sampe

Conference & Exhibition

SAMPE 2020

Virtual Presentation Series

sampe
Conference & Exhibition

Investigation Of The Temperature Influence In The Context Of Automated Fiber Placement Layup On Doubly Curved Tools

Alex Brasington
Graduate Researcher
University of South Carolina McNAIR Aerospace Center

Welcome Slide

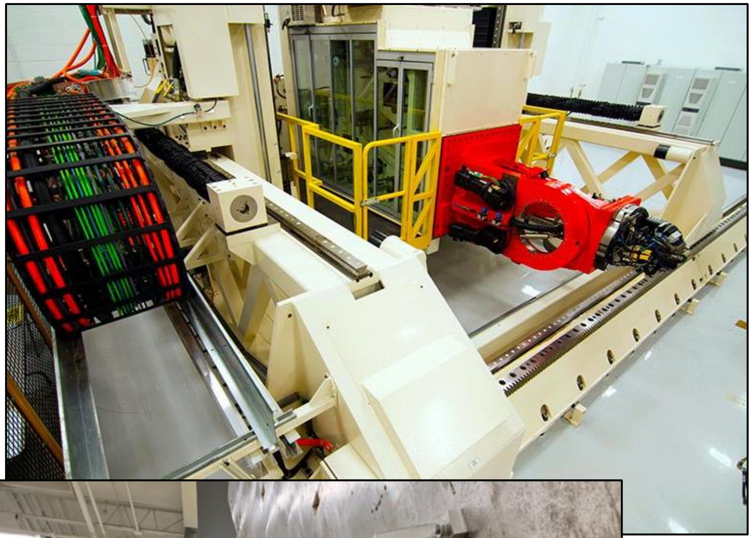
- Alex Brasington
- UofSC McNAIR Aerospace Center
- Graduate researcher
- I am a part of Dr. Ramy Harik's New and Emerging X Technologies (neXt) research team
- My research focus is advanced manufacturing of composite materials (automated fiber placement)

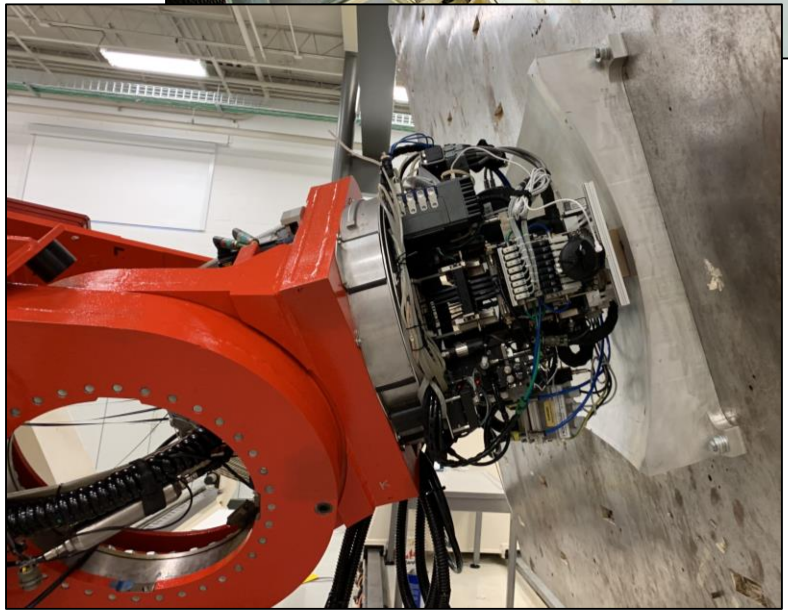
Outline

1. Introduction
2. Experimental Procedures
   - Experimental setup
   - Experimental procedures
3. Results
   - Single course layup trials
   - Surface layup trials
4. Discussion
5. Conclusion

Introduction

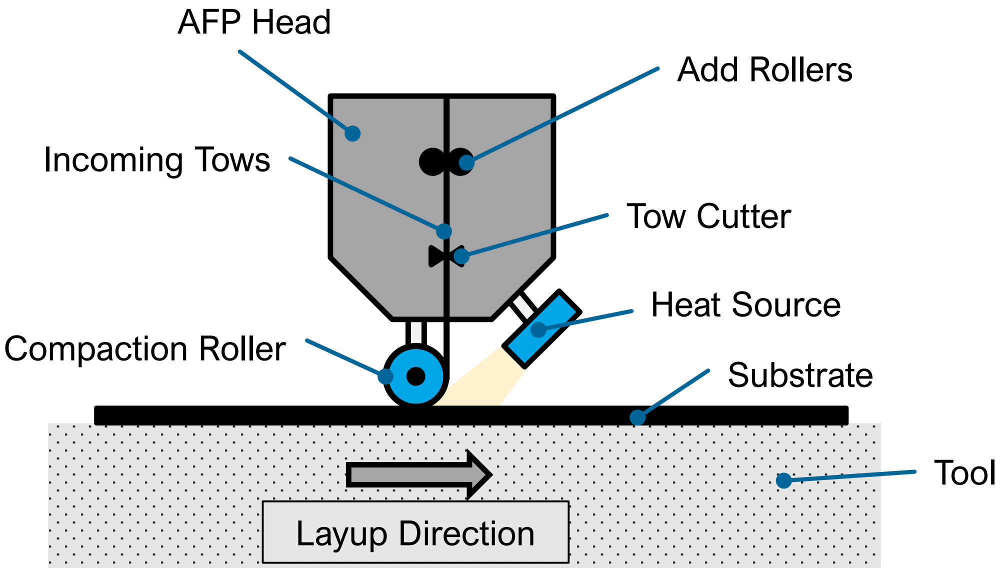
- Automated Fiber Placement is a composite manufacturing technique
- Machine advancements are leading to manufacturing increasingly complex shapes
- The effects of tool geometry are not fully understood
- **Temperature** is a crucial process parameter to achieve quality layups





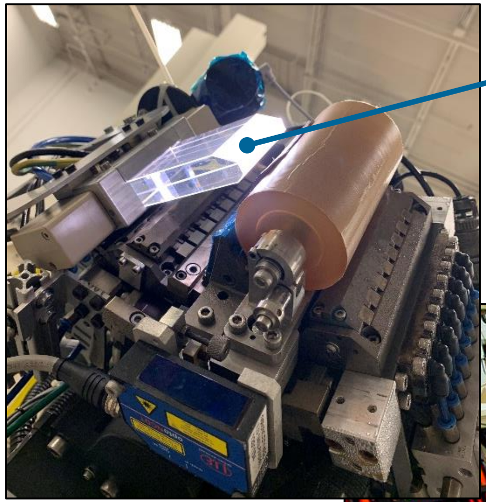
Introduction

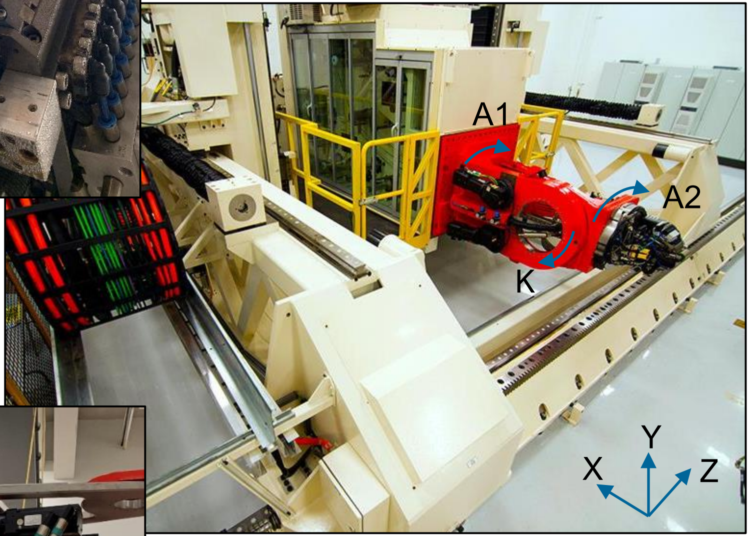
- Proper temperatures lead to **increased adhesion** and **higher overall part quality**
- Temperatures must be high enough to ensure **adequate tackiness**, but not so high that material degradation occurs
- Importance of sufficient temperature is increased when laying up on **complex tools**

