Advancing circularity through demanufacturing – testing thermally assisted peeling of fibre-reinforced thermoplastic tapes

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In this poster, we present the ongoing research efforts into thermally assisted peeling at the University of Nottingham. We have developed a test set-up which allows for a comprehensive experimental study addressing the challenges identified from feasibility studies and miniature tests to advance this demanufacturing method and help establish it as a future recycling technology.

Introduction

Circularity has become a popular argument for the use of fibre-reinforced thermoplastic polymers. However, actual closed-loop recycling remains a challenge as available recycling methods commonly result in a loss of fibre length and orientation leading to reduced mechanical performance in comparison with virgin material [1]. This is addressed by recently emerging demanufacturing concepts, such as thermally assisted peeling, which aim at preserving the original continuous fibre-matrix systems enabling direct reprocessing without (or with only minimal) post-processing of the recovered material.

Thermally assisted peeling – feasibility and miniature testing

Recent feasibility studies investigating thermally assisted peeling for unidirectional (UD) tapes, such as used in tape winding, have yielded promising results [2-4] showing only minimal reduction in mechanical properties following reprocessing. The REWIND study at the University of Nottingham further explored the temperature-dependant peel characteristics under global heating using miniature T-peel tests. The findings indicated that beneficial peel conditions might be found below melting point and that the formation of the fracture surface as interlaminar or intra-laminar is dependent on the peel temperature (Fig. 1).

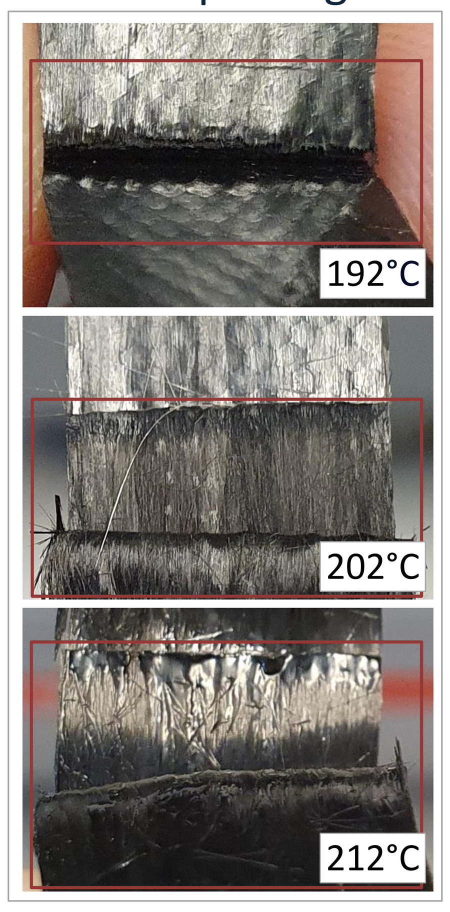


Figure 1 Variation in surface morphology of recovered carbon fibre-reinforced polyamide 6 tapes resulting from different peel temperatures.

Challenges

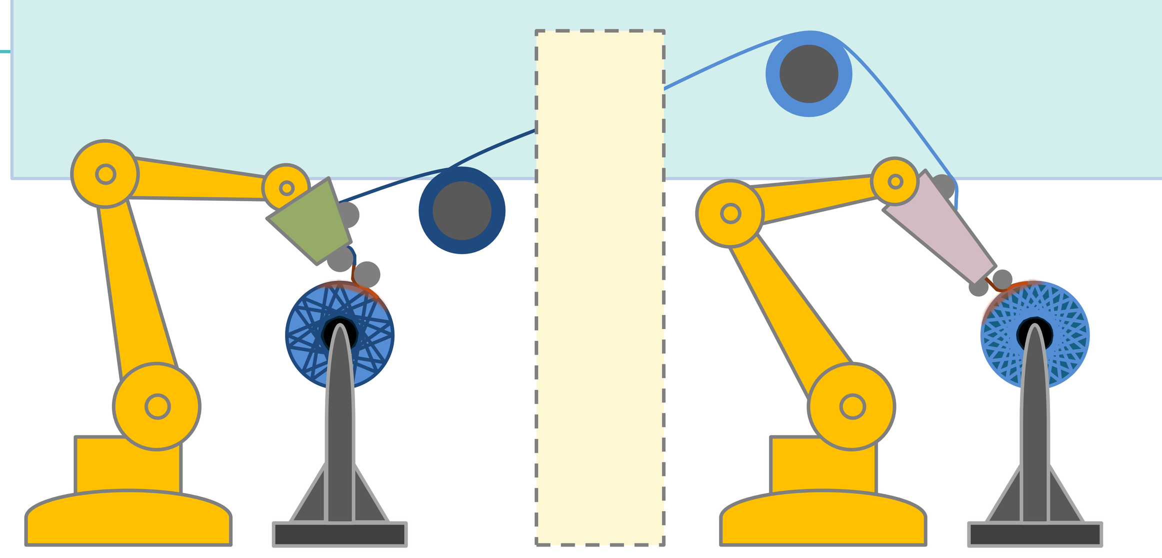
Several aspects require closer investigation to deepen the understanding of an industrially viable process:

Understanding tape recovery

What are beneficial peel parameters…
- … for avoiding resin-starved surfaces?
- … to ideally preserve the mechanical properties of the material?
- … in relation to the specific thermal characteristics of the material?
- … for cross-ply recovery?

Integration into existing process chains

- How can peel initiation be facilitated in end-of-life parts?
- Feasibility of multiple reprocessing cycles?
- Options for material regeneration?



Design

The test rig concept is illustrated in Fig. 2-4. The fixture design…

… enables both **ply-by-ply consolidation** of UD tapes and consecutive **mandrel peel testing**

… can be adapted to any regular **uniaxial test machine** (no additional motors or load cells needed)

… incorporates **locally concentrated heat** application, e.g. at the nip point.

For both consolidation and peel, the tape material passes through a roller unit driven by an upwards movement of the test machine head. Consolidation pressure is regulated by spring-loading one of the front rollers. For peeling, back tension can be applied to ensure conformation of the peel arm to the mandrel roller and reduce fibre damage in the recovered tapes.

Capabilities

Consolidation speed, peel speed and peel force are limited only by the test machine (e.g. with Tinius Olsen 10 ST: 500 mm/min, 10 kN). Dynamic variation of these parameters is possible.

Data acquisition and monitoring

Real-time temperature monitoring is realised using
- Pyrometer data and
- Thermal imaging data.

Temperature, machine head displacement and load cell data is collected and processed via a data acquisition (DAQ) system.

