# Structural Optimization for Automated Fiber Placement (AFP)

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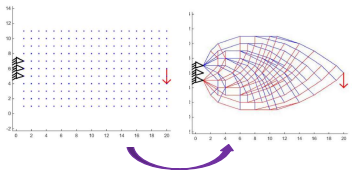
## Automated Fiber Placement

- Used in industry
- Able to make massive structures
- Material and process benefits

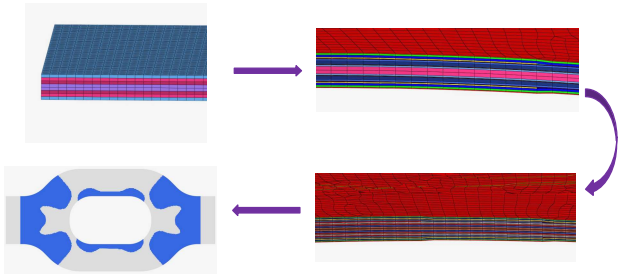

## Structural Optimization

- Create a design space
- Optimize an objective function
  Subject to constraints
- Objective functions like:
  Mass
  Stiffness
  Resonant Frequency
- Constraints like:
  Peak Stress
  Peak Displacement
  or, Also Mass



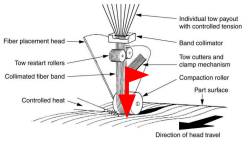
## Composite Design Process

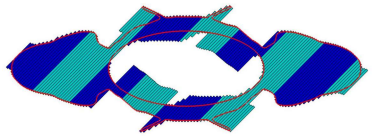
- Set up design space
- Carry out freesize optimization
  Result not manufacturable
- Carry out composite size optimization
- Shuffle plies for stacking sequence requirements



## Minimum Tow Length

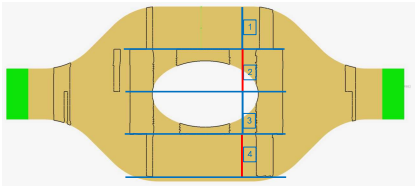
- Current process does not account for manufacturing limitations
- All AFP equipment has a minimum length it can lay down
- Distance from knit point to internal cutting module



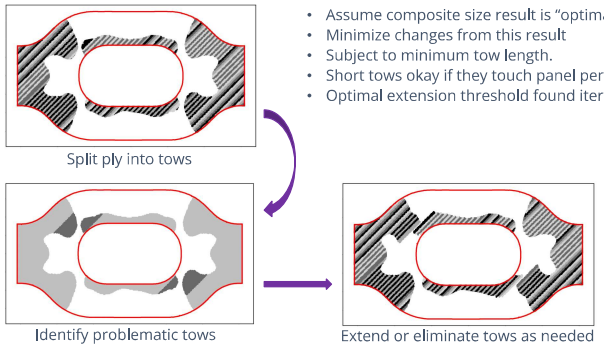
## Current State of Art

- Optistruct has a minimum tow constraint built into it
- Does not work well
- Over constrains the design space
- Only generates tows of multiple of minimum length



## Novel Constraint Implementation

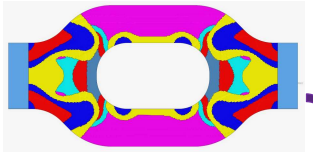
- Assume composite size result is "optimal"
- Minimize changes from this result
- Subject to minimum tow length.
- Short tows okay if they touch panel perimeter
- Optimal extension threshold found iteratively



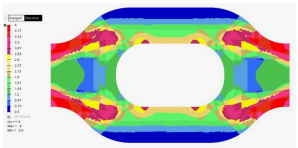

## Results and Analysis

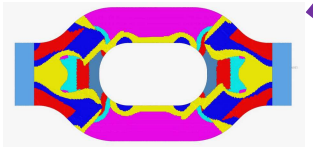
- All plies modified for AFP
- Mass increased by 1%
- 1% reduced maximum displacement
- Unexpected buckling failure mode
- Meets design criteria!

Before and after constraint application



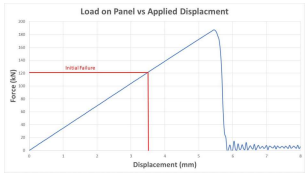
Contour map of panel thickness



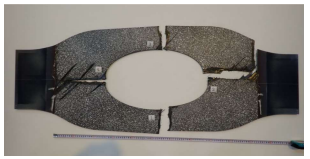


Compressive failure mode in fibers






Simulation matches experimental Results [1]



Failure loads of different process stages

| Criteria | Failure Load |
|---|---|
| Design | 100kN |
| Free size (Tsai-Wu) | 103kN |
| Composite Size (Tsai-Wu) | 112kN |
| Explicit Sim, Initial (Hashin) | 121kN |
| Explicit Sim, Ultimate (Hashin) | 187kN |

## Future Work, References, and Acknowledgments

- Implement 3d mesh functionality
- Manufacturing demonstration in ACC
- Improve threshold optimization

Faculty: Marco Salviato, Francesco Deleo, Jeff Wollschlager

[1] Y. Aoki, S. Sugimoto, Y. Iwahori, and T. Nakamura, "Manufacturing and evaluation of an optimized composite panel with a cutout," 33rd Technical Conference of the American Society for Composites 2018, pp. 1350–1357, Jan. 2018.

[2] W. Prager, "Nearly optimal design of trusses," Computers & Structures, vol. 8, no. 3, pp. 451–454, 1978

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