Vacuum infusion and analysis of noobed 3D preforms with integrated recycled carbon fibers

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Background

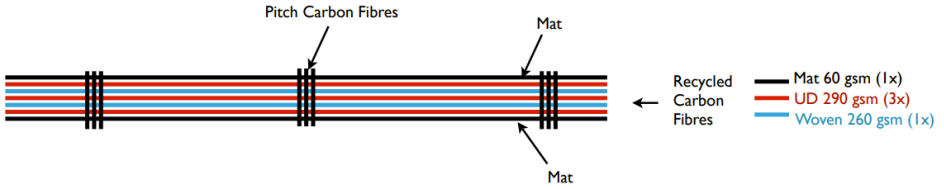
Alongside reducing the weight of battery casing using composite materials, the casing must also be made functional to dissipate heat through the casing walls. With conventional laminated composite materials this is hard due to their low thermal conductivity transverse to the fibers.

Therefore, a suitable 3D fabric construct is required wherein its through thickness direction fibers are of pitch carbon type due to their high thermal conductivity.

For this project, development of a composite material bottom plate of a battery casing has been explored using recycled fibres in planar directions and pitch carbon fibres in the thickness direction.

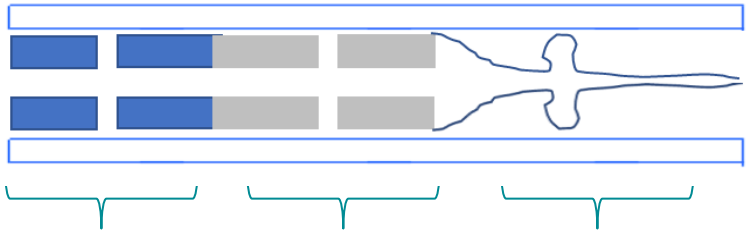
Preform

- A design has been developed and a 3D preform have been manufactured by Fureho from recycled carbon fiber with three rows of pitch fibers incorporated the thickness direction of the laminate.
- The pitch fibers are brittle and therefore protruding straight from the laminate and needs to be handled with care to avoid fiber failures.



Alternative infusion processes

- Three different approaches (see picture) have been conceptualized to enable vaccum infusion while protecting the pitch fibers in the thickness direction.
- To enable three separate trials the preform was cut into pieces and the approach with a folded vaccum bag was attempted initially.



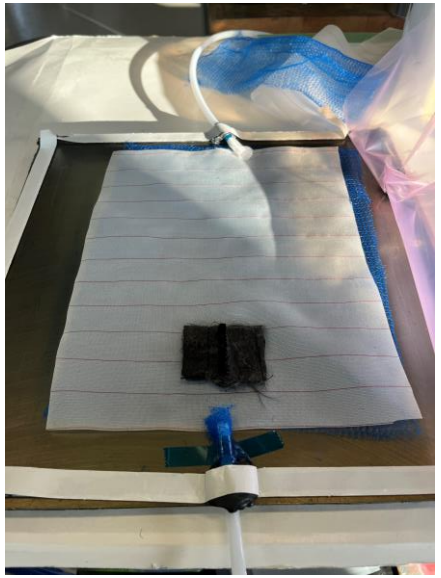
Cut preform

Materials and process paramenters

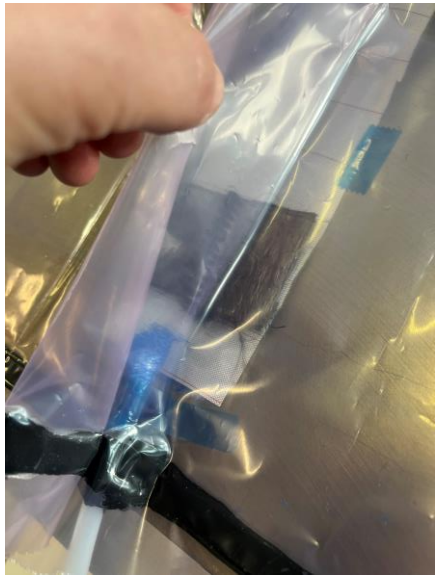
- Layup on heat plate:
  - Flow layer
  - Peel ply
  - Preform
  - Vaccum bag
- Resin:
  - Epoxy: Araldite LY 1564 SP
  - Hardener: Araldite XB 3404-1
  - Epoxy/hardener ratio: 100/36
- Cure cycle: 8 hours at 80°C

