NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

March 30, 2004

ADDENDUM NUMBER 15 TO THE STRUCTURES GROUP CHAIRMAN'S FACTUAL REPORT

DCA02MA001

A. ACCIDENT

Location:	Belle Harbor, NY
Date:	November 12, 2001
Time:	09:16:14 EST
Aircraft:	American Airlines Flight 587, Airbus Model A300-605R, N14053 Manufactures Serial Number (MSN) 420

B. STRUCTURES GROUP

Chairman:	Brian K Murphy National Transportation Safety Board Washington, DC

C. AIRBUS REPORT

1. "AAL587 Airbus Structure Investigation, Lug Test#2 – Results Test / FEA Comparison"

Technical Note

Report Nr.: TN – ESGC – 1020/04

Author:
Department.:

Title

AAL587 Airbus Structure Investigation

Lug Test#2 – Results Test / FEA Comparison

Date: 25.03.2004

Summary:

As part of the AAL587 accident investigation the LHS Rear Main Lug Test#2 was carried out under the leadership of the NTSB at the Airbus Deutschland GmbH test facility in Hamburg on the 17th of December 2003.
The Lug Test#2 specimen was a LHS Rear Main Attachment fitting which was removed from the A300-600R MSN513 VTP. The load level reached during the 1997 event and the RHS rear main lug damage detected in March 2002 indicated that in the reached configuration the fin was considered as unserviceable. In 2003 the cut out was done by American Airlines in Tulsa.
The test of this damaged main lug specimen shall demonstrate the residual strength of this lug under load conditions to which the fin of AA flight 587 has been exposed during the accident.
The loading conditions for the Lug Test#2 was the same as for Lug Test#1. The agreed NASA W375 MOD load case with a pre-adjusted Rx bolt rotation of Rx=0.45° was used.

This report provides a comparison between the measured strain gauge values from the rear main Lug Test#2 specimen and the FE-analysis.
The test performed show consistently that the structural strength of the fin attachment lug significantly exceeded the design requirements.

	Issue	Date	No. of page	Revised pages	Valid from/for
	1	25.03.2004	55		

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1. Introduction

The test specimens for Lug Test#2 and #3 are parts of the VTP from MSN513. The load level reached during the 1997 event and the after RHS rear main lug damage detected in March 2002 indicated that in the reached configuration the fin was considered as unserviceable.

The LHS and RHS rear main lug, including the side skin panel, rib1 to 5 were removed from this VTP for test purposes (see figure 1.1). The cut out of the LHS and RHS test specimen was done by American Airlines in Tulsa. An Airbus specialist assisted the cut out process. The specimen were shipped to Airbus Hamburg and an incoming inspection was done.

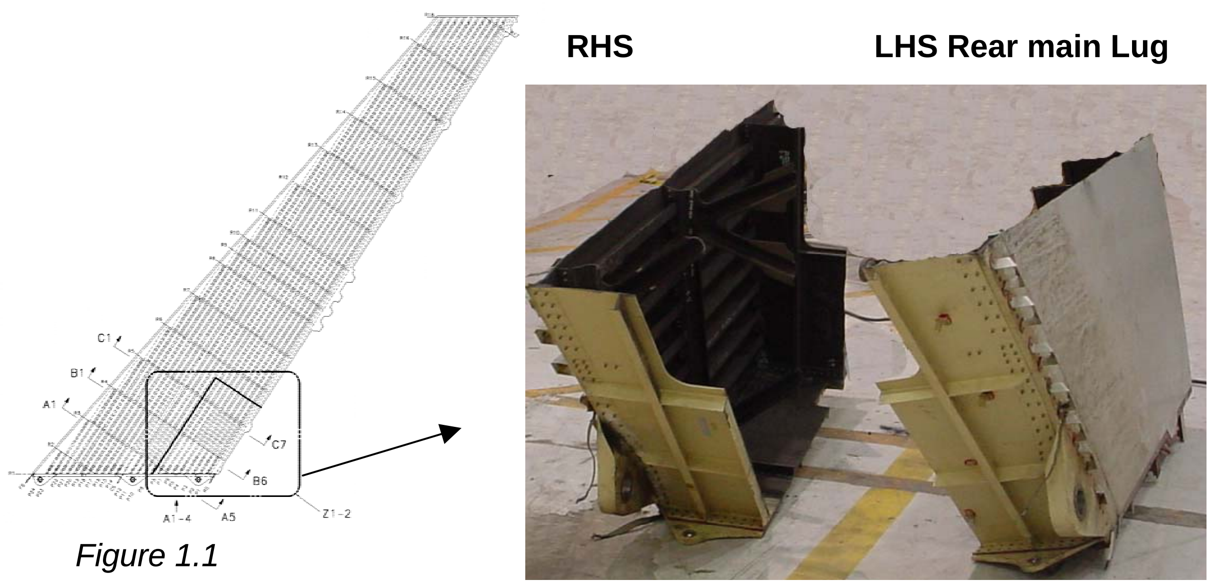


Figure 1.1

The incoming inspection showed, that the part had new or increased defects compared to the inspection made in March 2002.

As of today the origin of these differences are not explained and therefore the test should not be considered reflecting the standard behavior of the lugs.

As part of the AAL587 accident investigation the LHS rear main Lug Test#2 was carried out under the leadership of the NTSB at the Airbus Deutschland GmbH test facility in Hamburg on the 17th of December 2003.

The loading conditions for the Lug Test#2 (same as for the Lug Test#1) are based on the W375 load case (Ny Integration issue 18 - criteria: maximum lateral acceleration Ny) provided by the Airbus Loads department. In a meeting at Airbus Hamburg on the 12th of August 2003, it was agreed by NTSB, NASA, American Airlines and Airbus to select the NASA W375 MOD load vector for the Lug Test#1.
This report provides a comparison between the measured strain gauge values from the rear main Lug Test#2 specimen and the FE-analysis. For the purpose of a direct strain gauge comparison a strain gauge tracking subroutine was developed and implemented in the ANSYS nonlinear contact models.

The measured strain values of the rear main Lug Test#2 specimen are compared to

- RHS ANSYS 3D contact model
- LHS ANSYS 3D contact Lug Test#2 model Rx=0.45°

All the ANSYS FEA-models include a detailed contact surface definition for the fuse-lage/fin bolt connection. The strain distribution of the RHS model is the reference for the comparison with the calculated strains from the test model FEA and the measured strain from the lug test itself.
The LHS ANSYS contact Lug Test#2 model represents the reinforced and modified test specimen and includes the test rig load introduction and test specimen support.

2. LHS Rear Main Lug Test#2 specimen from MSN513 VTP

The location of the test specimen in the vertical stabilizer is shown in figure 2.1 and the test part itself in figure 2.2.

A300-600R Vertical Stabilizer

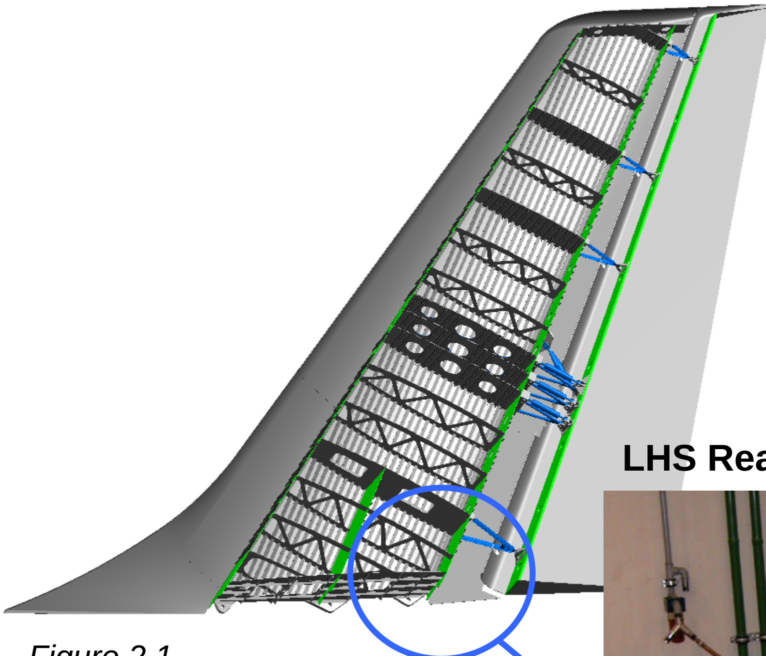


Figure 2.1

LHS Rear Main Lug Test#2 specimen

Figure 2.2

2.1 Comparison of the test specimen dimension between Lug Test#1 and #2

The following figures 2.3 to 2.6 show the different dimensions between the test specimen of Lug Test#1 and #2.

