J. APPENDIX F

AIRBUS	Technical Note	

Report Nr.: TN – ESWOG – 1266/04

Author:
Department.:

Title

AAL587 Investigation

RH side Lug sub-component test #3, Lab investigation

Date: 07.07.2004

Summary:

The lab investigation of the static tested Lug subcomponent of a RH side rear main attachment lug cut out of MSN513, labeled as **Lug Test #3,** shows the following results:

- The lay up is in accordance with the drawings.
- 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. 137° as well as 37° to rib #1.
- Beside the translaminar fractures, a further buckling/compression failure is visible on outboard side in front of the 137° failure.
- Within the precured outer part of the lug, delamination through the entire width of the lug, below the bush-hole was found after the lug went up to rupture loads. This occurred in the area where the pre test delamination was detected.
- The dark area on the pre test delamination, as well as the chamfer of the outboard-sided outer bush, show indications of silicone. Silicon were found also on the further delaminated area, whereby the silicon content decrease with increasing delamination length.

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1. Introduction

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

2. Visual inspection

After the static test, the main attachment lug shows two translaminar fractures through the lug and a translaminar fractured area caused by buckling/compression as well as multiple delaminations (s. fig. 1-4,6). The delamination size, found by NDT, is visible in figure 6. The outboard-sided outer bush shows a lot of debris besides a green colored coating on the lug sided chamfer surface (s. fig. 5). The inner bush shows circumferential traces indicating a possible movement of outer bush of approx. 1mm and further 2.5 mm (s. fig. 5). After the first visual inspection, several cut outs were taken to obtain a closer view of the damaged areas.

3. Macroscopic investigation

After cutting along rib #1 and separation of several fractured parts (cf. fig. 1-6) 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 137° failure, because the fracture path on the outboard side is orientated approx. 137° to rib #1 (s. fig. 1-4).
- A further translaminar fracture (labeled as 37° failure) thru the entire wall thickness was found (s. fig. 1-4). 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. 1-4,6), besides several other smaller delaminations.

- A crack in the radius area of rib #1 was found (s. fig. 7).

4. Metallographic investigation

One macro section (S3-S3) 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. Determination of delamination path

- A crack, located in the radius, followed by a delamination was found on section S3-S3. The detailed delamination length is given in fig. 7.
- The pre test delamination length detected on microsection S3 (also visible on macro section S3-S3) is comparable with the result of the incoming NDT inspection. This delamination is located within the precured outboard part of the lug.

4.2. Validation of the lay up

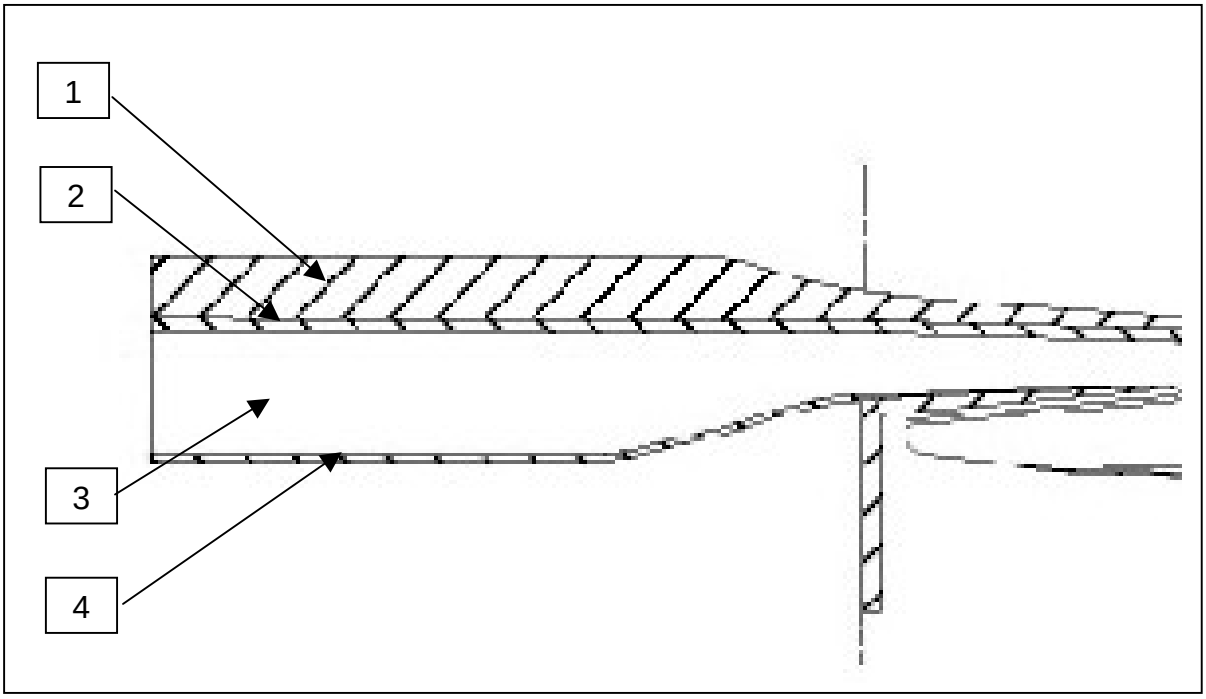
Microsection S3 was used for the validation of the lay up. This microsection is located above the bush-hole and is orientated approx. 90° to rib #1 (s. fig. 6).
The determination of the lay up was done in 2 steps:
Step 1: The fiber orientation was determined based on the orientation of the microsection 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).

The result is, all detected layers as well as the location of the precured/cured transitions (s. fig. 8) are in accordance with the drawings.

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	Thickness
Outer part (1)	11.0 mm
Skin and Reinforcement (2)	6.0 mm
Inner Part (3)	33.0 mm
Additional layers (4)	2.0 mm



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 137° failure (s. fig. 1, 10), 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 (TN-ESWNG-1239/03). This sample obtained dark coatings in the area of the pre test delamination and was investigated in uncleaned and cleaned condition. But a useful documentation is not possible in the uncleaned condition; 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. 11,13). The areas where the fracture path is perpendicular to the fiber direction shows features of mode I and II loadings (s. fig. 10,12).

The pre test delamination surface (sample **F2**) contains indications of Mode I (tension) and Mode II (shear), too. These features are typical for a ply separation/delamination surface. Furthermore broken fibers were found on the bush-hole, most probably failed due to compression loads of the fiber.

7. Chemical analysis of pre test delamination surface, bolt–hole surface and bush

The dark layers, found on the surface of the pre test delamination, as well as the bolt-hole surface just beside this area 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 silicone oil also called polysiloxane oil. It was not possible to extract any material from the backside of the sample, thus the part is not generally contaminated.
- Silicon (Si) was found by XPS on the pre test delamination area, the further de-laminated area and the bolt-hole surface. Whereby the silicon content decrease with increasing delamination length. The found Si_{2P} bonding energy corresponds to siloxane. But, based on the measurement method, an explicit verification of si-loxane (silicone) is not possible.

