H. APPENDIX D

AIRBUS	Technical Note	

Report Nr.: TN – ESWOG – 1264/04

Author:
Department.:

Title

AAL587 Investigation

LH side Lug sub-component test #1, Lab investigation

Date: 29.06.2004

Summary:

The lab investigation of the static-tested LUG sub-component of a LH side rear main attachment lug of an A310 CFRP fin box, labeled as **Lug Test #1**, shows the following results:

- The lay up is in accordance with the drawing.
- The measured degree of cure was sufficient.
- A translaminar fracture starts from the bush-hole side, whereby the fracture path is orientated approx. 123° to rib #1.
- Further translaminar cracking was found, most likely starting from the bush-hole as well.
- The main ply separation is located within the skin layers, furthermore delaminations within the precured outer part of the lug were found.

0. Table of contents

1. Introduction

The tested component is a LH-side rear main attachment lug cut out from an A310 CFRP fin box. The test shall demonstrate the behavior of the lug under load conditions to which the fin of AA flight 587 has been exposed during the accident
The objectives of the lab investigation after the static test are the following:

- Description of the main ply separation and the fracture path.
- Determination of the fracture origin.
- Validation of the lay up, according to the drawings.
- Validation of a sufficient curing.

2. Visual inspection

After the static test, the main attachment lug shows a translaminar fracture and multiple delaminations in the area of the precured/cured transition between outer part of lug and skin (s. fig. 1-5)
The delamination size, found by NDT, is visible on figures 3 and 4.
After the first visual inspection, several cuts were taken to obtain a closer view to the damaged areas (cf. fig. 6).

3. Macroscopic investigation

After cutting along rib #1 and thru the bolt-hole (cf. fig. 3,4,6) the following damages were detected:

- Translaminar fracture was found, between the main ply separation and the outboard surface, labeled as 123° failure, because the fracture path is orientated approx. 123° to rib #1 (s. fig. 6). Further translaminar cracking was found below the main ply separation (s. fig. 7-10). The maximum failure depth (with fiber fracture) of the bush-hole side is 25.2 mm (s. fig. 7-8). Generally, the bush-hole side is more damaged than the lower side (s. fig. 7-10).
- Secondary translaminar cracking, labeled as 35° failure because of the estimated crack path in approx. 35° to rib #1, was found only on the bush-hole side (s. fig. 11). The maximum failure depth, including fiber fracture, is 31.4 mm.
- The main ply separation (delamination/cracking) was found in the area of the pre-cured/cured transition, i.e. the outer part, the precured/cured transition themselves as well as within the skin layers (s. fig. 6-10).

4. Metallographic investigation

Two sections (S1-S1 and S2-S2) and two microsections (S3 and S3B) were used for the metallographic investigation (s. fig.12).

4.1. Determination of delamination path

Section S1-S1 and S2-S2 were mainly used to obtain the depth and path of the main ply separation and further delaminations. These samples were only grinded or slightly polished due to their large dimension.
The main ply separation length, measured from the lower edge in upper direction of the lug, is 65.4 mm on section S1-S1 and 58.1 mm on section S2-S2 (s. fig. 13,14). Both values are in good correlation to the NDT results (s. fig. 12).
The depth, measured from the outboard side is not constant (s. fig. 13,14). Generally, the main ply separation is located within the skin layers, just below the 4 tape layers (s. fig. 13, 14 and 15 of S3). Furthermore, section S1-S1 contains a delamination within the outer precured part of the lug (s. fig. 13).

4.2. Validation of the lay up

Microsection S3 was used for the validation of the lay up. This microsection is located below the bush-hole and is orientated approx. 85° to rib #1 (s. fig. 12).
The determination of the lay up was done in 2 steps:

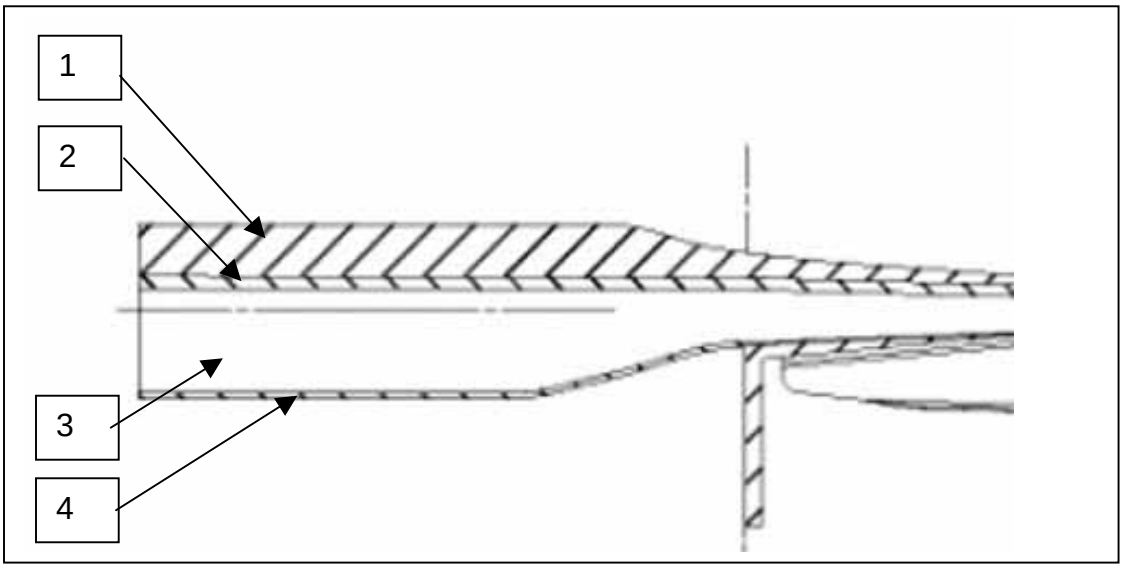
Step 1: The fiber orientation was determined based on the orientation of the microsection S3, i.e. fibers with a circular cross section were labeled as 90°, elliptical fibers were labeled as 45° and elongated fibers were labeled as 0°.
Step 2: The in step 1 obtained orientations were transformed into the axis of the drawing. There is a shift of 45° between the microsection S3 and the drawing (0° fiber orientation given by the drawings is equal to 45° fiber orientation of microsection S3).

All layers as well as the location of the precured/cured transitions (s. fig. 15) are in accordance with the drawings.

4.3. Thickness Measurement

Microsection S3 was also used to confirm, that the measurement of the thickness of the individual parts were as per documentation.

Part
Outer part (1)
Skin and Reinforcement (2)
Inner Part (3)
Additional layers (4)



5. DSC Investigation

The DSC-Analysis by MDSC has been performed on specimens that were taken from

- The skin layers (between the two precured parts) beside microsection S3
- The fin, outside of the lug test sample, as a reference sample before final curing of the reinforcement in the area of the load introduction fittings.

When comparing the measured residual heat release values, it is verified that this values indicate that this minimal excess of energy are correlative with a sufficient degree of cure.

6. Fractographic investigation

A section containing the main ply separation (delamination) and the translaminar fracture was separated from the lug in the lab (s. fig. 16, 17). The obtained section was cut into two samples labeled as SEM sample F1 and F2 (s. fig. 16, 17).
The translaminar fracture **(F1**) shows indications of Mode I (tension) and Mode II (shear) loadings in the area of matrix cracking (s. fig. 18). The fractured fibers obtained radial fracture patterns, locally indications to bending or compression (kinking) were found (s. fig. 19, 20). I.e. the direction of the local fiber fracture is visible.

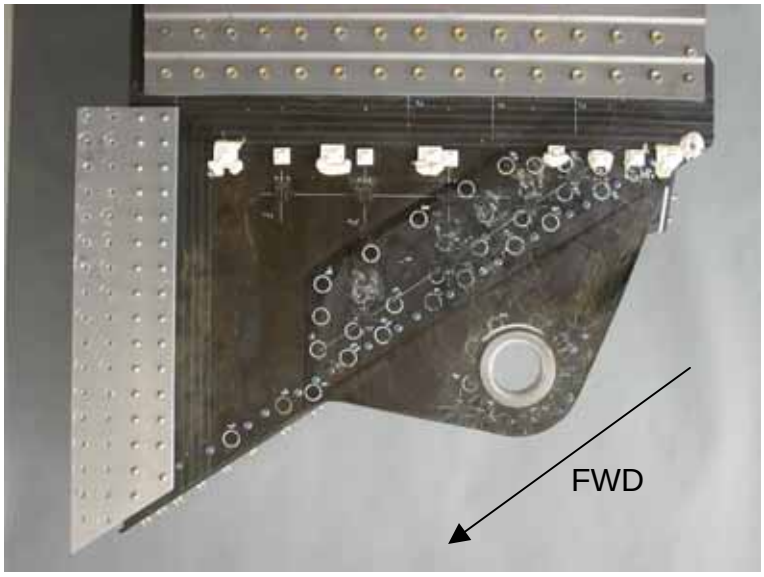
The delamination surface (sample **F2**) contains indications of Mode I (tension) and Mode II (shear), too (s. fig. 21-25). Furthermore, broken fiber bundles caused by delamination bridging or by local cracking thru the layer as well as indications of the resin hardener were found (s. fig. 22, 24).
Locally, multiple fractured fibers were found, most probably due to release of elastic energy after fracture (s. fig. 26).

7. Summary

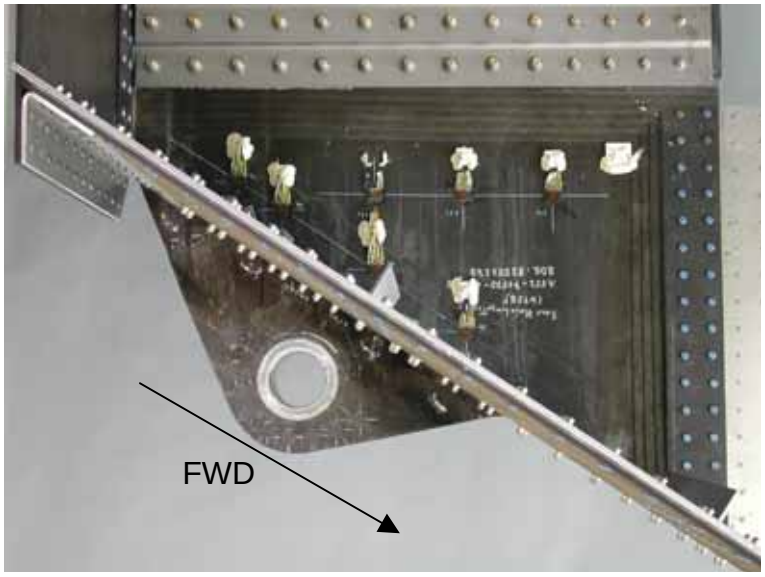
The lab investigation of the static tested Lug subcomponent of a LH side rear main attachment lug of an A310 CFRP fin box, labeled **as Lug Test #1,** shows the following results:

- The lay up is in accordance with the drawings.
- The measured degree of cure was sufficient.
- A translaminar fracture, starting from the bush-hole side, occurred on the FWD side of the lug. The fracture path is orientated approx. 123° to rib #1. Further cracking including fiber fracture was found on the bush-hole side of this area.
- A secondary translaminar cracking, including fiber fracture, starting from the bush-hole was found. The estimated crack path is orientated 35° to rib #1.
- The main ply separation is located within the skin layers, mostly just below the tape layers. Furthermore, delaminations within the precured outer part of the lug were found.