Preparation for vacuum infusion

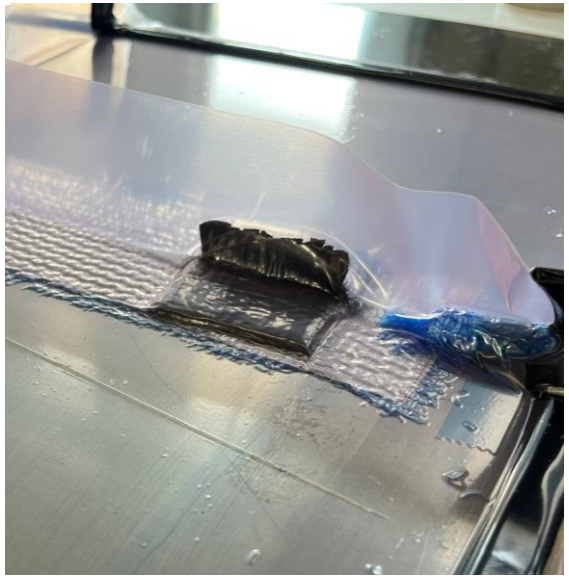
Preform positioned on a peel ply



Inlets and outlets positioned

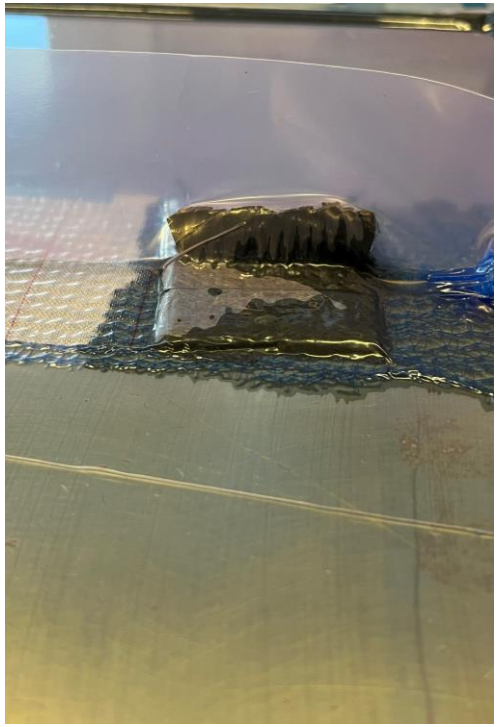
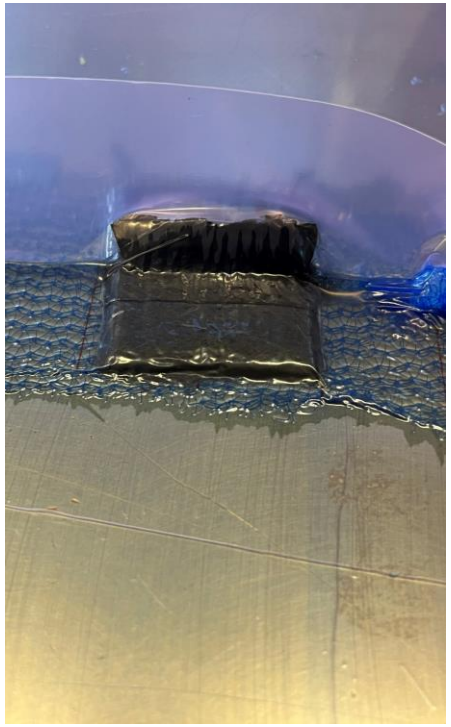
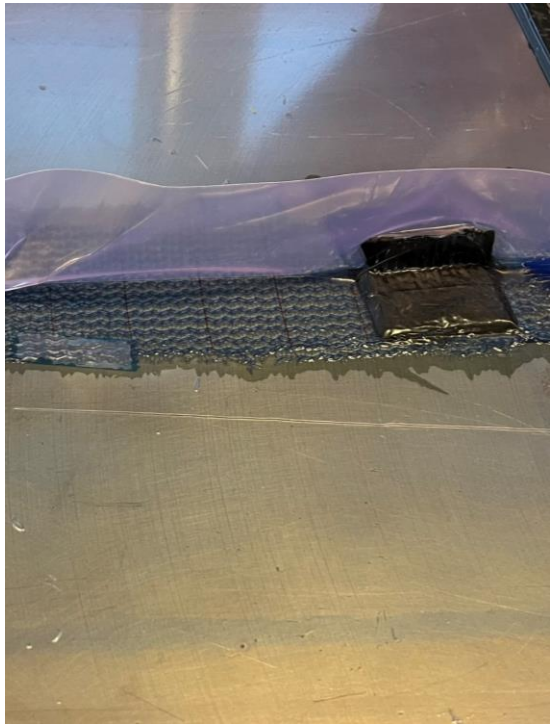


