FLOW AND FIBER ORIENTATION MEASUREMENTS OF DILUTE SUSPENSIONS DOWN AN INCLINED PLANE

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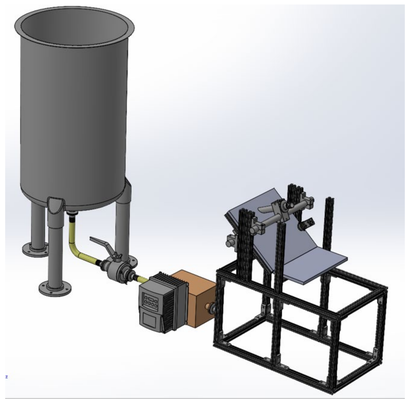
Introduction

Tailored universal Feedstock for Forming (TuFF) aligns short fibers in sheet form. A fundamental understanding of the fiber rotation can lead to improved processing for higher throughput and alignment quality.

Objective: Collect and analyze data on the distributions and orientations of fiber suspensions flowing down an inclined plane.

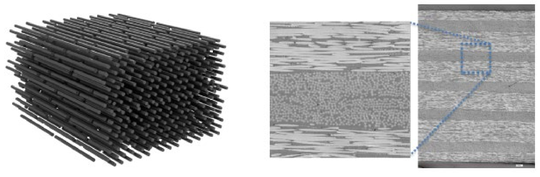


A

[A] CAD model of the experimental set up, consisting of a 20-gallon holding tank, water hoses, and 12” by 12” acrylic spillway incline plane

Background

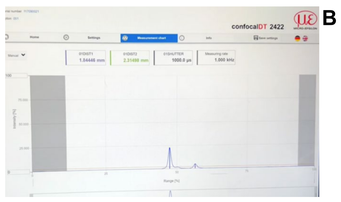
TuFF material is created with discontinuous fibers that are aligned to create sheets and can be converted into prepregs to manufacture composites by forming methods with properties like continuous fiber composites[1].



(a) TuFF alignment at microscopic level

Methods

- **Water Film Thickness (WFT) Study**
  - Utilizing Micro-Epsilon data processing software and Confocal DT IFS2406 sensors, data points were recorded at 50+ locations on the spillway (**B**). A closed loop system pumping a consistent flow was created to allow for consistent data acquisition. The data points were then analyzed using MATLAB to simulate the overall flow of water thickness across the spillway. Thickness measurements at the outer edges of the fountain flow were not captured accurately due to the depth of water film measuring at heights greater than 3 millimeters, which is the threshold of measurement for the sensor.
- **Fiber Orientation and Distribution (FOD) Study**
  - In order to measure the orientations and distributions of fibers, a suspension of carbon fibers and water was created to mimic the fiber density of production fiber suspensions. As the suspension travelled down the acrylic spillway at a constant flow rate, a high-speed camera was used to record 500 images at 100 and 4000 frames per second. Overall, a total of 108 sets of images were captured and 40 sets have been processed thus far (**C**).
- **Velocity and Depth Correlation (VDC) Study**
  - Using the data acquired in the WFT and FOD studies, the VDC study began to validate the hypothesis of fiber behavior along its journey on the spillway. Flow analysis confirms that fibers travelling closer to the surface of the water film travel at a higher velocity than fibers travelling at a lower depth within the water film. This study tracked positions of various fibers at varying depths along the central loci of the spillway across a series of continuous frames (**D**). The respective velocities were then calculated and plotted to observe the patterns of fiber travel against time.



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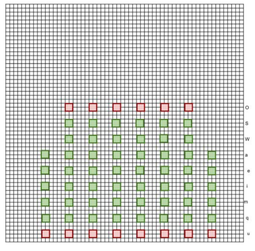

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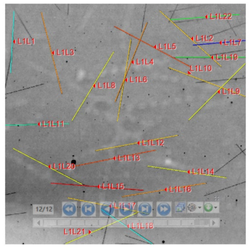
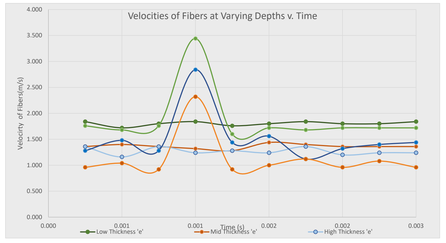


D

[B] Image processing of water thickness using με software, peaks shown on screen depict the thickness of the water film
[C] Grid of positions measured on the polyacrylic spillway; red indicates positions in need of reimagining
[D] Image Pro software processing a series of 12 frames to measure fiber velocities

Results and Analysis

- **Water Film Thickness (WFT) Study**
  - Using MATLAB plotting, the thickness of the water film was mapped. The mapping provided a spatial map of water volume along the spillway (**F**).
- **Fiber Orientation and Distribution (FOD) Study**
  - Using MATLAB plotting, the fiber distributions and degree orientations were created. The analysis showed that as the fibers travel closer to the center of the spillway, they are more aligned.
- **Velocity and Depth Correlation (VDC) Study**
  - With the data collected in the FOD and WFT studies, the correlation of fiber depth, fiber velocity, and time was observed. The VDC study was able to validate the theory that the depth at which fibers travel directly affects the velocity at which they travel (**E**).



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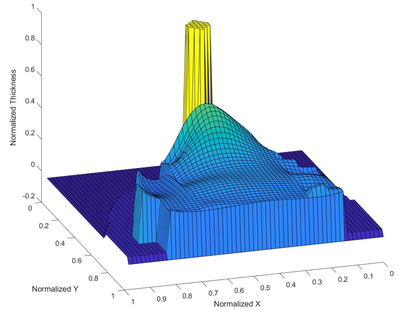


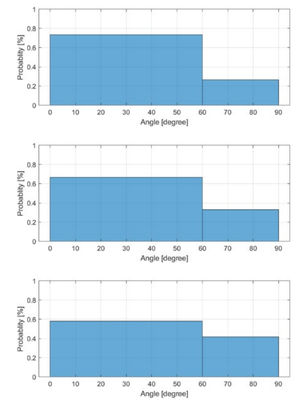
F

[E] Velocity of Fibers travelling at different depths through the water film plotted against the time travelled down the plane
[F] 3D Plot of water thickness mapping

Conclusion

Using mathematical principles and image processing, it was observed that the fiber orientations and distributions across the spillway are more aligned between 0 and 60 degrees towards the middle of the spillway where the flow is more laminar (**G**). The flow on the outer edges, where we were not able to measure the thickness, is more turbulent, the fiber orientation was greater than 60 degrees.

The alignment of this fibers can be further manipulated, and the orientations further adjusted, by introducing obstacles or hindrances on the plane. This will create a new channel of flow for the fibers to reorient as they travel down the acrylic spillway. Adjustments of the obstacles as well as their locations on the plane will be added as the project progresses to the next stage.



G

Acknowledgements and Contact Information

The authors would like to thank, Dr. Simacek and Dr. Deitzel of the Center for Composite Materials. This work is supported by Composite Automation LLC under STTR prime contract # W911NF21C0034.