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

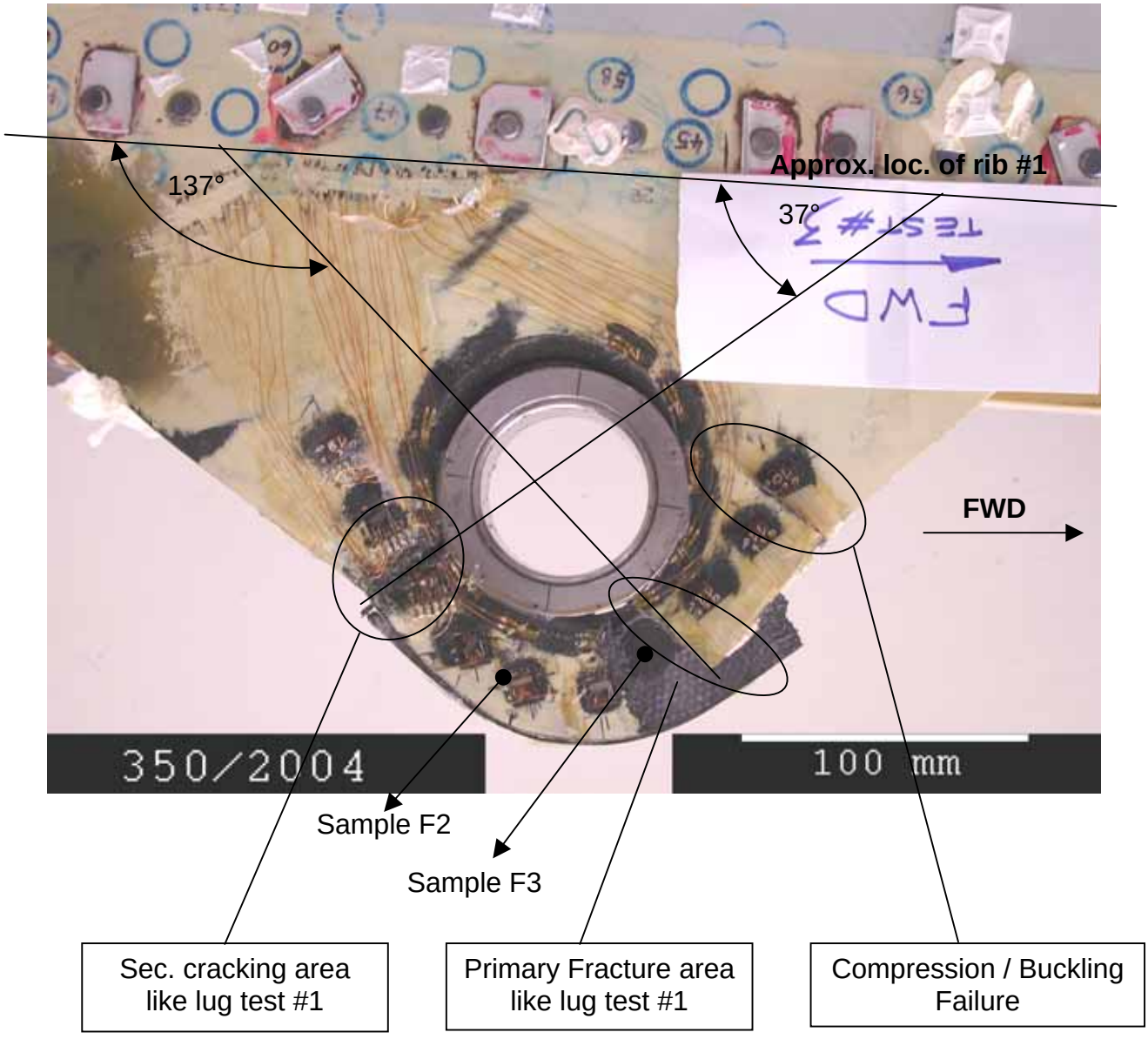
- The green layer is detected as an epoxy, most probably used for bonding of the bush.
- Silicone-rubber particles, probably caused by protection of strain gages with sili-cone during the static test, were detected.
- The isolated residues, after extraction with Dichloromethane, show traces / indica-tions to silicone oil, comparable to the residues from the delamination surface.

8. Summary

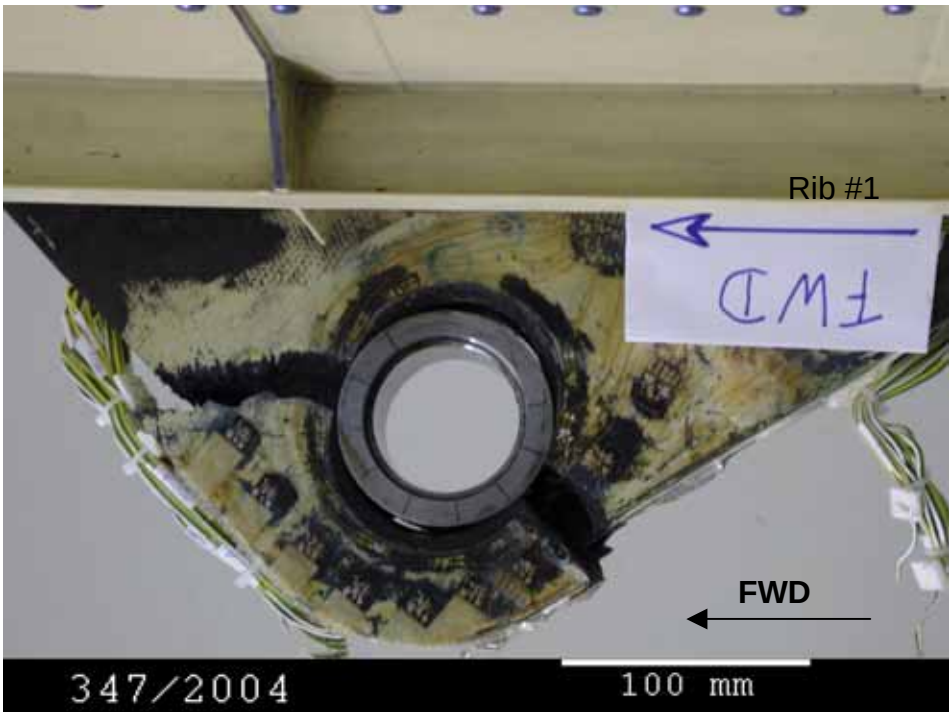
The lab investigation of the static tested Lug subcomponent of a RH side rear main attachment lug cut out of MSN 513, labeled as **Lug Test #3,** shows the following results:

- The lay up is in accordance with the drawings.
- The measured degree of cure was sufficient.
- A typical spectrum of silicone oil was found on isolated residues of the pre test delamination comparable to the spectrum obtained on isolated residues of the chamfer of the outboard-sided bush.
- Two translaminar fractures occurred in comparable locations to lug test #1. The fracture path on outboard side is orientated approx. 137° as well as 37° to rib #1.
- Beside the two-translaminar fractures, a further buckling/compression failure is visible on outboard side in front of the 137° failure.
- Within the precured part of the lug, delamination through the entire width of the lug, below the bush hole was found after the lug went up to rupture loads. This occurred in the area where the pre test delamination was detected.

