I. APPENDIX E

AIRBUS	Technical Note	

Report Nr.: TN – ESWOG – 1265/04

Author:
Department.:

Title

AAL587 Investigation

LH side Lug sub-component test #2, Lab investigation

Date: 30.06.2004

Summary:

The lab investigation of the static tested Lug subcomponent of a LH side rear main attachment lug cut out of MSN513, labeled as **Lug Test #2**, shows the following results:

- The lay up is in accordance with the drawing.
- The measured degree of cure was sufficient.
- Two translaminar fractures occurred in comparable locations to lug test #1. The fracture path on outboard side is orientated approx. 134° as well as 39° to rib #1.
- Beside the translaminar fractures, a further buckling/compression failure is visible on outboard side in front of the 134° failure.
- A delamination located within in the gap between outboard and inboard bush was found beside the main ply separation.
- The delamination found within the precured outer part of the lug was larger that the pre test delamination detected before the lug was tested up to rupture load.
- Only, the pre test delamination surface obtained residues of grease or oil.
- The chamfer of the outboard-sided outer bush shows minor traces of grease, as well.

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1. Introduction

The tested component is a LH-side rear main attachment lug cut out of the MSN513 CFRP fin box, operated by American Airlines. The test shall demonstrate the behavior of the lug under static loading.

The objectives of the lab investigation after the static test are the following:

- Description of the main ply separation and the fracture path.
- Validation of the lay up, according to the drawings.
- Validation of a sufficient curing.
- Chemical analysis of the dark coatings on the pre test delamination and outer bush.

2. Visual inspection

After the static test, the main attachment lug shows two translaminar fractures through the lug (by mostly tension loading) and a translaminar fractured area caused by buckling/compression as well as multiple delaminations (s. fig. 1-3,5). The delamination size, after test, found by NDT, is visible in figure 1.
The outboard-sided outer bush shows a lot of debris besides a green colored coating on the lug sided chamfer surface (s. fig. 4). The inner bush shows circumferential traces indicating a possible movement of outer bush of approx. 2.2mm (s. fig. 4).
After the first visual inspection, several cut outs were taken to obtain a closer view of the damaged areas.

3. Macroscopic investigation

After cutting and separation of the fractured parts of the lug the following damages were detected:

- A translaminar fracture thru the entire wall thickness of the lug was found. The location/orientation on outboard side is comparable to the primary translaminar fracture of lug test #1 (cf. TN-ESWOG-1264/04). This fracture is labeled as 134° failure, because the fracture path on the outboard side is orientated approx. 134° to rib #1 (s. fig. 1-3,5).

- A further translaminar fracture (labeled as 39° failure) thru the entire wall thickness was found (s. fig. 1-3,5). The location/orientation on outer side is comparable to the secondary translaminar cracking of lug test #1 (cf. TN-ESWOG-1264/04).

- The main ply separation area is located in the area of the precured/cured transition, i.e. the outer part, the precured/cured transition themselves as well as within the skin layers (cf. fig. 1-3,5). Furthermore, a delamination located within the gap between outer and inner bush was found (s. fig. 3), besides several other smaller delaminations.

- A crack in the radius area of rib #1 was found (s. fig. 6).

4. Metallographic investigation

Three macro sections (S3-S3, S4-S4 and S5-S5) and one microsection (sample S3/ part of macro section S3-S3) were used for the metallographic investigation (s. fig. 4 and 5). It was decided between NTSB, BEA and Airbus, that the sections S1 and S2, to obtain the detailed location of the main ply separation (comparable to lug test #1), were not investigated.

4.1. Investigation of macro sections

Section S3-S3 and S4-S4 were mainly used to obtain the path of delamination in the area of rib #1. Section S5-S5 was used to determine the length and location of the pre test delamination. All these samples were only grinded or slightly polished due to their large dimension. The results are the following:

- A crack, located in the radius, followed by a delamination was found on section S3-S3 and S4-S4. The detailed delamination length is given in fig. 6.
- A further delamination from the lower edge, growing up in direction of rib #1, was found on section S4-S4.
- Concession layers, according to the concession were found on inboard side of section S4-S4.
- The pre test delamination, detected on section S5-S5, was 14.3 mm long before the test and 33.5 mm after the test. This delamination is located within the pre-cured outboard part of the lug.

4.2. Validation of the lay up

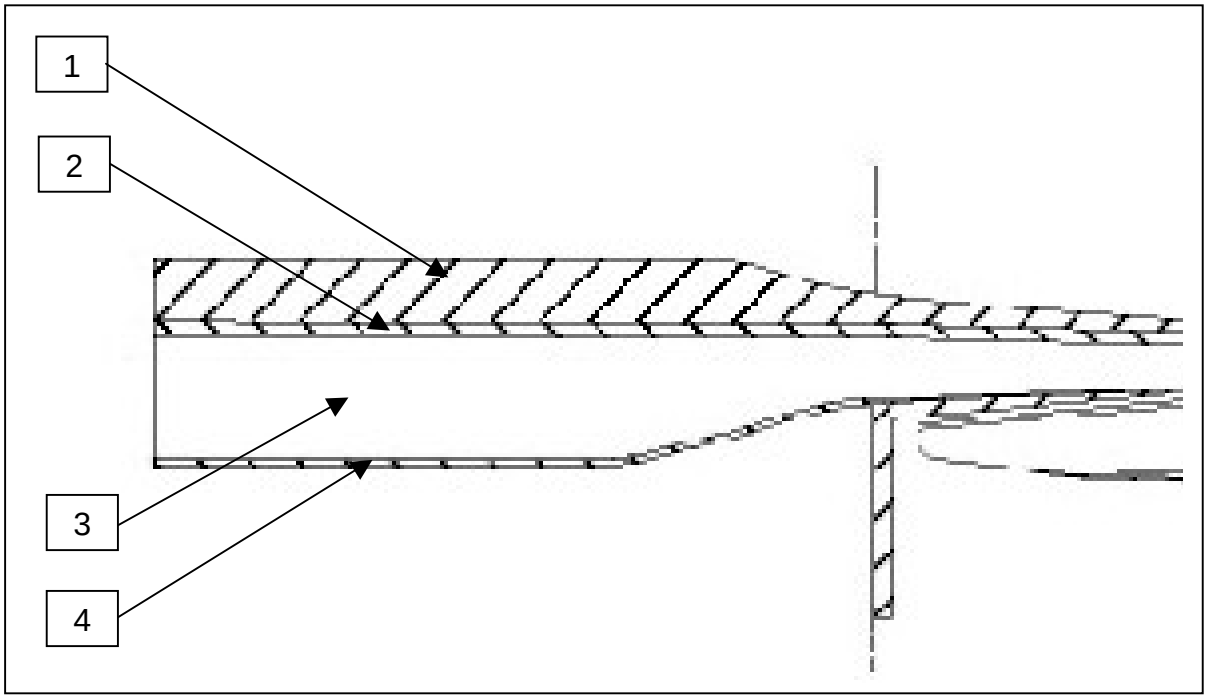
Microsection S3 was used for the validation of the lay up. This microsection is located above the bush-hole and is orientated approx. 90° to rib #1 (s. fig. 5).
The determination of the lay up was done in 2 steps:
Step 1: The fiber orientation was determined based on the orientation of the microsection 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 are in accordance with the drawings and concession of the inner part.

4.3. Thickness measurement

Microsection S3 was also used to confirm that 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 obtained values of residual heat verify a sufficient degree of cure.

6. Fractographic investigation

The fractographic sample **F1** was taken from the translaminar fracture of the 134° failure (s. fig. 2, 8), comparable to sample F1 of lug test #1. I.e., sample F1 obtained mainly the precured outer part of the lug.
Sample **F2** obtained the pre test delamination after lab separation (cf. fig. 2, 5), found during the incoming NDT inspection. This sample obtained dark coatings in the area of the pre test delamination and was investigated in uncleaned and cleaned condition. The uncleaned condition shows a marked transition between the area with and without dark coatings. But a useful documentation is not possible; thus all figures were made in a cleaned condition.

Radial patterns on fractured fibers were only locally visible on the translaminar fracture of sample F1; most of the fibers were covered with debris (s. fig. 9,10) The main ply separation surface of sample F1 shows locally indications to Mode I and II loadings (s. fig. 11).

The pre test delamination surface (sample **F2**) and the larger post ruptured delamination area contain indications of Mode I (tension) and Mode II (shear), too (s. fig. 12 -15), whereby the pre test delamination area shows a lot of debris (s. fig. 13). The lab fracture shows mostly indications of Mode I (s. fig. 16-17).

7. Chemical analysis of pre test delamination surface and bush

The dark layers, found on the surface of the pre test delamination, were investigated by Infrared Spectroscopy (IR) and X-ray photoelectron spectroscopy (XPS), also called Electron Spectroscopy for Chemical Analysis (ESCA).

- The infrared investigation of the isolated residues (extracted with Dichloro-methane) shows a typical spectrum of grease or oil. It was not possible to extract any material from the backside of the sample, thus the part is not generally contaminated with grease or oil.
- The XPS analysis shows a layer, possibly consisting of grease or oil, which cover the pre test delamination surface.