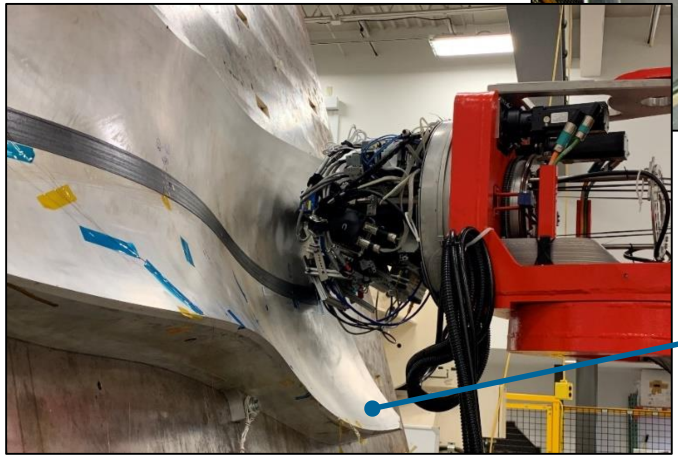


Experimental Setup

- Ingersoll Machine Tools Lynx AFP machine
- 3 linear axes (X, Y, Z) and 3 rotational axes (A1, K, A2)
- Humm3® head attachment for heat source
- 8 6.35 mm (0.25 in) tows used for each course
- Doubly curved tool



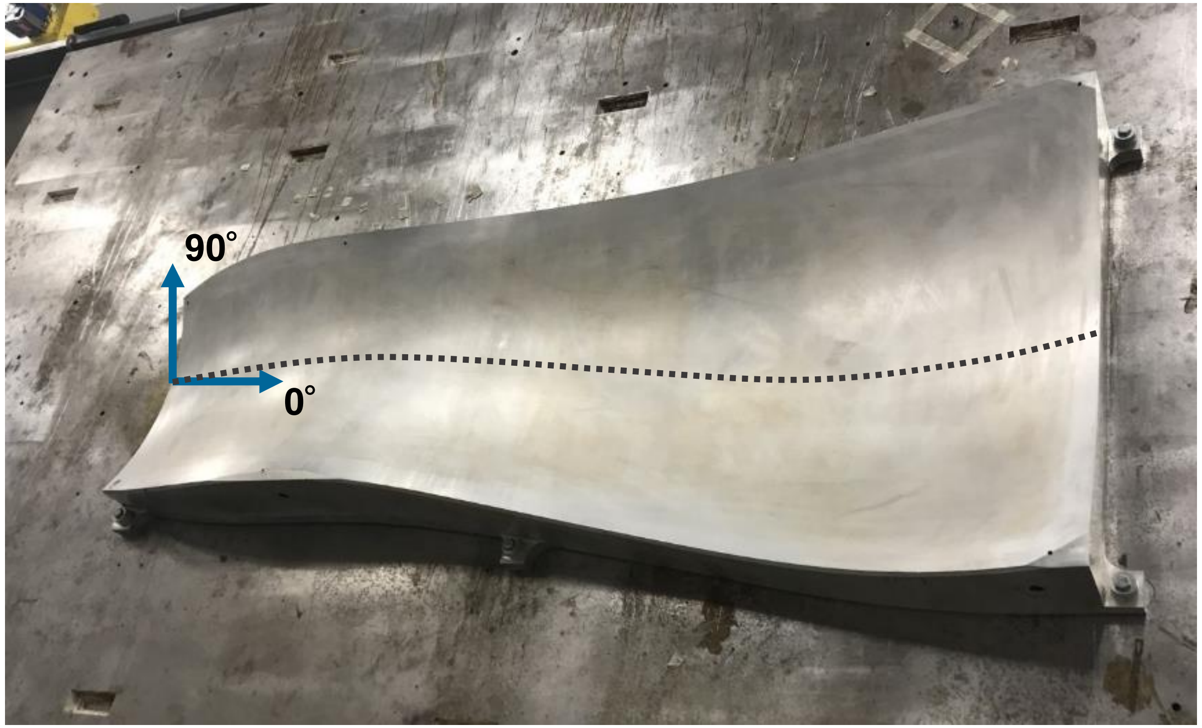




sampe
Conference & Exhibition

Experimental Setup

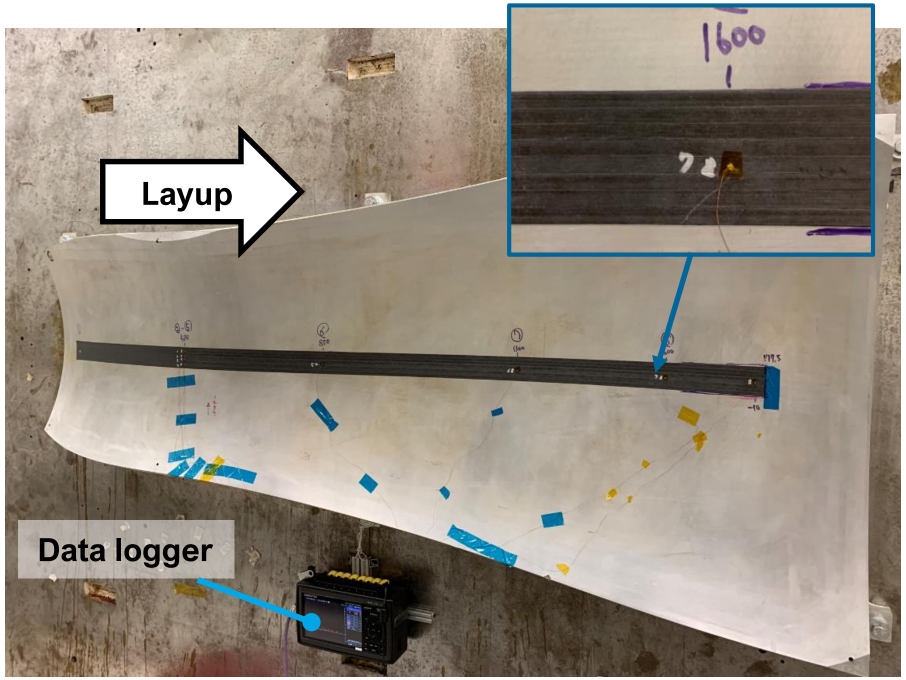
- Doubly curved surface with varying curvature in zero direction
- Allows for experimentation with various curvature values on same tool
- Multiple substrate layers required due to aluminum tool absorbing applied heat



