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Experimental Study of Delamination in GFRP during Drilling using Single AE Sensor

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ABSTRACT

A Non-destructing testing (NDT) and an unconventional method that is being used for identifying the location and detection and determining the various characteristics of defects in products is Acoustic Emission Technology (AET), which can be applied for understanding the various events associated with drilling process, that occurs from the time when the drill bit comes into contact up to the completion of the drilling process. This paper focusses in finding the maximum thickness to detect drilling related delamination using single AE sensor. Delamination has been artificially induced by placing non-adhesive Teflon tape between the layers at the exit. Various AE parameters are analyzed to find its relation with the thickness of the composite material. Peak amplitude and slope of the cumulative RMS curve decreases with the increase in thickness of composite. Hence, the range of the thickness has been found out beyond which a single AE sensor cannot be used effectively to analyze different events that occur during drilling.

Keywords - GFRP, AET, Sensor, Thickness, Delamination

1. INTRODUCTION

Composite materials are most widely used in aerospace, marine and automobile industries due to their omni potential properties such as high strength to weight ratio and a high specific stiffness. For application in structural field, composite materials have the advantage of tailoring and achieving the desired size, properties and shape as per the requirement. Although we can tailor and mould composite material to the required pattern, to achieve surface quality and accuracy in dimensions, final finish machining of these materials becomes a mandatory operation in all the situations. In this regard, persistent efforts were made to apply the theories available and metal cutting practices for understanding the machining process of composite materials. With these despite efforts, results show that the success is only, because the existing knowledge of metallic materials is not directly translatable to understand and explain what actually happens during machining. While machining the two phases of composite, the fiber and the matrix, which are coexistence will behave in a different manner than when they are separate. The orientation problem that arises in fiber reinforcement should be addressed, in addition to their properties being much different from metal counterparts. Because of their anisotropic and non-homogenous nature, they pose peculiar problems that impede performance of sound analysis on them.

On composite laminates, amongst all machining operations performed, the widely used simplest operation is drilling, which is used for producing small rivet and bolt holes, using twist drills. However, drilling introduces some amount of damages on the hole peripheries in the form of delamination, which are a great threat to the structural rigidity and are amenable to grow under the service conditions. Therefore, in order to suit structural design requirements this delamination has to be detected, quantified and correlated to process variables so that they are optimized to achieve desired quality.

Under stress, a powerful technique for examining the material deformation behavior is Acoustic Emission (AE) method. In AE method, a transient elastic wave will be generated by the rapid release of energy within a material. Materials tends to "talk" when they are in trouble: with Acoustic Emission equipment you can "listen" to the sounds that arises of cracks growing, breaking of fibers and many other modes of active damage in the stressed material. AE signal generated during drilling composite laminates carries valuable information on the state of material being cut. It provides real time information on damage progression. Hocheng and Dharan (1988) suggested a quantitative model based on a delamination fracture mechanics and introduced two distinguishable mechanisms that are responsible for delamination in push-out at exit and peel-up at entrance [1]. Lin, H.J., and Tsai, C.C. (1995) employed failure analysis of bolted connections of composites with drilled holes and the numerical and experimental results were compared and discussed [3]. Ravishankar and Murthy (2000) applied acoustic emission technique for monitoring the drilling of composite material and characterized the drilling operation of composite laminates [6]. A Uni-directional plastic laminates reinforced with glass were drilled with a twist drill and the AE sound waves generated were monitored. The investigation results reveals that, the complexion of the acoustic emission root mean square (AE-RMS) signal response changes from drill entry to exit thus giving an overall understanding about different events that takes place during drilling. The present work attempts to determine the maximum thickness of the composite material to detect delamination during drilling using single AE sensor.

