Advanced Manufacturing

Degrees Offered
• Graduate Certificate in Advanced Manufacturing
• Graduate Certificate in Smart Manufacturing
• Master of Science in Advanced Manufacturing (Non-Thesis)

Program Description
The Advanced Manufacturing Program provides graduates and professional students with the practical, interdisciplinary skills to apply cutting-edge manufacturing techniques to a wide range of industries, including aerospace, biomedical, defense and energy, among others. This program highlights the design, materials and data aspects of advanced manufacturing with an emphasis on additive manufacturing of structural materials.

Program Requirements - Advanced Manufacturing
Graduate Certificate (12 credit hours)
The graduate certificate portion of the Advanced Manufacturing program is pending the accreditation of Mines online learning program by the Higher Learning Commission (HLC).

Core Requirements
AMFG401ADDITIVE MANUFACTURING 3.0
or AMFG501ADDITIVE MANUFACTURING
Select 2 of 3 of the Remaining Core Courses:
AMFG531MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG421DESIGN FOR ADDITIVE MANUFACTURING 3.0
or AMFG521DESIGN FOR ADDITIVE MANUFACTURING
AMFG511DATA DRIVEN ADVANCED MANUFACTURING 3.0
Electives:
ELECT Select electives from the Advanced Manufacturing list below

Total Semester Hrs 12.0

Please note: Only 3 of the 12 credit hours can include coursework at the 400-level or lower to achieve the Graduate Certificate.

MASTER OF SCIENCE, Non-Thesis (30 credit hours)

Core Requirements:
AMFG401ADDITIVE MANUFACTURING 3.0
or AMFG501ADDITIVE MANUFACTURING
Select 2 of 3 of the Remaining Core Courses:
AMFG531MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG421DESIGN FOR ADDITIVE MANUFACTURING 3.0
or AMFG521DESIGN FOR ADDITIVE MANUFACTURING
AMFG511DATA DRIVEN ADVANCED MANUFACTURING 3.0
Electives:

Mines’ Combined Undergraduate / Graduate Degree Program
Students enrolled in Mines’ combined undergraduate/graduate program (with uninterrupted registration from the time the student earns a Mines undergraduate degree to the time the student begins a Mines graduate degree) may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any courses that count towards the graduate degree requirements as either “Required Coursework” or “Elective Coursework”, as defined below, may be used for the purposes of double counting at the discretion of the advisor (MS Non-Thesis) or thesis committee (MS Thesis or PhD). These courses must have been passed with a "B-" or better and meet all other University, Department, Division, and Program requirements for graduate credit.

Advanced Manufacturing Electives:

Materials for Additive Manufacturing
MEGN511FATIGUE AND FRACTURE 3.0
MEGN515COMPUTATIONAL MECHANICS 3.0
MLGN505MECHANICAL PROPERTIES OF MATERIALS 3.0
MTGN514DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS 3.0
MTGN531THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING 3.0
MTGN536OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS 3.0
MTGN557SOLIDIFICATION 3.0
MTGN560ANALYSIS OF METALLURGICAL FAILURES 3.0
MTGN564ADVANCED FORGING AND FORMING 3.0
MTGN565MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES 3.0
MTGN580ADVANCED WELDING METALLURGY 3.0
MTGN583PRINCIPLES OF NON-DESTRUCTIVE TESTING AND EVALUATION 3.0
PHGN585NONLINEAR OPTICS 3.0
AMFG531MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG511DATA DRIVEN ADVANCED MANUFACTURING 3.0
AMFG421DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG521DESIGN FOR ADDITIVE MANUFACTURING 3.0
ELECT Electives As Approved By Advisor

Design for Additive Manufacturing
FEGN525ADVANCED FEA THEORY & PRACTICE 3.0
FEGN526STATIC AND DYNAMIC APPLICATIONS IN FEA 3.0
FEGN527NONLINEAR APPLICATIONS IN FEA 3.0
FEGN528FEA FOR ADVANCED DESIGN APPLICATIONS 3.0
AMFG531MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG511DATA DRIVEN ADVANCED MANUFACTURING 3.0
AMFG421DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG521DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG4XX/5XXLEAN MANUFACTURING 3.0
MEGN592RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN 3.0

ELECT Select electives from the Advanced Manufacturing list below Up to 6 hours may be replaced with project-based independent study
The Smart Manufacturing Graduate Certificate is offered fully online to accommodate working professionals outside the immediate geographic area. These courses are also available as elective courses in the current Advanced Manufacturing Masters (Non-Thesis) and Additive Manufacturing certificate programs.

