

# Joby Electric Aircraft Control Surface inspection approach



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# Introduction

- Jos Huibers, more than 20 years UT L3 (ASNT and NAS410) at Fokker
- Fokker was founded by Anthony Fokker in 1919, and has more than 3500 employees in Netherlands, Mexico, Romania and Turkey.
- GKN Fokker Hoogeveen, in the north of the Netherlands.
- GKN Fokker Hoogeveen has more than 1000 employees
- Our R&D center is now renamed as a GKN Global Technology Centre, specializing mainly in thermoplastic composites and filament winding



# GKN Fokker Hoogeveen figures and NDI

- GKN Fokker Hoogeveen is the Fokker composites production site, using both thermoset (epoxy/BMI) and thermoplastic composites. Also a machine shop for high speed machining of Aluminium and Titanium (thin walled)
- Large Hoogeveen programs are F35, Apache, Gulfstream, Patriot missiles

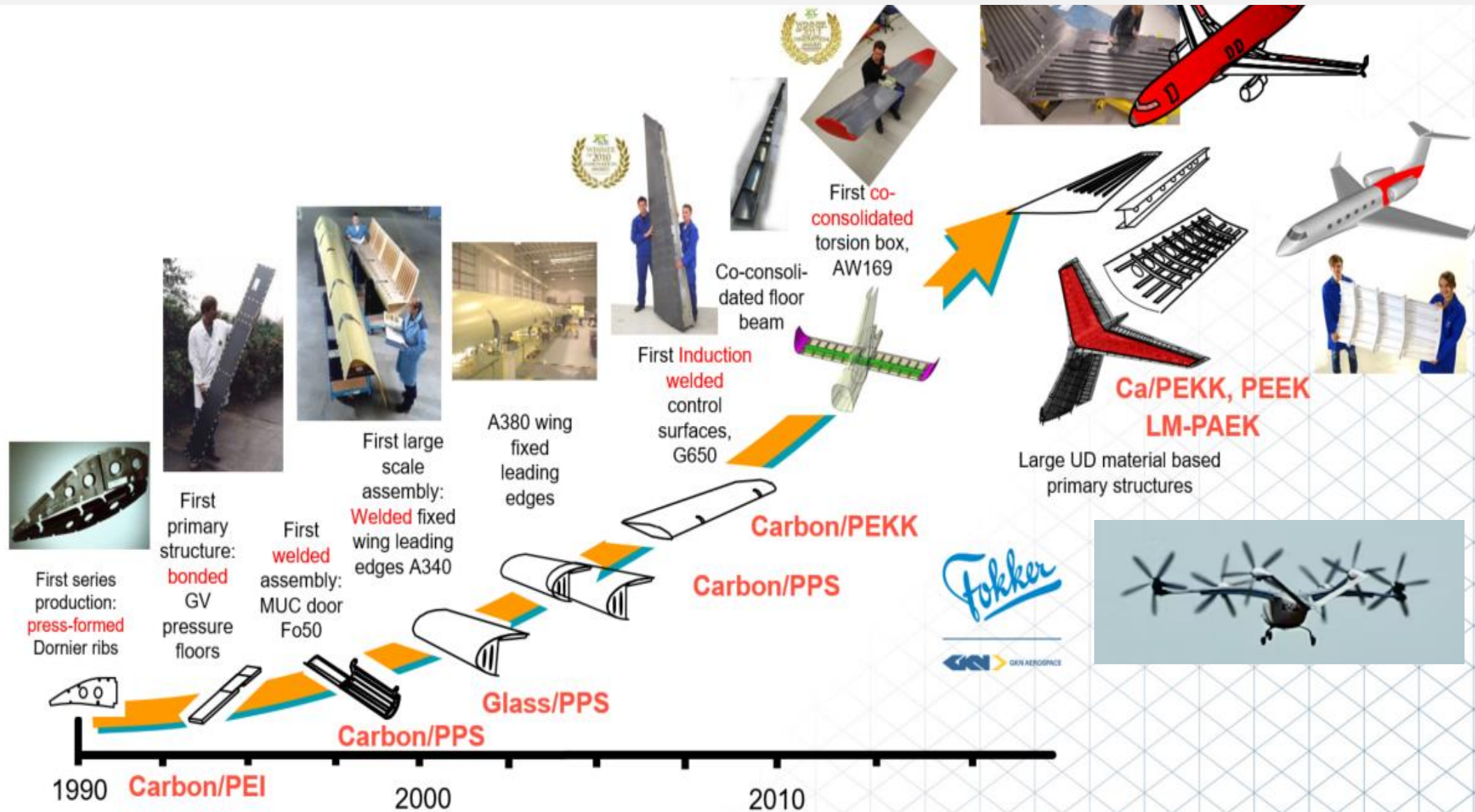
## NDI department (UT/CT)

