



ATTACHMENT 5

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

DCA16FA217

**UTAS Aerospace Systems 737NG CFM56-7B24 Southwest Airlines ESN 874112 Pensacola
Inner Barrel/Back Skin Investigation Metallurgical Report dated October 26, 2018**



**737NG CFM56-7B24 Southwest Airlines
ESN 874112 Pensacola
Inner Barrel/Back Skin Investigation
Metallurgical Report**

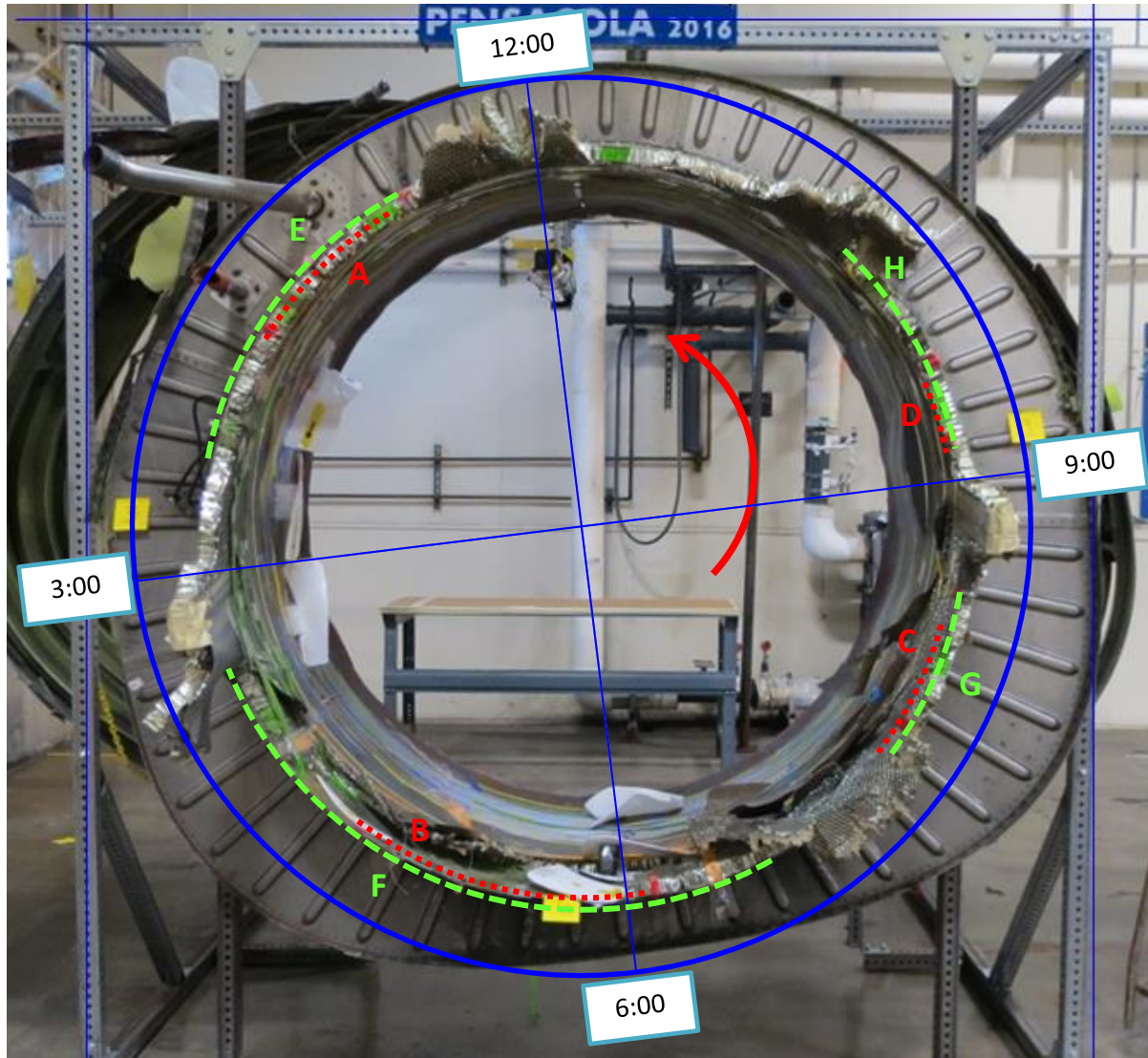
October 26, 2018

Conclusions:

- 1) 6:00 - Back Skin Doubler Gouge Exhibited Titanium
 - Confirmed Blade Tip was Stopped - Back Skin/Doubler
 - Titanium Blade Debris Transfer in Fwd Edge of Doubler
- 2) All Fracture Surfaces Exhibited Ductile Overload
 - Micro-Void Coalescences Dominated by Shear
 - Fatigue Striations were Not Observed
- 3) Maximum Back Skin Damage **210** ° (Blade Debris)
 - 12:45 to 2:30 Blade Debris - Clock Wise Shear
 - 3:30 to 6:45 Blade Debris - Clock Wise Shear
 - 7:30 to 8:30 Blade Debris - Clock Wise Shear
 - 9:15 to 10:15 Blade Debris - Clock Wise Shear
- 4) Source of Iron and Stainless Particles Unknown

737NG CFM56-7B Fan Blade-Out: Southwest ESN874112
Pensacola

– **Min/Max** Inner Barrel Through Damage from Fan Blade Fragments



– – – **Min Damage**

Min Damage Segments

A - 12:45-1:45, $\Delta = 1:00$

B - 4:30-6:15, $\Delta = 1:45$

C - 7:30-8:15, $\Delta = 0:45$

D - 9:15-9:30, $\Delta = 0:15$

Min Total Δ Damage

$= 1:00 + 1:45 + 0:45 + 0:15$

$= 3:45$

$= 112.5^\circ$

– – – **Maximum Damage**

Max Damage Segments

E - 12:45 to 2:30, $\Delta = 1:45$

F - 3:30 to 6:45, $\Delta = 3:15$

G - 7:30 to 8:30, $\Delta = 1:00$

H - 9:15 to 10:15, $\Delta = 1:00$

Max Total Δ Damage

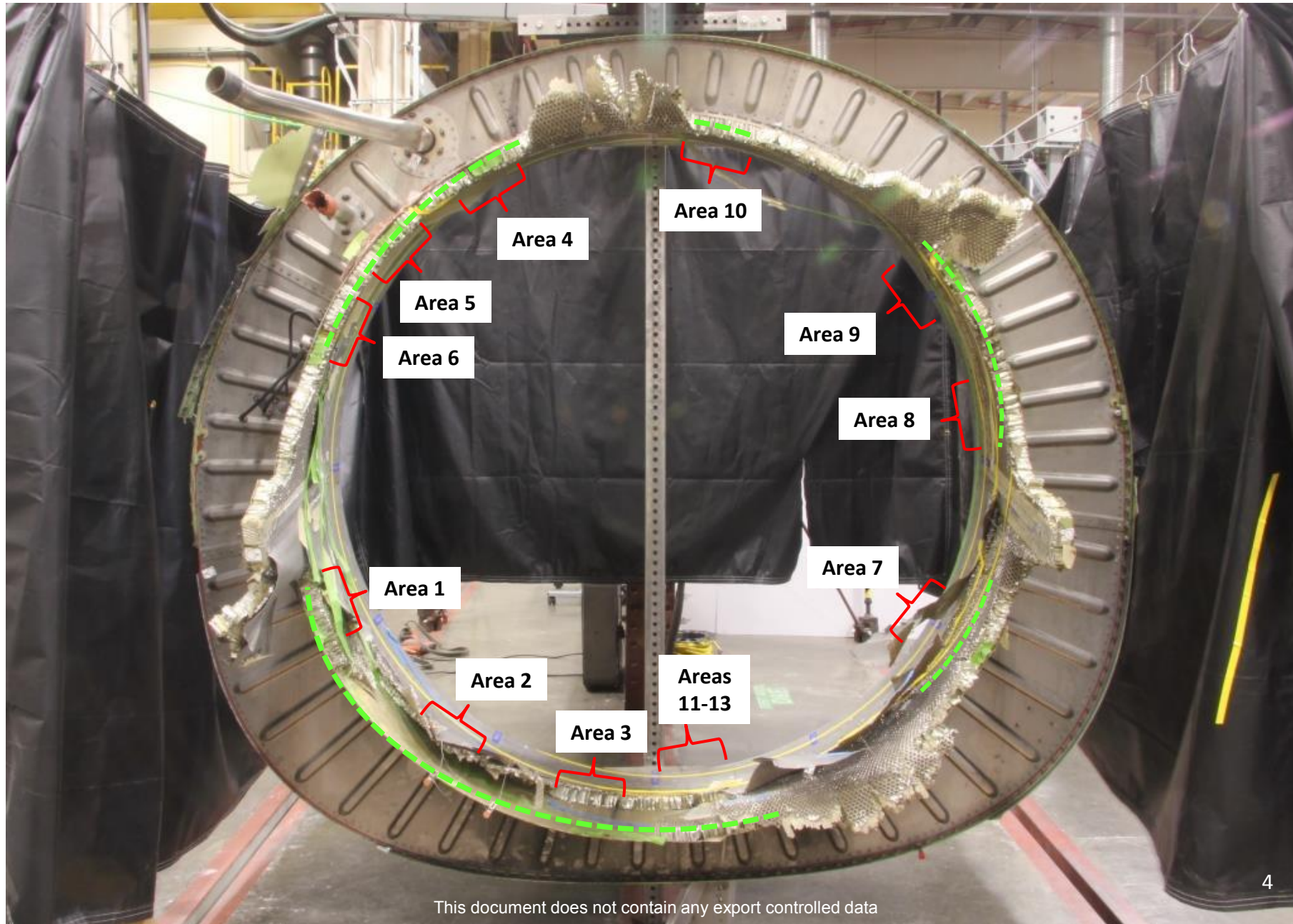
$= 0:15 + 1:45 + 3:15 + 1:00 + 1:00$

$= 7:15$

$= 210^\circ$

Clocking is based on nacelle coordinate system and is in alignment with blue tape clocking on ID of attach ring

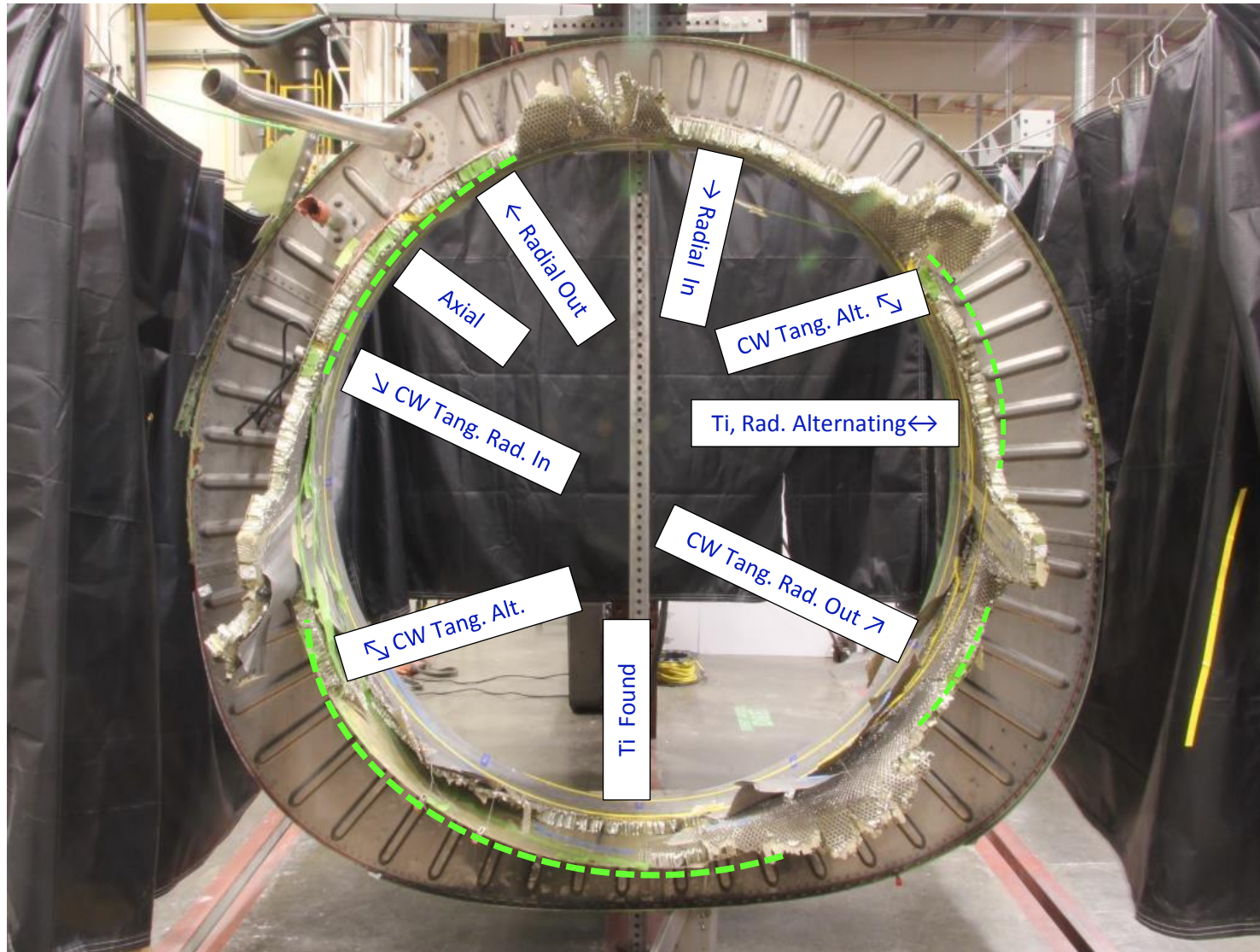
Identified Areas for Examination



Summary of Findings

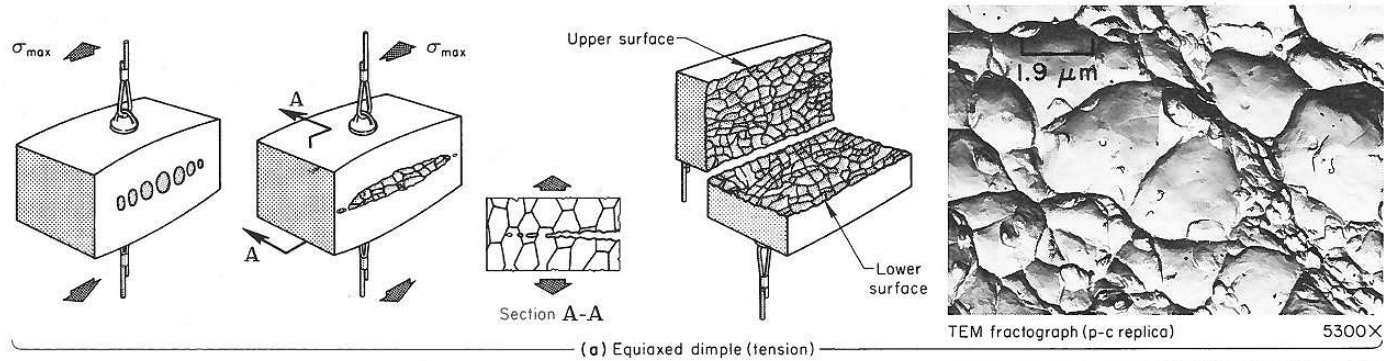
Area	Clocking Position	Material Impact	Fracture Surface (AFT looking FWD)
1	3:30 – 4:00	No Material Transfer Observed	Clock Wise Tangential Alternating Inboard – Outboard, Shear
2	4:30 – 5:00	No Material Transfer Observed	N/A
3	5:30 – 6:00	Iron and Titanium Imbedded - Containment Shield	N/A
4	1:00	Iron Particles Imbedded - Containment Shield	Radial Outboard, Shear
5	1:30 – 2:00	No Material Transfer Observed	Axial Tension
6	2:00 – 2:30	Iron Particles Imbedded - Containment Shield	Clock Wise Tangential Radial Inboard, Shear
7	8:00	Stainless Steel Imbedded - Back Skin	Clock Wise Tangential Radial Outboard, Shear
8	9:00 – 9:30	Stainless Steel and Titanium Imbedded - Back Skin	Alternating Radial Inboard – Outboard, Shear
9	10:00	No Material Transfer Observed	Clock Wise Tangential Alternating Inboard – Outboard, Shear
10	11:30 – 12:00	No Material Transfer Observed	Radial Inboard, Shear
11	6:00 – 6:30	Titanium Particles Imbedded - Back Skin – Blade Tip	N/A
12	6:00 – 6:30	Titanium Particles Imbedded - Al Core - Blade Tip	N/A
13	6:00 – 6:30	Titanium Particles Imbedded - Al Core - Blade Tip	N/A

Back Skin Fracture Surface Directionality - FWD of Containment Shield

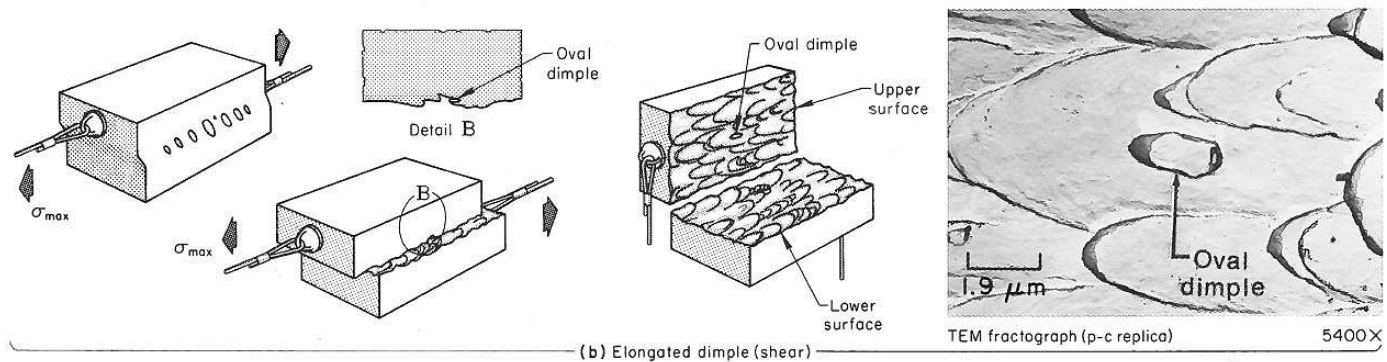


ASM Handbook Vol. 12: Fractography; Section: Mode of Fractures; Copyright © 2012, ASM International

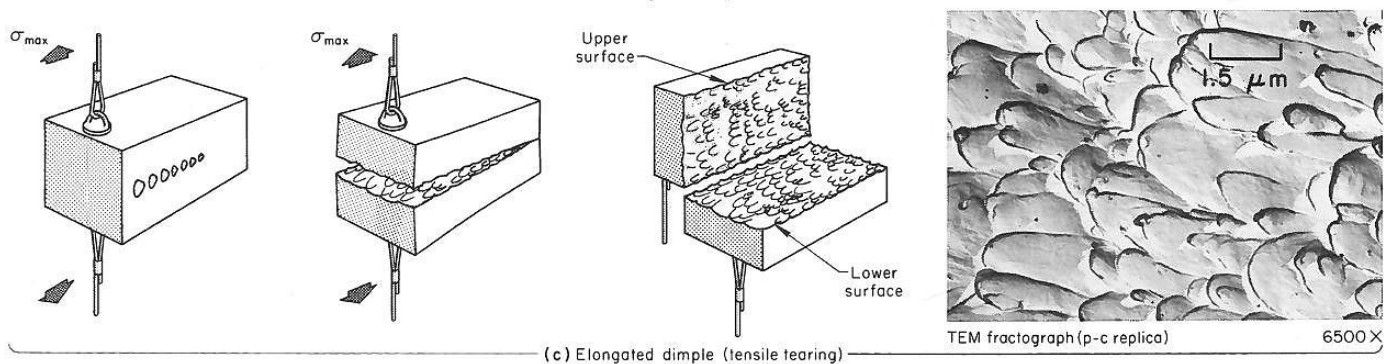
Tensile



Shear



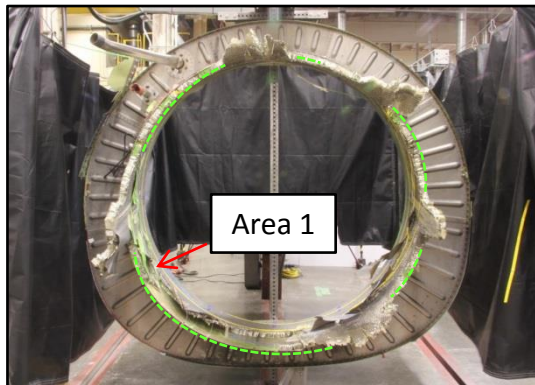
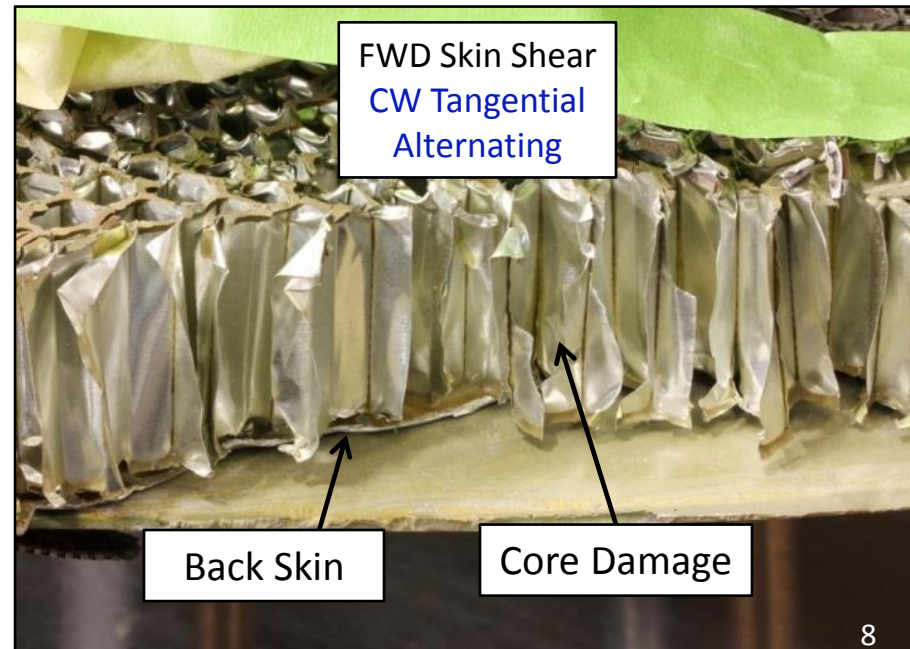
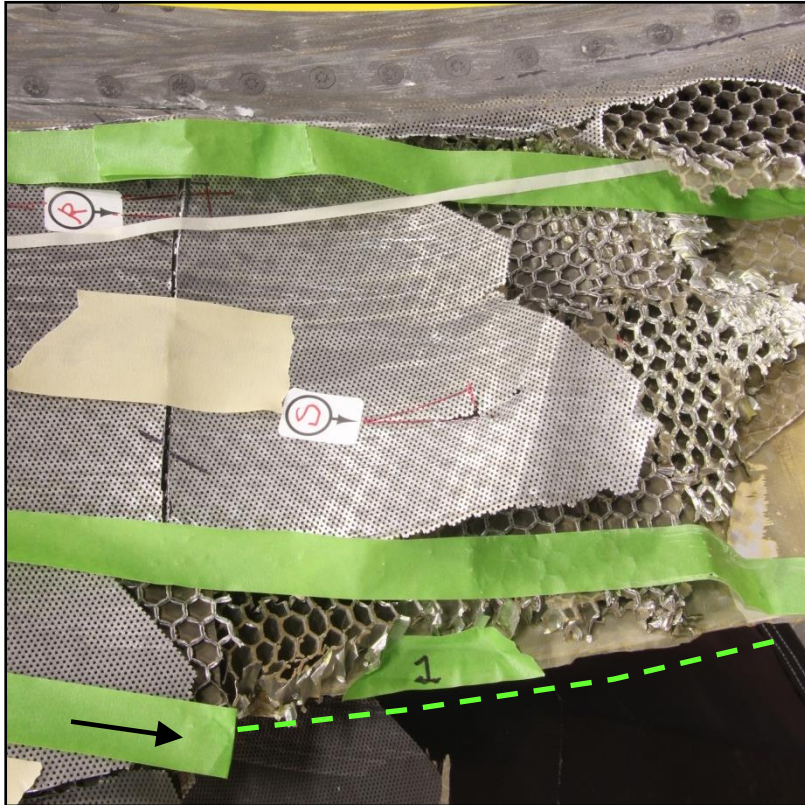
Tensile Tearing