Visual Inspection



350/2004
Fig. 1: Lug Test #3, determination of approx. angle between rib #1 and visible fracture path on outer side, view from outboard side, condition: after test



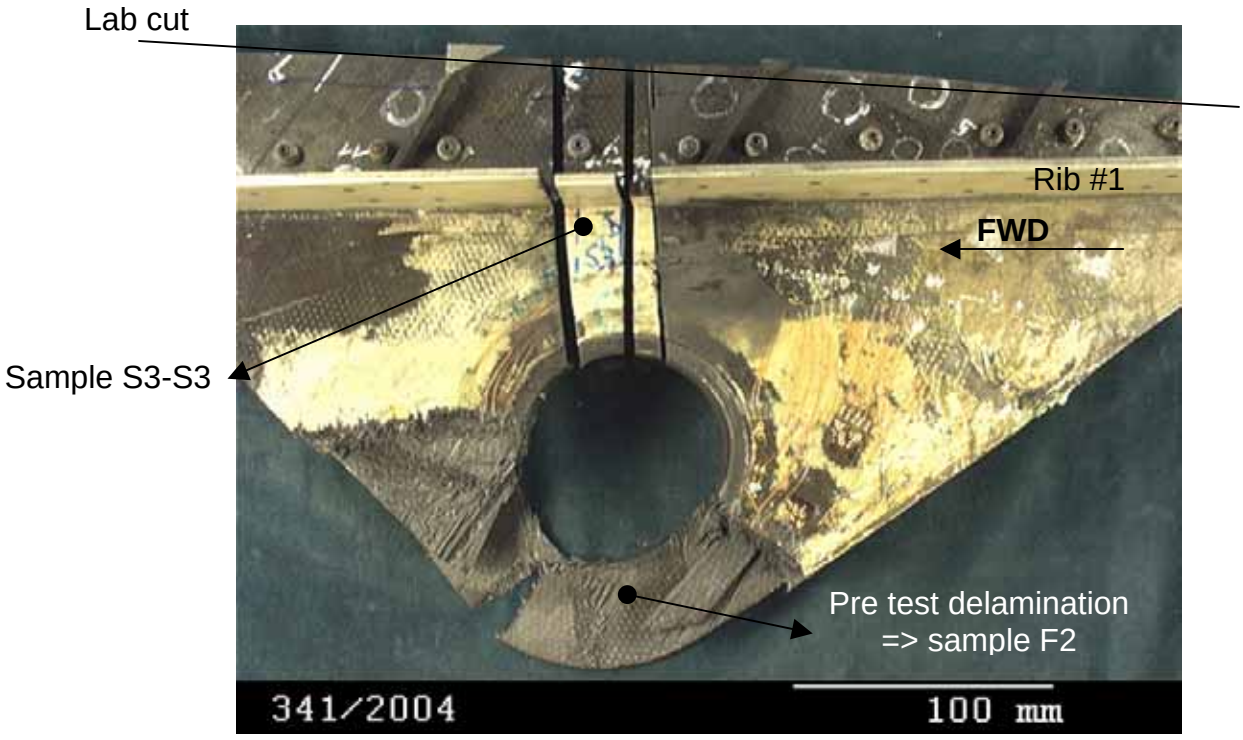


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Fig 2: Lug Test # 3, fracture path, view from inboard side, condition: after test (upper fig.) and after lab separation of fractured parts (lower fig.)