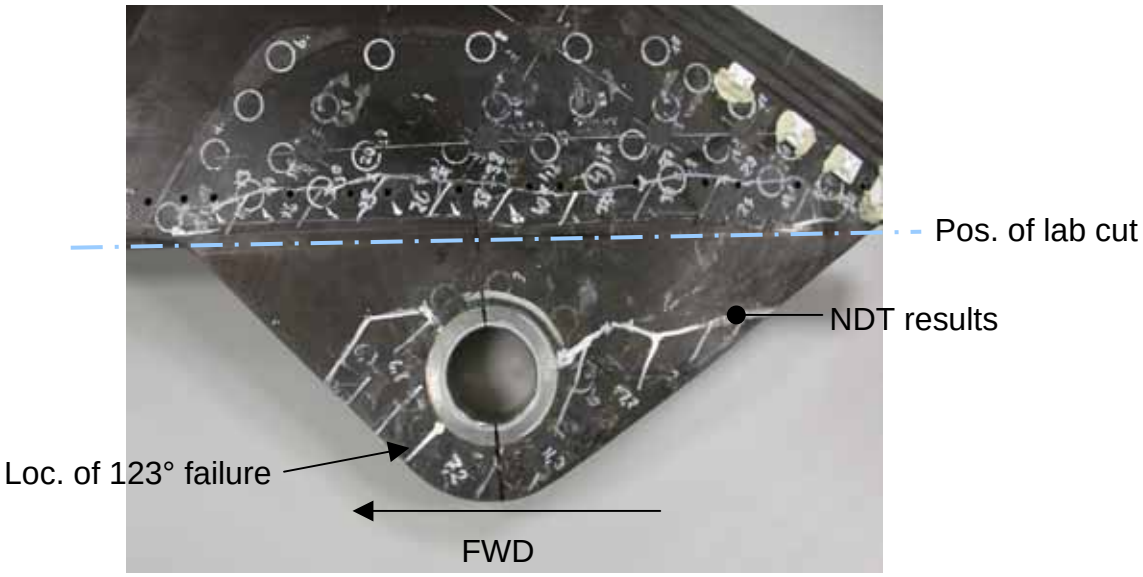
Visual Inspection



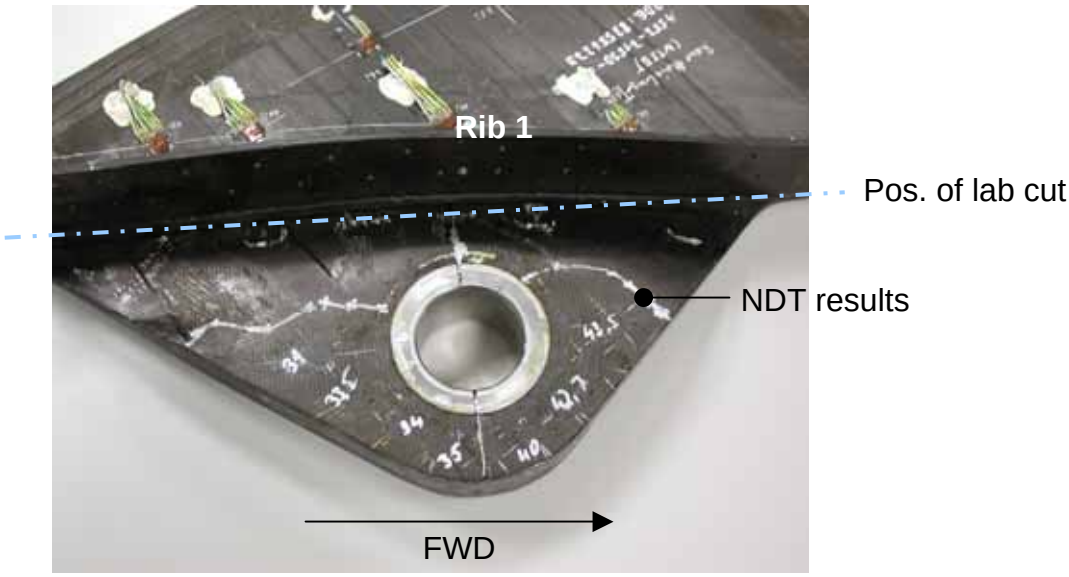
09358/03 State as delivered
Fig. 1: Lug test #1, condition: after static test, view from outboard side



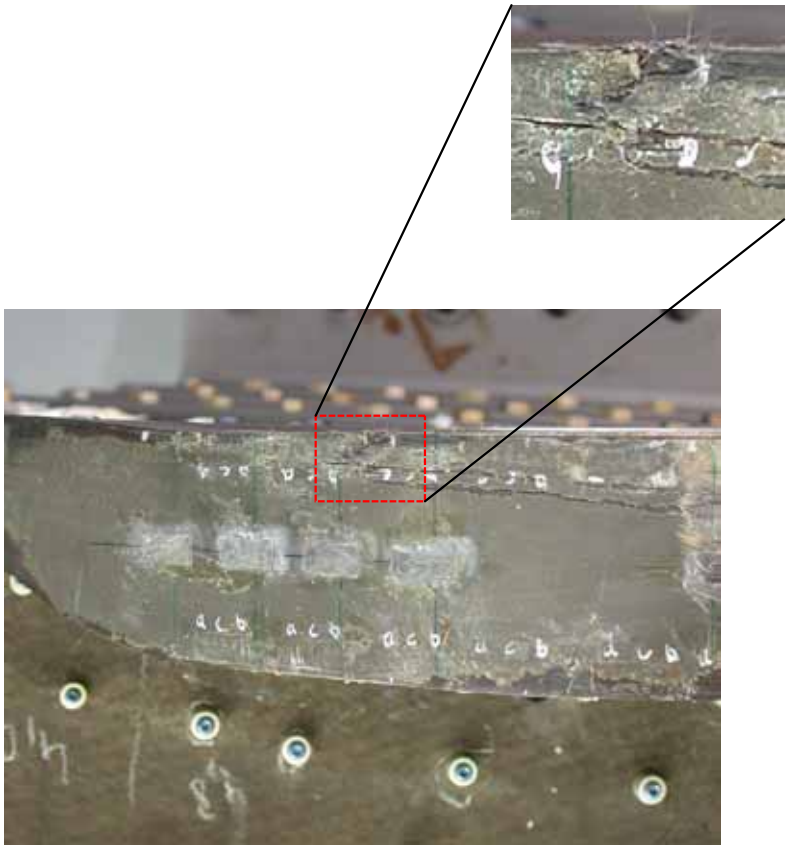
09363/03
Fig. 2: Lug test #1, condition: after static test, view from inboard side



00877/04
Fig. 3: NDT results after static test and separation of load introduction fitting, view from outboard side

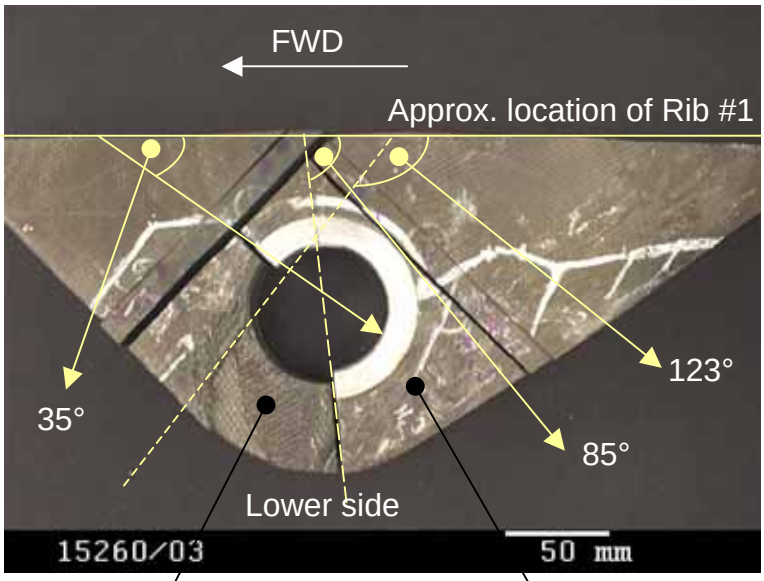


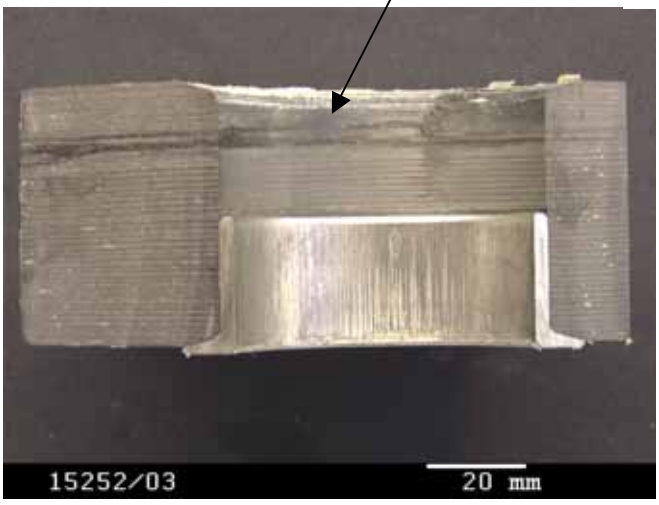
00879/04
Fig. 4: NDT results after static test and separation of load introduction fitting, view from inboard side



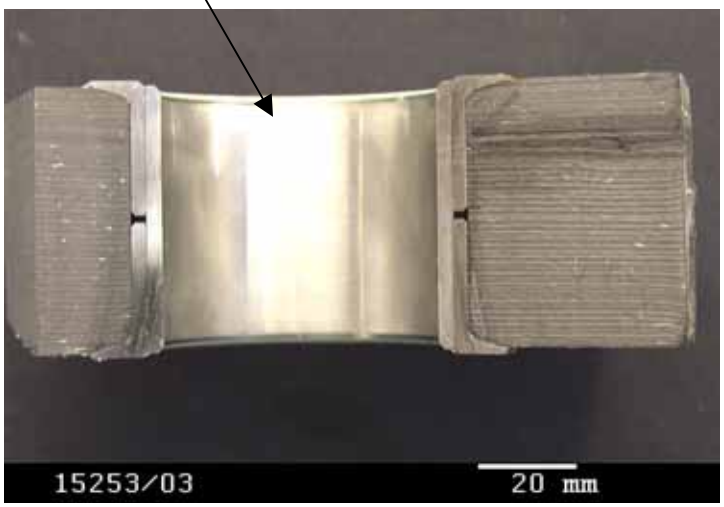
09368/03 09369/03
Fig. 5: Delamination path, translaminar fracture path (arrow), view from lower side, condition: after static test