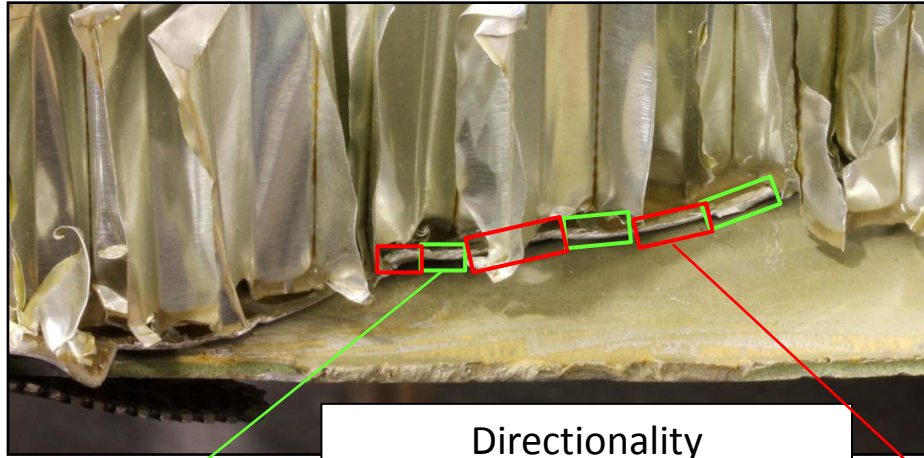
Fractographs show shapes of dimples formed. (a) In tension, equiaxed dimples are formed on both fracture surfaces. (b) In shear, elongated dimples point in opposite directions on matching fracture surfaces. (c) In tensile tearing, elongated dimples point toward fracture origin on matching fracture surfaces.

Fig. 1. Influence of direction of maximum stress (σ_{max}) on the shape of dimples formed by microvoid coalescence

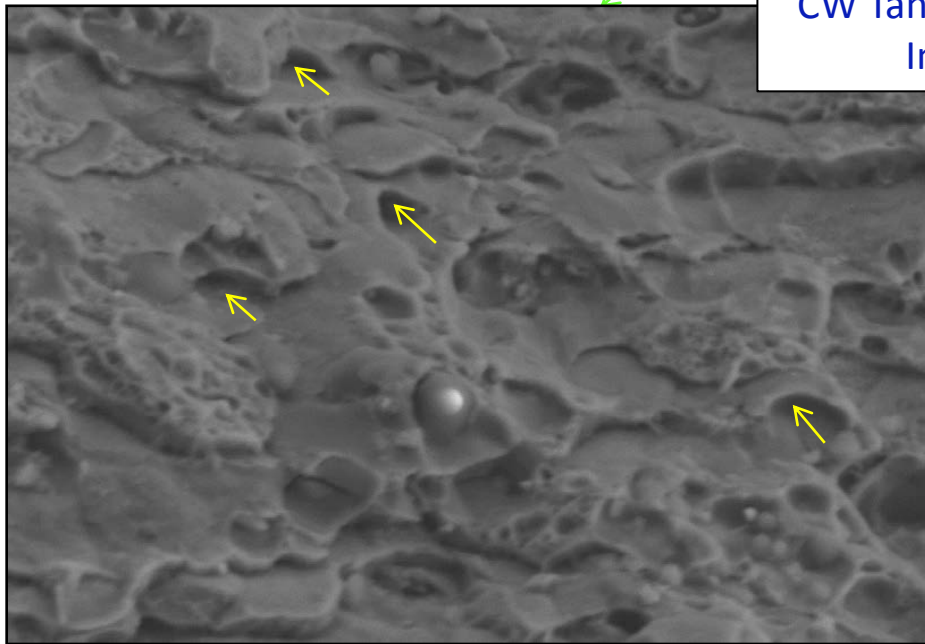
Area 1 – Position: 3:30 – 4:00 (Macro)



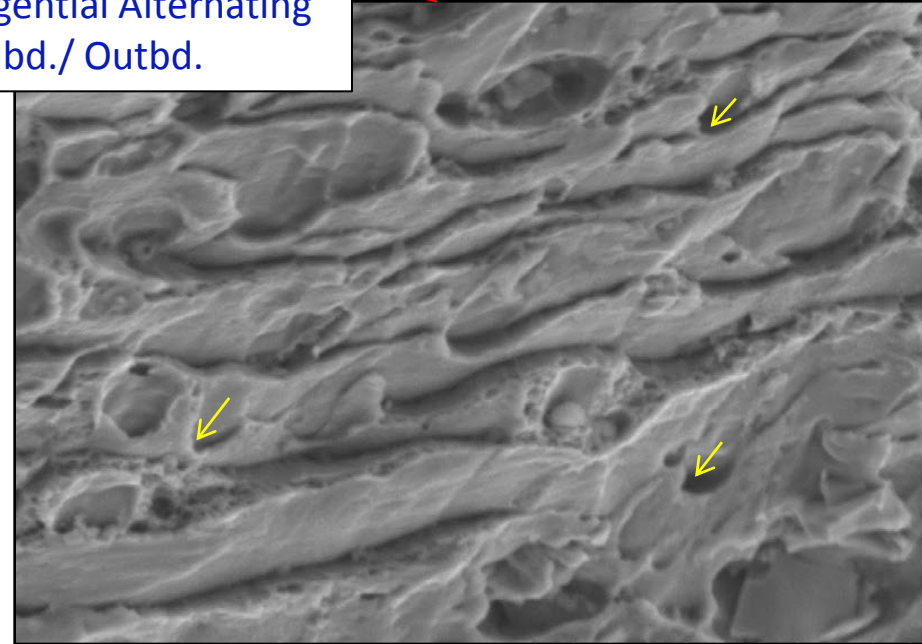
Area 1 – Position: 3:30 – 4:00 (Micro)



Directionality
CW Tangential Alternating
Inbd./ Outbd.

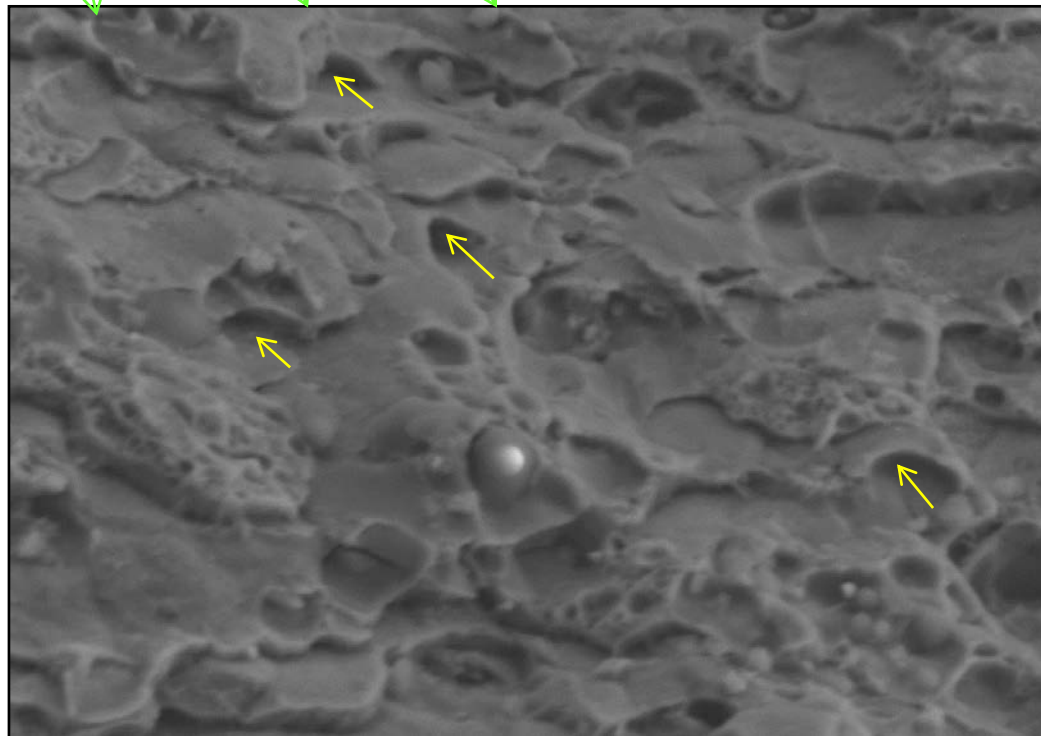
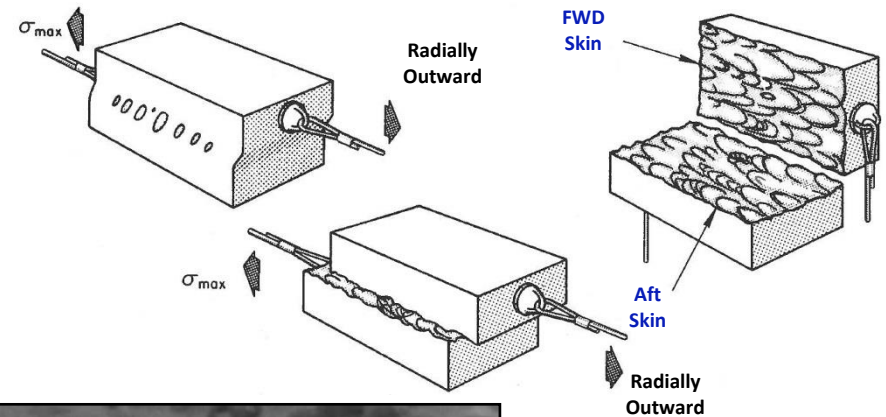
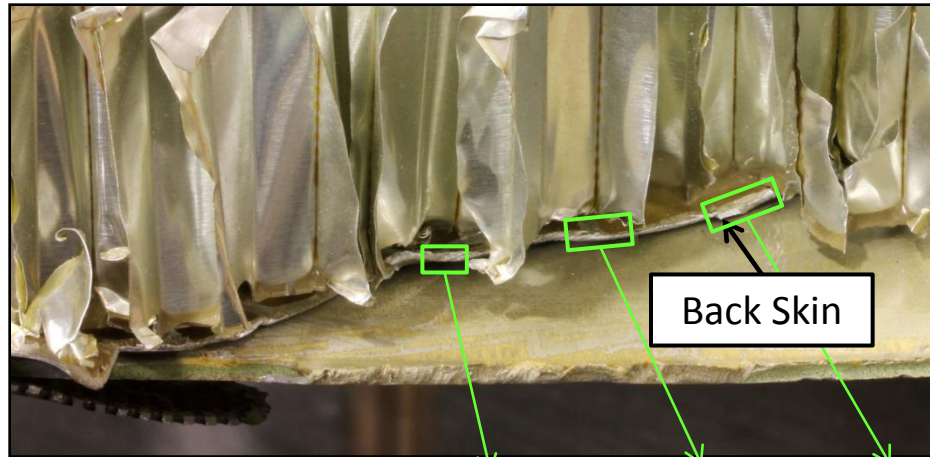


↘ FWD Skin Shear
Tangential CW Radial Outboard



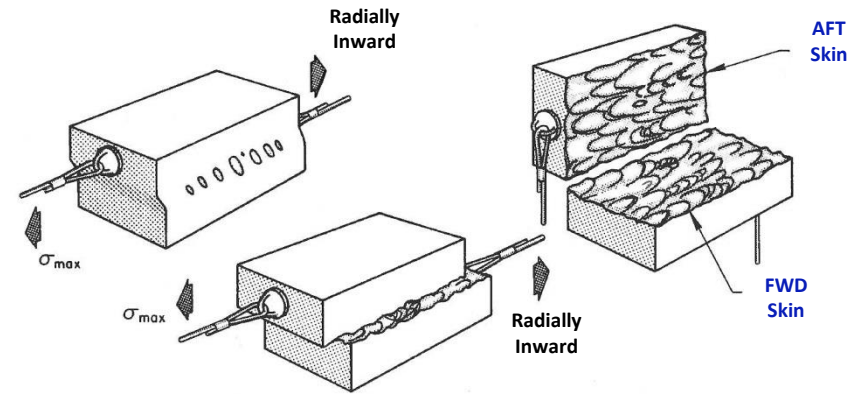
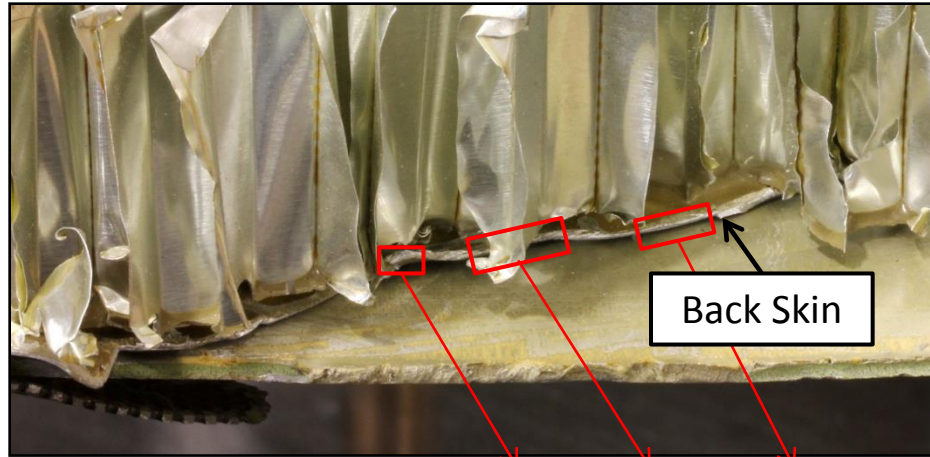
↗ FWD Skin Shear
Tangential CW Radial Inboard

Area 1 – Position: 3:30 – 4:00 (Micro)