- 3 C-scans (8x2x2 meter)
- 1 immersion tank (6x1x1 meter)
- CT scan (450 kV, 4x1.5 meter)
- 15 UT L2 and 2 UT L3
- 2 RT L2 and 1 RT L3



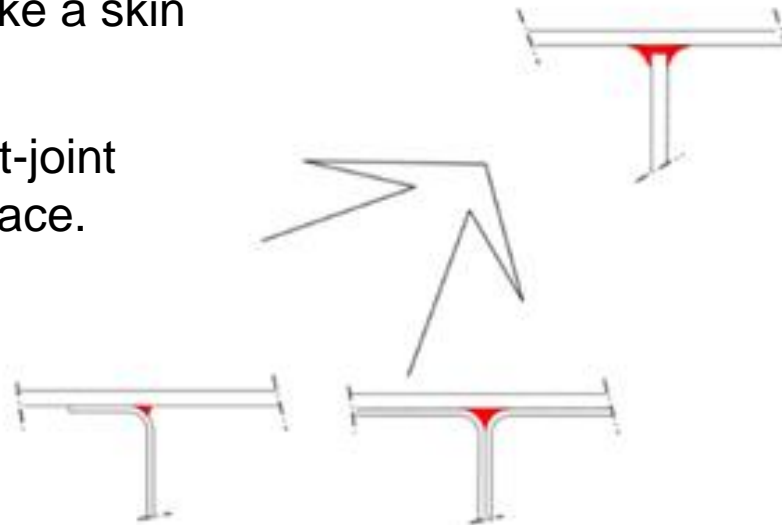


# Thermoplastic production current and past



# Butt-Joint technology

- Years ago we started with the TAPAS project.
- TAPAS stands for Thermoplastic Affordable Primary Aircraft Structure, and introduced UD fibre placement and the Butt-Joint technology.
- Butt-joint technology was developed to investigate the possibility to make a skin and rib/spar in one step.
- First series product with the butt-joint technology are the Control Surface.



Conventional joints



butt joint concept

# What is Joby

- Joby is a electric aircraft, one pilot and four riders
- Powered by six electric motors, the aircraft takes off and lands vertically
- GKN Fokker is responsible for the design, certification and production of the control surfaces
- One aircraft has 10 control surfaces





# Control Surfaces



# Butt-joint qualification

- 2 qualifications are required: Engineering Qualification and Production Qualification
- Engineering Qualification results in Fokker specification FP and TH update wrt butt joint inspection method
- Production Qualification results in start Production
- The Engineering Qualification should be finished mid 2024.
- The engineering qualification contains the following steps:
  - Butt-Joint defects and means of detection overview
  - Butt-Joint allowable – Selection of artificial defects
  - Inspection of butt-joint configurations by means of PAUT-PE



