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Study of Failure Mechanisms in GFRP Laminates during Drilling by AE Technique

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ABSTRACT

The project centers on the development of acoustic emission techniques to Investigation the failure mechanism of Glass fiber Reinforcement Polyester (GFRP) laminates during drilling. Minor defects which may grow during loading may be undetected during their normal NDT. Fiber reinforced plastics have been widely used in manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high strength to weight ratio and also stiffness. Drilling of these composite materials can be considered as a critical operation owing to their tendency to delaminate when subjected to mechanical stresses. To study the failure mechanism of GFRP laminates during drilling by Acoustic Emission Technique with different feed rate with the same orientation of fiber mats. This necessitates an online technique, which can be used to monitor and measure the denomination as it occurs. Acoustic emission (AE), an online monitoring tool, is ideally suited for this purpose. This work discusses the experimental investigations carried out on Glass Fiber reinforced plastic (GFRP) composite specimens in which the acquired AE data is analyzed.

KEY WORDS: Composites, Drilling, Acoustic Emission (AE).

1. INTRODUCTION

Composite Material: It is becoming more common to find composites incorporated into structural components, especially in the aviation industry. The great advantage of these kinds of materials is their strength to weight and stiffness to weight ratios. Weight savings on the order of 25% are generally considered to be achievable using current composites as compared to metals. The weight saving in turn contributes to the greater payload capability. With an increased use of composite materials, continuing research in the assessment and quality control of components made from these materials is a necessity. Since the fibers are designed to be the primary load bearing members, when the fibers begin to break, the structural integrity begins to suffer. Therefore, it is advantageous to develop a method of proof testing the composite hardware, at the same time minimizing the unintentional degradation. Composite structure's integrity is sensible to service life. To insure their integrity NDE evaluations is required. One of the main obstacles to the further development and diffusion of composite material applications is the lack or scarcity of NDE methods being inexpensive, reliable, non-intrusive and relatively easy to apply. Acoustic emission (AE) has been proven as one of the appropriate nondestructive techniques for quality control and periodic in-service inspection of the fiber reinforced plastic (FRP) structural components. This is because AE is reliable, cost effective, and capable to detect various defect sources in FRP.

Acoustic Emission (Ae) Technique: Acoustic techniques are employed in decades for the detection of failures in the composite laminates. The AE measurement technique is based on the generation of acoustic (elastic stress or pressure) waves by fast propagating micro-failure processes or other sources. Highly sensitive piezoelectric transducers passively detect these waves by dynamic surface motion on Nanometer scale and convert it into an electric signal. The practically used frequency range is about 50 kHz… 1 MHz. Lower frequencies are often associated with extraneous noise sources or resonance effects of the transducer case. Higher frequencies are excessively attenuated by polymer matrix materials and, hence, these frequency parts of waves are carried to a distance no longer than a few centimeters from the source location.AE testing is a real time measuring and on-line evaluation technique. It basically shall give information as to when (time, external loading parameter), how many (rate), how intense (amplitude, energy) and where (location of AE sources) stress wave emitting damage processes in specimens or structures occur.

Drilling Machine - Auto Feed rate: A portable drilling machine, whose feed rate is automated with the help of microprocessor, gear unit and stepper motor. In the drilling machine, hand wheel is removed and gear box is attached to machine shaft and the other end of the gearbox is coupled to the stepper motor. The gear box ratio is 1: 100. The stepper motor input is taken from the microprocessor control unit. The control unit consists of Step down transformer, Bridge rectifier, Pi filters, Microprocessor and Digital display.

2. MANUFACTURING TECHNIQUE

Sizing and weighing of fiber mats: The Unidirectional fiber mat roll was spread over the table and cut into 8 pieces of size 360 x 360 mm to form a composite plate (Zero orientation). The above sets of pieces are weighed by means of electronic weighing machine. The weight of fiber mats (Mf) is noted.

Fig.1. Fiber Mat Pieces

Preparation of Resin: The resin should be prepared carefully as its composition plays a significant part in the properties of the pipe. Before using that, gel time has to be estimated first. Gel time is the time taken for a reason to come to gel state once the hardener is added from its initial (liquid) start. The gel time of the resin can be controlled by varying the hardener content. The entire process of winding should be complete before the gel time of the resin. Thus, if the gel time of a resin is too short it is inconvenient. The gel time of the resin should be optimized for the process should be completed within that. The reason that is being used in this case is epoxy resin with a certain amount of hardener. The hardener is mixed with the resin so that the resin is allowed to solidify. 10% the weight of the resin of Diamino Diphenyl Methane is used as hardener here. The gel time of this mixture is found out to be 15–20 minutes.

Specification of Laminate: Length: 150 x 150 mm and Thickness: ~6.5 mm

Fig.2. GFRP Laminate [0] Orientation – unidirectional ply

AEWin Setup: Once the sensor is fixed on to the specimen, the location of the sensor has to be entered in the AEWin setup in the location view menu. Before starting the test, check whether Line display is enabled. All the parametric graphs should be enabled. Once the drilling test is initiated in the machine, Acquire option is selected to start acquiring the AE signals.