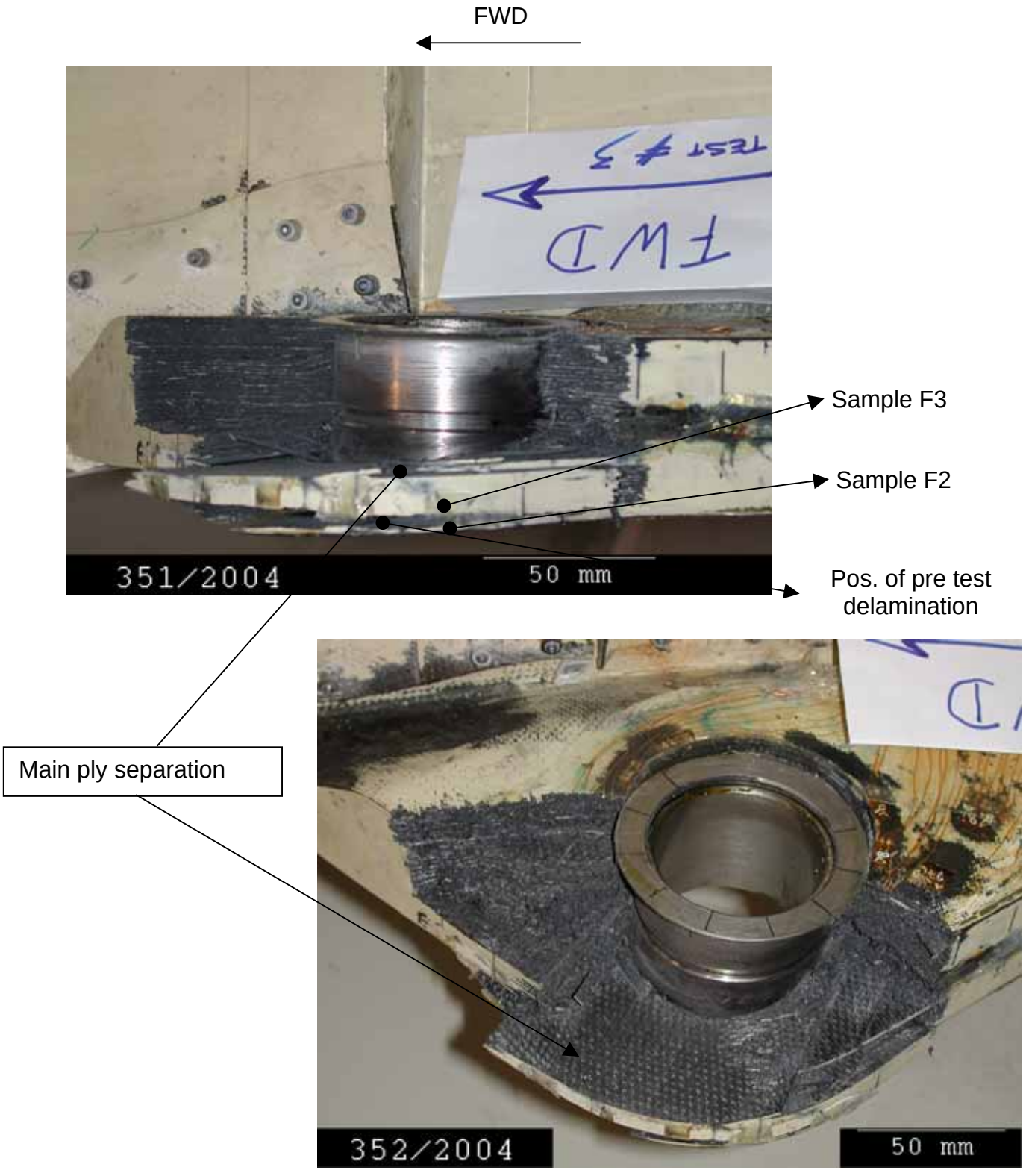

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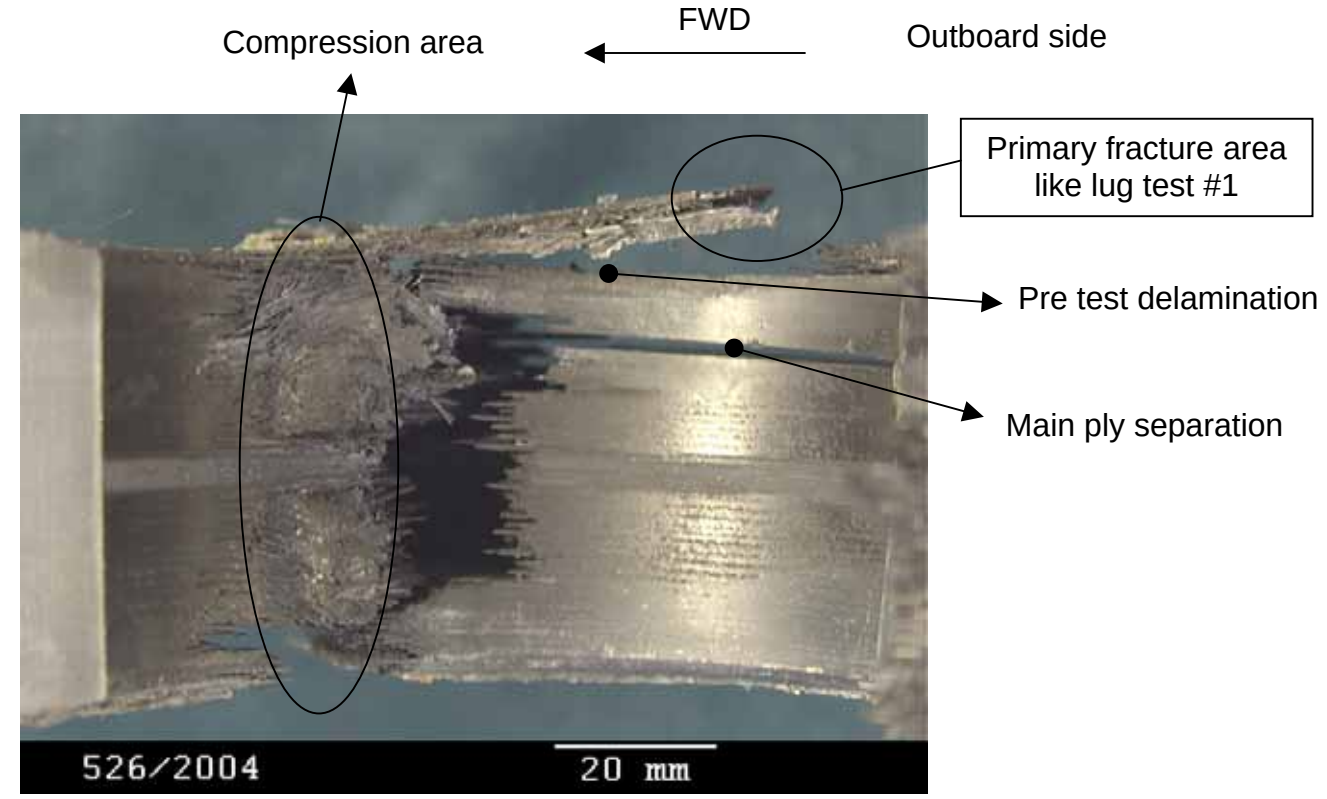
Fig 3: Lug Test # 3, fracture path, view from inboard side, condition: after test and partly separation of fractured parts



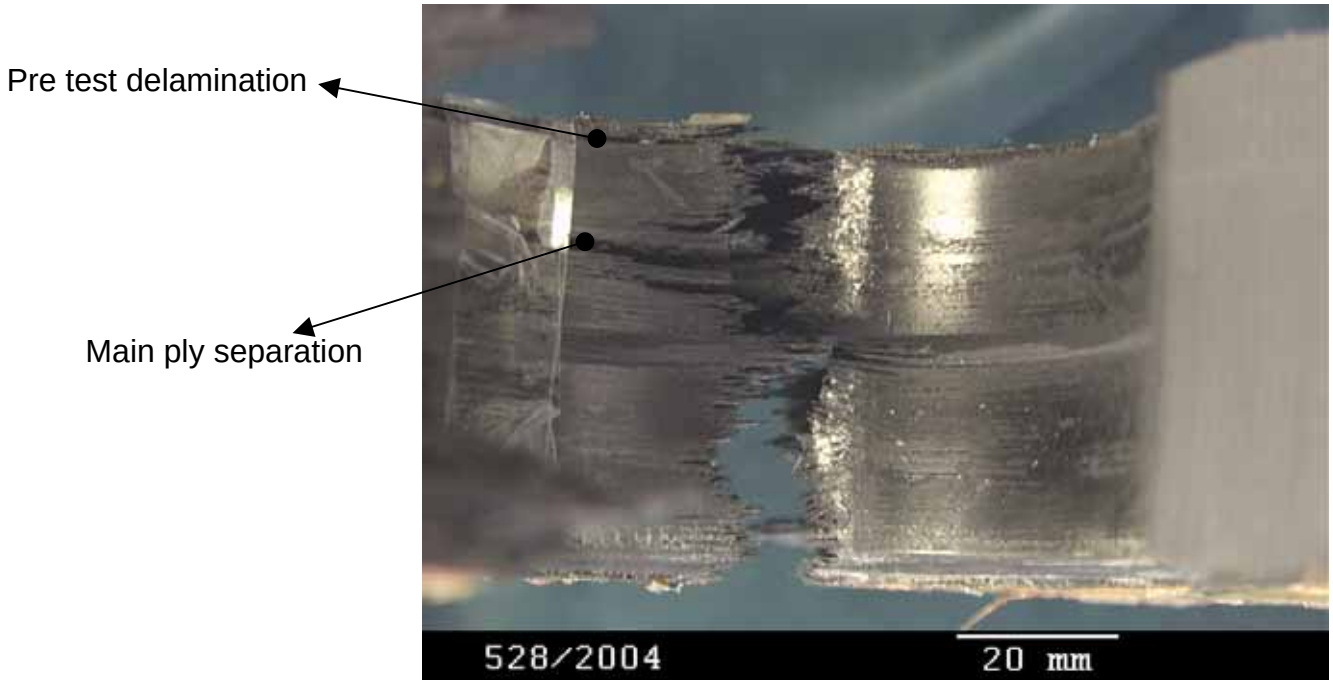


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Fig 4: FWD and AFT translaminar fracture path

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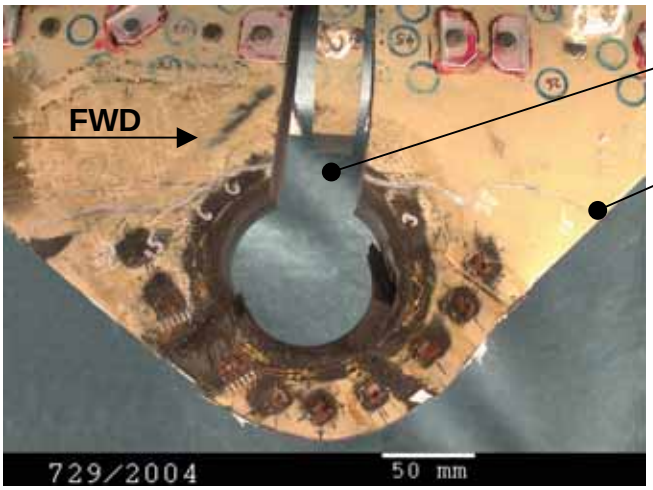
Fig 5: Inner and outer bush, residues as well as a yellow/brownish colored layer on the chamfer of the bushes, circumferential markings on the inner bush indicating a possible movement of outboard sided outer bush of approx. 1 mm (step 1) and further 2.5 mm (step 2)