The four-core courses in the Smart Manufacturing program explore the emerging skillsets of Lean Manufacturing, Life Cycle Assessment, Operations Research and Product/Process Development for creating the next generation of optimized manufacturing facilities, saving companies both time and money. Students and professionals enrolled in the professional certificate program will complete the four core courses found below:

- AMFG422 LEAN MANUFACTURING 3.0
- ORWE5XX OPTIMAL PLANNING OF MANUFACTURING OPERATIONS 3.0
- EBGN576 MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS 3.0

Total Semester Hrs 12.0

Please note: Only 3 of the 12 credit hours can include coursework at the 400-level or lower to achieve the Graduate Certificate.

Courses

AMFG501. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.

(II) Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

AMFG511. DATA DRIVEN ADVANCED MANUFACTURING. 3.0 Semester Hrs.

(I) Although focused on materials manufacturing, this course is intended for all students interested in experimental design and data informatics. It will include both directed assignments to reinforce the concepts and algorithms discussed in class and a term project that will encourage students to apply these concepts to a problem of their choosing. Some programming background would be beneficial but is not necessary; the basics of python and the sklearn machine learning toolkit will be covered in the first weeks of the course. 3 hours lecture; 3 semester hours.

Program Requirements - Smart Manufacturing

Graduate CERTIFICATE (12 CREDIT HOURS)

The Graduate Certificate in Smart Manufacturing is pending the accreditation of Mines online learning program by the Higher Learning Commission (HLC).

The graduate certificate program is targeted to train recent graduates, as well as professionals interested in expanding their knowledge and skills to address the opportunities and challenges in advanced manufacturing. A 12-credit hour, graduate certificate requires a set of four core courses taught by multiple departments and interdisciplinary programs on campus.

The Smart Manufacturing Graduate Certificate program is anchored by four signature core courses. Three technical skills-based courses focusing on Lean Manufacturing and Six-sigma, Life Cycle Assessment and Optimal Planning of Manufacturing Operations provide students with skillsets for implementing efficiency and optimization skillsets into any process in industry. All three of these courses are also tailored towards advanced manufacturing with real world examples, projects and analysis being performed in current manufacturing settings. The fourth core-course, EBGN 576 Product Management, will teach students how to implement change in their workplace with the new skillsets learned throughout the program. EBGN 576 focuses on bringing
AMFG521. DESIGN FOR ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Design for Additive Manufacturing (DAM) introduces common considerations that must be addressed to successfully design or re-design parts for additive manufacturing methods. Industry-leading hardware and FEA software will be used to explore all phases of the DAM workflow, including topology optimization, additive process simulation, distortion compensation, and in-service performance. 3 hours lecture; 3 semester hours.

AMFG522. LEAN MANUFACTURING. 3.0 Semester Hrs.
Throughout the course, students will learn to apply skillsets to real world problems, focusing on lean and six-sigma principles and methodologies. The course is taught with a focus on the DMAIC structure of implementation (Define, Measure, Analyze, Improve and Control) for improving and implementing process efficiencies in industry. The course is split into three general subject areas; 1) Lean manufacturing principles, 2) Six-sigma and statistical process control (SPC) methodologies and 3) Implementation techniques focusing on graphical and numerical representation of processes using R. Students will receive an in-depth overview of Lean manufacturing principles and will perform case studies at local industries to implement learned skill-sets. Next, students will step-through several hands-on activities using real products to investigate six-sigma and perform SPC analysis, identifying shifts in process data and learning how to shift processes into capable processes. Lastly, students will learn about various implementation techniques for industry and will perform an in-depth analysis of the course topics based on the industry tours performed.

AMFG531. MATERIALS FOR ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) This course will cover various structural materials used in additive manufacturing (AM) processes. Focus will be on polymer, ceramic, and metallic compositions. General chemistry of each material will be covered with additional focus on the behavior of these materials when processed using AM. The course will span the entire AM lifecycle from feedstock fabrication to fabrication by AM to post processing and inspection of as-fabricated material. Students will have hands-on exposure to AM processes and will conduct laboratory studies of AM material properties. Additionally, students will conduct a semester-long research project exploring some aspect of AM materials. 3 hours lecture; 3 semester hours.

AMFG598. SPECIAL TOPICS IN ADVANCED MANUFACTURING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

Director and Professor of Practice
Craig A. Brice