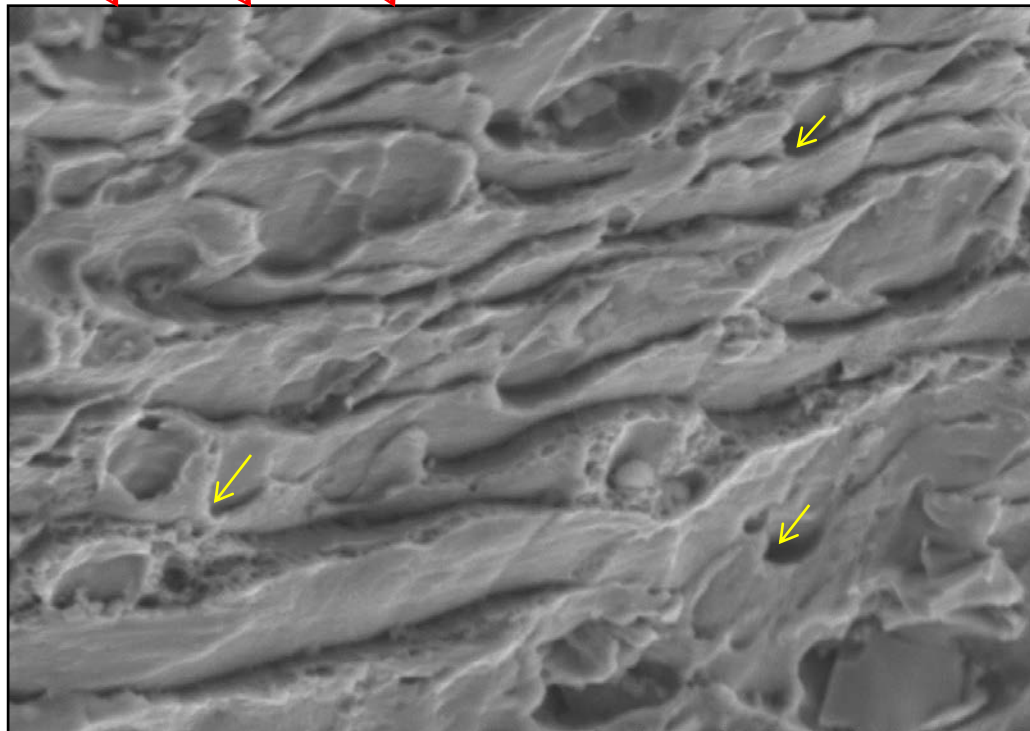


↙ FWD Skin
Shear
Tangential CW
Radial Outboard

Back Skin Microvoid Coalescence

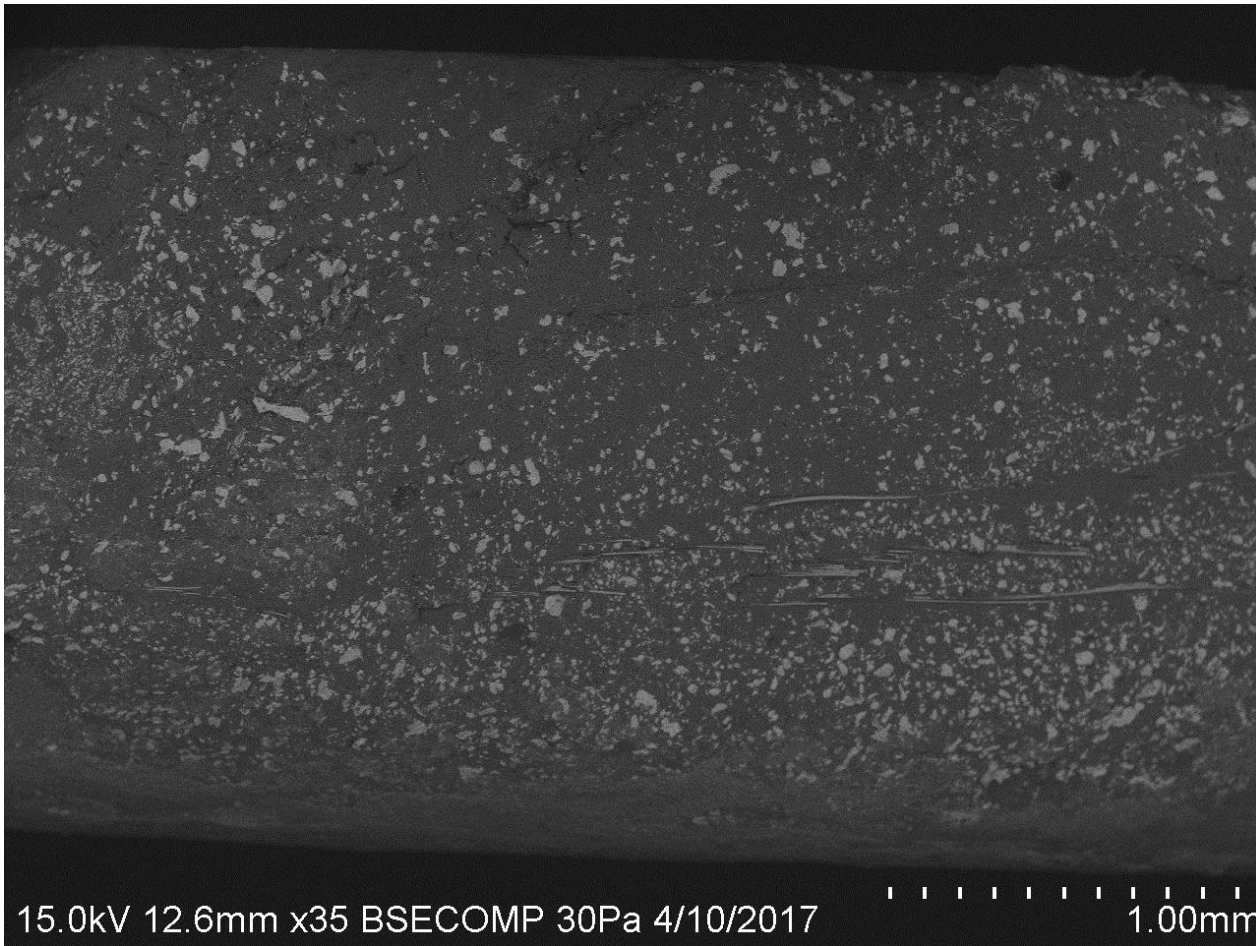


↗ FWD Skin
Shear
Tangential CW
Radial Inboard

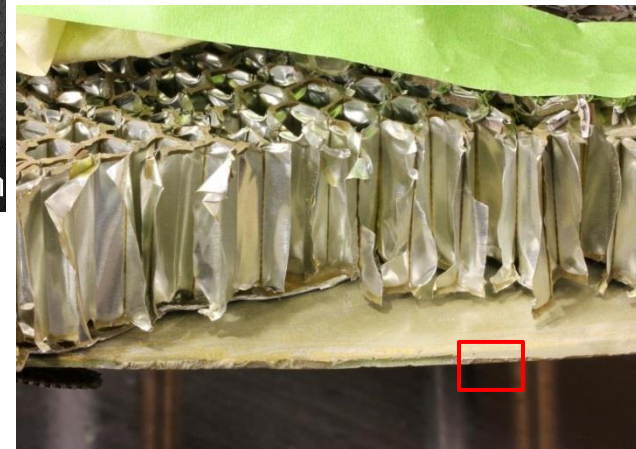


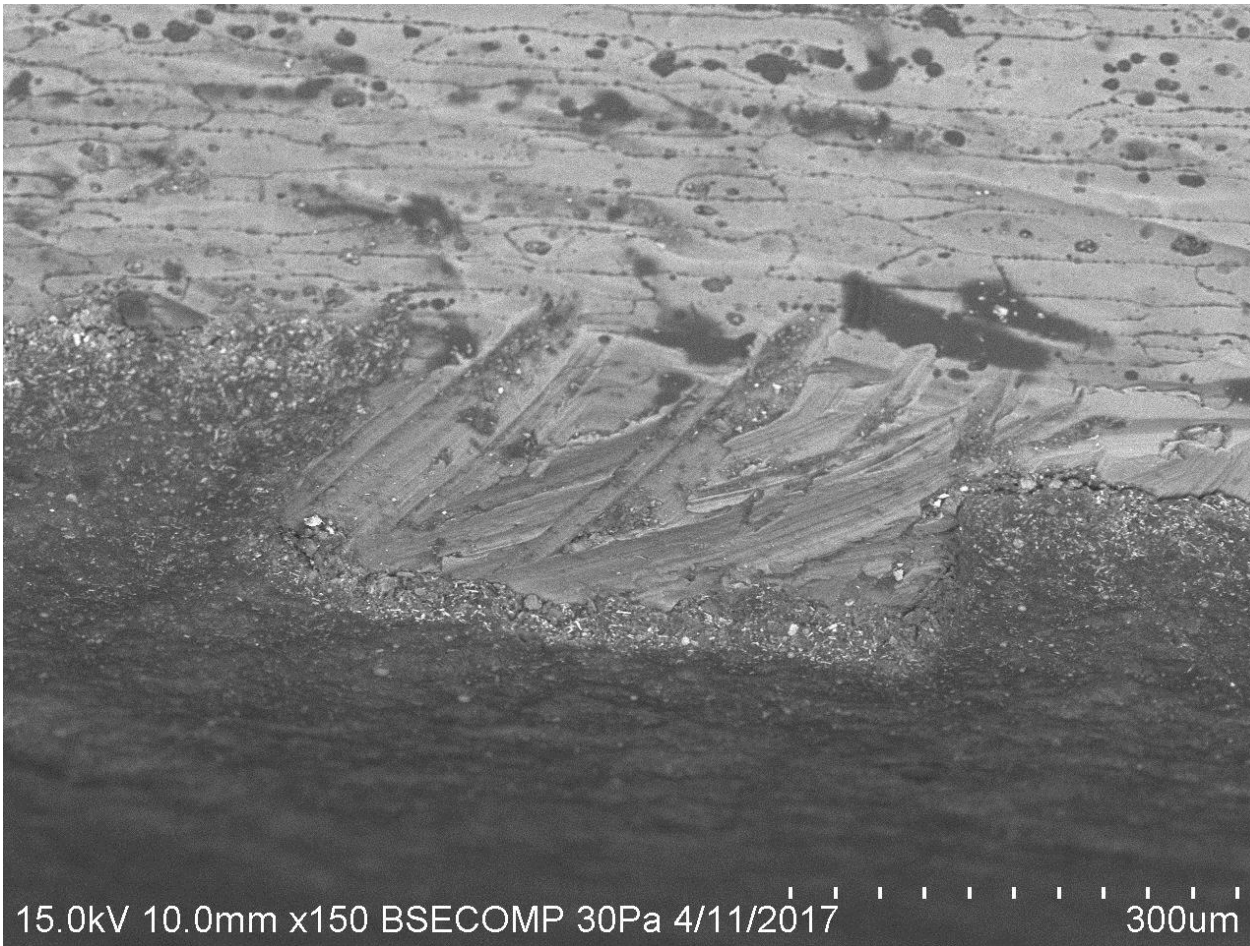
Back Skin Microvoid Coalescence

This document does not contain any export controlled data

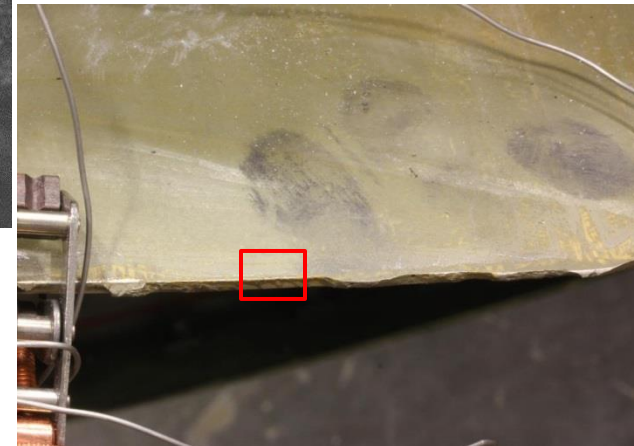


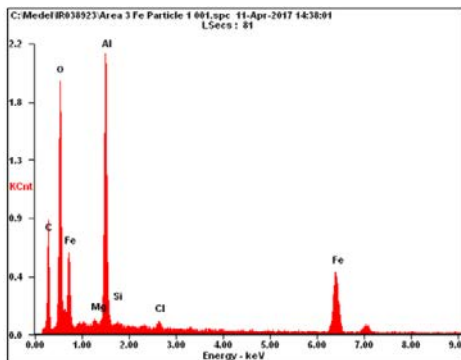
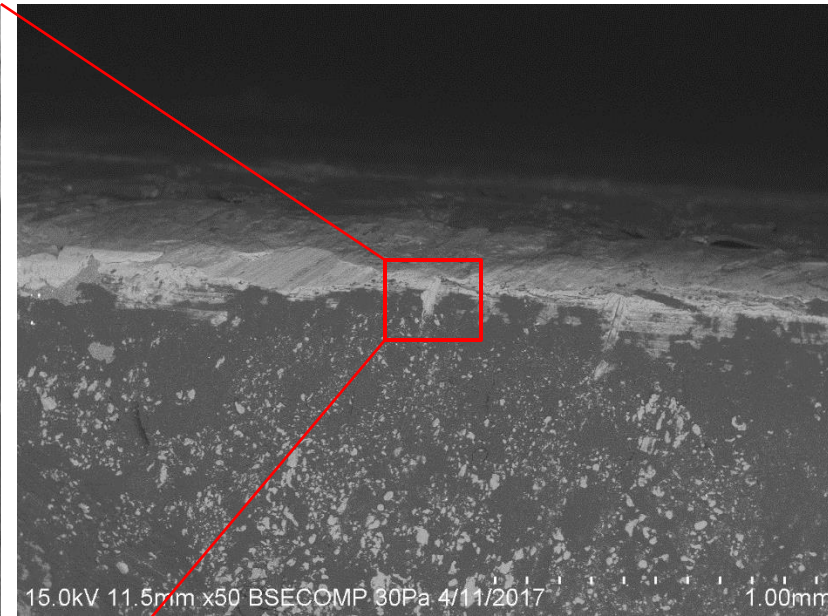
- Adhesive Edge.
- No Material Transfer Observed





- Adhesive Edge.
- No Material Transfer Observed

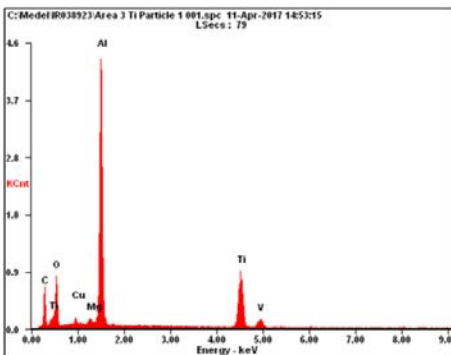
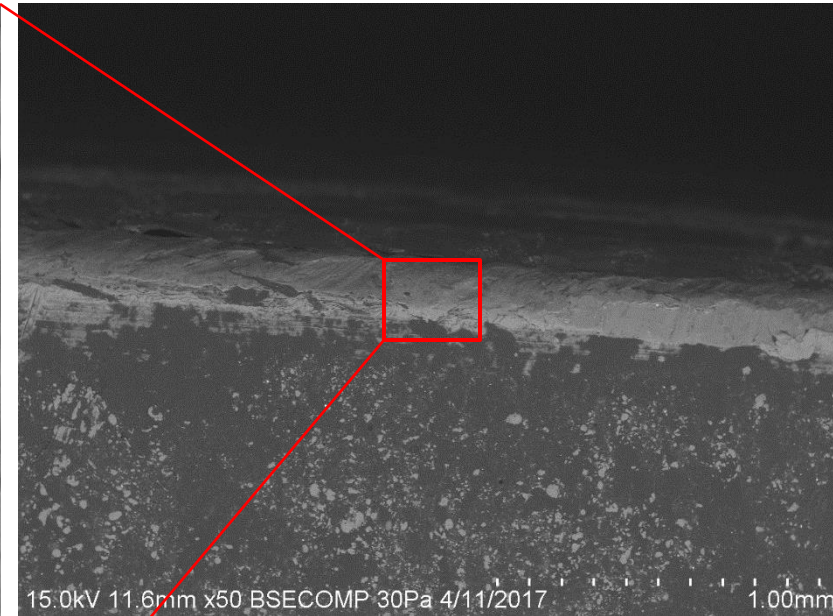
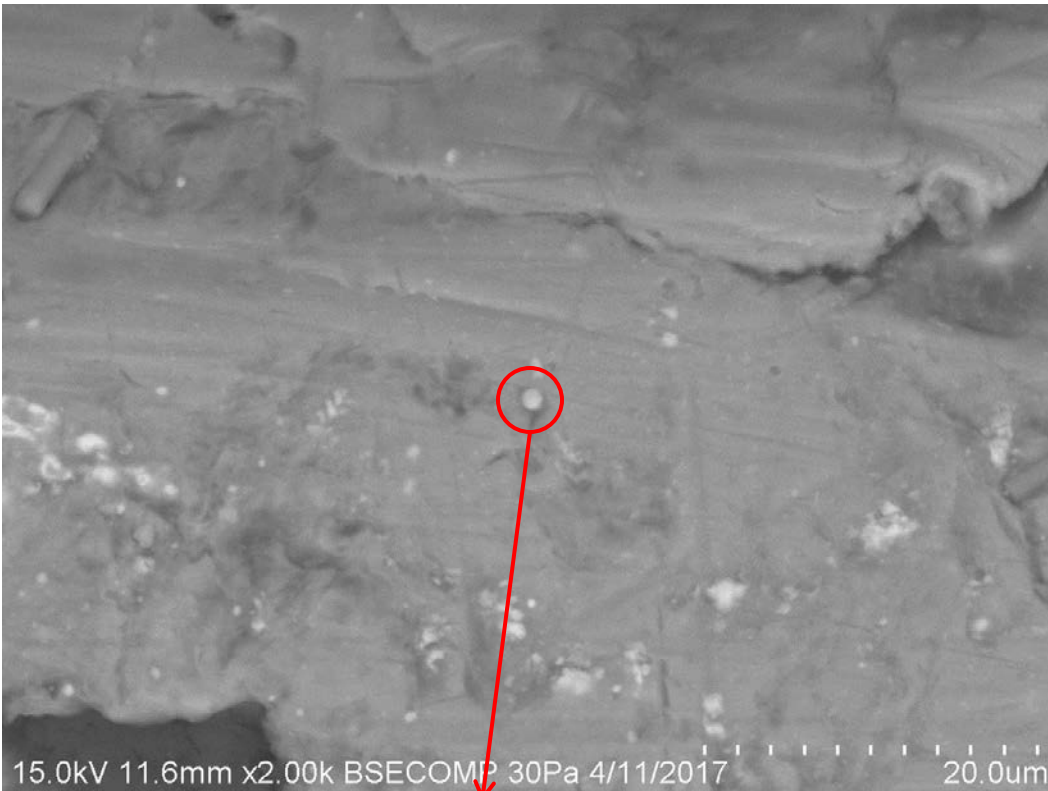




Element	Wt%	At%
CK	30.19	49.03
OK	22.99	28.03
MgK	00.47	00.38
AlK	16.49	11.92
SiK	00.22	00.15
ClK	00.64	00.35
FeK	29.01	10.13



- **Iron based Particle Imbedded - Containment Shield**

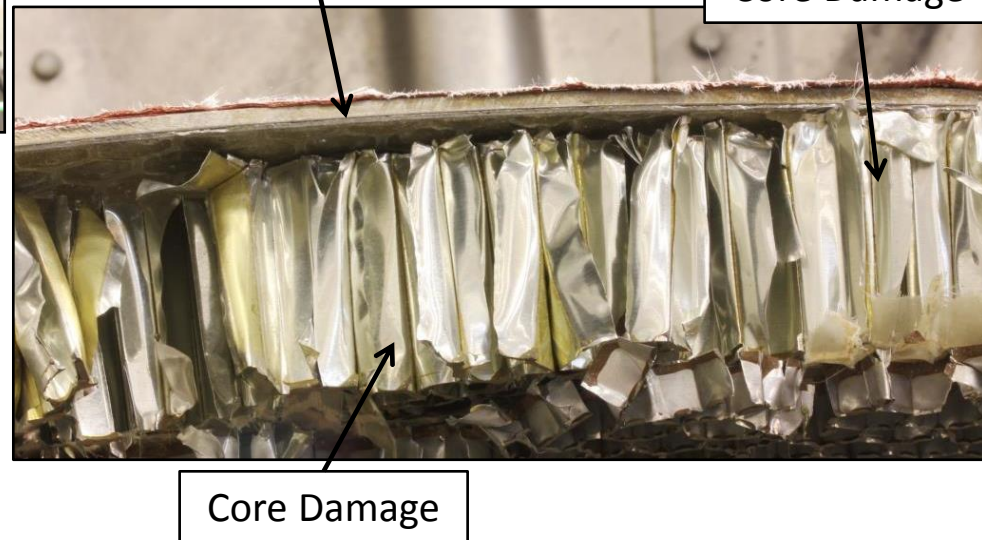
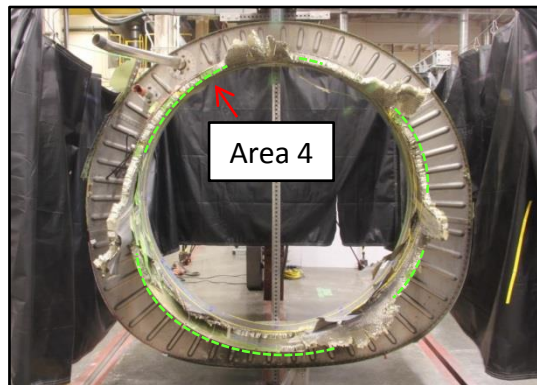
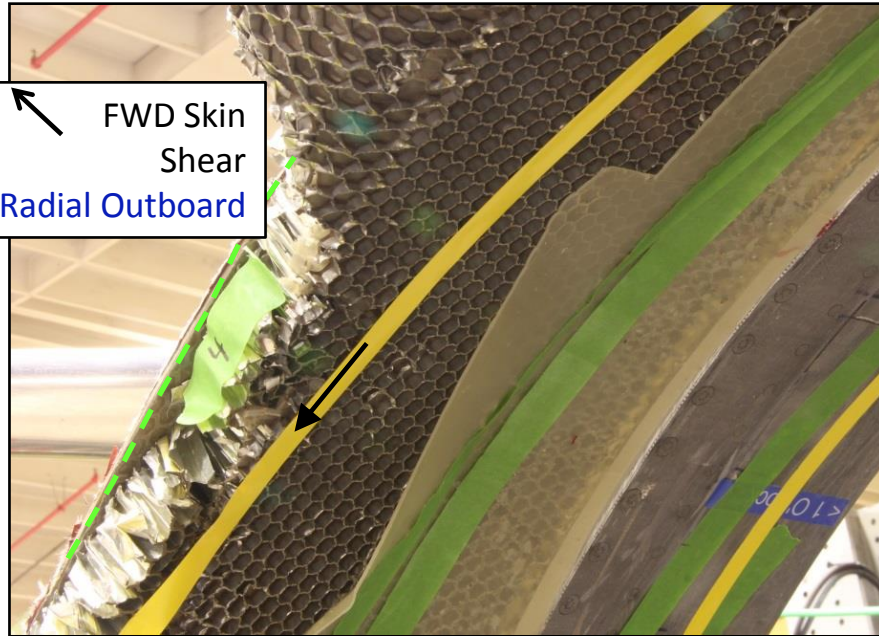


Element	Wt%	At%
CK	27.26	45.64
OK	16.39	20.60
CuL	01.58	00.50
MgK	00.64	00.53
AlK	30.81	22.96
TiK	22.42	09.41
VK	00.89	00.35

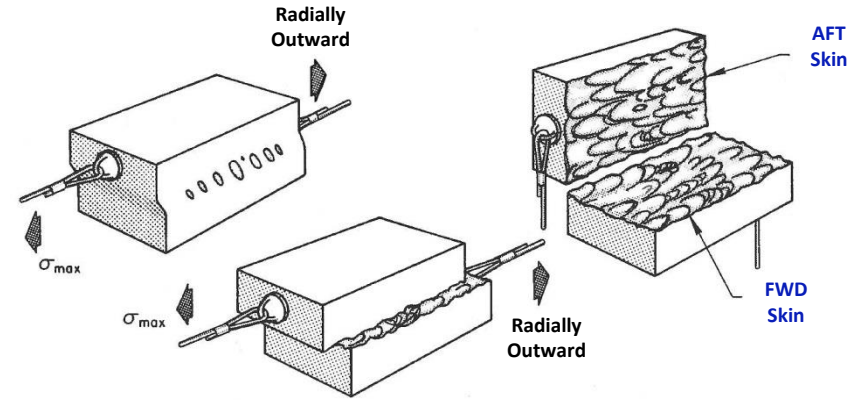
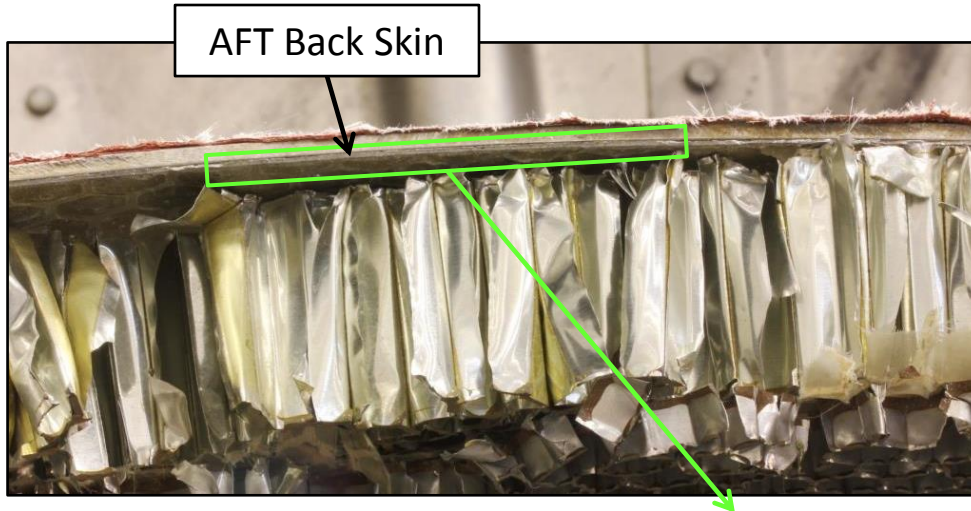


- **Titanium based Particle Imbedded - Containment Shield**

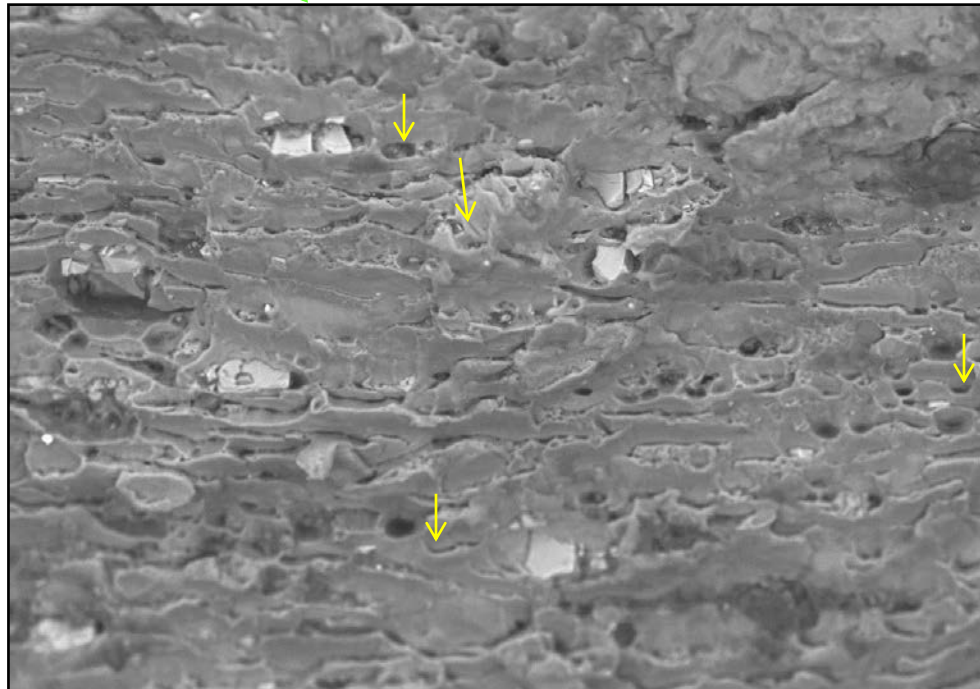
Area 4 – Position: 1:00 (Macro)



