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# Prediction of the crack density evolution in multidirectional laminates under fatigue loading

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**Abstract**

*An innovative procedure is proposed for the prediction of the crack density evolution in multidirectional laminates subjected to cyclic loading. The crack initiation and propagation phases are treated separately and described by means of a master S-N curve and a Paris-like curve, respectively. A damage-based multiscale strategy is adopted for the prediction of multiple crack initiation, accounting for the statistical distribution of fatigue strength and crack propagation resistance within a ply. The procedure has been implemented in a Matlab® code for the simulation of the fatigue damage evolution in multi-directional symmetric laminates. Comparisons with experimental results taken from previous works show a very good agreement.*

**List of symbols**

| | |
|---|---|
| a | Exponent of S-N curve equation |
| $a_{LHS}$ | Exponent of the S-N curve under LHS-driven stress state |
| $a_{LMPS}$ | Exponent of the S-N curve under LMPS-driven stress state |
| c | Crack length |
| C, $C_{tot}$, $C_I$ | Coefficients of the CGR-ERR curve |
| $c_0$ | Length of crack initiation process zone |
| CGR | Crack Growth Rate |
| D | Damage parameter |
| d, $d_I$, $d_{tot}$ | Exponent of the Paris-like curve |
| $E_1$, $E_2$, $E_3$ | Ply elastic moduli |
| ERR | Energy Release Rate |
| $G_{12}$, $G_{23}$, $G_{31}$ | Ply shear moduli |
| $G_{eq}$ | Equivalent ERR |
| $G_{eq,c}$ | Critical value of $G_{eq}$ |
| $G_{eq,th}$ | Threshold value of $G_{eq}$ |
| $G_I$ | Mode I component of ERR |
| $G_{II}$ | Mode II component of ERR |
| $G_{ss}$ | Steady state ERR |
| $G_{tot}$ | Total ERR ($G_I$+$G_{II}$) |