# Butt-Joint defects and means of detection overview

- An overview is made of possible BJ defects in Control Surfaces and how these defects are to be found by inspection methods and covered by KDF's in design.
- It lists the possible part defects, the probability of occurrence, check during the first part tear down (FPQ), process control, visual inspection, ultrasonic inspection, Knock Down Factor (KDF) in design-allowable and KDF in design – Barely Visible Impact Damage (BVID)
- Possible defects are listed as:
  - Incident with yet unknown cause → voids
  - Tool-part process effect → surface porosity/cracks, voids, delamination, waviness
  - FOD/contamination incident → FOD (tape), voids, porosity
  - Impact damage incident → cracks in filler due to tool release or drop impact
  - Forgotten filler incident → deformed surface
- FOD between filler and skin and large voids need to be detected by PA

## Butt-Joint allowable

- To select a representative artificial defect in butt joint allowable samples, tests have been performed to understand and measure the effect of the artificial defect on first crack of the butt joint at the critical condition (-55°C).  
Samples with voids are tested to check if the artificial defect covers just detectable global voids with regard to average strength and B-value.
- 61 butt joint blade stringers were made, 343 samples in total
- From the results it is concluded that a folded 7mm wide upilex foil can be used as artificial defect in butt joint allowable samples.
- Based on this defect, allowables for peel and web bending are derived that can be used until the final FAA allowable test program has been completed.
- The artificial defect size versus allowable sample length is used to develop NDI reject criteria.

# Butt-Joint allowable – PA and CT inspection

- All samples are inspected with PA and the void samples are also inspected with CT (not in-house as we don't have a micro CT)