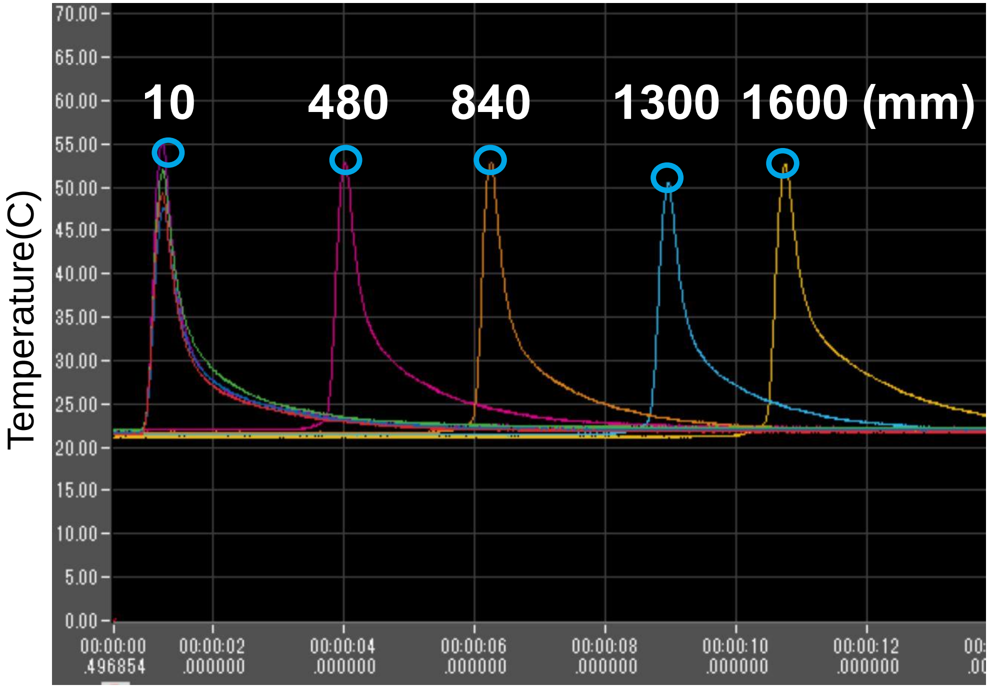
Experimental Setup

- K Type sensor probe thermocouples (0.1 mm diameter)
- Graphtec GL980 used to record data with high sampling rate