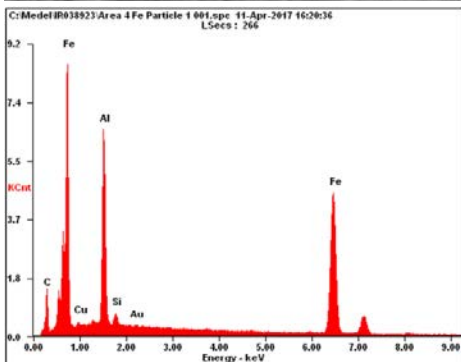
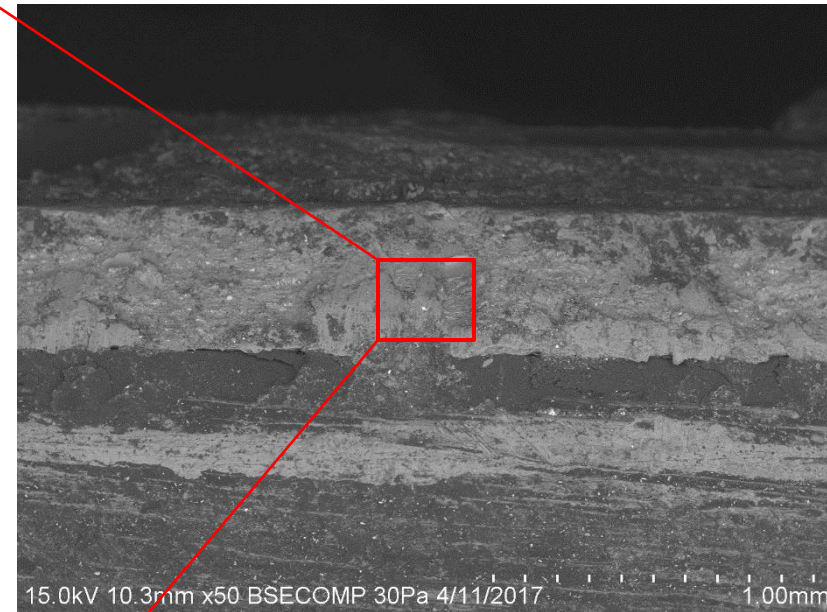
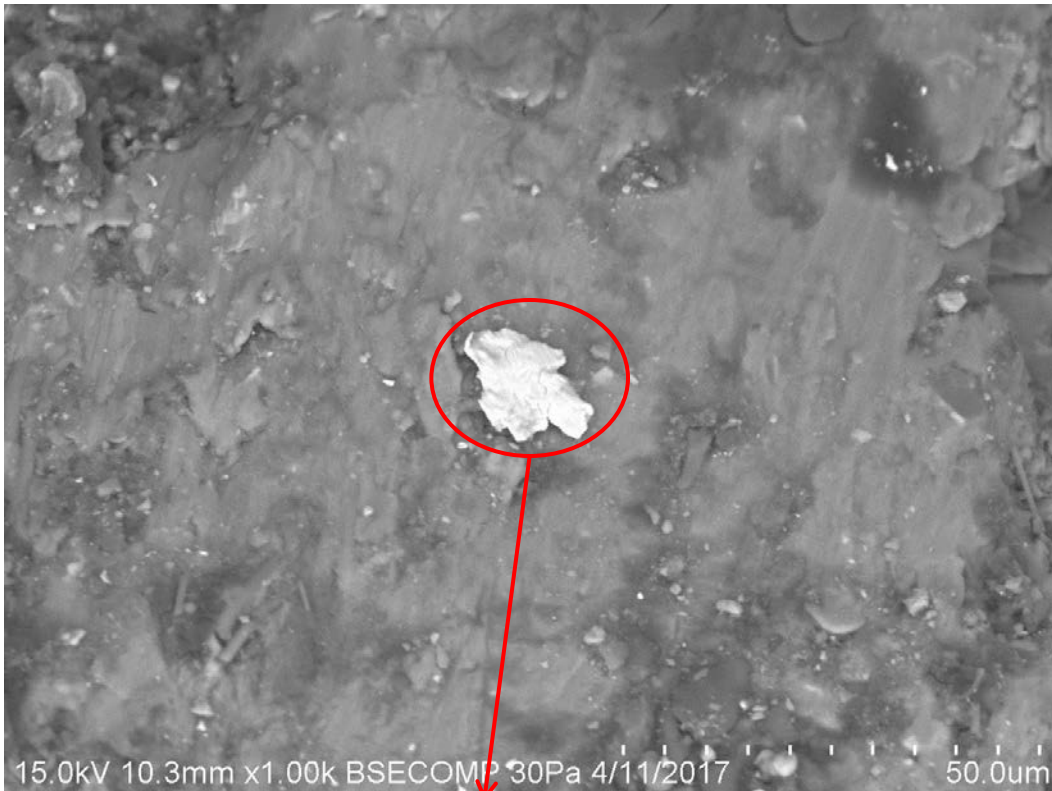
Area 4 – Position: 12:45-1:00 (Micro)



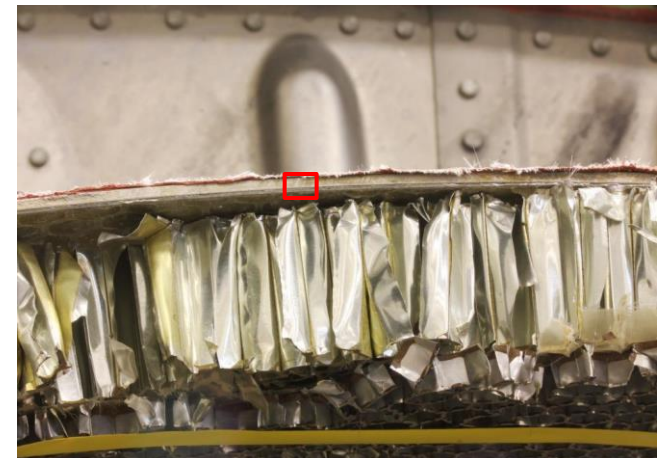
↑ FWD Skin
Shear
Radial Outboard



Back Skin Microvoid Coalescence



Element	Wt%	At%
CK	17.07	44.35
CuL	00.96	00.47
AlK	15.01	17.36
SiK	00.95	01.05
AuM	00.28	00.04
FeK	65.73	36.73



• Iron based Particle Imbedded - Containment Shield

Area 5 – Position: 1:30 – 2:00 (Macro)

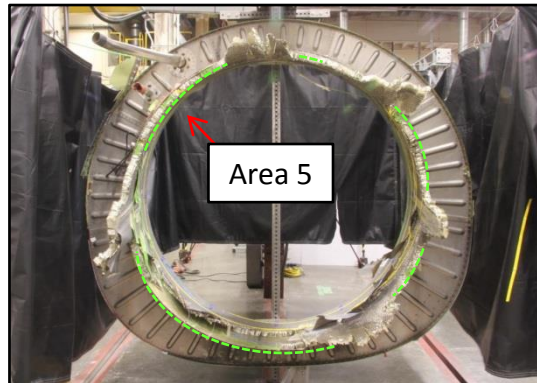
FWD Skin
Axial Tensile



Back Skin

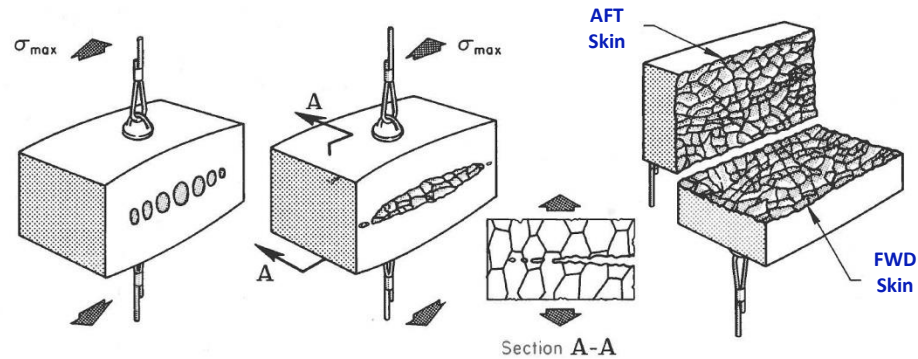
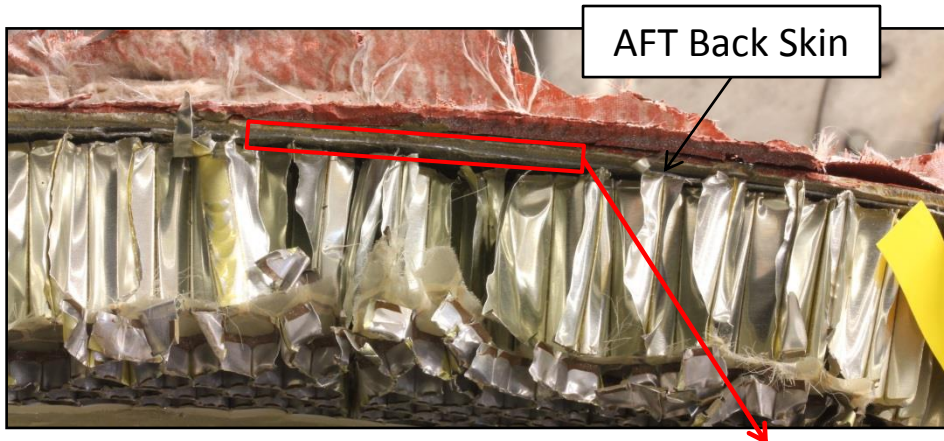


Core Damage

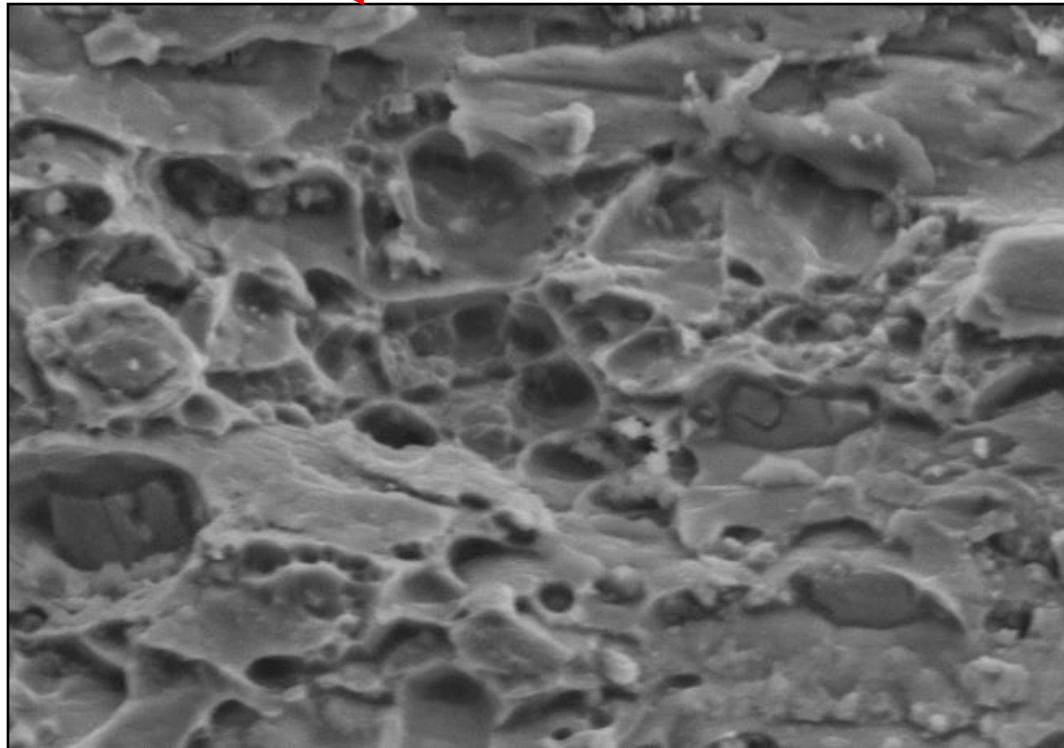


Area 5

Area 5 – Position: 1:30 – 2:00 (Micro)



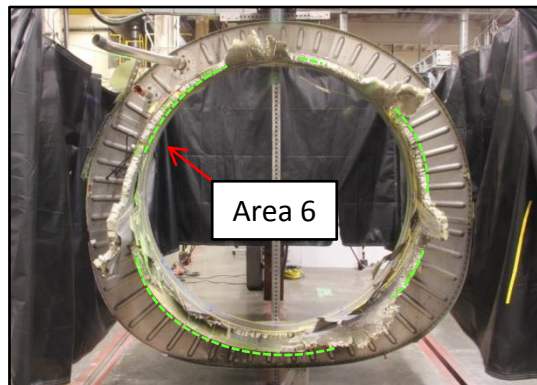
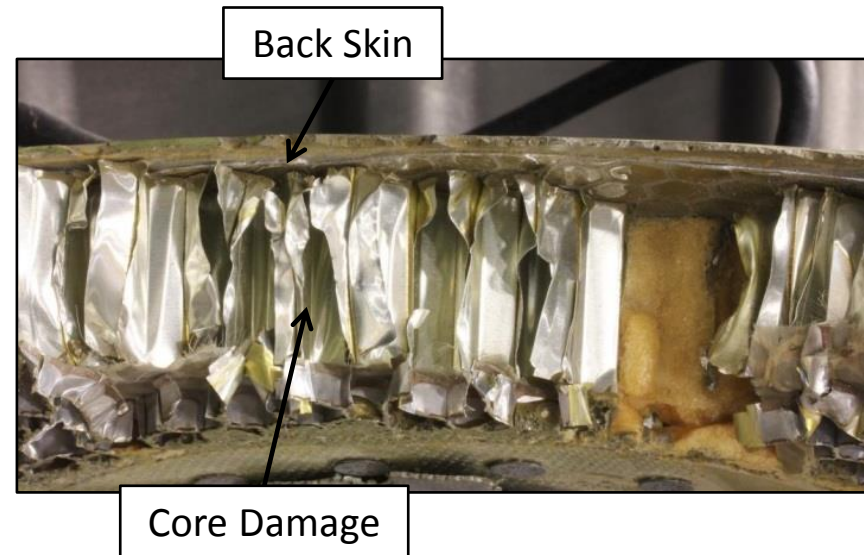
FWD Skin
Shear
Axial Tensile

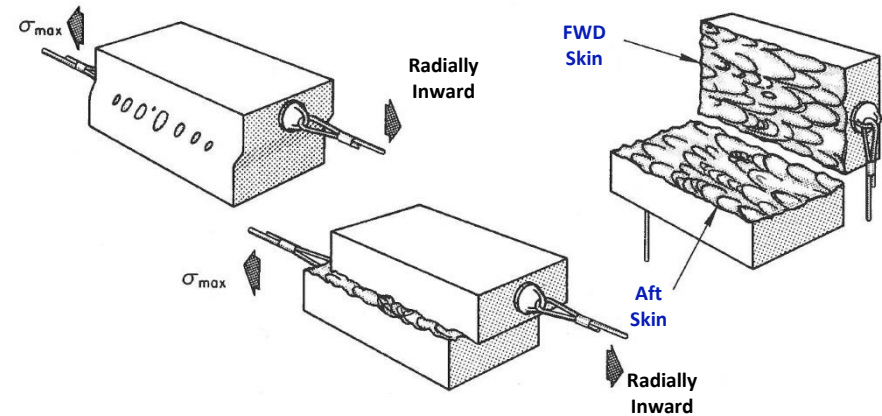
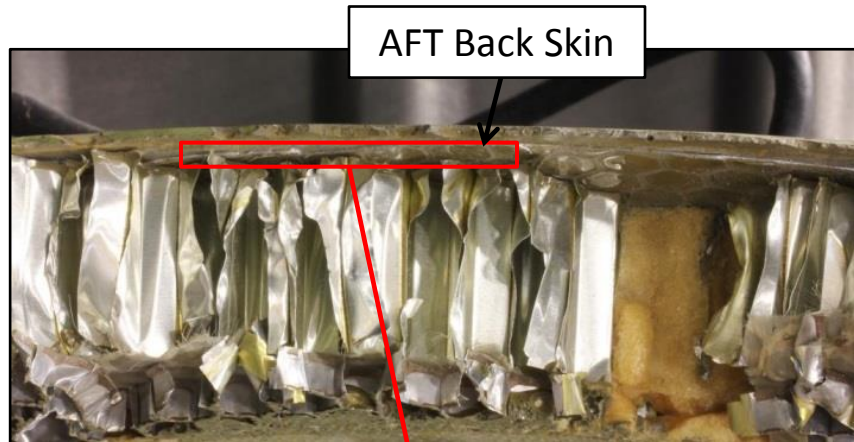


Back Skin Microvoid Coalescence

This document does not contain any export controlled data

Area 6 – Position: 2:00 – 2:30 (Macro)



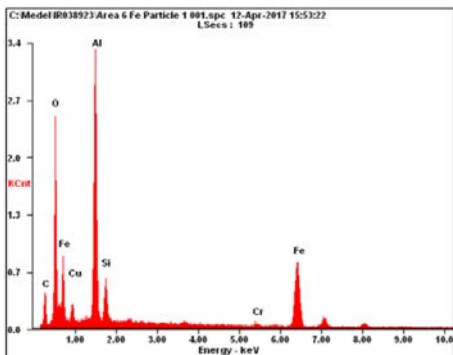


↙ FWD Skin
Shear
Tangential CW
Radial Inboard

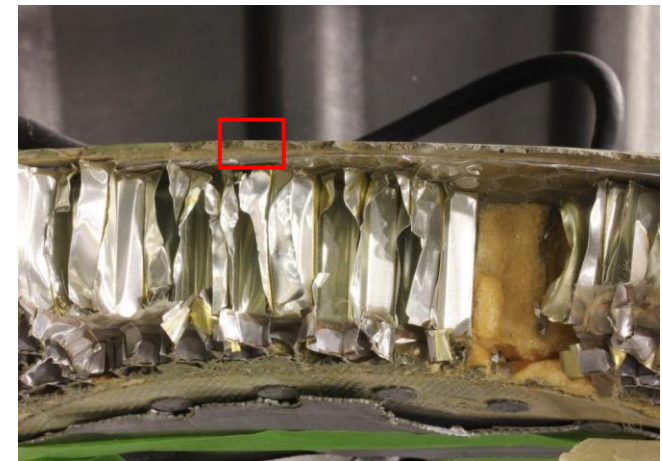


Back Skin Microvoid Coalescence

This document does not contain any export controlled data

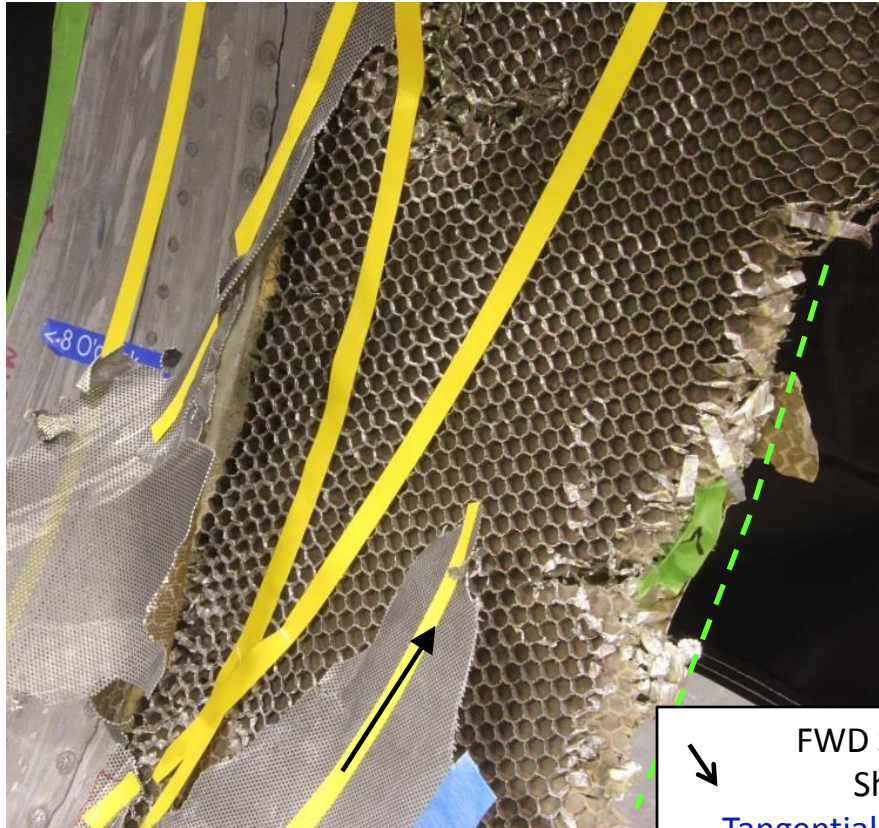


Element	Wt%	At%
CK	14.91	30.40
OK	19.68	30.12
CuL	04.37	01.68
AlK	19.85	18.02
SiK	03.88	03.38
CrK	00.86	00.40
FeK	36.46	15.99

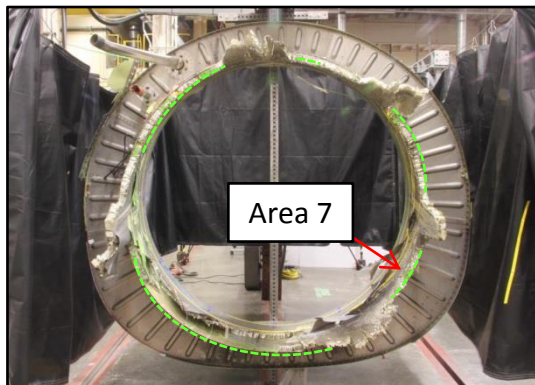
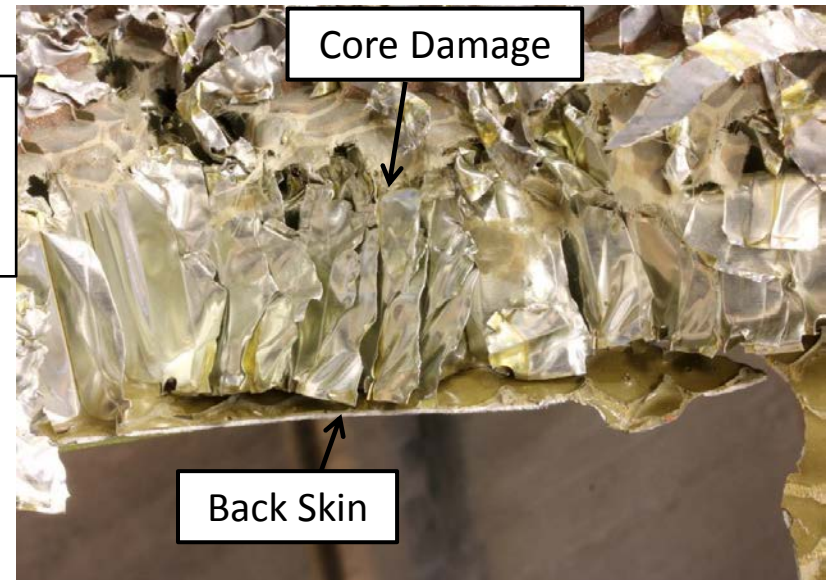


