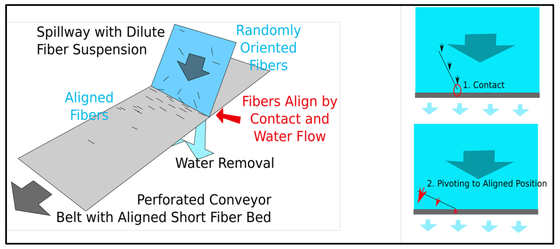
FIBER DEPOSITION IN T*u*FF PROCESS: THE DETERMINATION OF PROCESSING WINDOW

Dr. Pavel Šimáček[1,2], Prof. Suresh G. Advani[1,2], Prof. John W. Gillespie, Jr.[1,2,3]

[1]Center for Composite Materials, [2]Department of Mechanical Engineering,[3]Department of Materials Science, Engineering Department of Civil and Environmental Engineering, Department of Electrical and Computer Engineering, Department of Material Engineering

Introduction

- TuFF Fiber Deposition Allows, in General, Use of Various Fibers
- Process Throughput Depends on Fluid Velocity and Dilution of Fibers
- Is It Possible to Predict Effects of Fiber or Process Condition on Deposition Outcome?
- Possible Complications to Be Predicted by Modeling Include Fiber Breakage, Extensive Deposition Time and Unsuitable Fiber Bending



TuFF Fiber Deposition

Fiber "Landing" Model

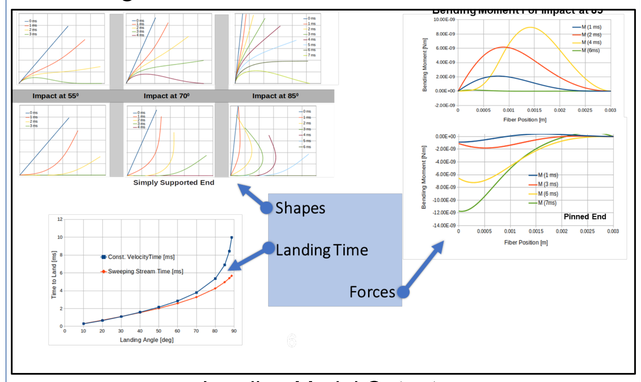
- Fiber Described as Eulerian Beam with Large Displacements
- Conveyor Provides Support
- Fluid Provides Loading Coupled to Fluid and Fiber Velocity Depending on *Re*
- Solves for Loads and Velocities. Velocities Are Integrated into Displacement.

$$N' - k_1 T + C_1(\boldsymbol{v} - \dot{\boldsymbol{u}}).\boldsymbol{g}_1 - \boldsymbol{r}\cdot\boldsymbol{g}_1 = 0 \quad (a)$$
$$T' + k_1 N + C_1(\boldsymbol{v} - \dot{\boldsymbol{u}}).\boldsymbol{g}_2 - \boldsymbol{r}\cdot\boldsymbol{g}_2 = 0 \quad (b)$$
$$M' + T = 0 \quad (c)$$
$$M - EJ\,\boldsymbol{g}_2\cdot\boldsymbol{u}'' = 0 \quad (d)$$
$$\dot{\boldsymbol{u}}'\cdot\boldsymbol{g}_1 = 0 \quad (e)$$
$$r = max(0, -k.u_y) \quad (f)$$

Governing Equations: (a)-(c) Momentum (d) Euler Bending (e) Inextensibility (f) Conveyor Belt Reaction

Data Evaluated by Model

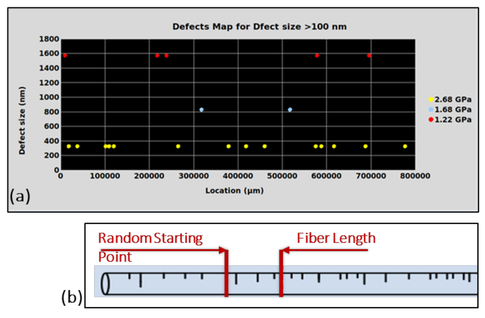
- Solution Tracks Shape and Load of Fiber During Landing
- Additional Data Can Be Evaluated Such as Time to Land or Fiber Fracture If Local Strength is Provided