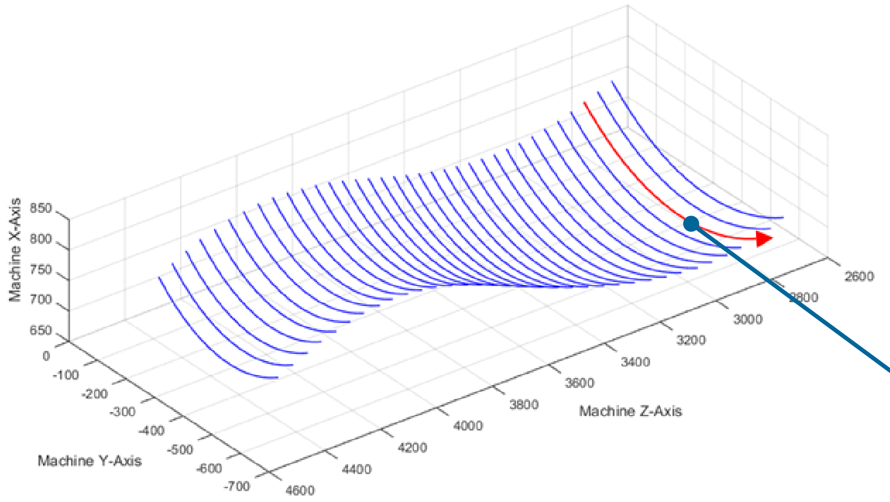
Thermocouple

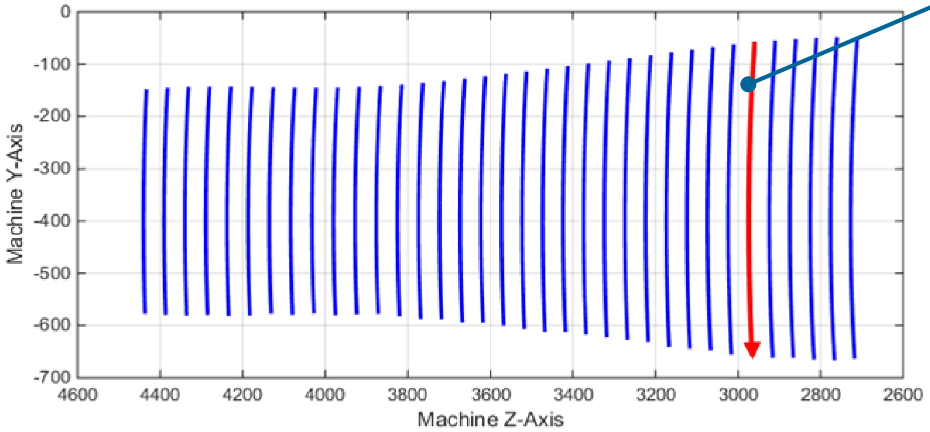


Temperature profile collected with Graphtec



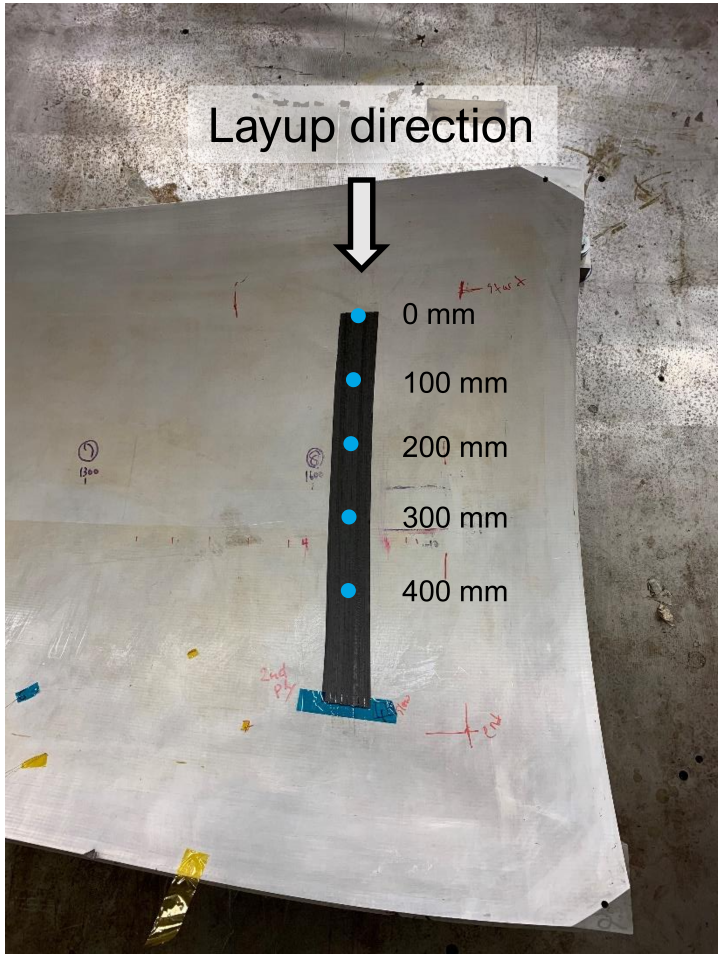
Experimental Procedures



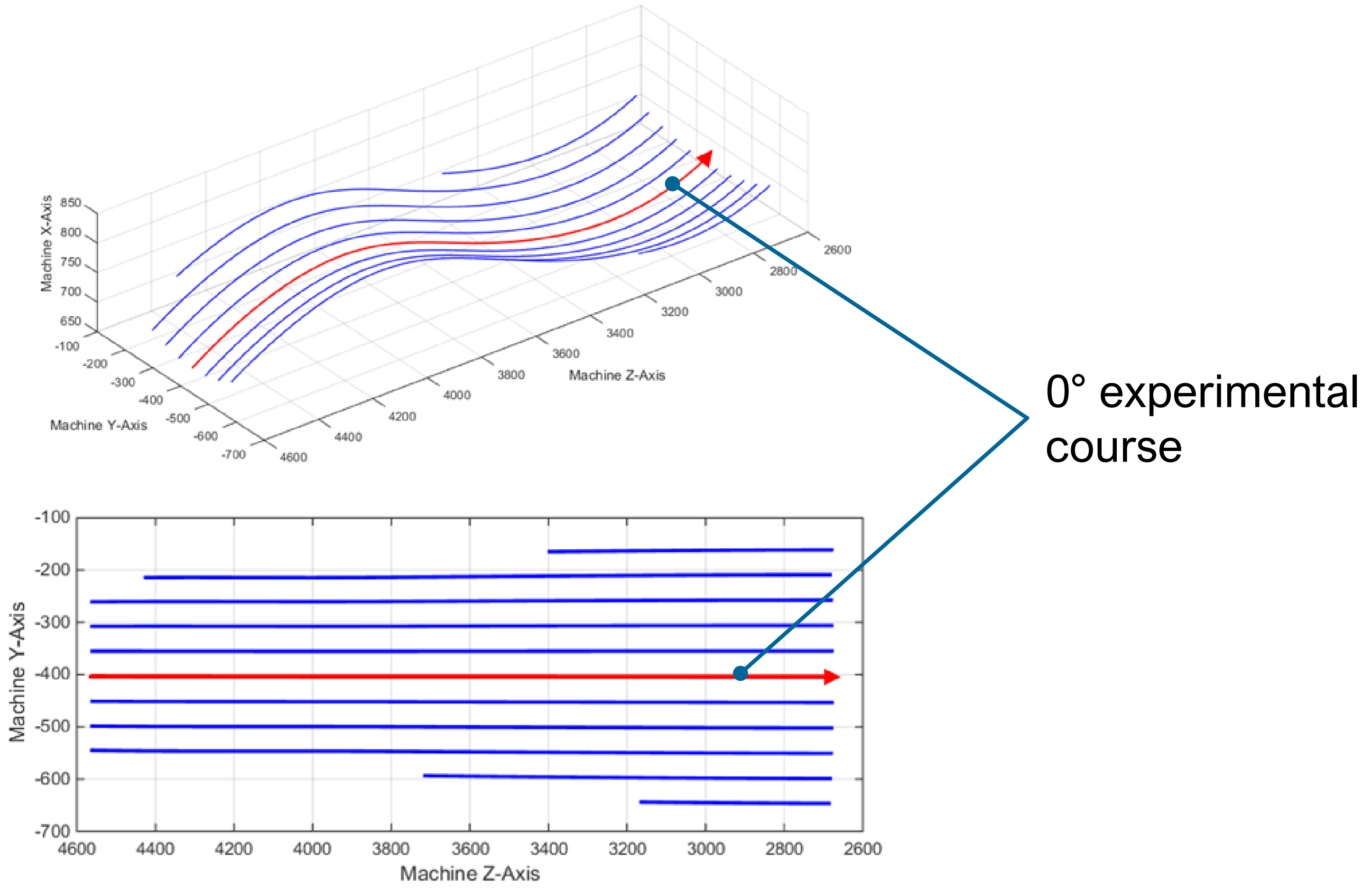


90° experimental course

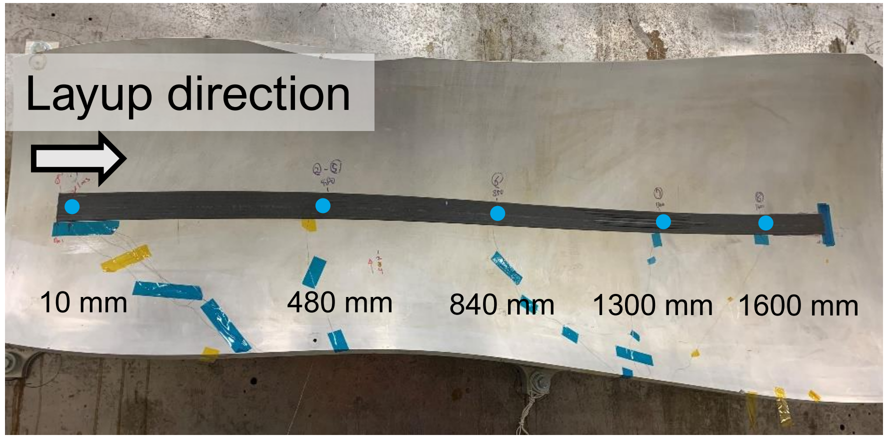
Thermocouple Locations



Experimental Procedures

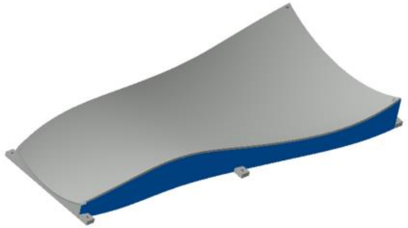


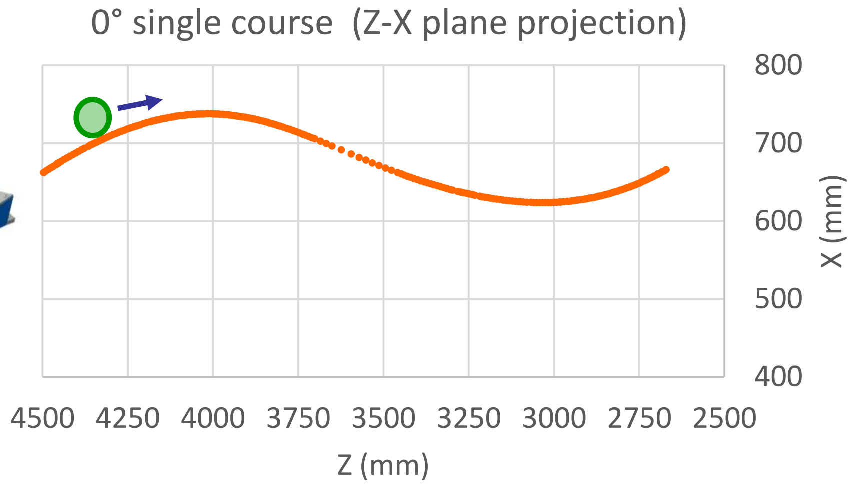
