# FATIGUE PERFORMANCE OF THERMOPLASTIC TUFF COMPOSITES

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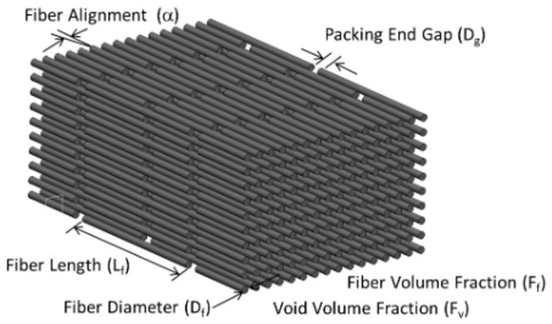
## INTRODUCTION

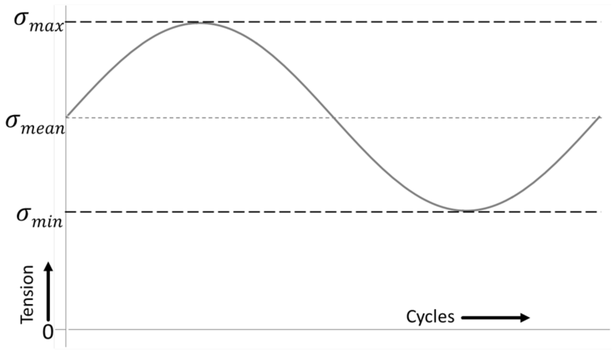
- The TuFF process produces highly aligned short fiber preforms and when consolidated with a matrix material leads to properties comparable to continuous fiber counterparts at high fiber volume fraction (57%).
- Composite structural components undergo repeated cycles through in its service time, which is not accounted for in quasi-static testing.
- The fatigue performance of TuFF must be characterized to determine materials design limit.




## FATIGUE LOADING PARAMETERS

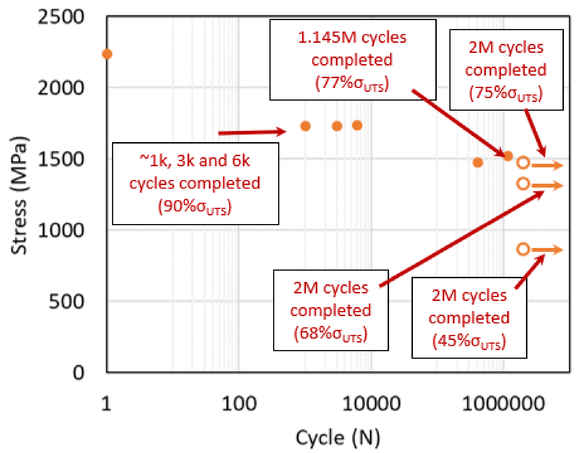
- Assess the material performance over repeated cyclic loading:
  - –Life-time predictions
  - –Design criteria for maximum cyclic loads
- Tension-Tension cyclic loading
  - –Typically follows sinusoidal waveform
  - –R-ratio 0.1 @ 3 Hz
  - –Ultimate Tensile Stress (UTS) from panel QS measurements and with variability as the standard deviation (std)
  - –Stress levels: 50% - 90% x (UTS-3*std)

