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# Hole-quality evaluation in drilling fiber-reinforced composites

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## Abstract

This paper presents a novel approach for a complex evaluation of the quality of drilled holes in fiber-reinforced composite materials. The proposed methodology is based on non-destructive quantification of visible defects based on the numerical analysis of drilled hole images. Automatic contour definition and profile formation for the uncut fibers and delamination were implemented via modularized algorithms. Four criteria for the evaluation of the defect height and width distribution were developed and combined into an overall quality parameter,  $Q$ . The methodology was validated experimentally by drilling carbon-fiber-reinforced polymer (CFRP) samples with a cemented carbide drill bit. The results showed a linear relation between the hole quality  $Q$ , the drilled hole number, and tool wear.

**Keywords:** drilling, hole quality, CFRP, uncut fibers, delamination.

## Nomenclature

$D_{\text{nom}}$	Nominal diameter of drilled hole
$D_{\text{max}}$	Maxima diameter of drilled hole delamination
$F_d$	Tsao-Hocheng criterion of delamination length evaluation
$F_f$	Tsao-Hocheng criterion of delamination area evaluation
$F_{\text{ed}}$	Tsao-Hocheng complex criterion of delamination evaluation
$F_{\text{da}}$	Davim criterion of delamination evaluation
$F_{\text{nd}}$	Voss criterion of delamination length evaluation
$F_{\text{A,d}}$	Voss criterion of delamination area evaluation
$F_{\text{L,95\%}}$	Voss criterion of uncut fiber distribution
$F_n$	Voss criterion of uncut fiber number
$F_{\text{Acov}}$	Voss criterion of uncut fiber area
$w_1-w_5$	Voss weight coefficients
$K$	Voss scaling factor
$l_{\text{del}}$	Maximum delamination length
$\alpha_i$	Angle of $i$ -th uncut fiber position
$r$	Radius of drilled hole circumference
$T$	Line corresponding to tolerance
$M$	Average line of the profile
$S_1$	Profile area under the $M$ line
$S_2$	Profile area above the $M$ line
$k_i$	Length of $i$ -th defect
$a_i, b_i$	Width of $i$ -th defect
$h_i$	Height of $i$ -th defect
$A$	Average of defect heights
$S$	Standard deviation of defect heights
$C_f$	Acceptance value of uncut fiber length
$C_d$	Acceptance value of delamination length
$H_d$	Criterion of delamination height
$H_f$	Criterion of uncut fiber height
$W_d$	Criterion of delamination distribution
$W_f$	Criterion of uncut fiber distribution
$Q$	Complex criterion of quality

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