- Iron based Particle Imbedded - Containment Shield

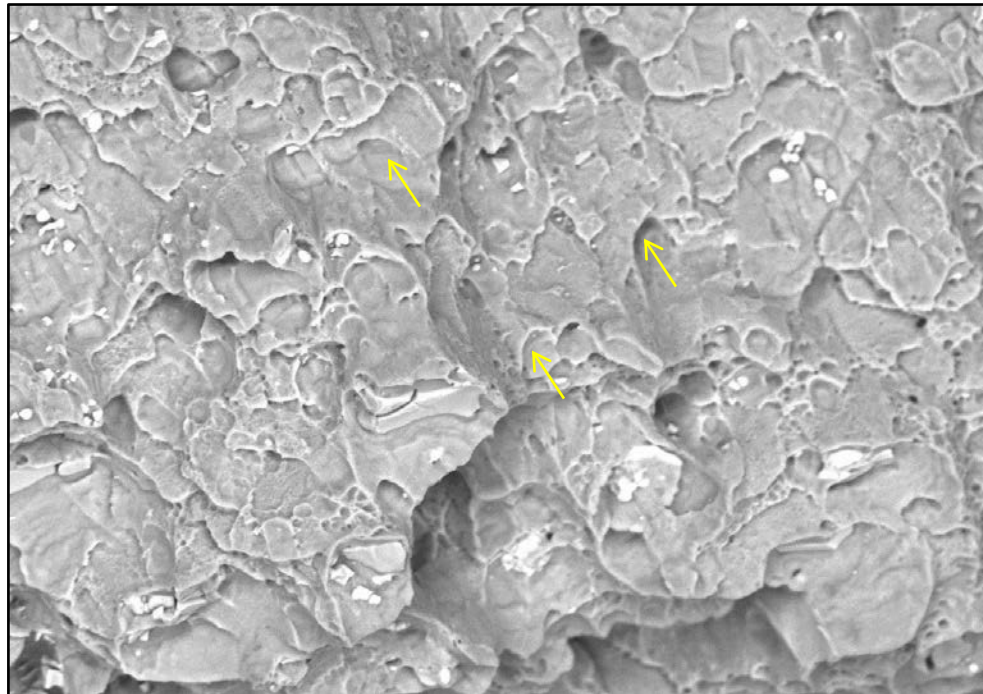
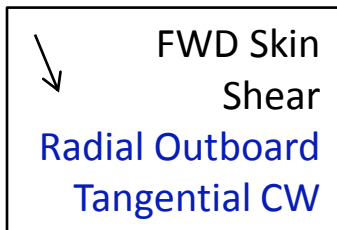
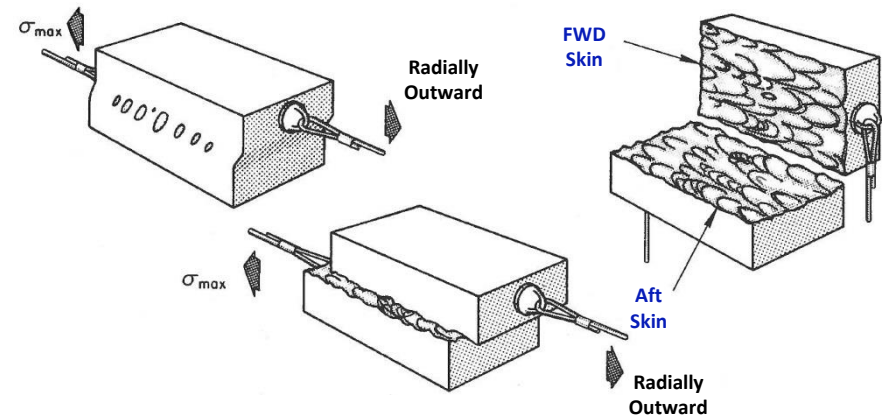
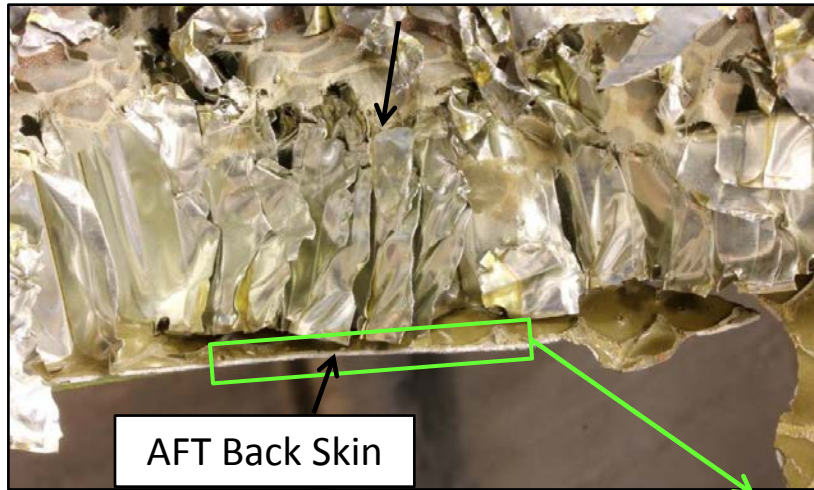
Area 7 – Position: 8:00 (Macro)



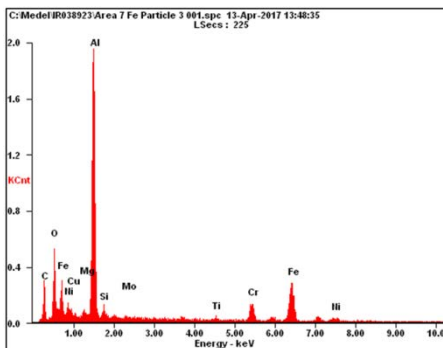
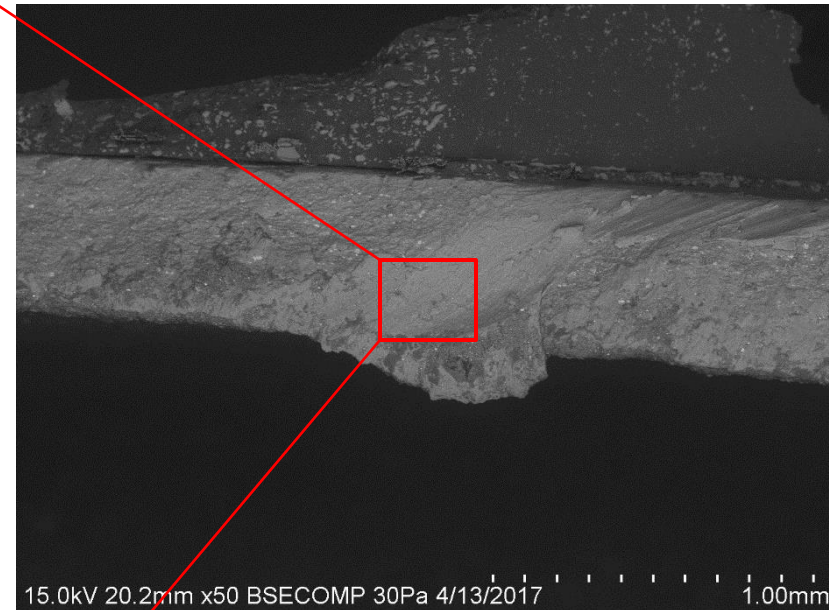
↙ FWD Skin
Shear
Tangential CW
Radial Outboard



Area 7 – Position: 8:00 (Micro)



Back Skin Microvoid Coalescence

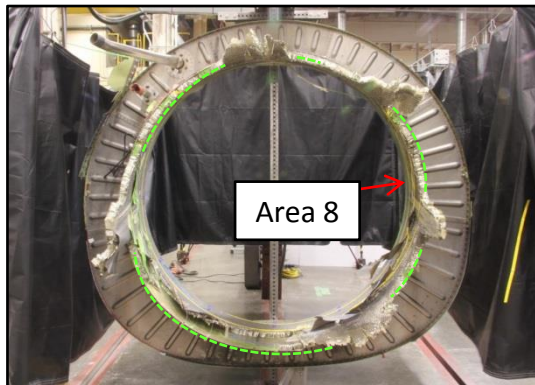
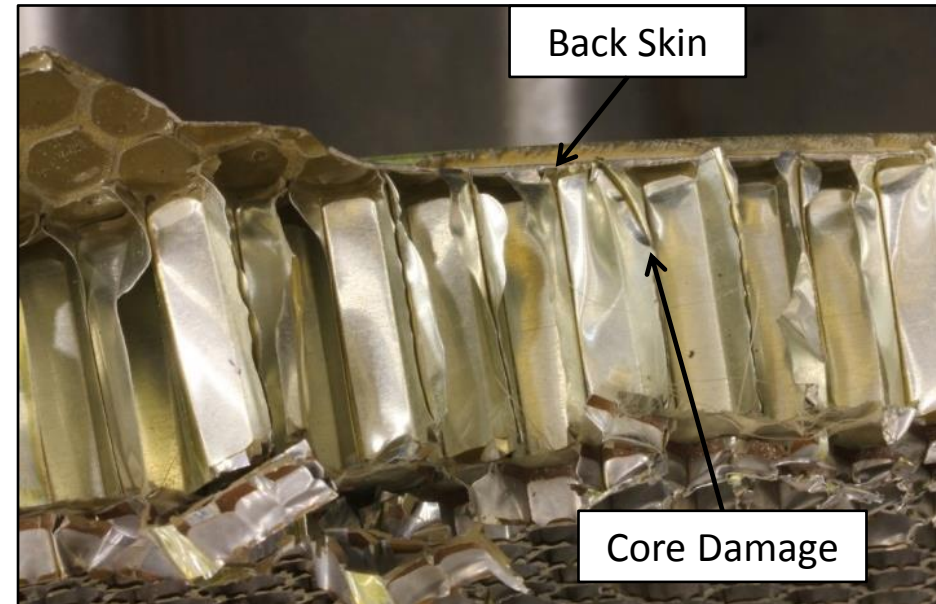
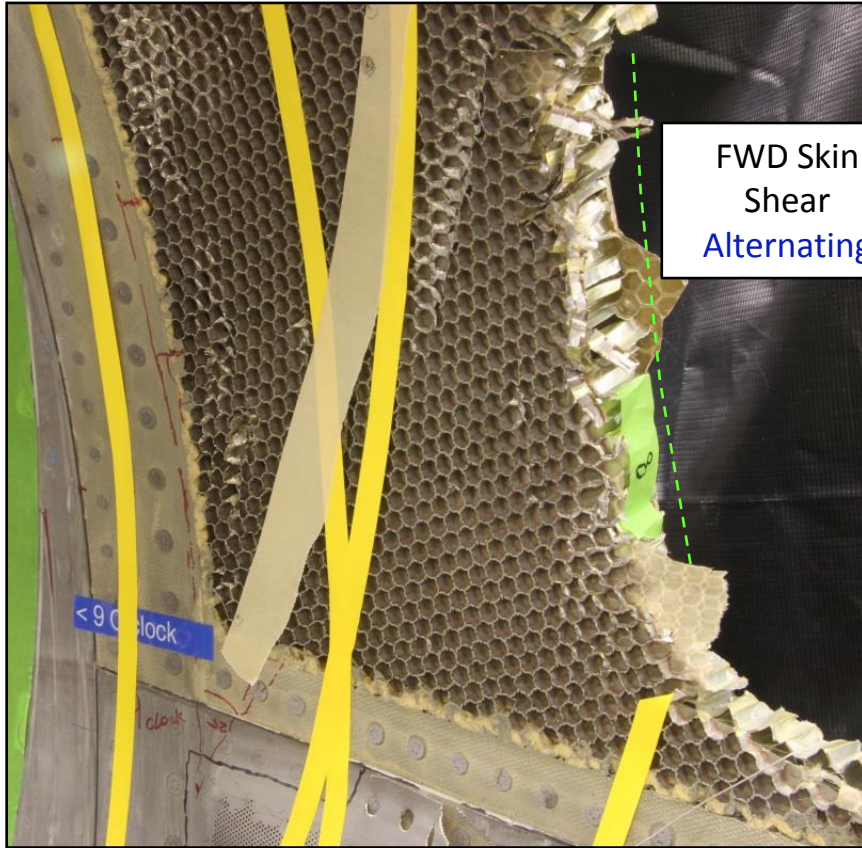


Element	Wt%	At%
CK	18.31	38.57
OK	09.17	14.49
CuL	01.85	00.74
MgK	00.60	00.62
AlK	27.19	25.50
SiK	01.23	01.11
MoL	00.67	00.18
TiK	00.96	00.51
CrK	07.54	03.67
FeK	28.20	12.77
NiK	04.28	01.84

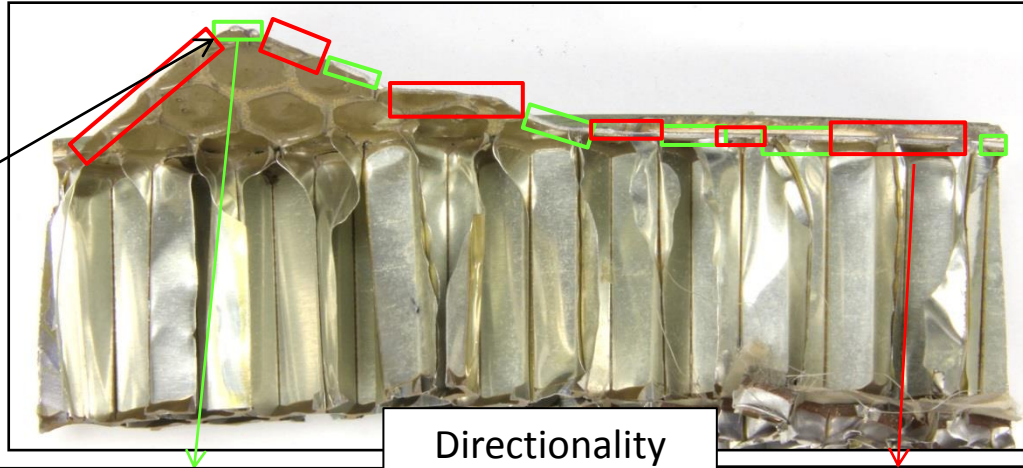


- Iron based Particle (Stainless Steel) Imbedded - Back Skin

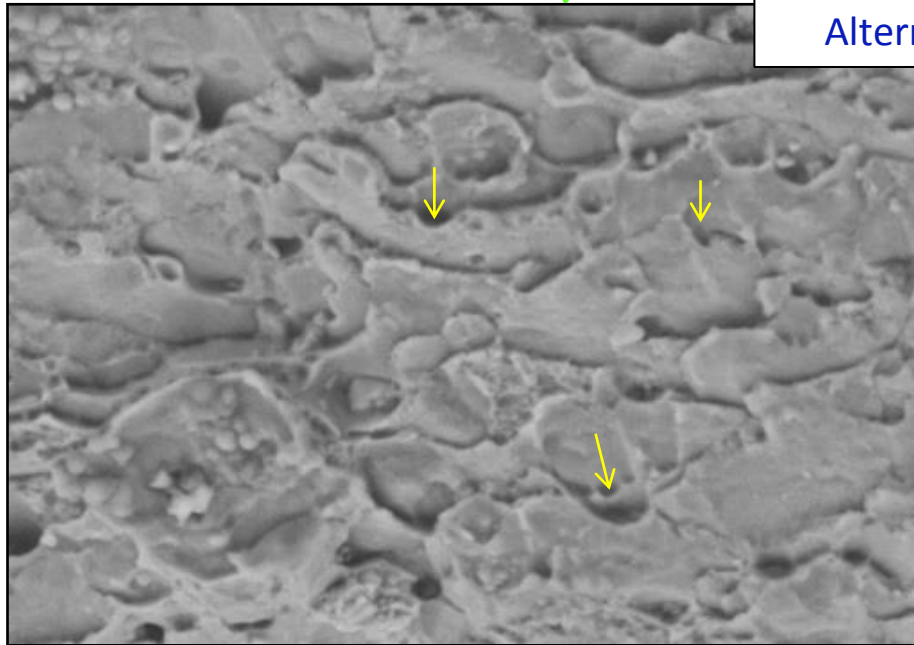
Area 8 – Position: 9:00 – 9:30 (Macro)



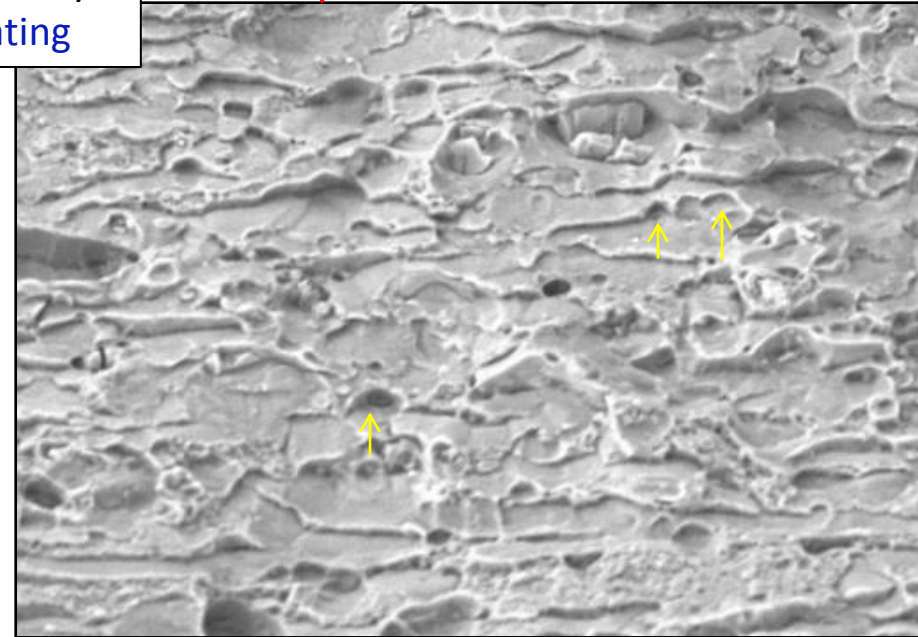
Ti Found



Directionality
Alternating

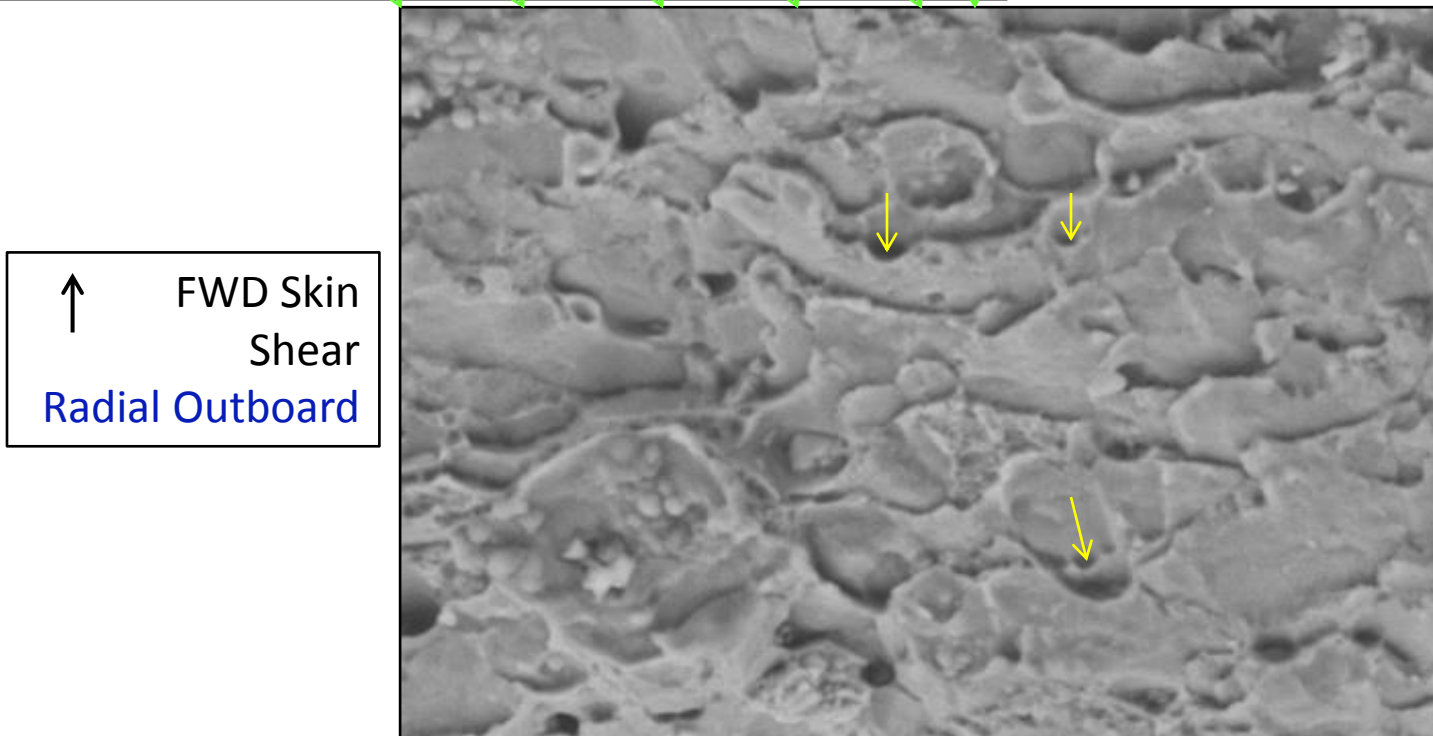
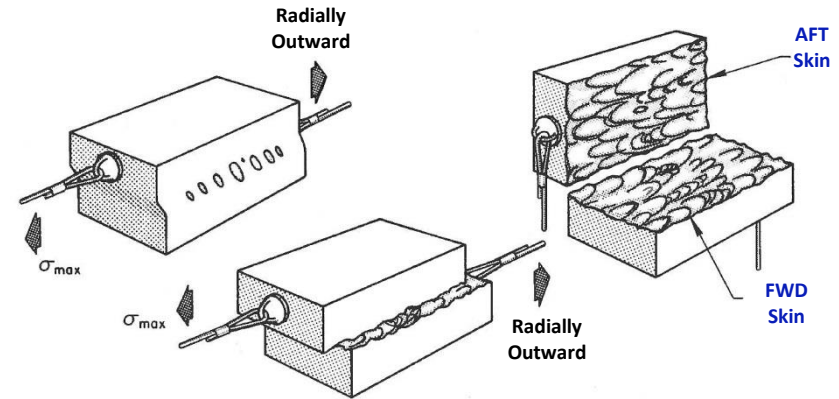
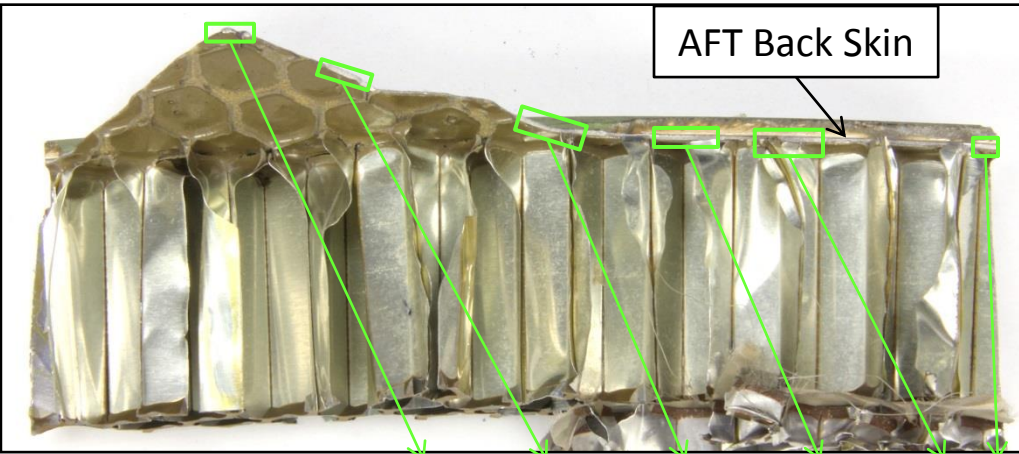