Thermocouple Locations

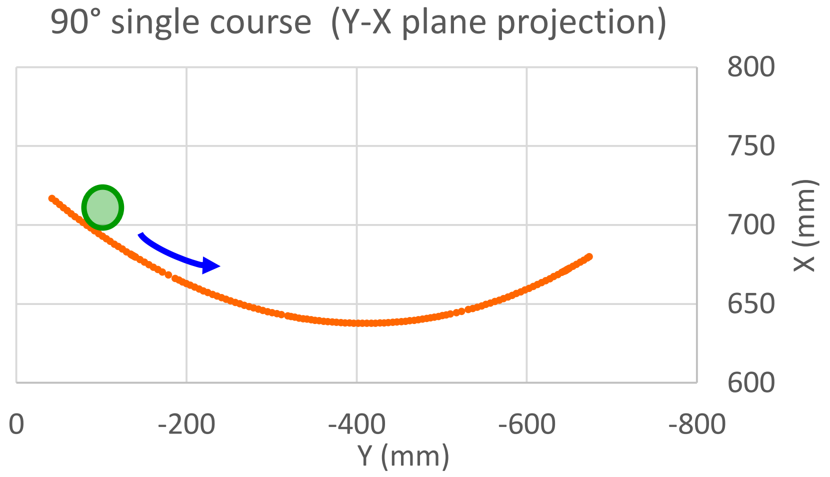


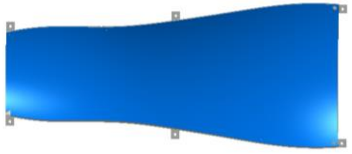
Experimental Procedures

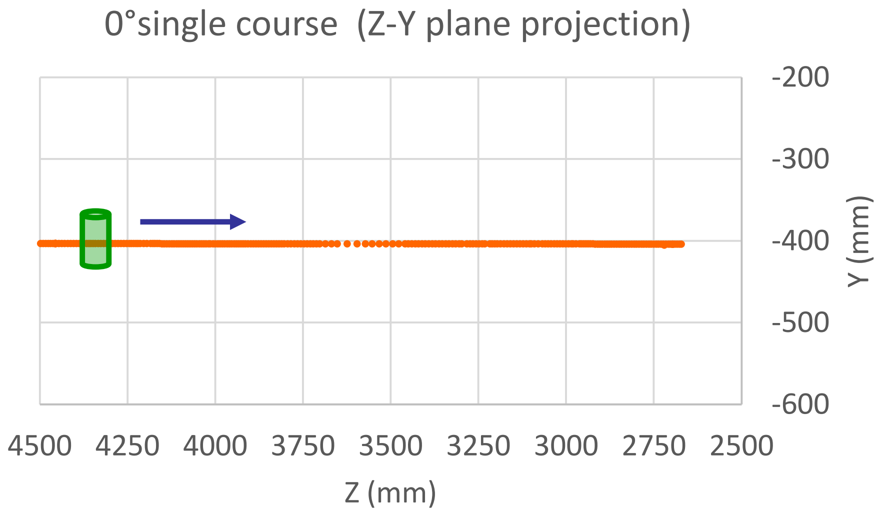
- Experimental course projections

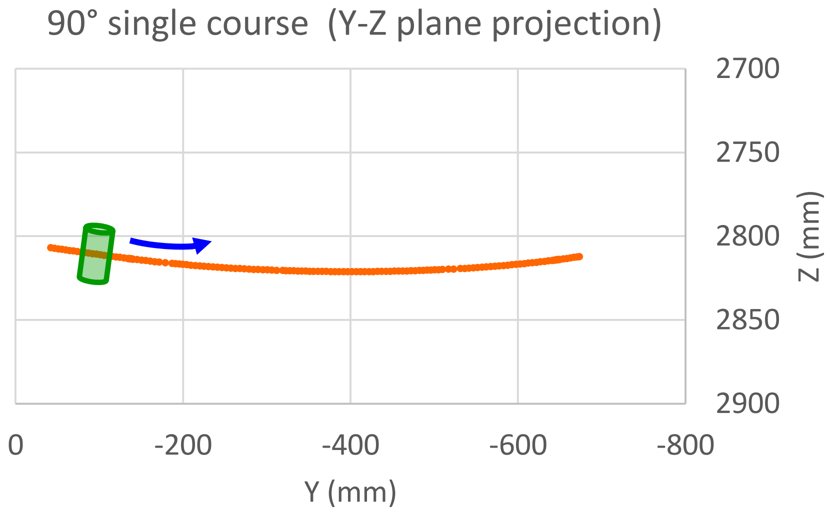












Experimental Procedures

- 2 materials with different properties
- Voltage for Humm3 was changed to achieve desired temperatures
- Other process parameters remained constant

