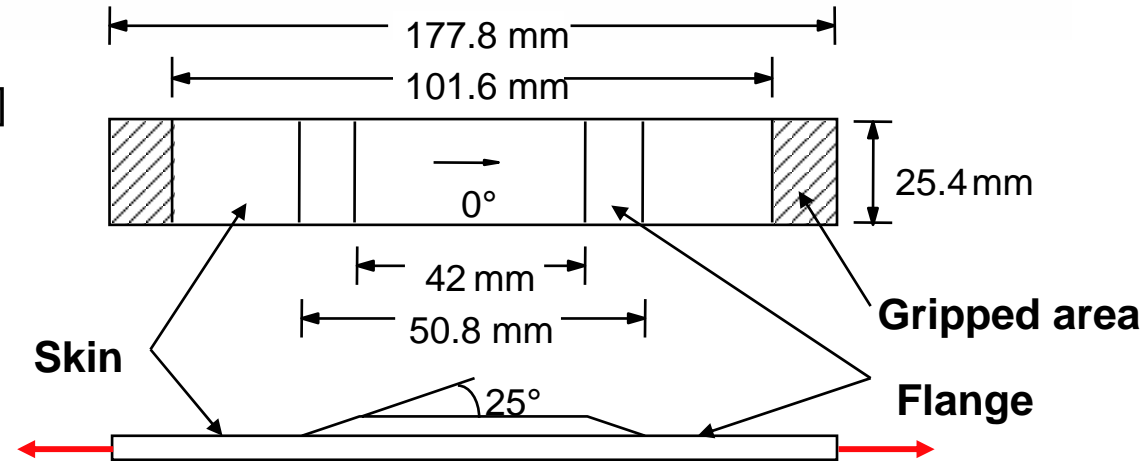


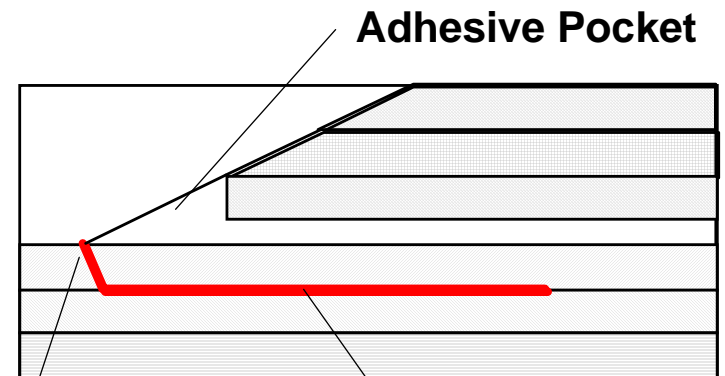
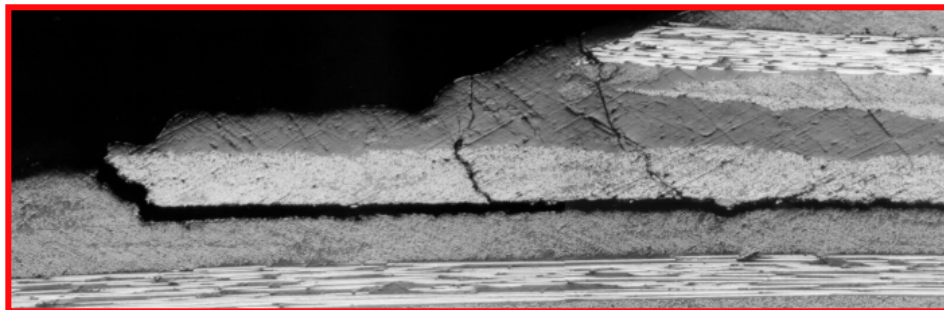
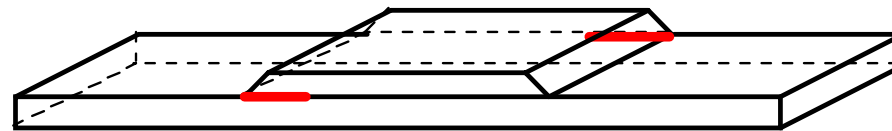
SKIN/STRINGER DEBONDING SPECIMEN AND OBSERVED DAMAGE PATTERNS



- **Layup:**
 - Skin [45/-45/0/-45/45/90/90/-45/45/0/45/-45]
 - Flange [45/0/45/0/45/0/45/0/45]_f
- **Material: Graphite/epoxy**
 - Prepreg tape (skin)
 - Plain weave fabric (flange)
- **Adhesive:**
 - FM300 adhesive film