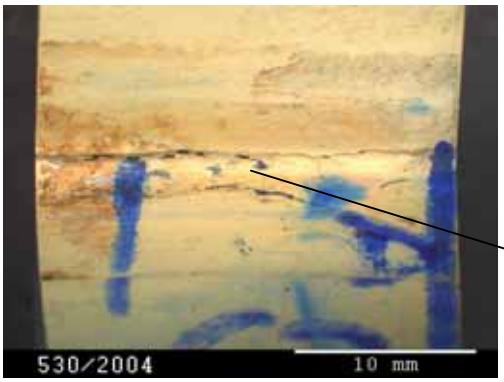
Metallographic Investigation



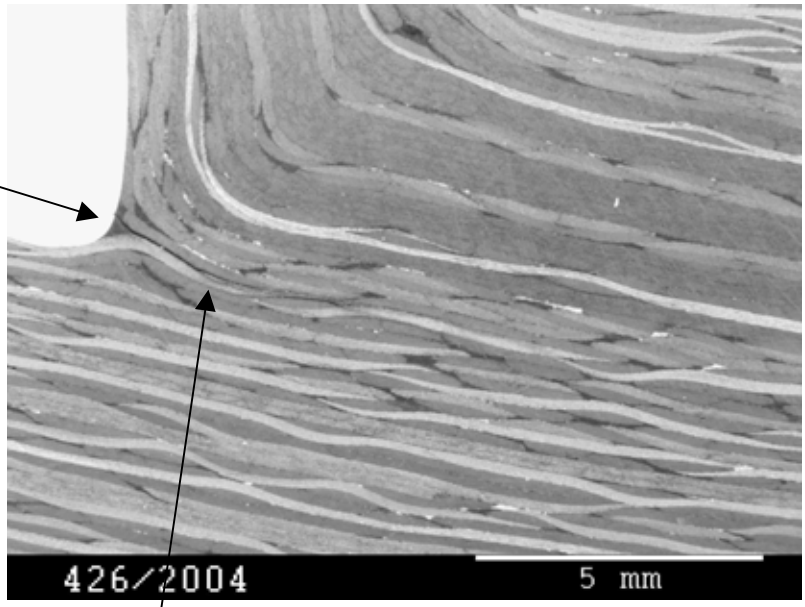
View from outboard side

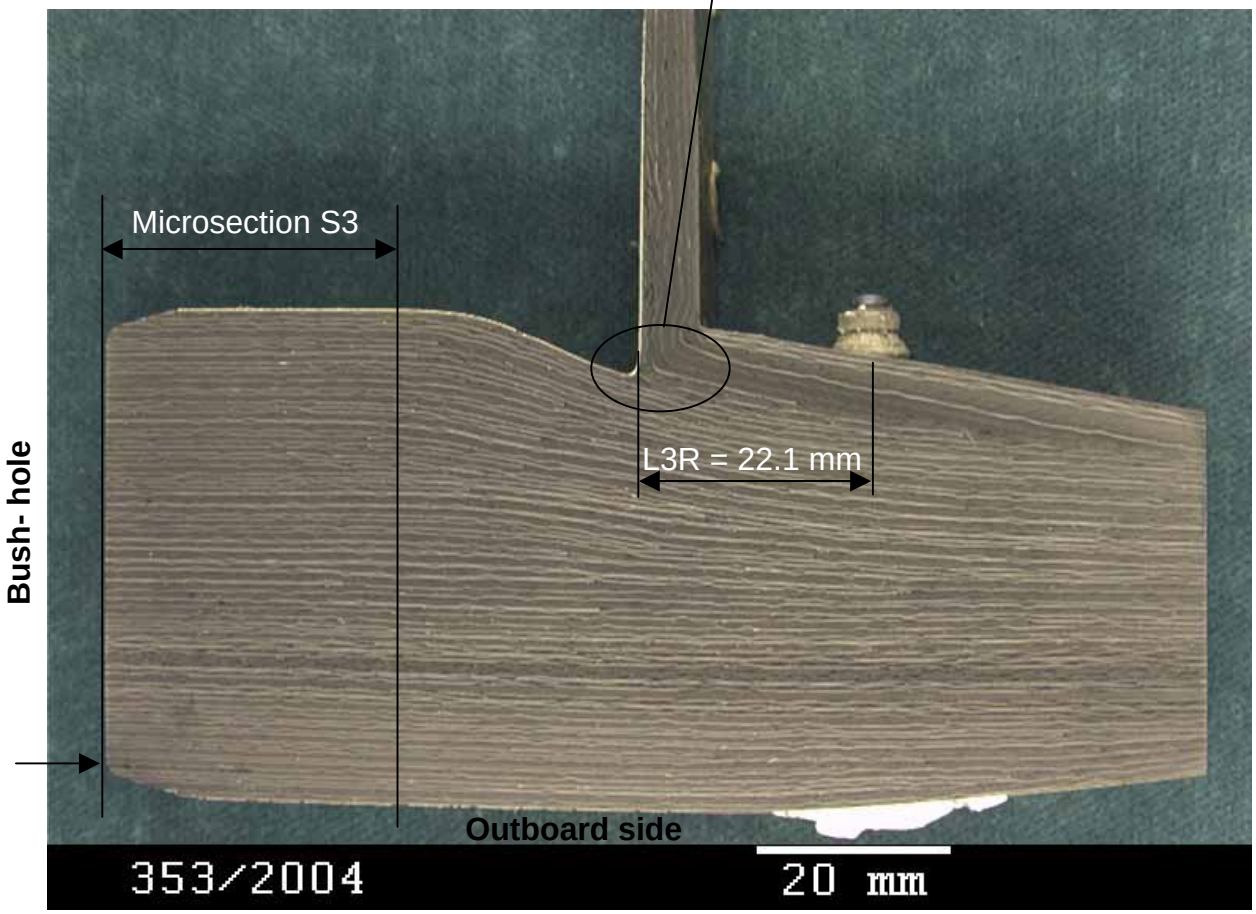
View from inboard side

729/2004 340/2004
Fig. 6: Location of section S3-S3 and microsection S3



Visual visible crack
at rib #1

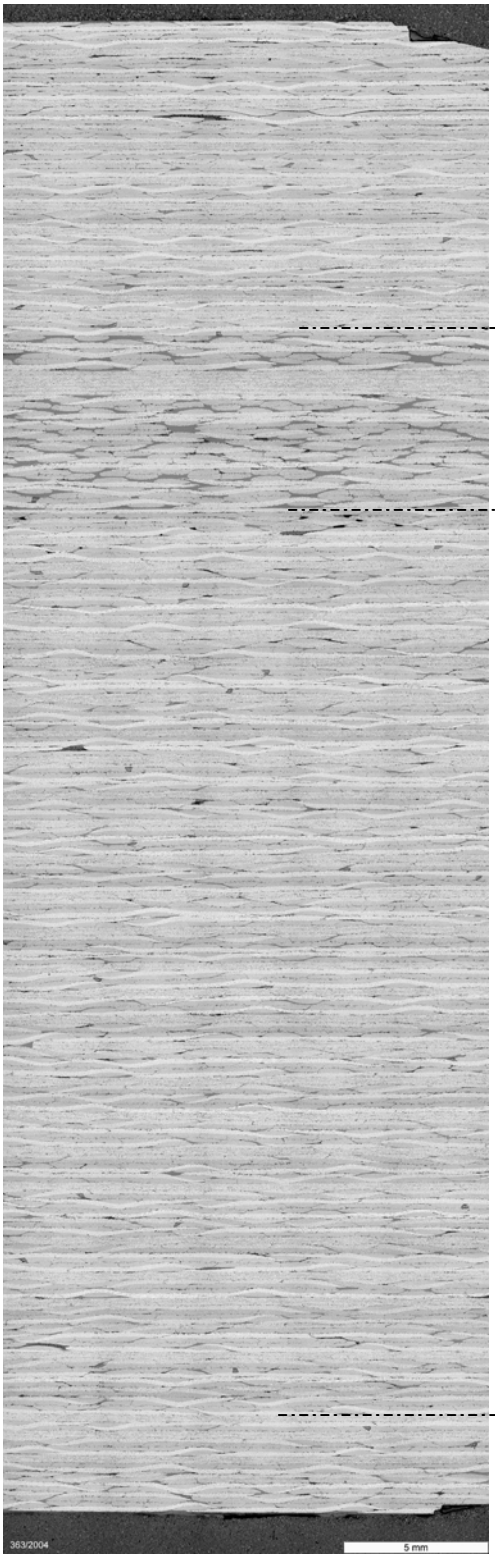




530/2004 426/2004 353/2004 Grinded

Fig. 7: Delamination starting from crack at rib #1, further delamination starting at bush-hole (arrow), loc. of microsection S3, delamination length L3R, section S3-S3