Landing Model Outputs

Fiber Breakage

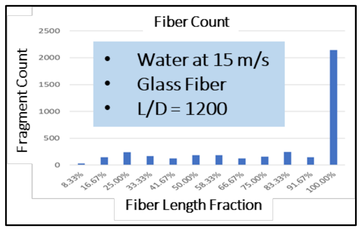
- Local Strength Data is Assigned to Fiber Segments Based on Defect Map
  - Strength is Transferred from Random Section of the Map
  - If No Defect Present, Ultimate Fiber Strength is Used
- Fiber Breaks if *local* Bending Moment Exceeds *local* Strength



Defect Map: (a) Defect Size Converted into Maximal Bending Stress (b) Extraction of Fiber Strength from Map

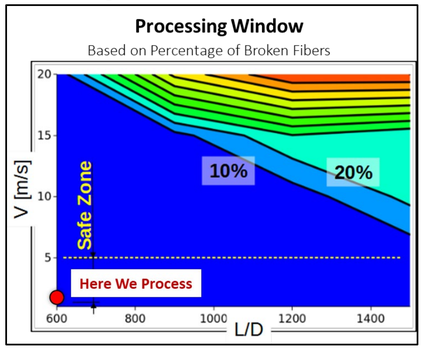
Fiber Fragmentation: Statistics

- Collection of 3000 Random Fibers is Generated and Landing is Modeled
- Random Values Are (i) Strength, (ii) Impact Angle and (iii) End Support



Predicted Fiber Length Distribution

- Count of Fragments Based on Velocity and Fiber Length Can Serve as Processing Window

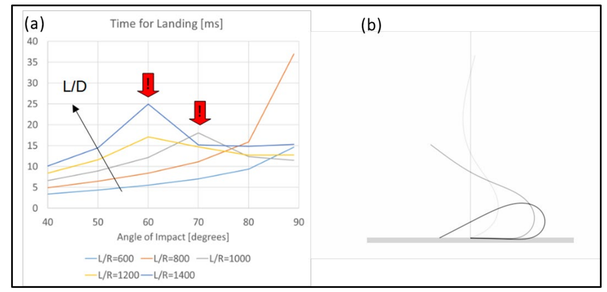


Percentage of Glass Fibers Broken Based on Velocity and Fiber Aspect Ratio (Length)

- **Glass Fiber Fragmentation is Practically Impossible**

Deposition Time

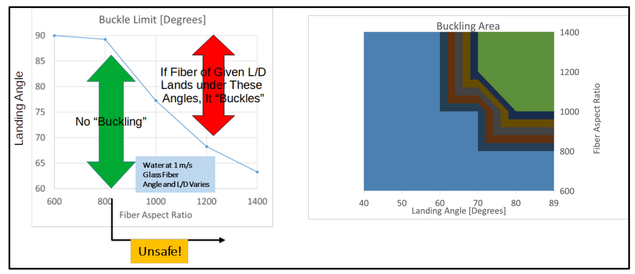
- Deposition Time and Shape Can Be Related to Required Dilution
- Time Depends on Fiber Length and Impact Angle
  - For Large Angle (Orthogonal to Conveyor) Can Be Much Larger Than Length over Flow Velocity
- For Longer Fibers/Higher Velocity Suddenly Drops
- **Undesirable: Fiber Folds (Buckles)**
- **Not Present for Currently Used Lengths**



Landing Time Based on Length and Impact Angle. (a) Peaks Where Time Drops and Fiber Buckles Are Shown (b)Fiber "Buckling"

Time, Folding and Processing Window

- Fiber Folding Depends on Fiber Length, Flow Velocity and Impact Angle
- **We Cannot Control Impact Angle**
  - Thus, We Cannot Process Fibers that Fold at Almost Any Impact Angle
  - Aspect Ratios of 600 (Current) or 800 Seem Fine (Model Accuracy Has Not Been Verified)



Processing Limits for Fiber Length and Impact Angle. Glass Fiber, Flow Velocity 1 m/s.

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