EFFECT OF PROCESSING METHODS ON CONSOLIDATION OF COBONDING T-STIFFENED SKIN STRUCTURE USING AUTOCLAVE

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Abstract

The integral composite structures have been widely used in aircraft industry, especially for carbon fiber reinforced resin matrix composite parts. To ensure the performances of integral structure, the manufacturing quality must be carefully controlled, which depends on the design of processing methods and processing parameters. In this article, a typical integral structure, T-stiffened skin structure was chosen and was manufactured using carbon fiber/epoxy resin prepreg with cobonding autoclave process. The influences of debulking tool assembly, curing and cobonding sequence on the consolidation quality of T-stiffened skins were studied. Thickness, surface quality at the stiffener core and defects in the composites were analyzed to evaluate the processing quality. The experimental results show that the processing procedure with two rigid tools is easier to result in voids and fiber wrinkle at the corner section than the case with flexible and rigid tool assembly, and the degree of fiber wrinkle has relationship with the precompaction and stiffener corner filling process. Moreover, the difference in thickness of the flanges can be observed, which is resulted from the uneven pressure transfer. Surface texture at the corner section can be found and is attributed to the lay-up of the prepreg stacks. In addition, the sequence of prior curing of T-stringer or skin has little effect on the quality of T-stiffened skins. These results provide important information to optimize process method for the fabrication of stiffened skin structure.

1 General Introduction

In the recent years, advanced composites have wide application in aircraft and aerospace areas for the remarkable advantages of high strength-to-density, high stiffness-to-density and high-corrosion resistance. The integral molding technologies such as cobonding and cocuring in autoclave process gave a novel impetus to investigate and utilize the advanced composites. But it is inevitable to generate defects in the fabricated process, so optimizing and controlling the processing procedure and parameter, and further exploring the mechanism has important significance.

In the past literature, many researches investigated the forming mechanism of defects in laminates [1-2] and some simple curvature structures, for example L-shape component, were discussed by modeling and experimental measures. Naji [3] has researched the thickness and fiber volume fraction. H.Y. Deng [4] has studied the reason and correlation between defects and process procedure. X.M. Wang [5-7] has investigated the effect of tool assembly, core fillers, curvature radius and other process or structure parameter on the mechanical property and produce of defects during autoclave bleeding process. Other researchers [8-9] emphasized on the mechanical property and fracture behavior of T-stiffened skin. However, according to the integral molding technology in this study, controlling the defects by selecting the suitable process parameters and conditions was essential to ensure the quality of the part in autoclave process. So this article will discuss the influence of process factors and preliminary interpret the cause of the results.

2 Experiments

2.1 Fabrication of T-stiffened skin

The T-stiffened skin was fabricated by zero-bleeding process with carbon fiber/epoxy prepreg

supplied by Cytec Corporation. The thickness of pregpreg after cured was 0.125mm. Before curing, a precompaction process was used at the temperature of 60℃ under the pressure of 0.1MPa. The cycle of cure process can be obtained in Fig.1.

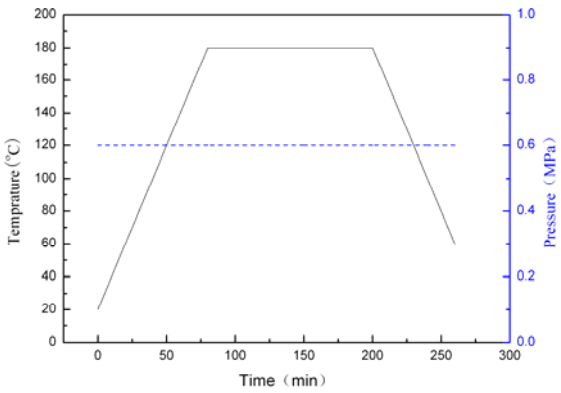


Fig.1. The curing cycle of cure stage

The T-stinger consisted of two L-shaped stiffeners([+45/-45/0/0/0/-45/0/90/+45/0]) with the same radius of 5mm, a 300mm × 60mm skin ([0/+45/90/0/-45/0/0/0/-45/+45]), and the unidirectional prepreg filled among the area of them which can be seen in Fig.2. A adhesive film existed between the T-stringer and the big skin. The schematic diagram was shown below in Fig.2.

