Laser Ablation Surface Treatment

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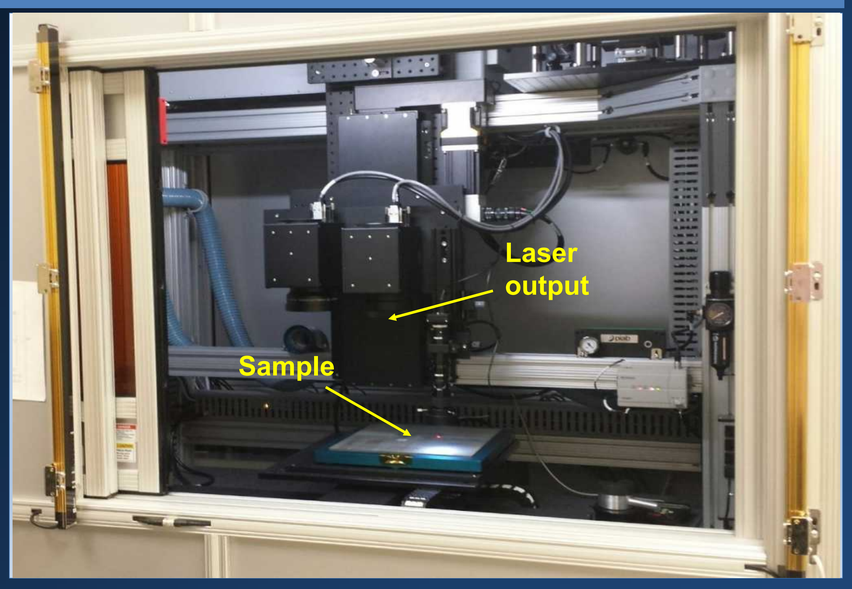
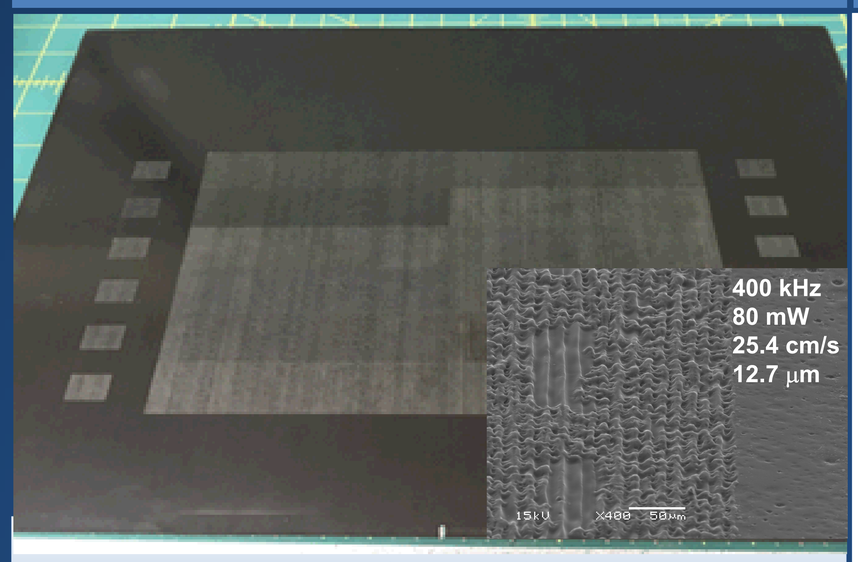
To advance the use of adhesive bonding in primary structural applications on commercial transports, the development of high fidelity surface treatment methods has been under investigation in the Advanced Composites Project (ACP). Laser surface treatment has shown significant promise as a rapid, precise, reproducible and broadly applicable method to prepare aerospace structural composites and metal alloys for adhesive bonding.