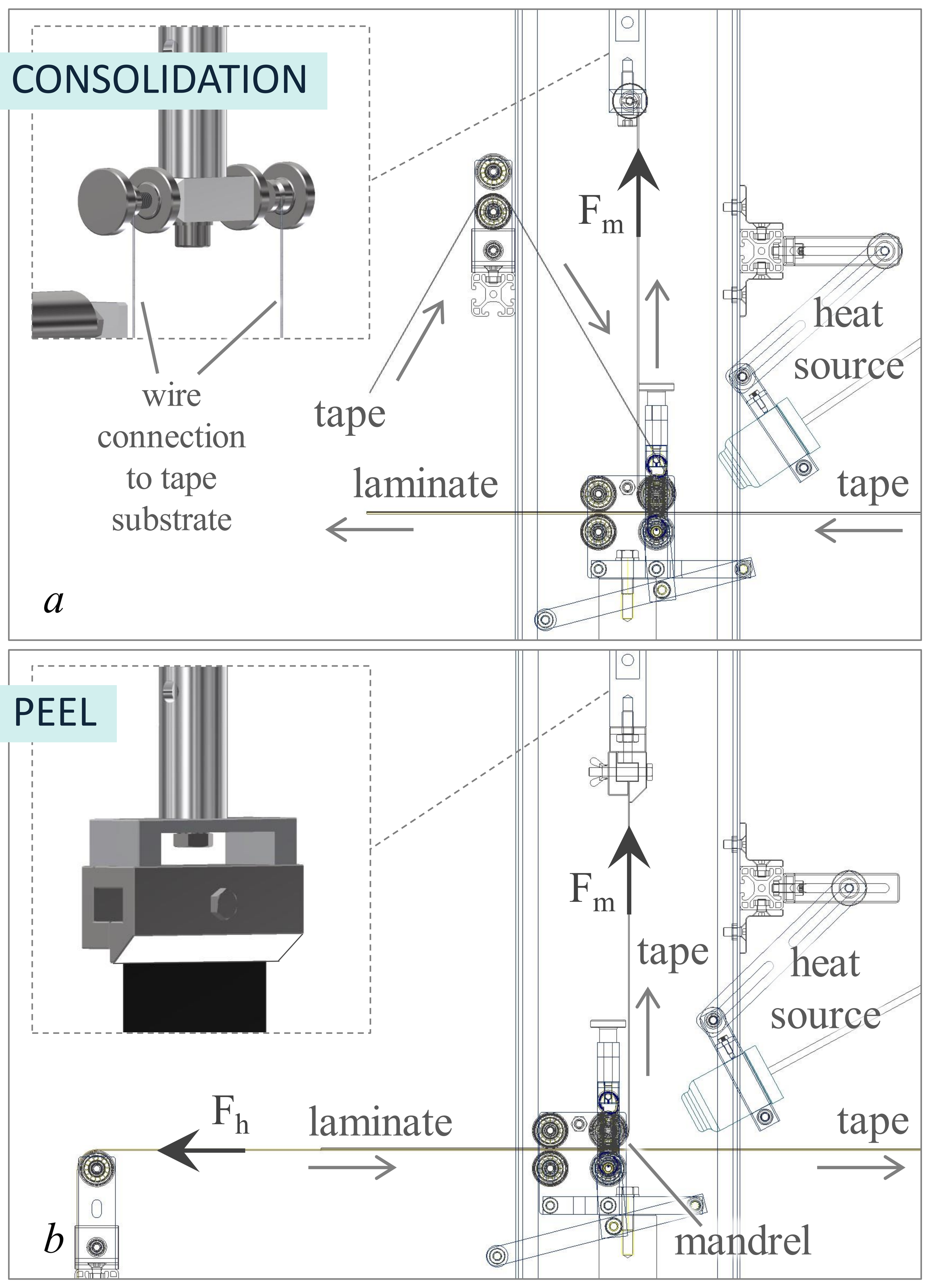


Figure 2 (a) Consolidation test rig configuration with F_m: Tensile load applied by test machine to move the tapes through the consolidation set-up; (b) Peel test rig configuration with: F_m: Tensile load applied by test machine for specimen peeling, F_h: Horizontal load ensuring conformation of the peel arm to the mandrel roller.

Figure 3 Consolidation test rig configuration.

Figure 4 Peel test rig configuration with applied back tension.

Future work

Future work will focus on developing a scientific understanding of the tape peel process as well as establishing the limitations of thermally assisted peeling as a recycling technology.

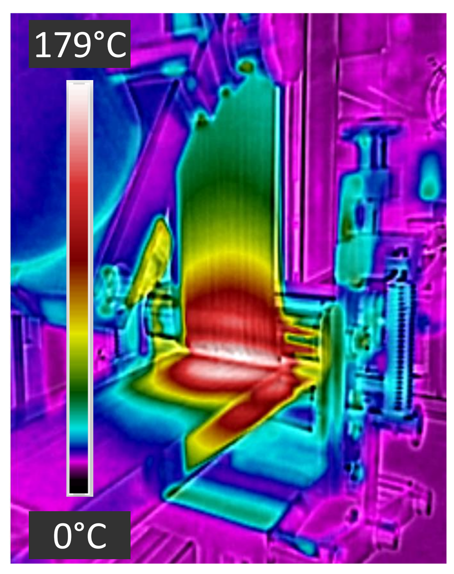


Figure 5 Thermal imaging during peel testing.

Roadmap

- *Define* — optimum peel conditions
- *Identify* — suitable peel initiation mechanisms
- *Assess* — number of viable reprocessing cycles
- *Explore* — material regeneration paths to extend the number of lifecycles

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