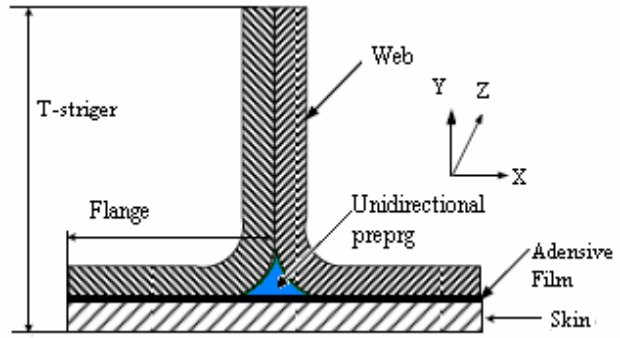


Fig.2. Schematic diagram of T-stringer

Two different tool assemblies were employed in this paper. One was two rigid aluminum convex tools and the other was a rigid aluminum tool with AIRTECH flexible rubber. Soft rubber was applied to fill the gap between the two L-shaped tool to prevent the resin flow.

In order to observe the possible discrepancy between the sequence of curing and bonding by the adhesive film, firstly we cured the T-stringer (left T-stringer in Fig.3) and then bonded with the uncured 400mm × 300mm skin ([+45/-45/0/0/90/0/-45/90/+45/0]$_s$). Secondly, a uncured T-stringer (right T-stinger in Fig.3) bonded with the previous cured skin. Finally a typical integral structure, T-stiffened skin with two stringers was manufactured which showed in Fig.3.

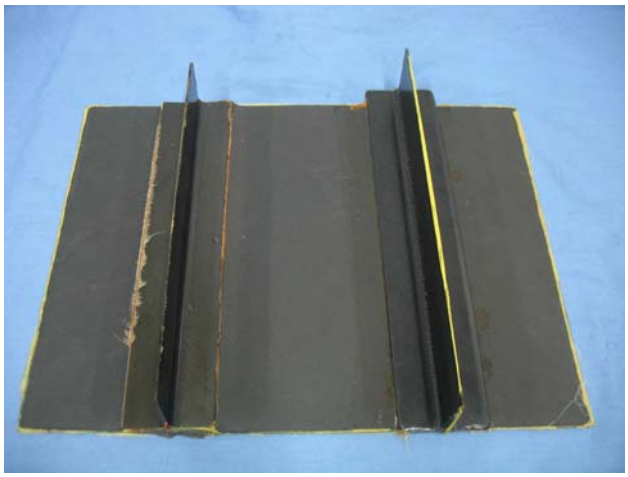


Fig.3 Picture of T-stiffened skin structure

2.2 Evaluation measures

As we all known, thickness of the cured laminates is a direct and easy method to reflect the compaction of the T-stiffened skin structure. So we measured the thickness of web and flange of T-stringer in various tool assemblies with spiral micrometer in the position of Z-direction as shown in Fig.2.

Metallographic observation was used to investigate the micro-structure of T-stiffener. Before the observation with Olympus BX51M optical microscope, the cross sections of samples were grinded by the sand papers with 800, 1000, 1200 and 1500 grit and polished with chromium oxide.

