8th European Solid Mechanics Conference
Gerhard A. Holzapfel and Ray W. Ogden (Eds)
Graz, Austria; July, 2012

Image-Based Damage Evaluation in Drilled Carbon/Epoxy Laminates

Luís Miguel P. Durão[†], **João Manuel R. S. Tavares**[‡], **Victor Hugo C. de Albuquerque**[‡]
Daniel J. S. Gonçalves[‡]

[†] ISEP/CIDEM, Instituto Superior de Engenharia do Porto
Centro de Investigação e Desenvolvimento em Engenharia Mecânica
Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
lmd@eu.ipp.pt

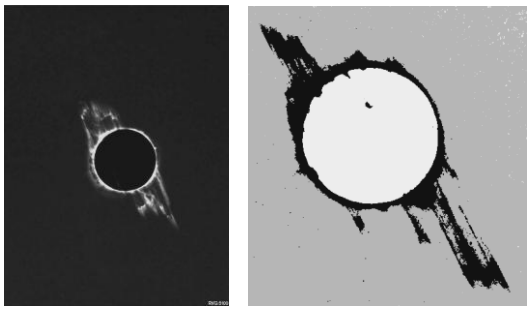
[‡] Instituto de Engenharia Mecânica e Gestão Industrial (INEGI), Universidade do Porto
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
tavares@fe.up.pt

ABSTRACT

The extensive usage of composites nowadays, from aircrafts to sporting goods, increases the demand for optimized solutions for production at reasonable costs. Advantages in their use are related with lightweight combined with good mechanical properties. As parts in composite materials are to be assembled in complex structures, joining of these parts to other materials is always needed. Drilling is by far the most common machining operation in industry. To complete one large passenger aircraft thousands of holes are needed. Due to the abrasive nature of carbon fibers, combined with the laminar nature of parts, several damages are due to occur during drilling operations, like push-down delamination, fiber pull-out or thermal damages. Another issue is the reduced tool life that can also contribute to larger damage extension. The most frequent and noticeable evidence of these damages is the existence of an edge around the machined hole, namely at the exit side of the drill, as a consequence of the drilling process. In this region, it is possible to observe, by visual or enhanced inspection, the separation of adjacent plies of the laminate. This damage is known as delamination, Fig. 1, and has been considered as the most severe damage, as it can contribute to a substantial decrease in the mechanical strength of the part. So, the reduction of this damage is of capital importance to the composites industry.

A non-destructive inspection method like enhanced radiography can help on the detection and measurement of the delaminated area around the hole, Fig. 1. Delamination assessment has been accomplished using existing damage models based on the ratio of the maximum delaminated diameter or damaged area to the hole nominal diameter or area [1-3].

In this work, a batch of carbon/epoxy plates was drilled using different drills and the resultant delamination extension were measured in the correspondent digital enhanced radiographies using techniques of computational vision [4]. Using these measurement results, traditional damage models [1-3] are compared with a new model based on a circularity index which reflects the shape of the damaged areas. Finally, the findings of the damage models are correlated with the results of the bearing test, ASTM D-5961-07.



(a) (b)

Figure 1: Example of an enhanced radiography acquired from a drilled composite laminate (a) of a damage region identified using techniques of computational vision (b).

The experimental findings let us conclude that the damage models are useful in the monitoring of composite laminates drilling process and can be used in complex structures to assist delamination reduction.

Acknowledgement. This work was partially supported by FCT (Fundação para a Ciência e a Tecnologia), in Portugal, in the scope of the project Pest-OE/EME/UI615/2011.

References

[1] W.C. Chen, Some experimental investigations in the drilling of carbon fibre-reinforced plastic (CFRP) composite laminates. *Int. J. Mach. Tool. Manu.* 37:1097-1108, 1997.

[2] J.P. Davim, J.C. Campos Rubio and A.M. Abrão, A novel approach based on digital image analysis to evaluate the delamination factor after drilling composite laminates, *Comp. Soc. Tech.* 67:1939-1945, 2007.

[3] A. Faraz, D. Biermann and K. Weinert, Cutting edge rounding: An innovative tool wear criterion in drilling CFRP composite laminates. *Int. J. Mach. Tool. Manu.* 49:1185-1196, 2009.

[4] Luís M.P. Durão, Daniel J.S. Gonçalves, João M.R.S. Tavares, Victor H.C. de Albuquerque, A.A. Vieira and A.T. Marques, Drilling tool geometry evaluation for reinforced composite laminates. *Comp. Struct.* 92:1545-1550, 2010.