First delamination observed at skin 45/-45 interface

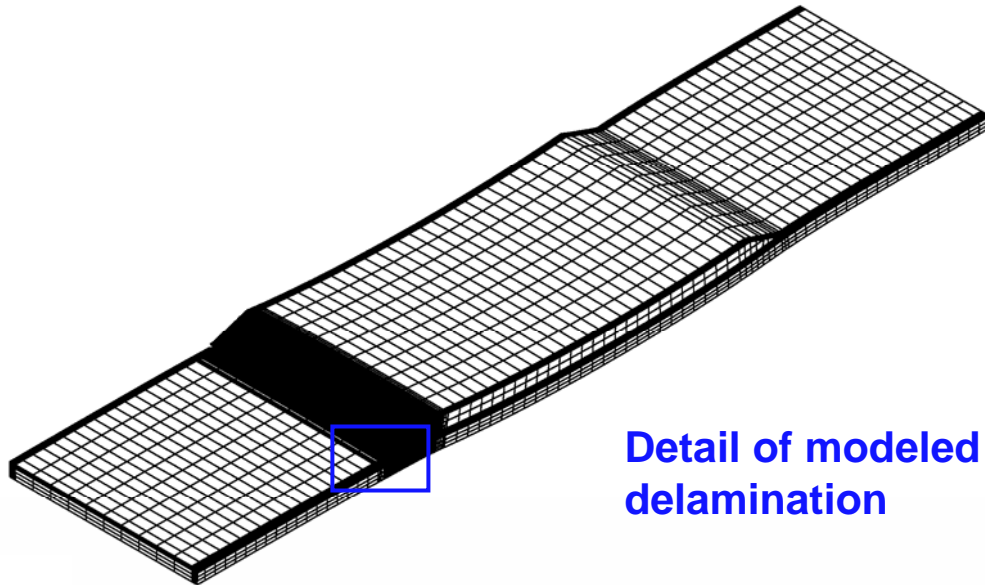


Initial Matrix Crack

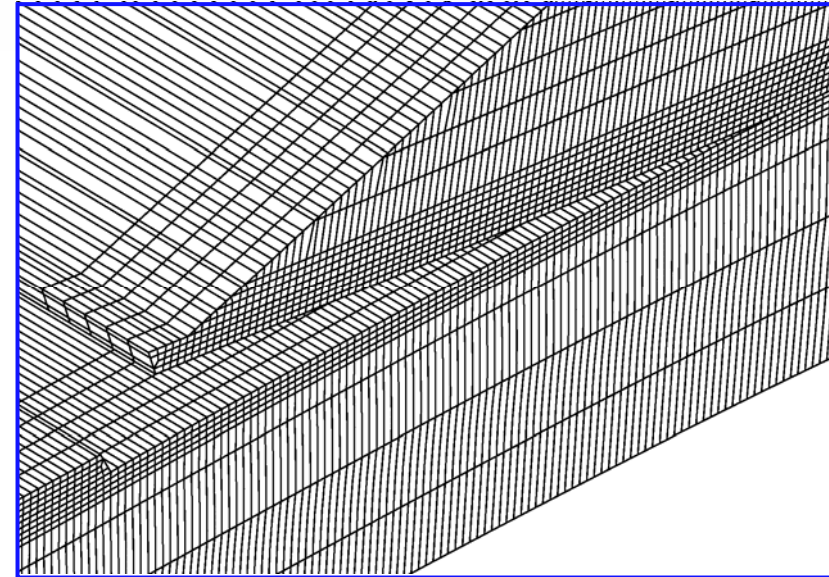
Delamination

SKIN/STRINGER DEBONDING

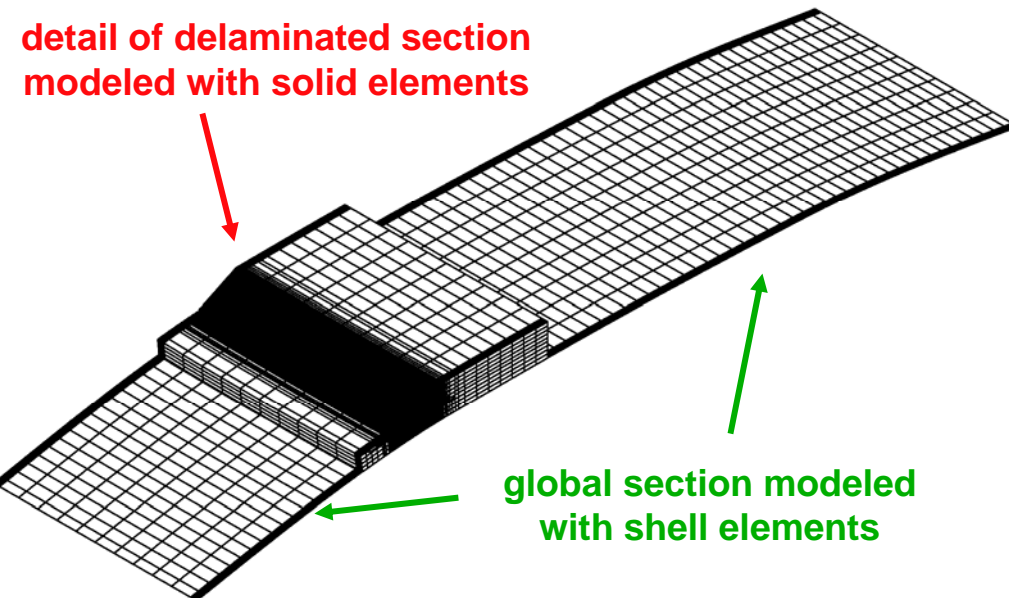
FULL 3D AND SHELL/3D FINITE ELEMENT MODEL