The infrared investigation on the chamfer of the outboard bush (connecting side to the lug) shows the following results:

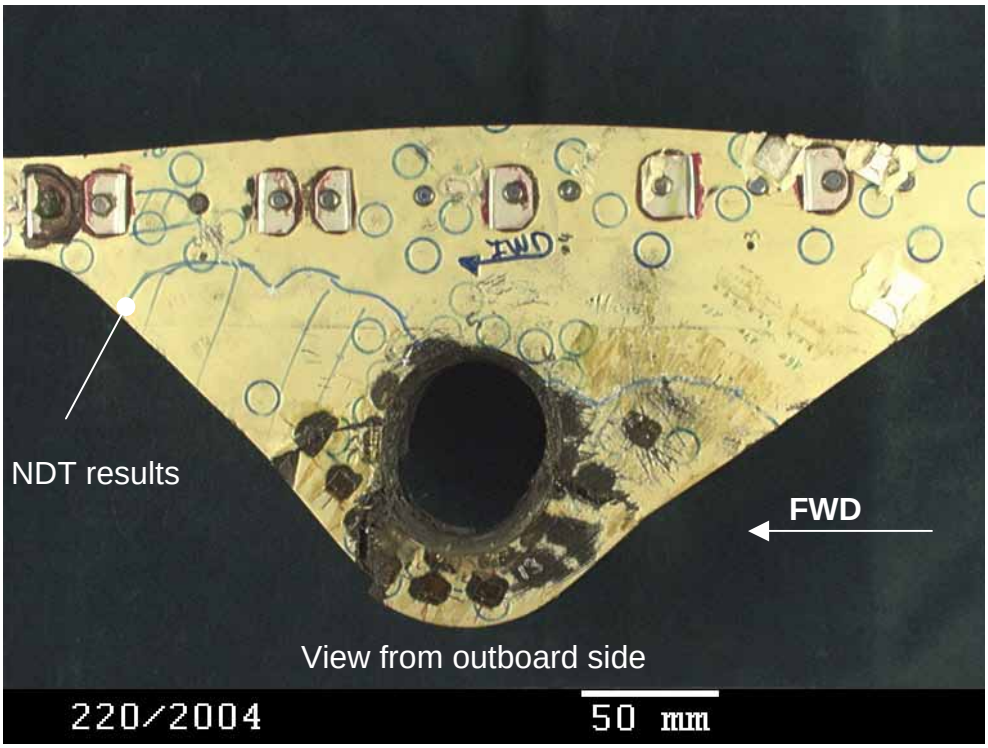
- The green layer is detected as an epoxy, most probably used for bonding of the bush.
- Silicone-rubber particles, probably caused by protection of strain gages with Silicone during the static test, were detected.
- The isolated residues, after extraction with Dichloromethane, show minor traces / indications to grease.

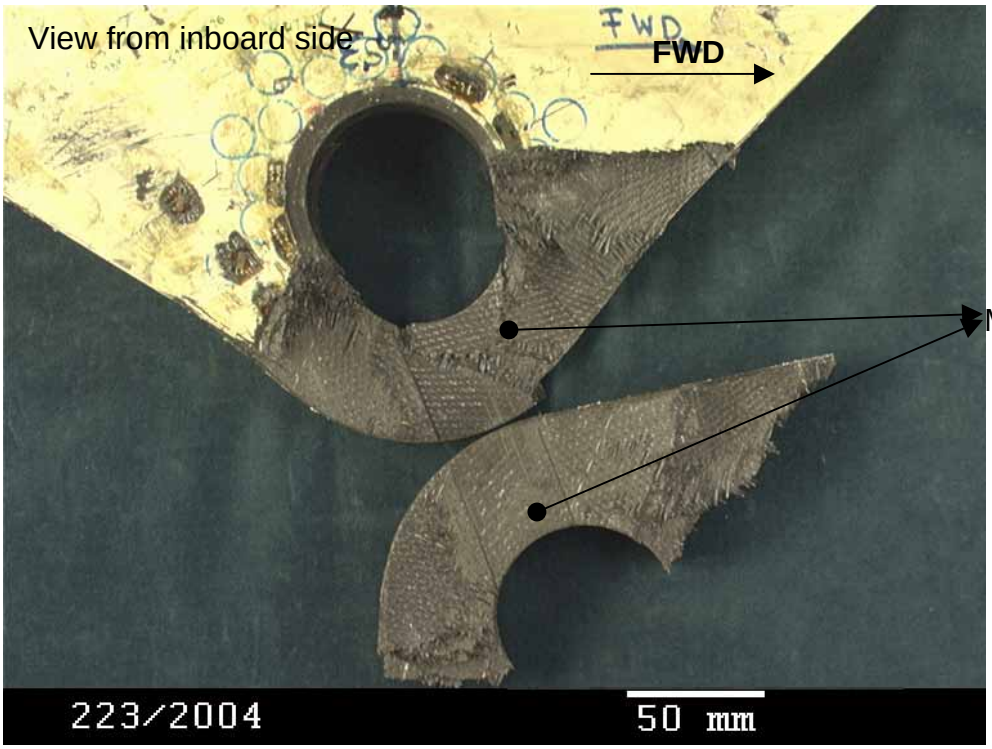
8. Summary

The lab investigation of the static tested Lug subcomponent of a LH side rear main attachment lug cut out of MSN 513, labeled as **Lug Test #2,** shows the following results:

- The lay up is in accordance with the drawings.
- The measured degree of cure was sufficient.
- A typical spectrum of grease or oil was found on isolated residues of the pre test delamination surface. The reference delamination does not show any indications to grease or oil.
- The chamfer of the outboard bush shows minor traces of grease, as well.
- Two translaminar fractures occurred in comparable locations to lug test #1. The fracture path on outboard side is orientated approx. 134° as well as 39° to rib #1.
- Beside the two-translaminar fractures, a further buckling/compression failure is visible on outboard side in front of the 134° failure.
- Beside the main ply separation, a delamination located in the gap between outboard and inboard bush was found.
- The delamination found within the precured outer part of the lug was larger than the pre test delamination detected before the test lug was tested up to rupture load.