FWD Skin Shear
Radial Outboard



FWD Skin Shear
Radial Inboard

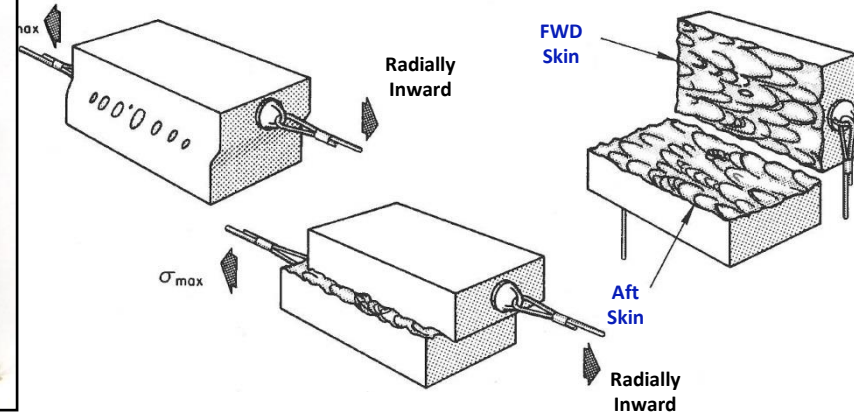
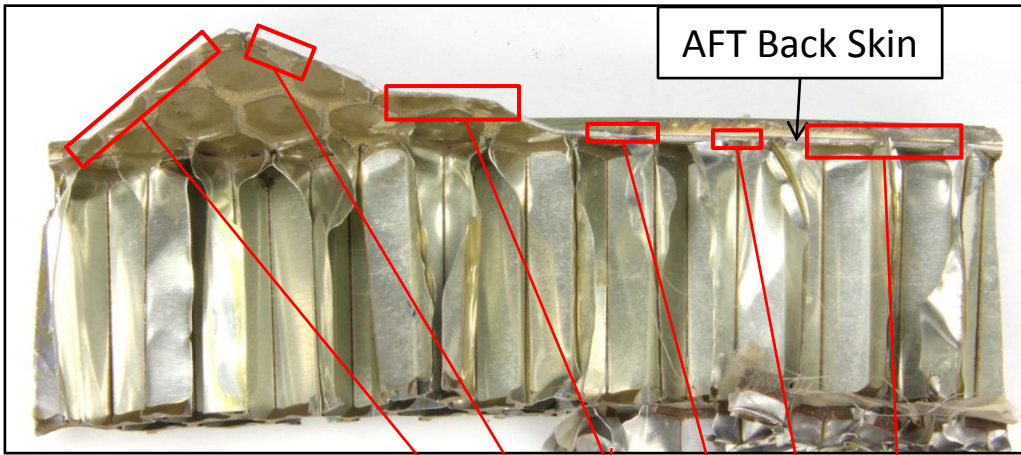
Area 8 – Position: 9:00 – 9:30 (Micro)



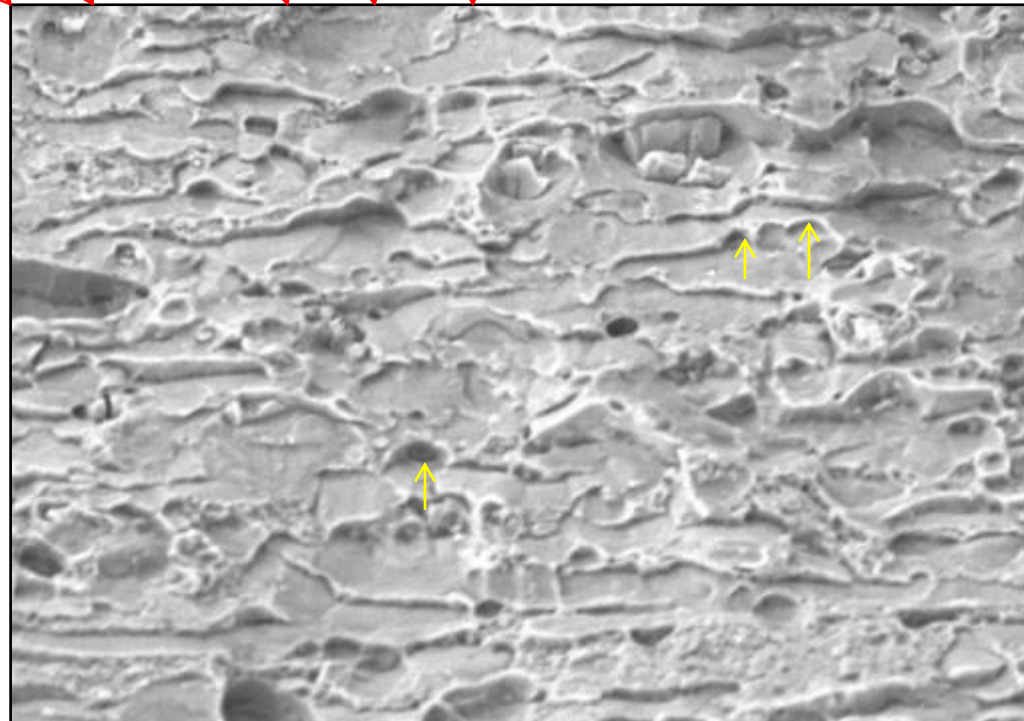
↑ FWD Skin
Shear
Radial Outboard

Back Skin Microvoid Coalescence

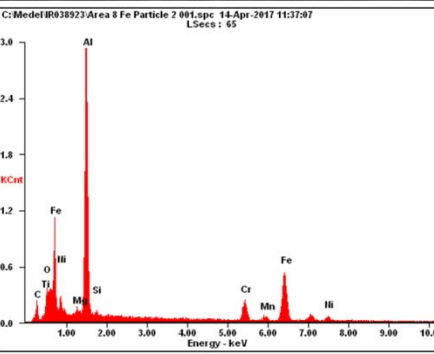
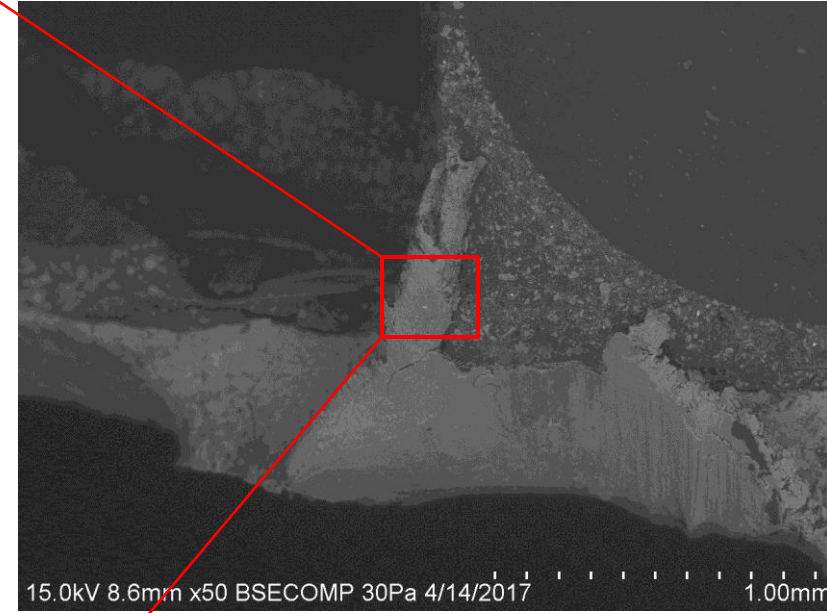
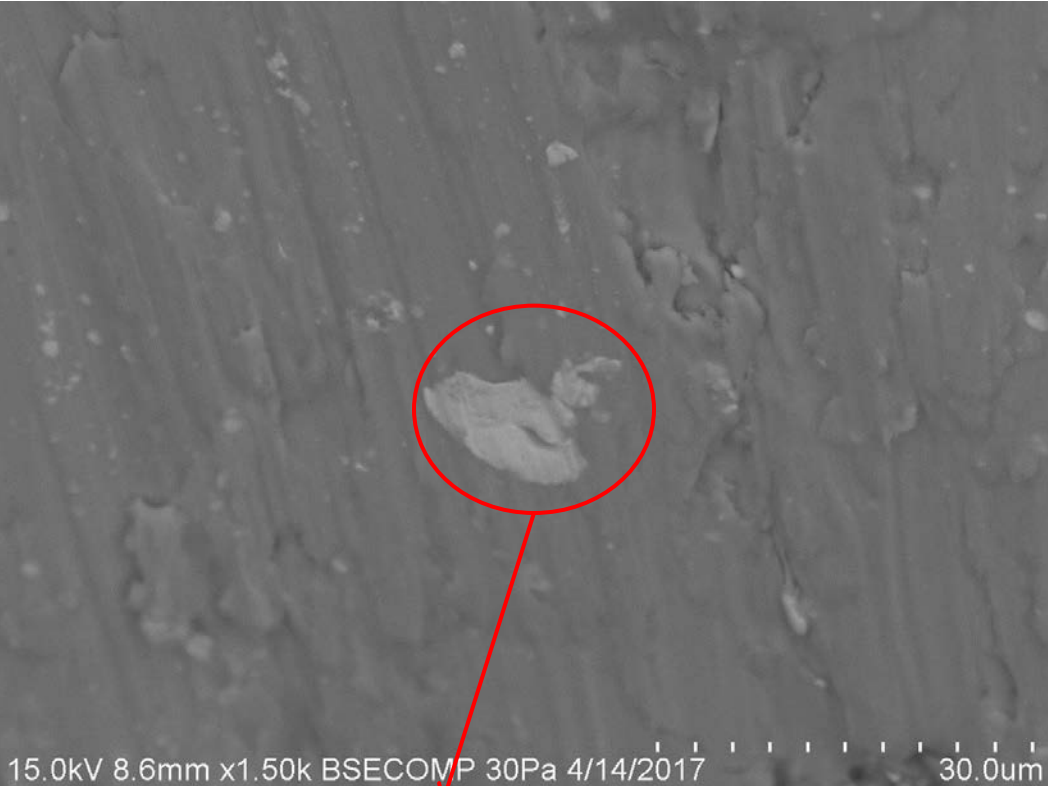
Area 8 – Position: 9:00 – 9:30 (Micro)



↓ FWD Skin
Shear
Radial Inboard



Back Skin Microvoid Coalescence

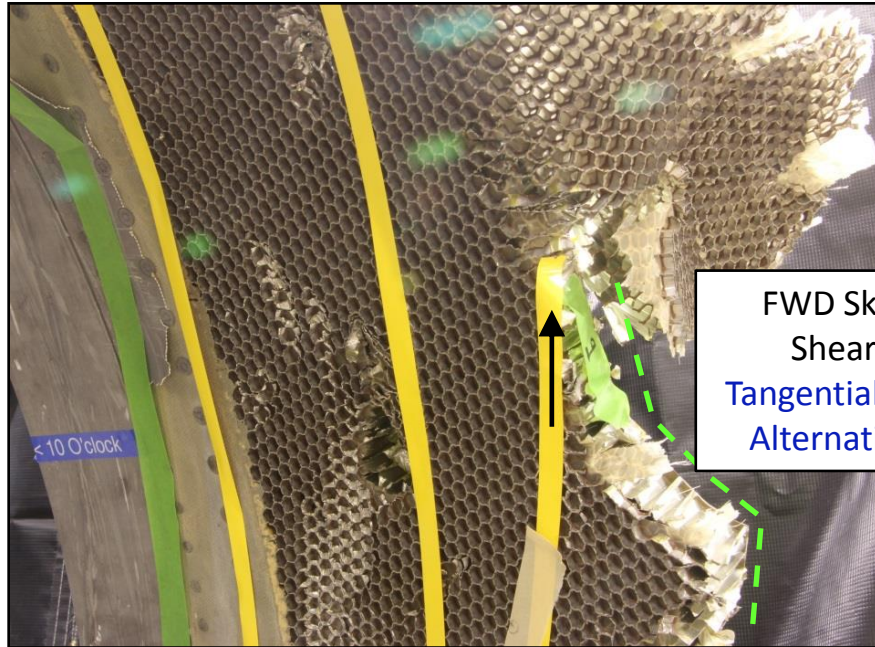


Element	Wt%	At%
CK	10.44	26.14
TiL	10.33	06.48
OK	06.09	11.46
MgK	00.48	00.60
AlK	27.23	30.36
SiK	00.54	00.58
CrK	07.74	04.48
MnK	01.09	00.60
FeK	31.67	17.06
NiK	04.40	02.25

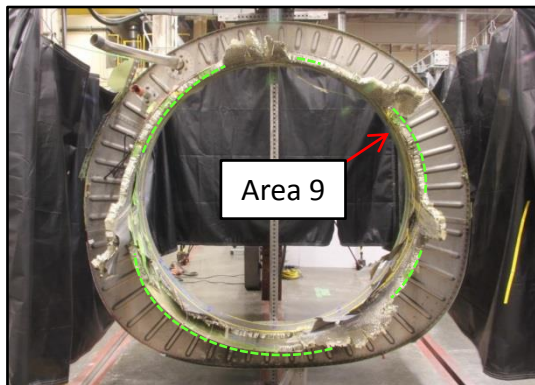
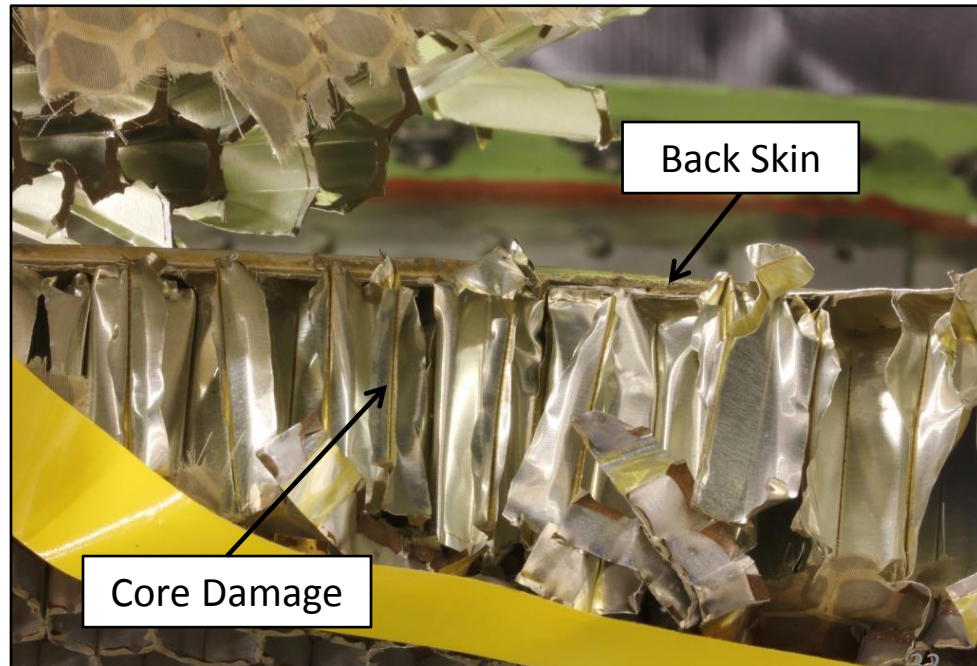


- **Iron based particle (Stainless Steel) and Ti Imbedded - Back Skin.**

Area 9 – Position: 10:00 (Macro)

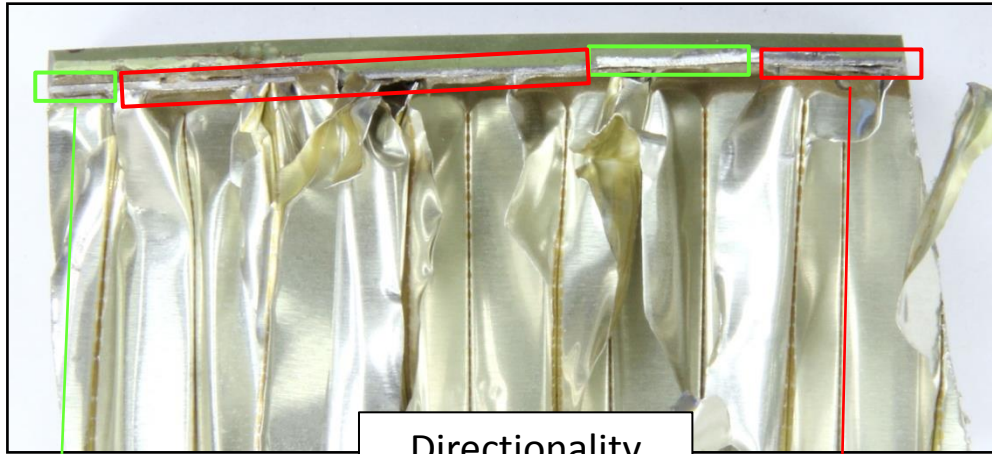


FWD Skin
Shear
Tangential CW
Alternating

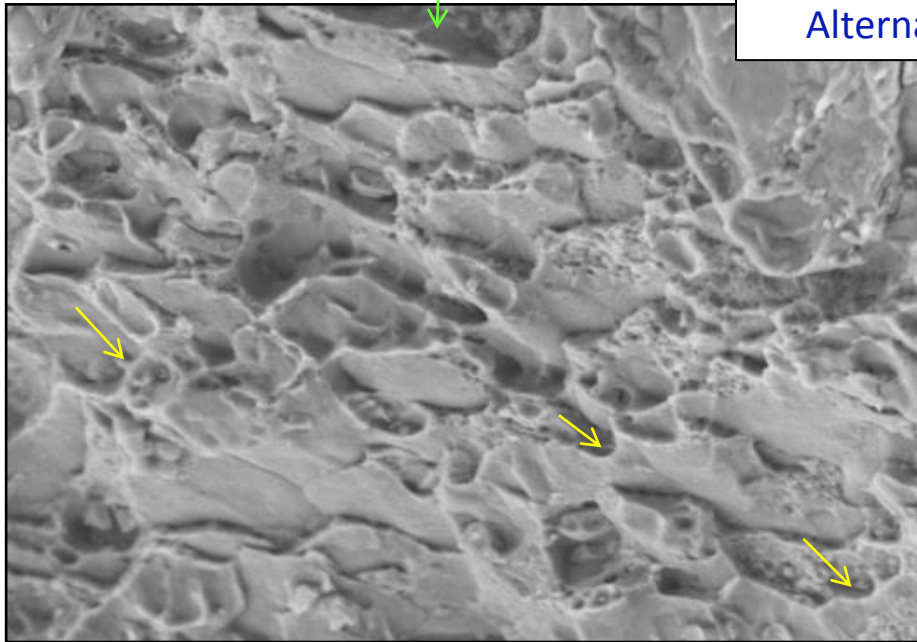


Area 9

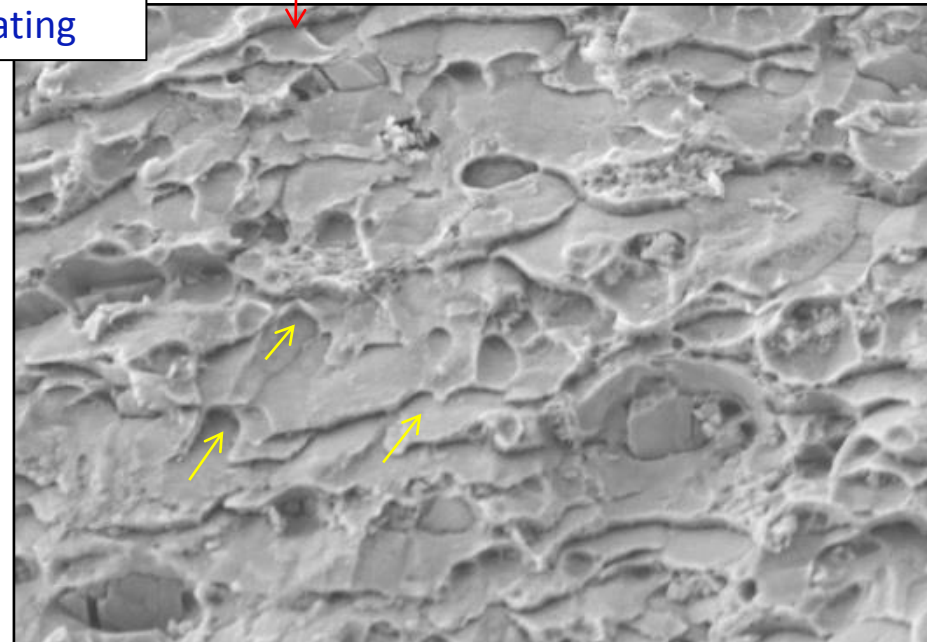
Area 9 – Position: 10:00 (Micro)



