

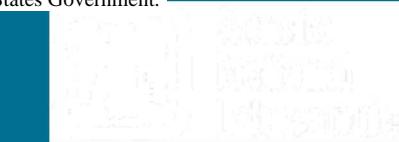
Effects of Defects on Blade Laminates



PRESENTED BY

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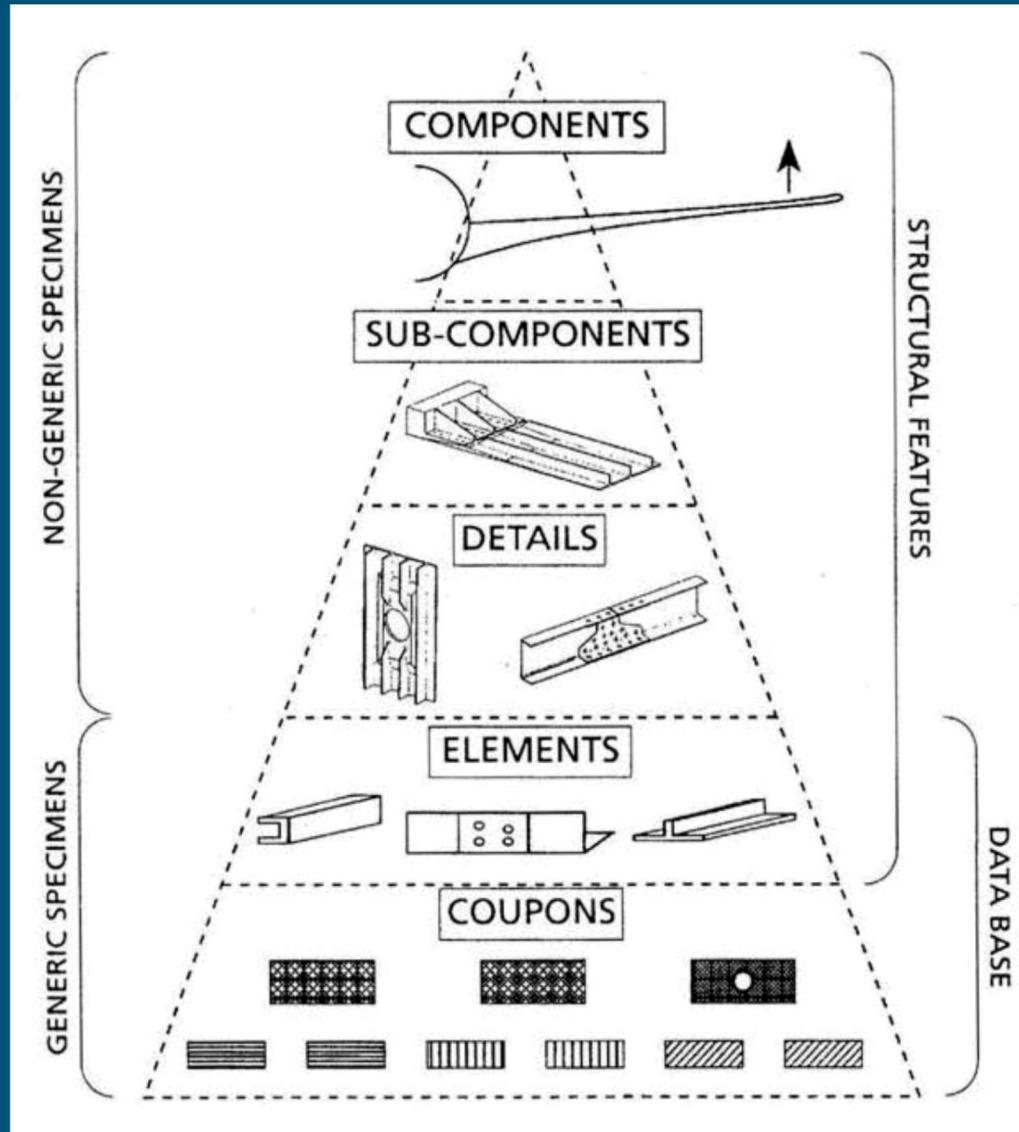
Introduction

Composite analysis difficult especially with structures due to manufacturing variations

Building block testing is required to validate models and should include samples with flaws

Life extension has been extensively studied developed for civil aviation

- Accomplished by supplemental inspection documents (SIDs)
- Structure is acceptable for further use, but must be inspected frequently
- New designs are based on durability and damage tolerant design



