RTM PROCESSING OF TOUGHENED INTEGRAL CFRP STRUCTURES

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1 General Introduction

Resin Transfer Molding (RTM) is one of the most promising processing method, which is especially suitable for the manufacture of integral CFRP structures because of its excellent production efficiency and lower cost. But the brittle nature of the RTM resin due to the low viscosity requirement of fiber impregnation becomes the major drawback of this rapid-developing technology, resulting in low interlaminar toughness and poor impact damage resistance.

One solution to this problem is presented in this paper, which comprises two key technologies. The first key technology is the introduction of pretreated reinforcements with well-designed toughening agent layer on the surface. Preforms made of these special reinforcements exhibit a sandwich structure; after injection and curing cycle, a high toughness resin layer forms between adjacent plies. This will greatly improve the impact damage resistance of the laminate. The second key technology is the utilization of a novel VARI-like injection procedure. Special designed resin distributors are placed in the RTM mold, forming a homogenous resin pressure field in the mold cavity and forcing the resin through the toughening layers.

The toughened RTM laminate shows excellent mechanical performance. And typical integral parts demonstrate the good manufacture ability of this processing technology.

2 Toughening of RTM Composites

2.1 Ex-Situ Toughening Concept

One of the major drawbacks of polymeric matrix composite materials is the low toughness of matrix resins. When the composite panels are impact loaded, the brittleness of interlaminar resin results in fracture and delamination, which in turn leads to significant decrease in compression strength of the laminates.

Many works have been done to improve the damage resistance and damage tolerance of CFRP panels. We have developed the Ex-Situ concept as a solution of the interlaminar weakness [1-4]. The basic idea is the introduction of thermoplastic toughener in between selected plies, forming a phase-inversed morphology with TP-rich phase as continuous phase, thus the most damage-prone interlaminar resin can be well toughened and the impact resistance of the laminates as a whole can also be greatly improved.

2.2 ES-Fabric for RTM Composites

Significant toughness improvement being obtained with Ex-Situ concept in autoclave cured composites, there is also possibility to get toughened RTM composites in the similar way. The first stage in RTM procedure is the preparation of the preform, where is suitable for toughening agent particles being loaded on top of the carbon fabric. Then the preform is put into mold and resin is injected into it. The toughening agent particles solves in the matrix resin at elevated temperature, but phase separation follows and a co-continuous two phase morphology dominates the interlaminar resin layer. That is just the same as in Ex-Situ toughened prepregs.

Yet another thing is different in RTM procedure. Preforms are prepared with dry fabric, so some tackifier is needed to bind their together. Toughener particles and tackifier particles are distributed and fixed on top of pre-treated fabric, which is called ES-Fabric™ multi-functional reinforcements (Fig. 1). Composites with these fabrics exhibit significant toughness improvement as well as excellent processing handiness.

2.3 Resin Injection in Toughened RTM Composites

Toughening agent is separated from the matrix resin in Ex-Situ RTM composites. During the injection stage, injected resin keeps low viscosity, which makes the full impregnation of preform feasible.
But there are situations where long distance should be covered during injection. The solution of toughening agent in matrix resin leads to much higher viscosity, forming a barrier between adjacent plies, hinders the interlaminar resin flow.
In this case a VARI-like injection technique will be used. A specially designed resin distributor is put into mold cavity, which turns the planar resin flow into thickness penetration. Injected resin is rapidly distributed throughout the mold, establishing a nearly homogeneous press field. All the surface of the preform contact resin at the very beginning. The in-flowing resin takes the shortest path to penetrate the thickness of carbon fabric, driven by the high back pressure building up with more resin injected into mold.
The specially designed resin distributor is the key to the success of completing large integral composite structure toughened using Ex-Situ concept. It comprises of two layers. The support layer forms the backbone of the distributor as well as channels for resin flow. The surface layer helps building up a uniform high pressure, and keeps the surface of composite parts smooth (Fig.2).

3 Toughness Improvement

Ex-Situ toughened RTM composites exhibit great improvement in damage resistance and residual strength. A comparison of Compression Strength After Impact (CAI) of T300/BMI composite, original and toughened, shows that the toughened composite has higher CAI than the untoughened system at every impact energy level (Fig. 3).
At 4.45 J/mm impact energy level, the toughened composite has a 250 MPa CAI. This is an impressive performance for RTM parts.

4 Integral Structure Demonstration

Using the VARI-like injection technique, large, impact-critical, integral parts can be manufactured. As shown in Fig. 4, a monolith wing-box demonstrates the effectiveness of this processing technology. One single part manufactured in a one-stage procedure, no fasteners and assembly needed.