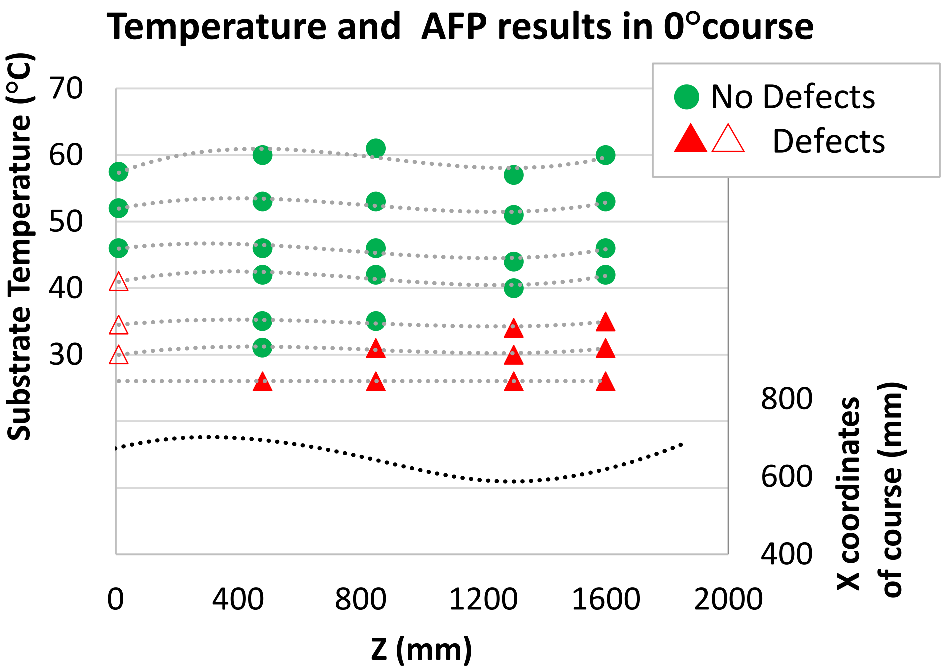
Materials
Material A
Material B

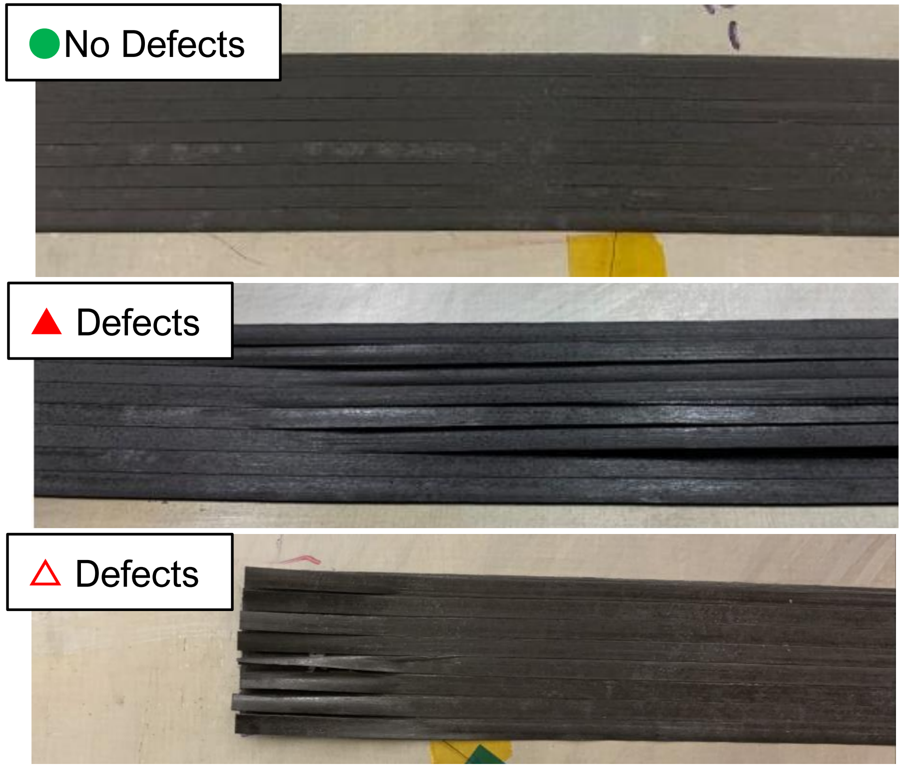
HUMM3 Settings	
Pulse Frequency	60 Hz
Pulse Duration	2000 ms
Voltage	Changed based on observations

Process Parameters	
Compaction Force	100 lbs
Feedrate	10 m/min
Tow Tension	3 N
Temperature	Varies

Results – Single Course Layup

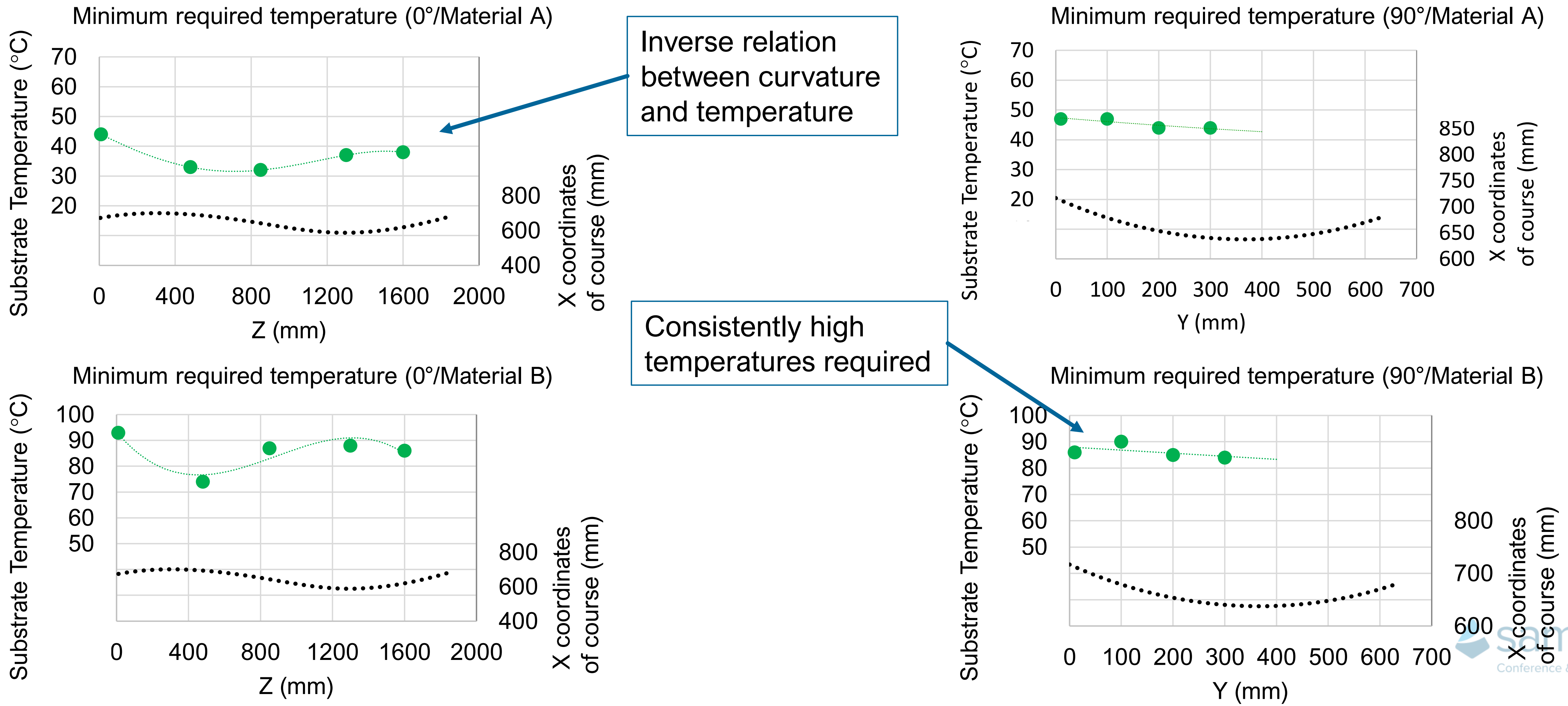
- Temperature results were plotted and categorized based on defect type
- This was used to find the lowest possible temperature at each point





