MECH 502: Advanced/Additive Manufacturing Engineering

COURSE DESCRIPTION

In this course you will learn the importance of additive manufacturing (a.k.a. 3D Printing) and its huge role in global product development and innovation. You will develop a rich knowledge of 3D printing technologies, devices, capabilities, materials and applications. You will learn the trade-offs between various 3D printing processes and technologies, along with the various related software tools, processes and techniques, such as 3D scanning, injection molding and casting. You will explore the broad range of 3D printing applications, including biomedical, aerospace, consumer products, and creative artistry, to mention a few. And finally, you will learn the latest trends and opportunities in 3D printing, localized services, production parts, mass customization, and how to commercialize your ideas.

CONTENT OVERVIEW

- Advanced/Additive manufacturing processes - extrusion, jetting, photopolymerization, powder bed fusion, direct-write, sheet lamination, directed-energy deposition and the latest state of the art.
- Design and fabrication processes - data sources, software tools, file formats, model repair and validation, post-processing
- Designing for additive manufacturing (DfAM)
- Bio-printing, biomaterials, scaffolds and tissue and organ engineering
- Materials: Metals, polymers, ceramics, composites and material selection
- Applications of additive manufacturing, such as in biomedical, aerospace, surgical simulation, architecture, art, and health care
- The new age of distributed manufacturing, direct part production and mass customization.
- Processes related to AM, such as 3D scanning, mold-making, casting and sintering

LEARNING OBJECTIVES

- Learn what Advanced/Additive manufacturing (AM) is and understand why it has become one of the most important technology trends in decades for product development and innovation.
- Demonstrate comprehensive knowledge of the broad range of AM processes, devices, capabilities and materials that are available.
- Understand the various software tools, processes and techniques that enable advanced/additive manufacturing and personal fabrication.
- Learn how to create physical objects that satisfy product development/prototyping requirements, using advanced/additive manufacturing devices and processes.
- Articulate the various tradeoffs that must be made in selecting advanced/additive manufacturing processes, devices and materials to suit particular product requirements.
- Opportunity to design, engineer and fabricate an actual multi-component object using advanced/additive manufacturing devices and processes (the “project”).
- Understand the latest trends and business opportunities in AM, distributed manufacturing and mass customization.

CURRICULUM – (for details, see "Weekly Lecture Topics" below)

1. Introduction to the Basic Principles of Advanced/Additive Manufacturing
2. Overview of Additive Manufacturing Processes and Technology
3. AM Technology: Extrusion, Beam Deposition, Sheet Lamination, Direct-Write, Photopolymerization, Sintering, Powder Bed Fusion, Jetting and the latest new methods, such as HP's Multi-Jet Fusion, CLIP and the latest methods for printing metal parts
4. Design/Fabrication Processes: Data Sources, Software Tools, File Formats, Model Repair and Validation, Pre- & Post-processing
5. Designing for Additive Manufacturing
6. Process & Material Selection : Biomaterials, Metal Technology & Processes, Multiple Materials, Hybrids, Ceramics and Bioceramics, Composite Materials and future directions
7. Direct Digital Manufacturing, Distributed Manufacturing and Mass Customization
8. Related Technologies: 3D Scanning, Injection Molding and Casting
9. Applications of AM: Aerospace, Biomedical, Automotive, Bio-printing, Tissue & Organ Engineering, Architectural Engineering, Surgical simulation, Art, Health care and many more
10. Intellectual Property, Product Development, Commercialization
11. Trends, Business Opportunities and Future Directions in Additive Manufacturing

Delivery Modes: Traditional classroom instruction with student participation and On-line. On-line students participate through Canvas, blogs and discussion boards.

Project (if applicable): The project will consist of teamed students (optional for on-line students, who would be teamed with classroom students) who will identify, design and build a project in the www.idea2product.net laboratory. Guidelines and requirements are provided. On-line students may also use local 3D printing capabilities if available, e.g. in local libraries, etc.

Section#/CRN: MECH 502-001 (classroom; CRN 26129), MECH 502-801 (on-line; CRN 80086)
Terms: Section 001 – Spring term only; Section 801 – Spring, Summer or Fall terms
Credit: 3 Credit hours, including course project
Lab Fee: yes, see https://idea2product.net/pricing/
Prerequisites: Engineering Design, Materials Science or instructor approval
Work Load: this class is expected to require approximately 4-6 hours per week, exclusive of class time

LEARNING MATERIALS

Textbook: Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 2nd Ed. (2015), Ian Gibson, David W. Rosen, Brent Stucker
Assigned readings from advanced/additive manufacturing literature and industry

GRADING

Quizzes & Readings 15%
Mid-Term examinations (2) 15% each = 30%
Comprehensive Final Examination 30%
Course Project 25%

Lecture Topics

Introduction
Module 1: The Basics
Basic Principles 1
Basic Principles 2
AM Processes 1
AM Processes 2
The Personal Printer Revolution
AM Process Workflow
A Closer Look at Rep-Rap Machines
Preparing Files for 3D Printing
Choosing the Right Materials

Module 2: AM Technology-Part 1
Extrusion Systems (1)
Extrusion Systems (2)
Sheet Lamination
Jetting
Direct-Write
Bioprinting

Module 3: AM Technology-Part 2
Sintering Overview
Powder Bed Fusion (1)
Powder Bed Fusion (2)
Directed Energy Deposition
Photopolymerization (1)
Photopolymerization (2)
The latest AM Methods

Module 4: Software & Methods
Designing for Additive Manufacturing (DfAM)
Software Tools vs. Requirements
Pre- & Post-processing
3D Scanning & the Scanning Process
Sculpting & Repairing data
AM File Formats
STEP file format
More detail on NURBS
Model Validation

Module 5: Materials
Choosing Materials for Manufacturing
Multiple Materials
Metal AM Processes & Materials
Composite Materials
Biomaterials, Heirarchical Materials & Biomimetics
Ceramics & Bio-ceramics (e.g. bone surrogates)
Shape-Memory Materials, 4D Printing & Bio-active materials
Advanced AM Materials

Module 6: Key Related Processes
Choosing the Right Manufacturing Process
Injection Molding
Casting
Mold-making

Module 7: Applications of AM
Direct Digital Manufacturing
Distributed Manufacturing
Mass Customization
Biomedical Applications
Aerospace & Automotive Applications
Architectural Engineering
Food & Consumer Applications
Personalized surgery
Art, Fashion, Jewelry, Toys & Other Applications

Module 8: The Business of AM
Intellectual Property
Tradeoffs of Open Source vs. Proprietary Systems
Gartner hype cycle *viz* 3D Printing
Total cost of ownership
Business Considerations for Material Selection
Commercialization
Trends, Business Opportunities & Future Directions