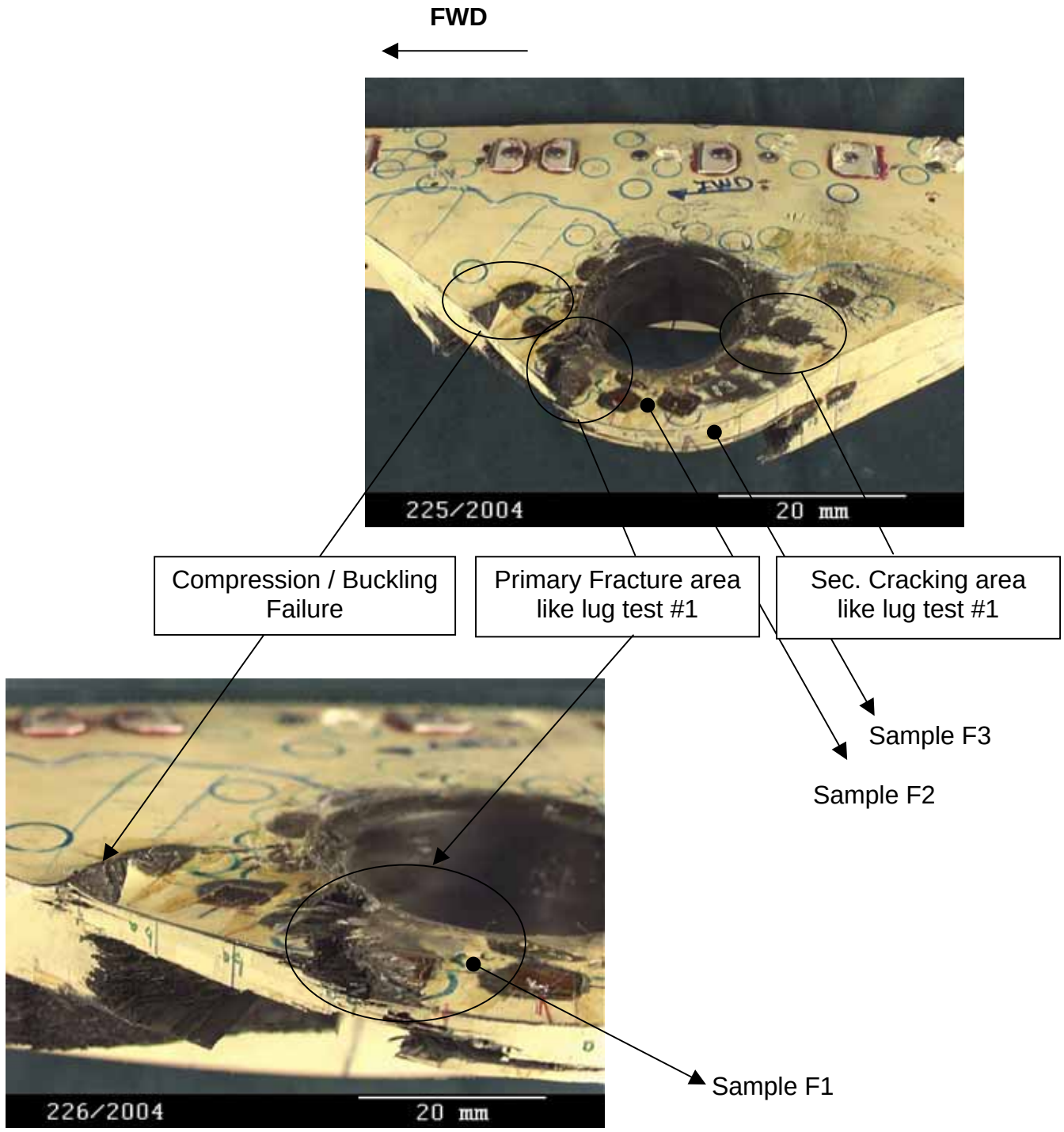
Visual Inspection





223/2004 220/04

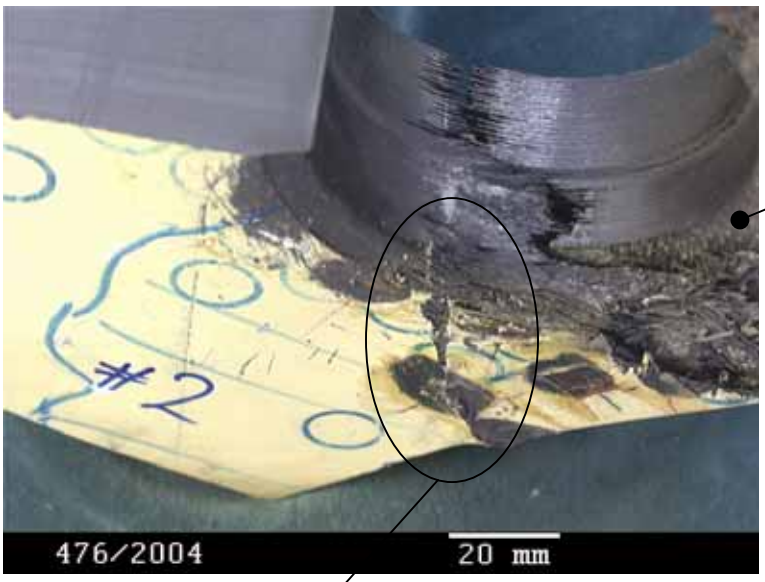
Fig. 1: Lug Test #2, oval elongation of bore-hole, main ply separation, condition: after test and separation of Lug area above rib #1



225/2004 226/2004
Fig. 2: Location of translaminar fractures, approx. location of sample F1, F2 and F3, view from outboard side

FWD (approx.)

FWD-sided translaminar fracture path (134° failure)



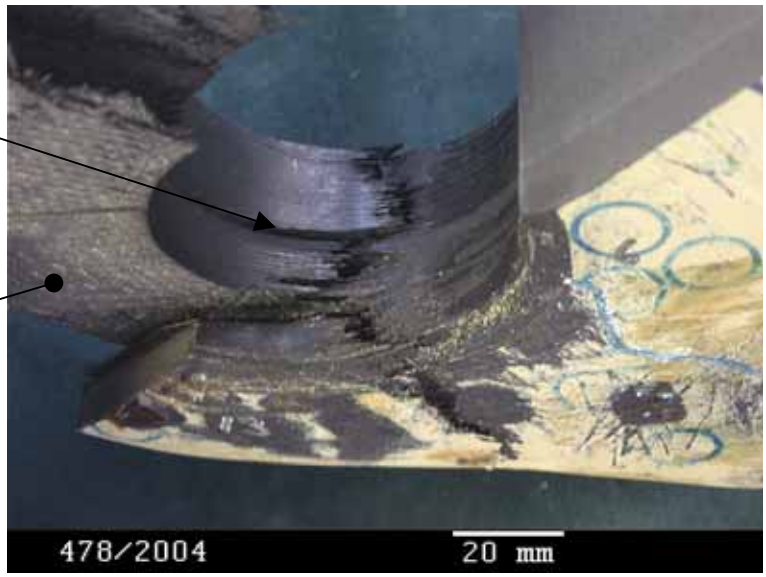
Main ply separation

Compression / Buckling failure

AFT-sided translaminar fracture path (39° failure)

