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Mechanical Safety of Re-injected Carbon Fiber Reinforced Acrylonitrile-butadiene-styrene Components in Transportation Applications

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INTRODUCTION

Backround information & Market Context

DO WE HAVE TO SACRIFICE ONE FOR THE OTHERS?

environmental sustainability↔mechanical safety↔performance↔cost-competitive

Problem Statement & Stakeholders

- **Acrylonitrile butadiene styrene (ABS)**—high impact resistance [1]
- **Carbon fibers (CF)**—enhance strength, stiffness, thermal stability, and fatigue resistance; decrease impact resistance [2-5]
- Mechanical recycling of ABS+CF composites

Research Objectives & Expected Impact

- How CF content and re-injection affect the impact resistance of ABS+CF composites
- Comparison of **maximum impact force (F_{max})** and **Charpy impact strength (a_c)**
- Technologically simple and cost-effective method

MATERIALS, METHODS & IMPLEMENTATION

Materials

•Base Material: ABS – Novodur HH-112 (INEOS Styrolution)
•Reinforcement: Chopped CF – 3 mm length (Havel Composites CZ)
•Specimens with or without a notch:
- Pure ABS
- ABS+CF composites (1 wt%, 3 wt%, 5 wt% CF)
- Re-injected ABS+CF

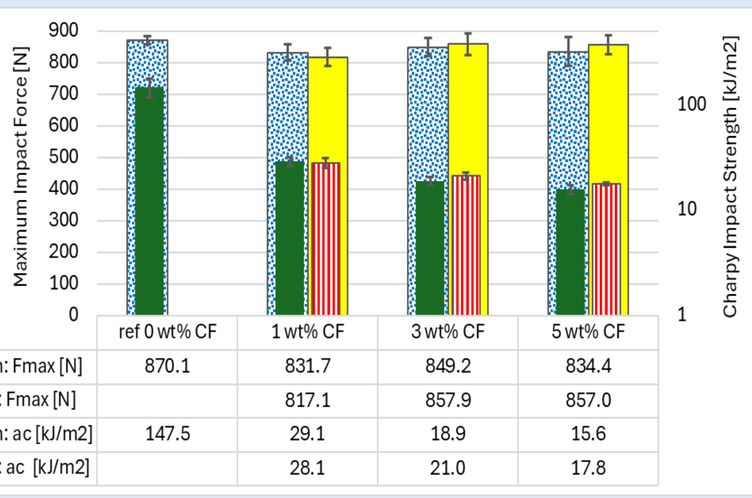
Methods

•re-injection of grit obtained from the initially injected composite
•Charpy impact test—ISO 179-2:2020
•Specimens and determination of ABS material properties.—ISO 19062-2:2019
•fracture surfaces display—confocal microscope

Implementation

•Assessment of recyclability and mechanical performance trade-offs
•Optimization of ABS+CF reprocessing for sustainable applications

RESULTS



	ref 0 wt% CF	1 wt% CF	3 wt% CF	5 wt% CF
1st injection: Fmax [N]	870.1	831.7	849.2	834.4
re-injection: Fmax [N]		817.1	857.9	857.0
1st injection: ac [kJ/m2]	147.5	29.1	18.9	15.6
re-injection: ac [kJ/m2]		28.1	21.0	17.8

Fig. 1. Impact test results of specimens without a notch.

First injection—specimens without a notch:

- Slight decrease of the F_{max} after the addition of CF (approximately 2.4 to 4.4 %)
- Sharp drop of the a_c values after the addition of CF (to about one-fifth the value of the pure ABS for the specimen with 1 wt% CF; the drop further deepened)

Re-injection of ABS+CF—specimens without a notch:

- Tested impact properties similar to the first injection
- For 3 wt% and 5 wt% CF, both F_{max} and a_c improved

Without a notch

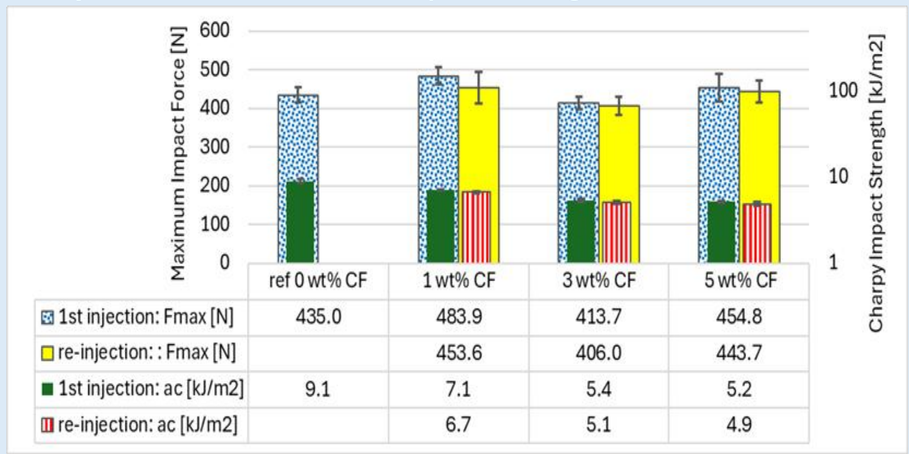
With a notch

First injection—specimens with a notch:

- F_{max} values comparable for pure ABS and ABS+CF
- specimen with 1 wt% CF exhibited an increase in F_{max} (approximately 11% compared to pure ABS)
- The a_c values showed a rounded 20-40% decrease upon adding CF

Re-injection—specimens with a notch:

- F_{max} values comparable to the first injection
- The a_c value around 6% lower than that of the first injection, with the same percentage of CF added



	ref 0 wt% CF	1 wt% CF	3 wt% CF	5 wt% CF
1st injection: Fmax [N]	435.0	483.9	413.7	454.8
re-injection: : Fmax [N]		453.6	406.0	443.7
1st injection: ac [kJ/m2]	9.1	7.1	5.4	5.2
re-injection: ac [kJ/m2]		6.7	5.1	4.9

Fig. 2. Impact test results of specimens with a notch.

Fracture surfaces images—specimens with a notch:

- Greater homogenity of re-injected composite in terms of CF distribution
- Broken CF

CONCLUSION & IMPLEMENTATION PATH

- Adding CF to ABS and re-injection reduce Charpy impact strength, while the maximum impact force remains largely unaffected
- Proposed method of crushing and re-injecting ABS+CF grit proved to be technologically simple and cost-effective
- This method can be generally used in components that are not incorporated directly into crumple zones – e.g. interior panels or enclosures for electrical and mechanical systems, where the reduction in energy absorption is acceptable, but stiffness and durability are still required [6,7]

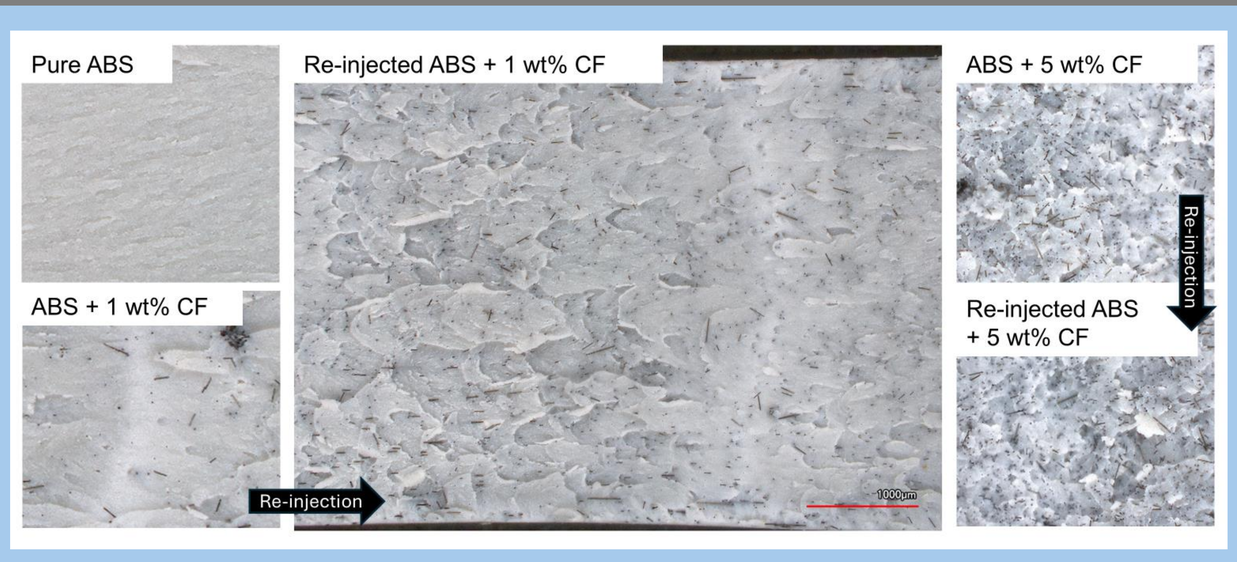


Fig. 3. Microscope images (x60) of the fracture surfaces—specimens with a notch.

Proposals for further research:

- Compare the tensile and flexural properties and thermal stability
- Mechanical recycling of the composite in practice also needs to consider the ageing of the material and any contamination

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[1] Czepiel et al. (2023) https://doi.org/10.3390/ma16175802 [2] Aravind et al. (2023) https://doi.org/10.1002/app.54007 [3] Hwang, Lee & Cho (2021) https://doi.org/10.3390/polym13142298 [4] Lee & Cho (2021) https://doi.org/10.1002/app.50674 [5] Lobov et al. (2024) https://doi.org/10.3390/polym16081106 [6] Lukoševičius et al. (2020) https://doi.org/10.21307/tp-2020-035 [7] Reddy et al. (2018) https://doi.org/10.1080/13588265.2017.1306824