Outboard side



Outboard part (A553-71674 sheet 4 (-006))

Bush- hole side

Inboard part (A553-71675 sheet 4 (-006))

Additional layers (A553-71591 sheet 62)

363/2004 391/2004 393/2004 395/2004 Polished

Fig. 8: Loc. of precured/cured transitions, loc. of determination of lay up, microsection S3

Microfractographic investigation

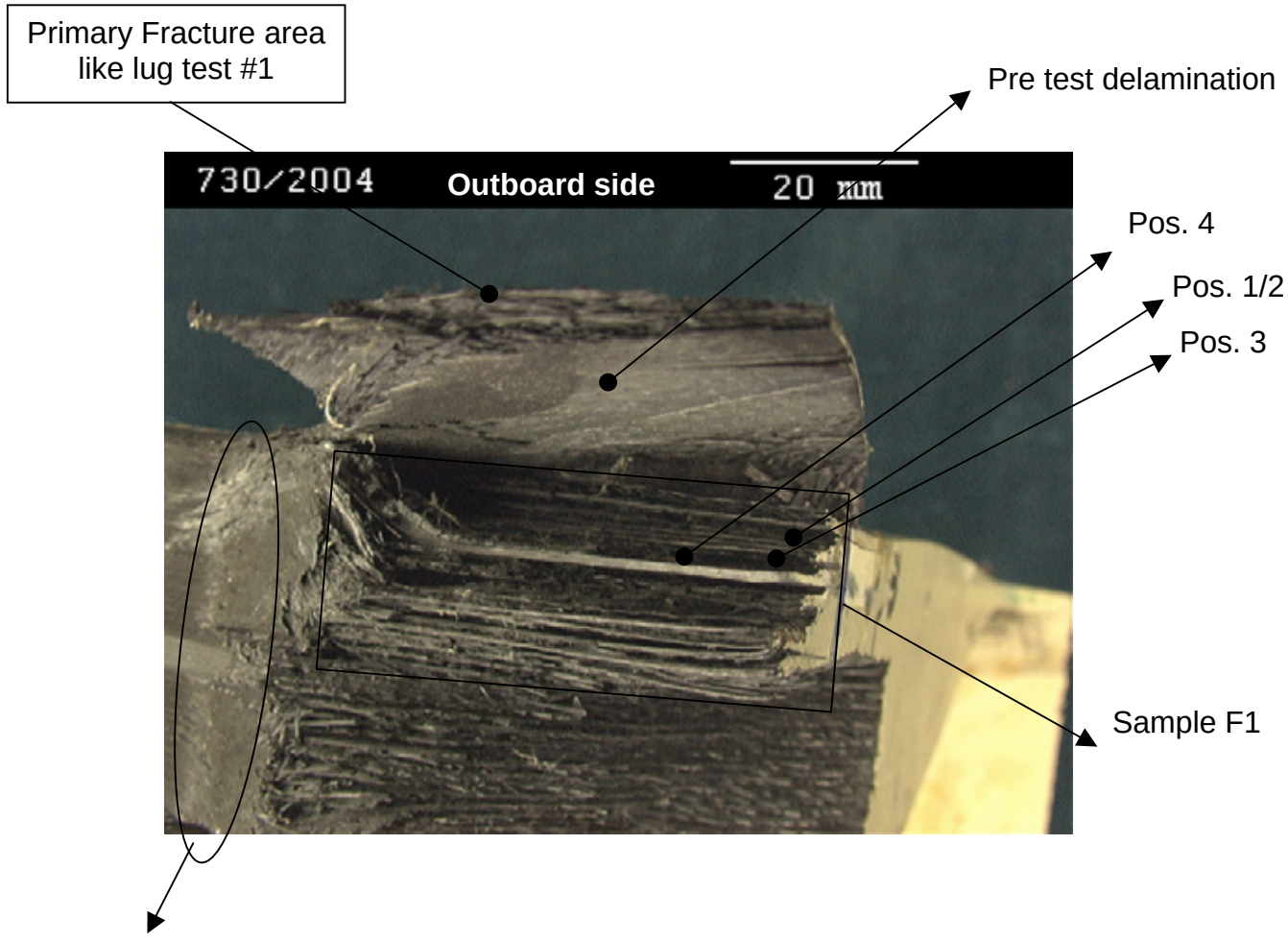


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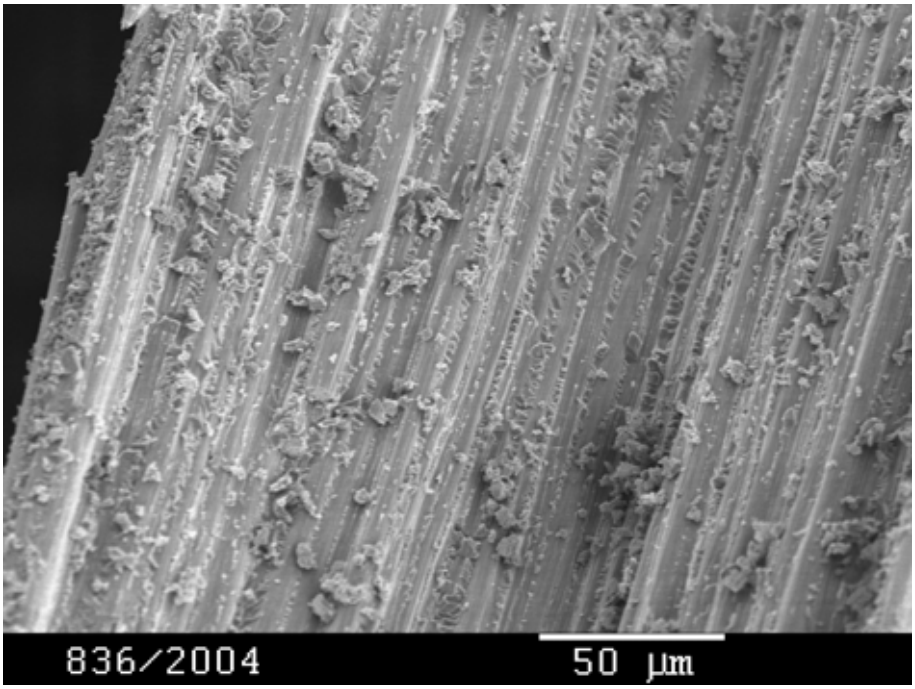
Fig 9: Lug Test # 3, **F1**, translaminar fracture path



