduate standing with pre-requisites met
31. Please choose which scenario best describes undergraduate enrollment in this course.
c. 50000-level: Juniors and Seniors may enroll.
32. Who is permitted to register?
c. any student.
33. Anticipated Graduate Enrollment
15 per semester
34. Anticipated Undergraduate Enrollment
15 per semester
35. Additional Restriction
a. None (most common)

Additional Course Fees

36. Does this course require additional fees?
a. No (most common)
37b. Fee Rationale

Instructor Contact Information

37. Provide the name, rank, and department/program affiliation of the instructor(s).
Michael Titus, Associate Professor, School of Materials Engineering
38. Contact for follow-up questions during review (if not Originator):
Michael Titus, titus9@purdue.edu