Detail of modeled delamination



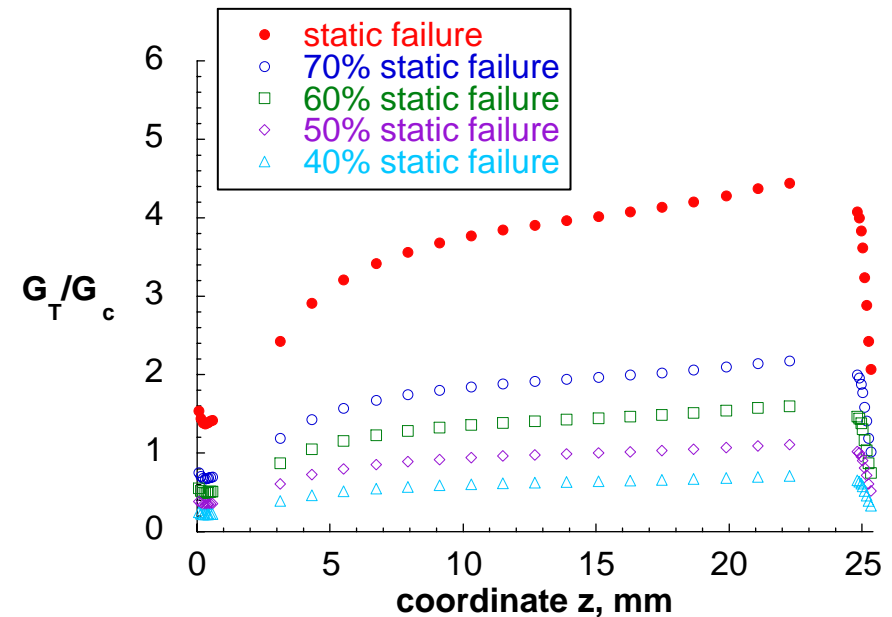
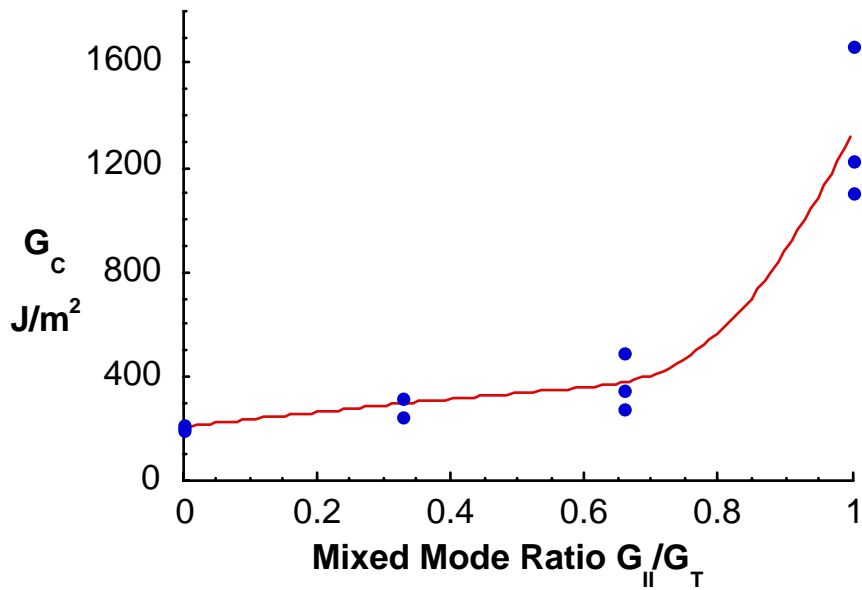
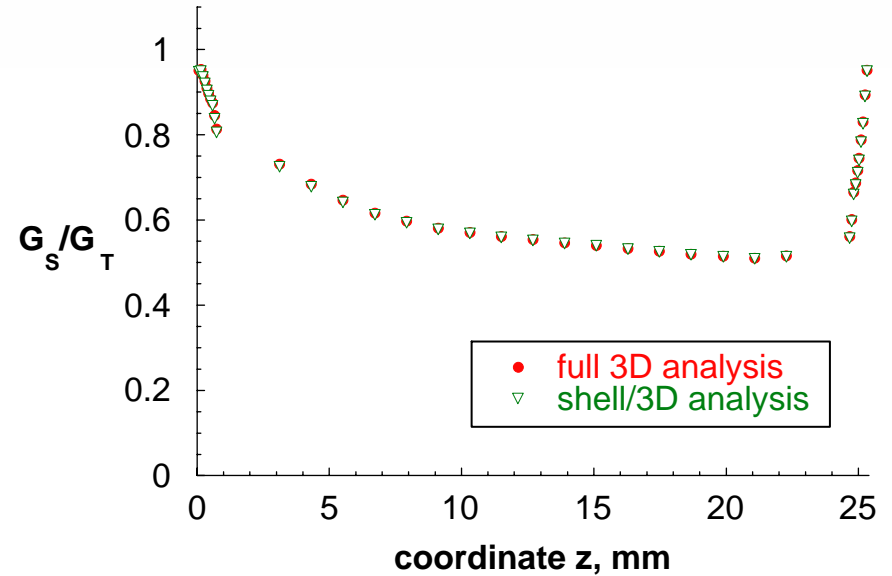
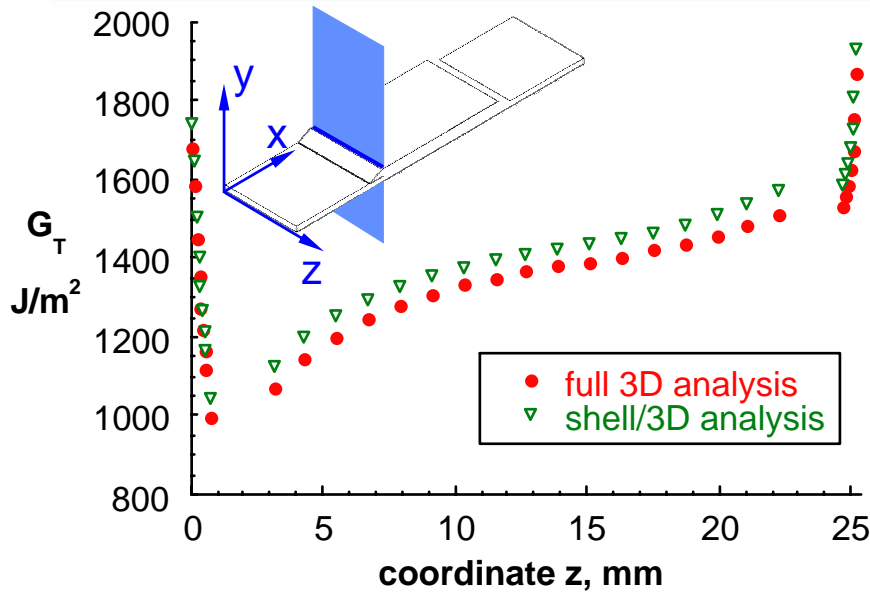
detail of delaminated section modeled with solid elements