Delamination located in the gap btw. outer and inner bush

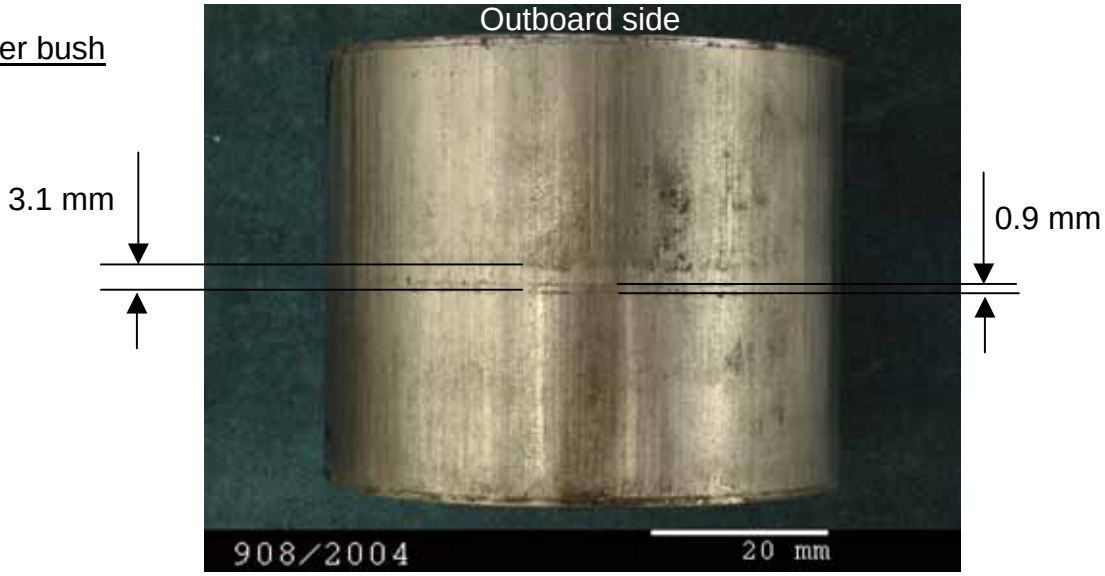
Main ply separation



476/2004 478/2004
Fig 3: FWD and AFT translaminar fracture path

Outer bush

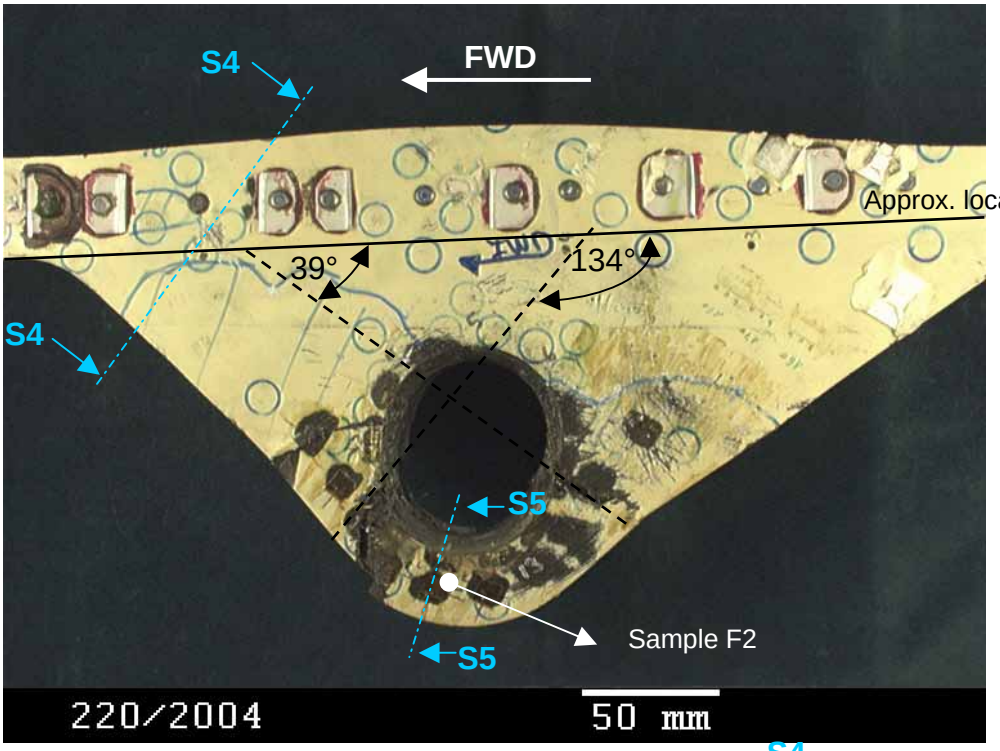
Inner bush

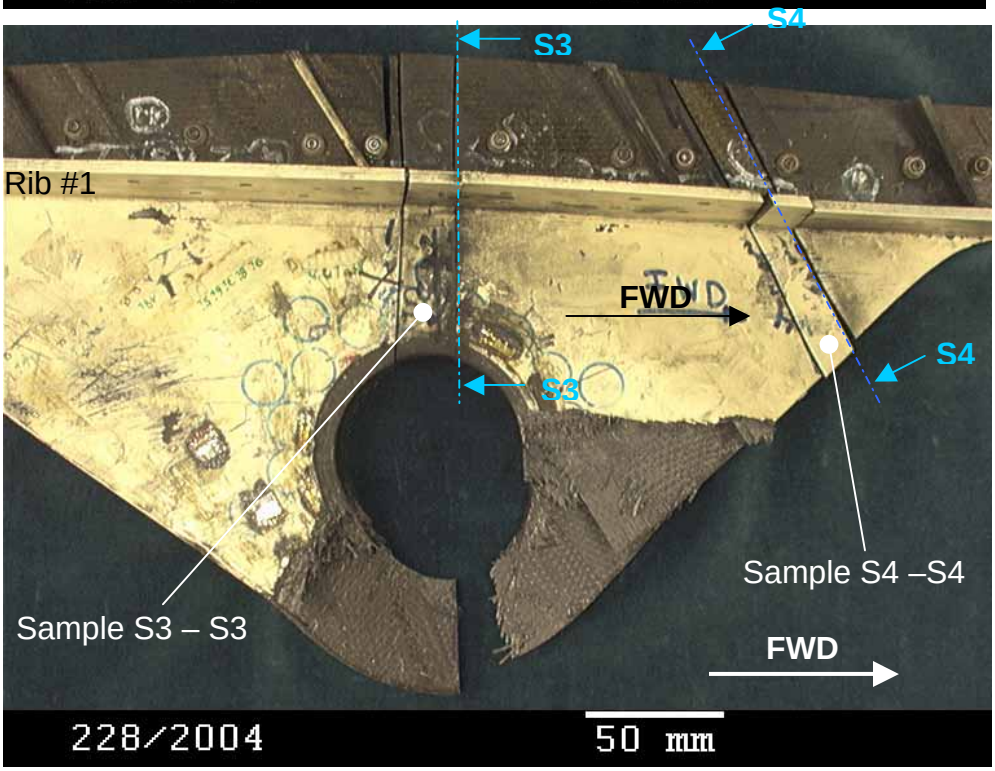


903/04 908/04

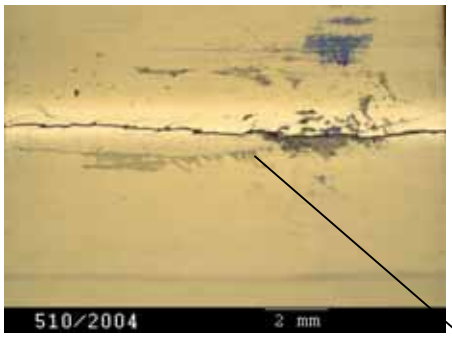
Fig 4: Inner and outer bush after disassembling, residues as well as a green colored layer on the chamfer of the outer bush, circumferential markings on the inner bush indicating a possible movement of approx. 2.2mm

Metallographic Investigation

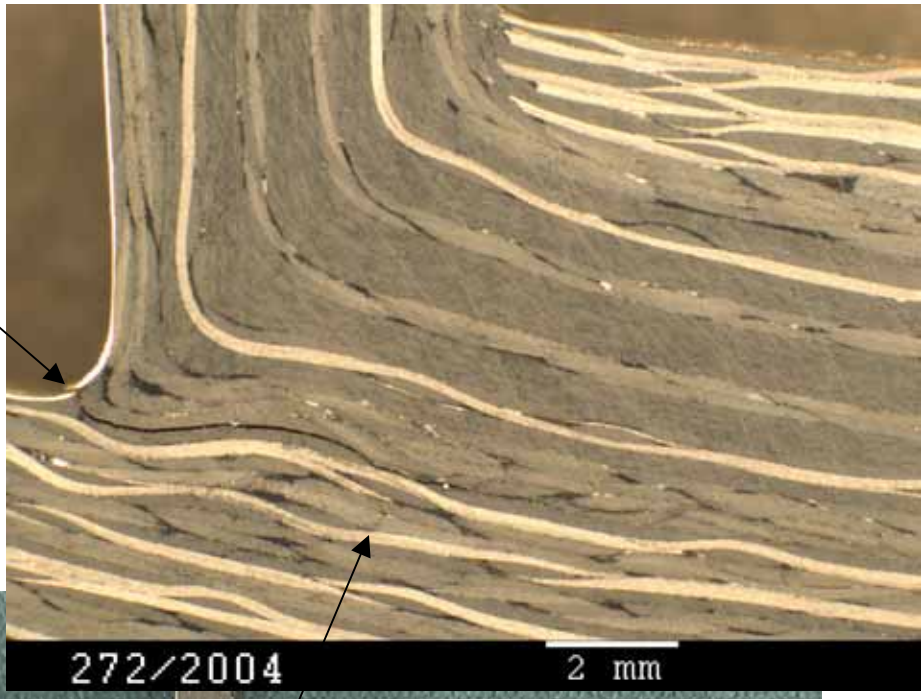


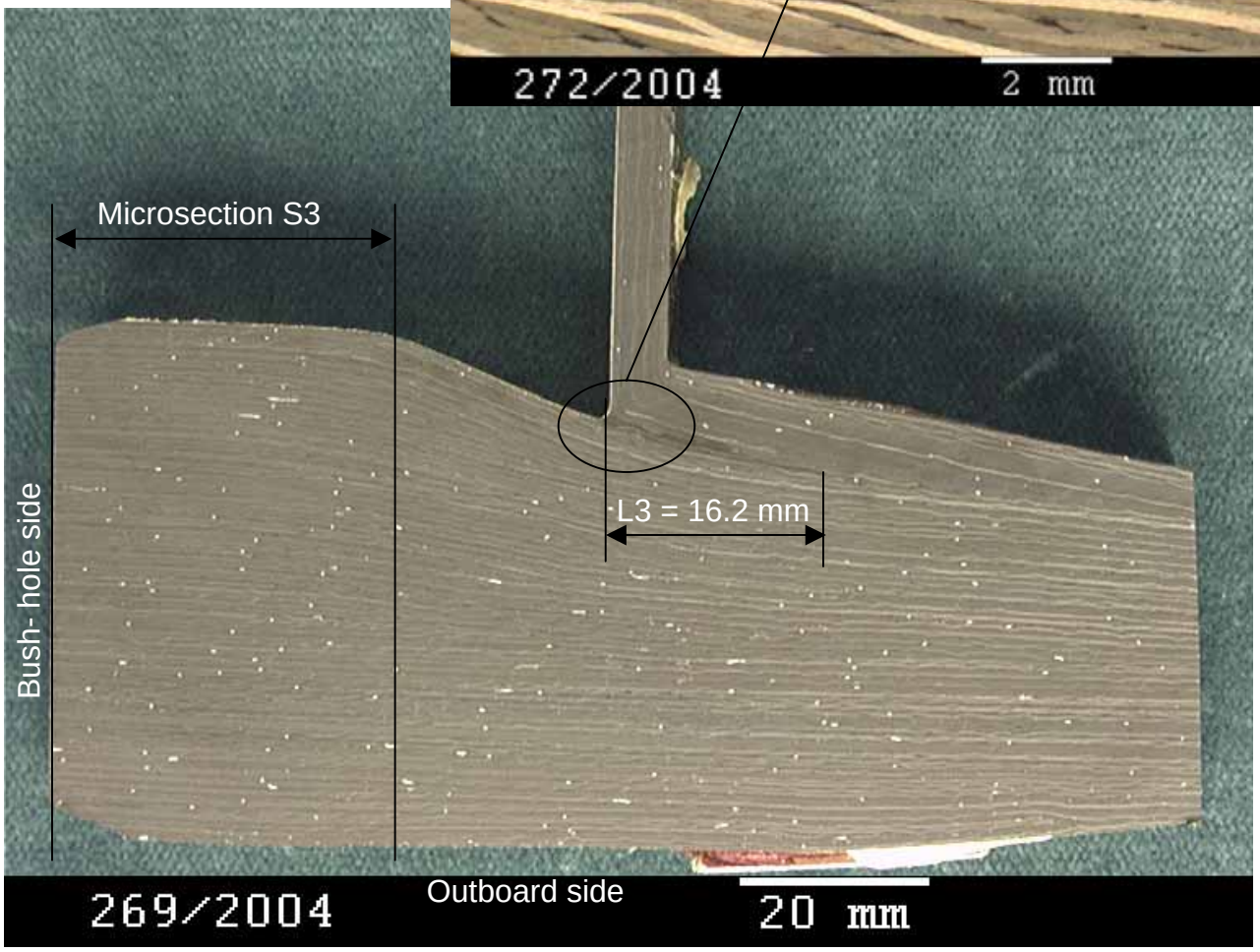


228/2004 220/2004
Fig. 5: Location of sections, determination of angle between rib #1 and visible fracture path on outer side



Visual visible crack
at rib #1





269/2004 272/04 (510/2004) Grinded

Fig. 6: Delamination starting from crack at rib #1, location of microsection S3, Section S3-S3

Outboard side ↓ Determination of lay up

Outboard part (A553-71674 sheet 3 (-004))

