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

AMFG401 ADDITIVE MANUFACTURING 3.0
or AMFG501 ADDITIVE MANUFACTURING 3.0

Select 2 of 3 of the Remaining Core Courses:

AMFG531 MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG421 DESIGN FOR ADDITIVE MANUFACTURING 3.0
or AMFG521 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG511 DATA 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:

AMFG401 ADDITIVE MANUFACTURING 3.0
or AMFG501 ADDITIVE MANUFACTURING 3.0

Select 2 of 3 of the Remaining Core Courses:

AMFG531 MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG421 DESIGN FOR ADDITIVE MANUFACTURING 3.0
or AMFG521 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG511 DATA DRIVEN ADVANCED MANUFACTURING 3.0

Electives:

ELECT Electives As Approved By Advisor

Total Semester Hrs 21.0

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

MEGN511 FATIGUE AND FRACTURE 3.0
MEGN515 COMPUTATIONAL MECHANICS 3.0
MLGN505 MECHANICAL PROPERTIES OF MATERIALS 3.0
MTGN514 DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS 3.0
MTGN531 THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING 3.0
MTGN536 OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS 3.0
MTGN557 SOLIDIFICATION 3.0
MTGN560 ANALYSIS OF METALLURGICAL FAILURES 3.0
MTGN564 ADVANCED FORGING AND FORMING 3.0
MTGN565 MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES 3.0
MTGN580 ADVANCED WELDING METALLURGY 3.0
MTGN583 PRINCIPLES OF NON-DESTRUCTIVE TESTING AND EVALUATION 3.0
PHGN585 NONLINEAR OPTICS 3.0
AMFG531 MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG511 DATA DRIVEN ADVANCED MANUFACTURING 3.0
AMFG421 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG521 DESIGN FOR ADDITIVE MANUFACTURING 3.0
ELECT Electives As Approved By Advisor

Design for Additive Manufacturing

FEGN525 ADVANCED FEA THEORY & PRACTICE 3.0
FEGN526 STATIC AND DYNAMIC APPLICATIONS IN FEA 3.0
FEGN527 NONLINEAR APPLICATIONS IN FEA 3.0
FEGN528 FEA FOR ADVANCED DESIGN APPLICATIONS 3.0
AMFG531 MATERIALS FOR ADDITIVE MANUFACTURING 3.0
AMFG511 DATA DRIVEN ADVANCED MANUFACTURING 3.0
AMFG421 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG521 DESIGN FOR ADDITIVE MANUFACTURING 3.0
AMFG4XX/5XX LEAN MANUFACTURING 3.0
MEGN592 RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN 3.0
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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>AMFG422</td>
<td>LEAN MANUFACTURING</td>
<td>3.0</td>
</tr>
<tr>
<td>or AMFG522</td>
<td>LEAN MANUFACTURING</td>
<td></td>
</tr>
<tr>
<td>CEEEN401/501</td>
<td>LIFE CYCLE ASSESSMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>ORWE5XX</td>
<td>OPTIMAL PLANNING OF MANUFACTURING OPERATIONS</td>
<td>3.0</td>
</tr>
<tr>
<td>EBGN576</td>
<td>MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS</td>
<td>3.0</td>
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### 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.

(II) 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.
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 redesign 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