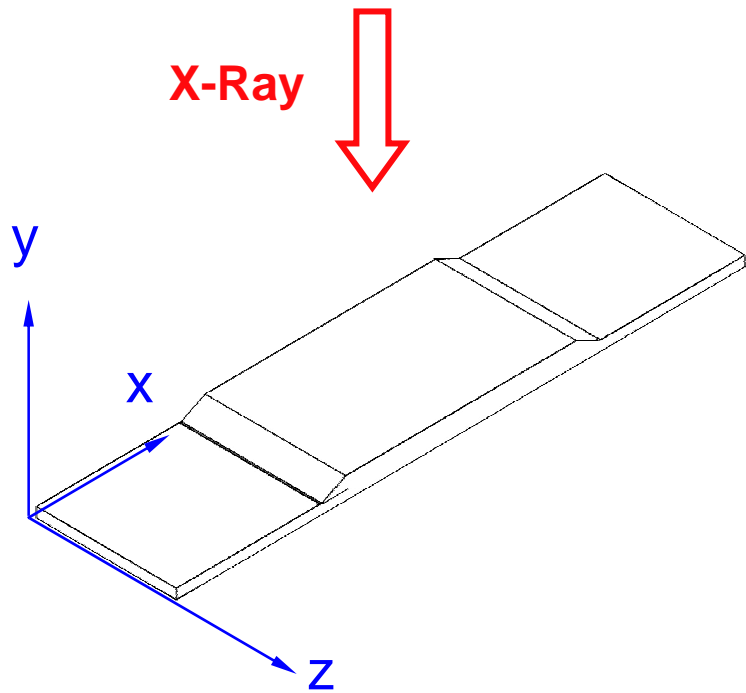
global section modeled with shell elements

- Full 3D model with C3D20R elements
 - 64,180 elements
 - 858,312 DOFs
- Global model with S8R elements and local 3D model with C3D20R elements
 - 56,084 elements
 - 753,637 DOFs

