Recycling of high performance thermoplastic composites with high voltage fragmentation

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• How to **process** and **recycle** a complex aerospace part made of high performance carbon fiber reinforced thermoplastic?

Steel door hinge
Airbus Helicopter
EC135 Germany

Source: www.helis.com
Materials and processing

- Carbon fiber (CF) reinforced thermoplastic composite

Chopped (Discontinuous) tapes
55 Vol% Carbon fibers (20mm)

Temperature: 360°C
Pressure: 75 Bars

Thermoplastic composite hinge
Weight saving: 83%

Compression molding
Motivation

Cradle-to-Cradle

Thermoplastic Composite

Efficiency

Recycled Fragments
How to recycle CFRP materials from aerospace industry?

Pyrolysis

- **Recovery of the carbon fibers** by removing the matrix through thermal processes

- Reuse of matrix - generate fuels, oils

- Energy intensive

- Some polymers very expensive (e.g. PEEK)
How to recycle CFRP materials from aerospace industry?

**Mechanical Shredding**

- **Grinding** of carbon fiber composite to smaller fragments

  • Direct reprocessing of fragments possible
  • Significant loss of mechanical properties
  • Composites with high CF content wear out shredding blades very quickly

[Image of mechanical shredding process]

http://www.itsgreen.com.au

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IEA IA-HEV Task 17 Workshop  
09.10.2014
High Voltage Fragmentation (HVF)

Process parameters
- Voltage between 50 - 200 kV
- Pulse rise time below 5 µs

Source: Selfrag AG
High Voltage Fragmentation (HVF)

- Breakdown voltage versus pulse rise time: **Water acts as isolating medium**
Technology: High Voltage Fragmentation

- **Explanation HV fragmentation**
  Creation of the discharge: Plasma channel + shockwave

- Discharge pressure along the plasma channel: **10 GPa**
- Plasma temperature: up to **10,000 °C**
Technology: High Voltage Fragmentation

• Current applications

• Main Advantages
  • No tool wear
  • No dust
  • Selective fragmentation

Source: Selfrag AG, Tyvek
Recovery: Fragmentation of the CFRP hinge

HV Fragmentation → Sieving

Powder <1mm → Fragments with targeted size

Large Fragments >4mm → Recycled fragments

Initial hinge

- 200 pulses (2 cycles)
- 300 pulses (3 cycles)
- 600 pulses (6 cycles)

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Successful processing of door hinges with 100% of recycled fragments.
Analysis of the recycled fragments

Recycled chips:
Polymer partly removed from the surface of the fragments, (estimated 3wt% loss)
Mechanical testing: Recycled versus original

- Maximal load:
  - 17% reduction compared to chopped tapes (20mm)
Observations: Fracture analysis

- **Chopped tapes:** Fibers still covered with polymer: **Cohesive failure**

- **Recycled chips:** Fibers partially covered with polymer: **Cohesive failure**

Polymer is **removed** from the surface of the fragments: **Adhesive failure**
Discussion: High voltage fragmentation process in a CFRP

First impact on a CFRP plate during HVF

Random impact on a door-hinge during HVF

I: Loss of fibers

II: Cleaned fibers with no polymer on surface

III: Bundles of fibers lifted up still embedded in polymer
Mechanisms of fragmentation induced by HV pulses in composites

- **I**: Fiber sublimation
- **II**: Polymer pyrolysis
- **III**: Mechanical delamination
- **IV**: Pressure waves

(Ogasawara 2010; modified)
Conclusions

Successful fragmentation of CF thermoplastic composite with high content of carbon fibers

Production of a complex part with 100% of recycled materials

Promising results:
  • Slight reduction of the mechanical properties (shorter fragments, less polymers at the surface of the fragments)
Acknowledgements

- IKT Research Group, FHNW, Switzerland
- Clean Sky JTI, Eco-Design ITD
- Airbus Helicopters
- Selfrag AG, Switzerland.
Thank you for your attention. Questions?

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Technology: Electrodynamic fragmentation

- Propagation in the material
  - Interfaces with different dielectrical properties
  - Inclusion with high dielectrical constant (metallic or CF) attract the discharge track
- Heterogeneity
  - Residual stresses.

- Separation of the material:
  - A compression wave is transformed into a tensile and shear wave by reflection and refraction at an inclusion and separate it from the matrix.

Source: Selfrag AG