Picosecond Laser System

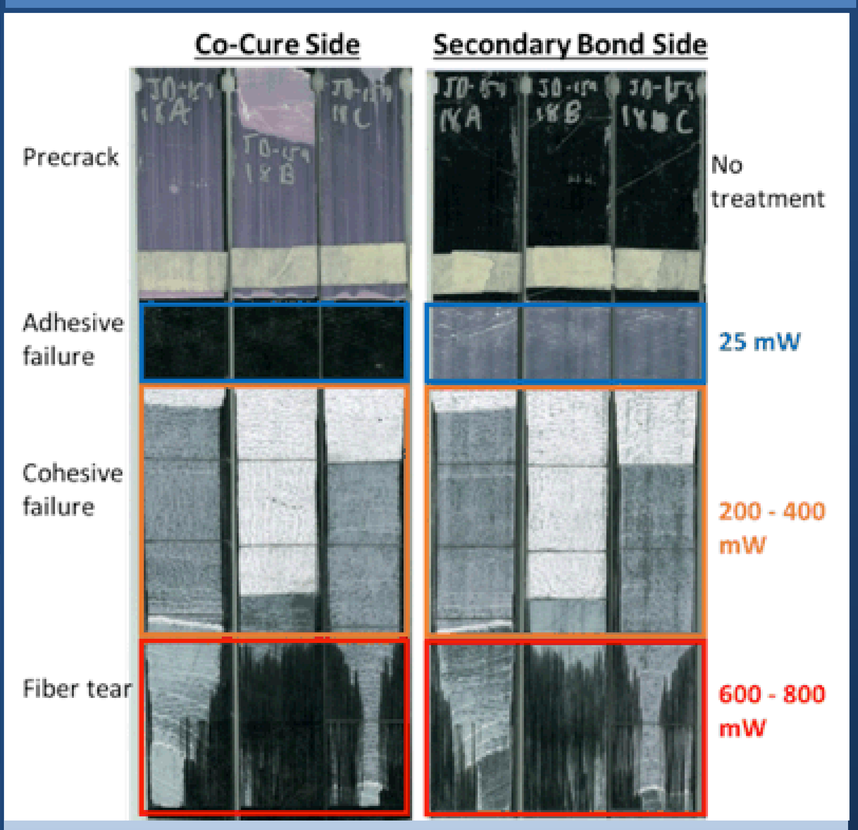


Rapid Screening DCB Test



- Laser ablated carbon fiber reinforced composite
- Inset is microscopy image of laser treated surface

Failure Mode Analysis



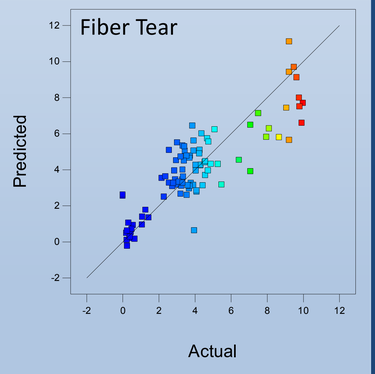
- ImageJ software used to quantify failure modes
- Simplified to 3 failure modes
- Mode changes occur with treatment changes
- High laser powers lead to more fiber tear

Laser Processing Parameters

Design of Experiments (DoE) Analysis

- 4 factors (independent variables)
- Laser power, frequency, scan speed, number of passes
- 94 experiments!
- 6 responses (measured results)
- Adhesive and fiber tear failure modes from double cantilever beam (DCB) testing
- Water contact angle (WCA)
- Silicon-to-carbon ratio (Si/C)
- Ablation depth and width

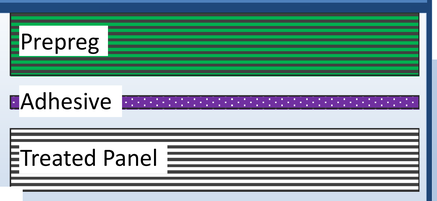
Responses	R-squared	Precision
Si/C	0.92	33.9
Adhesive failure	0.95	46.7
Fiber tear	0.74	21.3
WCA	0.85	27.4
Ablation depth	0.83	25.1
Ablation width	0.92	38.6



- 3rd order models
- Precision > 4 needed to navigate the design space
- Data should fall on or near predicted=actual line

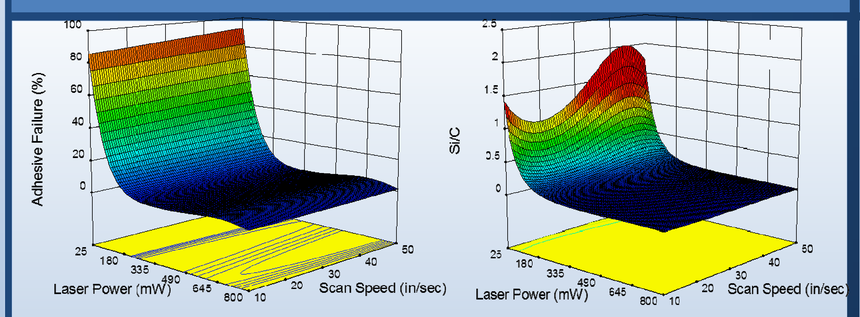
Bonding and Testing

- Co-bonded panels used for evaluation and testing

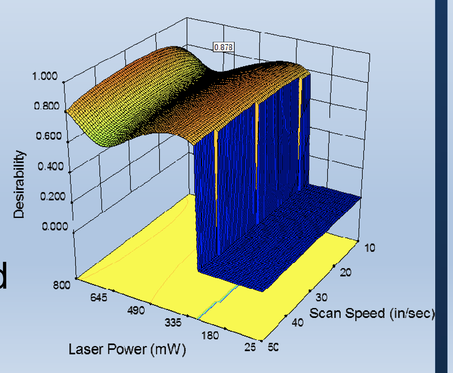


- DCB tests used to assess failure modes and to perform validation testing

DoE Output Analyses



- Si/C and adhesive failure models correlate strongly
- Large plateau indicates laser treatment has a broad process window



Conclusions

- Picosecond laser surface treatment is robust and provides for a broad processing window
- Laser power was the most important parameter
- Powers > ~200 mW gave good adhesive bonds with cohesive failure mode
- Above 400 mW, fiber tear was observed
- Ablation depth stops on fiber surface, no damage to fibers
- Fiber tear failure mode increases with laser power
- DoE model validated by mechanical testing

Frank L. Palmieri, Rodolfo I. Ledesma, Joseph G. Dennie, Teersa J. Kramer, Yi Lin, John W. Hopkins, Christopher J. Wohl and John W. Connell, “Optimized Surface Treatment of Aerospace Composites Using a Picosecond Laser”, J. Composites Part B, 175, 107155-107164, 2019.

US Patent 8,987,632 B2 “Modification of Surface Energy via Direct laser Ablative Surface Patterning”, March 24, (2015).

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