

Chapter 36

Quickstep Processing of Polymeric Composites: An Out-Of-Autoclave (OOA) Approach

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ABSTRACT

This chapter gives an overview of Quickstep processing method, which is relatively a new technique for manufacturing composites. In this chapter, different aspects of Quickstep processing are highlighted. Since Quickstep processing is an Out-Of-Autoclave (OOA) technique, a brief description of autoclave processing is provided. Basic principle of Quickstep processing and functionality of typical Quickstep plant are also explained. Due to changed chemo-rheology, methodology for cure optimization of different prepregs and composites are discussed with examples. This chapter also includes the literature survey of different aerospace materials being investigated in Quickstep, the potential of new materials development for this process, the melding technique, in service capabilities of Quickstep cured samples and journey of Quickstep from patent to commercialization. Although the technique is commercialized now, few suggestions in the end are provided for the improvement of process.

1. INTRODUCTION

The word ‘composite’ in composite materials signifies that two or more components with different properties are combined on a macroscopic scale to form a useful material. Modern structural composites are a blend of two major components, one of them is strong, stiff and thin fibers (long, short or woven) and the other is matrix which holds the fiber in place. The fiber’s strength and stiffness is usually several times greater than that of the matrix material (Jones, 1999). When the fibers and matrices are joined together, they retain their individual identities and directly affect the composites final characteristics (Jones, 1999).

The significant advantages of composite materials over the traditional metals are high strength or stiffness to weight ratio, high resistance to corrosion, excellent fatigue and fracture resistance, ability to meet stringent dimensional stability requirements, flexibility to design and its exceptionally long life

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span. There are, however, some disadvantages of composites too, which include high cost of raw materials and fabrication, weak transverse properties, difficult to reuse, difficult analysis and more importantly that most of the matrices are susceptible to environmental degradation (Mallick, 1993).

Fiber or reinforcement is major component of composite materials, providing strength and integrity to the structure by carrying the majority of any imposed structural loads. The principle fibers in commercial use are several types of glass, carbon and Kevlar. Other fibers are also available such as boron, silicon carbide and aluminum oxide, but their application and usage quantities are limited.

The matrix material binds the reinforcing component together in the desired orientation, provides rigidity and shape to the structure, acts as a load transfer medium, helps to determine the physical properties of the end product and protects it from hostile environmental conditions. As a continuous phase, the matrix also controls the transverse properties, interlaminar strength and elevated temperature strength of composites (Miracle, Donaldson & Vander Voort, 2001). The matrix material may be a polymer, a metal or a ceramic. Several chemical compositions and micro-structural arrangements are possible in each category (Mallick, 1993).

Polymeric composites can be broadly categorized as thermosets and thermoplastics. Thermosetting resins usually consist of a resin and a compatible hardener. This mixture then cures either due to internally generated (exothermic) or externally applied heat. The curing reaction forms one large molecular network structure, resulting in an intractable solid which cannot be reprocessed on reheating. Thermoplastics, on the other hand, start as fully reacted polymeric materials which do not crosslink when heat is applied. On heating thermoplastics either soften or melt, thus can be reprocessed a number of times (Mallick, 1993). Polyester and epoxy are the most widely used matrices in high and low end applications.

The “Prepreg” is a contracted term for pre-impregnated materials. It consists of unidirectional fibers or woven fabric combined with a resin matrix to produce a uniform lamina structure. The resin matrix can be either thermoset or thermoplastic. The drape and tack characteristics of thermosets enable them to stick together in the manufacturing of laminate structure of different shapes. Certain characteristics of prepregs such as ease of handling, uniform fiber alignment, resin content control and the fact that they are ready to use, have successfully introduced them in the high performance composites markets like aerospace and automobiles (Kelly & Zweben, 2000).

The autoclave is a device that can generate a controlled pressure and temperature environment. The maximum void content acceptable in aerospace component is less than 2% and with the selection of prepreg and proper cure cycle, a void free component is achievable through autoclave molding.

Currently, high performance composites parts (like in aerospace industry) are predominantly manufactured by the use of prepreg materials and autoclave cure. This requires high manufacturing temperature, pressure, heavy tooling and a cycle time of several hours. As the aerospace timescale requirements are shortening, an increase in production rates is required and this is difficult to achieve with traditional autoclave manufacturing. Also, high capital expenditure, infrastructure requirements and time to commission has made autoclave processing, increasingly undesirable (Hodgkin & Rabu, 2000; Ryder, 2009).

Extensive research has been conducted on the development of new resin systems to match the existing processing techniques; however, the development of new processes for curing high performance composites is limited. Few methods have been used for manufacturing of aerospace composites such as resin infusion, resin transfer molding (RTM) as well as with minor modifications like VARTM, LRTM, RFI, etc. These methods found to be advantageous in terms of speed of manufacturing over traditional autoclave manufacturing. The major disadvantages associated with RTM, however, are expensive tooling and resin impregnation systems are required. RTM used only for small, intricate parts in aerospace

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