Directionality
Alternating



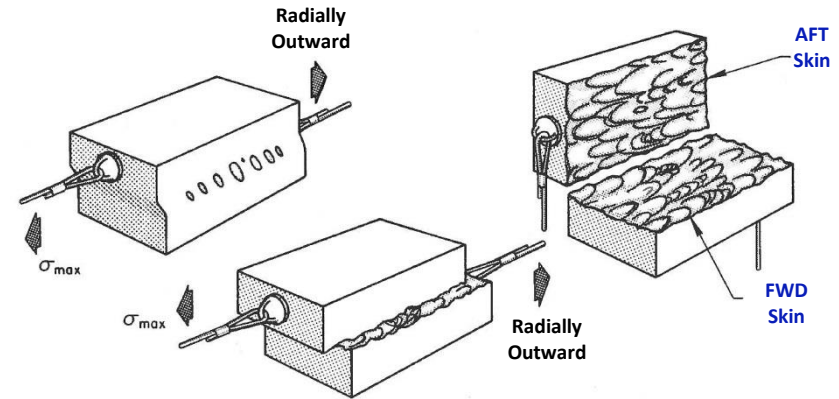
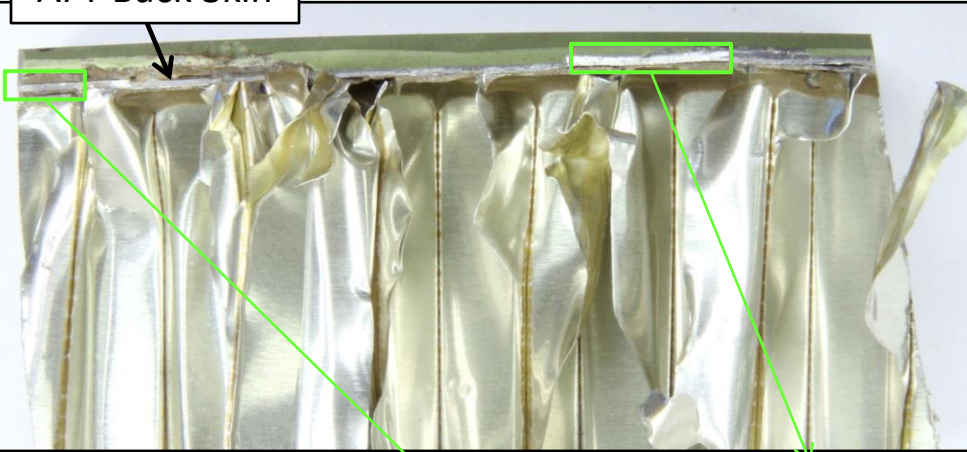
↖
FWD Skin Shear
Tangential CW Radial Outboard



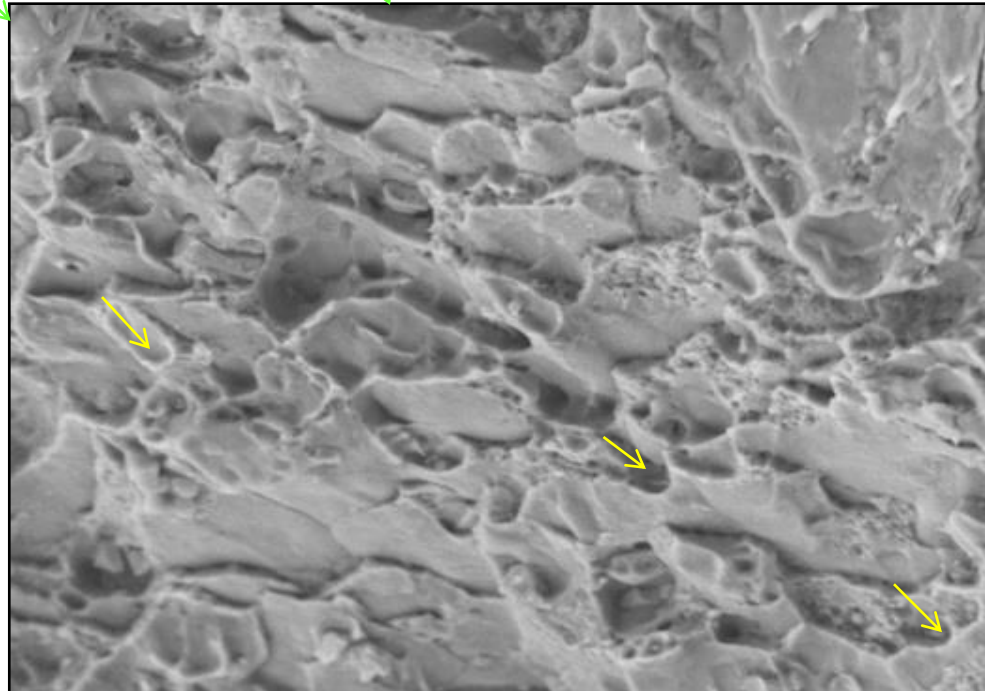
↙
FWD Skin Shear
Tangential CW Radial Inboard

Area 9 – Position: 10:00 (Micro)

AFT Back Skin



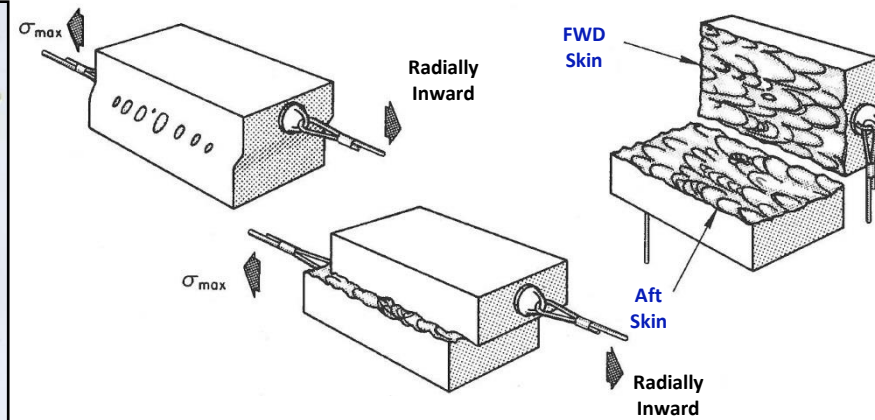
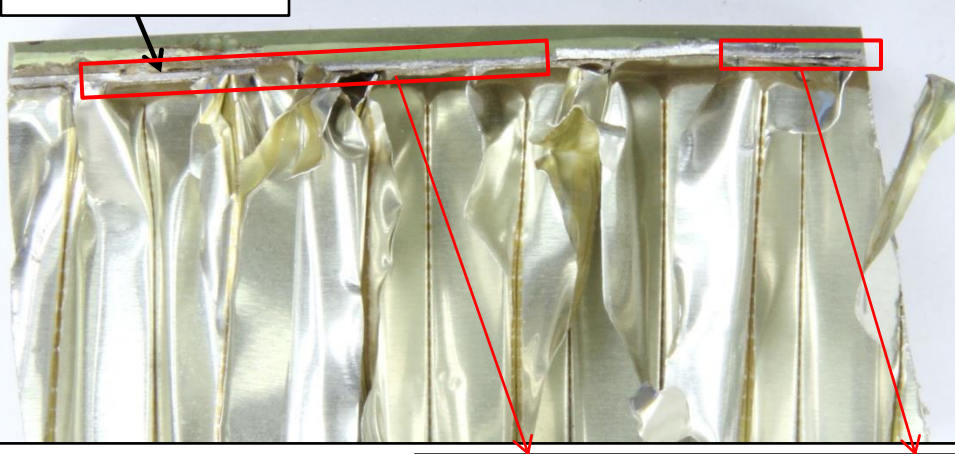
↖ FWD Skin
Shear
Tangential CW
Radial Outboard



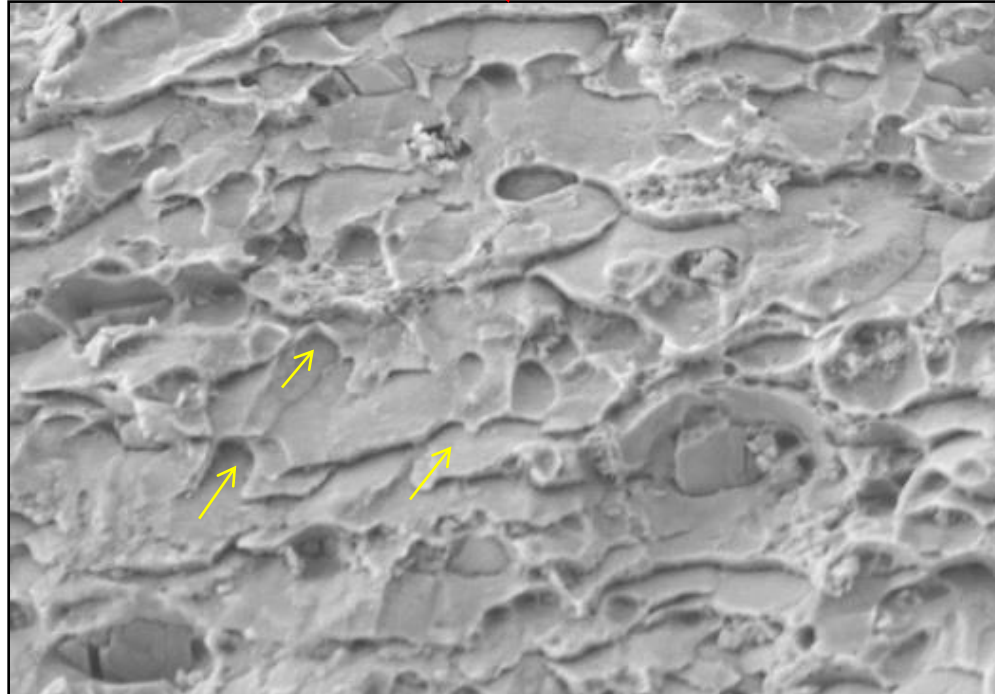
Back Skin Microvoid Coalescence

Area 9 – Position: 10:00 (Micro)

AFT Back Skin

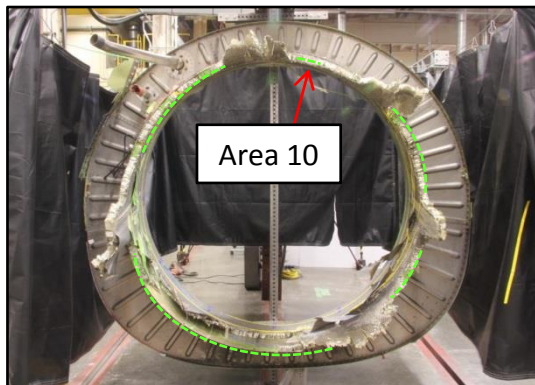
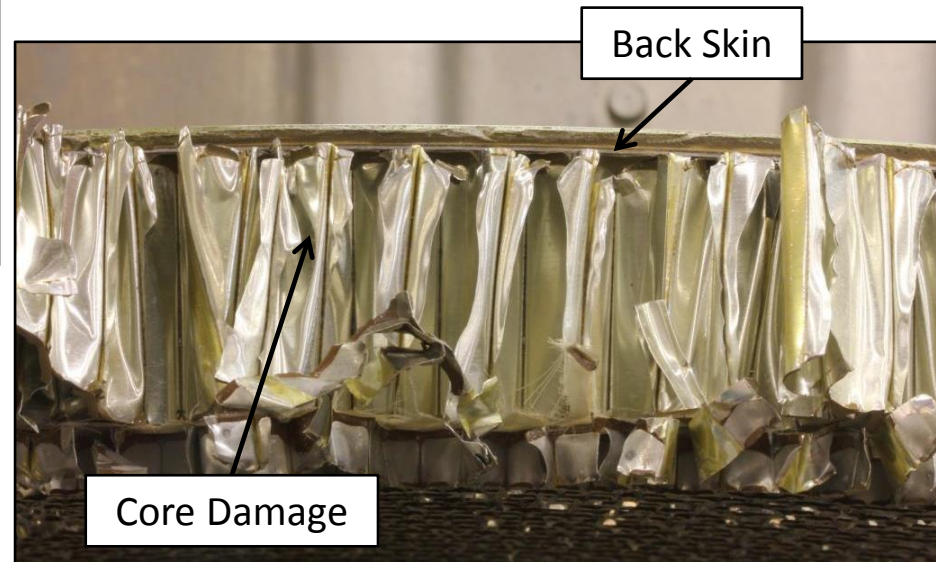
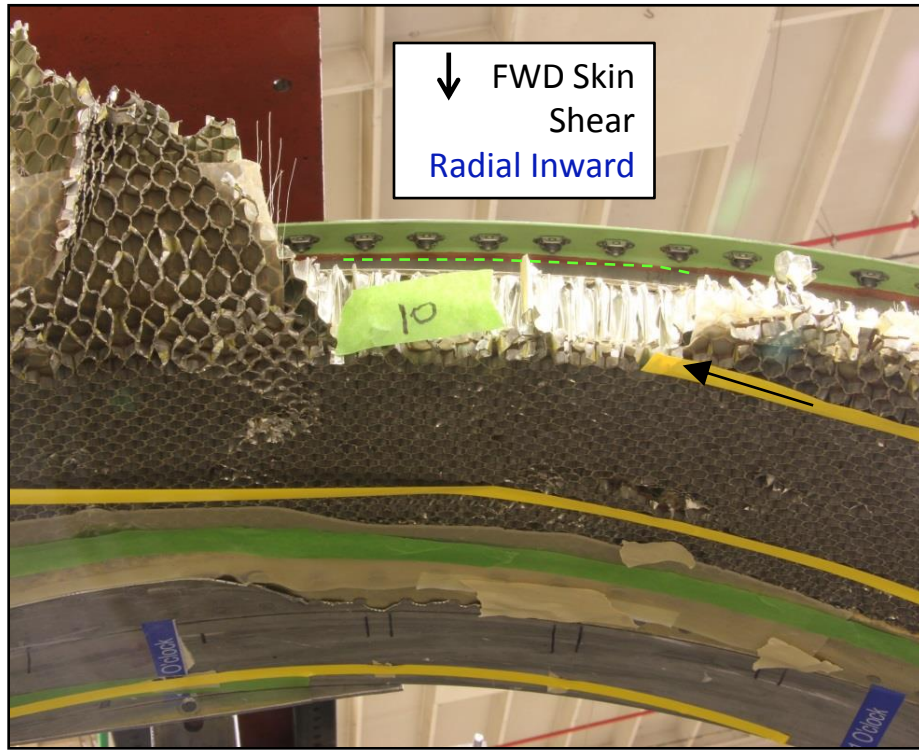


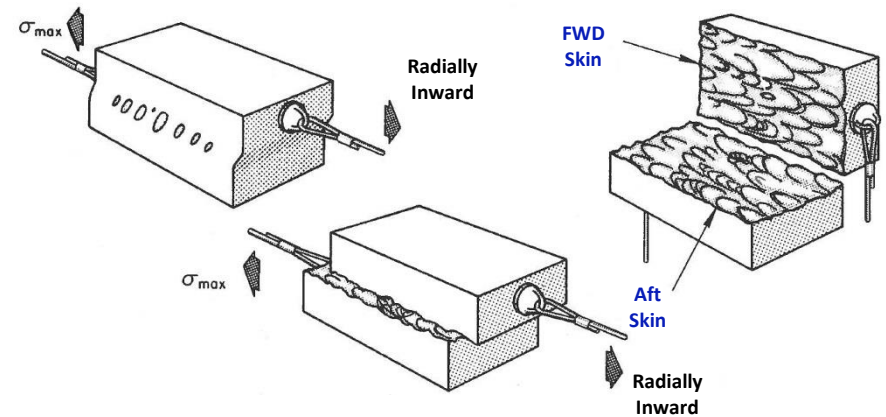
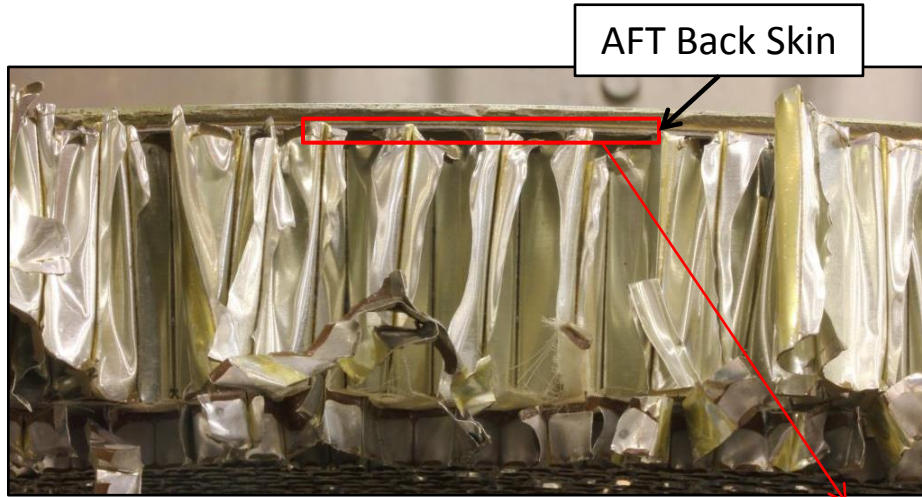
↙ FWD Skin
Shear
Tangential CW
Radial Inboard



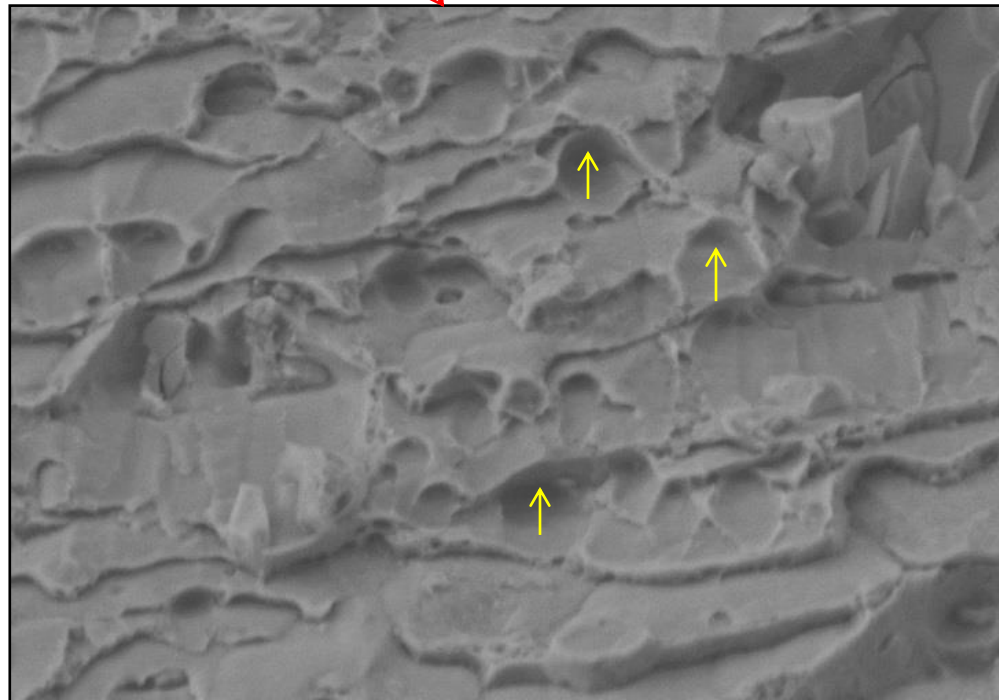
Back Skin Microvoid Coalescence

Area 10 – Position: 11:30 – 12:00 (Macro)



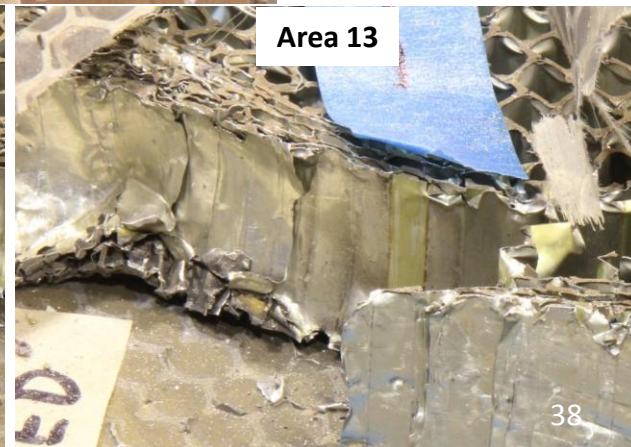
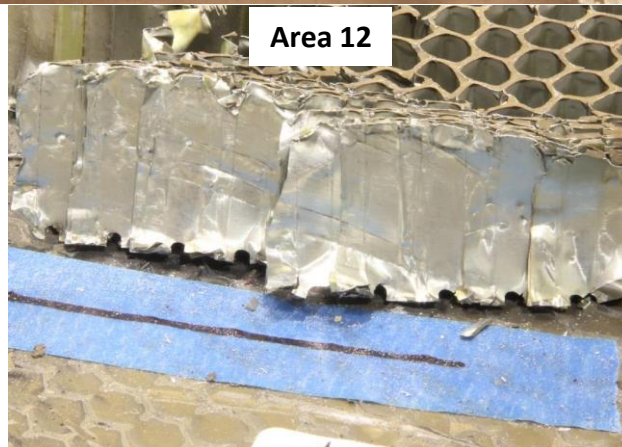
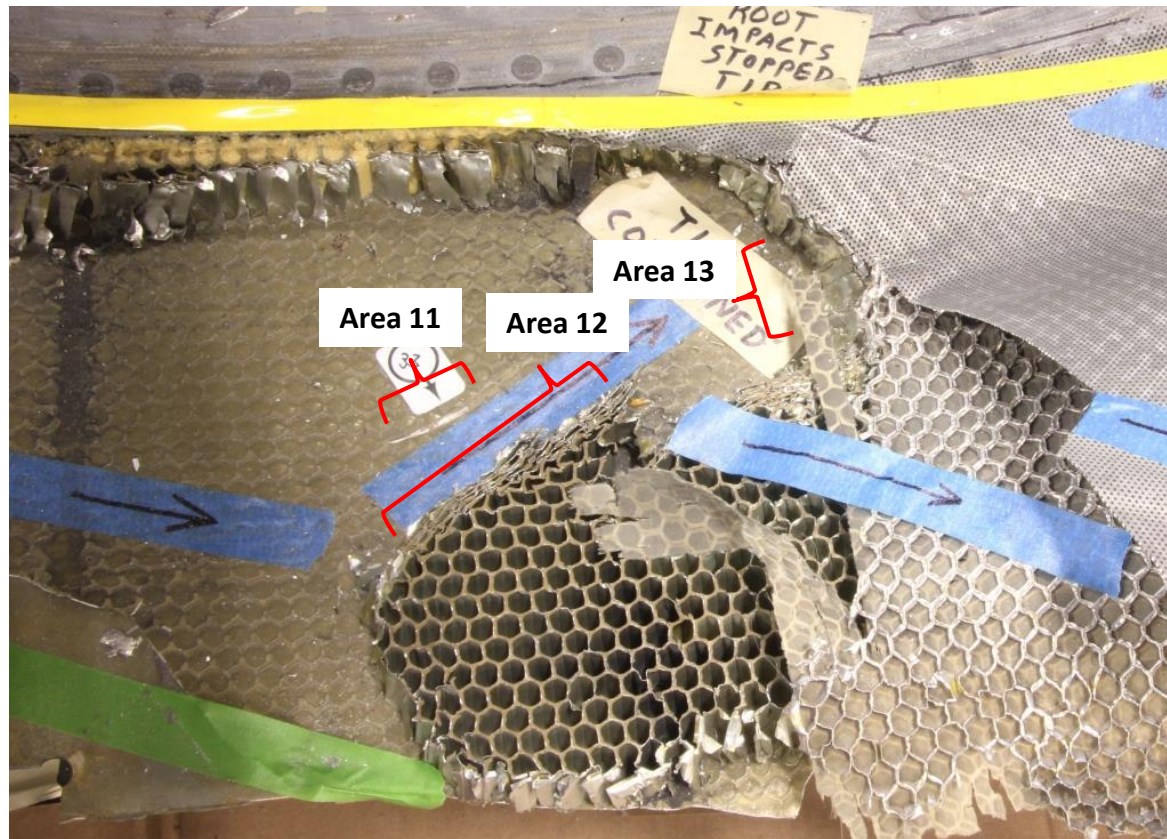


