DEVELOPMENT OF CONTIUNUOUS CURVED COMPOSITE STRUCTURE MANUFACTURING TECHNOLOGY

Takeshi Tanamura*, Yutaka Iwahori, Yuichiro Aoki** and Keita Terashima****
***Central Research Laboratory, Shikibo ltd., Shiga, Japan**
****Japan Aerospace Exploration Agency, Tokyo, Japan**

Keywords: *Liquid Resin Molding, Curved preform,*

Abstract

The unique preform "D3D" that is low cost and high performance developed by Shikibo can be applicable to make various shapes of preform such as curved beam, tapered cylinder and hemispherical structure. In this study, a large scale cylindrical preform including curved stringers and a partial thick section along the stringer was fabricated, and the demonstrator of the composite was fabricated from this unique preform by one-shot LRM process with the improved resin. Mechanical properties of CFRP laminates by using LRM process for D3D preform were evaluated through coupon tests. From this research, low cost and high performance large cylindrical composite could be produced by using this technology.

1. Introduction

Making an aerospace structure lighter provides many economic advantages, especially in terms of structural performance and fuel efficiency. However, low-cost and high-quality manufacturing technologies must be developed to utilize composite materials in aerospace field since structures made from composite materials are far more expensive than conventional aluminum alloy structures. Therefore, recently, many researchers have studied on a low-cost manufacturing technology based on the "Liquid Resin Molding" (LRM) known as Resin Transfer Molding (RTM), Resin Film Infusion (RFI) and Vacuum-assisted Resin Transfer Molding (VaRTM).

In LRM process, the preform is made with the final shape, and resin is infused into the preform by the vacuum and/or pressure. Therefore, the LRM process offers the potential to reduce fabrication costs because it requires no expensive prepreg and autoclave equipment. The low-cost composite materials made by this LRM method have already been used for many industrial applications, windmill blades and boats for example. To use this type of materials for aerospace structures, however, it is necessary to establish a LRM technology to guarantee higher mechanical properties and more stable quality. The stability of fiber preform is one of key element to achieve a stable LRM process as well as a resin development.

Shikibo ltd. conducted a cooperative research on developing an innovative composite structure with Japan Aerospace Exploration Agency (JAXA), through "JAXA Space Open Lab." program. The goal of this research is to establish a manufacturing technology for curved composite structure using LRM process. This paper describes an overview of new technology to fabricate continuous curved composite structure and test results of the materials fabricated by the developed technology and LRM process.

2. Overview of D3D weaving technology

The unique preform "D3D" developed by Shikibo can be applicable to make various shapes of preform such as curved beam, tapered cylinder and hemispherical structure. Moreover, not only a curved shape but also the changes of the thickness and width are realized.

"D3D" technology is based on a weaving technique and enables in-plane fibers to arrange in any direction along the principal direction of structure without cutting fibers. So this technology which is the direct manufacturing method to produce the preform from fiber to the near net shape consists of only two processes of the dry fiber placement and assembly, unlike conventional process such as

"Cloth" and "NCF". Therefore, this preform is cost competitive preform.
Overview of D3D technology is shown in Fig.1.

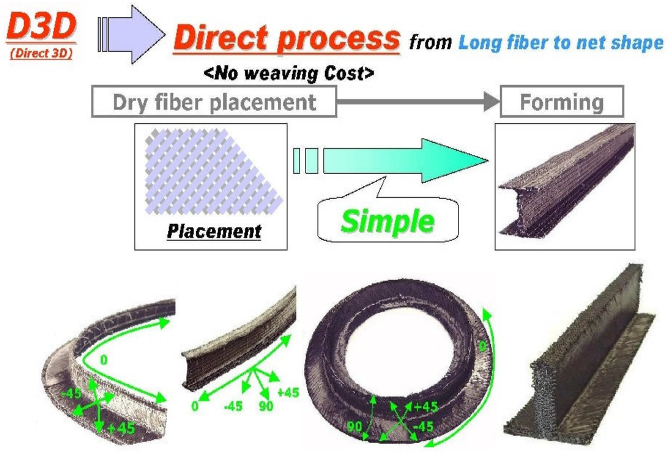

Fig. 1 Overview of D3D technology

3. Experimental approach

In this program, study has been conducted by a step-by-step approach and many tests have been done at each step to evaluate the formability and mechanical properties of the material as well as resin improvement. The material system used in this study was IM600 high strength carbon fiber and RTM purpose 180℃ cure epoxy resin.