Defect and Damage Types

Voids/Porosity: inclusion of air pockets in matrix

Waves: bending or waviness along fiber length

- In-plane (IP): fiber waves on surface (left)
- Out-of-plane (OP): fiber waves through thickness

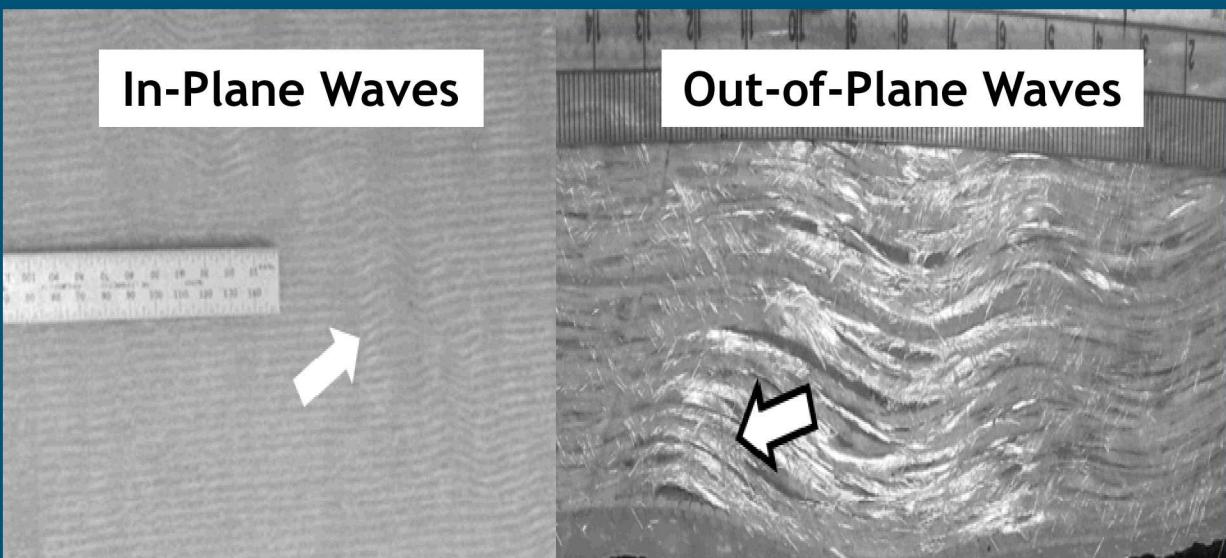
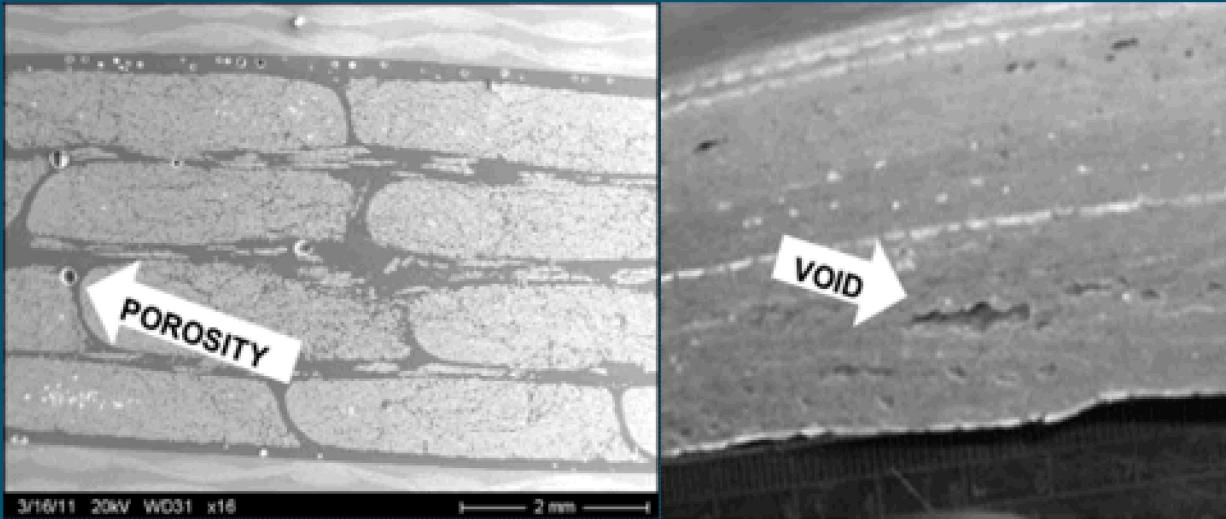
Disbonds