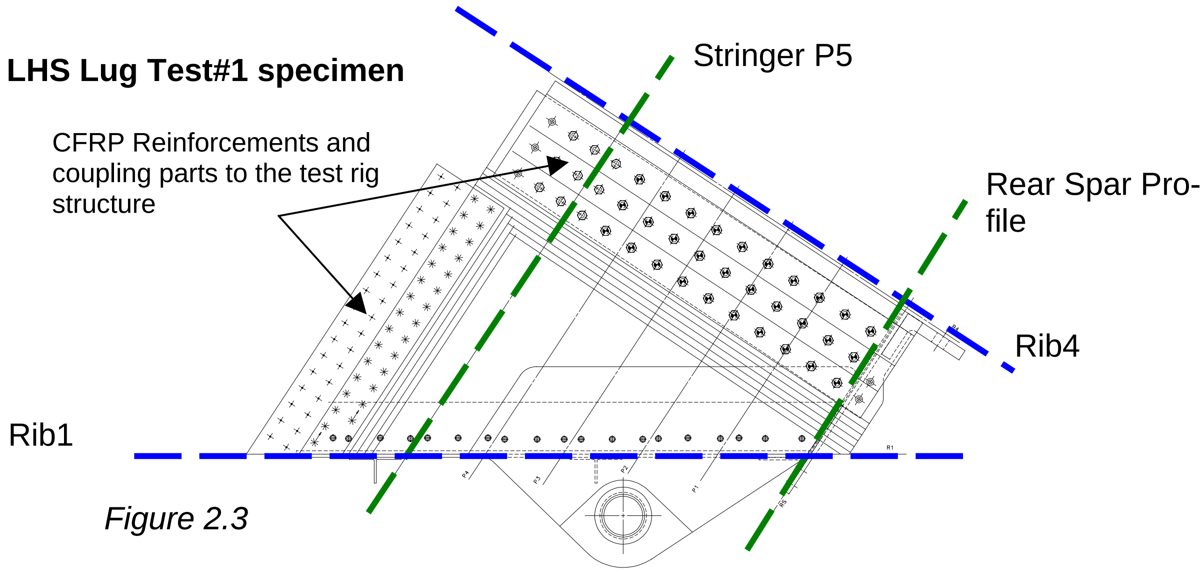


Figure 2.3

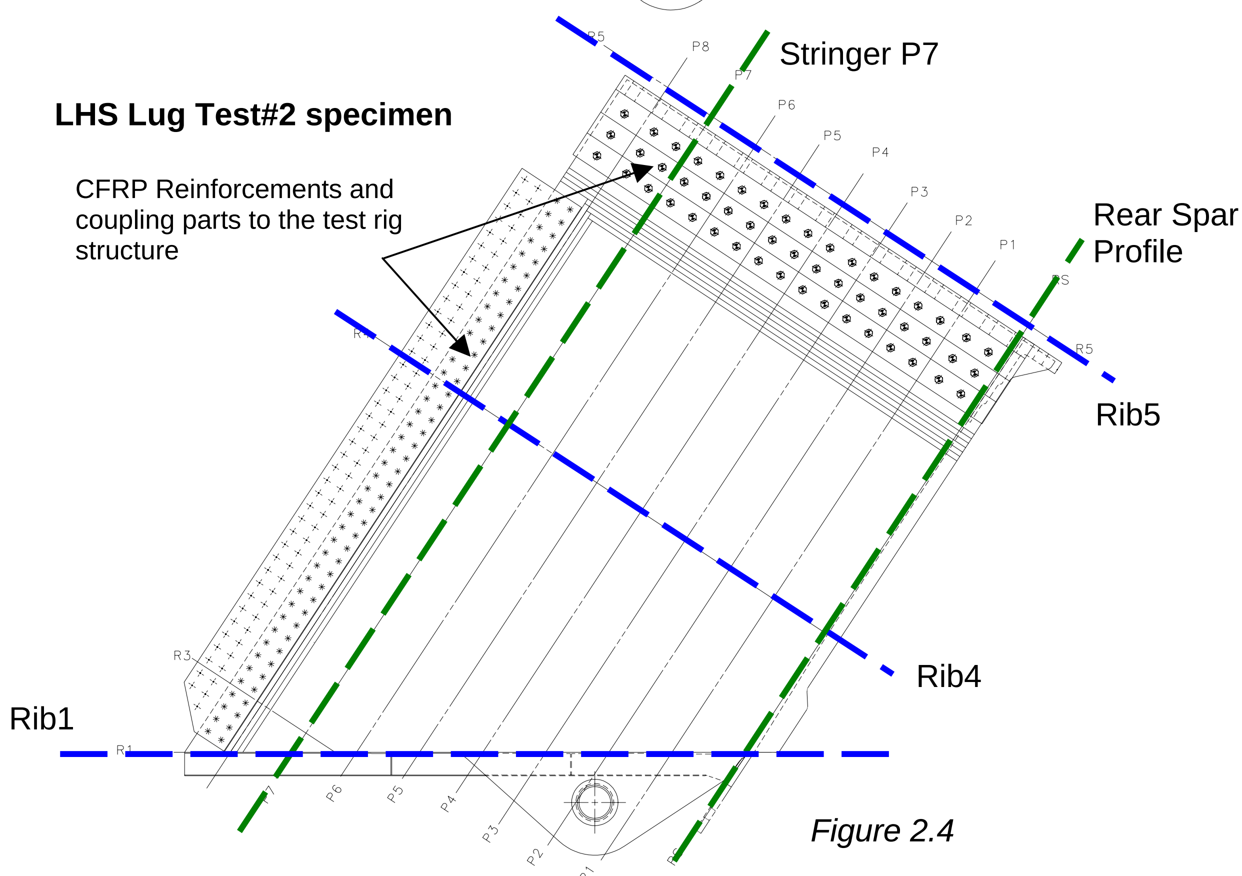


Figure 2.4

LHS Lug Test#1 specimen

Figure 2.5

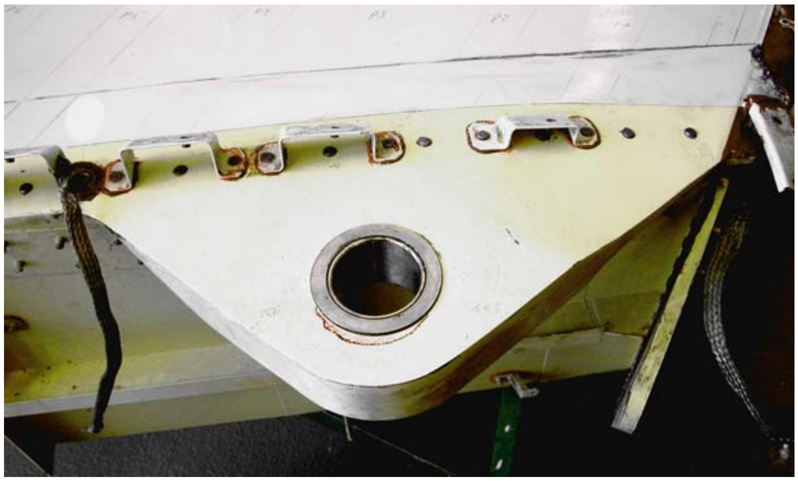
LHS Lug Test#2 specimen

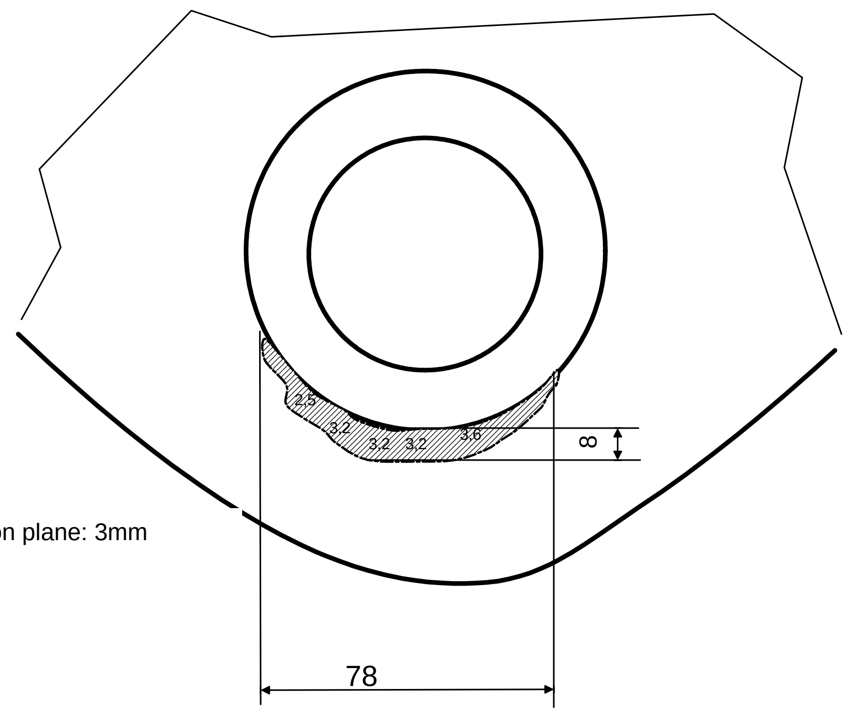
Figure 2.6

2.2 NDI Inspection results for the LHS Lug Test#2 specimen

The incoming inspection for the LHS Lug Test#2 specimen showed, that the test specimen had new or increased defects compared to the inspection made in March 2002 (see figure 2.7 and 2.8).