Cutting schedule





Cut out #1



Cut out #2

15260/03 15252/03 / 15253/02

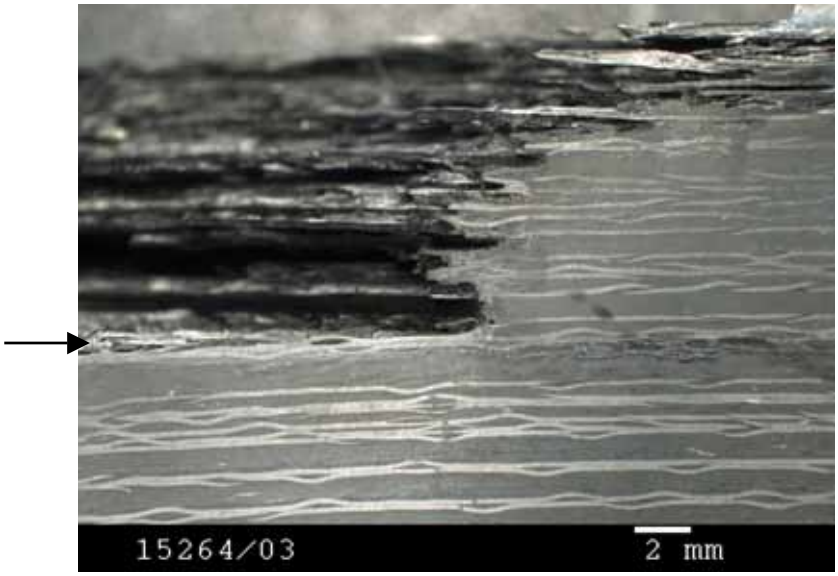
Fig. 6: Schedule of cut out #1 and #2, approx. angle between Rib #1 and:

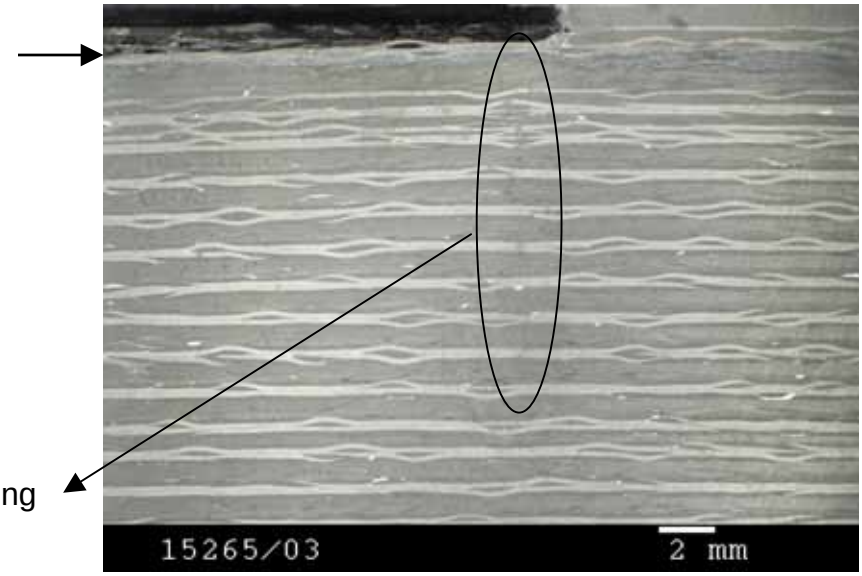
- Translaminar fracture (labeled as 123° failure)
- Sec. cracked area (labeled as 35° failure)
- Section S3 – S3

Macroscopic Investigation

Translaminar fracture

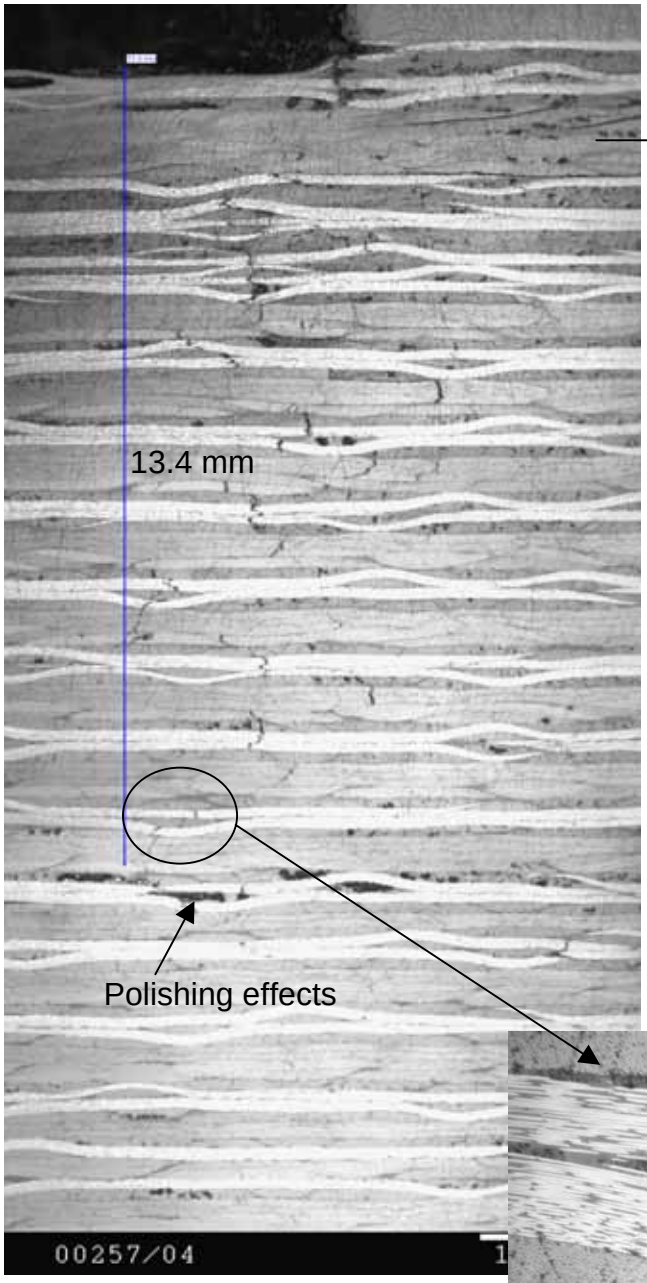
Outboard side

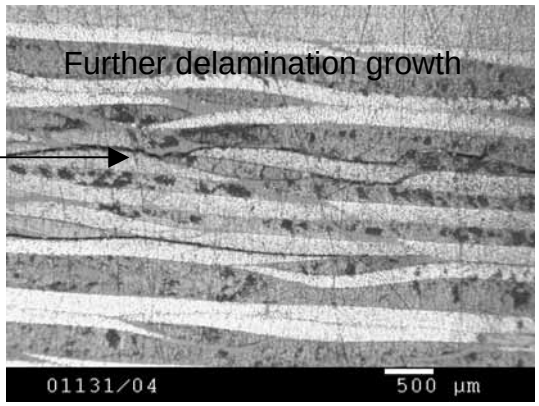


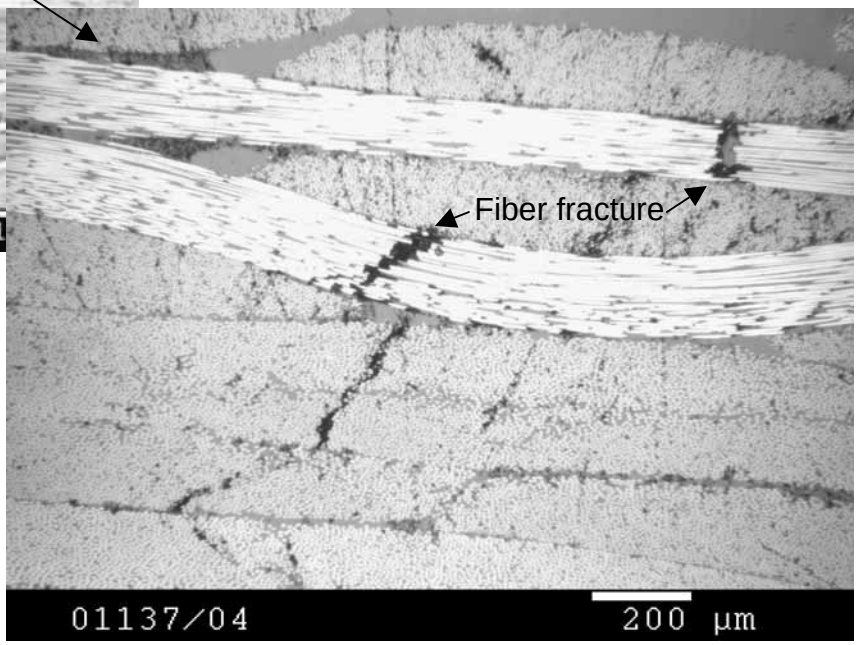


15264/03 15265/03 Grinded

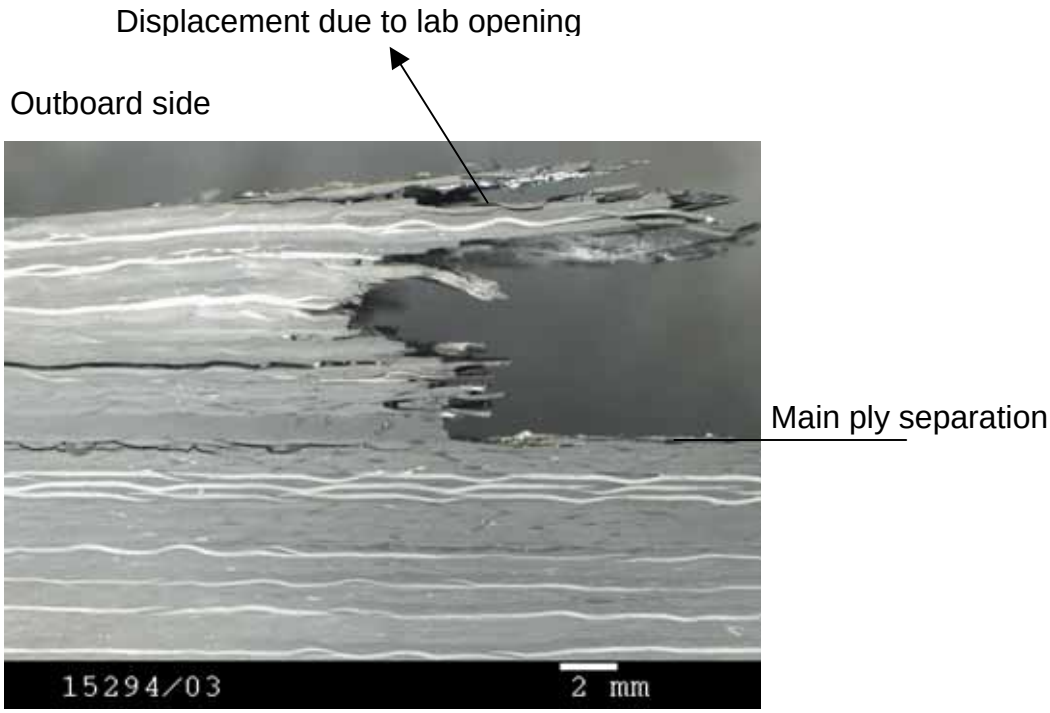
Fig. 7: Translaminar fracture path above and further cracking below main ply separation (arrow), detail of fig. 6 /view from bush-hole side/123° failure