SKIN/STRINGER DEBONDING APPLICATION OF FRACTURE MECHANICS



X-RAY OF DELAMIANATED SPECIMEN



flange edge

delamination

specimen width

flange

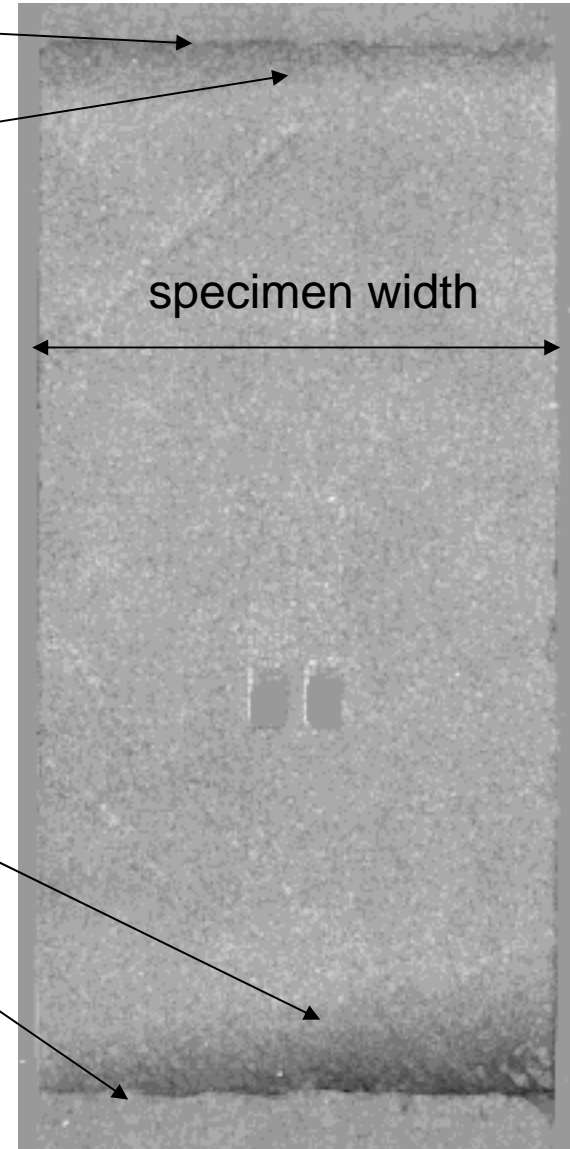
delamination

