Manufacturing Thermoplastic Fibre Metal Laminates by the In Situ Polymerisation Route

CIMComp
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Future Composites Manufacturing Research Hub

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Introduction

Fibre Metal Laminates (FMLs) are hybrid composites based on metallic sheets and layers of fibre reinforced plastics (FRPs). FMLs are characterised by excellent fatigue and fracture properties, damage tolerance, impact resistance and strength in comparison to the monolithic metallic alloys and FRPs [1-3]. Thus, FMLs are promising lightweight materials for aeronautic and automotive applications [1, 2]. However, the ultimate performance of the FMLs is not only determined by the involved constituents, but is also influenced to a large extent by the interface formed between them.

Objectives

- Preparation of the aluminium (Al) alloy surface with suitable chemical or physical treatments to achieve an acceptable level of interfacial bonding with the composite (FRP).
- Manufacture FMLs using the vacuum assisted resin infusion route (VaRTM) with liquid thermoplastic resin, glass reinforcements and Al alloy sheets.
- Investigate the mechanical properties of the FMLs in comparison to a baseline GFRP laminate with no metal interlayer.

Materials

- Liquid thermoplastic resin
- Unidirectional E-glass fabric
- Aluminium (Al) alloy sheets

Methodology

Surface Treatments of Al Alloy Sheets
- Chemical: alkali and acid
- Anodising
- Plasma

Surface Characterization
- Wettability/Surface energy
- Surface roughness
- Microscopy: Optical, SEM

Manufacturing
- FML fabrication with surface treated Al alloy sheets by VaRTM
- Baseline GFRP laminates

Mechanical Characterization
- Interlaminar shear strength (ILSS)
- Flexural test
- Interlaminar fracture toughness (DCB-Mode I)

Results

Wettability

Measurements of contact angle (CA), surface energy γ_{SV} and roughness (Sa) for the various surface treatments (±standard deviation).

Al alloy treatment	CA (°)	γ_{SV} (mJ/m^2)	Sa (μm) 50X
Degreased-only	82 ± 1	34.3	0.220
Alkali	65 ± 2	44.8	0.784
Acid	59 ± 3	48.4	0.224
Anodising	57± 1	49.6	0.263
Plasma	32±2.5	63.5	0.256

3D Surface Topography of Al after Surface Treatments

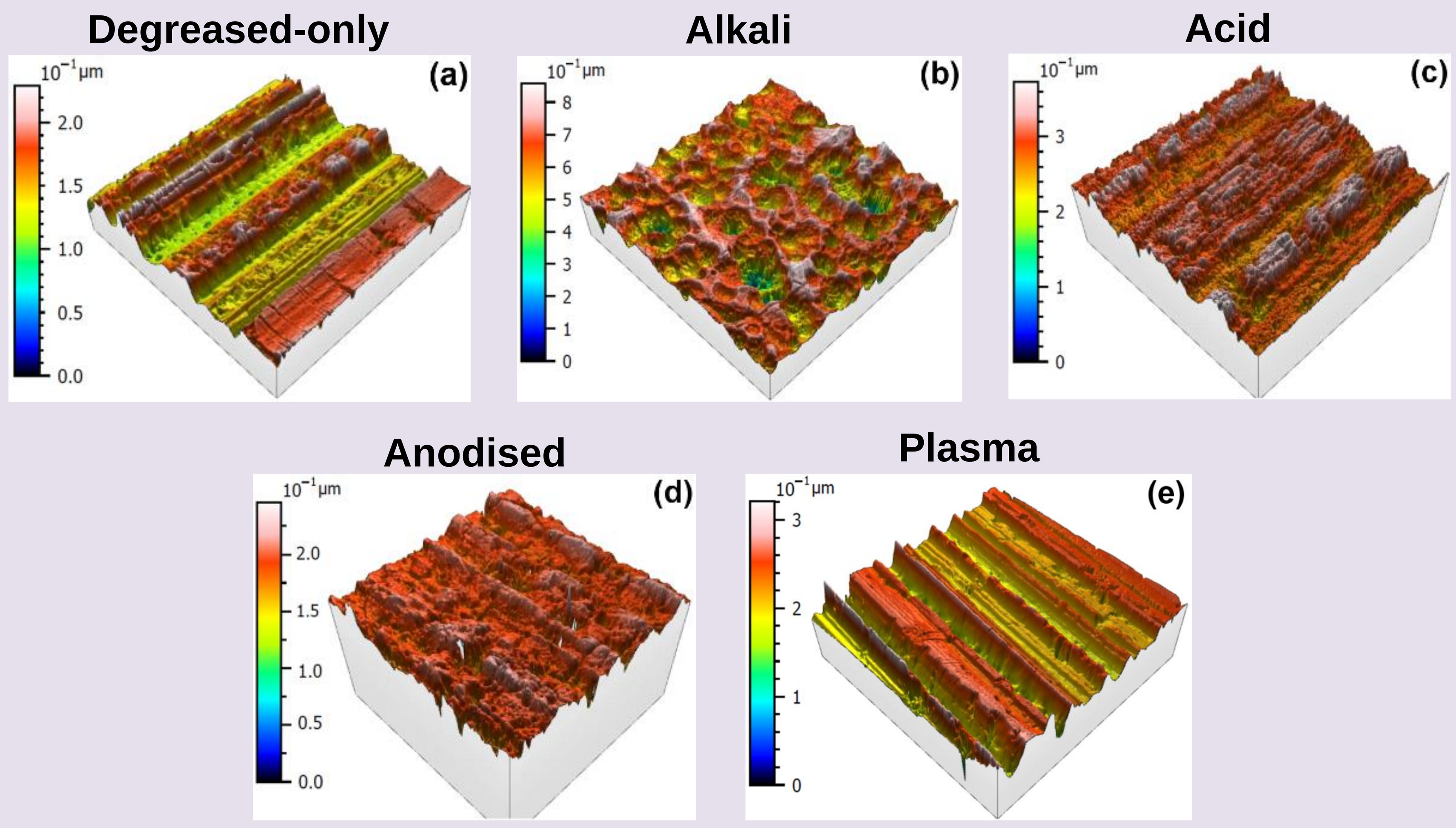
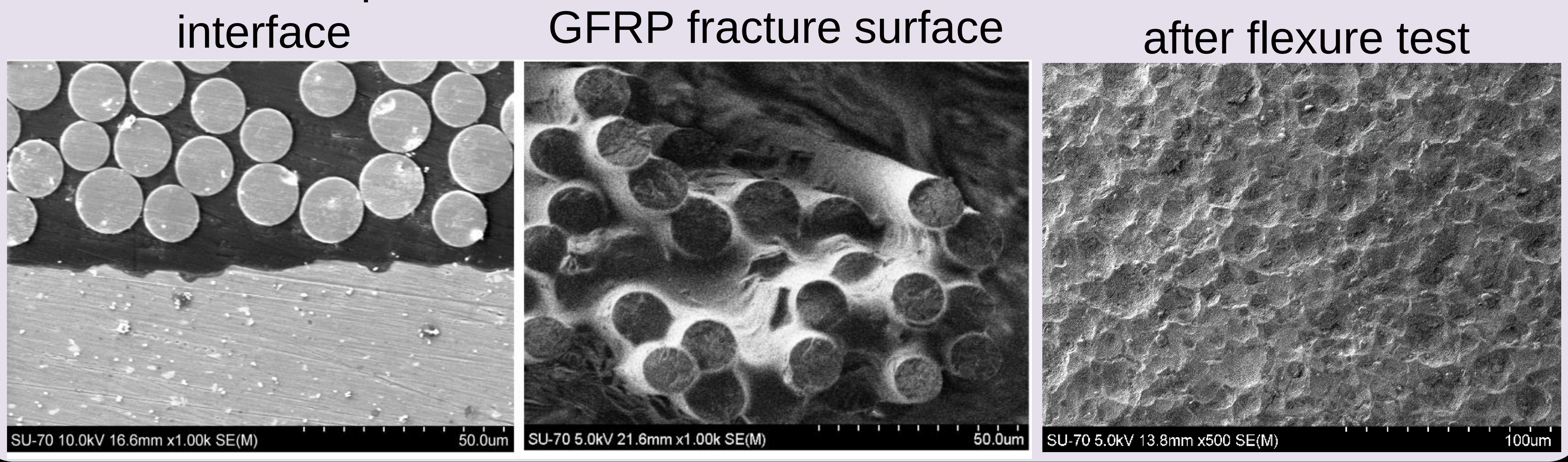


