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ABSTRACT

One of the important features of smart composite structures is their capability to observe their own performance for proper functioning and self-diagnostic purposes. The low velocity impact damage of composite structures (matrix cracking, fiber breakage, delamination, etc.) is often difficult to detect visually and can significantly reduce the strength of the structure. The objective of this research is to develop a technique for fabricating composite laminates that will facilitate the embedment of optical fibers. Composite test specimens will be fabricated in the composite material laboratory. The fabrication of composite laminates with a health monitoring and damage assessment system capable of providing real time data using embedded optical fibers will be investigated. The existing impact test facility will be extensively modified in order to extract the real time data.

INTRODUCTION

The primary purpose of this research is to develop a consistent and fail-safe method of producing composite laminates that will facilitate the embedment of optical fibers. In the pursuit of this goal, we needed first to acquire knowledge on the use of the new Dake 75 ton hydraulic laboratory press available in the composite material laboratory. We familiarized ourself with the use of the Dake press by fabricating a composite laminate using the conventional method. The construction of this composite laminate gave us insight on both the use of the press as well as the limitations of the conventional fabrication method. After analyzing the limitations of this method, it was apparent that this method needed much refinement if we were going to be successful in embedding optical fibers in to composite laminates. Therefore, a mold was designed that would eliminate the problems that arose using the conventional method. The effectiveness of this mold was verified by using it to fabricate additional composite laminates. After this method of fabricating composite laminates was established, a low velocity impact test apparatus was developed for future testing of the composite laminates.

SET-UP AND USE OF NEW DAKE PRESS

In order to fabricate the composite laminates it was necessary to learn how to operate the new Dake 75 ton hydraulic press (model # 44-806). The Dake press differs from the old press in that it is equipped with a 180 series single relay output controller. The single relay output controller will regulate the temperature input of both the upper and lower platens of the press. The desired final temperature of the upper and lower platens is input into the controller as the set point. The major advantage of this controller is that the temperature of the platens can be read easily from the LED display.

To make a composite laminate, both pressure and elevated temperature need to be applied to the composite. For a particular pre-impregnated material, a specific pressure and temperature is required, which is specified by the manufacturer. From the data supplied by the manufacturer and using the area of the composite, we calculated the force needed to produce the desired pressure. This force is applied by first closing the release valve, which is located of the left side of the press base, then the platens are brought into contact by pushing the pump handle until the calculated force is reached. This force, in tons, can be read off the gauge located in the upper right hand corner of the press

After the set point for the temperature is reached, the platens can be cooled by use of the water channel system that is embedded within the platens of the press. The cooling water can be injected into the platens by opening the water control valve. This valve is opened gradually to prevent too rapid a change in temperature.

FABRICATION OF COMPOSITE USING THE CONVENTIONAL METHOD

The first plate that we manufactured was to familiarize ourselves with the new Dake press and the limitations of the conventional method of manufacturing composite laminates. The conventional method consists of using two flat aluminum plates between which the composite material is placed. The material that was available for this project was a glass epoxy pre-impregnated tape. To aid in the construction of these composite plates, the manufacturer of this particular material supplied us with a heating-cooling curve which was followed to obtain desirable results.

Constructing Composite - Plate #1

The first step in the construction of our first composite plate was to sandblast the aluminum plates. This sandblasting procedure removed any excess debris on the plate. Next, the aluminum plates and the work area were cleaned with acetone to eliminate any contaminates. The cleaned aluminum plates were then treated with Frekote 44. The purpose of this treatment process is to prevent the composite from sticking to the aluminum plates. Next, two sheets of release fabric were cut for placement between the composite and the aluminum plates. The function of the release fabric was to allow air and moisture to flow from the composite during the heating and cooling process. The glass epoxy pre-impregnated tape was then cut according to a previously specified size and orientation. Our first plate was a 12" X 12", 4-ply, symmetric cross-ply laminate. The next step is to place the layered laminate on top of the release fabric which lays on the aluminum plate. Then the high temperature sealant, "tacky tape", is placed approximately 1/8" away from the laminate to allow for the expansion of the sealant during compression. The sample was then placed into the Dake press and the heating-cooling curve that was supplied by the manufacturer was followed.

Analysis on Conventional Method

Plate number one had some difficulties with the matrix flowing past the "tacky tape" at the edges of the plate. This makes it difficult to obtain a perfectly square and consistent plate. This problem is encountered more drastically in the thicker plates that have been made in the past. This problem seems to be the major downfall of the conventional method.

Other complications encountered with this first sample were the Frekote 44 being fairly ineffective in keeping the composite from sticking to the aluminum plates and controlling the heating-cooling curve within its specifications. As a result of the Frekote 44 being ineffective, plate number 1 has delamination due to prying the aluminum plates apart to remove the composite. The heating-cooling curve was difficult to maintain within the desired specifications because of the difficulty in operation of the controller on the Dake press. To achieve a more precise approximation of the curve, we found it necessary to periodically turn the controller on and off until we reached the desired temperature slope.