Bush- hole side

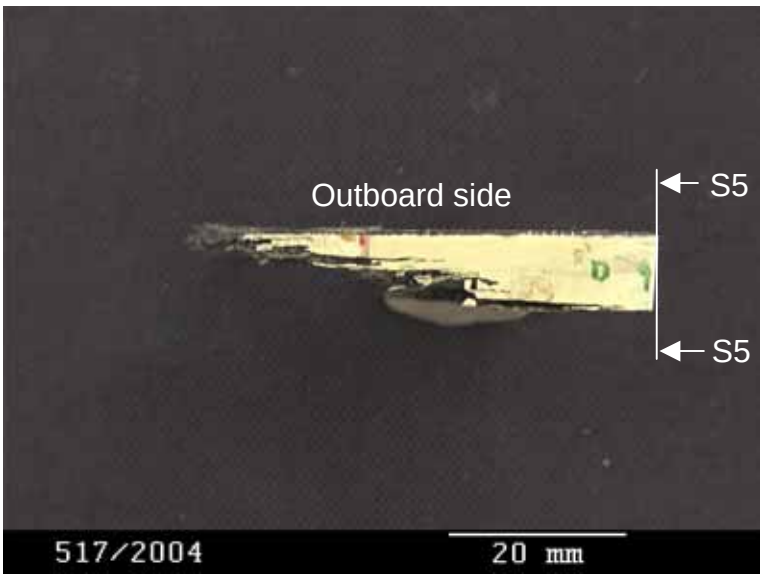
Inboard part (A553-71675 sheet 3 (-004))

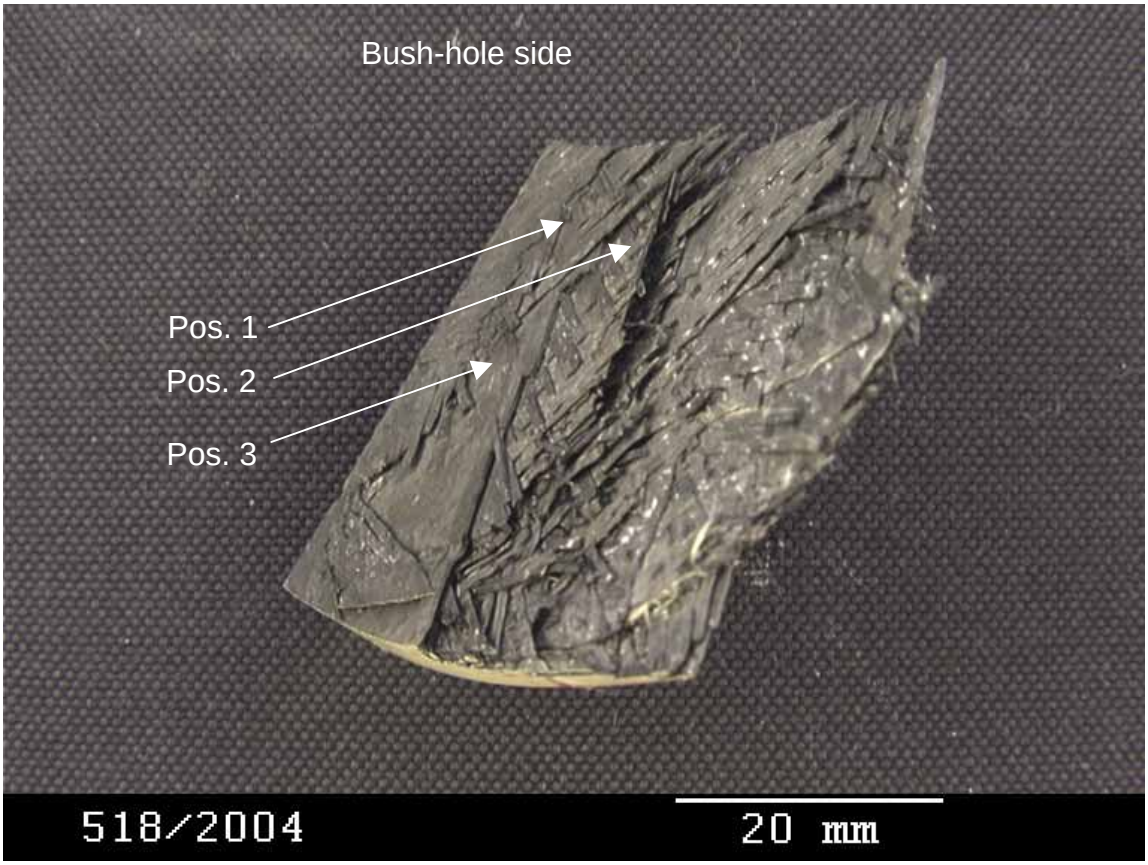
Additional layers (A553-71591 sheet 21 (-006))

504/2004 384,386,388/2004 polished

Fig. 7: Loc. of precured/cured transitions, loc. of determination of lay up, microsection S3