Figure 2.7





Depth of indication plane: 3mm

Figure 2.8 LHS rear main lug outboard view with the delamination and cracks around the bushing. (findings not existing in the inspection at Tulsa in 2002)

2.3 FEA-model and Lug Test#2 overview

Figure 2.9 and figure 2.10 show two different FEA-models, which are compared with the Lug Test#2 specimen test (see figure 2.11) results.

RHS ANSYS 3D contact model (Global /Local model)

The general description of the RHS ANSYS 3D contact model can be found in the report TN – ESGC - 1018/03. For the comparison with the Lug Test#2 described in this report the RHS ANSYS model was modified at two points:

- the area of the fuselage structure was increased for the application of the boundary displacements
- The advanced connection bolt idealization described in chapter 2.7 was also used for the RHS ANSYS model

Loading Condition:

W375 boundary displacements conditions from global 2D FEA-model with embedded LHS and RHS 3D models.

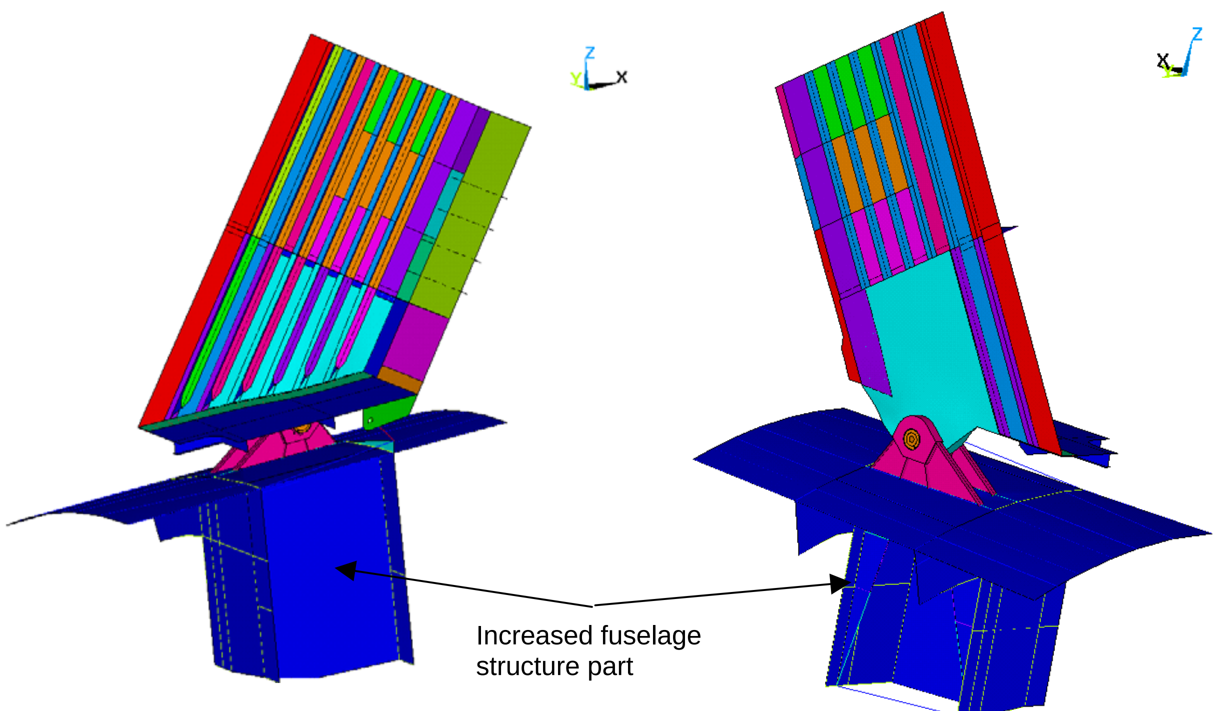


Figure 2.9

LHS ANSYS 3D contact Lug Test#2 model

The general description of the LHS ANSYS contact Lug Test#1 FEA model can be found in report TN – ESGC - 1020/03 and is still valid for the Lug Test#2 model. The Lug Test#2 model was adapted and modified:

- to the dimension of the larger specimen up to rib 5 (see figure 2.4 and 2.10) and the new connection bolt idealization (chapter 2.7)
- to the new support structure (see figure 2.10)
- the test rig load introduction (Z1/2 main rod bearing point aligned to the bolt axis)
- and implementation of the complete test rig structure in the ANSYS model (see figure 2.12)

Loading Condition:

NASA W375 MOD load vector

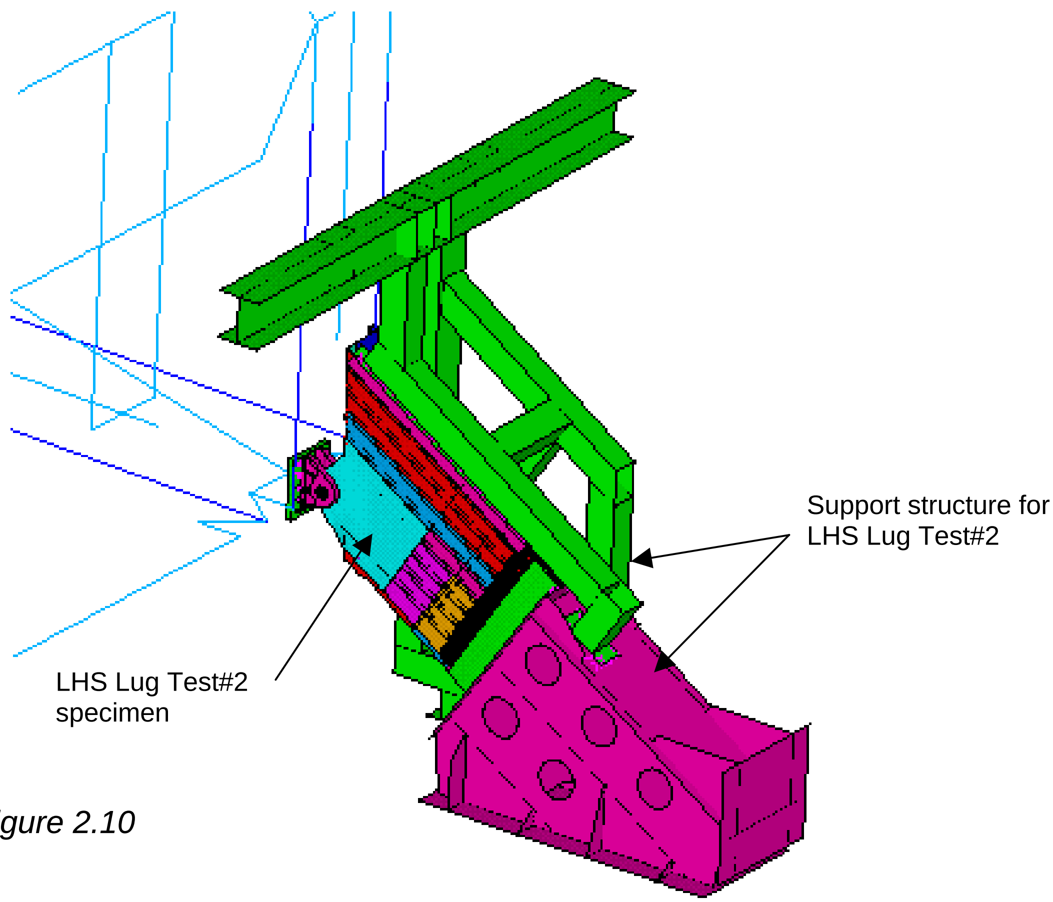


Figure 2.10

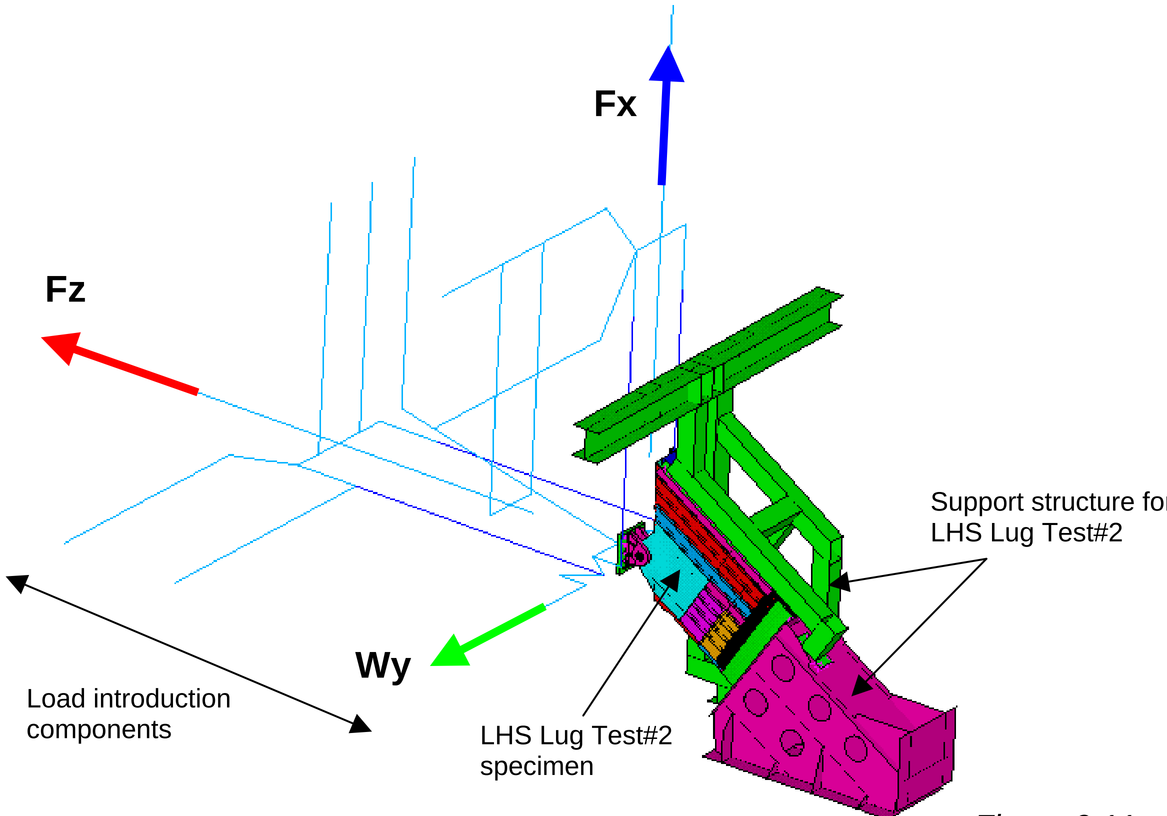
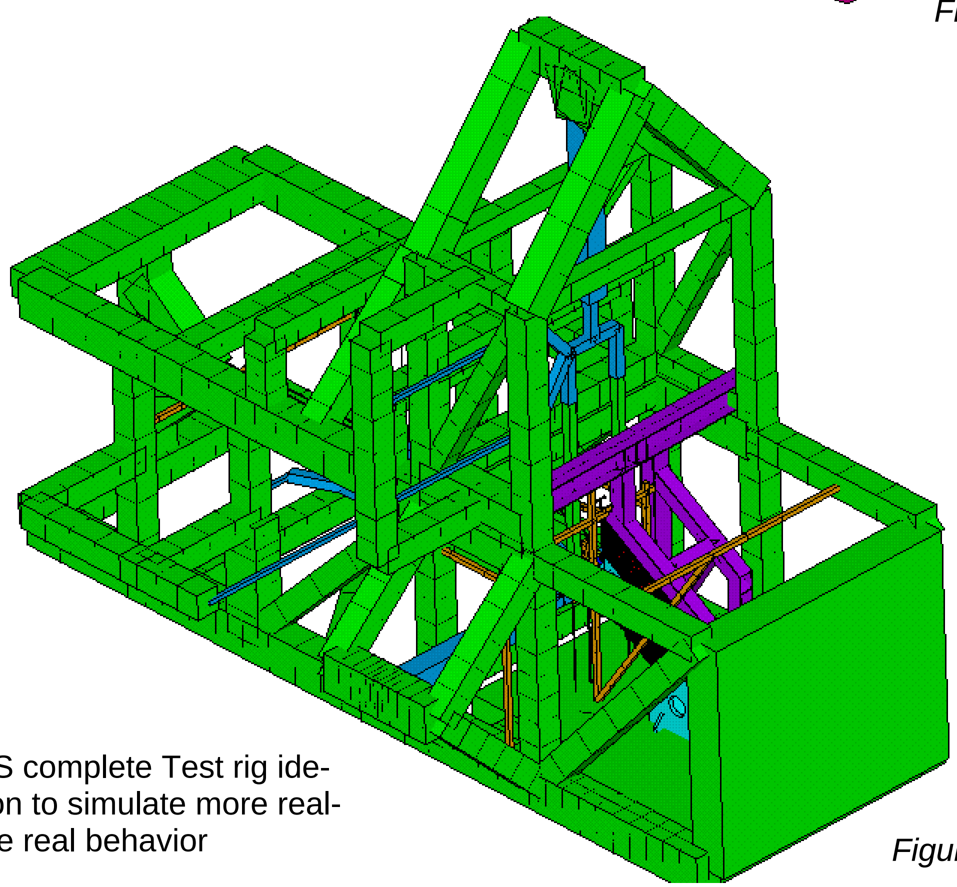


Figure 2.11



ANSYS complete Test rig idealization to simulate more realistic the real behavior

Figure 2.12

Lug Test#2 specimen

Lug Test#2 is described in the test requirement 32 X 029 K4 805 P34.

Loading Condition:

NASA W375 MOD load vector

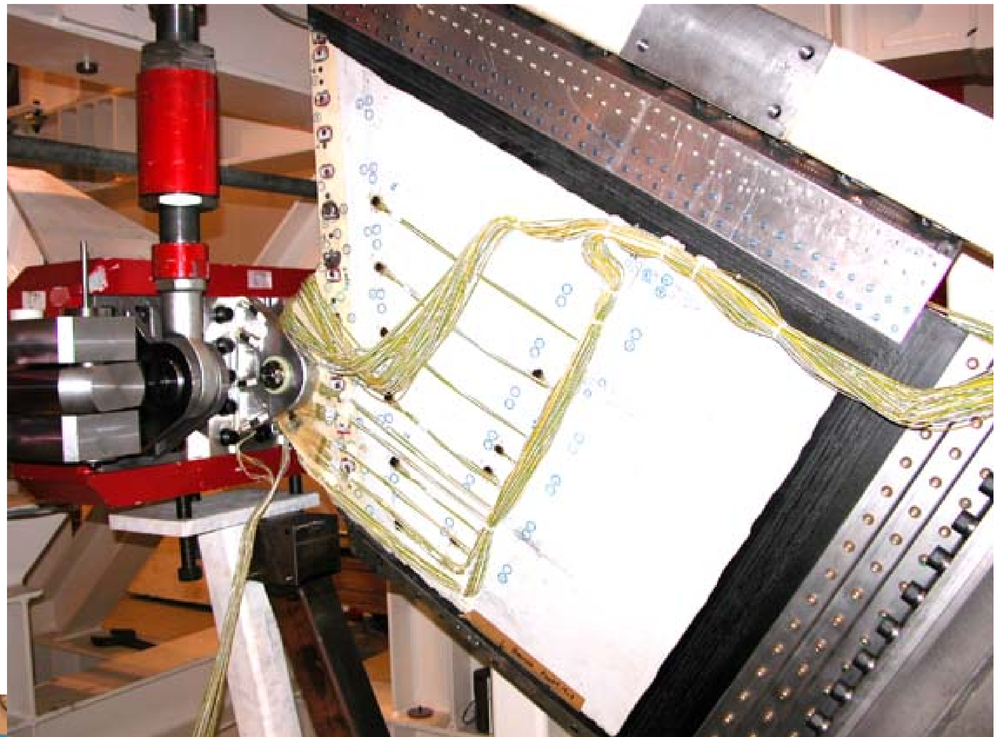


Figure 2.13

Figure 2.14

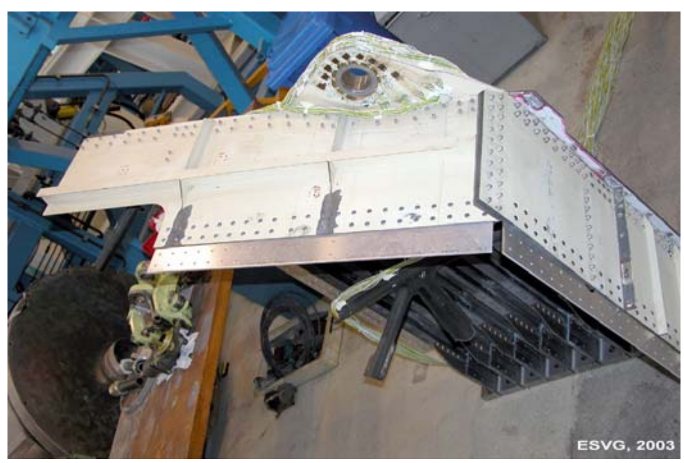


Figure 2.15

2.4. Description of the test rig

2.4.1 Global view

Figure 2.16 illustrates the global design of the lug test rig. The global coordinate system corresponds to the Aircraft coordinate system on this test rig and aligns to the three load introduction axes of the test rig.