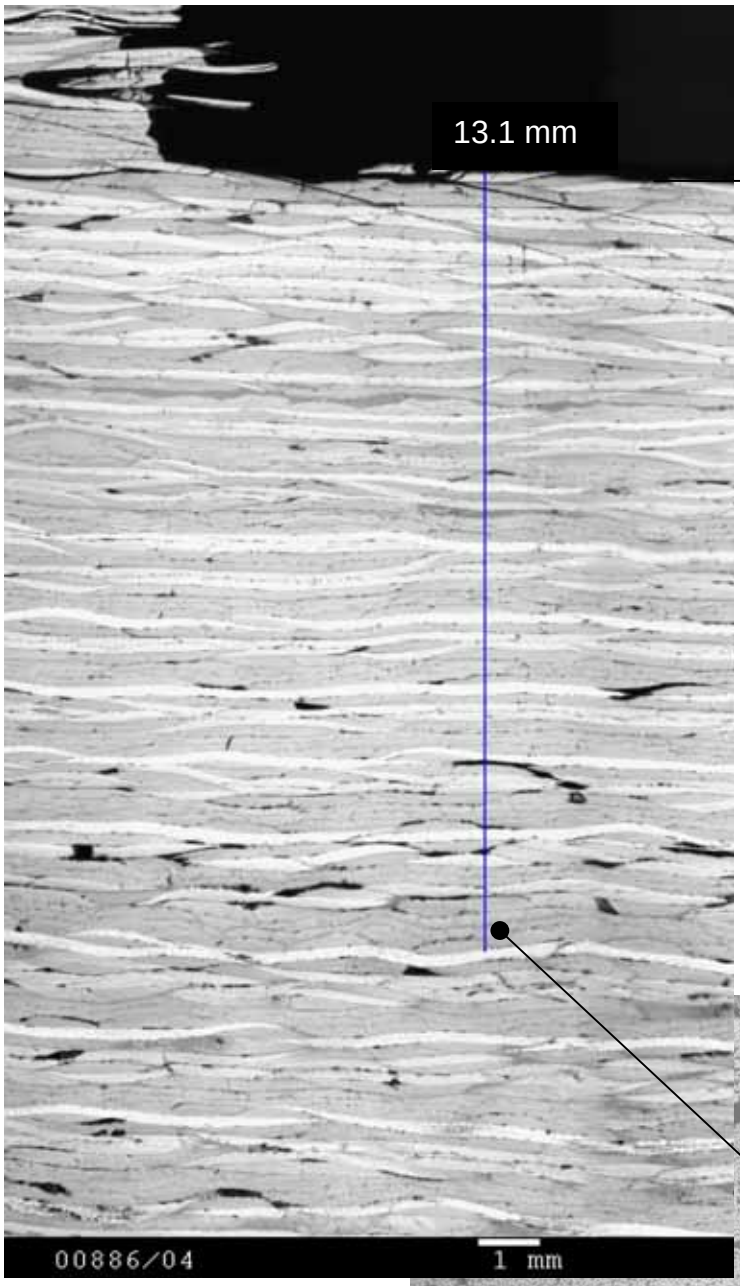


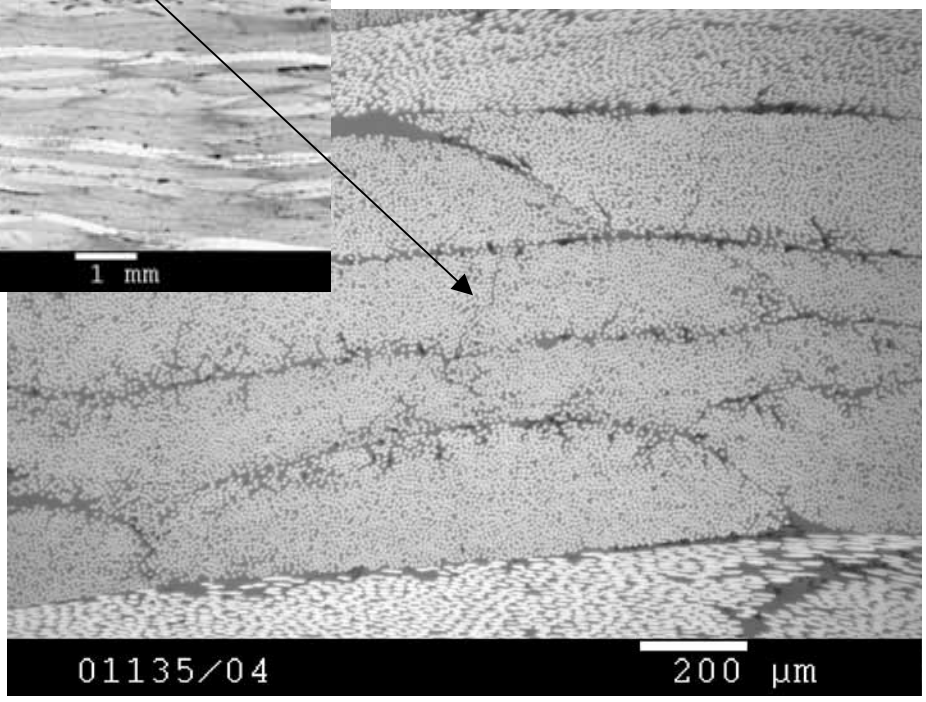


00257/04 Slightly polished
Fig. 8: Crack path with fiber fracture below main ply separation, detail of fig. 7, view from bush-hole side

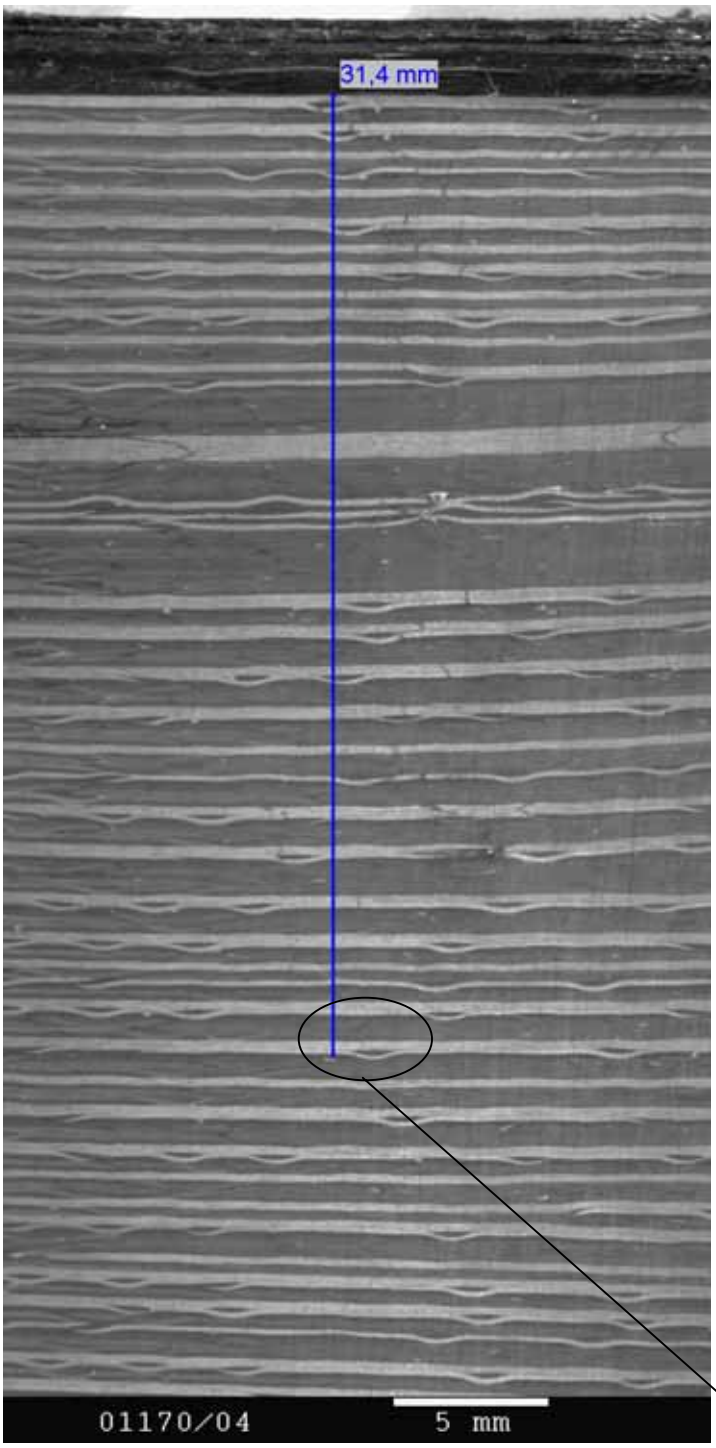


15294/03 Grinded
Fig. 9: Translaminar fracture path, view from lower side, 123° failure / cf. fig. 6





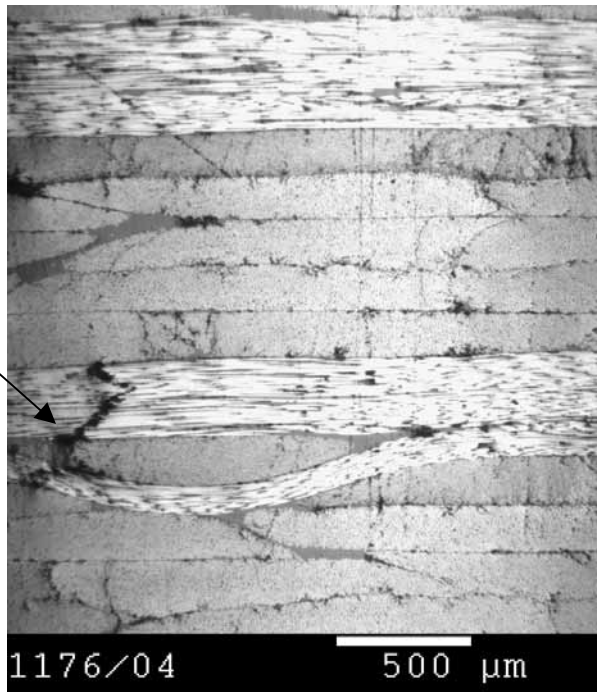
00886/04 00248/04
Fig. 10: Further matrix cracking below main ply separation, cf. fig. 9, view from lower side