- Separations of bond lines either from manufacturing or operation

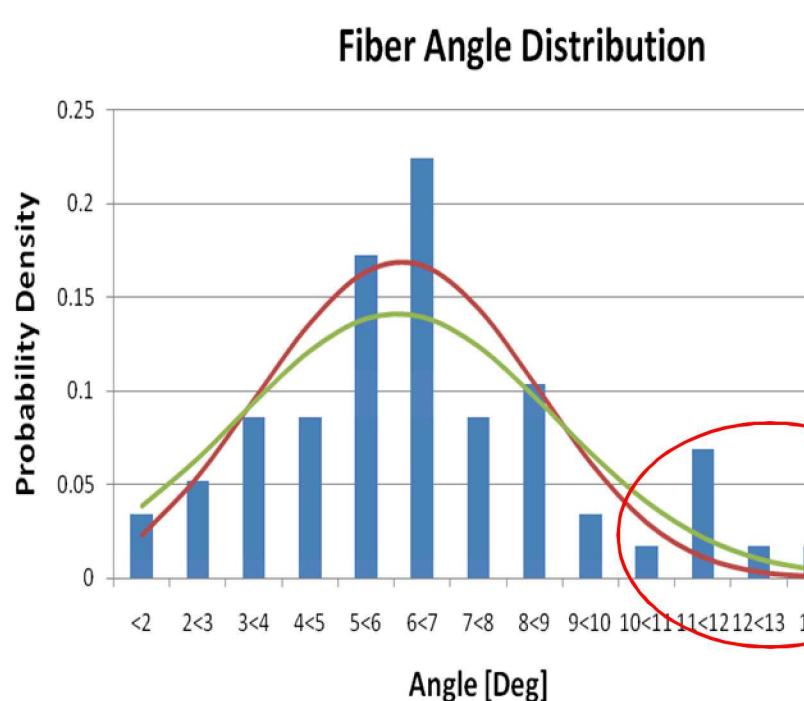
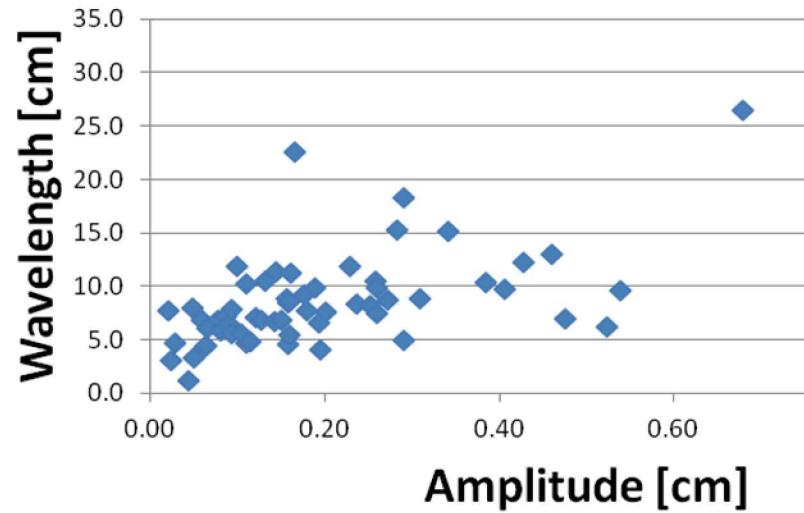
Delamination

