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Abstract

Damage Propagation in Drilled Carbon/Epoxy Plates under Cyclic Loading †

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Abstract: There is a wide use of composites in the production of load bearing structures. Recently it was recognized that composites can be affected by cyclic loading. Drilling act as a stress concentration notch, leading to damage propagation and failure. In this work, a batch of carbon/epoxy plates is drilled under different conditions, thrust force is monitored and hole surrounding region is inspected. The area and other features of the damaged region are computed. Finally, the specimens are subjected to Open-Hole Fatigue tests. Results will help to establish a relation between the damaged region and the material's fatigue resistance.

Keywords: bearing load; cyclic load; drilling damage; damage propagation

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Carbon/epoxy composite laminates are widely used in the production of load-bearing primary structures due to their high strength-to-weight ratio when compared with metallic alloys. Initial studies were concerned with the static loading of drilled parts and their strength, as the general perception was that these materials were not susceptible to cyclic effects. However, it has been established that composites can be affected by cyclic loading, leading to the need to establish the grounds for fatigue behavior knowledge. The initial drilling operation can act as a stress concentration notch, as some delamination is prone to occur and there is the possibility of damage propagation from that point on, leading to multifaceted damage propagation sequences and final failure. This notch sensitivity can be affected by several factors including the laminate thickness, ply orientation, laminate size, notch size and machining quality. This quality is governed by the drilling parameters—cutting speed and feed rate—as well as by the drill material and even by the drill bit geometry.

In this work, a batch of carbon/epoxy plates was drilled under different machining conditions regarding the drill geometry and feed rate. During drilling, the thrust force was monitored to identify the possibility of delamination onset. After drilling, the hole surrounding area was inspected by enhanced radiography, a non-destructive method that combines a contrasting liquid penetrant agent with a digital image of the hole plus the delaminated edge. Radiographic images were obtained with the help of a 60 kV, 300 kHz Kodak 2100 X-ray system associated with a Kodak RVG 5100 digital acquisition system. From these images, it was possible to compute the damaged area and other geometrical features of the damaged region, using appropriate MatLab® tools, such as the Image Processing Toolbox.

After this step, the test specimens were subjected to cyclic bearing forces, as described in ASTM Bearing Fatigue Response of Polymer Matrix Composite Laminates—ASTM

D6873—19. In this work, specimens were not loaded until failure, as the test was halted after a defined number of cycles. Then, a new inspection was carried out, and damage propagation extension was determined by comparing consecutive digital images. This sequence can be repeated for as many times as possible, providing that final failure does not occur. Finally, specimens were static bearing loaded until failure for residual strength assessment.

The results of this experimental sequence will help to establish a relation between the damaged region caused by the drilling operation and the material's resistance to cyclic loading.

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