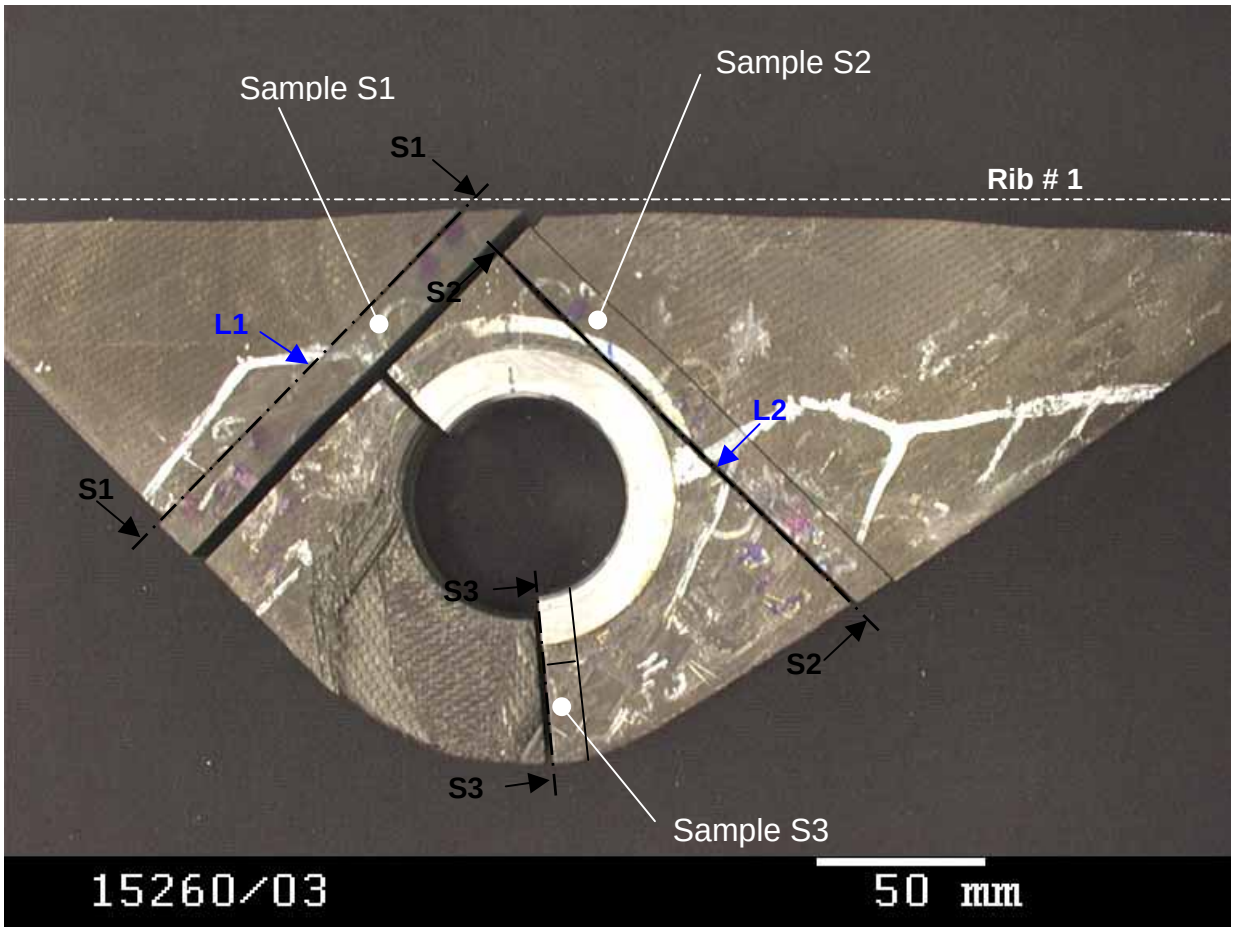
01170/04 grinded

01176/04 slightly polished

Fig. 11: Further cracking, maximum failure depth is 31.4 mm, cf. fig. 7, view from lower edge, 35° failure

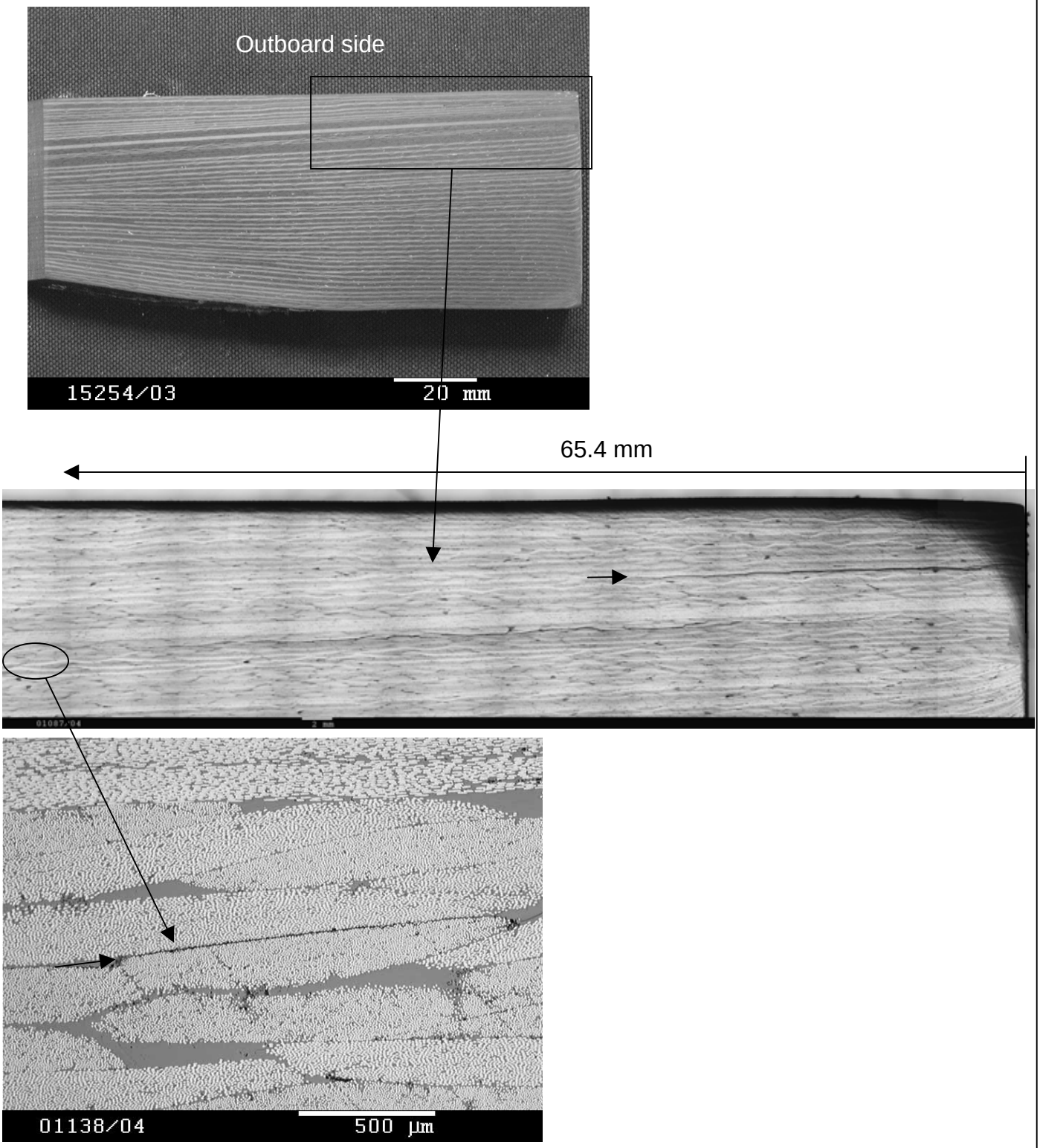


Metallographic Investigation of section S1 to S3



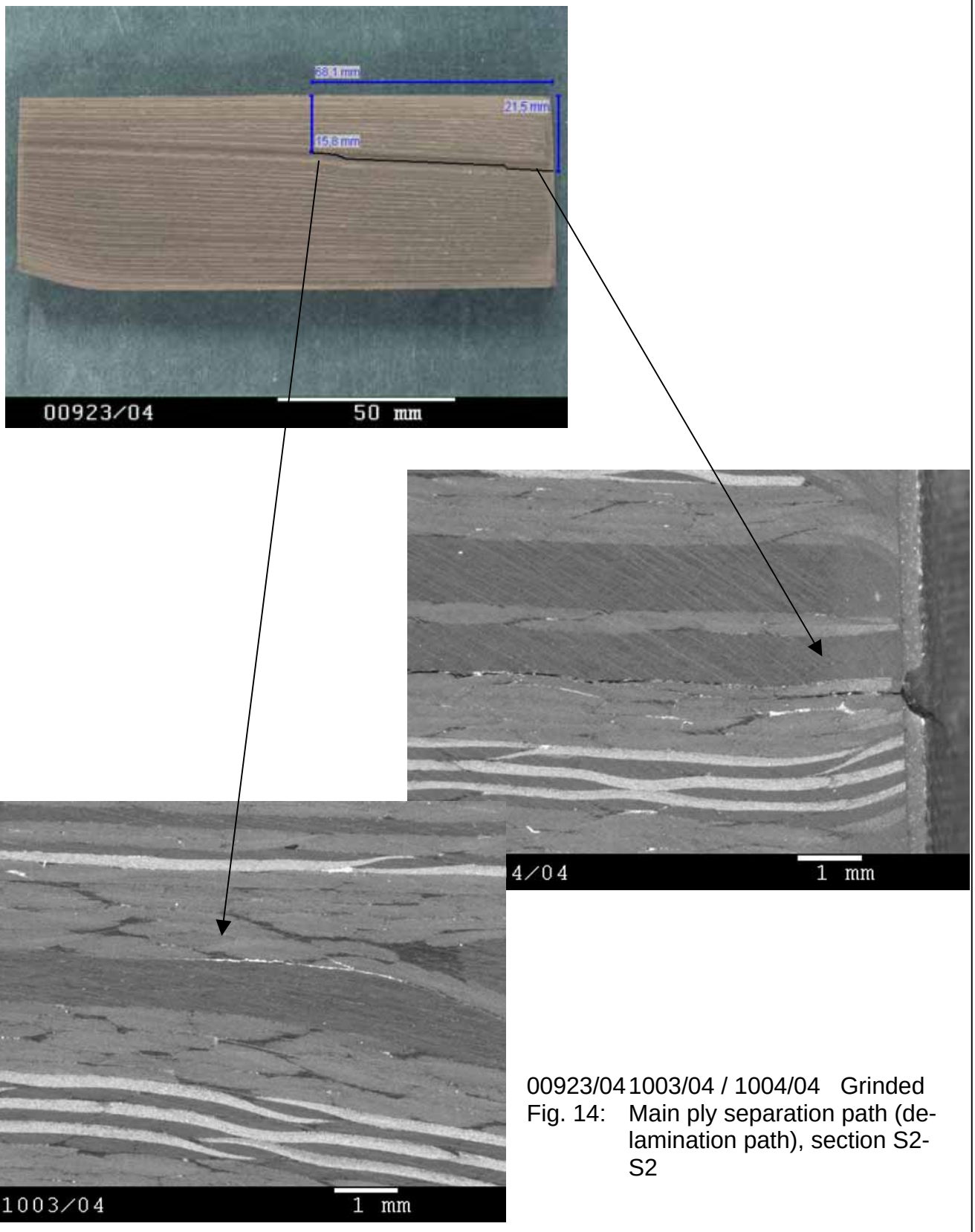
15260/03

Fig. 12: Location of sections S1-S1, S2-S2 and S3 – S3, microsection S3 (sample S3), maximum delamination length L1 (65.4 mm) and L2 (58.1 mm) found on section S1 and S2, the 0° orientation acc. to the drawings is approx. 45° to rib #1



