Author's Accepted Manuscript

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PII: S0890-6955(14)00090-X
DOI: http://dx.doi.org/10.1016/j.ijmachtools.2014.06.004
Reference: MTM2959

To appear in: *International Journal of Machine Tools & Manufacture*

Received date: 3 April 2014
Revised date: 10 June 2014
Accepted date: 11 June 2014

Cite this article as: Yosra Turki, Malek Habak, Raphaël Velasco, Zoheir Aboura, Kamel Khellil, Pascal Vantomme, Experimental investigation of drilling damage and stitching effects on the mechanical behavior of carbon/epoxy composites, *International Journal of Machine Tools & Manufacture*, http://dx.doi.org/10.1016/j.ijmachtools.2014.06.004

Experimental investigation of drilling damage and stitching effects on the mechanical behavior of carbon/epoxy composites

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Abstract

The main purpose of composite materials drilling is the need to put together different parts of a structure, in aeronautics for example. Machining generates damages which affect mechanical properties and have to be taken into account during manufacturing process. The objective of this study is to experimentally analyze the influence of drilling on a carbon/epoxy composite, to investigate the relationships among damages, cutting forces, mechanical properties of the drilled specimens and crack propagation. Stitching and a range of spindle speed and feed have been tested when drilling with a classic twist drill. The effect of each parameter has been assessed in terms of thrust force, moment (during machining) and defects, and then linked to mechanical test results. Experimental results have shown significant influences of feed and composite configuration on delamination. Furthermore, cyclic tensile tests have shown that reducing damage and using stitching help increasing tensile strength.

Keywords: Carbon/epoxy composite, drilling, stitching, cutting force, delamination, mechanical properties.

1. Introduction

Carbon fiber-reinforced plastic (CFRP) has many applications in various fields such as aerospace, automotive, nuclear, where its high strength-to-weight ratio is wanted. Drilling is a needed machining operation since it is the most common one to put together different parts of a structure. The mechanism of material removal can cause damages and lead to the ruin of the structure. In composite laminates drilling, it has been shown that drill geometry and cutting parameters are the key factors that determine holes quality and delamination occurrence.

Composite drilling generates some specific damages, such as delamination, cracks or matrix thermal degradation. Delamination is the most critical mode of damage in CFRP [1]. To quantify it, this defect is observed using several non-destructive means, such as optical microscope [2], ultrasonic C-scan [3], shadow moiré laser based on an imaging technique [4], X-ray computerized tomography (CT) [5, 6], enhanced radiography [7]. F_d factor, which does not take the damaged area into account, is commonly used to quantify delamination. Some studies [8, 9] have highlighted the fact that a delamination factor F_{da}, adjusted by the delamination area contribution, doesn't give more information than F_d. But Tsao et al. [10] have noticed that in some cases, F_d at the hole exit remains constant whatever the drilling conditions while F_{da} is not stable.

Comparative studies of composite drilling have been conducted using several drill geometries (twist drill, core drill, step drill, brad drill, spur drill and dagger drill) and various cutting conditions [11, 12]. They have shown that drill geometry has a significant influence on thrust force and delamination. For example, spur drill reduces consequently delamination and uncut fibers, compared to twist drill. It has been explained that the two extreme points of this tool better shear so cut carbon fibers [12]. Some authors have shown that lower feed rates reduce thrust force and delamination [12-14]. According to Phadnis et al. [1], when the feed