

Fabrication and Processing of Advanced Composites (FPAC)

Subject convenor: Dr Nilanjan Das Chakladar (19006) and Dr Atul Jain (17076)

Students:

1st Year Manufacturing Science and Engineering PG (Mechanical)

1st Year Mechanical Systems Design PG (Mechanical)

1st Year Aerospace Engineering PG (Aerospace)

1st Year Structural engineering PG (Civil)

1st Year Metallurgical and Materials Engineering PG (Metallurgical and Materials)

1st Year Ocean Engineering and Naval Architecture PG (Ocean Engg and Naval architecture)

2019-2020 Autumn Semester – Credits – 3-1-0 – Elective

Subject outline

This course would cover specific areas in composites science and manufacturing – particularly focusing on automated manufacturing processes of advanced composites. The students will learn the science of automated composite manufacturing of large-scale structures used in the field of aviation, marine and renewable sectors. It will include latest composite processing capabilities and understanding of composite manufacturing process models. The students will conceive the four pillars of a composite manufacturing industry following the industry 4.0 strategy in Composites (also called as the Composites 4.0) – Make the Material, Develop the Process, Predict the Process, followed by Design and Optimize the part/process.

Lecture layout (Audio-visual support and board work):

1. Recap of previous lecture (if any) – 1/2 slide; 2. Objectives and learning outcomes of current lecture – 1 slide
3. Content of today's lecture – 12/15 slides (2 hrs); 4. Quiz, case study and interactive learning – 2 slides
5. Summary – 1 slide

Lecture plan (40 hrs) plus Tutorial (12 hrs):

- Evolution and Types of composite materials, fibres and resin (1 hr)
- Thermal and Mechanical properties of matrices, reinforcements and composites (1 hr)
- Traditional and Automated Manufacturing Processes of composites (1hr)
Tutorial 1: *What is ABD matrix and rule of mixtures? Application of traditional and robotic manufacture. What are the different derivatives of vacuum bagging technique? (1 hr)*
- Autoclave and Out-of-Autoclave curing processes – their pros and cons (1 hr)
- Die/mould making for complex composite geometries (1 hr)
- Types, Design and kinematics of Composite Robot head (1 hr)
Tutorial 2: *Why out-of-autoclave manufacture is more popular? How to manufacture curved moulds for composites? (1 hr)*
- Design and performance of thermoplastic and thermoset robot heads (1 hr)
- Automated Tape Laying and Automated Fibre Placement methods (1 hr)
- Challenges in laying thermoplastic and thermoset prepregs (1 hr)
Tutorial 3: *Draw schematic of thermoplastic and thermoset robot heads. What precautions to be taken while laying up of thermoplastic prepregs and why? (1hr)*
- Importance of Dry Fibre Automated Fibre Placement method and its advantages (1 hrs)
- Manufacture and processing of hybrid metal composites (1+1 hrs)
Tutorial 4: *Why composite industries are drifting toward dry fibre AFP? How is it better than prepreg layup? (1 hr)*
- Joining of thermoplastic composites and their process defects (1+1 hrs)
- How composites are polished, and surface finished (1 hr)
Tutorial 5: *Describe polishing methods of composites. What is thermoplastic welding and discuss its applications. (1 hr)*
- Abrasive Water Jet Machining of large-scale composites structures and its analyses (1+1 hrs)
- Conventional drilling of composite structures and its cons (1 hr)
Tutorial 6: *Why AWJM is preferred over conventional cutting for composites? What are the challenges of using AWJM of composites and how can they be controlled? Explain basic empirical equations of AWJ Cutting of composites. (1 hr)*
- Laser Beam Machining of composite structures and its analyses (1+1 hrs)
- Fusion bonding of thermoplastic composites (1 hr)

Tutorial 7: *Compute laser power for cutting of composites. What are the main hurdles of using laser on composites? How to choose a laser source for cutting carbon composites? (1 hr)*

- Recyclability and methods of recycling of Advanced Composites (1+1 hrs)
- Performance and quality of sustainable composites (1 hr)

Tutorial 8: *How much recycled carbon composites can be used to attain a fibre volume fraction of 60%, all other material and geometrical data can be assumed to be same? What are the different process of recycling of composites? (1 hr)*

- Industrial Health and Safety policies of composites (1 hr)
- Protective measures of handling constituent materials and manufacturing techniques (1 hr)
- Safety and workplace hazards in composites industries (1 hr)

Tutorial 9: *What are the risks and hazards involved in composite processing? What is WHandS and why is it an absolute necessity in composites research? (1 hr)*

- Structural Health monitoring of automated composites (1 hr)
- Introduction of optical sensors and use of fibre Bragg grating sensors during and post-manufacture (1+1 hrs)

Tutorial 10: *Why FBG sensor is preferred over other sensors? Understand the peak reflected power as a function of wavelength? How to calculate strains from the obtained signals? (1 hr)*

- Industry 4.0, IIoT, Understanding the world composites market and reviews (0.5+0.5+0.5+0.5 hrs)
- Automated Composites fabrication and Composites 4.0 (1 hr)

Tutorial 11: *Why is it necessary to understand market reports in terms of application, product, materials and manufacturing processes? How is in-line monitoring and control of composite production achievable, discuss? (1 hr)*

- Manufacturing process models of thermoset and thermoplastic Composite layup – a thermo-mechanical perspective and simulating resin flow and cure (1+1 hrs)
- Significance of coupon-, component- and product-level simulations (0.5 hrs)
- Modelling of composite damage during manufacturing (0.5 hrs)

Tutorial 12: *How can we predict warpage of a post-cured composite specimen? Calculate deflection of a multilayer beam due to uneven thermal expansion coefficient of multimaterials? How does it relate to composite warpage? (1 hr)*

- Understand variable stiffness manufacture and its important in composites fabrication (1 hr)
- Modelling of composite damage during secondary processing such as AWJM, LBM(1 hr)
- Characterization and quantification of defects in composites (1 hr)

Case Study of a selective stiffness AFP manufactured composite structure (1hr)

Class Tests

- 1) Background, manufacturing of automated composites and selection of composite materials for a structure (25 marks – 1 hr – 10% of total weightage)
- 2) Processing of advanced composites and concepts behind prediction of composites manufacturing process (25 marks – 1 hr – 10% of total weightage)