15254/03 Grinded // 01087/04 / 01138/04 slightly polished

Fig. 13: Main ply separation path and further delamination path (arrow) within precured outer part of lug, section S1-S1



00923/04 1003/04 / 1004/04 Grinded
Fig. 14: Main ply separation path (de-lamination path), section S2-S2

Outboard side

Outboard part (32 A553 71674)

Main ply separation

Lower edge

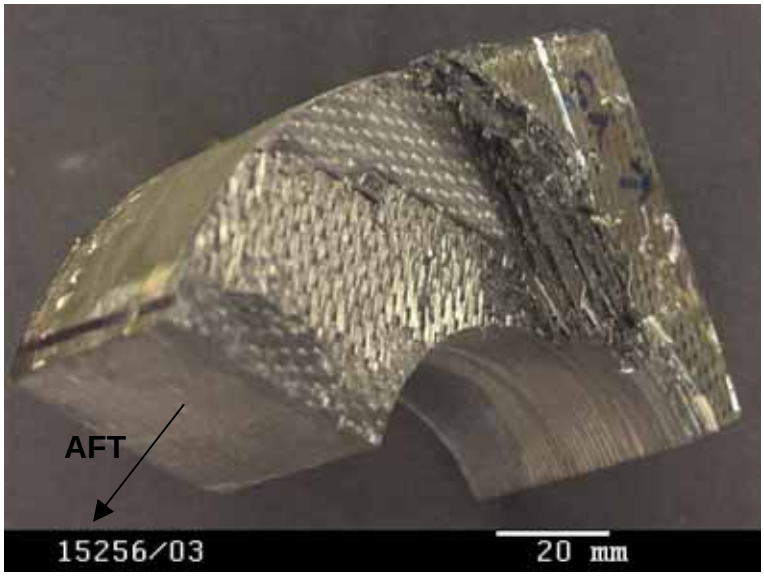
Inboard part (32 A553 71675)

Additional layers (32 A553 71591 sheet 2)

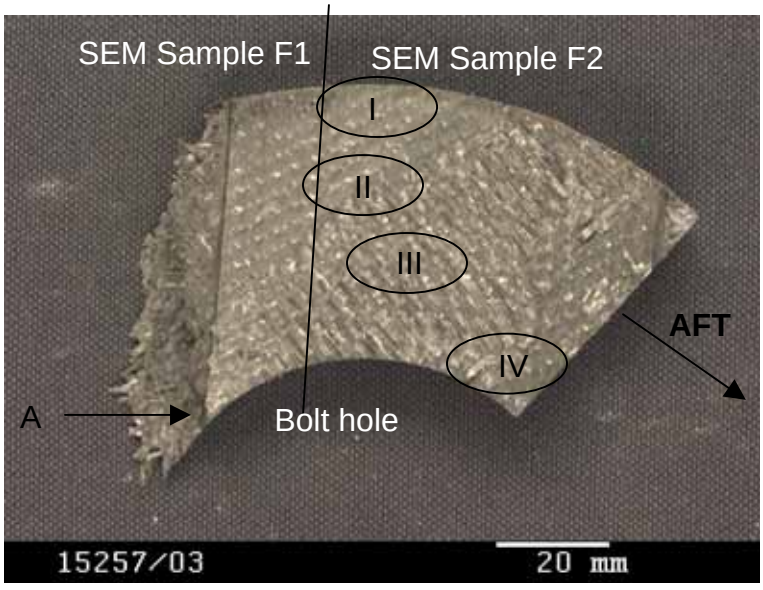
00843/04 Polished

Fig. 15: Microsection S3, lay up sequence, precured/cured transition (interrupted lines)

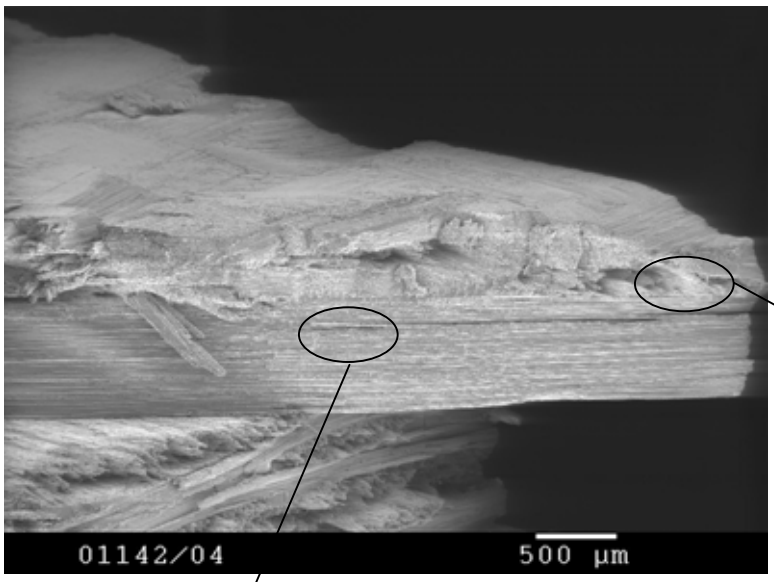
Fractographic Investigation

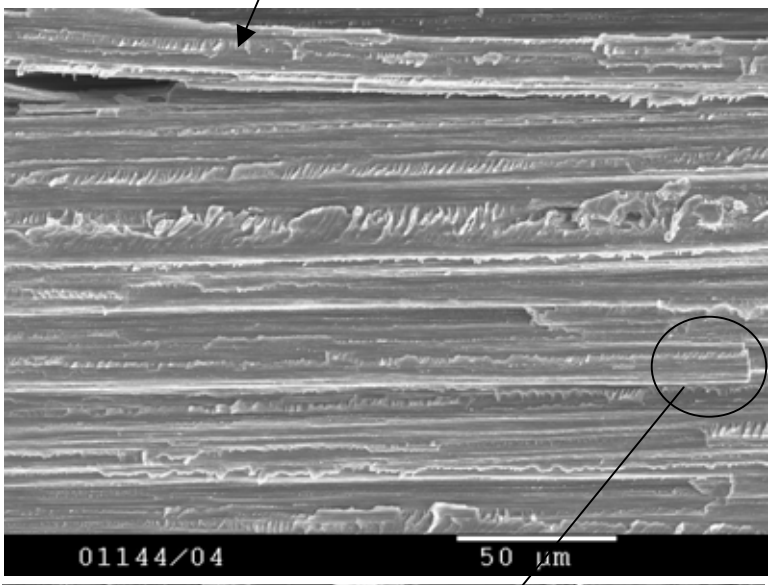


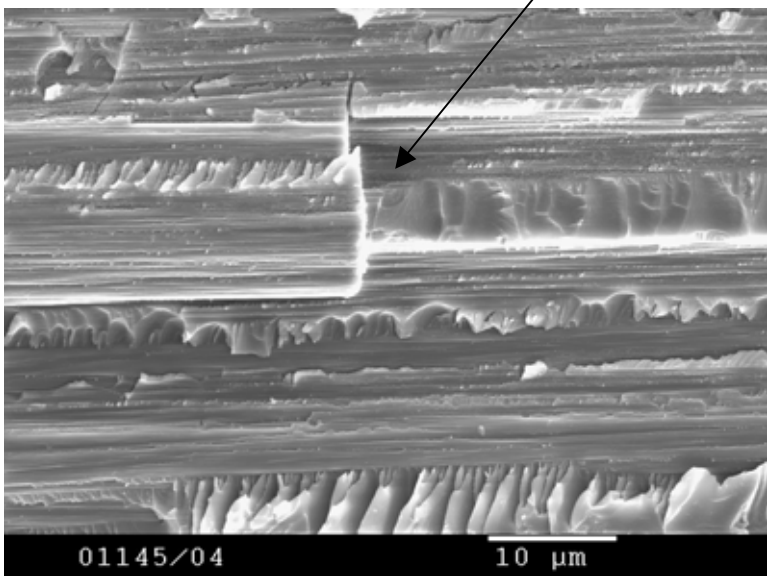
15256/03
Fig. 16: General view of cut out #1 after lab separation of main ply separation



15257/03
Fig. 17: General view of main ply separation and fracture after lab separation, location of SEM details

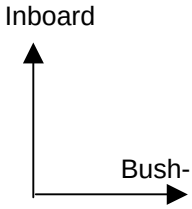


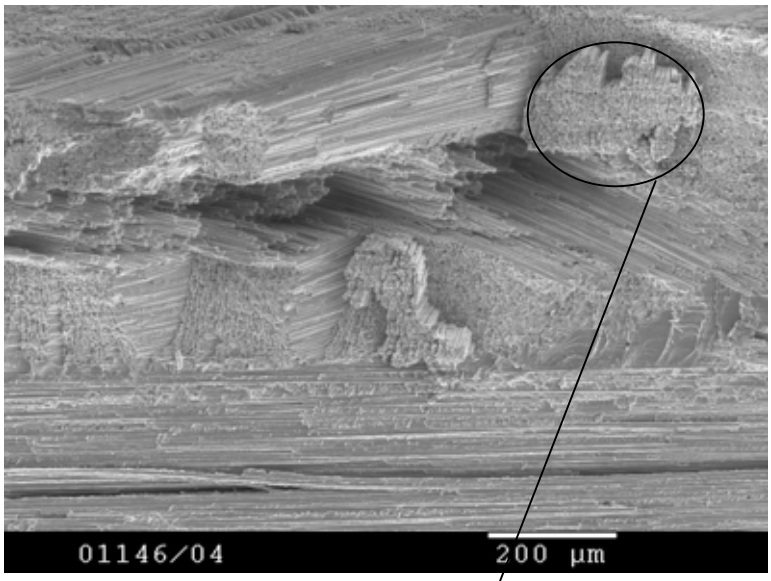


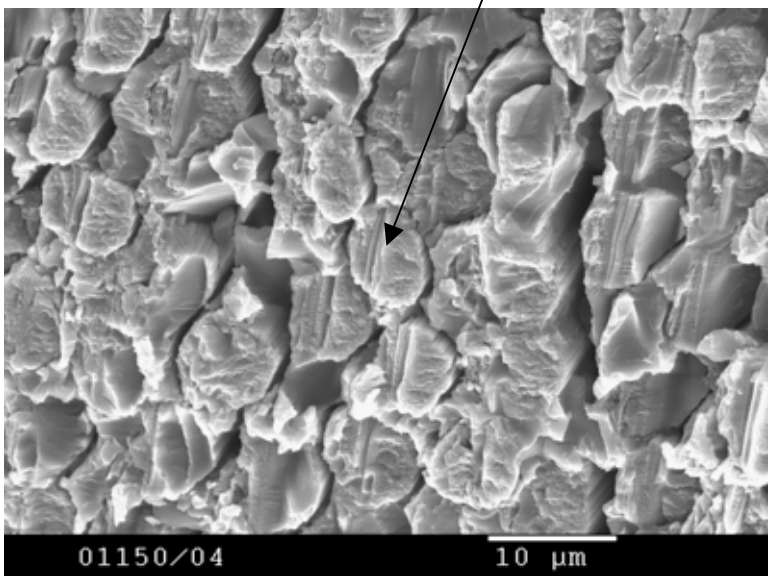


01142/04 01144/04 01145/04
Fig. 18: Translaminar fracture, Mode I and II features, SEM sample F1, pos. A/cf. fig. 18