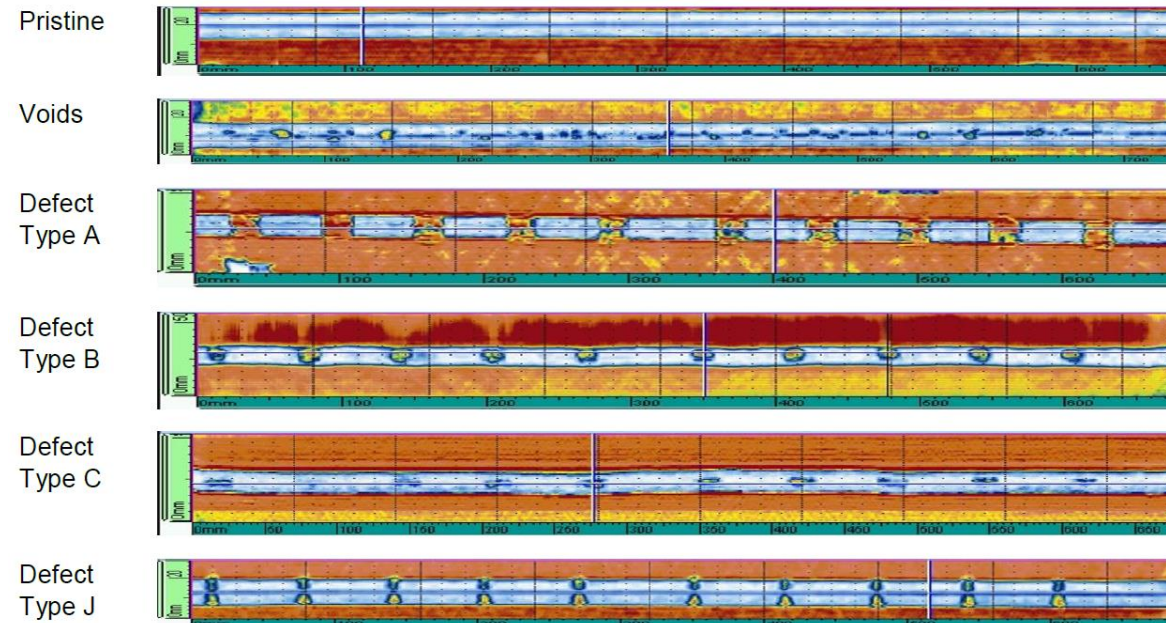


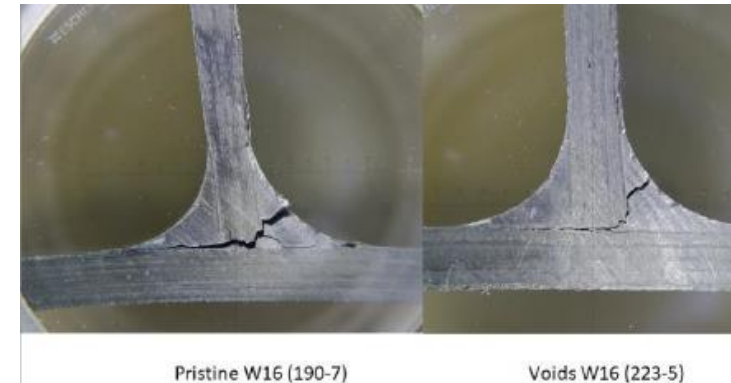
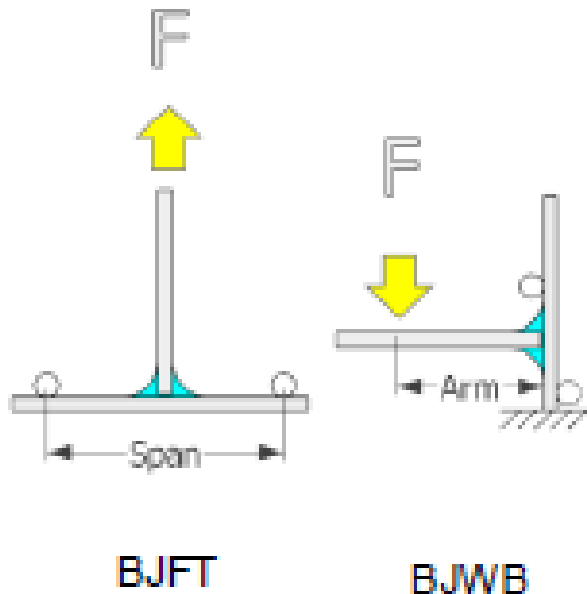
Figure 5 – Typical PA scans of stringers



# Butt-Joint allowable – Destructive tests and KDF

Artificial defect for BJ allowable sample

- Type J defect is selected as artificial defect for BJ allowable samples.
- For first failure, the type J defect is slightly worse than the samples with voids, so it can be used in the BJ allowable samples as representative for global voids.



## Butt-Joint allowable – NDI reject criteria

### NDI reject criterion for butt joint

- The NDI rejection criteria for butt-joints will be included in the Fokker FP technical handbook
- The minimum detectable defect size is 3 x 2 mm
- The rejectable defect size is 7x14 mm

# Butt-Joint allowable – NDI reject criterion

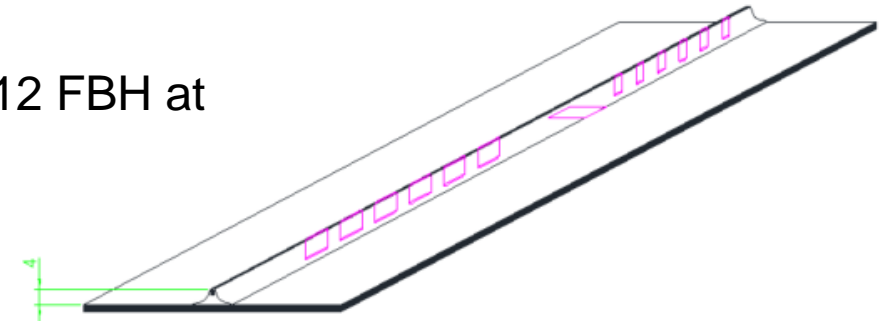
- The Inspection Date Sheet (part of the drawing) is updated
- The NDI inspector needs this information to inspect and evaluate the part.
- The butt-joint NDI reject criteria from the previous slide will be part of the updated FP

