

METALLURGICAL ENGINEERING

The metallurgical engineering program in the department of materials science and engineering offers comprehensive graduate education in a number of areas including physical and mechanical metallurgy, extractive metallurgy, metals casting, joining and forming, and advanced additive manufacturing. Further information on these opportunities and facilities available to carry out research in metallurgical engineering may be found under materials science and engineering.

Degree Requirements

M.S. and Ph.D. degrees are offered in metallurgical engineering. Recognizing the educational value of research, most metallurgical engineering M.S. degree candidates complete a thesis program. Non-thesis exceptions may be granted in special circumstances.

The total number of hours required for the M.S. in metallurgical engineering is 30. A minimum of 6 hours of 6000-level lectures and a minimum of 11 hours graduate research on the Missouri S&T campus are required. A maximum of 6 hours of 4000-level lectures may be accepted.

The minimum number of hours (beyond the bachelor's degree) required for the Ph.D. in metallurgical engineering is 72. At least 12 hours of course work outside metallurgy is recommended, a minimum of 24 hours will be dissertation research, and a minimum of 24 hours must be course work. Students will also be required to take and pass qualifying and comprehensive exams in accordance with Missouri S&T rules.

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Iron and Steel Metallurgy

Missouri University of Science and Technology offers a graduate certificate in Iron and Steel Metallurgy for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Iron and Steel Metallurgy Certificate Program is open to all persons holding a bachelor's, master's, or doctorate degree in engineering, science, and/or mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses. In order to receive a graduate certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

A student admitted to the Iron and Steel Metallurgy Certificate Program will have non-degree graduate status; however, they will earn graduate

credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the student admitted to the master's degree program will count toward their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Iron and Steel Metallurgy Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Choose one required course from the following:

MET ENG 5450	Advanced Steelmaking	3
MET ENG 6320	Advanced Steels and Their Treatment	3

Choose three courses from the following:

MET ENG 5310	Corrosion and Its Prevention	3
MET ENG 5440	Metal Deformation Processes	3
MET ENG 5450	Advanced Steelmaking	3
MET ENG 5470	Ferrous Metals Casting	3
MET ENG 6320	Advanced Steels and Their Treatment	3
MS&E 6130	Kinetic Theory for Materials	3

Note: MET ENG 5450 and MET ENG 6320 can be taken as the required course or as an elective, but not both.

Laura Bartlett, Associate Professor
PHD Missouri University of Science and Technology

Arezoo Emdadi, Assistant Professor
PHD Missouri University of Science and Technology

Yijia Gu, Assistant Professor
PHD Pennsylvania State University

F Scott Miller, Teaching Professor
PHD University of Missouri-Rolla
Associate Chair for Undergraduate Programs

Michael Scott Moats, Professor
PHD University of Arizona
Associate Chair for Graduate Programs

Joseph W Newkirk, Professor and Department Chair of Nuclear Engineering and Radiation Science
PHD University of Virginia

Ronald J O'Malley, Professor
PHD Massachusetts Institute of Technology
F. Kenneth Iverson Chair Professor in Steelmaking Technologies, Director of the Kent D. Peaslee Steel Manufacturing Research Center.

David C Van Aken, Professor Emeritus¹
PHD University of Illinois Urbana

Haiming Wen, Assistant Professor
PHD University of California-Davis

MET ENG 5000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MET ENG 5001 Graduate Special Topics (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

MET ENG 5040 Oral Examination (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

MET ENG 5099 Research (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

MET ENG 5110 High Temperature And Corrosion Resistant Alloys (LEC 3.0)

Fabrication and use of nickel, titanium, and refractory metal based alloys for use at high temperatures or in chemically corrosive environments. Properties and strengthening mechanisms of these alloys. Theory of high temperature oxidation and corrosion and design of alloys to prevent them. Prerequisites: Met Eng 3130, 2125.

MET ENG 5150 Introduction to Metal Additive Manufacturing (LEC 3.0)

Metal and alloys associated with Additive Manufacturing (AM). Issues with powders and wires as starting materials, safety, solidification mechanisms and development of microstructure and defects, AM part performance, and mechanical properties. Current alloys being utilized and future materials being developed. Prerequisite: Met Eng 2110.

MET ENG 5160 Mechanical Metallurgy (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication. Prerequisites: Met Eng 3120, 3125, Civ Eng 2210.

MET ENG 5170 Nuclear Materials I (LEC 3.0)

Fundamentals of materials selection for components in nuclear applications. Design and fabrication of UO₂ fuel; reactor fuel element performance; mechanical properties of UO₂; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110.(Co-listed with Nuc Eng 4241).

MET ENG 5171 Nuclear Materials II (LEC 3.0)

Extractive metallurgy of uranium, thorium, and zirconium. Equation of state of UO₂ and fuel chemistry. LMFBR fuel and interaction of sodium and stainless steel. Materials for fusion and other advanced nuclear applications. Reprocessing of spent fuel and disposal. Prerequisite: Met Eng 5170.

MET ENG 5220 Recent Advances In Extractive Metallurgy (LEC 2.0)

A survey of extractive processes recently developed in the light of modern requirements with respect to raw materials, product quality, environmental impact, energy consumption, capital cost and process control. Prerequisite: Met Eng 4350.

MET ENG 5270 Mineral Processing II (Mechanics and Design) (LAB 1.0 and LEC 2.0)

Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisite: Min Eng 3412. (Co-listed with Min Eng 5424).