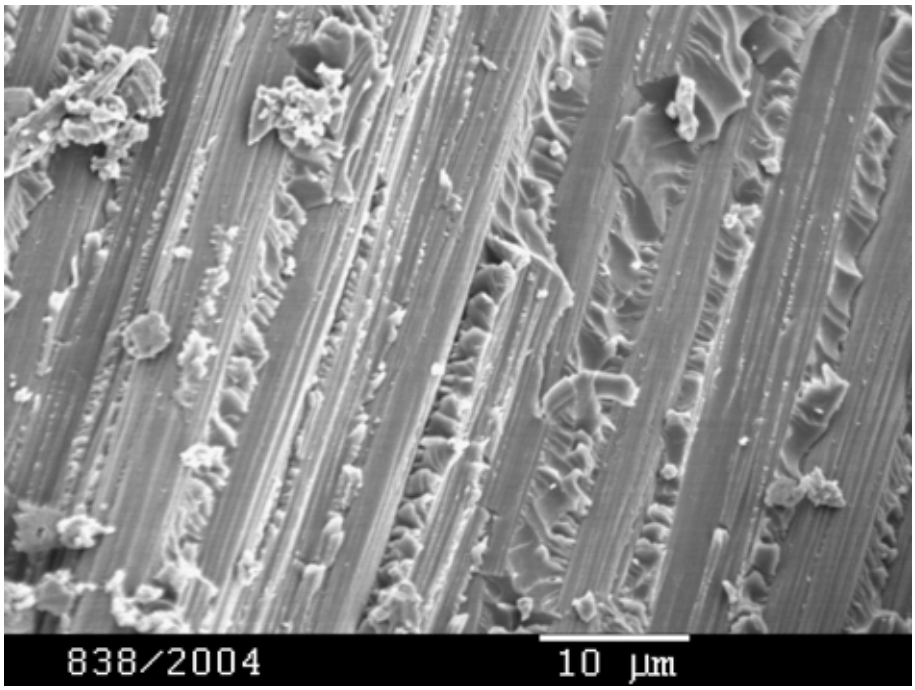


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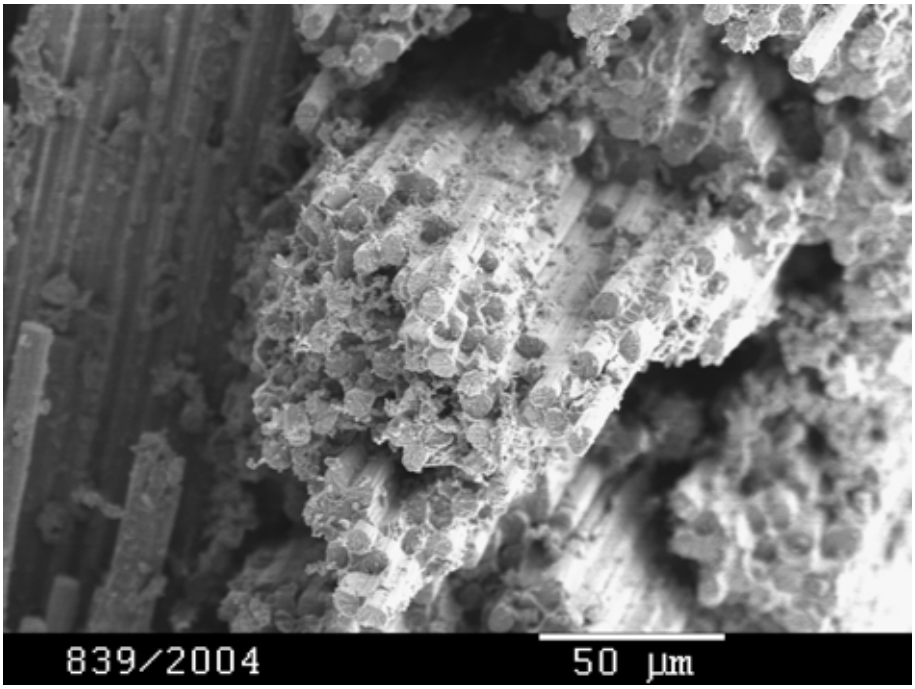
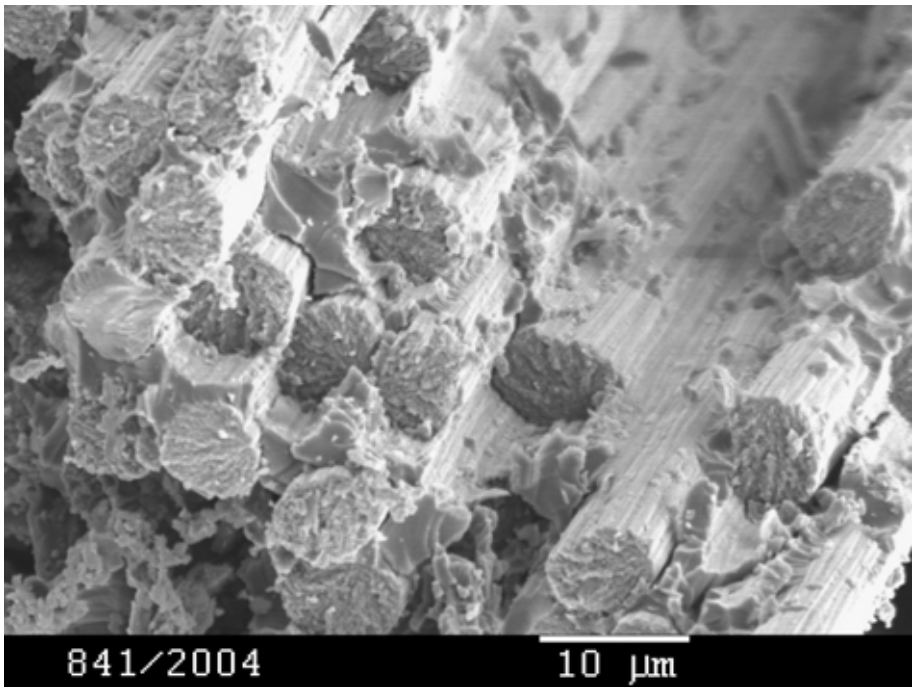
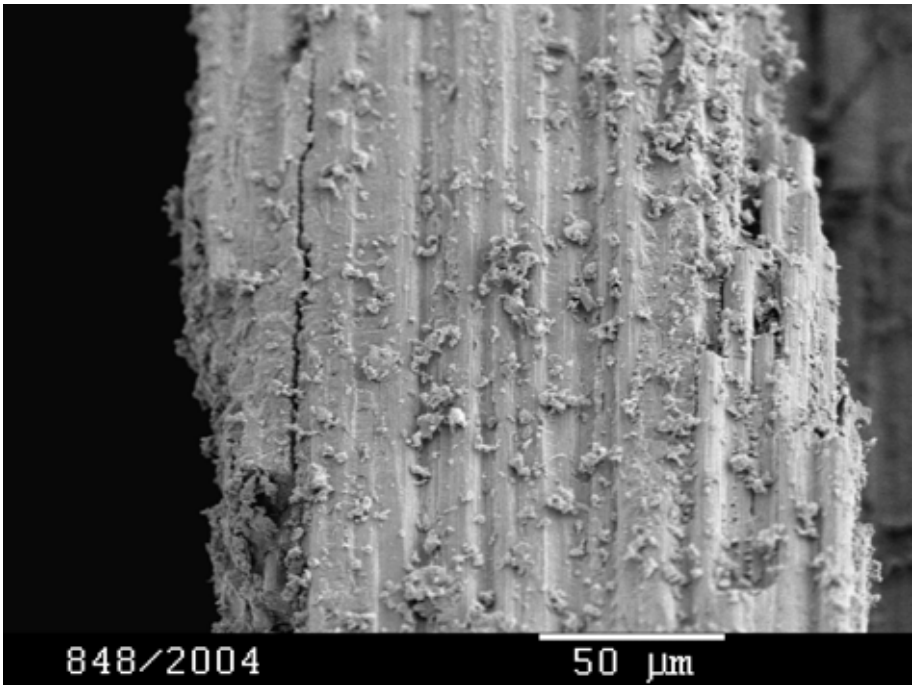
Fig. 10: Features of mode I and II loadings, fracture path approx. parallel to the fibers, det. of fig. 9 / **pos. 1**