Fig.3. Drilling of GFRP

Actual Test: The input value of feed rate is entered in the Digital display. Eg.99 [feed rate is 0.333 mm/Sec (20 mm/min.)]. After receiving the signal from the microprocessor, the stepper motor starts. Based on the input value feed rate differs. Drilling has been done for three different orientations of composite laminates namely unidirectional ply [0] for different feed rates and its respective AE data are acquired by AEW in software. These various AE parameters are analyzed for the failure mechanism of drilling on the composite laminates.

Parametric Plots of AE Data: Acoustic emission (AE) technique was utilized in tracking the damage accumulation profile during drilling. Various AE data obtained during drilling in GFRP Laminates for Different feed rate with same laminates orientation. Time Vs Cumulative Signal, Time Vs Cumulative Counts, Time Vs Cumulative Energy, Location Vs Events.

3. RESULTS

Unidirectional laminates drilled with different feed rate:

Amplitude vs hit: The figure 4 shows the plot of Amplitude Vs Hit of Unidirectional ply [0] oriented laminates with different feed rates, such as 7.5mm/min., 10mm/min, and 20mm/min. During drilling with AE monitoring.

From these plots it is observed that the Number of Hits for an amplitude range of 46-55 are more due to matrix cracking. It is also observed that the Number of Hits is more for low feed rate and less for high feed rate and also there is a gradual increase and decrease in the trend of Number of Hits with respect to Amplitude range. But for laminate with Teflon insert, there is a sudden increase in number of Hits after the gradual decrement. This is often because of pre induced delamination.

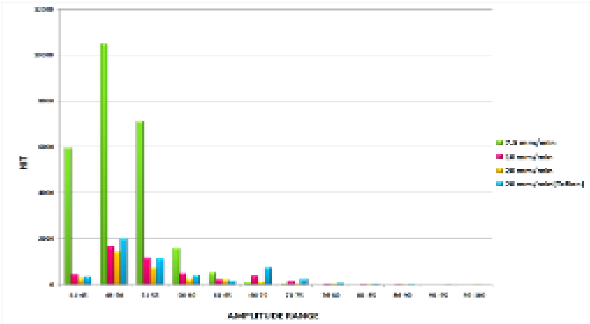

Fig.4. Amplitude vs No. of Hits

Time vs cumulative count: The figure 5 shows the plot of Cumulative count Vs Time for Unidirectional ply [0] laminates drilling with different feed rates, such as 7.5mm/min., 10mm/min. and 20mm/min. with AE monitoring. From the plot, it is observed that for a feed rate of 10 mm/min, (0.166mm/sec) the plot of Cumulative count Vs Time is linear up to 63 seconds which indicates a slight matrix cracking failure mode. The matrix cracking is associated with lower cumulative counts. Beyond 63 seconds the AE activities are higher with a remarkable increase in cumulative counts. The knee represents initiation of delamination. Similarly for 20mm/min. (0.33mm/sec) the AE activities are quite less up to 35 seconds and beyond 35 seconds the AE activities are higher with a remarkable increase in cumulative counts. But the laminate with Teflon insert as there is a pre-induced delamination, the cumulative counts and acoustic emissions are very high even from the start of drilling. For the feed rate of 7.5mm/min. (0.125mm/sec.), the AE signals are comparatively very less than other two feed rates.

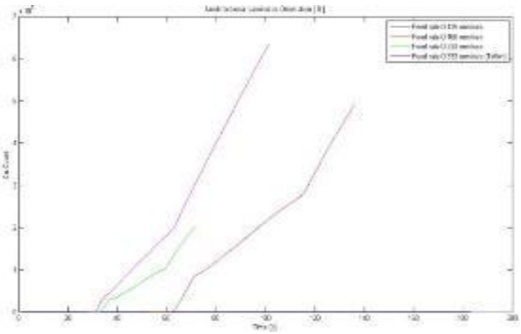

Fig.5. Time vs Cumulative count

Time Vs Cumulative Energy: The figure 6shows the plot of Cumulative energy Vs Time for Uni-directional ply [0] laminates with drilling at the feed rates such as 7.5mm/min., 10mm/min. and 20mm/min. with AE monitoring. From the plot, it is observed that for a feed rate of 10 mm/min, (0.166mm/sec) the plot of Cumulative energy Vs Time is linear up to 63 seconds which indicates a slight matrix cracking failure mode. The matrix cracking is associated with lower cumulative energy. Beyond 63 seconds the AE activities are higher with a remarkable increase in cumulative energy. The smooth curve represents initiation of delamination. Similarly for 20mm/min. (0.333mm/sec) the AE activities are quite less up to 35 seconds and beyond 35 seconds the AE activities are higher with a remarkable increase in cumulative energy.