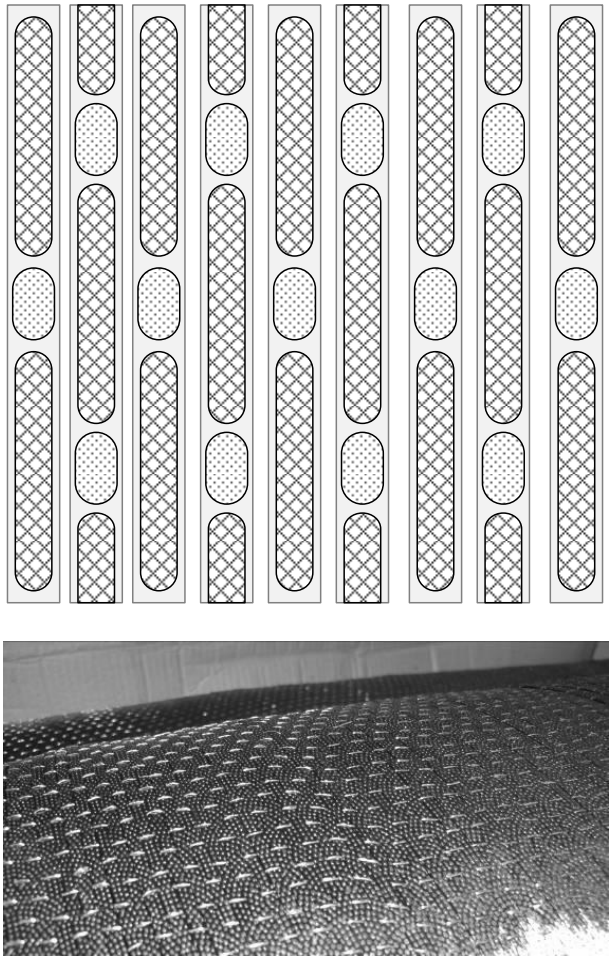

Fig.1. ES-Fabric™ multi-functional reinforcements are pretreated commercial carbon fabrics used in RTM products. Composites with these fabrics exhibit significant toughness improvement as well as excellent processing handiness..

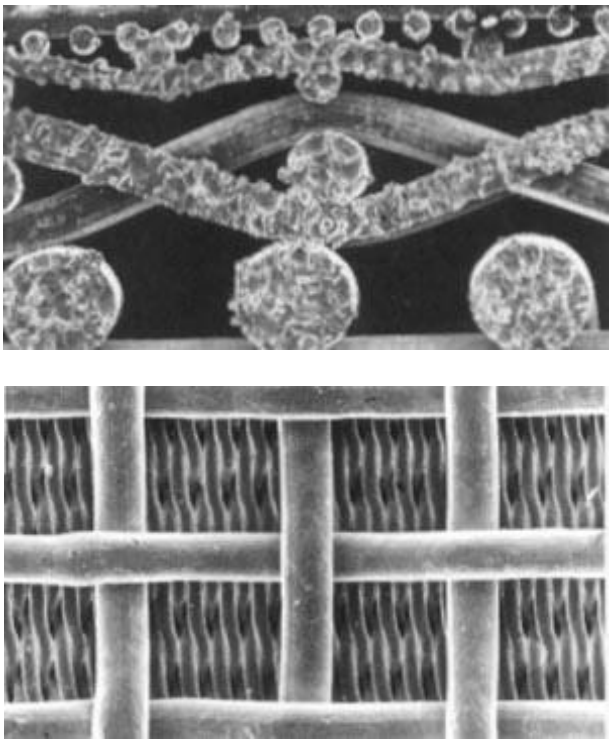

Fig.2. Details of the in-mold resin distributor used in the Ex-Situ toughened RTM composites. Thick sparse supporting layer also serves as the flowing channel of injected resin.

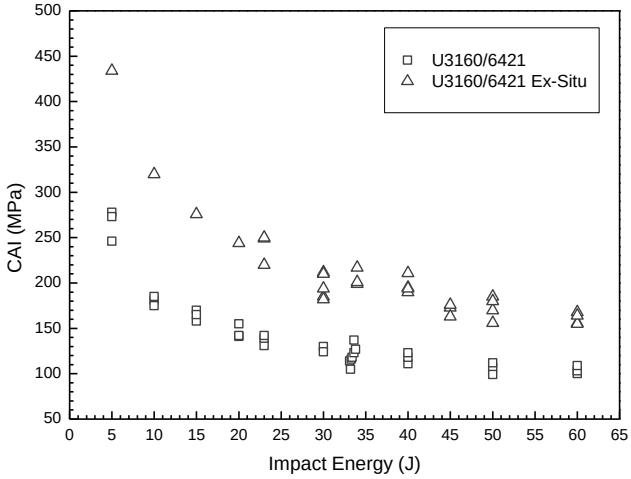

Fig.3. CAI comparison of toughened and original T700/BMI composite. The toughening shows significantly improved damage resistance. 250 MPa maintained after 4.45 J/mm impact.

Fig.4. Monolith wing-box demonstration. It is a typical toughened integral RTM structure, exhibiting excellent manufacture efficiency.

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