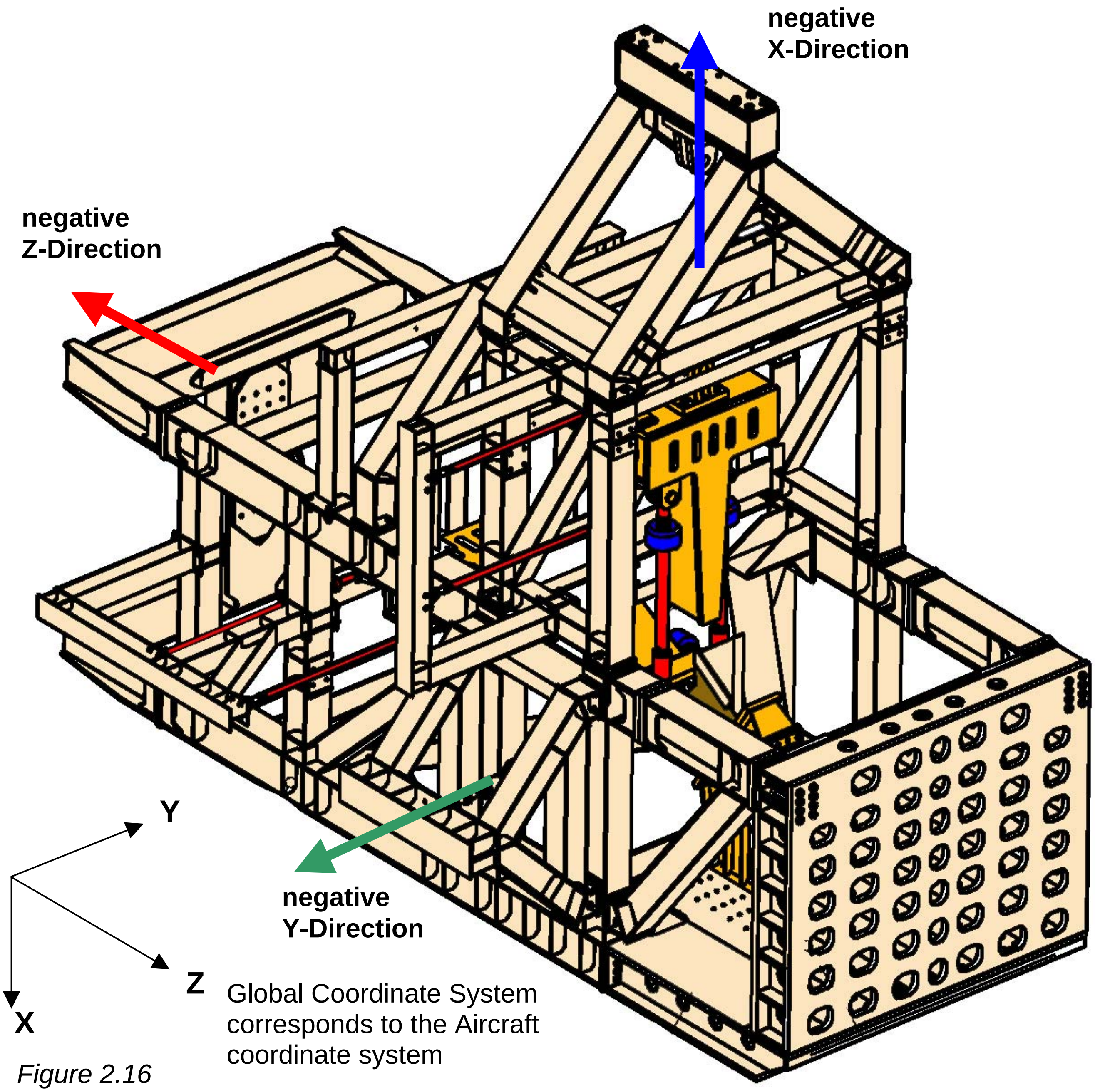


Figure 2.16

2.4.2 Load introduction and location of the test specimen in the test rig

The figure 2.17 shows the load introduction components of the test rig and the location of the Lug Test#2 specimen itself.

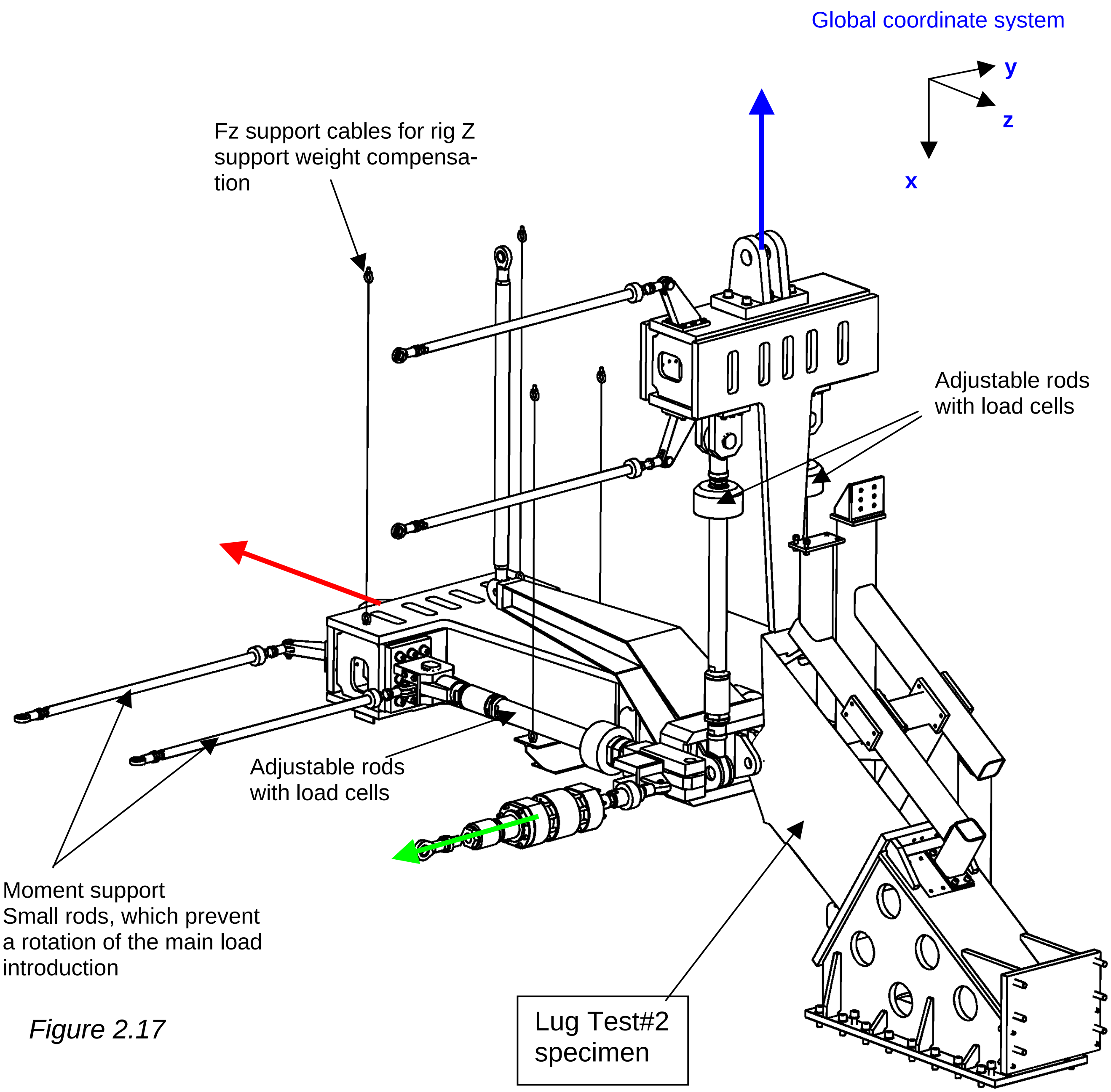


Figure 2.17

2.4.3 Test rig sign convention for local lug reaction moments

The sign convention for the local lug reaction moments are illustrated in figure 2.18.

