MASC 599 - Composites Manufacturing

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M-W at 10

Course Objective: This course covers the science and technology underlying composites manufacturing processes from the perspectives of process selection, materials efficiency, and sustainability. The scope includes constituent materials, manufacturing challenges, defect control strategies, as well as bases for material and process selection and design, and practical issues of producing composite structures. Students will learn (1) how to analyze, evaluate, and select a manufacturing process appropriate for a given part within various constraints, (2) how to evaluate different processes, (3) how process parameters affect part quality and performance, and (4) how processes can be adjusted to control part quality.

Course Description: This graduate seminar course will cover both fundamental and applied aspects of manufacturing methods for polymer composites. We will rely on journal articles, presentations, and discussion as the primary sources of content and as a platform for learning. We start by introducing the basic constituent materials – fibers and matrices – commonly used in composites, and the distinguishing characteristics of these materials that justifies selection for different applications. The task of combining these materials and curing the matrix comprises composite manufacturing, and there are dozens of approaches, each with limitations and advantages. We cover prepregs (VBO and conventional), liquid molding techniques (RTM, VARTM and infusion), compression molding, automated tape layup (ATL), filament winding, and pultrusion. Attention is devoted briefly mechanics and analysis of composites, the principles and concepts being generic to all fiber-reinforced materials. In addition to manufacturing techniques, we introduce the basic processes and phenomena involved, such as fluid flow through permeable media, dynamic viscosity, gas removal, and cure kinetics. We also introduce technical issues and scientific phenomena associated with the manufacture of sandwich structures. The final portion of the course is devoted to engineering issues, such as joining and repair, diagnostic techniques, and design.

Course Plan

1. **Fibers, Matrices, and Interfaces (Weeks 1)**
    1. Synthetic fibers, their properties, production, and available forms.
    2. Textile forms – fabrics, UD, non-crimp
    3. Matrix materials – properties and families of resins.
    4. Control of interface properties - coatings and treatments, measurements.
2. **Composite Manufacturing Methods – Overview (Week 2)**
    1. Molding techniques – RTM, VARTM, infusion, compression
    2. Prepregs – autoclave and VBO
    3. Filament winding, pultrusion, and automated processes

3. **Basics of Polymer Science (Week 3)**
    1. Polymers – epoxies, urethanes, vinyl esters, polyesters, phenolics, BMI
    2. Flow characteristics and cure reactions
4. **Cure Kinetics (Week 4)**
    1. Polymer reaction kinetics.
    2. Flow through permeable media
    3. Cure reactions in manufacturing contexts
5. **Prepreg Fundamentals (Weeks 5-6)**
    1. Materials and process fundamentals
    2. Manufacturing protocols
    3. Manufacturing challenges and process modeling
6. **Liquid Molding Techniques (Weeks 7-8)**
    1. Preform design
    2. Flow through permeable media
    3. Characteristics of process variants – infusion, RTM, VARTM
7. **Sandwich Structures (Week 9)**
    1. Analysis of Plates
    2. Design and manufacture of sandwich panels
8. **Filament Winding and Pultrusion (Weeks 10-11)**
    1. Process modeling – pressure and pulling in pultrusion
    2. Process modeling – thermochemical and fiber motion models
9. **Automated Tape Layup (Week 12)**
    1. Machine simulation/validation
    2. Evaluating producibility
10. **NDE Diagnostic Techniques (Week 13)**
    1. Ultrasound
    2. Eddy current
    3. X-ray techniques
11. **Manufacturing Technology (Week 14)**
    1. Design and selection of manufacturing techniques
    2. Joining
    3. Repair

Reading List. There is no required textbook for the course. Several background texts are listed below, but much of the material will be gleaned from lectures based on academic journals and through weekly presentations given by students in the class.

1. Manufacturing of Polymer Composites, B.T. Astrom, Chapman & Hall
2. Manufacturing of Polymer Composites, vol 6, American Society for Composites, ed. by A.C. Loos
3. Manufacturing Processes for Advanced Composites, Elsevier, F.C. Campbell
4. Processing of Composites, Hanser, ed by R.S. Dave and A.C. Loos
5. Principles of the Manufacturing of Composites, DEStech, S.V. Hoa

Examinations/ Grading

- One in-class presentation. 25%
- One written review paper with literature review. 25%
- In-class quizzes – 25%
- Final exam will be closed-book, closed-notes. 25%