Arrangement of vaccum bag



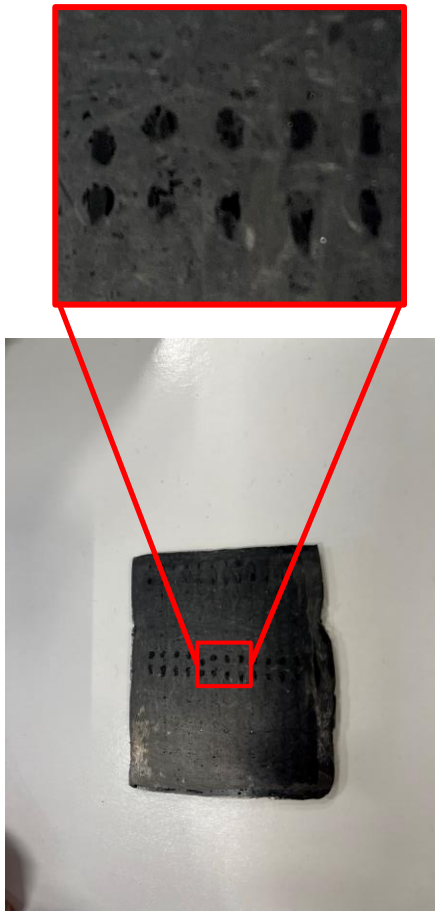
Vaccum applied

Infusion progress

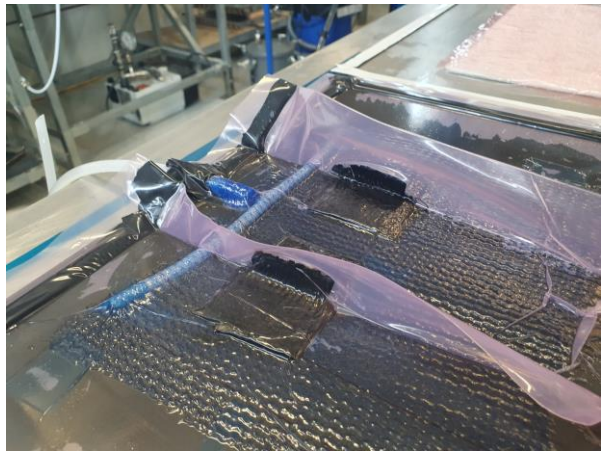
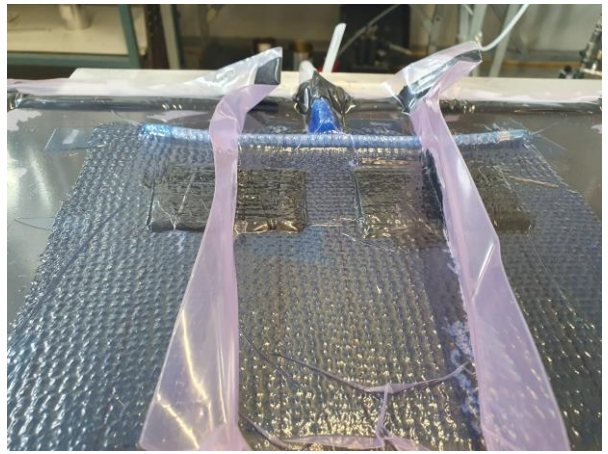





Demoulded and sanded flat

- To achieve a flat plate the sample was manually sanded.
- The positions of the through-thickness pitch carbon fibers became clearly visible after sanding.
- This approach for vaccum infusion of the preforms was assessed to be feasible and the remaining two preforms were infused using the same approach.