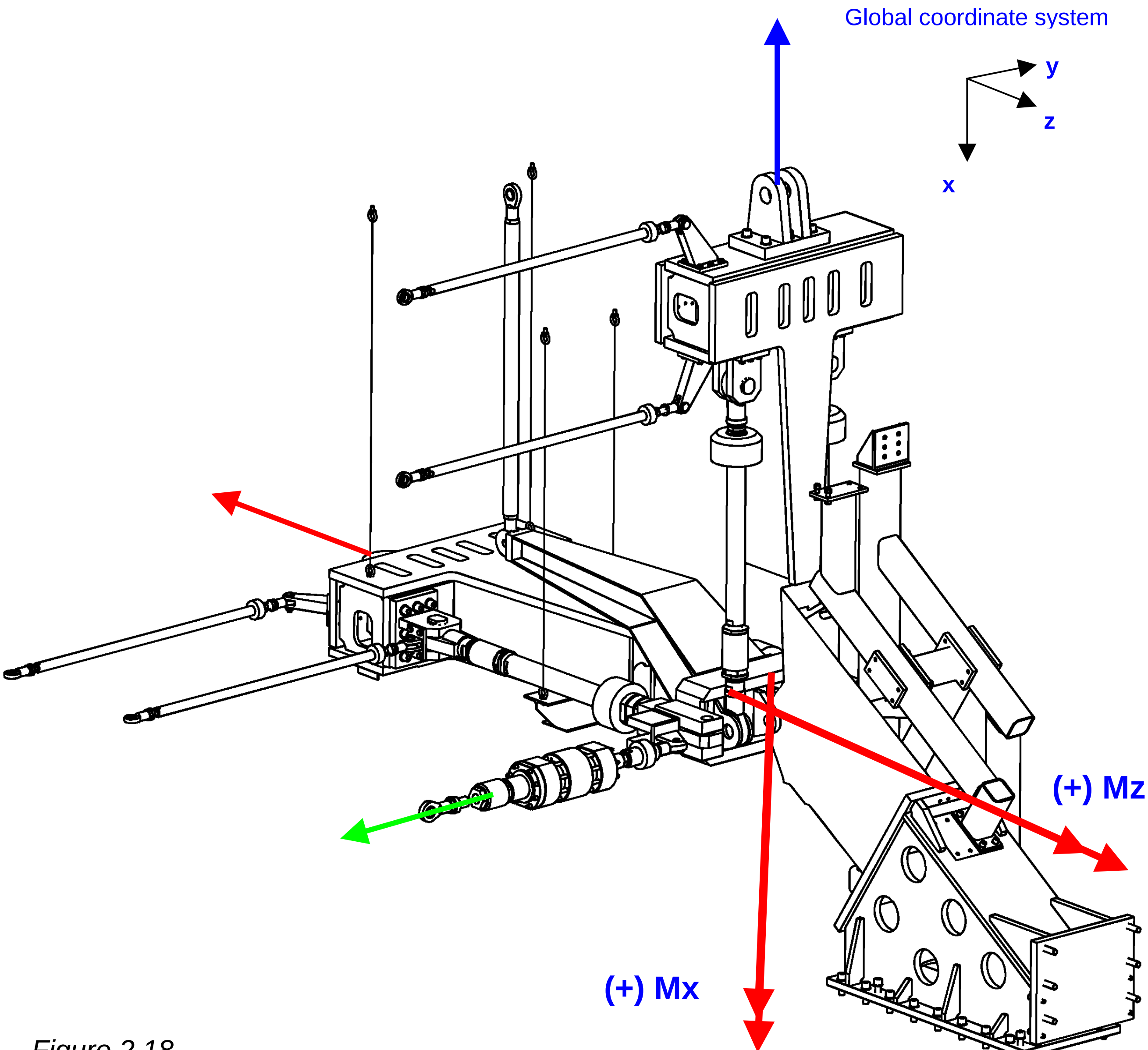


Figure 2.18

2.4.4 Test rig modification for Lug Test#2

The principle design and functioning of the test rig load introduction remain unchanged. For the Lug Test#2 Airbus has decided to align the main rods Z1 and Z2 bearing points with the test specimen connection bolt axis. In the previous Lug Test#1 the bearing points have had an offset to the bolt axis of 245mm. Figure 2.19 show a section cut through the Z-load introduction YZ-plane.

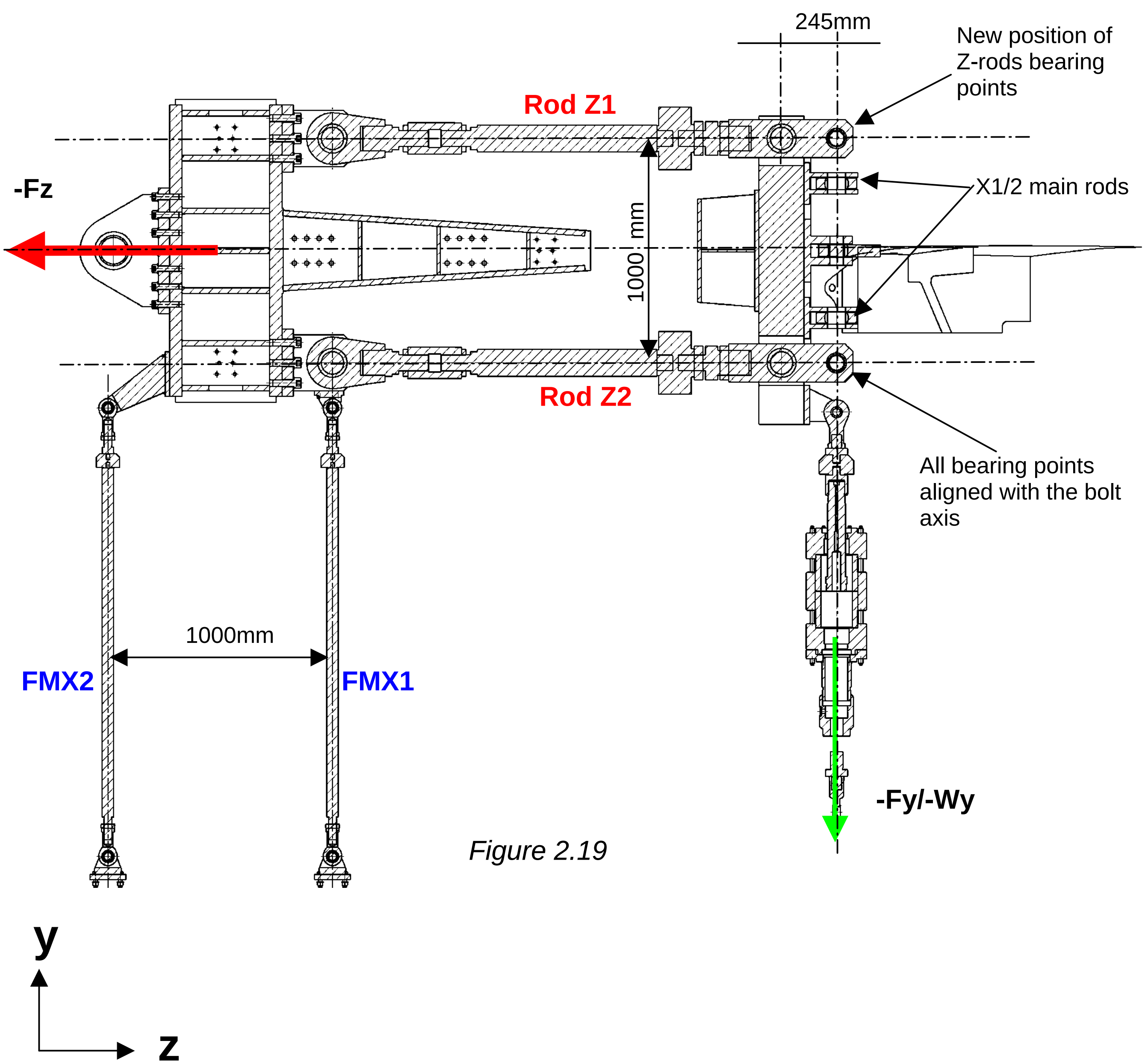


Figure 2.19

2.5 Lug Test#2 local lug moment Mx and Mz Equations

With the experience of Lug Test#1 and taking into account the modified load introduction, the local lug moment calculation was reduced to two simple equations (see figure 2.20).