INSPECTION DATA SHEET FIBRE REINFORCED COMPOSITES									
AREA		GRADING LEVEL FP				STRUCTURAL CLASS 2			
		A	B	C	D				
F01	1		X						
F02	2	NOT APPLICABLE							
F03	3		X						
PRODUCT TECHNIQUE DATA SHEET AVAILABLE <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO TH14.2000									
AQL : N/A									
FAMILY :									
METHOD : XXXXXXXXXXXXXXXX									



# Inspection of butt-joint configurations by means of PAUT-PE

- Qualification of the PAUT-PE inspection procedure for large voids detection in butt-joint configurations for large void detection.
- Based on the Butt-joint allowable program type J foil inclusions and large voids have to be detected.
- Reference panels are designed based on the Control Surface configuration (skin thickness and LSP materials).
- In total 6 reference panels
- Reference panels contain one type J defect of 7x14 mm and 12 FBH at different depths
- FBH simulate a void, end mill with Radius  $R=4$  mm is used
- 6 FBHs are 3x1.9 mm (minimum detectable defect size)
- 6 FBHs are 6x1.9 mm (minimum reject defect size)



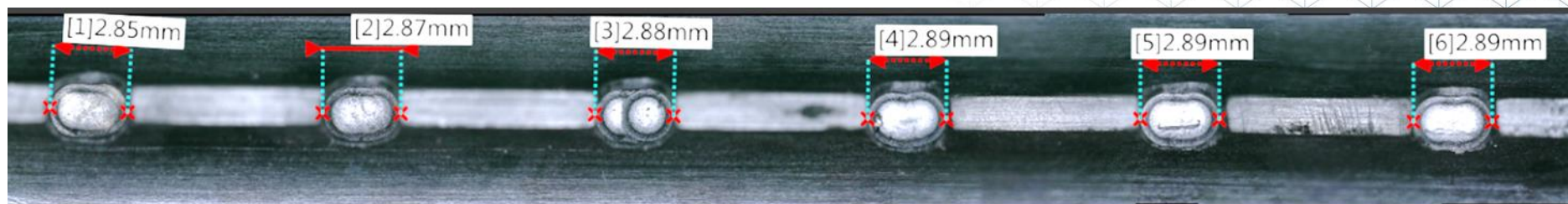
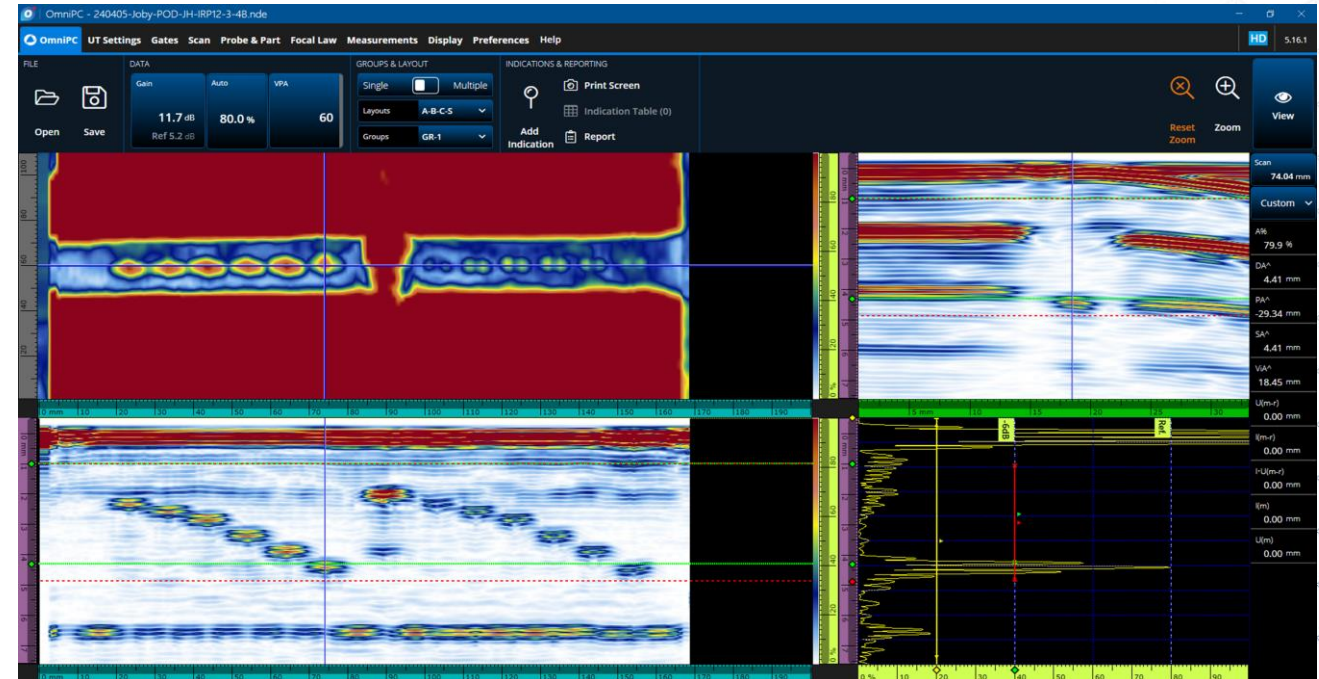
# Inspection of butt-joint configurations by means of PAUT-PE