$$\text{UTS} = \sigma_{avg} - 3 * (\sigma_{std})$$

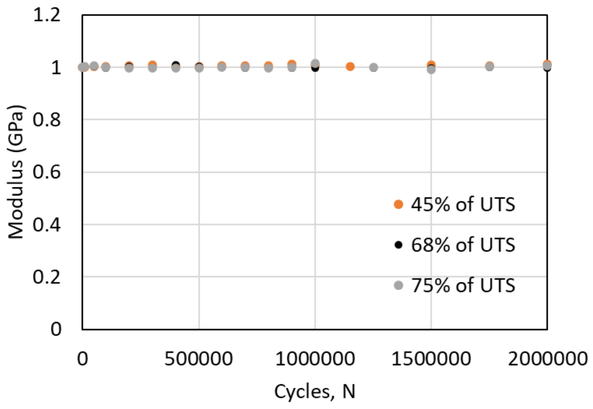



$$\text{R-ratio} = 0.1 = \frac{\sigma_{min}}{\sigma_{max}}$$

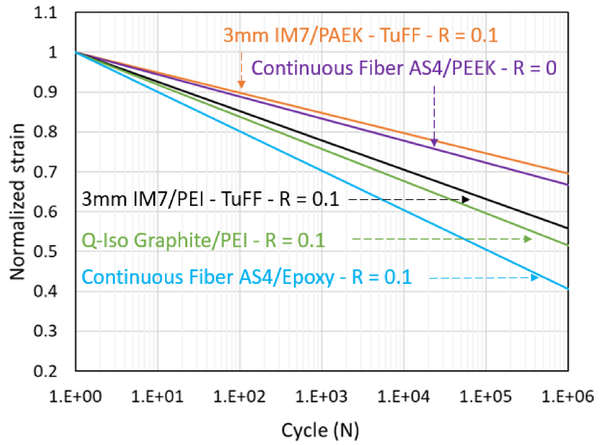
## S/N CURVE (SEMI-LOG) FOR IM7/PAEK TUFF [0]4



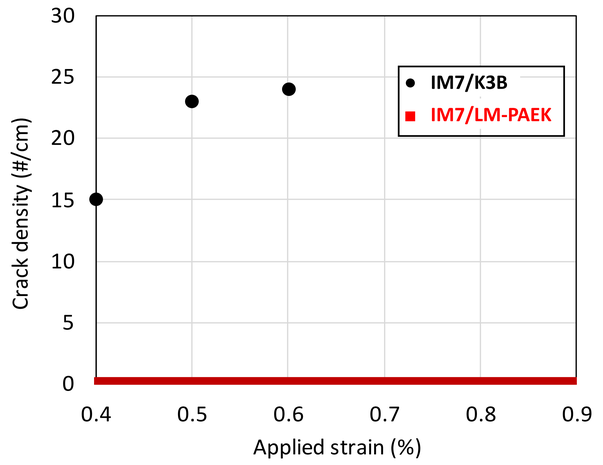

## NO CHANGE IN MODULUS AT 2 MILLION CYCLES



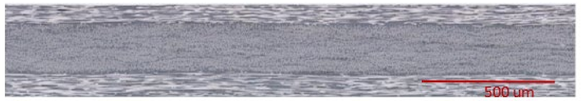

## NORMALIZED S/N CURVE (SEMI-LOG) WITH $[0]_4$ TUFF AND COMPARISON TO LITERATURE




## FATIGUE PERFORMANCE OF [0/90/0] CROSS-PLY TUFF LAMINATE AND COMPARRISON TO LITERATURE




- Matrix crack density development in 90° plies of [0/90/0] laminates at ~1 million cycles ( ● dots – IM7/K3B (continuous fiber/thermoplastic) and ■ squares – 3mm IM7/LM-PAEK cross-ply).
- **3mm IM7/LM-PAEK has zero crack density (does not microcrack from 0.4% - 0.9% strain)**




- The maximum fatigue strain applied is ~0.9%.
- There is no through-thickness microcracking observed in the sample after 1.5 million cycles.
- There is no significant modulus reduction observed up to 1.5 million cycles as shown

## DISCUSSION AND FUTURE WORK

- Normalized S/N curves of $[0]_4$ TUFF indicate IM7/PAEK TuFF having higher performance to other thermoplastic composites
- 240 gsm (thickest) TuFF cross-ply composite has suppressed/delayed transverse micro cracking up to 1.5 million cycles (max strain ~ 0.9%)
- Factors contributing to micro crack suppression:
  - High interface strength between the fiber and the resin (~129 MPa)
  - Higher resin toughness (strain to failure, >40% for LM PAEK vs <10% for K3B/IM7)
  - K1c & G1c is higher for LM-PAEK
- Future work should focus on more in-depth failure analysis to determine lower length scale failure modes during fatigue loading.

## ACKNOWLEDGEMENTS

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