2. EXPERIMENTAL WORK

Bidirectional GFRP Composite plates of thickness varying from 4mm to 18 mm were prepared from the base materials of Resin (Dobeckot 520F) and Hardener (LY758), in a 30 tonnage capacity compression moulding machine. In the bottom fiber layer, Teflon tapes were introduced for inducing delamination artificially at the exit during drilling. In the radial drilling machine, experiments were performed. A miniature type sensor (S9220) with operating frequency in the range of 100 – 1000 KHz is utilized for capturing the AE signals generated from the plates during drilling. A preamplifier having 40/60 dB gain is selected with a filter system in the range of 50 – 200 KHz. Drilling was done on all the plates. Trial runs were conducted and the experiment was done based on the results obtained from the trial runs. The Schematic diagram and the photograph of the experimental setup are shown in the figures 1 and 2.

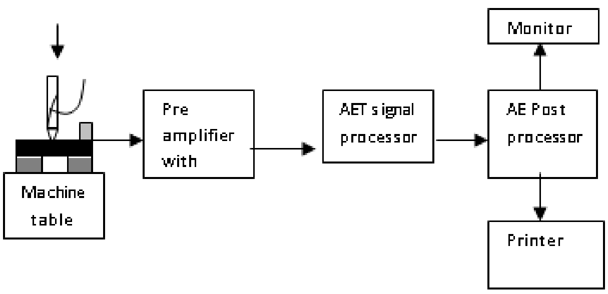

Figure 1: Schematic diagram of experimental setup

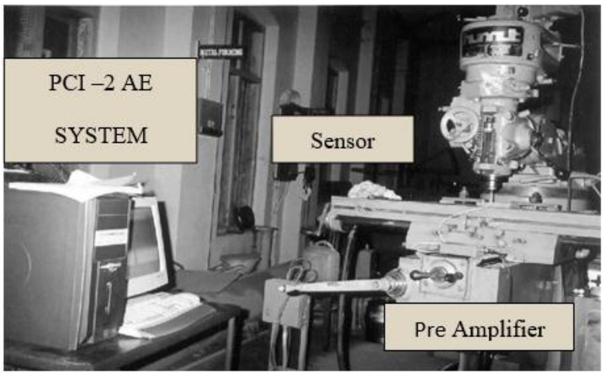

Figure 2: Photograph of experimental setup

Delamination Factor (J.Paulo Davim And Pedro Reis, 2003) Is Found With The Help Of Machine Vision System For The Drilled Holes. Figure 3 Shows The Drilled GFRP Plate with Teflon Tape.

Figure 3: Drilled 8 mm GFRP plate

3. RESULTS AND DISCUSSIONS

Initially drilling was done on the plates of wider thickness such as 4mm, 8mm, 13mm and 18mm. The time vs. Cumulative AE RMS graphs for 4mm, 8mm, 13mm and 18mm plates are shown in the figures 4, 5, 6 and 7 respectively.