flange edge

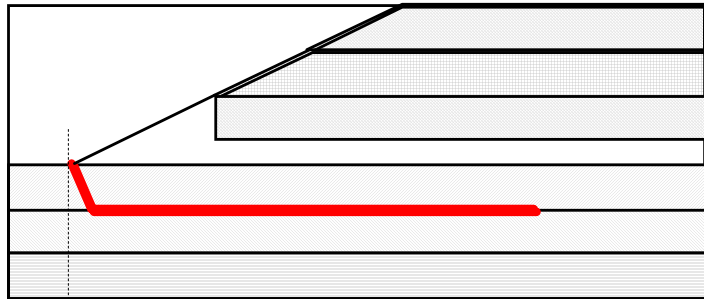
x

z

730 cycles

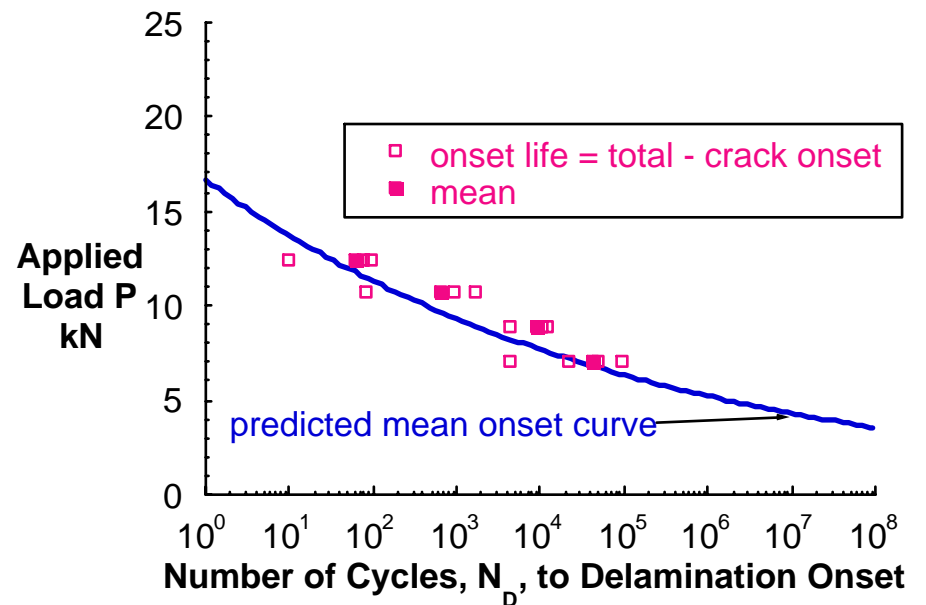
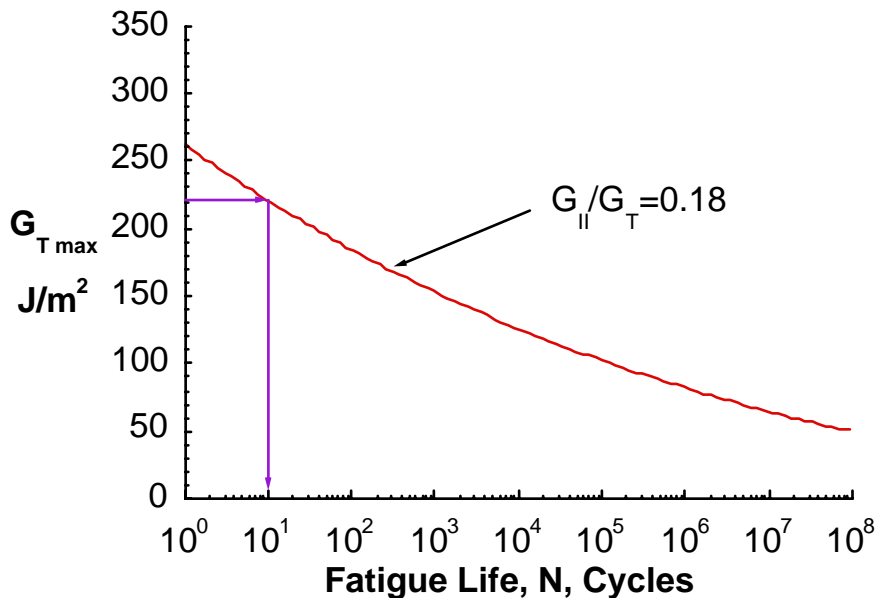
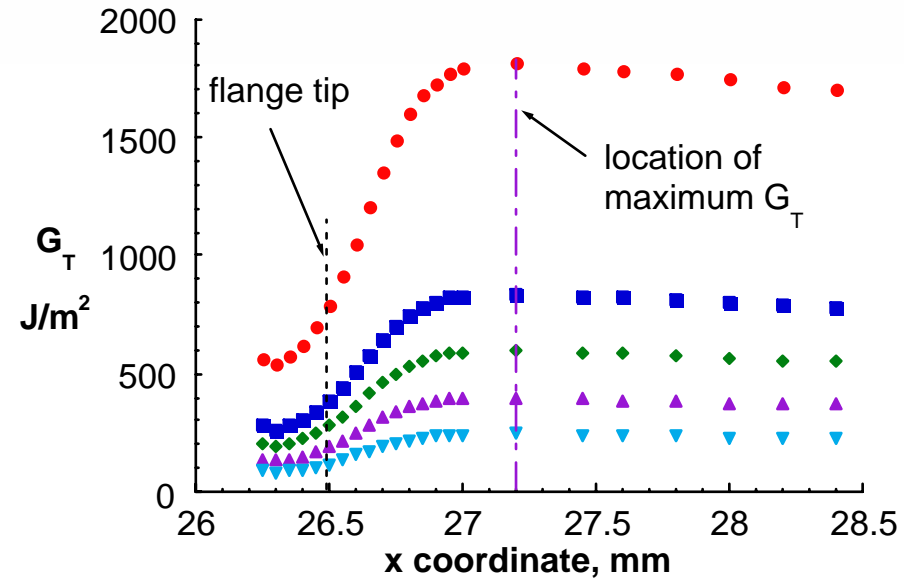