3.1 Evaluation of mechanical properties

A number of tests were conducted to evaluate the in-plane strength as well as impact resistance of the CFRP laminates fabricated by “D3D” weaving technique. The tests include tension, compression and compression after impact (CAI) tests. Major normalized mechanical properties obtained from the tests are summarized in Fig.2 with reference information of conventional aerospace-grade prepreg lay-up CFRP laminates, IM600/133, taken from JAXA-ACDB website: http://www.jaxa-acdb.com. It was found that the strengths of first trial were not sufficient for aerospace structure especially in CAI strength. These degradations were caused by the poor mechanical properties of the resin used in the material system. Then, the resin has been improved to have a high mechanical behavior as well as low viscosity and resin flow process was carefully modified so that the resin can flow into the dry preform and fill it completely. For second trial specimen, CAI and compressive strengths were improved shown as Fig.1 and average delamination area after 6.7 J/mm drop-weight impact tests was 40% smaller than that of first trial shown as Fig. 3.

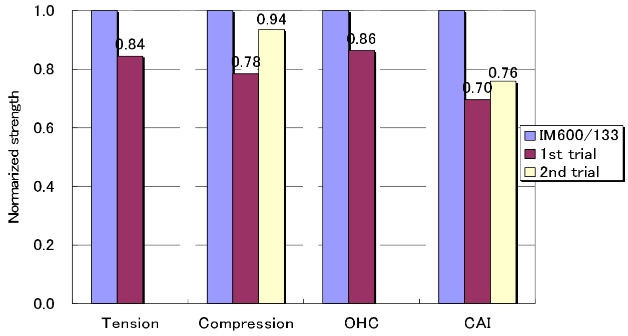

Fig.2 Comparison of mechanical properties

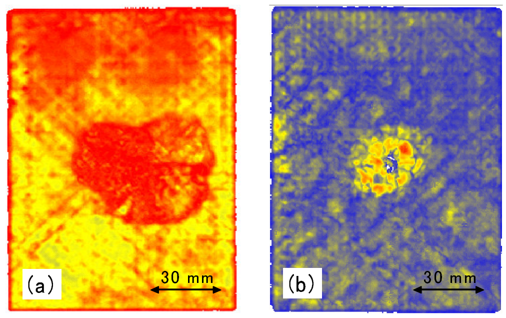

Fig.3 Ultrasonic C-scan images after impact test of 6.7 J/mm for (a) first trial specimen, (b) second trial specimen

3.2 Fabrication of demonstrators

Some demonstrators with different shapes have been fabricated to evaluate the formability of present LRM process. First trials, two small demonstrators that are used in "D3D" technology were prepared as shown in Fig. 3. These demonstrators simulate a portion of a rocket continuous curve structure and aircraft structure of curved I-stiffened panel

