EFFECTS OF DEFECTS IN COMPOSITE STRUCTURES

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DESIGN CRITERIA

FIRST PLY FAILURE

- DESIGN ULTIMATE STRAIN (DUS) IS STRAIN FOR FIRST PLY FAILURE

STATE OF THE ART

- DUS IS FAILURE STRAIN OF LAMINATE WITH 0.25-in. HOLE

POSSIBLE

- DUS IS FAILURE STRAIN OF LAMINATE WITH LOW-ENERGY IMPACT DAMAGE
- BUFFER AND SOFTENING STRIPS USED

UPPER BOUND

- DUS IS FAILURE STRAIN OF LAMINATE
- STRESS CONCENTRATIONS DESIGNED AROUND LEAST CONSERVATIVE

PREPREG DEFECTS

HOLLOW FIBERS

EXCESSIVE VARIABILITY IN FIBER PROPERTIES

RESIN-STARVED OR FIBER-STARVED AREAS

WRINKLES, WAVINESS, MISCOLLIMATION

FOREIGN PARTICLES, CONTAMINATION

PILLS AND FUZZ BALLS

NONUNIFORM AGGLOMERATION OF HARDENER

PREPREG OUT OF SPECS.

DEFECTS IN LAMINATES

HOLLOW FIBERS

DELAMINATIONS

FIBER BREAKS

PLY GAPS

EXCESSIVE POROSITY, VOIDS

RESIN-RICH AND RESIN-STARVED AREAS

FIBER WAVINESS, WRINKLES, MISCOLLIMATION

FOREIGN PARTICLES, CONTAMINATION, INCLUSIONS

INCOMPLETE AND/OR VARIABLE CURE

WRONG STACKING SEQUENCE

DENTS, TOOL IMPRESSIONS, SCRATCHES

LAMINATE POROSITY

STUDIED EXTENSIVELY

MATRIX DOMINATED PROPERTIES DEGRADED (DELAMINATION NOT INCLUDED)

- 5% STRENGTH REDUCTION FOR 1% POROSITY
- 50% LIFE REDUCTION FOR 1% POROSITY

FIBER-DOMINATED PROPERTIES NOT AFFECTED

DELAMINATION GROWTH AFFECTED - NOT WELL DOCUMENTED

MOISTURE ABSORPTION

- EQUILIBRIUM MOISTURE LEVELS INCREASED
- AGGRAVATES THERMAL SPIKE PHENOMENOM

EFFECT OF PLY GAP DEFECT

(REF. 1)

$[(0/45/90/-45)_S]_2$ LAMINATE

- 16.9% STRENGTH REDUCTION FOR GAP(S) IN 90 PLIES
- 8.7% REDUCTION FOR GAP(S) IN 0 PLIES

$[(0/45/0/-45/0)_S]_2$ LAMINATE

- 6.5% STRENGTH REDUCTION FOR GAPS IN 0 PLIES

(REF. 2)

$[(0/\pm45/90)_S]_2$ LAMINATE

- 12.8% STRENGTH REDUCTION FOR GAPS IN OUTER 45 PLIES

$[(0/-/45/0)_S]_2$ LAMINATE

- 6.2% STRENGTH REDUCTION FOR GAPS IN OUTER 45 PLIES

DEFECT CRITICALITY - BENIGN FOR DESIGN ULTIMATE STRAIN 0.7%

EFFECT OF PLY WAVINESS DEFECT

(REF. 3)

SURFACE 0 PLY WAVINESS IN $[(0/45/90/-45)_S]_2$ LAMINATE

STATIC TENSILE STRENGTH REDUCTION

- 10% FOR SLIGHT WAVINESS
- 25% FOR EXTREME WAVINESS

FATIGUE LIFE REDUCTION

- AT LEAST A FACTOR OF 10
- CONSISTENT WITH STATIC STRENGTH REDUCTION

DEFECT CANNOT BE FOUND BY STANDARD NDE

STRENGTH LOSS CAN BE PREDICTED BY ASSUMING LOSS OF LOAD CARRYING CAPACITY DUE TO THE WAVINESS

DEFECT CRITICALITY - INSUFFICIENT DATA FOR ACCURATE ASSESSMENT

- SHOULD BE BENIGN FOR DESIGN ULTIMATE STRAINS 0.7%

MACHINING DEFECTS

EDGE DELAMINATIONS	EDGE NOTCHES AND SURFACE NOTCHES
OVERSIZE HOLES	HEAT-DAMAGED MACHINED EDGES
UNDERSIZE HOLES	FIBER BREAK-OUT ON HOLE EXIT SIDE
TILTED HOLES	OUT-OF-ROUND HOLES
TILTED COUNTERSINKS	IMPROPER DEPTH OF COUNTERSINKS

DENTS, FIBER BREAKING FROM IMPACT

TEAROUT OR PULL-THROUGH IN COUNTERSINKS

EFFECT OF SURFACE NOTCHES

EXPERIMENTAL DATA

- STATIC STRENGTH REDUCED UP TO 50%
- LOCAL DELAMINATION AT NOTCH
- FATIGUE LOADING REDUCES STRESS CONCENTRATION
- RESIDUAL STRENGTH HIGHER THAN STATIC STRENGTH
- DATA AVAILABLE FOR VARIOUS STACKING SEQUENCES

ANALYSIS

- ECCENTRIC BEAM MODEL PREDICTS STRENGTH REDUCTION
- STRENGTH REDUCTION IS SMALL FOR SIZES EXPECTED IN SERVICE

DEFECT CRITICALITY

- NOT CRITICAL FOR DUS < 0.7

BOLTED ASSEMBLY DEFECTS

OVERTORQUED FASTENERS

IMPROPER FASTENER SEATING

MISSING FASTENERS

FASTENER INSTALLATION DAMAGE

OVERSIZED AND UNDERSIZED FASTENER

BONDING DEFECTS

ADHESIVE POROSITY

MISCURE

ADHESIVE-STARVED AREAS

IMPROPER SURFACE PREPARATION

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