MET ENG 5310 Corrosion and Its Prevention (LEC 3.0)

A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 3120 or Cer Eng 3230. (Co-listed with Chem Eng 5315).

MET ENG 5330 Nonferrous Alloys (LEC 3.0)

Structure and properties of nonferrous alloys (Al, Ti, Mg, Ni and Cu) are described. The role of processing and microstructure in the development of mechanical properties is emphasized. Prerequisite: Met Eng 3130 or Met Eng 5810.

MET ENG 5420 Advanced Metals Casting (LEC 3.0)

An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Design of castings and metals casting mold features using commercial casting process simulation software. Prerequisite: Met Eng 3420 or Mech Eng 2653.

MET ENG 5425 Metals Casting Laboratory (LAB 1.0)

An advanced laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, highquality castings. Prerequisite: Accompanied or preceded by Met Eng 4420.

MET ENG 5430 Metals Joining (LEC 2.0)

Metals joining processes such as welding and brazing. Effects of welding on materials. Treatment and properties of welded joints. Welding defects and quality control. Prerequisite: Met Eng 2110 or 3420.

MET ENG 5440 Metal Deformation Processes (LEC 3.0)

An introduction to metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisite: Met Eng 3120 and Met Eng 3420 both with "C" or better grade.

MET ENG 5450 Advanced Steelmaking (LEC 3.0)

This course is designed to provide students with an enhanced understanding of the chemistry and physics of ironmaking, steelmaking and casting, to apply these concepts to a wide range of problems in modern steelmaking and casting operations, and to perform advanced design and operational calculations associated with refining and continuous casting processes. Prerequisite: Grade of "C" or better in Cer Eng 3230 or Met Eng 3330.

MET ENG 5460 Metal Coating Processes (LEC 3.0)

Introduction to the current technologies used to enhance metal performance, particularly corrosion resistance, by overlay coatings. Deposition processes are emphasized and the fundamentals of the behavior of the films in high technology and electronic materials applications is discussed. Prerequisite: Senior or Graduate Standing.

MET ENG 5470 Ferrous Metals Casting (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment. Prerequisite: Met Eng 4420 or Met Eng 5420 or graduate standing with permission of instructor.

MET ENG 5480 Refining Of Metals (LEC 3.0)

Principles and applications of metal production by electrochemical methods. The course will address basic copper and zinc electrometallurgy. This includes discussion of anodes and anodic processes, cathode deposit control and contamination mechanisms, Faraday's Law and current efficiency, and current state of practice. Prerequisites: Cer Eng 3230, Met Eng 3220, graduate standing, or instructor approval.

MET ENG 5510 Nondestructive Testing (LEC 3.0)

Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Elec Eng 5670).

MET ENG 5515 Nondestructive Testing Laboratory (LAB 1.0)

Application of radiological and ultrasonic methods of nondestructive testing of metallic materials. A radiographic X-ray units and ultrasonic equipment are used in the inspection of a variety of materials and manufactured parts. Prerequisite: Accompanied or preceded by Met Eng 5510.

MET ENG 5520 Electron Microscopy (LEC 3.0)

A course in the theory and application of both scanning and transmission electron microscopy and x-ray microanalysis. Topics considered are electron optics, image formation and analysis; x-ray generation, detection and analysis; and characterization of fracture surfaces. Prerequisites: Met Eng 3130 and Met Eng 2125, or a course in optical microscopy.

MET ENG 5525 Scanning Electron Microscopy Lab (LAB 1.0)

A course in the practical use and operation of scanning electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

MET ENG 5620 Materials Behavior (LEC 3.0)

A course in crystal defects and deformation; mechanical testing; creep; fracture mechanics and fatigue. Prerequisites: Grade of "C" or better in both Met Eng 2110 and Met Eng 3120.

MET ENG 5630 Environmental Aspects Of Metals Manufacturing (LEC 3.0)

Introduction to environmental aspects of metal extraction, melting, casting, forming, and finishing. Subjects include history of environmental movement and regulations permitting, risk analysis, disposal and recycling of metal manufacturing residues, environmental ethics, environmental technologies and case studies. Prerequisite: Junior/Senior standing.

MET ENG 5810 Principles Of Engineering Materials (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Cer Eng 5810).

MET ENG 6000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MET ENG 6050 Continuous Registration (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

MET ENG 6099 Research (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

MET ENG 6160 Advanced Mechanical Metallurgy (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication.

MET ENG 6320 Advanced Steels and Their Treatment (LEC 3.0)

Industrially important ferrous alloys are described and classified. The selection of proper heat treatments to facilitate fabrication and to yield required service properties in steels suitable for various applications is considered. Prerequisites: Met Eng 3130 and Met Eng 2125.

MET ENG 6325 Advanced Ferrous Microstructures (LAB 1.0 and LEC 1.0)

Course provides an in-depth explanation of microstructural development during solidification, thermo-mechanical processing, and heat treatment of steel. Topics: microscopy, metallography, the Fe-C phase diagram, solidification, homogenization, grain size control, formation of microstructures upon heating/cooling. Term paper and presentation required.

MET ENG 6440 Advanced Metal Deformation Processes (LEC 3.0)

Advanced metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisites: A grade of "C" or better in both Met Eng 3120 and Met Eng 3420.

MET ENG 6470 Advanced Ferrous Metals Casting (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment.

MET ENG 6535 Transmission Electron Microscopy Lab (LAB 1.0)

A course in the practical use and operation of transmission electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.