DEVELOPMENT OF NEW FABRICATION PROCEDURE

Due to the difficulties encountered in the conventional method for making composite plates, it became apparent that a new and improved method for making these composite plates was required. The main objective of the new design was to ensure that the plate kept a consistent shape and thickness, therefore eliminating matrix flow past the "tacky tape". These requirements of the new mode are essential in making a quality composite laminate with health monitoring and damage assessment systems capable of providing real time data using embedded optical fibers. Our new mold design proved sufficient for solving these major problems.

Design and Manufacture of Mold

The design of the new mold can be seen in figures 1 and 2. Figure 1 shows the top plate design and figure 2 shows the bottom plate design. This design was sent to the machine shop to be made from aluminum plates. The mold was designed to facilitate a 12" square composite with a thickness up to 0.25". The ridge of the top plate is intended to keep the dimensions of the composite laminate at 12" X 12". The grove in the bottom plate is used for the placement of the "tacky tape" and to allow the ridge on the top plate to fit securely inside. As the mold is pushed

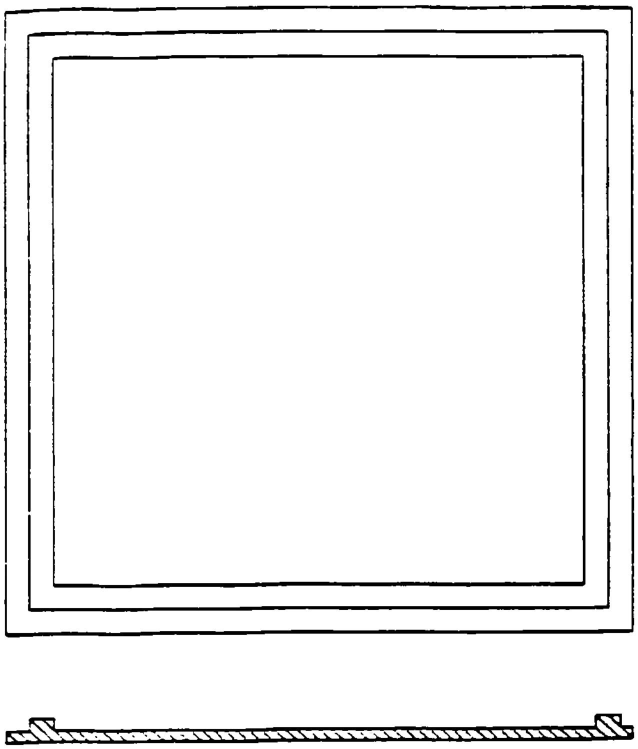

Figure 1: Top plate of mold used for improved fabrication method

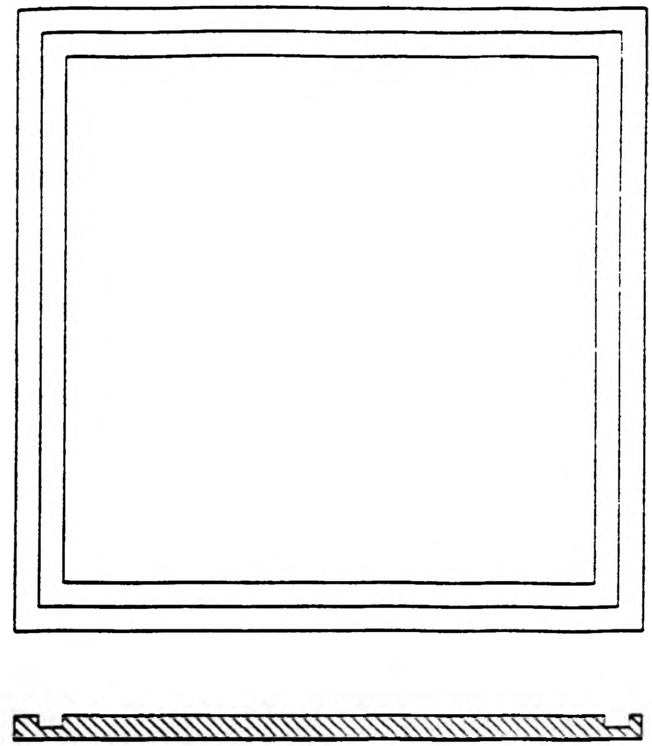

Figure 2: Bottom plate of mold used for improved fabrication method

together by the force of the hydraulic press the "tacky tape" will seep to fill any voids in the ridge-groove junction. As a result of the induced cavity, the plate is confined to maintain its desired shape.

To prove the effectiveness of this design, four additional composite laminates were fabricated. Each of these four plates were made using different techniques to find the optimum method of fabricating a consistent composite laminate. Three of these plates were 4-ply symmetric cross-ply laminates. These plates proved that the new mold was superior to the conventional method. The mold produced composite plates that held a consistent 12" X 12" dimension. The process used to manufacture these three plates was refined until we were able to find a process that would produce a quality plate. After we proved that the mold and process was capable of making a composite plate that had a consistent shape and thickness we made a ten ply composite laminate. The orientation of this 10-ply symmetric cross-ply laminate was $[0/90/0/90/0]_S$. This plate, being two and a half times thicker then the previous plates, was the ultimate test of the effectiveness of the mold and the process for fabricating composite laminates. The results of this plate indicated that the mold and process was capable of making a composite laminate that has a consistent shape and thickness. This technique will also facilitate the embedment of optical fibers into composite laminates.