- For the ultrasonic inspection the Olympus X3/MX2 phased array was used with a 128 element, 5 MHz and 0.3mm pitch transducer.  
Water with wetting agent is used as a couplant.
- All defects shall be detected.
- Detectability is defined as the delta dB attenuation between adjacent area and Flat Bottom Hole/foil insert, and should be larger than 4 dB.
- Probability of Detection (POD) shall demonstrate statistical proof for detection of defects in the butt-joint filler using PAUT-PE.
- POD: 3 operators, 6 reference panels each, 12 artificial defects, in total 216 measurements

Level of Confidence	Number of Misses	Probability of Detection		
		90%	95%	99%
90%	0	22	45	230
	1	38	77	388
	2	52	105	531
	3	65	132	667
	4	78	158	798
	5	91	184	926
	10	152	306	1,000+
95%	20	267	538	1,000+
	0	29	59	299
	1	46	93	473
	2	61	124	628
	3	76	153	773
	4	89	181	913
	5	103	208	1,000+
99%	10	167	336	1,000+
	20	286	577	1,000+
	0	44	89	458
99%	1	64	130	662
	2	81	165	838
	3	97	198	1,000+
	4	113	229	1,000+
	5	127	259	1,000+
	10	197	398	1,000+
	20	325	656	1,000+

# Inspection of butt-joint configurations by means of PAUT-PE

- Phased array data of 216 scans
- Evaluation is performed with calibration of backwall skin to 80% FSH.
- The 3x1.9 mm FBH look like figure 8. Microscope measurements show this is due to milling of the holes





# Inspection of butt-joint configurations by means of PAUT-PE

## Joby Buttjoint PAUT-PE inspection POD

- Inspection results summary
- Total misses over 216 measurements: 2 (still detected but delta dB measurement is resp 3,4dB and 3,7dB)

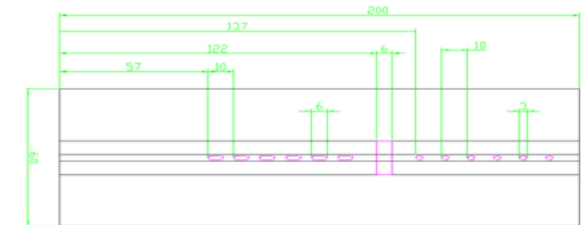
**Total # misses over 216 measurements:**