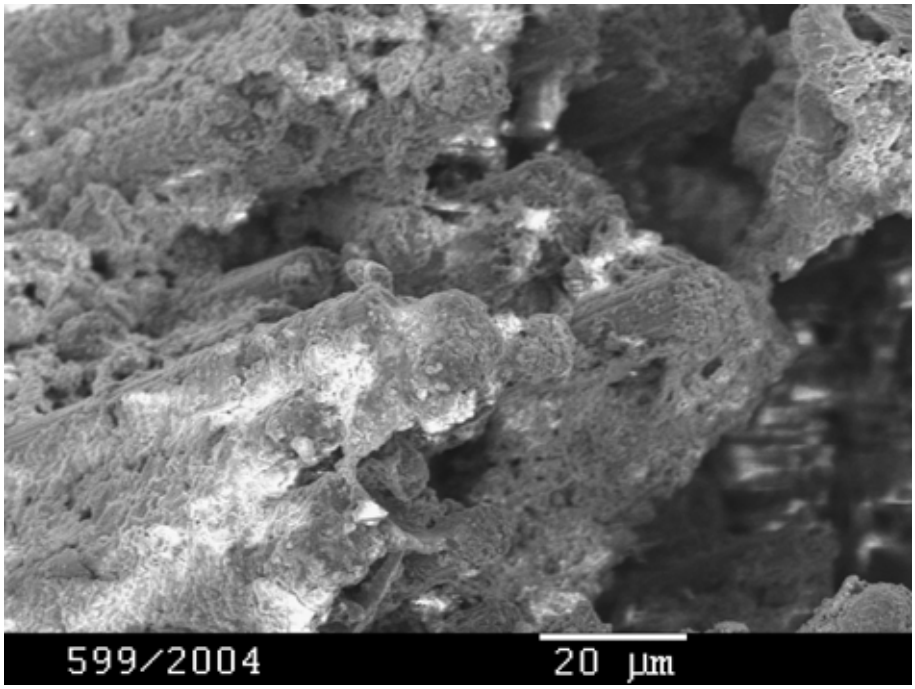
Microfractographic investigation

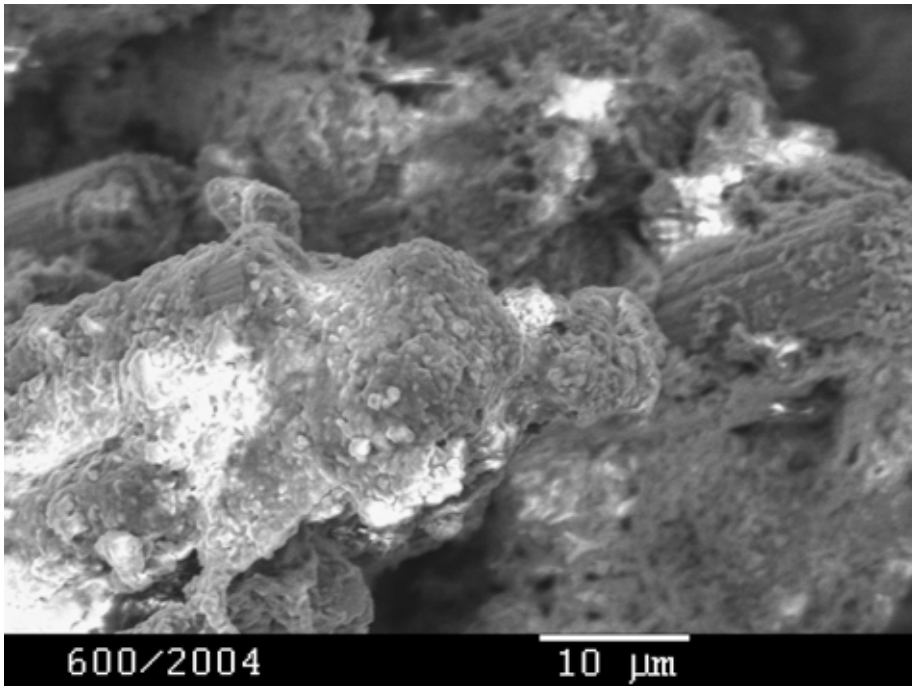




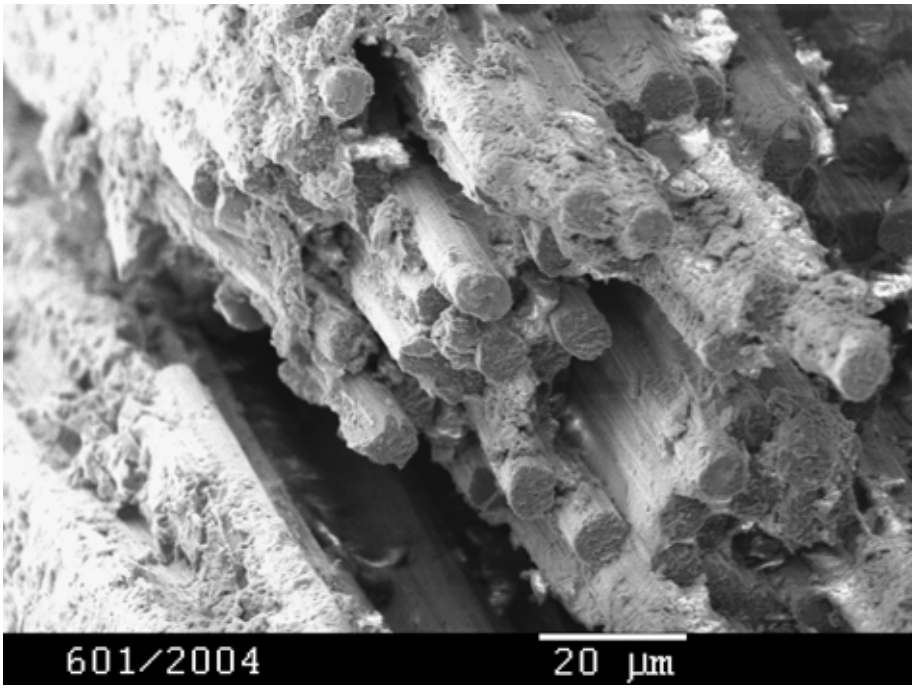
517/2004 518/2004 After lab separation

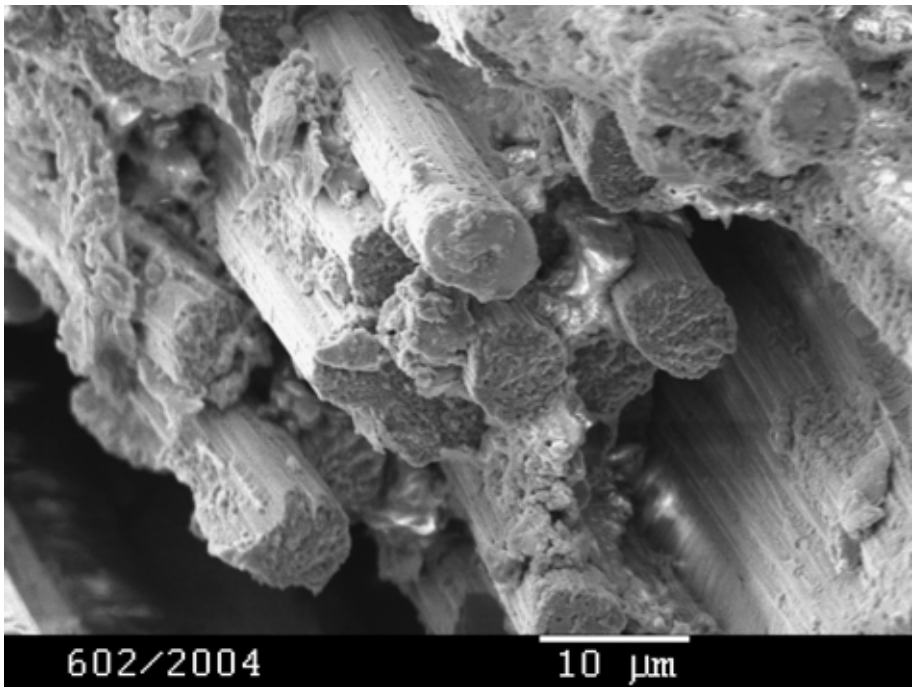
Fig. 8: Fractographic **sample F1**, loc. is comparable to sample F1 of Lug Test #1, location of sample F1 s. fig. 2



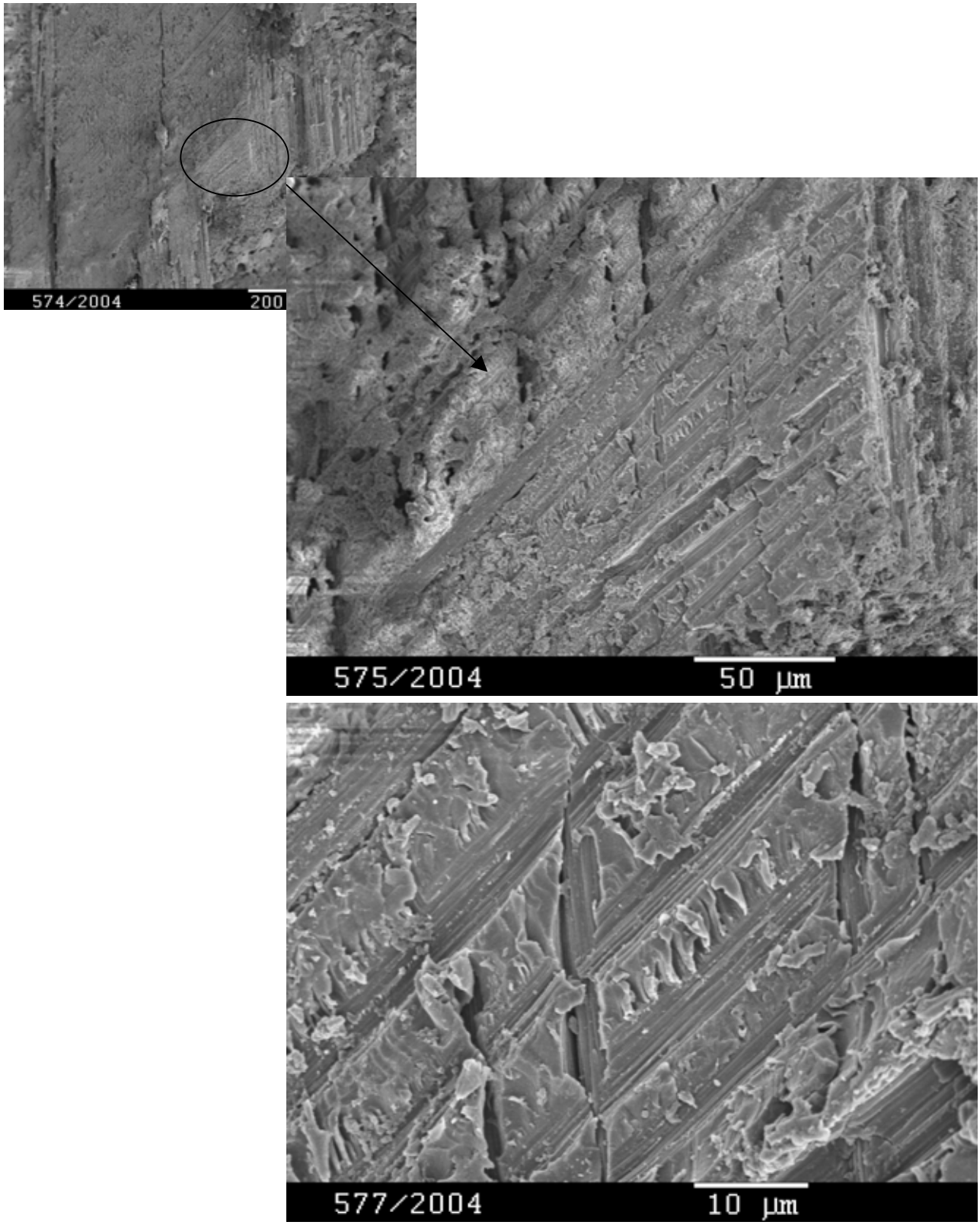


599/2004 600/2004
Fig. 9: Fiber fracture mostly covered with debris, detail of fig. 8



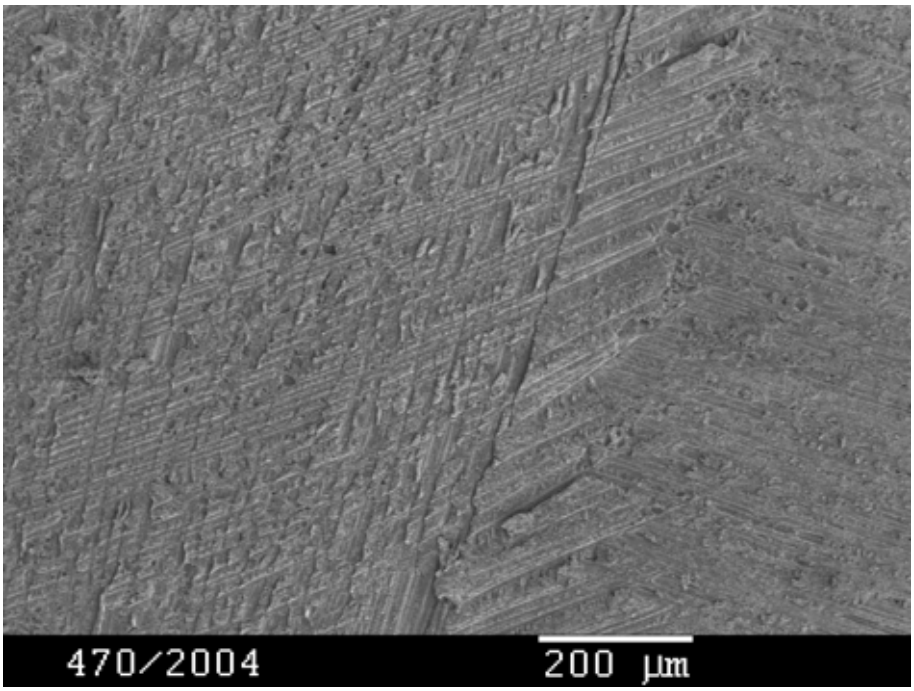


601/2004 602/2004
Fig. 10: Locally radial pattern, due to tensile fracture, detail of fig. 8