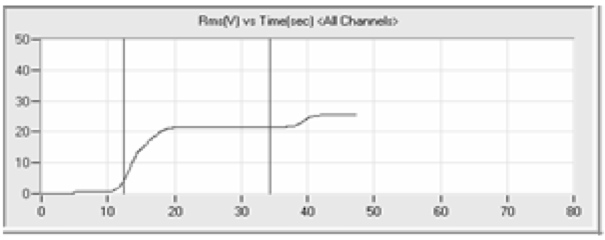

Figure 4: Cumulative AE RMS Vs Time for 4 mm plate

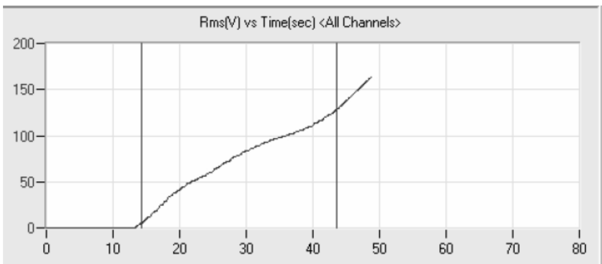

Figure 5: Cumulative AE RMS Vs Time for 8 mm plate

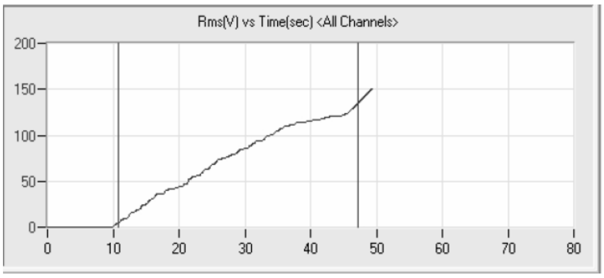

Figure 6: Cumulative AE RMS Vs Time for 13 mm plate

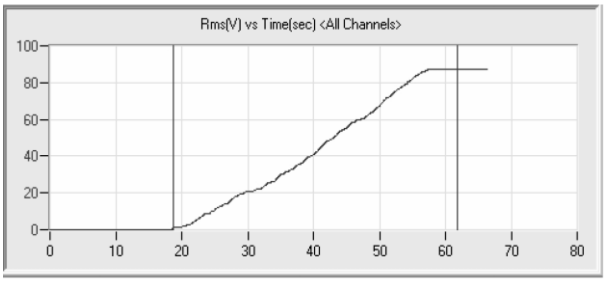

Figure 7: Cumulative AE RMS Vs Time for 18 mm plate

Figures 4, 5 and 6 which corresponds to the plates of thickness 4mm, 8mm and 13mm shows a drastic change in the increase in slope at the exit which indicates that the delamination or the push out at exit occurs. Whereas figure 7 that corresponds to the 18mm plate has a negligible change in slope at the exit, which indicates that the AE signal is attenuated, and the AE sensor is unable to capture the events that occurs at the exit.

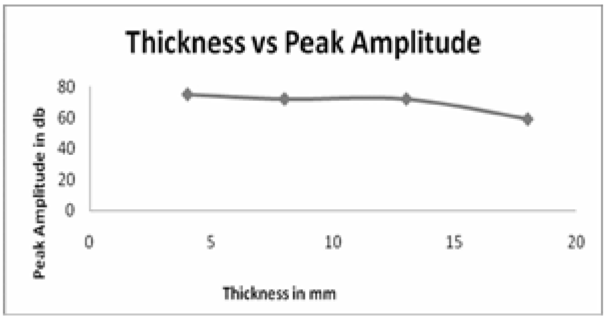

Figure 8: Thickness (mm) Vs Peak Amplitude at the exit (db)

Table 1 indicates the peak amplitude and the delamination factor for the holes drilled in 4mm, 8, 13mm and 18mm plates. It is observed that the peak amplitude decreases with increase in thickness of the GFRP plates as shown in the figure 8.

Figure 9 clearly shows that the slope at the exit is decreasing gradually with increase in thickness upto 13mm and it decreases largely for the 18mm plate as if no delamination occurred. However, in table 2, it indicates that the delamination factor for the 18mm plate is 1.224, which indicates that the delamination occurred at the exit. Thus, it is inferred that the AE sensor has not captured the events at the exit for the 18mm plate.

Table 1: Values of peak amplitude at the exit and delamination factor

S.No	Thickness in mm	Peak Amplitude in db	Delamination factor
1	4	75	1.425
2	8	72	1.268
3	13	72	1.196
4	18	59	1.224

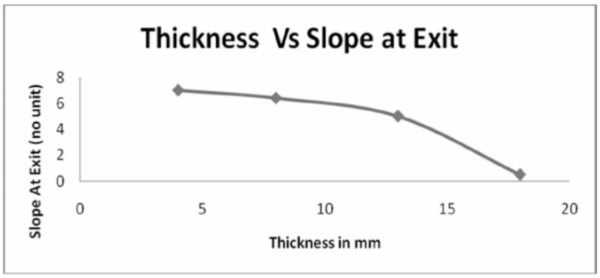

Figure 9: Thickness Vs Slope at Exit

Table 2: Values of slope at the exit and delamination factor

S.No.	Thickness in mm	Slope at exit	Delamination factor
1	4	7	1.425
2	8	6.4	1.268
3	13	5	1.196
4	18	0.5	1.224

From the above observations, the work has been narrowed to 14.5mm, 14.8mm, 16mm and 17mm plates. The time vs. cumulative AE RMS plots on drilling 14.5mm, 14.8mm, 16mm and 17mm plates are shown in the figures 10, 11, 12 and 13. The plot for 14.5mm plate shown in the figure 10 clearly shows the drastic change in the exit, which indicates the push out, or delamination at the exit. Similarly, the graphs for 14.8 mm and 16 mm also show the change in slope at the exit (figures 12 and 13) and hence captured the delamination at the exit. But the figure 13 which corresponds to the plate 17mm shows only negligible slope at the exit which indicates that AE sensor was unable to capture the event that occurred at the exit.