2

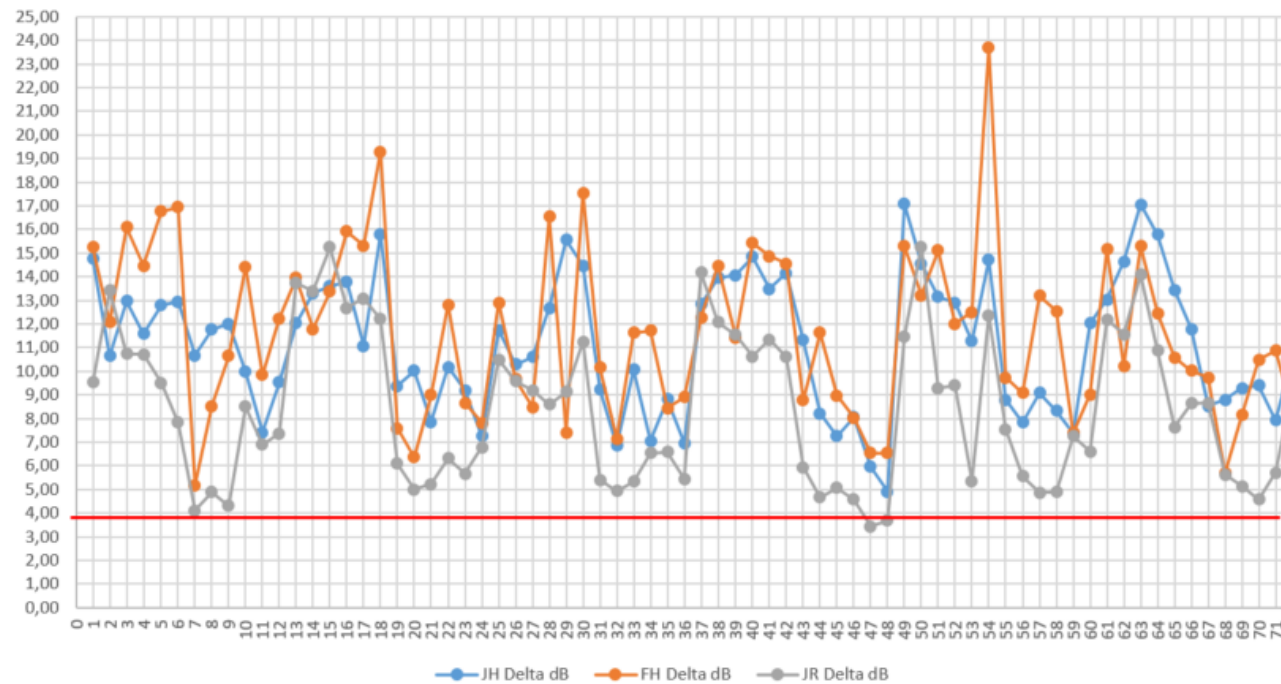
POD JH	POD FH	POD JR
0	0	2

**POD requirement:**

- Permitted number of misses  $n \leq 14$
- Conditions:**
- Visibility of defect [Y/N]
  - Delta dB ref. area - defect  $\geq 4$  dB



Delta dB FBH - Background [dB]



# Inspection of butt-joint configurations by means of PAUT-PE

- Qualification Test Report (QTR) will be finished with the PA results.
- Next step is to update the Fokker Technical Handbook (FP and TH) to include the Butt-joint inspection.
- Finish the Engineering Qualification
- Production Qualification is the internal GKN Fokker special processes qualification, to verify if we comply with the specification
- This qualification will be based on the QTP/QTR of the inspection of the butt-joint as the QTP/QTR is the base for the specification
- Inspection techniques, training for the UT L2 shall be finished before serial production and inspection is started.

# End of the presentation

Thank you for  
your attention



And remember:     *After design for manufacturing we need*

## Design for inspection