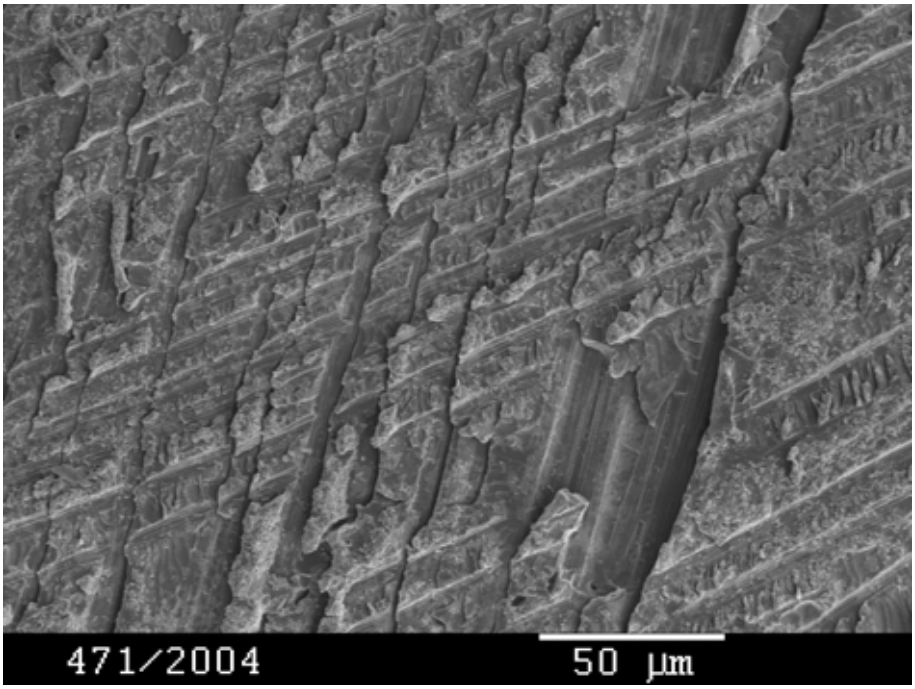


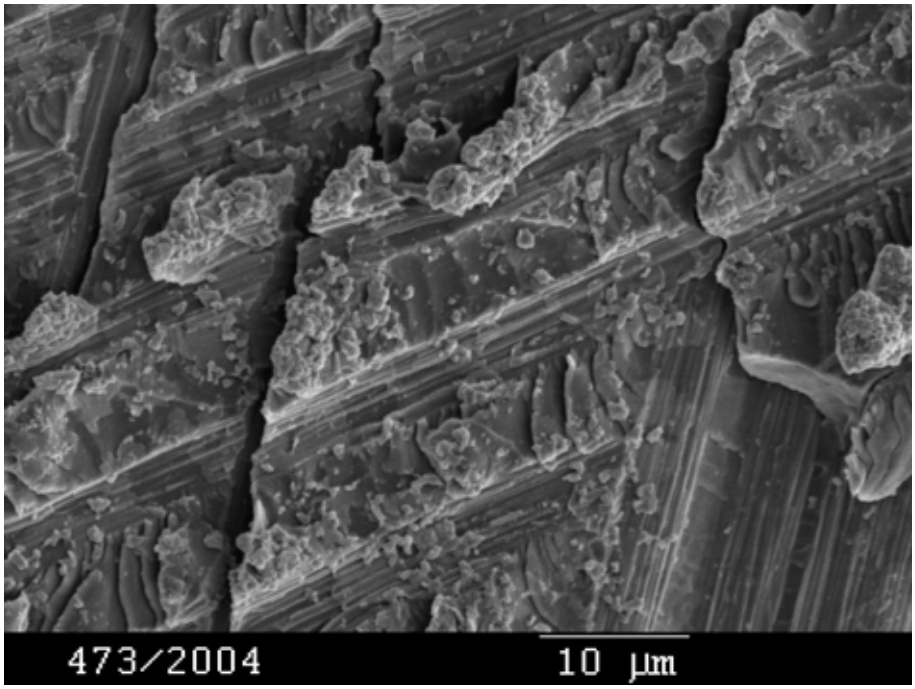
574/2004 575/2004 577/2004

Fig. 11: Main ply separation mostly covered with debris, locally hackles and river pattern, detail of fig. 8