SKIN/STRINGER DEBONDING ONSET FATIGUE LIFE PREDICTION METHODOLOGY

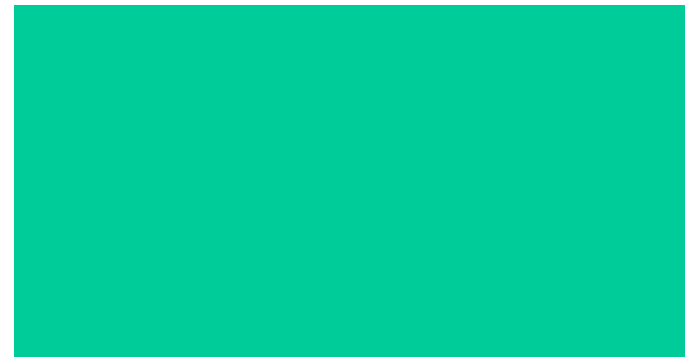
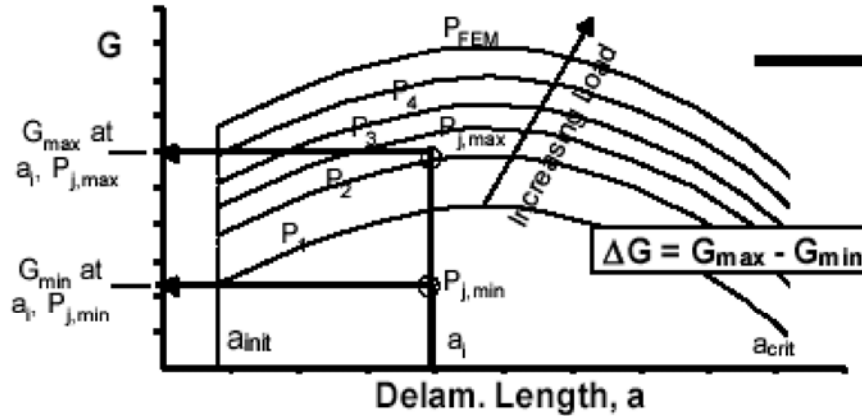
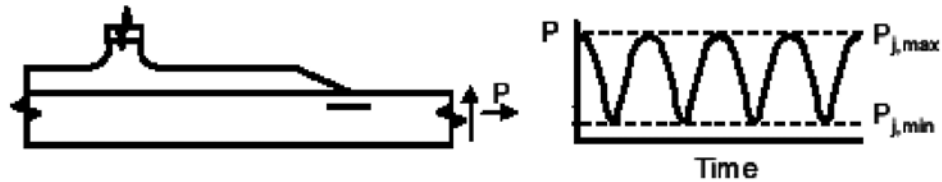