$$Mx = (Z2 - Z1)kN \cdot 500mm = Nm$$

$$Mz = (X2 - X1)kN \cdot 300mm = Nm$$

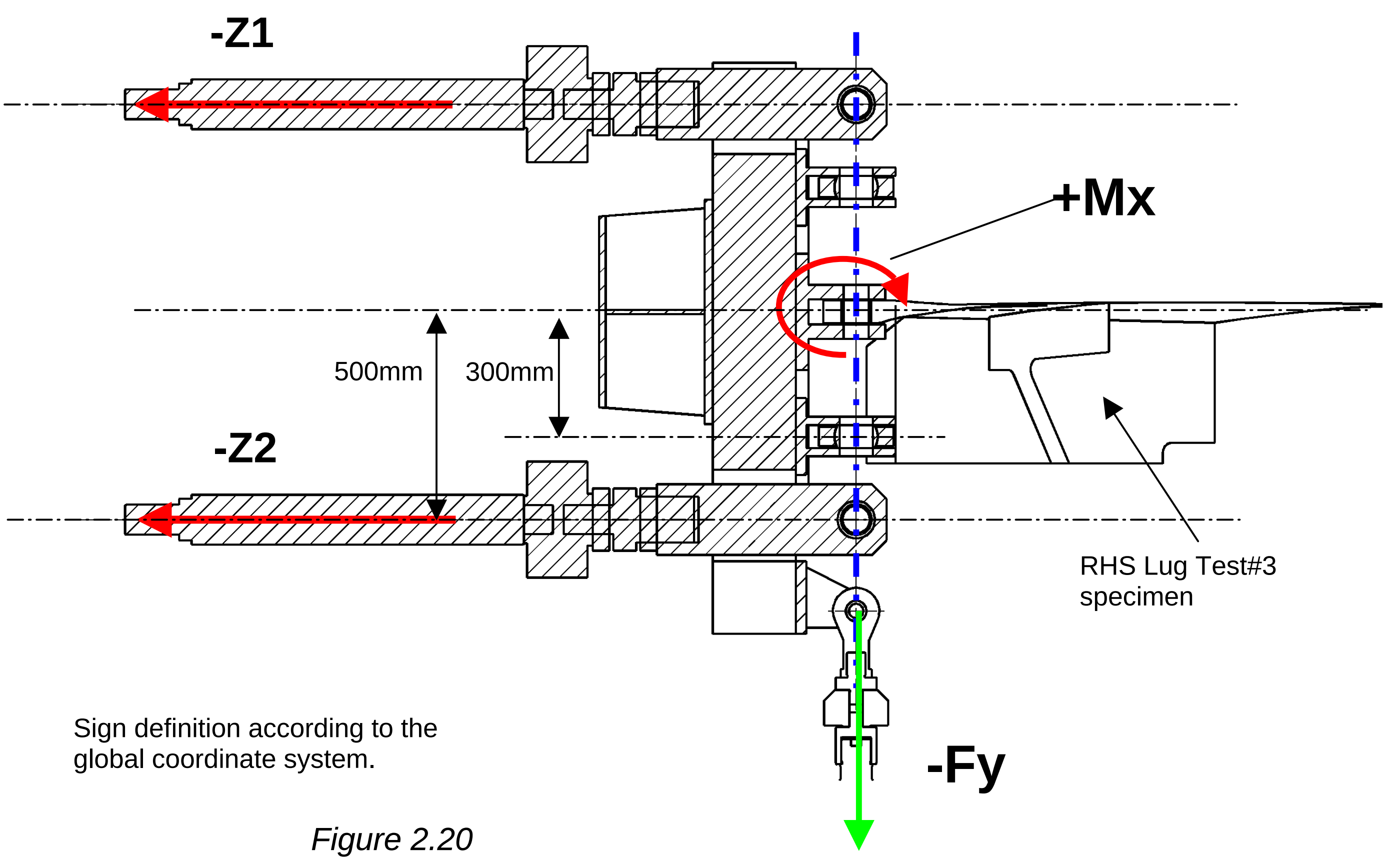


Figure 2.20

2.6 ANSYS Lug Test#2 FEA-model lug reaction calculation method

The local lug reactions are calculated for every load step at a cross section through the fuselage clevis (see figure 2.21 and 2.22) with a summation of the grid point force balance (GPFB) according to the deformed reference point in the bolt axis. With these information the local lug moment Mx and Mz are calculated.

In the ANSYS test specimen calculations the GPFP-method is used and also the method described in chapter 2.5 taking into account the measured main rod forces.

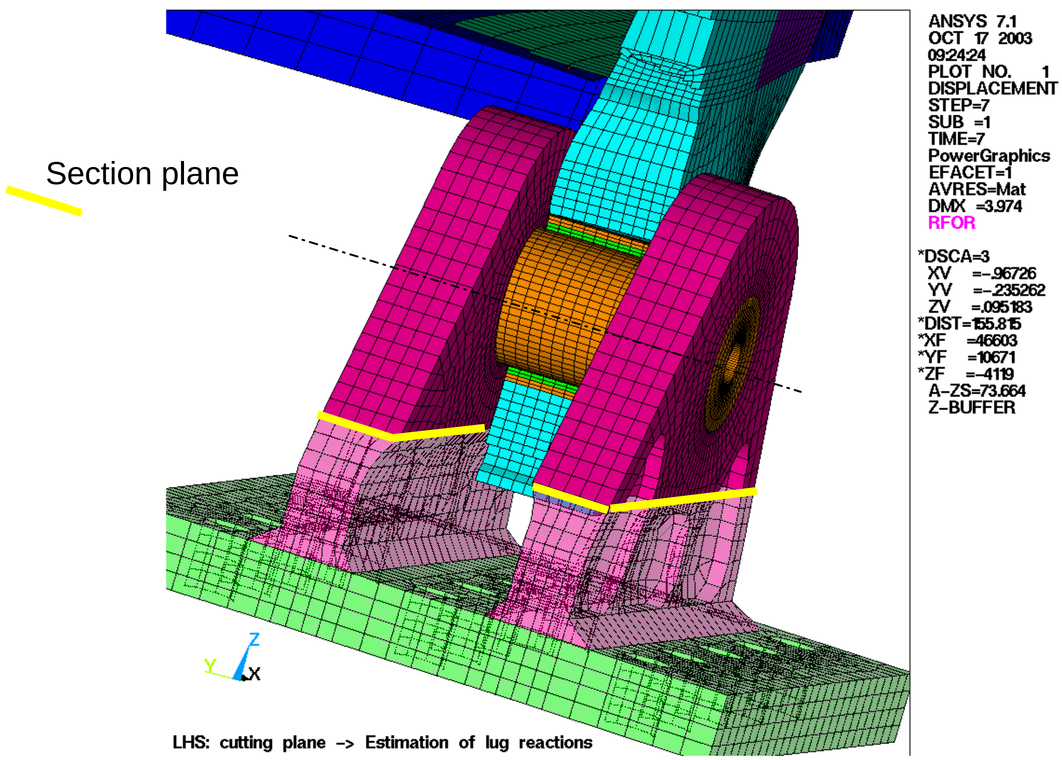
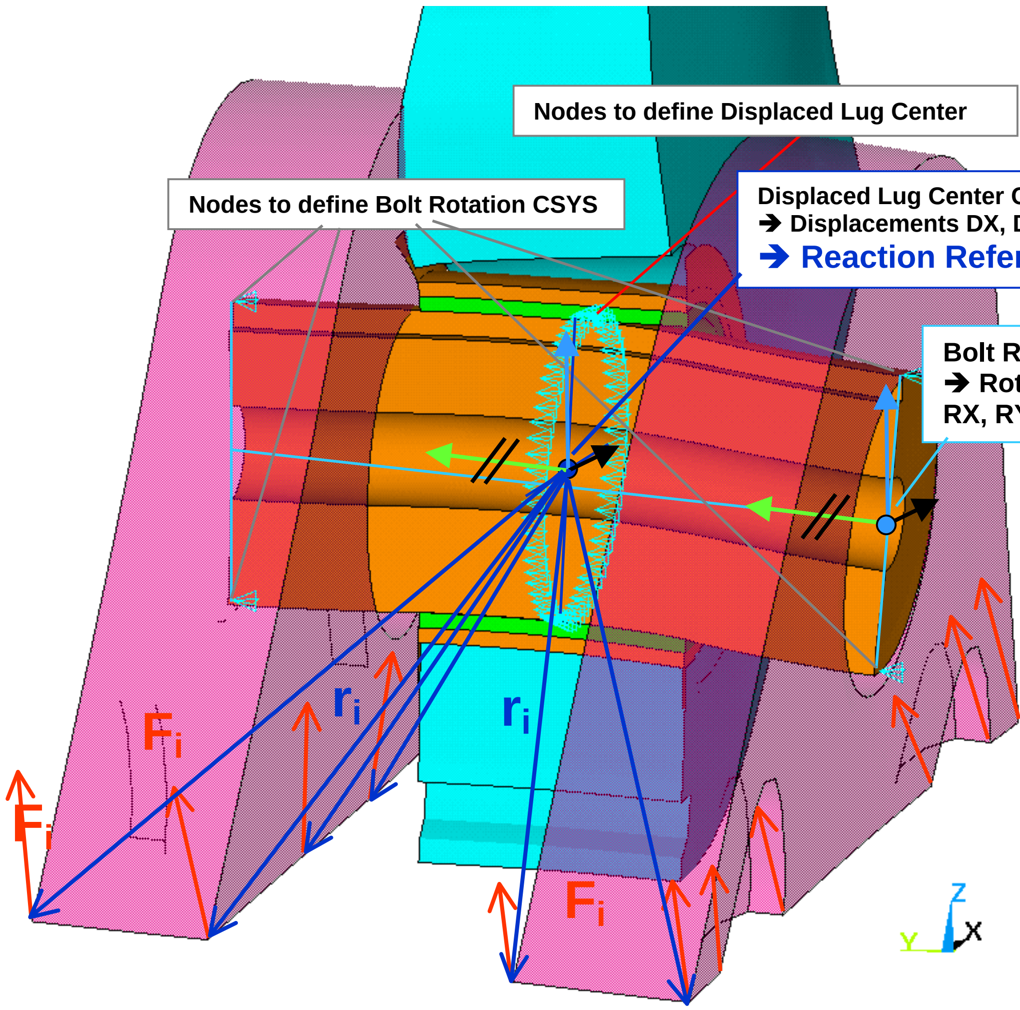