Simultaneous vacuum infusion of the two remaining preforms

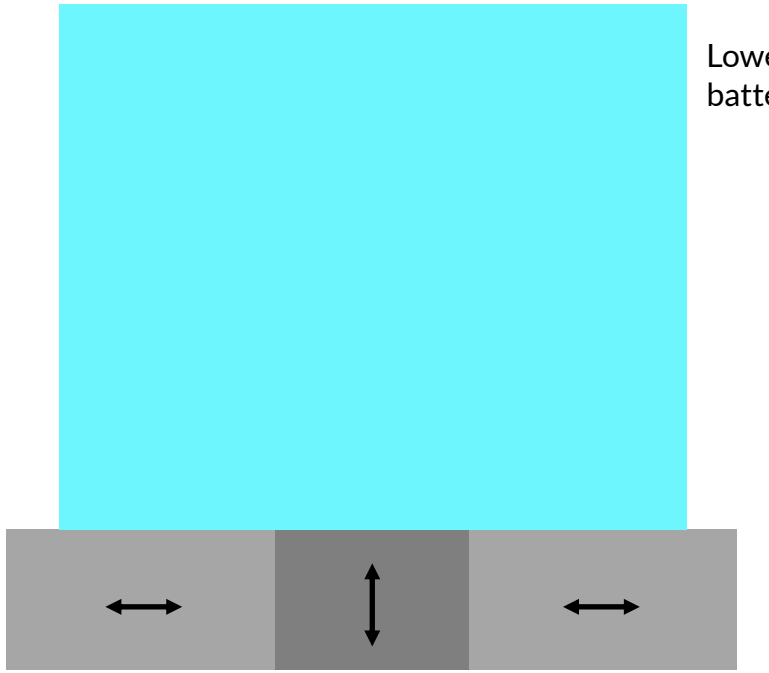




Measurements of thermal conductivity

- The initial intention was to perform a measurement using a TPS-equipment (https://ctherm.com/thermal-conductivity-instruments/thermal-conductivity-kit/) purchased by RISE in Piteå recently. Unfortunately, there were some issues in setting up this device within the timeframe of the project. Therefore, samples were sent to RISE in Borås who has a similar equipment and are accredited for performing measurements according to the standard ISO 22007-2.
- This approach was however not well suited for the samples manufactured (thin and anisotropic) which is why the results showed very small differences (up to 10 %) between measurements on the through-thickness pitch fibers and measurements on another region of the laminate.

Discussion regarding thermal conductivity for battery applications

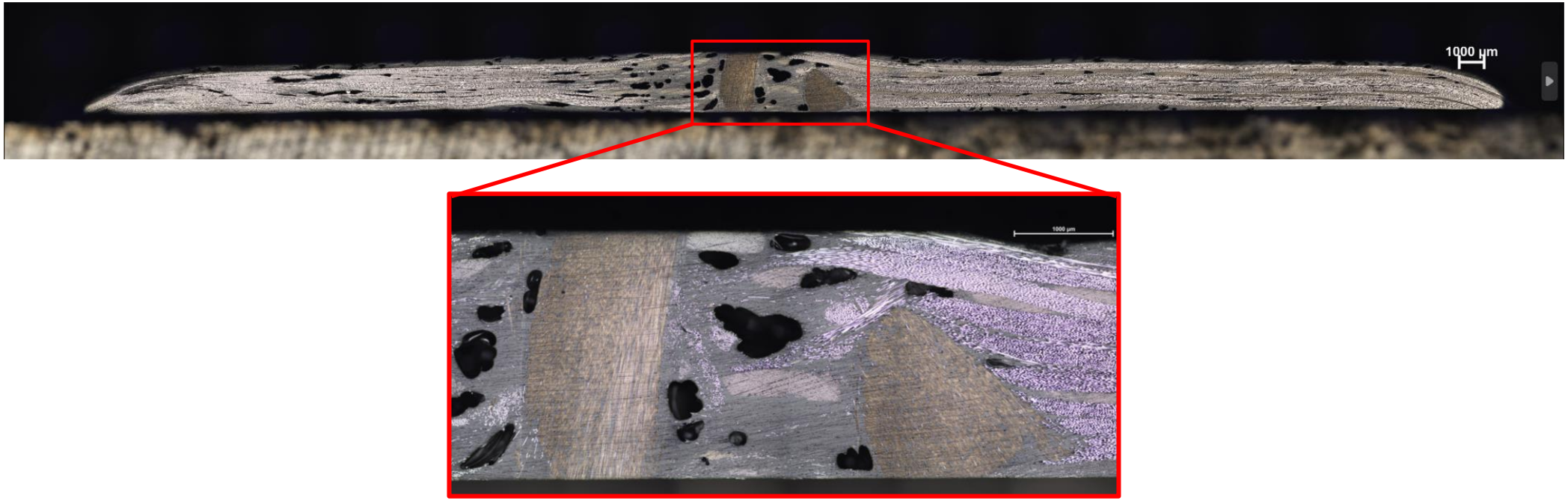
- The obtained through thickness direction thermal conductivity of the CFRP laminate is relatively low, about 2 W/mK.
- In the fibre direction of the through-thickness bundles, a thermal conductivity of 60-80 W/mK is estimated assuming fibres with a longitudinal thermal conductivity of 200 W/mK.
- If one assumes that a battery cell of diameter 21 mm is positioned on top of a row of through-thickness fibres with similar design as the manufactured plates the base of the battery cell would cover approximately 14 each bundles of diameter 1.5 mm. This would imply an average thermal conductivity in the through thickness direction of 8 W/mK, hence an improvement with about 400 % compared to a conventional laminate. A higher density of bundles or several rows would increase the thermal conductivity further.