↓ FWD Skin
Shear
Radial Inward

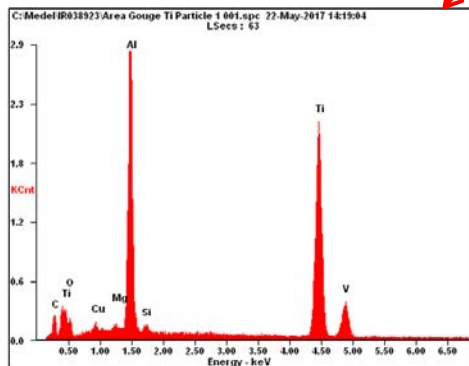
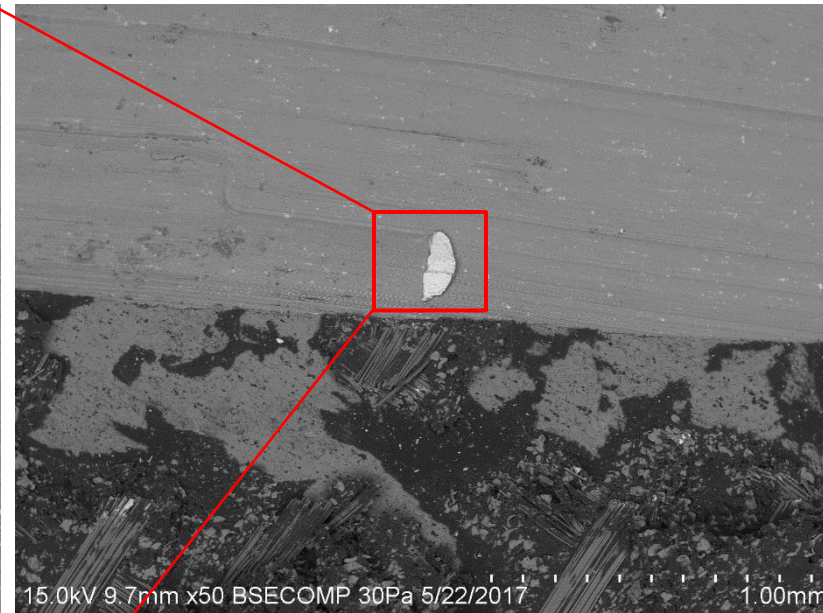
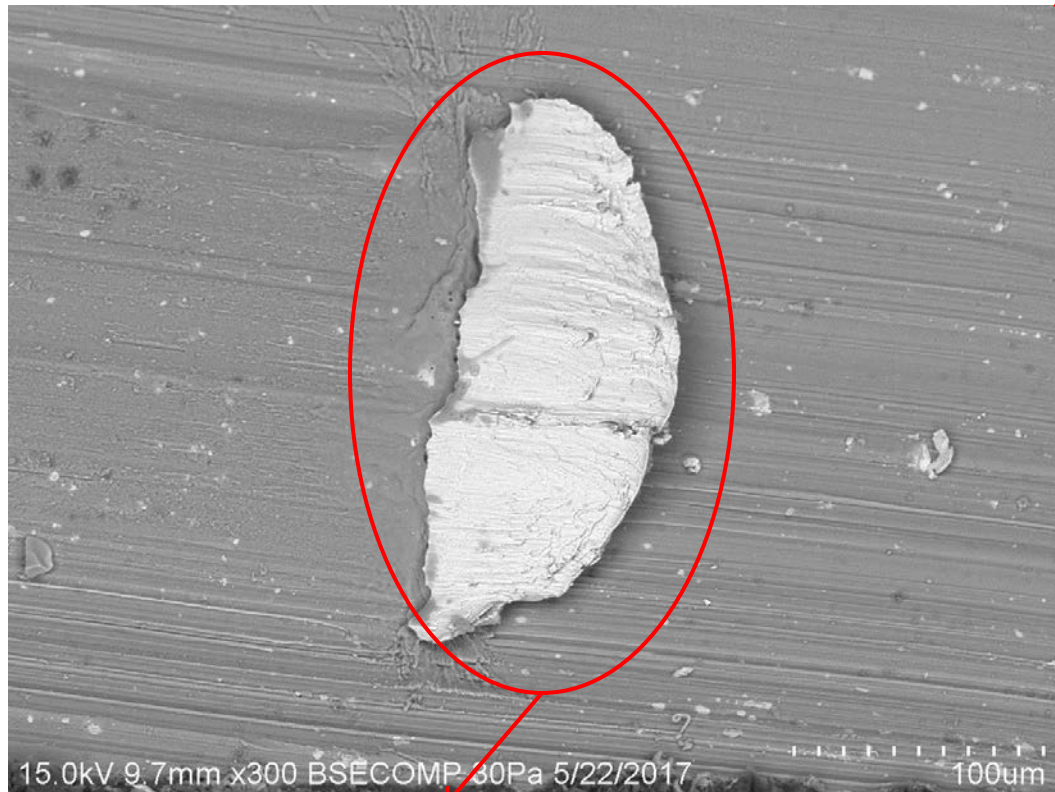


Back Skin Microvoid Coalescence

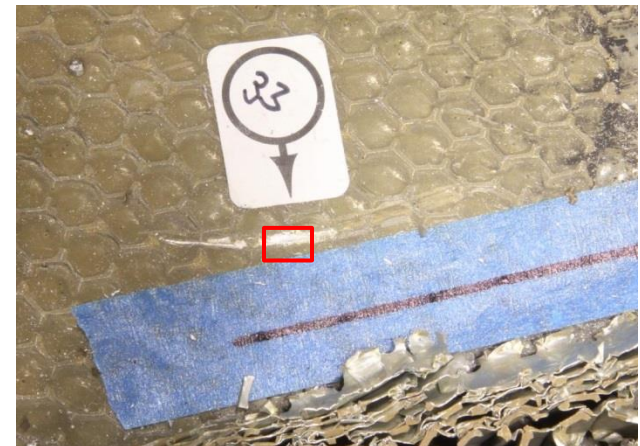
Areas 11-13 – Position: 6:00 – 6:30



Area 11 (Gouge) – Position: 6:00 – 6:30

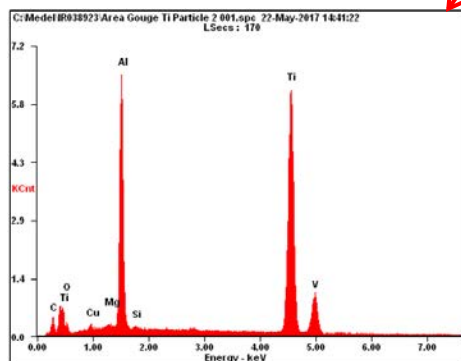
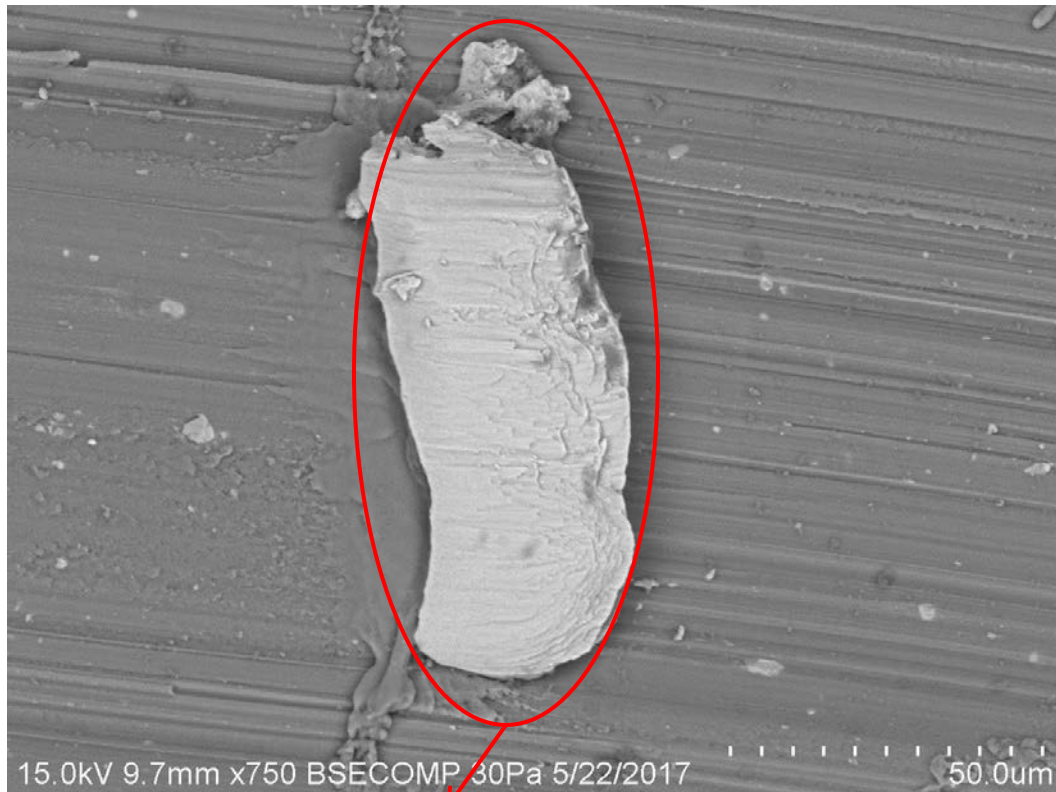


Element	Wt%	At%
CK	11.02	26.59
OK	05.91	10.71
CuL	01.86	00.85
MgK	00.51	00.61
AlK	25.83	27.76
SiK	00.77	00.79
TiK	52.17	31.58
VK	01.94	01.11

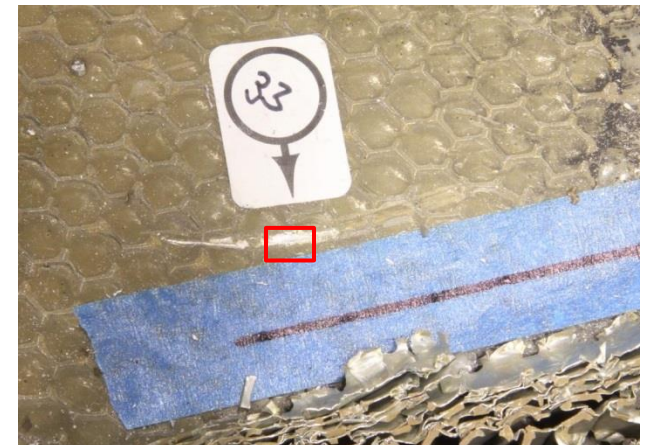


- **Titanium Particle Imbedded - Back Skin**

Area 11 (Gouge) – Position: 6:00 – 6:30

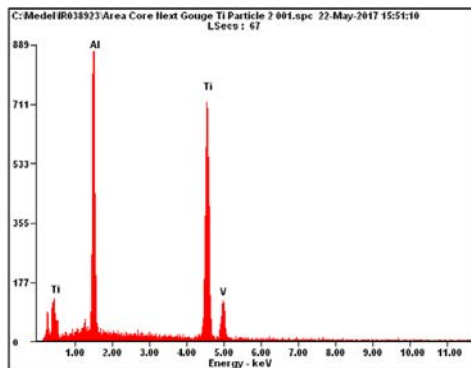
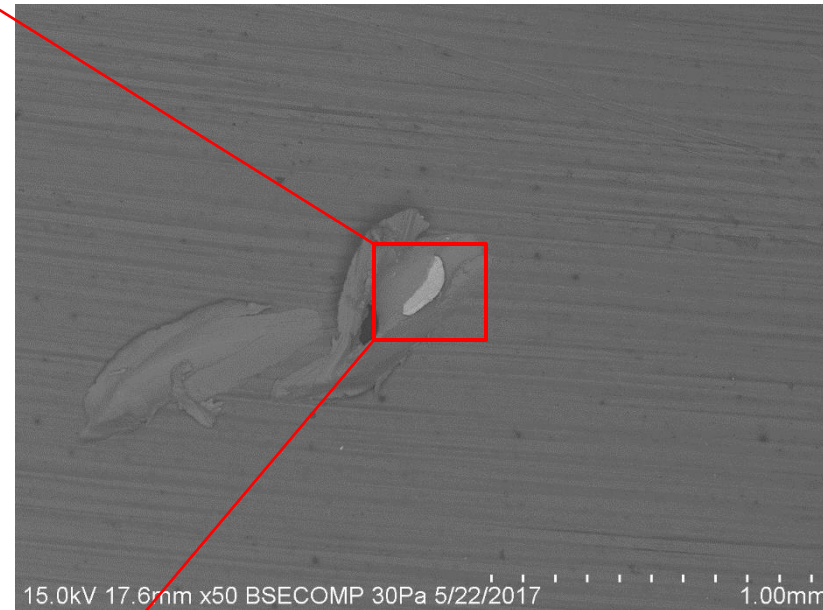
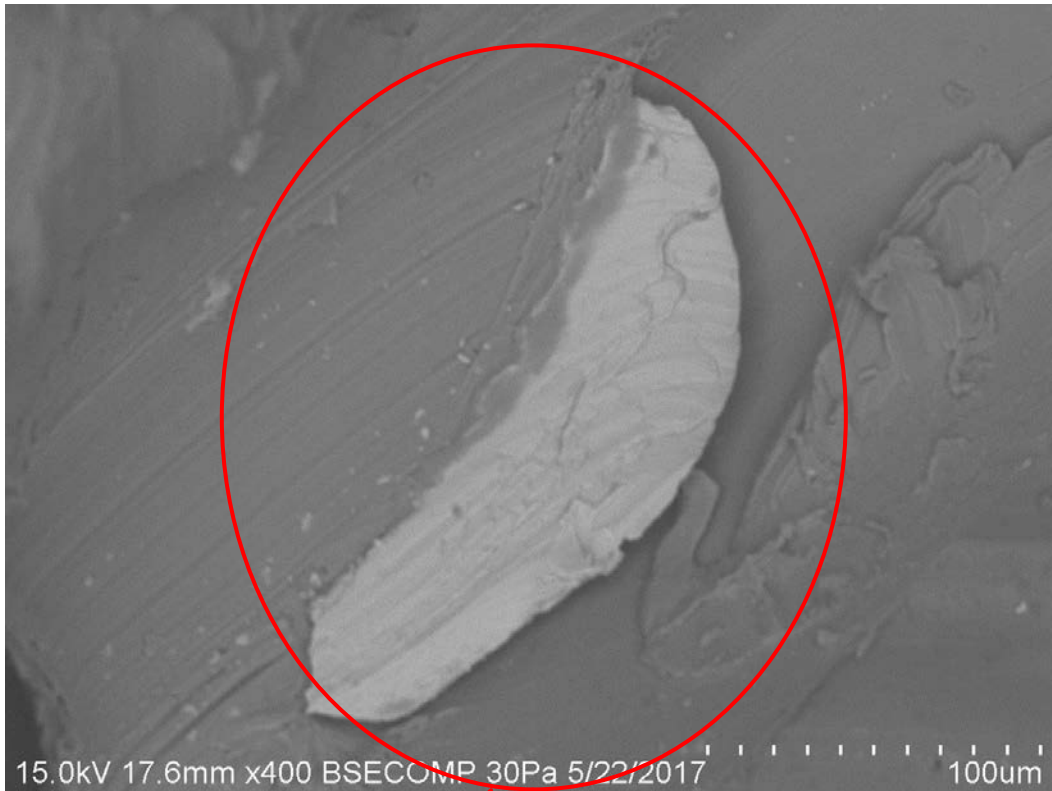


Element	Wt%	At%
CK	07.75	21.15
OK	03.26	06.68
CuL	01.20	00.62
MgK	00.38	00.51
AlK	21.05	25.57
SiK	00.27	00.32
TiK	64.33	44.02
VK	01.76	01.13



• Titanium Particle Imbedded - Back Skin

Area 12 (Core next to Gouge) – Position: 6:00 – 6:30

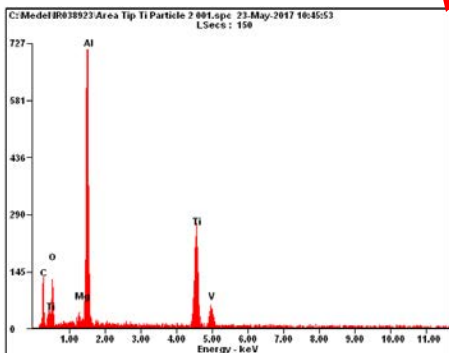
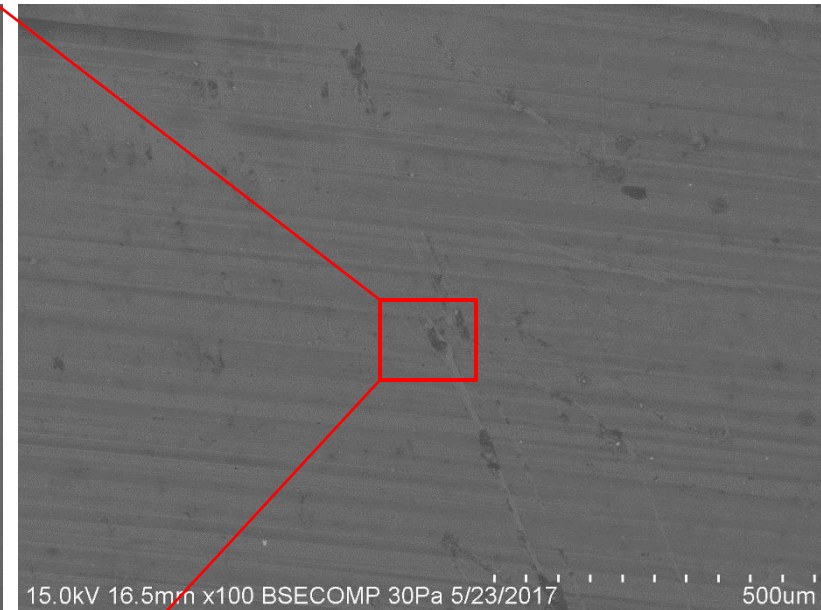
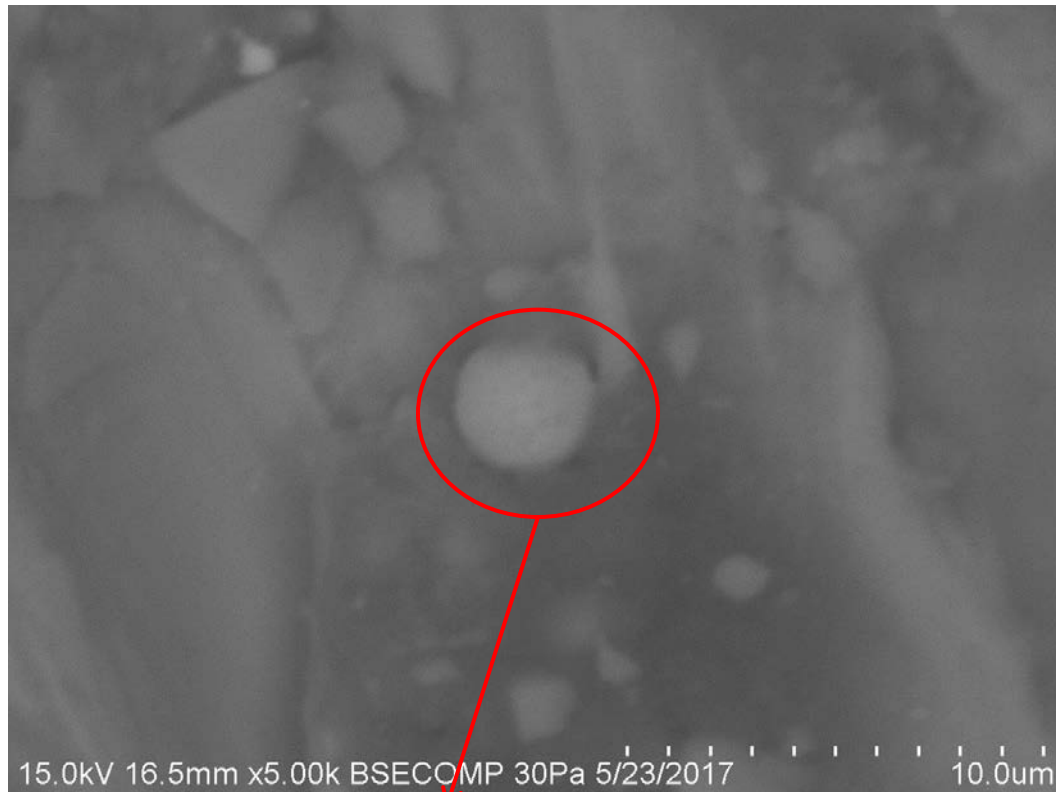


Element	Wt%	At%
AlK	29.61	42.80
TiK	68.16	55.49
VK	02.23	01.71

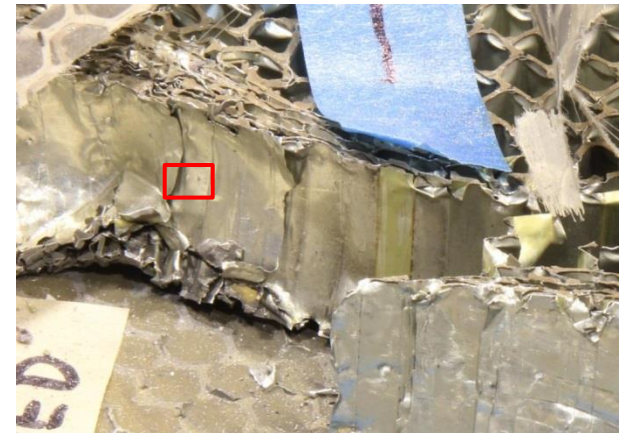


• Titanium Particle - Al Core

Area 13 (Contained Tip Area) – Position: 6:00 – 6:30



Element	Wt%	At%
CK	22.96	41.40
OK	15.49	20.97
MgK	00.74	00.66
AlK	27.24	21.87
TiK	30.97	14.00
VK	02.60	01.10



- Titanium based particle impacted and imbedded in Al core.

End