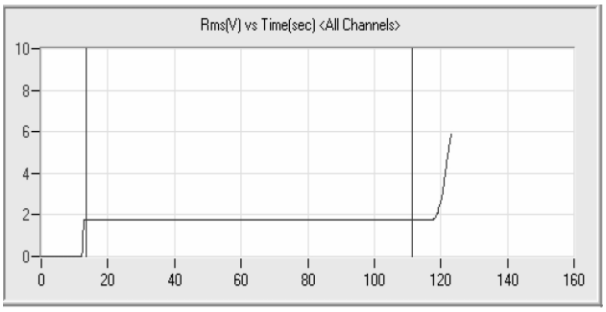

Figure 10: Cumulative AE RMS Vs Time for 14.5 mm plate

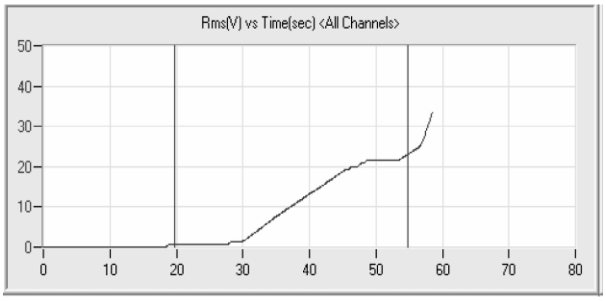

Figure 11: Cumulative AE RMS Vs Time for 14.8 mm plate

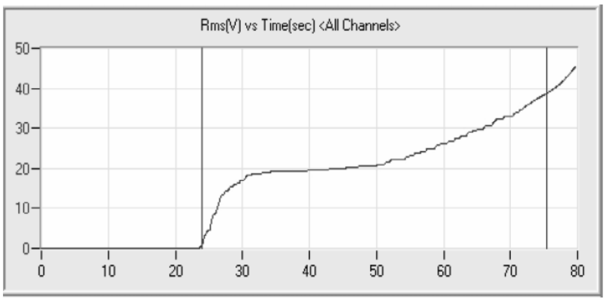

Figure 12: Cumulative AE RMS Vs Time for 16 mm plate

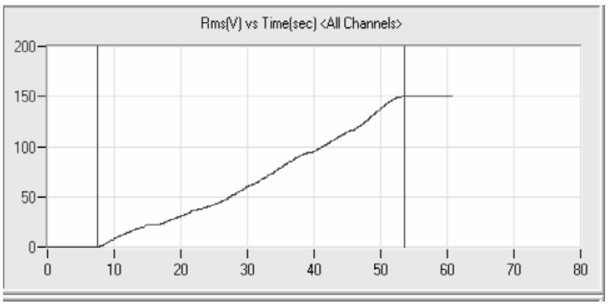

Figure 13: Cumulative AE RMS Vs Time for 17 mm plate

Table 2 shows the slope and the delamination factor at the exit for the holes drilled in 4mm, 8mm, 13mm and 18mm.

4. CONCLUSION

The present work attempted to find out the maximum thickness of GFRP composite that could be used with the aid of single AE sensor for detecting the delamination during drilling. The preliminary investigations conducted on the composite plates revealed that as the thickness increases the single AE sensor placed on the top of the composite plate does not capture the events effectively which occurs at the exit of the drilled hole. From the delamination factor at the exit for the various holes, it is observed that the delamination has occurred for all the holes. But the time vs. cumulative AE RMS plots reveals that as the thickness of the composite plate goes beyond 16mm, it does not show the drastic increase in slope at the exit. This indicates that single AE sensor can capture the AE events effectively only upto a maximum thickness of 16mm.

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