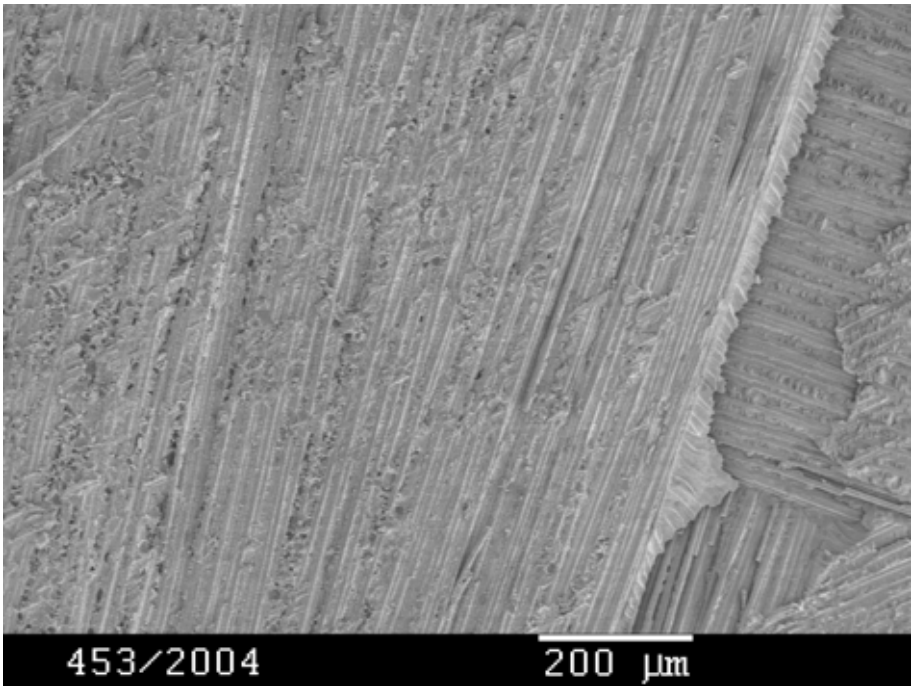


470/2004
Fig. 12: General view, Pos. 1, sample F2/cf. fig. 2

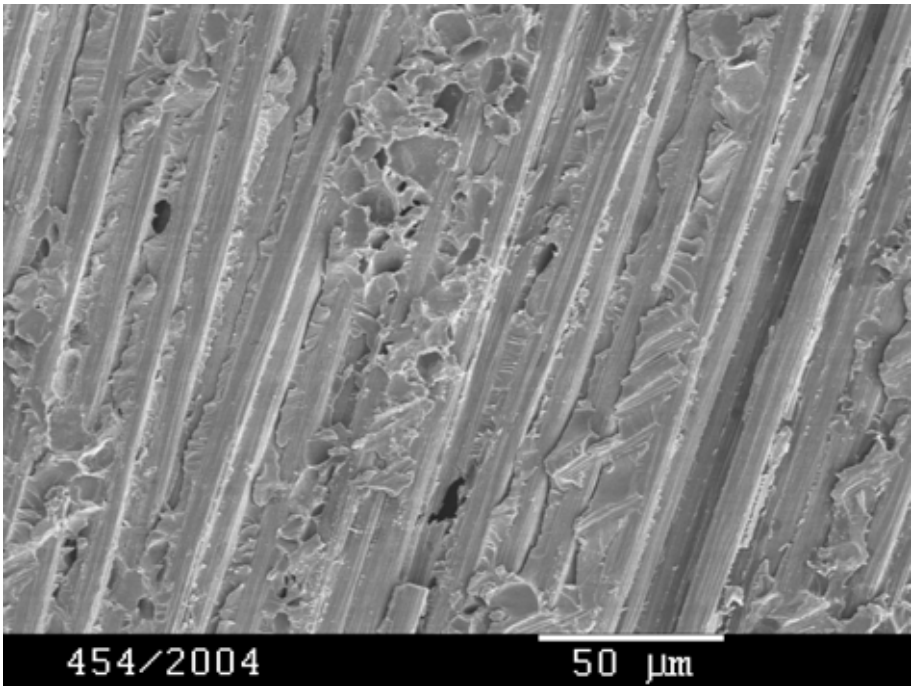


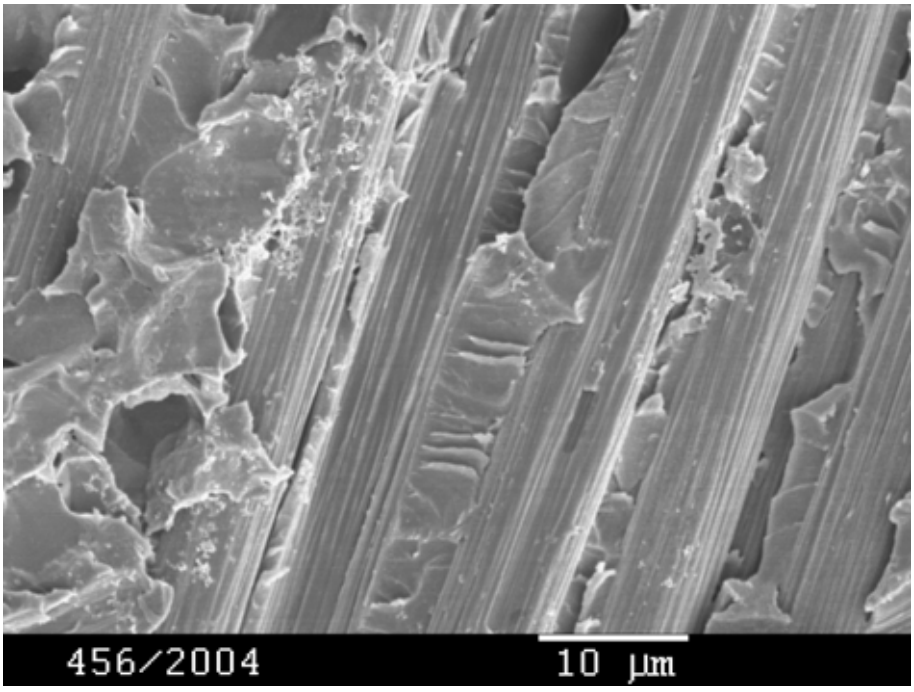


471/2004 473/2004
Fig. 13: Debris, features of Mode I and II loading, det. of fig. 12

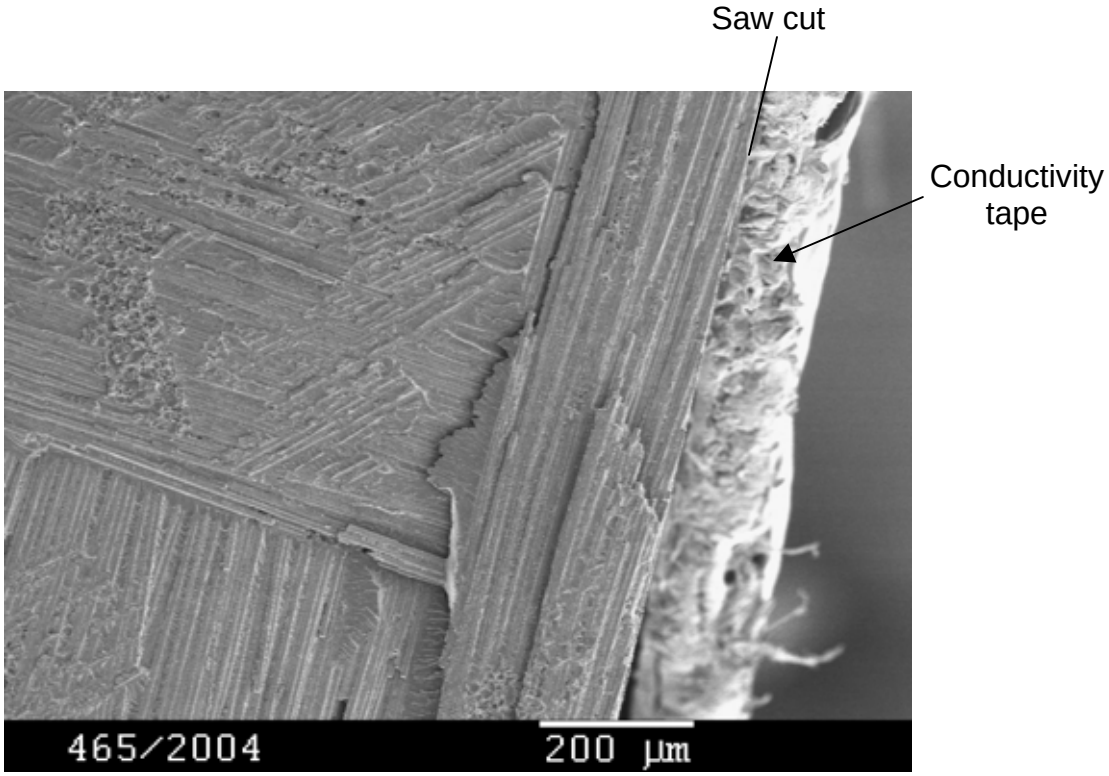


453/2004
Fig. 14: General view, Pos. 2, sample F2/cf. fig. 2

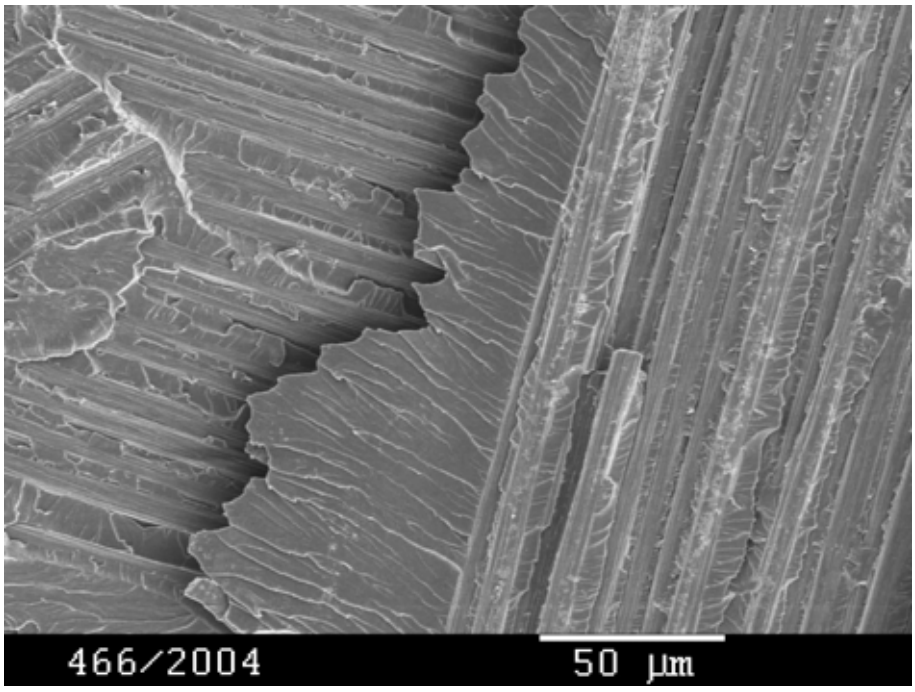


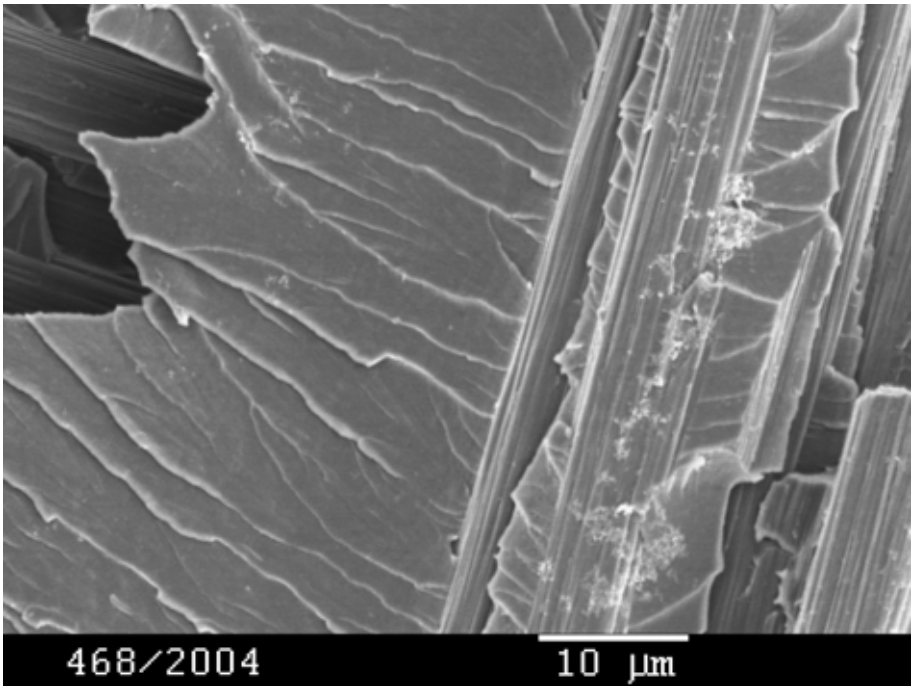


454/2004
Fig. 15: Features of Mode I and II loading, det. of fig. 14



465/2004
Fig. 16: Lab forced fracture due to lab. separation, Pos. 3, sample F2/cf. fig. 2





468/2004
Fig. 17: Mainly features of Mode I loading, det. of fig. 16