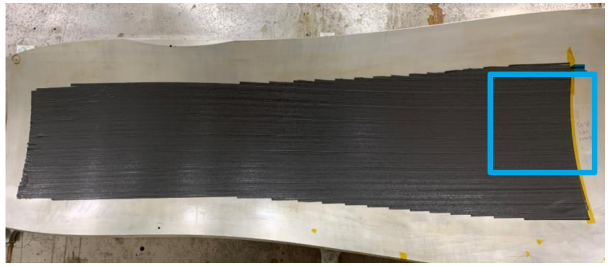
Results – Single Course Layup

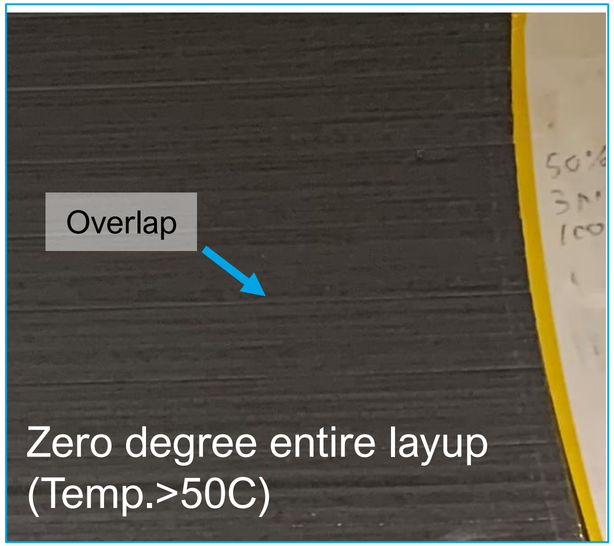
- Minimum required temperatures



Results – Surface Layup

Zero degree entire layup

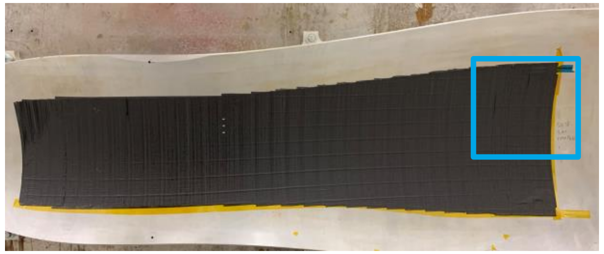


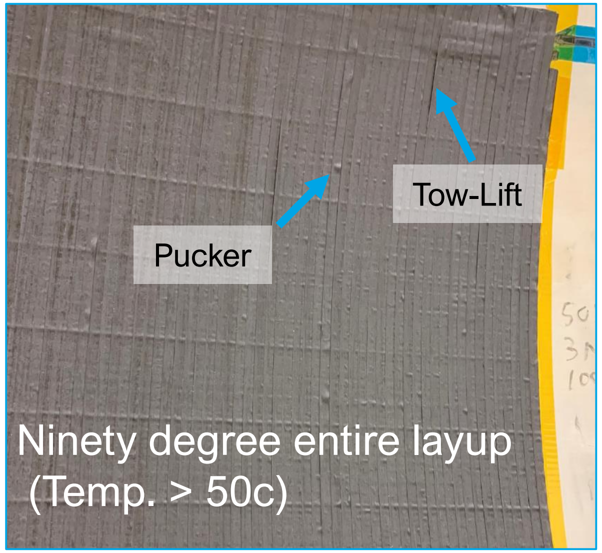


Zero degree entire layup
(Temp.>50C)

- Minimal defects
- Defects are due to tool geometry not temperature

Ninety degree entire layup

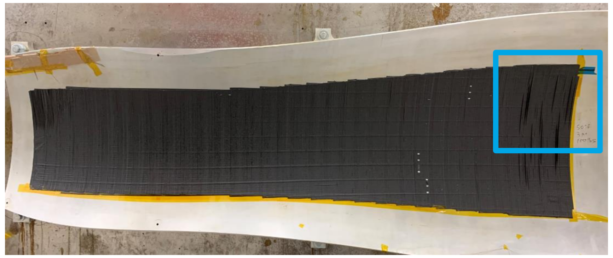


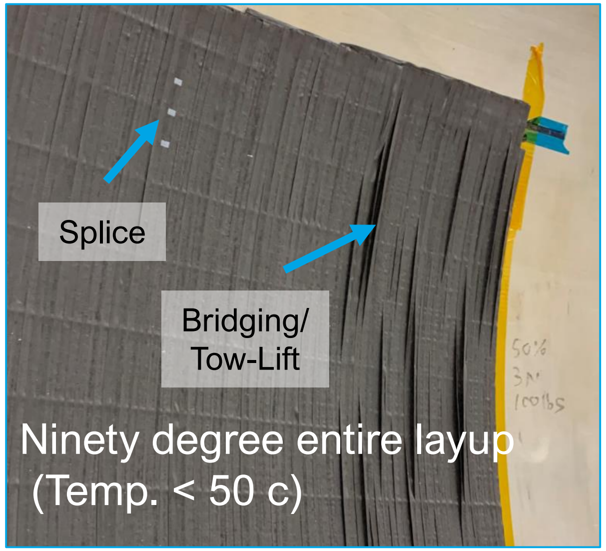


Ninety degree entire layup
(Temp. > 50c)

- Defects due to concave geometry
- Temperature high enough for complete tack

Ninety degree entire layup



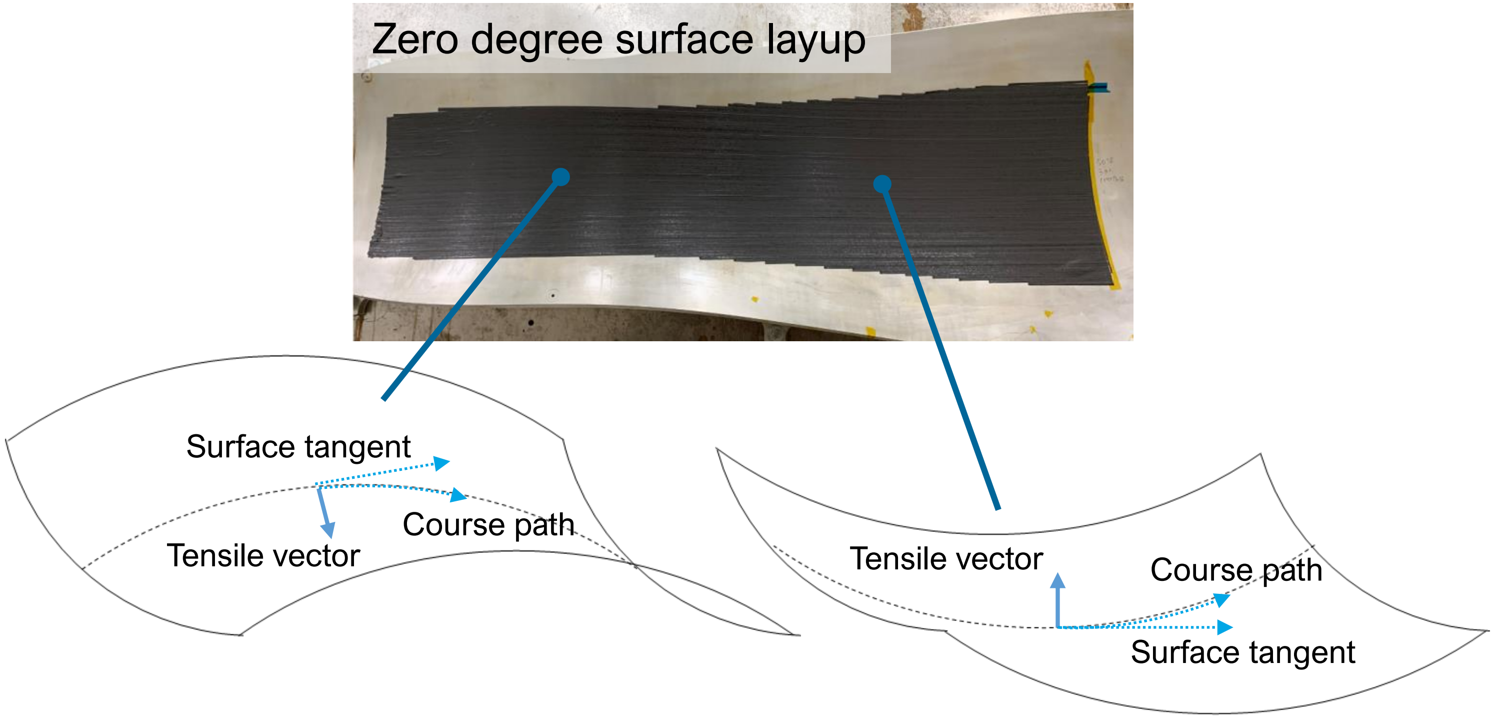


Ninety degree entire layup
(Temp. < 50 c)