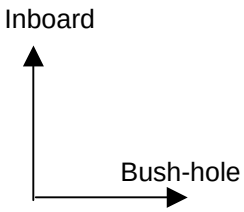
s. fig. 21

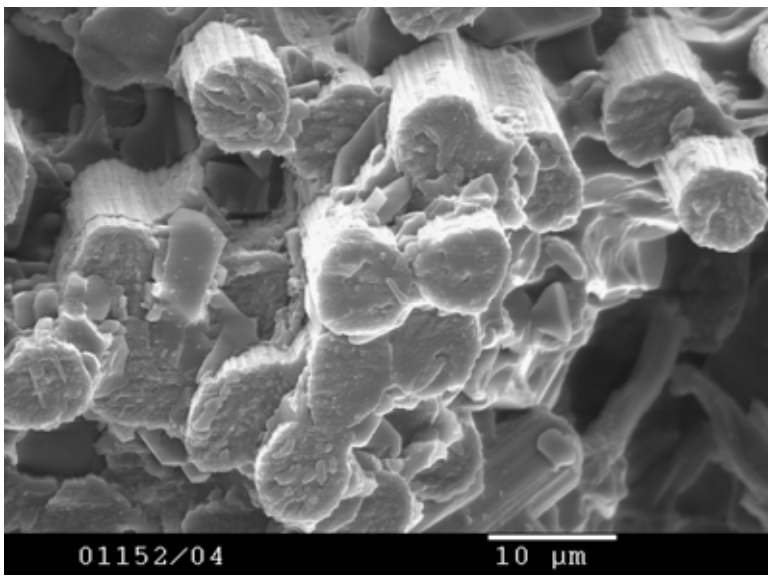




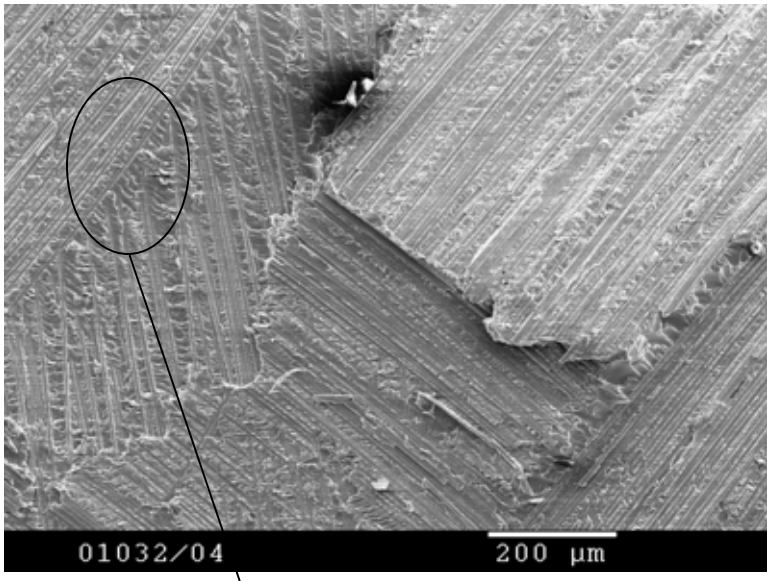


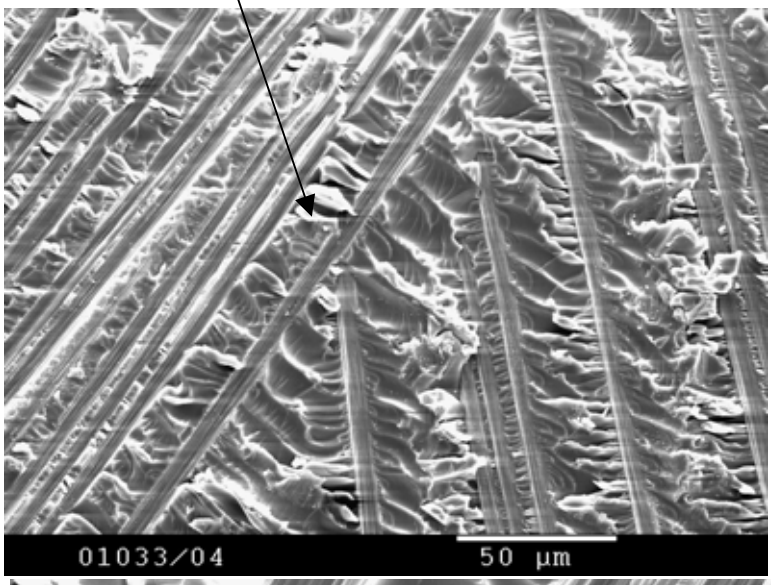
01142/04 01150/04
Fig. 19: Fiber fracture of 1st layer, indications to bending, det. of fig. 19, sample F1

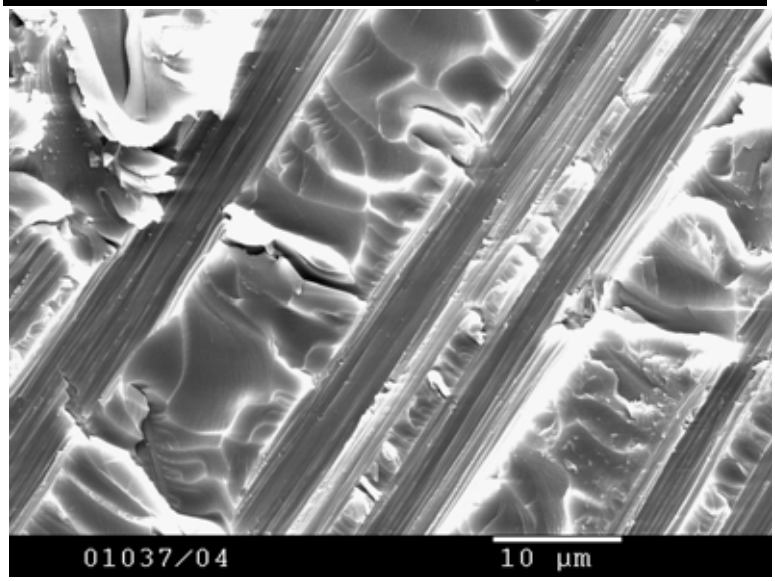




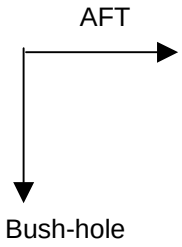
01142/04
Fig. 20: Fiber fracture due to tensile load, located just beside the bush-hole, det. of fig. 19, sample F1

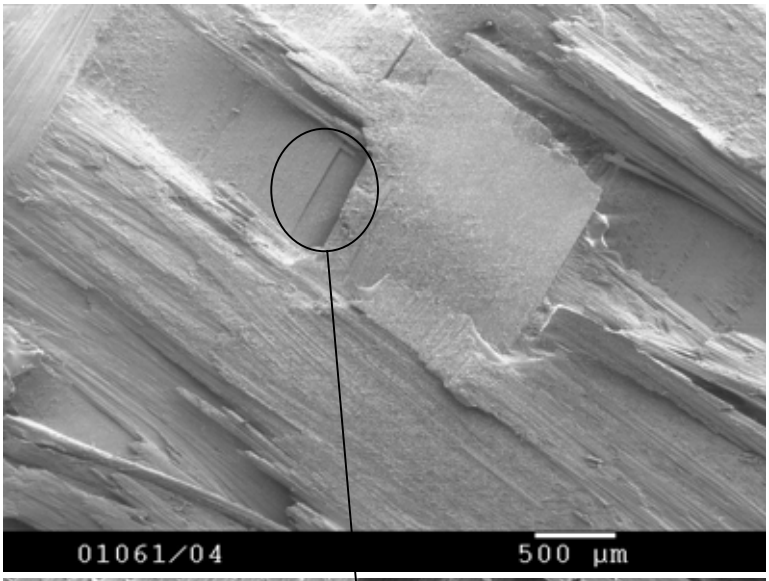


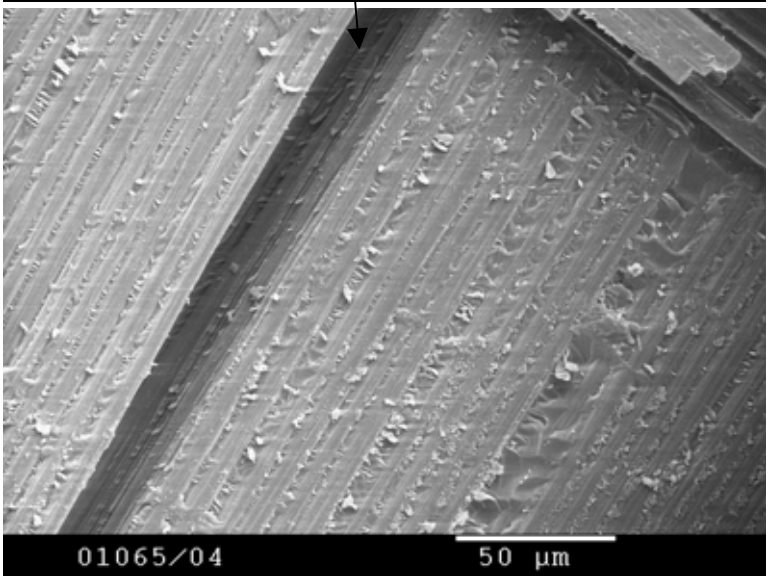


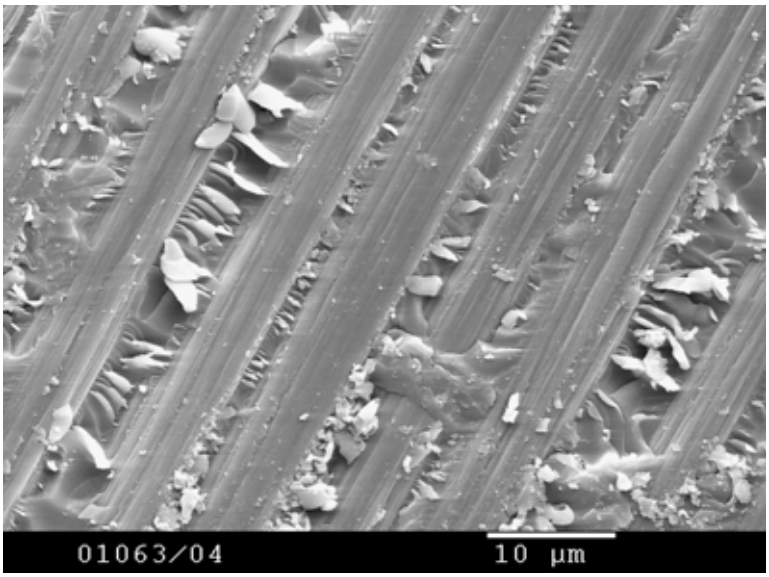


01037/04 01033/04 01037/04
Fig. 21: Indications of Mode I loadings, SEM sample F2/pos. I/s. fig. 18