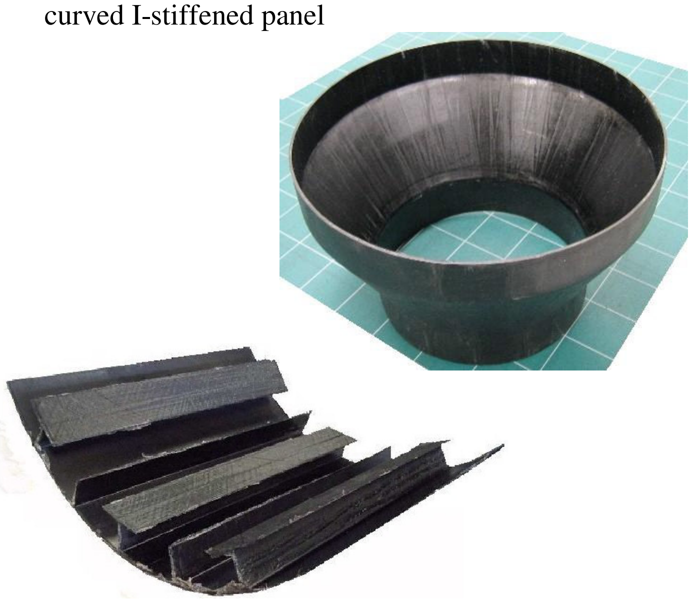

Fig. 4 First demonstrators

A large scale cylindrical demonstrator is fabricated, which includes some technical challenges, such as curved stringers and a partial thick section along the stringer shown as Fig.5. The diameter of cylinder changes continuously from 1.8m to 2m around the middle of the body. The cylindrical preform is fabricated by using D3D technology. This preform is including 24 I-beams. This demonstrator is fabricated by one-shot LRM process with the improved resin. (Fig.6)

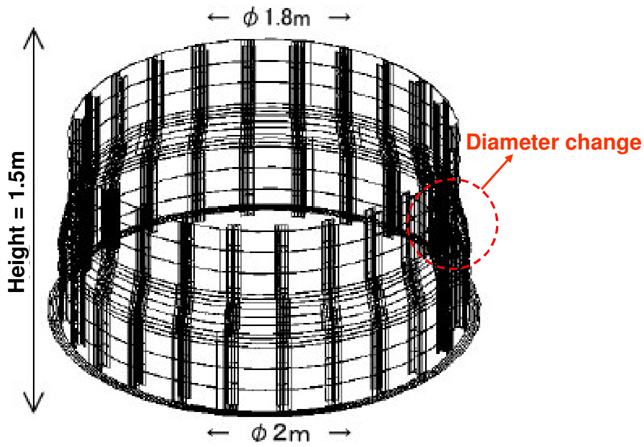

Fig.5 Overview of large scale demonstrator

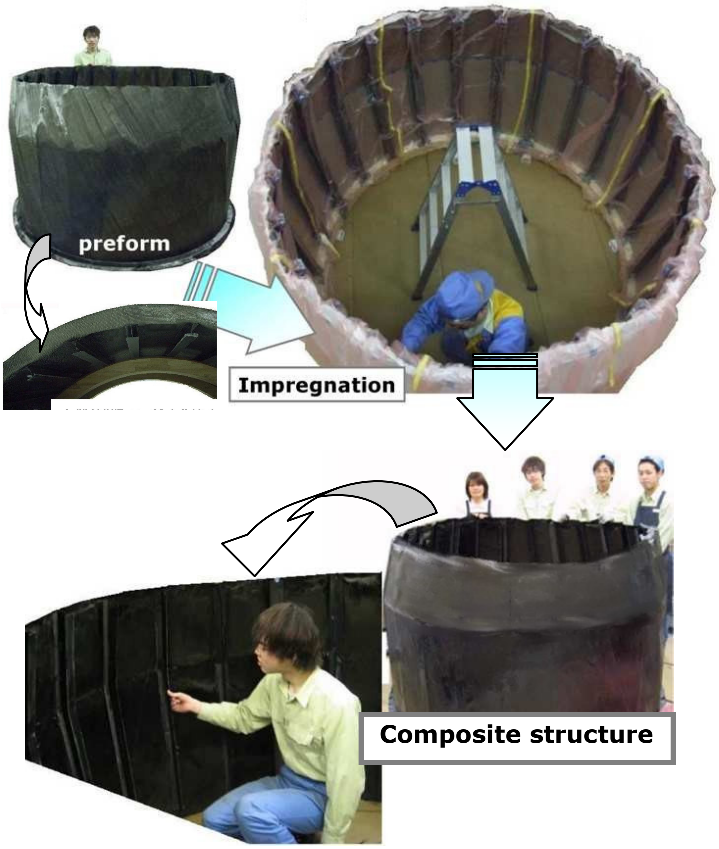

Fig.6 Large scale demonstrator

4. Summary

Mechanical properties and formability of CFRP laminates fabricated by “D3D” preform with LRM process are evaluated through coupon tests and demonstration tests. This technology can be applicable to make sophisticated shapes of dry preform structure. Moreover, the composite of large scale cylindrical structure of D3D preform can be produced by using LRM process. From this research, low cost and high performance large cylindrical composite can be produced by using this technology. The research program is on-going and ideal technology will be established for applying present technology to aerospace structure manufacturing.