$x=26.2$ mm

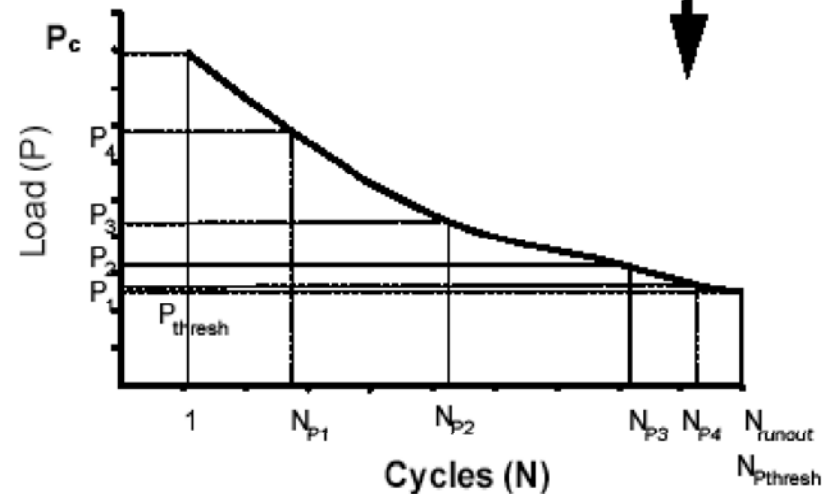
x



LIFE PREDICTION METHODOLOGY BASED ON DELAMINATION GROWTH*



$$\Delta N = \Delta a / (da/dN) \text{ at } a_i, P_j$$

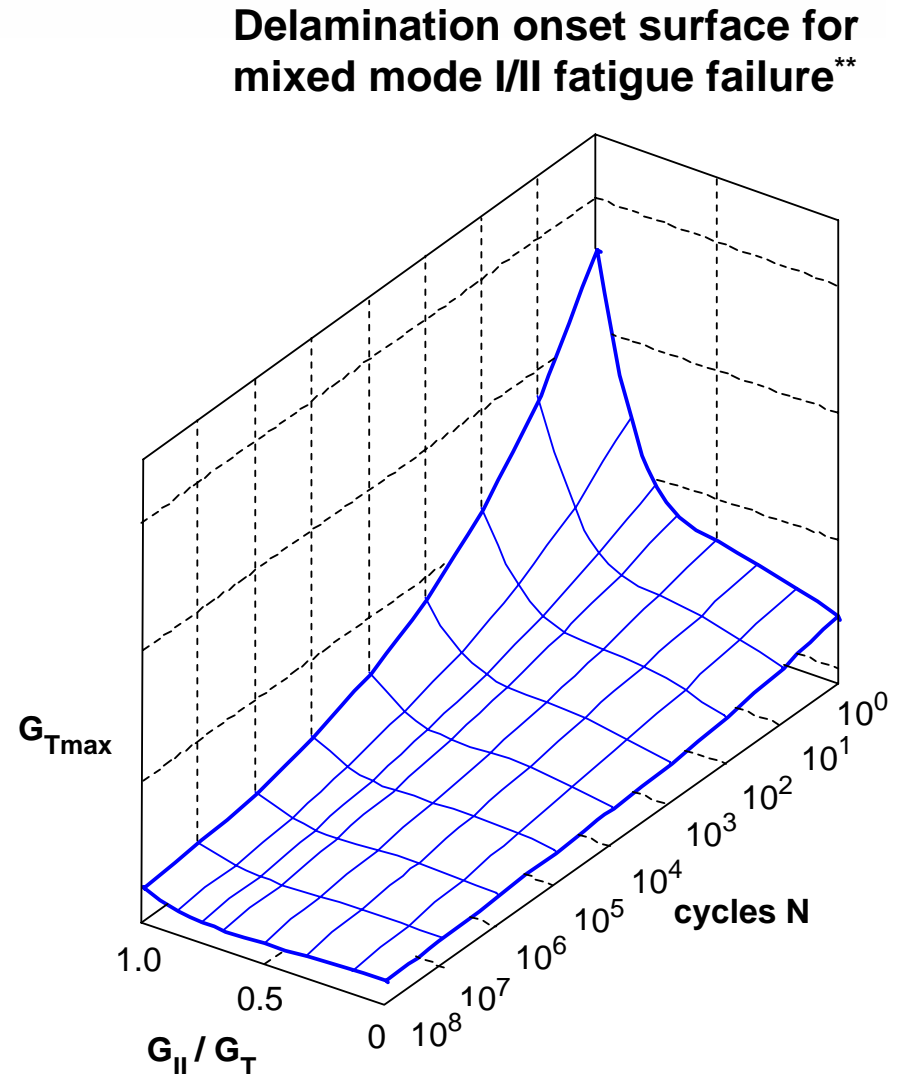


* D.M. Hoyt, Mil Hdbk-17, Vol. 3, Chapter 7

LIFE PREDICTION METHODOLOGY BASED ON DELAMINATION GROWTH - CHALLENGES*



- High fatigue data scatter
- Steep da/dN curve - Paris Law compared to metals
- Which G value(s) to use?
 - G_{tot_MAX} (G from max cyclic load)
 - ΔG_{tot} ($G_{tot_MAX} - G_{tot_MIN}$)
 - need mode mix?
 - normalize by R-curve?
- Together with current in-service NDI practices leads to “no growth” or onset approaches



Paris Law

* D.M. Hoyt

**Hansen and Martin, MERL