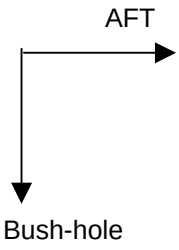


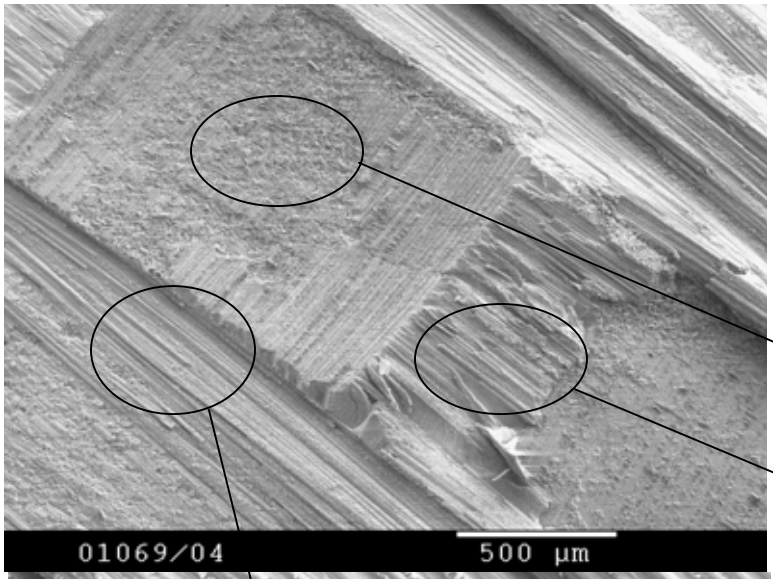






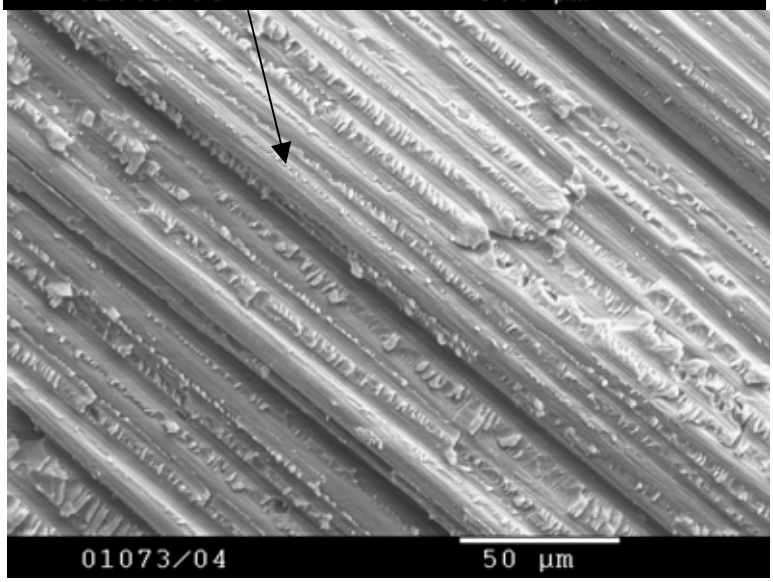
01061/04 01065/04 01063/04
Fig. 22: Indications of Mode II loadings, fiber fracture due to delamination bridging or cracking thru the layer, SEM sample F2/pos. II/s. fig. 18

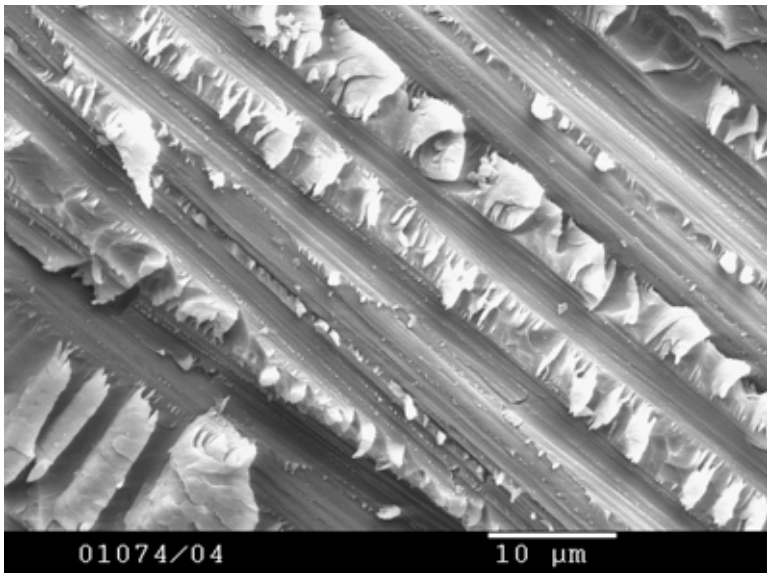




s. fig. 25

s. fig. 26

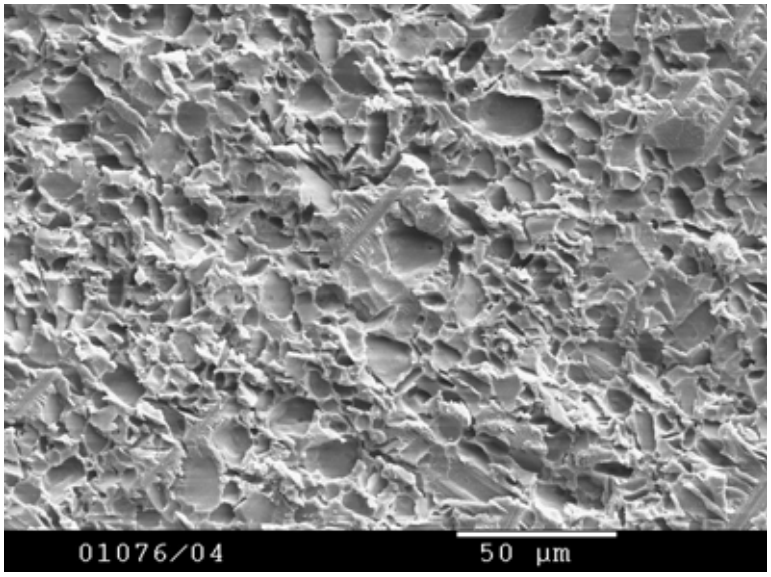




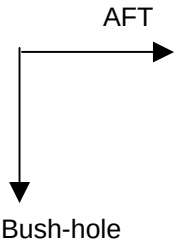
AFT

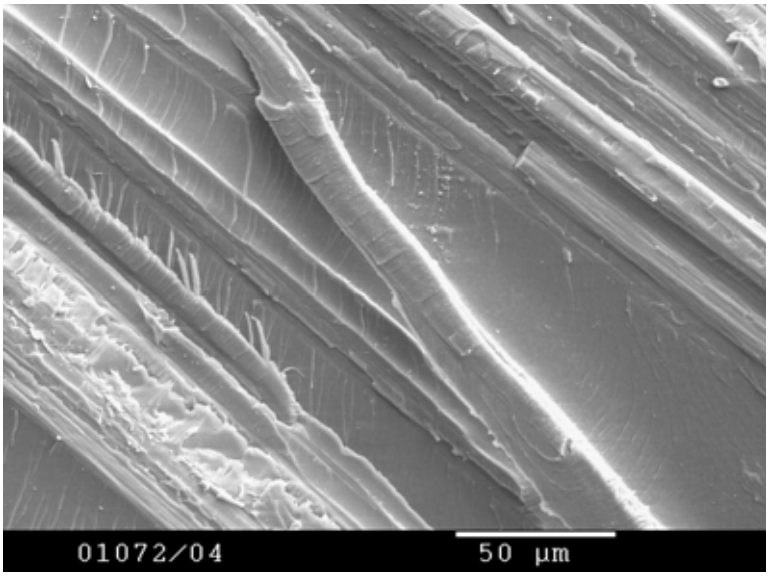
Bush-hole

01069/04 01073/04 01074/04
Fig. 23: Indications of Mode II loadings, loc. fiber fracture due to delamination bridging or cracking thru the layer, SEM sample F2/pos. III/s. fig. 18

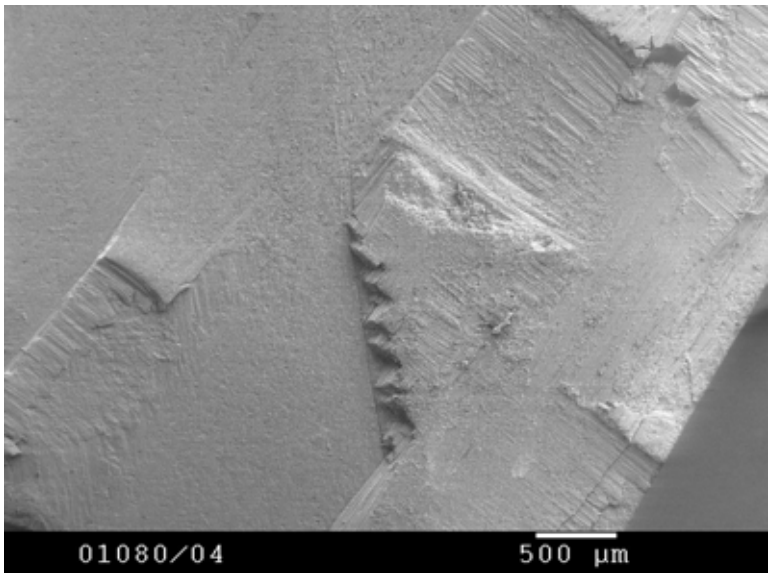


01076/04
Fig. 24: Indications of resin hardener, detail of fig. 24, sample F2





01072/04
Fig. 25: River marks, resin enriched area, detail of fig. 24, sample F2



01080/04
Fig. 26: Fiber fracture due to de-lamination bridging or cracking thru the layer, loc. multiple fiber fracture, SEM sample F2/pos. IV/s. fig. 18