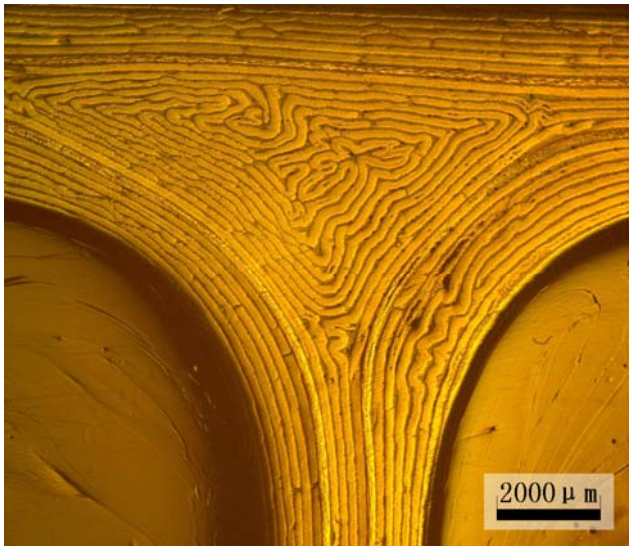
3 Result and discussion

3.1 Influence of tool assembly scheme

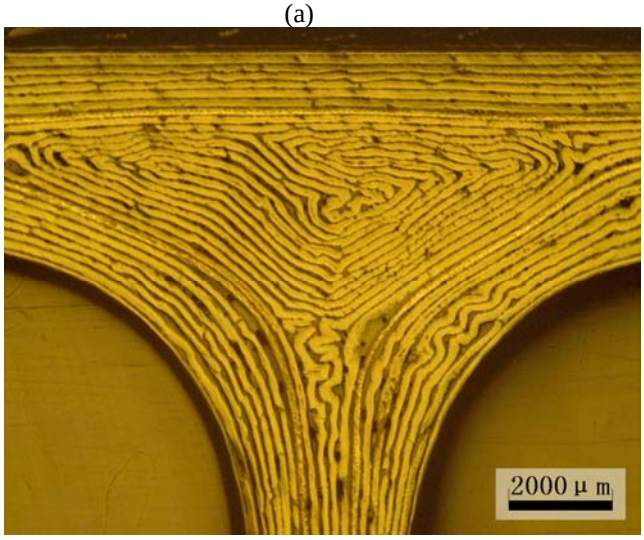
The tool is important in transferring temperature and pressure, restricting position and ensuring the dimension accuracy of composites in autoclave process. Using different tool assemblies in

integral technology usually produced distinctive quality of the composite component.

In our research, the results of the experiments with flexible/rigid tool assembly showed better corner compaction quality with less void and slight wrinkle which can be seen in Fig.4.



(a)



(b)

Fig.4 Micrograph of T-stringer in different tool assembly schemes (a)flexible(left side)/rigid (right side) tool assembly (b)rigid/rigid tool assembly

The reason was that flexible/rigid assembly scheme was easy to transfer sufficient pressure to the part as the flexible rubber tool. However, it induced the poor dimension accuracy of web and flange without enough restriction on the flexible tool side at the same time. The thickness of the flanges between the flexible and rigid tool sides can be seen in table 1.

Table 1. Thickness of flange and web with different tool assemblies (mm)

Tool assembly	Flange on rigid tool side	Flange on rigid or flexible side	web
Flexible/rigid tool assembly	4.05±0.03	4.03±0.04	3.20±0.10
Rigid/rigid tool assembly	3.88±0.05	3.14±0.04	3.52±0.05

3.2 Influence of the sequence of curing and bonding

The sequence of prior curing of T-stringer or skin had little effect on the quality of T-stiffened skins. However, it was found that the uncured skin was thinner at the position which was bonding with the cured T-stringer compared with other part of the skin. This reason was that the cured rigid T-stringer extruded the uncured skin and the resin flowed away from the juncture area.

3.3 Other phenomena of T-stiffened skin structure

Surface texture at the corner section which showed in Fig.5 can be found.

Fig.5 Surface texture of T-stringer at the corner section

It may have the relationship with the inner fiber wrinkle. So we cut the T-stringer from the position with surface texture. But from the Metallographic observation it was found that no necessary cause and

effect was indicated between the two factors. Another experiment was designed to explain the reason. The surface stack sequence of the L-shaped stiffeners was changed from 45° to 0° or 90° and fabricated with male tool to avoid effect of compaction. The result showed the surface texture only occurred on the 45° stack sequence. Therefore, combined with this result above, it may be the reason of easy slippage of the 45° fiber sequence or the plane bend of the fiber.

Fiber wrinkle was one common problem in the stringer especially in rigid/rigid tool assembly. It also can be seen in Fig.4 (b). Fiber wrinkle often occurred when the compaction pressure was not enough to compact the ply. However, it was found that the 0° plies were easier to wrinkle than other angle piles in this research. Fiber wrinkle may have relation with the sequence and angle of piles, tool assembly schemes and the property of prepreg.

In addition, precompaction also affected the quality of the T-stiffened skin in particular tool assembly scheme. The defects can be reduced in some degree for rigid/rigid by pre-compaction particularly in an appropriate high temperature such as 60^oC during laying ply in this study.

In a word, this research was discussed the some process parameters qualitatively and provided the preliminary experience on the practical production. Quantitative and further theoretical analysis need to carry out in the future.

Conclusion

In this study, a typical integral structure, T-stiffened skin structure was chosen and manufactured using carbon fiber/epoxy resin prepreg with co-bonding autoclave process. Tool assembly had a remarkable effect on the final quality of the part. Compared with the rigid/rigid tool assembly, the flexible/rigid tool assembly was helpful in pressure transfer, especially in corner section. In addition, fiber wrinkle, void and deformation of the stringer were the familiar defects in fabrication. Pre-compaction and in a suitable temperature can prevent the presence of these defects to some degree. The experiment result indicated that the sequence of prior curing of T-stringer or skin had little effect on the quality of the integral T-stiffened skins except that the skin became thinner when the uncured skin cured together with the cured T-stringer.

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