SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Vincent DiFilippo
FACULTY ADVISOR:	Dr. Hirotaka Sakaue
PROJECT PERIOD:	Spring/Fall 2022
PROJECT TITLE:	Optimization of Noise Reduction of a Propeller using Microfiber Coating for Wind Turbine Applications
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**( ) Energy Conversion and Efficiency** **( ) Smart Storage and Distribution** **( ) Sustainable Bio/Fossil Fuels** **( ) Sustainable and Secure Nuclear** **( ) Transformation Solar** **(X) Transformative Wind**

MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Collect Sound Level Data (dB) for a Propeller with Microfiber Coating Applied at Different Locations Along the Blade	Data was collected for the unaltered blade as well as 20 microfiber configurations at 13 rotational speeds. The spanwise and chordwise positions of the microfiber were varied, and both high- and low-density microfibers were tested in each configuration.	100%
Analyze Sound Level Data to Locate Effective Microfiber Locations Along the Span and Chord	I analyzed the data using Matlab, identified trends in data of effective and ineffective microfiber configurations at various speeds, and proposed mechanisms for noise reduction.	100%
Present Results at APS DFD 2022 Conference in Indianapolis, IN	I plan to present my results at the March 2023 FlowPAC meeting at the University of Notre Dame and receive feedback for additional research areas and improvements to data collection.	0%

RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS SUBMITTED	
EXTERNAL AWARDS RECEIVED	
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	FlowPAC March Meeting, "Microfiber Coating as a Noise Reducing Device for a Propeller Blade," Planned 03/01/2023, Hessert Lab for Aerospace Research, University of Notre Dame.
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	
INTERNAL COLLABORATIONS FOSTERED	Dr. Mitsugu Hasegawa, University of Notre Dame, expertise in applications and manufacturing of microfiber coating, weekly interaction.
EXTERNAL COLLABORATIONS FOSTERED	
WEBSITE(S) FEATURING RESEARCH PROJECT	
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models, curricula, instruments, education programs, outreach for ND Energy and other groups)	

RESEARCH EXPERIENCE

Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?

The Slatt Fellowship gave me a great opportunity to continue the research I had started during the Summer 2021 semester. This experience helped form my decision to go to graduate school by giving me a preview of the type of work I will be doing next year. I gained experience designing experiments, carefully collecting data, and finding patterns in the data during analysis. Attending weekly meetings with Dr. Sakaue and Dr. Hasegawa and biweekly meetings with Dr. Sakaue's team helped me focus my research and learn about the other projects being completed at the lab. Dr. Sakaue and Dr. Hasegawa were very helpful during the entire project and provided me with expertise and guidance when I had questions.

During the project, I experienced some logistical difficulties due to scheduling conflicts with other projects and the sensitivity of the experiment. In order to collect good data efficiently, I needed long blocks of time with relatively consistent background noise. Data collected under different conditions would make it impossible to distinguish the noise-reduction effects of the microfiber from changes in noise due to other environmental factors. I had to coordinate with other projects that produced noise to agree on times where I could operate my experiments without noise interference and also find large blocks of time in my class schedule to work. More data could have been collected in the same time period if it were not for these conflicts. The data analysis phase of the project ran smoothly since I could do it on my personal laptop.

FINAL WRITTEN REPORT

Noise generation is a fundamental problem in aerodynamics that has an impact on a wide range of technologies including wind turbines. Noise is produced by fluctuations in pressure generated by the unsteady flow conditions surrounding a wind turbine and is proportional to the magnitude of the pressure fluctuations. The flow field surrounding a wind turbine can be altered by passive flow control devices, which are applied to an aerodynamic surface and do not require input power. The flow control device studied in this project is a microfiber coating, which has been previously studied by Dr. Sakaue and Dr. Hasegawa as a drag reduction device for blunt bodies. The microfiber coating controls the flow by changing the boundary layer characteristics around the body resulting in breaking up large von Kármán vortices normally present downstream in the flow. A sketch of this mechanism is shown below in Figure 1.

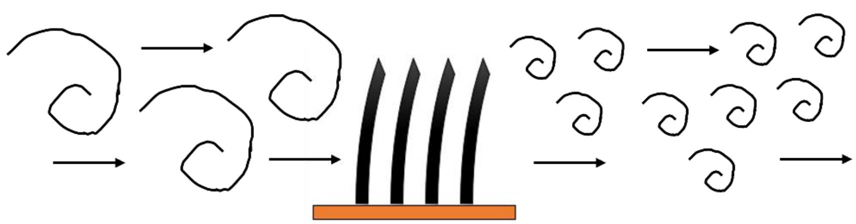
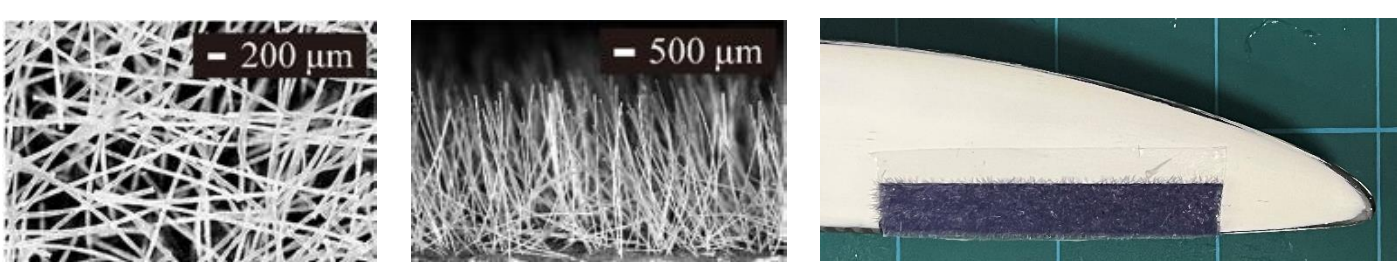


Figure 1. Proposed interaction between vortices and microfiber coating.

The focus of this project was to determine the noise reduction characteristics of the microfiber coating. To study the effects of the microfiber coating in different geometry, the 8" radius blade was divided into 1" segments, and 2" long rectangular sheets of microfiber coating was applied symmetrically on both blades along the blades' spans. The width of the sheets was one third of the mean aerodynamic chord of the blade, and the coating was either applied to the first chord of the blade, or on the leading edge; or on the last third of the blade, or the trailing edge. Each of the 10 geometries studied was tested at 13 rotational speeds and compared to a baseline test from the same test day where no microfiber coating was applied. Additionally, low- and high- area density fibers were studied to measure the interactions between fibers. If too few fibers are used, then the coating will have little impact on the flow, and if fibers are too densely packed, then the fibers will essentially alter the shape of the blade instead of serving as a permeable flow control device, contributing to increased noise generation. Magnified views of the microfiber and an example configuration are shown below in Figure 2.



a) **b)** **c)**

Figure 2a) Magnified view of microfiber (top) **b)** (side) and **c)** example microfiber coating geometry TE 5-6.

The data was collected in Hessert Laboratory at the University of Notre Dame and processed to yield the change in sound level due to the microfiber, ΔSL (dBA). Because the goal of the project is to reduce the noise heard by humans, the A-weighted decibel scale was used, which assigns weights to frequencies corresponding with the intensity they are heard by the human ear. After performing uncertainty analysis in prior testing, reductions or increases in sound level in magnitude greater than 0.5 dBA can be confidently attributed to the application of the microfiber coating.

The remainder of the report will be posted on the website once the data has been published by Dr. Hirotaka Sakaue (hsakaue@nd.edu).