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FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS - IFAM

New demolding technique and surface treatment for adhesive bonding of carbon fiber-reinforced polymer used in aircraft structural components



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INTRODUCTION

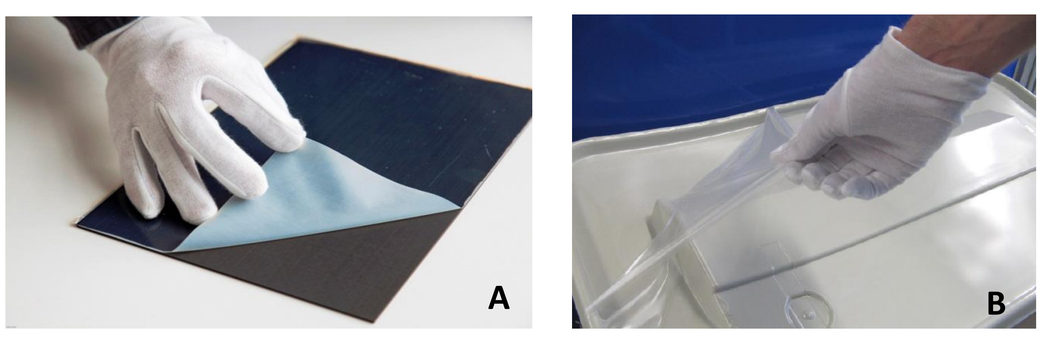
Carbon fiber-reinforced polymer (CFRP) material main advantages for application in **aviation**, aerospace, wind energy and vehicle sectors:

- **High strength-to-weight ratio;**
- **High corrosion resistance;**
- **Low thermal expansion.**

Adhesive bonding is the most suitable method for joining composite parts, however, the strength of bonded CFRP joints is directly related to the presence of contaminants on the adherent surface.

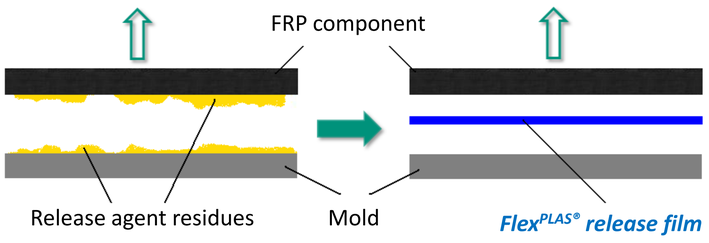
Composite parts are manufactured against metallic molds normally coated with release agents which may contain silicones and/or polymeric fluorinated hydrocarbons. **Traditional surface treatments** to remove release agents are time consuming, dusty, solvent emitting and requires manual work.

Researches of **Plasma Technology and Surfaces PLATO** at IFAM Bremen and experts in the **Fraunhofer Project Group Joining and Assembly FFM** at IFAM Stade (CFK Valley) developed a deep-drawable ***Flex$^{PLAS®}$ release film***.

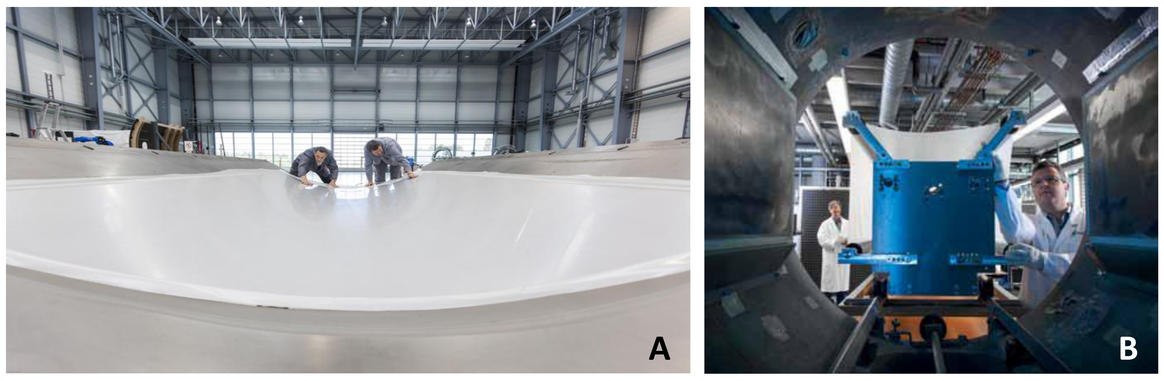


Flex$^{PLAS®}$ attached to A) CFRP laminate and B) in-mold gel coated FRP component

Flex$^{PLAS®}$ release film is an elastic polymer film with a flexible plasma-polymer release coating that allows easy removal of composite components from metallic mold, and has the potential to avoid many of the current composite surface pre-treatment issues. After curing process, ***Flex$^{PLAS®}$*** remains lightly attached to the whole surface of the composite, acting as a protective film during storage and transportation, avoiding contact with dust or moisture.