- Separations of laminate layers, often emanating from flaws

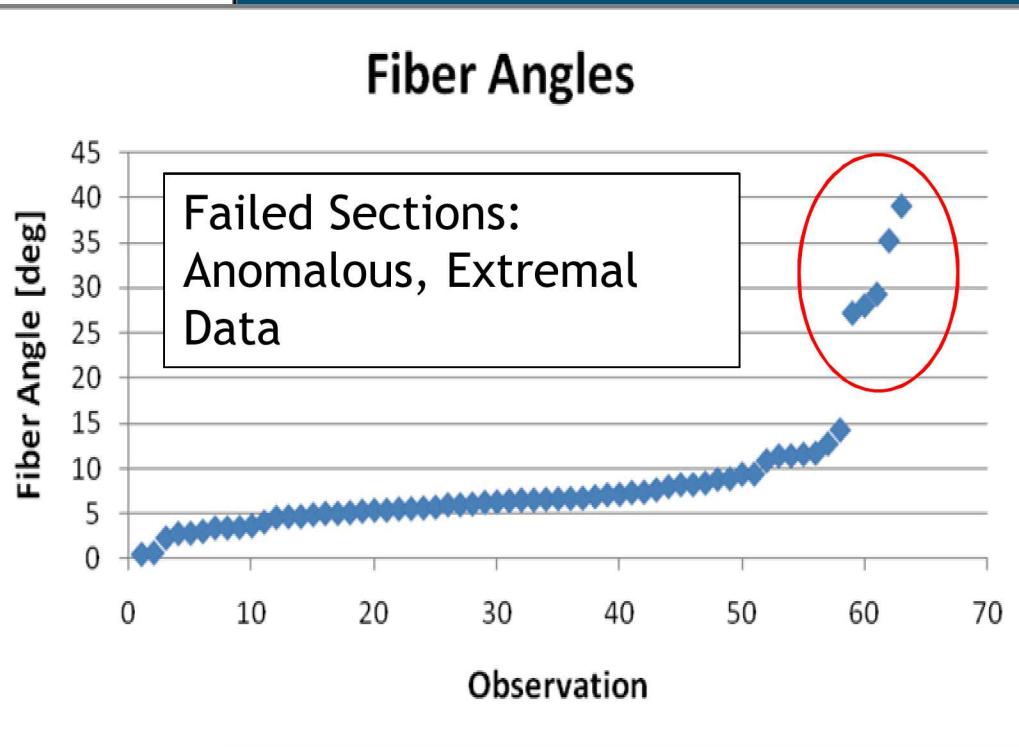
Leading Edge Erosion



Out-Of-Plane Wave Data



Fiber Angles



Example of data and statistics (necessary for Probabilistic Reliability): Out-of-Plane Waves