Schematic cross section over a through-thickness bundle with arrows showing fibre directions.

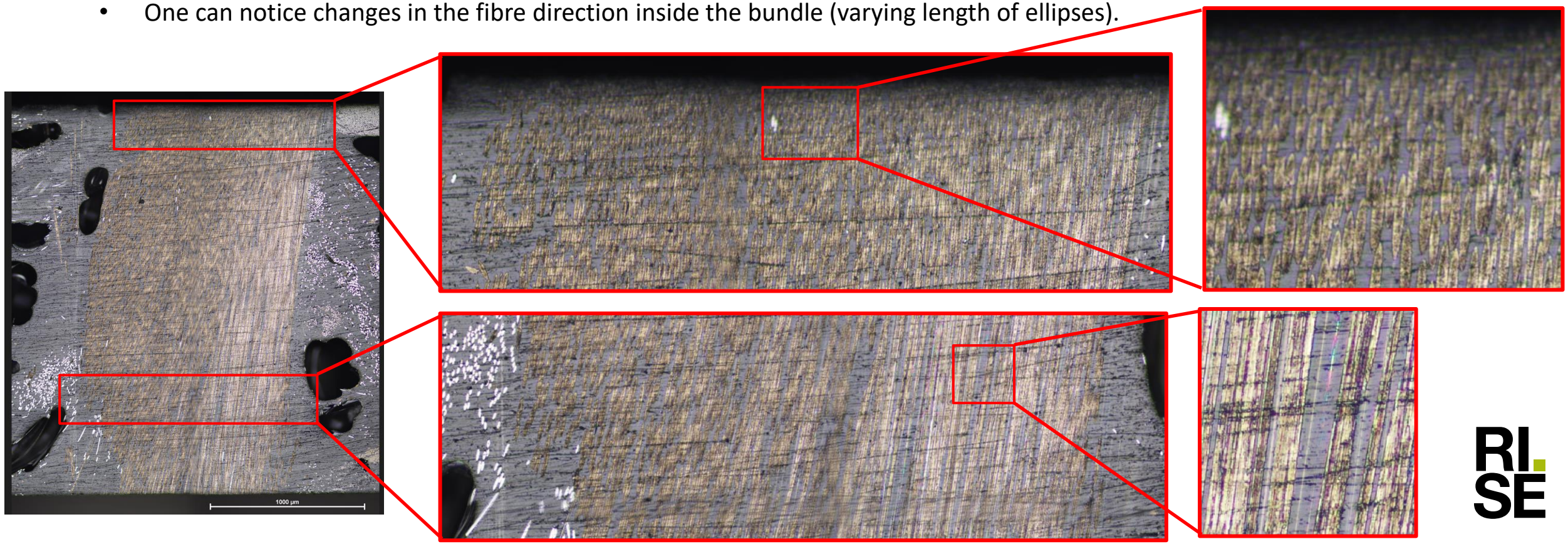
Microscopy of cross section

- The figure below shows a cross section of the plate going through two bundles of through-thickness pitch fibers.
- One can clearly see that the compaction of the conventional laminate is negatively affected close to the pitch fibers resulting in an increased thickness, lower fibre volume fraction and higher porosity.



Microscopy of through-thickness bundle

- The quality of the bundle itself is high with almost no porosity.
- One can notice changes in the fibre direction inside the bundle (varying length of ellipses).



Conclusions

- A design for integrating recycled carbon fibers with through thickness pitch-based fibers have been developed.
- A preform have been manufactured based on this design.
- An approach for vaccum infusion of these preforms while protecting the brittle through-thickness pitch fibers have been developed and first tested on one sample with successful results.
- Two more samples were manufactured later to verify the infusion methodology.
- One sample have been analysed from a thermal conductivity perspective as well as micrographed for observing the composite quality.
- The measurement of thermal conductivity did not produce a valid result. The reason for this was probably a poor choice of method due to time and resource constraints. However, a theoretical analysis shows that the thermal conductivity through the thickness can be locally improved by several hundred percents.
- The micrograph shows a high material quality inside the through-thickness bundles. The laminate close to the bundles however shows porosities and an increased thickness. The quality could probably be improved using suitably designed compacting plates or other means at the vicinity of the through thickness pitch fibers.

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