- Severe bridging
- Temperature not high enough for tack
- Combined effects from geometry and temperature

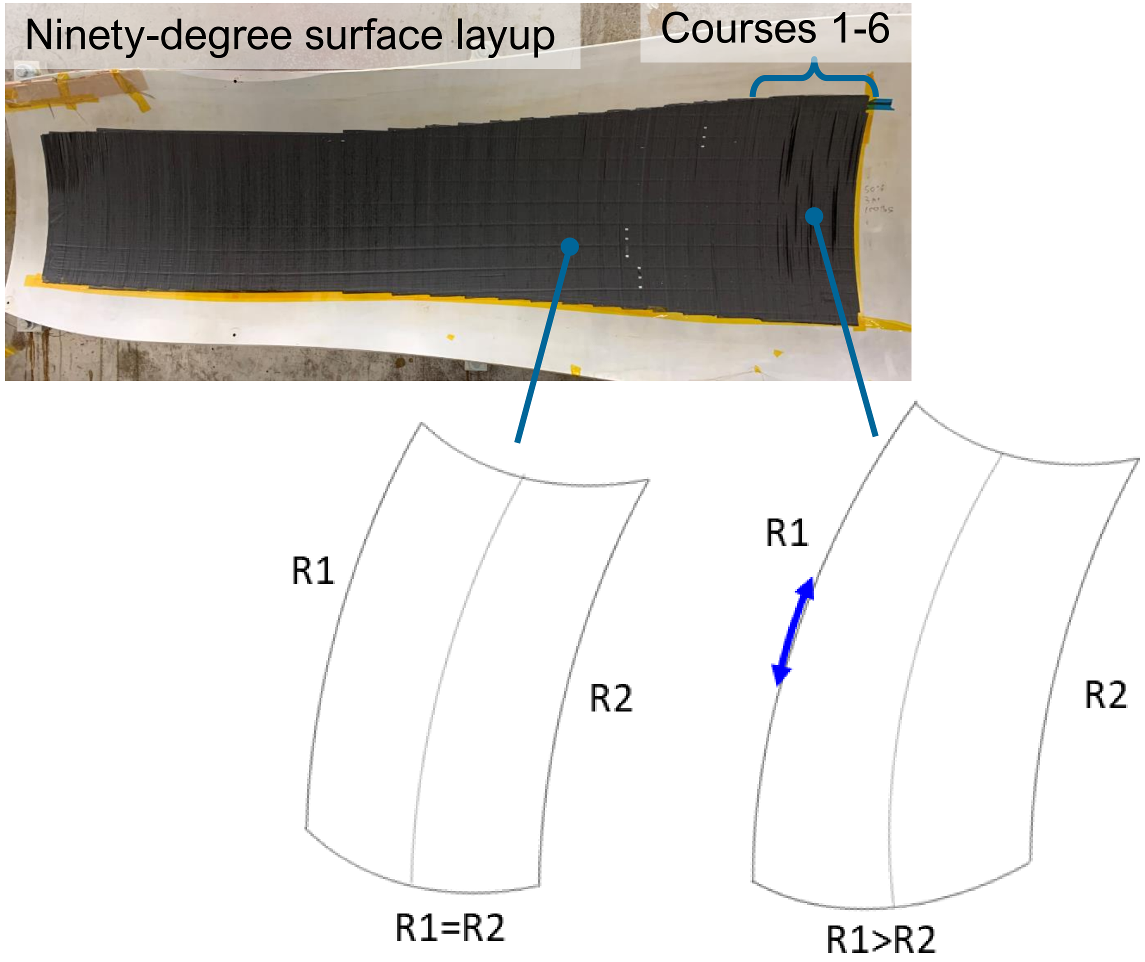
Discussion

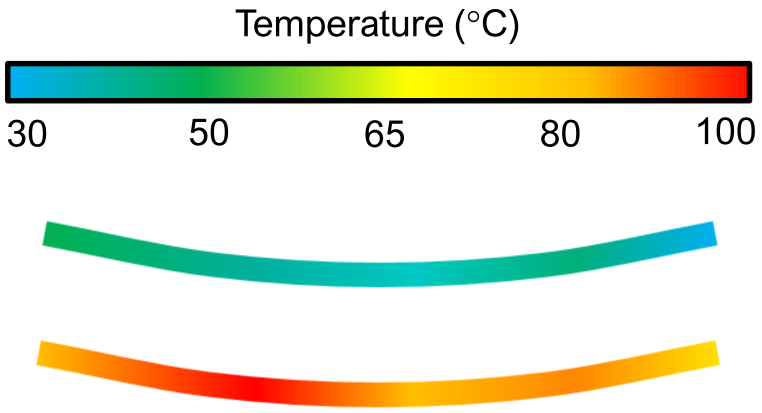
- Tool curvature creates tow tension and tensile strain
- Tensile vector in convex areas is towards substrate
- Concave areas result in tensile vector away from substrate
- This results in higher temperatures needed in concave areas



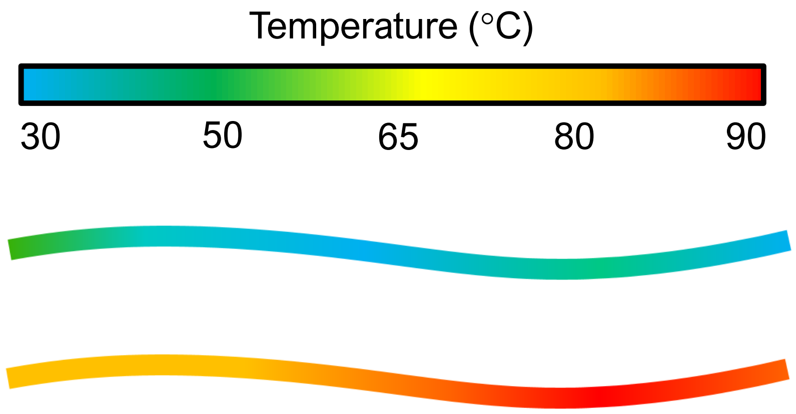
Discussion

- Guide curve projection creates induced steering
- Bridging/tow lift up occurred at the outside of the course, particularly on 1-6
- Defect caused from combination of steering and curvature
- Steering causes tensile strain at the outer edge of the curved tows





Conclusion



- Accurate evaluation of processing temperatures on a double curved tool were achieved
- Bridging/tow-lift defects occurred not due to heating deviation, but course shape geometry
- Concave areas with lower curvature radii need higher temperature for tow placement without defect occurrence
- Tensile strain in the tow while being placed on a curved path and a curved tool lead to insufficient adhesion
- Validated with entire ply layup with less defect occurrence and machine stoppages

Acknowledgements

Thank you to Tsuyoshi Saotome, Shingo Miura, Andrew Anderson, and Ramy Harik for the leadership and support throughout this project

Thank you for your attention!

Alex Brasington
Graduate Researcher
University of South Carolina McNAIR Aerospace Center
Email: alexrb@email.sc.edu