Fig. 1 3D height profiles, at 50X magnification, for the different Al alloy treatments.

SEM Micrographs (Fig. 2)

FML metal-composite interface | GFRP fracture surface | Debonded Al surface after flexure test



Key findings

- ✓ Suitable surface treatment conditions were identified for the Al alloy.
- ✓ Successful VaRTM of fully-wetted FMLs and extraction of test coupons.
- ✓ Good bond strength between the Al alloy and GFRP was achieved.
- ✓ A novel way of bonding Al alloy sheets and thermoplastic GFRP layers through the in-situ polymerisation was successfully achieved.

Flexural properties and ILSS

- Flexural strength: Baseline GFRP was **+9%** higher than FML.
- Flexural modulus: FML was **+17%** higher than baseline GFRP.
- Interlaminar shear strength: **-50%** decrease in the FML than GFRP.

Interlaminar fracture toughness

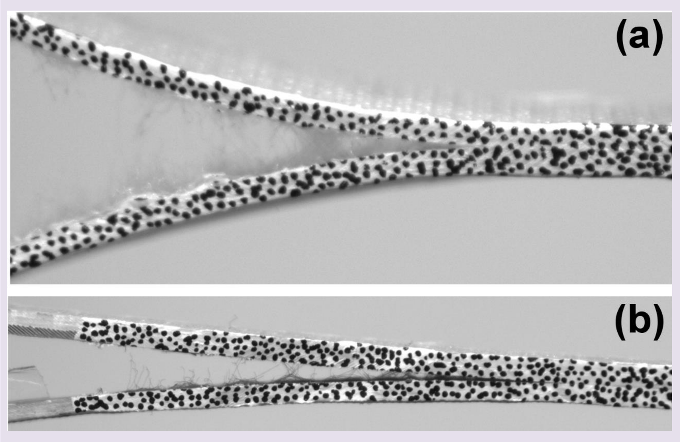


Fig. 3 Typical high-speed images of the crack tip zone of (a) GFRP and (b) FML.

- Mode I interlaminar fracture toughness of GFRP was **+495%** higher than FML.
- Fracture toughness of FML with alkali treated Al was **+315%** higher compared to a reported epoxy based FML [4].

Future work

- Further improving Al alloy-GFRP bond strength.
- Optimisation of the FML manufacturing process.
- Generating FML mechanical property data.
- Preliminary investigations of the recyclability, weldability and repairability.

References

[1] T. Sinmazçelik, E. Avcu, M.Ö. Bora, and O. Çoban, Mater. Des. 32, 3671 (2011).
[2] N.A. Patil, S.S. Mulik, K.S. Wangikar, and A.P. Kulkarni, Procedia Manuf. 20, 554 (2018).
[3] I. M. Sadighi, R.C. Alderliesten, and R. Benedictus, Int. J. Impact Eng. 49, 77 (2012).
[4] O. Laban and E. Mahdi, Int. J. Adhes. Adhes. **78**, 234 (2017).

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