839/2004 841/2004
Fig. 11: Locally radial pattern, det. of fig. 9, **pos. 2**



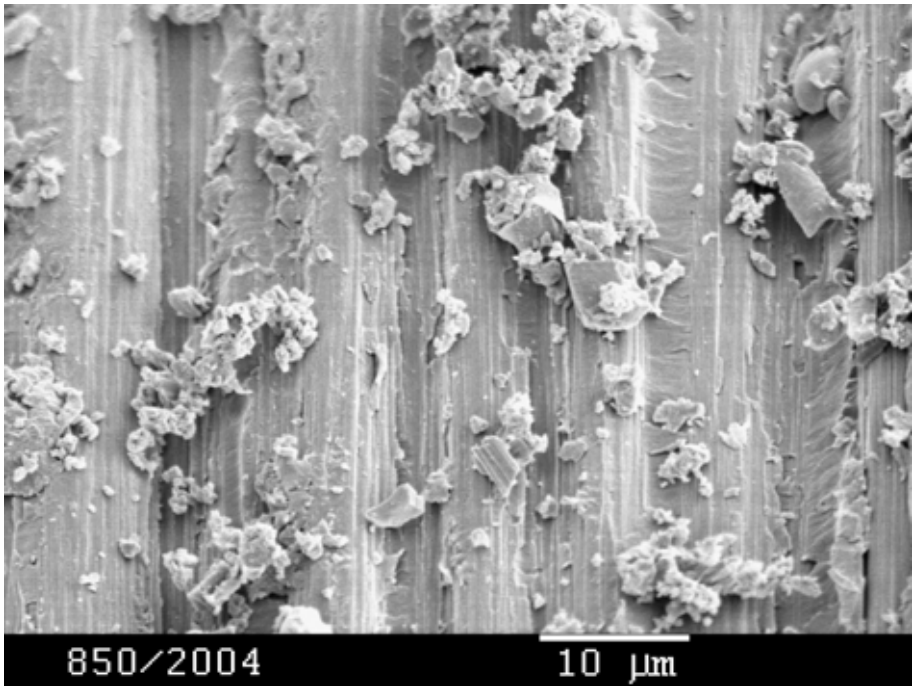


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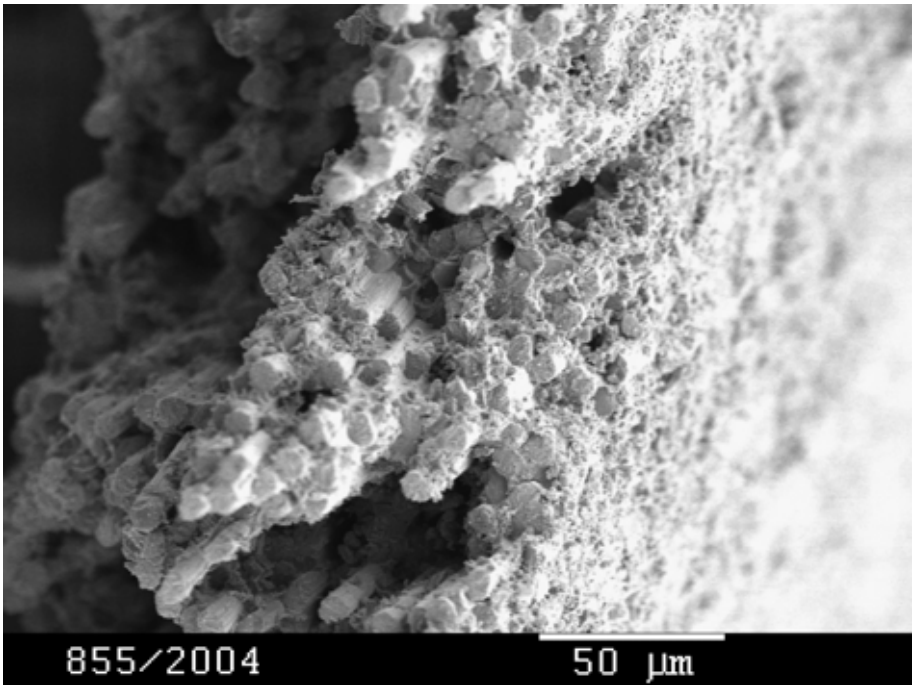
Fig. 12: Features of mode I loadings, fracture path approx. parallel to the fibers, det. of fig. 9 / **pos. 3**



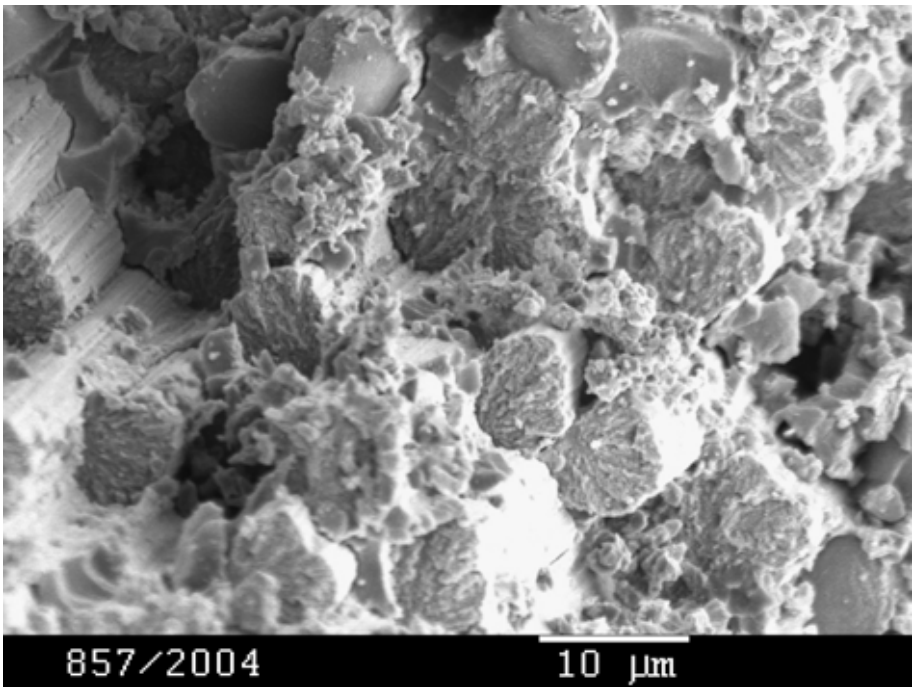


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Fig. 13: Locally radial pattern, det. of fig. 9, **pos. 4**