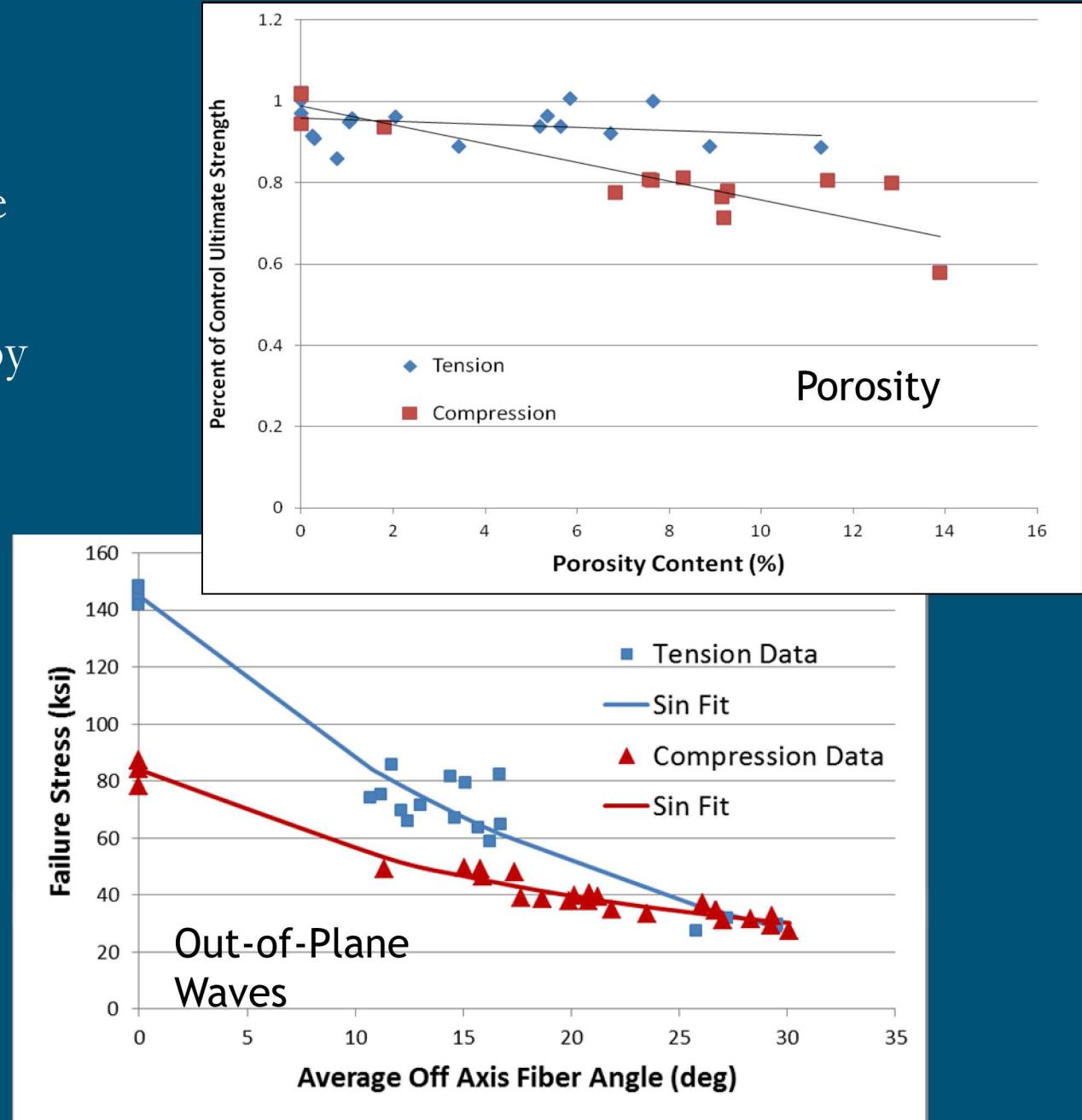
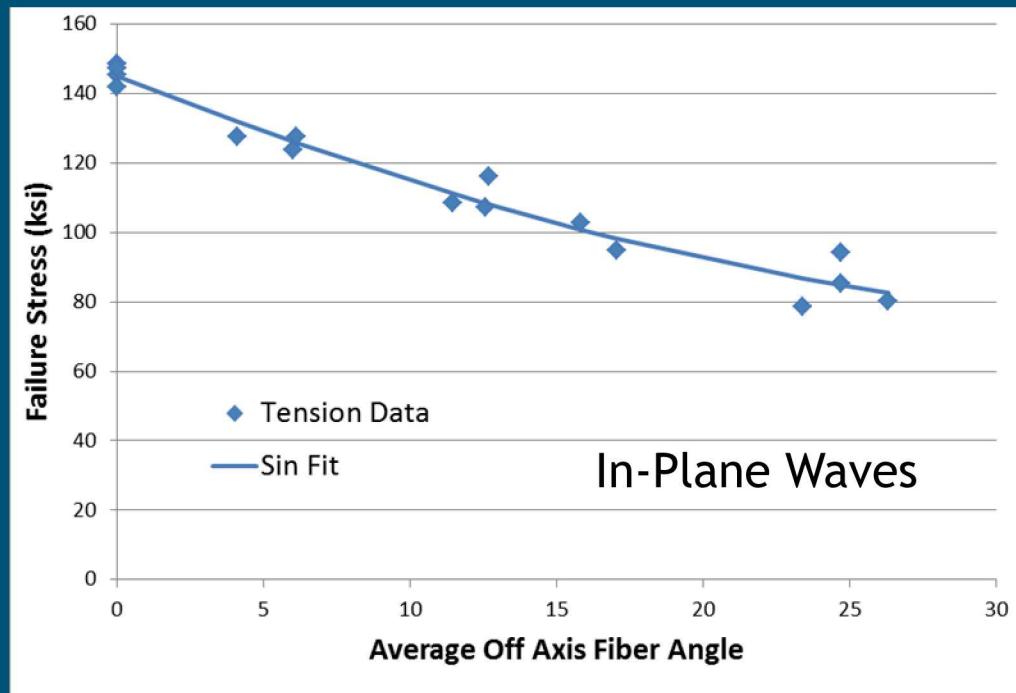
Test Specimens with Controlled Defects