Principle of demolding of FRP component using conventional release agent (left) and using the innovative Flex$^{PLAS®}$ release film (right)



A) Flex$^{PLAS®}$ release film applied on a 1:1 scale mold and B) roll-to-roll system for the coating of a polymeric film in the low pressure plasma reactor

MATERIALS AND METHODS

CFRP composite material: Hexcel's HexPly® M21E prepreg epoxy matrix reinforced with 8 unidirectional carbon fibers plies ($0^o/\pm45^o/90^o$) - 60% fiber volume. Autoclave curing process: 2h / 180^oC / 0.7 MPa (vacuum).

CFRP surface treatments:

1. Grinding to remove silicone based release agent (*Marbocote TRE 45 ECO*);
2. Ethylene tetrafluoroethylene (ETFE) release film (*Airtech's Wrightlon® 5200*);
3. Non-release-agent coated Polyamide 66 peel ply (*WELA T0098*);
4. ***Flex$^{PLAS®}$ release film***;
5. Set of ***Flex$^{PLAS®}$ release film*** over the *WELA* peel ply (to increase roughness).

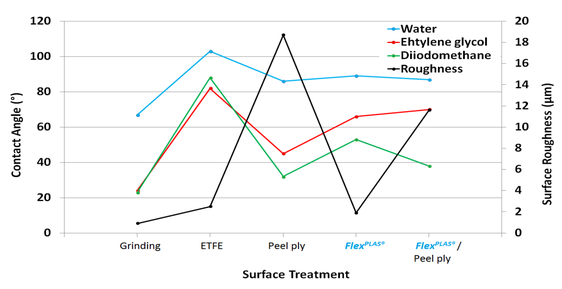
Analysis: Single-lap-shear and 180° Peel Strength Test; Digital Microscopy; 3D Laser Profilometry; Contact Angle; X-ray Photoelectron Spectroscopy.

RESULTS

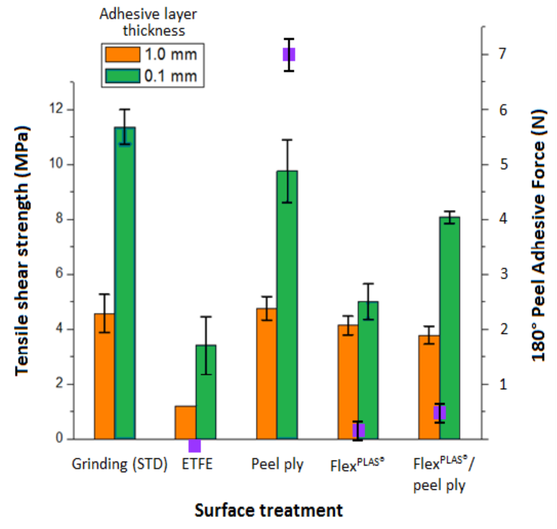
XPS Analysis - Element composition of CFRP surface for different treatments

Surface treatment	Surface composition (Atomic conc. %)					
	C 1s	O 1s	N 1s	F 1s	Si 2p	S 2p
Grinding (control)	78.3	19.4	1.6	0	0	0.7
ETFE	51.4	12.8	0	35.4	0.4	0
Flex$^{PLAS®}$	81.6	13.3	3.8	0	0	1.3

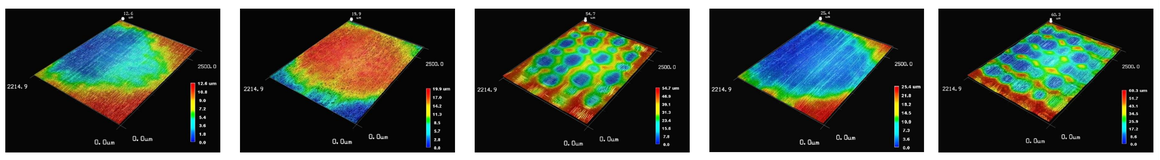
Contact Angle and Surface Roughness



Single-lap-shear and 180° Peel Strength Test



3D Profilometer images: Treated CFRP surface aspects – fiber protrusions and punctual resin peaks



Grinding | ETFE | Peel ply | Flex$^{PLAS®}$ | Flex$^{PLAS®}$ / Peel ply

CONCLUSION

- Peel ply increase 20 X surface roughness (compared to grinding), but not the adhesive strength;
- Grinding decrease contact angles, but do not increase adhesive strength;
- ETFE release film is not suitable for preparation of CFRP surface prior bonding. Necessary further treatments;
- The ***Flex$^{PLAS®}$ release film*** requires low force to be removed (around 170 X less) than peel ply. The set ***Flex$^{PLAS®}$*** /peel ply is 10 X easier to be removed;
- ***Flex$^{PLAS®}$ release film*** **could replace traditional liquid release agents for demolding CFRP parts and traditional surface preparation methods (grinding and peel ply) prior adhesive bonding.**

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