This research has led up to the design and development of a prototype health monitoring and damage assessment system capable of providing real time data using embedded optical fibers in composite laminates. Composite test specimens with embedded optical fibers can be fabricated in the composite material laboratory using the newly designed mold and fabrication process. The configuration for the embedment of optical fibers within a 4 - ply Kevlar/epoxy panel is shown if Figure 3.

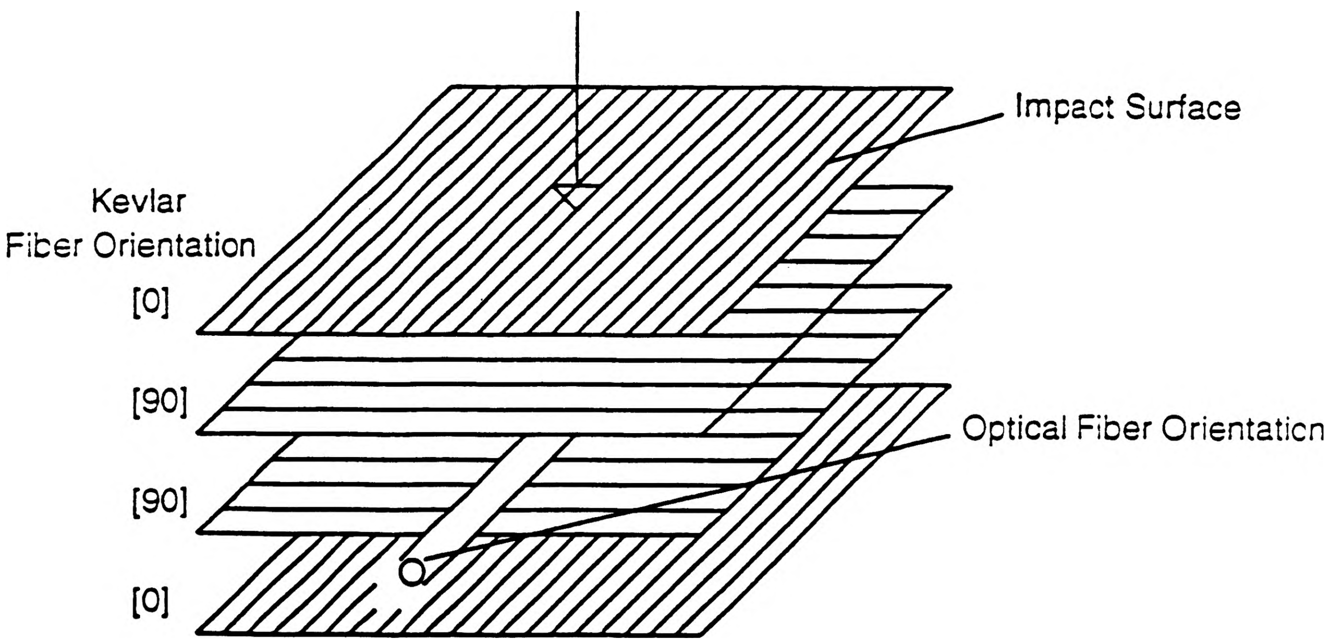

Figure 3: Configuration for the embedded optical fibers within a 4 - ply Kevlar/epoxy panel

DESIGN AND MANUFACTURE OF DROP WEIGHT TESTER

After developing and verifying a consistent method for making composites, we expanded our project to include setting up a low velocity impact test that will facilitate testing of the composite laminates that will be made with embedded optical fibers. Certain parameters had to be included into the design of this tester. First, height adjustability was needed to obtain the desired impact velocities. The inside dimension had to be 13" square so we could utilize the existing clamps to hold the sample to be tested. The tester is also able to be bolted to the floor for stability purposes. Also, the clamp on the bottom shelf had to be adjustable so that the drop weight would fall on the center of the sample. Finally, the top plate needed to have a hole in the center just large enough for the drop weight to fit through. A mechanical magnet was used for the release mechanism of the drop weight to eliminate any possible human error.

CONCLUSIONS

Overall, the major objectives of this project have been successfully accomplished. We have learned how to operate the Dake 75 ton hydraulic press and have been able to use it to make composites. We successfully designed, manufactured and verified our mold to produce higher quality composites. This new mold can also be used to fabricate composite laminates with embedded optical fibers. This research has led up to the design and development of a prototype health monitoring and damage assessment system capable of providing real time data using embedded optical fibers in composite laminates. We also designed and manufactured a drop weight tester that can be used for low velocity impact of the composite laminates.

ACKNOWLEDGMENTS

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