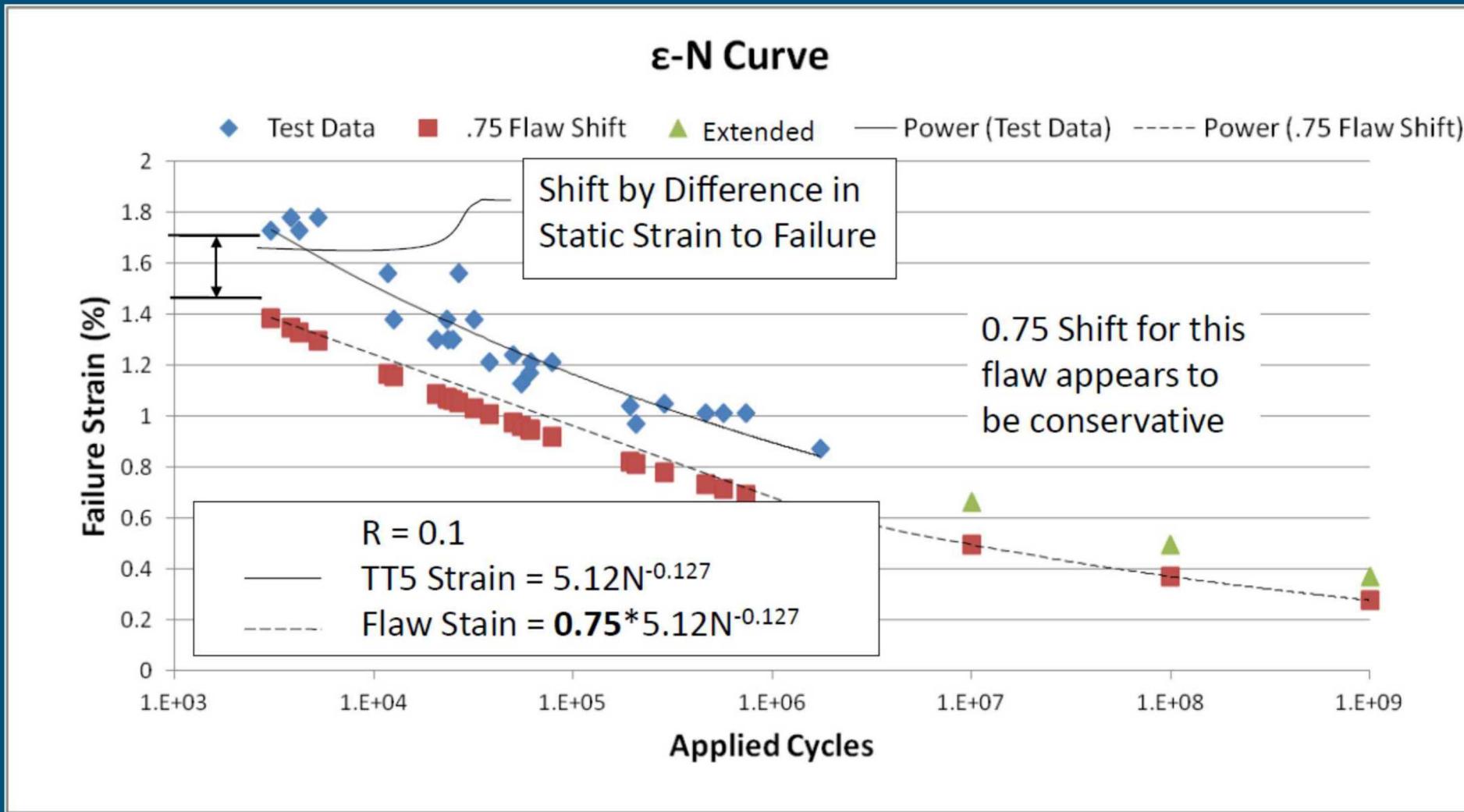
Laminate Testing Results

Wavy Laminates - Trend well with average misalignment fiber angle

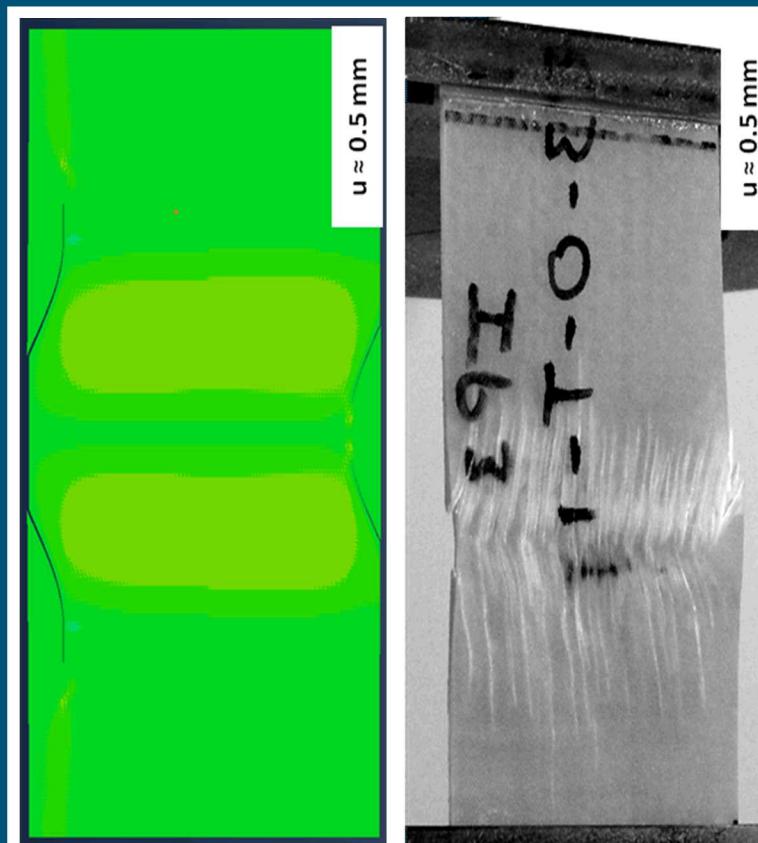
Porosity Laminates - Trend well with % by volume when accounting for fiber volume