But the laminate with Teflon insert as there is a pre-induced delamination, the acoustic emissions are very high even from the start of drilling and cumulative energy are also very high. For the feed rate of 7.5mm/min. (0.125mm/sec.), the AE signals are comparatively very less than other two feed rates.

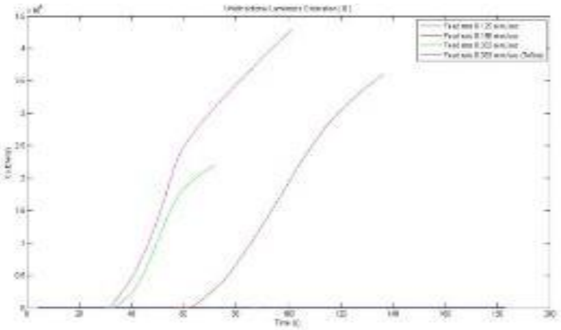

Fig.6. Time vs Cumulative Energy

Location Vs Events: The figure 7 shows the plot of Locations Vs Number of Events recorded during the drilling of a Uni-directional ply [0] orientation GFRP laminates with AE monitoring. Three wide band sensors were used for drill monitoring. The drill was carried out in three [0] laminates with different feed rate such as 7.5mm/min., 10mm/min. and 20mm/min. From the plots it is observed that the numbers of events are found to be 203 for 7.5 mm/min.,166 for 10mm/min and 53 for 20mm/min. Hence it is observed that as the feed rate increases the number of events decreases. But for laminate with Teflon insert as there is a pre induced delamination, the numbers events are comparatively more in the Teflon laminates than the normal laminates for the constant feed rate.

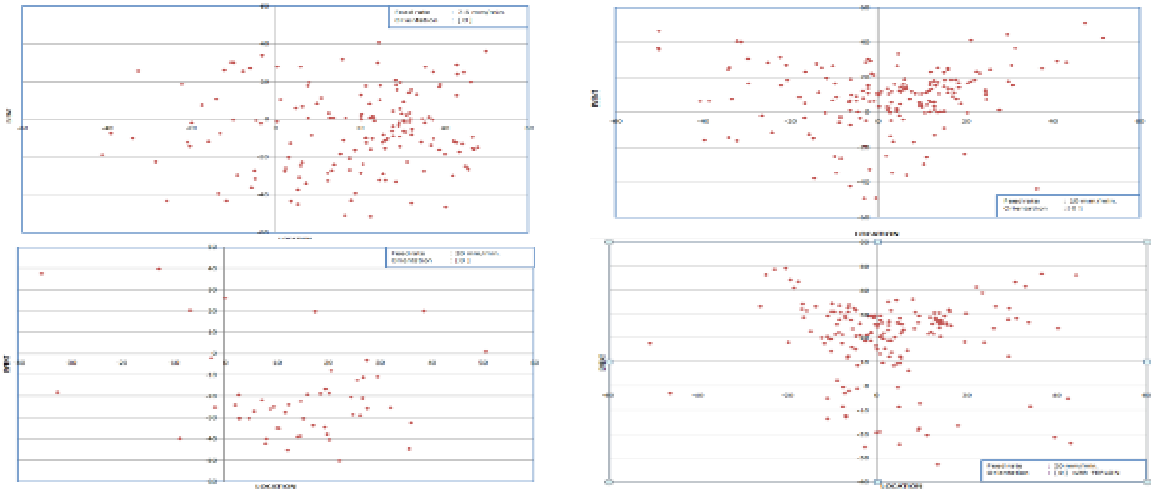

Fig.7. location vs events

4. CONCLUSION

The manufacturing of GFRP is mainly for an application of in automotive industry. So in this field the drilling used for secondary machining process for assembly purpose. While drilling GFRP delamination was the major defects. The delamination of the GFRP is unavoidable but we can control it by following ways by Suitable Feed Rate, insert the Teflon and reduce the speed.

REFERENCES

Bar H.N, Bhat M.R, Murthy C.R.L, Identification of failure modes in GFRP using PVDF sensors: ANN approach, Composite structure, 65, 2003, 23 – 67.

Giordano M, Calabro A, Esposito C, D'Amore A, Nicolais L, An Acoustic Emission characterization of the failure modes in polymer composites materials, Composites Science and Technology, 58, 1998, 1923-1928.

Hoskin B, and Baker A, Composite materials for Aircraft structures, American institute of Aeronautics and Astronautics Inc., 1986.

Ramirez-Jimenez C.R, Papadakis N, Reynolds N, Gan T.H, Purnell P, Pharaoh M, Identification of failure modes in glass/polypropylene composites by means of the primary frequency content of the acoustic emission event, Composites Science and Technology, 64, 2004, 1819–1827.

Sivanandam S.N, Sumathi S, Introduction to neural networks using MATLAB 6.0, The Mc Graw-Hill Publishing Company ltd., New Delhi, 2007.

Thomas M. Ely, and Hill E.V.K, Longitudinal splitting and fiber breakage characterization in graphite epoxy using acoustic emission data, Material Evaluation, 1995, 288-294.