A119

Composite materials engineering webinar series	
Perspectives article	
Document Type	Article
Document Identifier	119
Themes	• Thermal management • Material deposition management • Flow and consolidation management • Residual stress and dimensional control management

Introduction[edit | edit source]

The Composites Knowledge Network (CKN), in partnership with SAMPE Canada, hosted a 12-part webinar series on composite materials engineering from May through November 2020.

This series is intended for engineers, both junior and senior, who are looking to obtain a solid background in the fundamentals of composites to help make both engineering and business decisions. After completing this series, participants will have the skills to identity suitable applications for composites, select materials and processes, estimate composite mechanical properties, and identify appropriate testing procedures.

List of webinar episodes[edit | edit source]

The following table provides an outline of the webinar series and details on the topics covered in each webinar.

Webinar number	Webinar title	Contents
1	Introduction	This first session is an introduction to what composite materials are. It gives an overview of common applications, and discusses challenges and success stories. The latter half of the session provides an overview of the remainder of webinar series.
2	Constituent Materials - Fiber	Composites are made up of two separate and distinct materials referred to as constituent materials. In this session we focus on commonly used fiber reinforcement materials such as carbon fiber, glass fiber and aramid (Kevlar) fiber. Examples of typical applications are presented along with information on selecting the right fiber for a specific application.
3	Constituent materials - Resin	Composites are made up of two separate and distinct materials referred to as constituent materials. In this session will focus on commonly used polymer matrix materials such as epoxy, polyester, and PEEK. Both thermoset and thermoplastic materials are discussed. Examples of typical applications are presented along with information on selecting the right resin for your application.

4	Thermal management and resin cure	Thermal management involves heat transfer into and out of the composite material during the curing/forming process. In this session we will look at factors affecting heat transfer, how to control them, and how to simulate the thermal management of a process.
5	Manufacturing processes - Introduction	This session provides an introduction and overview of common manufacturing processes. Examples of when and where these processes are applicable are given with an emphasis on how to select the right process for your application.
6	Manufacturing processes - Prepreg processing	Prepreg materials are composed of fiber and partially cured resin that is combined at a specific, tightly controlled ratio. It is the most common form of material used in aerospace. This session goes into more detail on prepreg materials and the processes used to manufacture parts with them.
7	Manufacturing processes - Liquid composite moulding	Liquid composite moulding is a family of processes that involve saturating dry fiber reinforcement with a resin using a pressure differential in the mould. Common processes include vacuum infusion (vacuum assisted resin transfer moulding (VARTM)), resin transfer moulding (RTM), and light resin transfer moulding (LRTM). This session describes the fundamental differences in the aforementioned processes, and when and where each process is applicable. We introduce resin flow theory based on Darcy's law and a procedure for process design.
8	Mechanics of composites - Part 1: Lamina level	In this session we introduce the basics of calculating the mechanical properties of a composite material. We introduce and define a lamina, a single ply of composite material. Then we go into micromechanics, which is used to predict basic mechanical properties. With that groundwork set, we introduce Hooke's law for orthotropic materials and describe how a lamina reacts to loading from different directions/fiber orientations.
9	Mechanics of composites - Part 2: Laminate level	In this session we build on what was introduced at the lamina level in the last session and build it up to a full laminate. We introduce laminated beams and plates, including laminate plate theory and the [ABD] matrix.
10	Failure of Composites	Building on Sessions 8 and 9, this session goes into both the analytical and practical aspects of failure. Stress analysis and failure theories are introduced. Failure modes are discussed and demonstrated with micro and macroscopic images of actual failure on a laminate level.
11	Defects	Defects in composite materials are a major concern. They typically occur during processing and often become the limiting factor of a part's performance. In this session we introduce and classify various types of defects, then go into more detail on common defects such as thermal issues during cure, dimensional control, porosity, and fiber misalignment.
12	Testing	Given the wide variety of constituent materials, processing methods, and configurations, testing composites is critical. This session introduces the common methods of destructive and non-destructive testing and how to navigate through the myriad options.

The Society for the Advancement of Material and Process Engineering (SAMPE).

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

The individual materials that combine to form the composite material. The constituent materials are separate and distinct on a macroscopic level.

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

Thermosets are a class of polymer that undergo polymerization and crosslinking during curing with the aid of a hardening agent and heating or promoter. Initially they behave like a viscous fluid. During curing, they change from viscous fluid to rubbery gel (viscoelastic material) and finally glassy solid.

If heated after curing, initially they become soft and rubbery at high temperatures. If further heated, they do not melt but decompose (burn)

Comes in two parts: part A (resin) and B (hardener). When mixed, curing reaction starts and is not reversible.

Examples include epoxy or polyester.

A class of polymer, some common examples include polypropylene and polyethylene.

They soften and melt upon heating (i.e. potentially recyclable), high viscosity when melted, therefore difficult to saturate fibres. Usually needs a lot of pressure and heat to process.

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

A central processing theme in the manufacturing cycle. This theme is concerned with managing the thermal response of materials during storage and handling or parts/tools when they are subsequently heated.

Pre-impregnated (prepreg) material refers to fibre that is already combined with resin. It is the most common material form used in aerospace.

During prepreg production, (e.g. fibres are run through a resin bath), prepreg is heated and partially cured to B Stage (< 5 % degree of cure). Thermoset prepregs (e.g. epoxy prepreg) have to be kept in a freezer at around -20 °C. At room temperature, the epoxy starts to cure.

Vacuum assisted resin transfer moulding (VARTM) - also known as vacuum assisted resin infusion (VARI), vacuum infusion process (VIP) or often just resin infusion. VARTM is a liquid composite moulding (LCM) closed mould process with a single side tool and vacuum bag where the resin is drawn through the preform using vacuum.

Resin transfer moulding (RTM) involves loading a preform into a two (or more) piece, matched tool, closing it, and injecting resin under pressure (~15-100 psi, or ~1-7 bar).

Well suited to small to medium sized parts, limited to large sizes due to injection pressure loads and tool cost.

Light Resin Transfer Moulding (LRTM) uses a semi rigid tool half (A side) that is similar to those used in VIP and a semi flexible tool half (B side) (typically made of thin fibreglass).