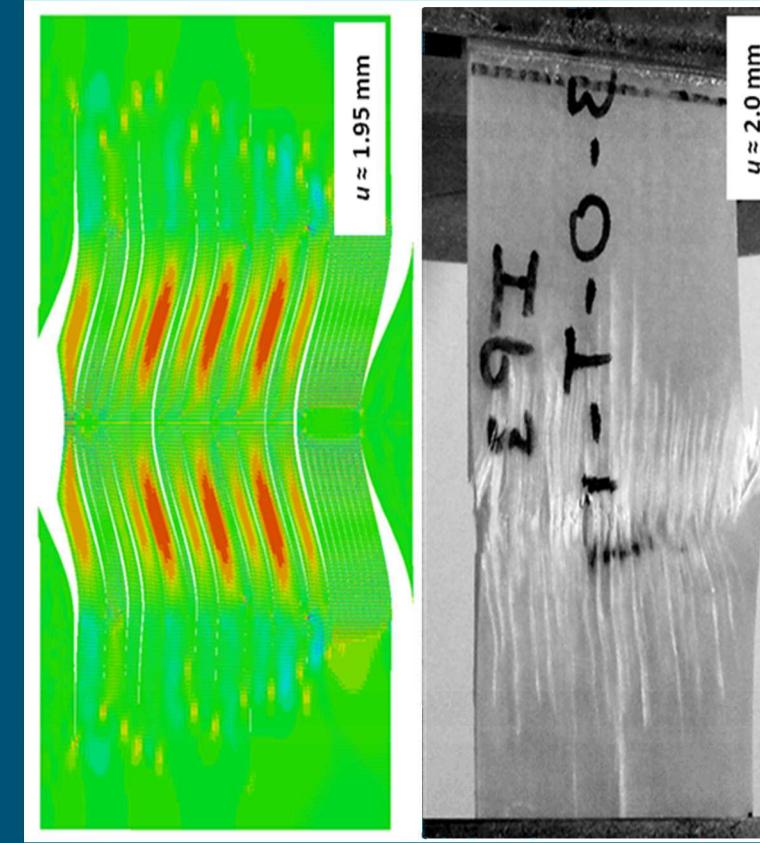
Fatigue Results



Combined CDM & DDM Approach: In-Plane Wave in Tension



Continuum Damage
Modeling

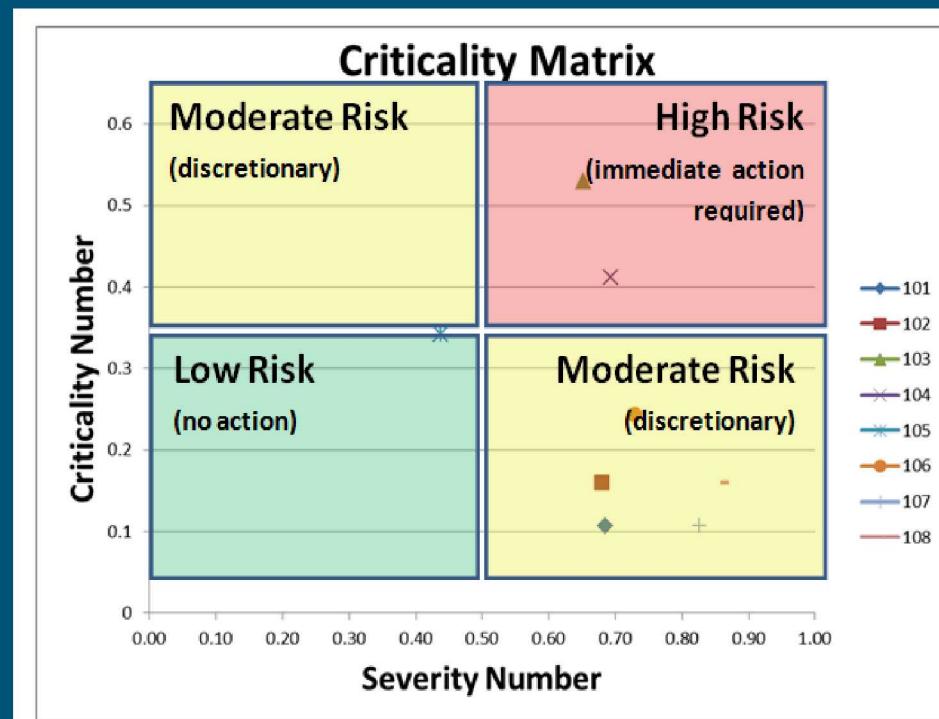


Discrete Damage
Modeling (CZM)

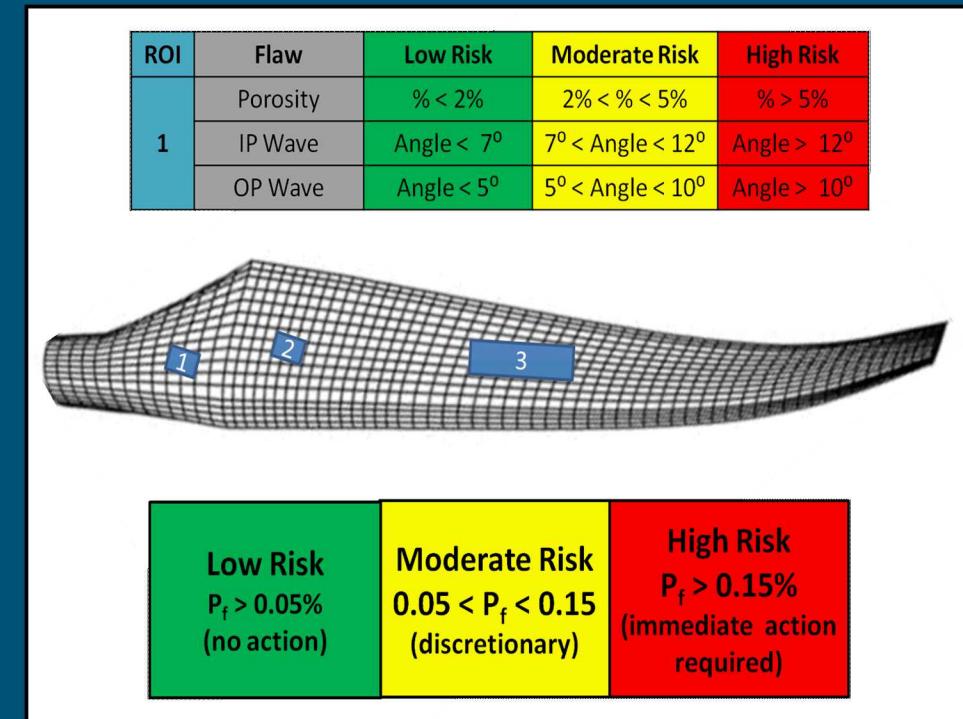
Criticality Matrix

Communicate from designer/engineer to manufacturing/ maintenance technician

- Modeled after NASA/DOD Failure Mode and Effects Analysis (FMEA)
- Risk of operating flawed structure; scrap, repair, operate as-is
- Criticality = Normalized Strain by Location
- Severity = Complement of Flaw Knockdown



Criticality Matrix



Criticality Map

New Design Methodology

IEA Wind Technical Experts Meeting #91: *Durability and Damage Tolerant Design of Wind Blades*

- Bring together wind and aerospace communities
- Develop a vision for how durability and damage tolerant design can be implemented for wind blades

Topics:

- Aerospace Experience and Wind Standards
- Manufacturing & Inspection
- Modeling & Testing
- Operations

<https://community.ieawind.org/home>



IEA TEM #91 Participants, Bozeman, MT, June, 2018