Figure 2.21

The calculation of bolt orientation and lug reactions (see figure 2.22) on deformed lug center was made with user written subroutine in ANSYS (APDL).



Deformed structure! (Displacements scaled by a factor 10)

➔ Reactions in Displaced Lug Centre:

$$M_{RsP} = SUM(r_i \times F_i) \qquad F_{RsP} = SUM(F_i)$$

Figure 2.22

2.7 ANSYS detailed connection bolt idealization

For the Lug Test#1 calculations the connection bolt was idealized as a cylindrical bolt with four contact surfaces and a friction coefficient of 0.3. A detailed description can be found in report TN-ESGC-1020/03.

Airbus decided for the Lug Test#2 to improve the connection bolt idealization in the ANSYS models.

The optimised connection bolt idealization includes

- a tapered bolt with a nut
- a slotted sleeve, both are pre-stressed with a friction coefficient of 0.05
- a cone bushing in the CFRP lug
- all parts with separate contact surfaces with a friction coefficient of 0.3

The detailed connection bolt idealization is implemented in the ANSYS LHS Lug Test#2 and the RHS Global/Local model. Compared to the cylindrical bolt idealization, the detailed connection bolt shows only negligible influence on the Fx-, Fy- and Fz-forces but a significant reduction in the local lug moments.

The following figures 2.23 to 2.26 explain the details of the connection bolt idealization.

Bushing with cone idealization

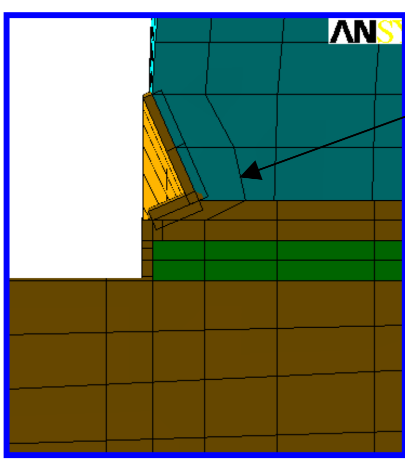


Figure 2.23

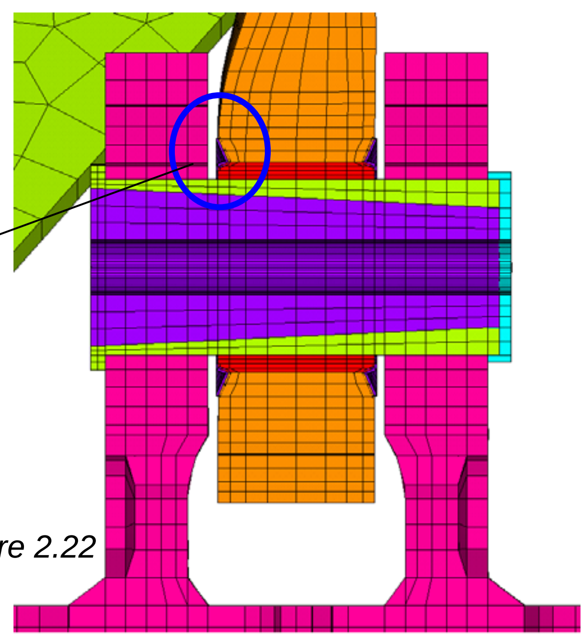


Figure 2.22

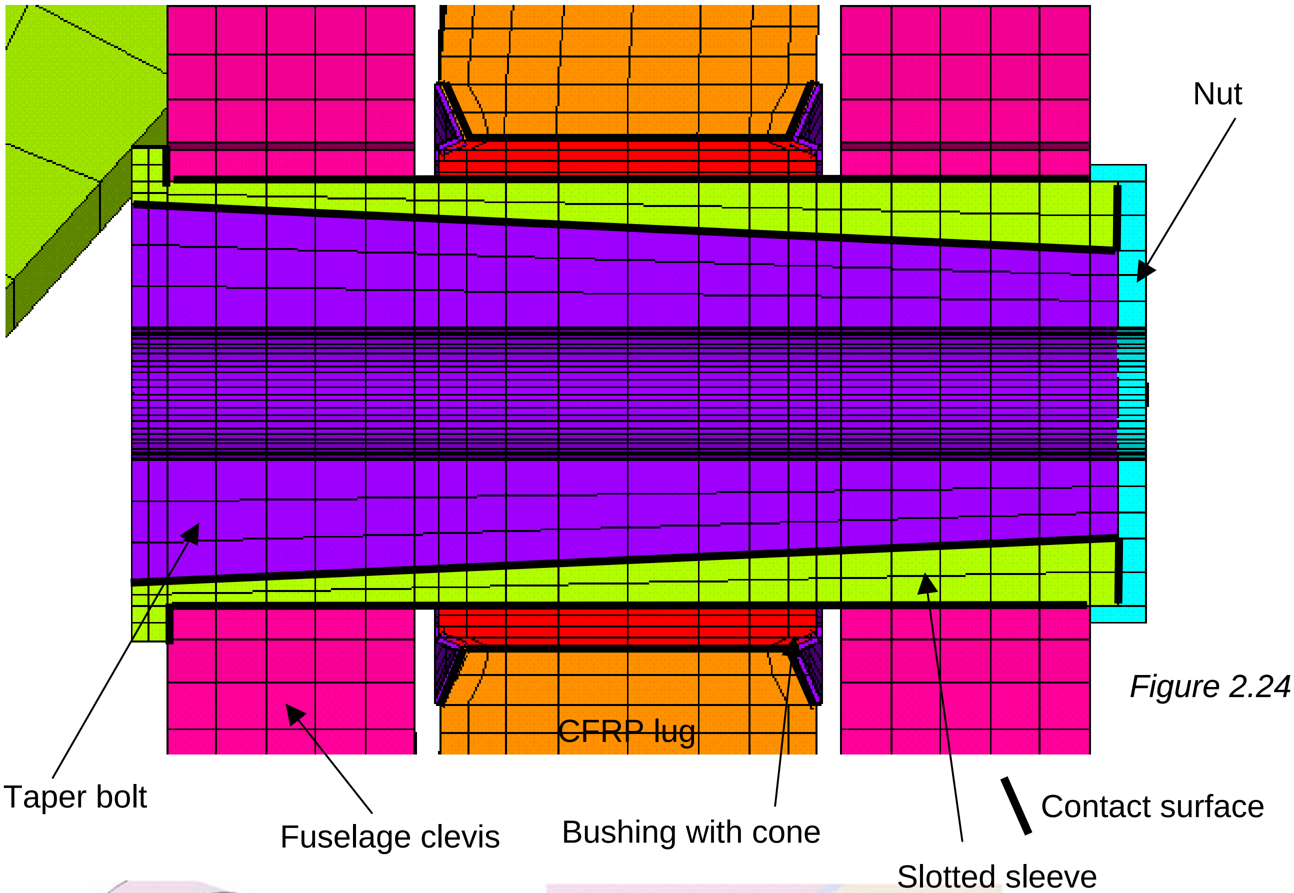


Figure 2.24

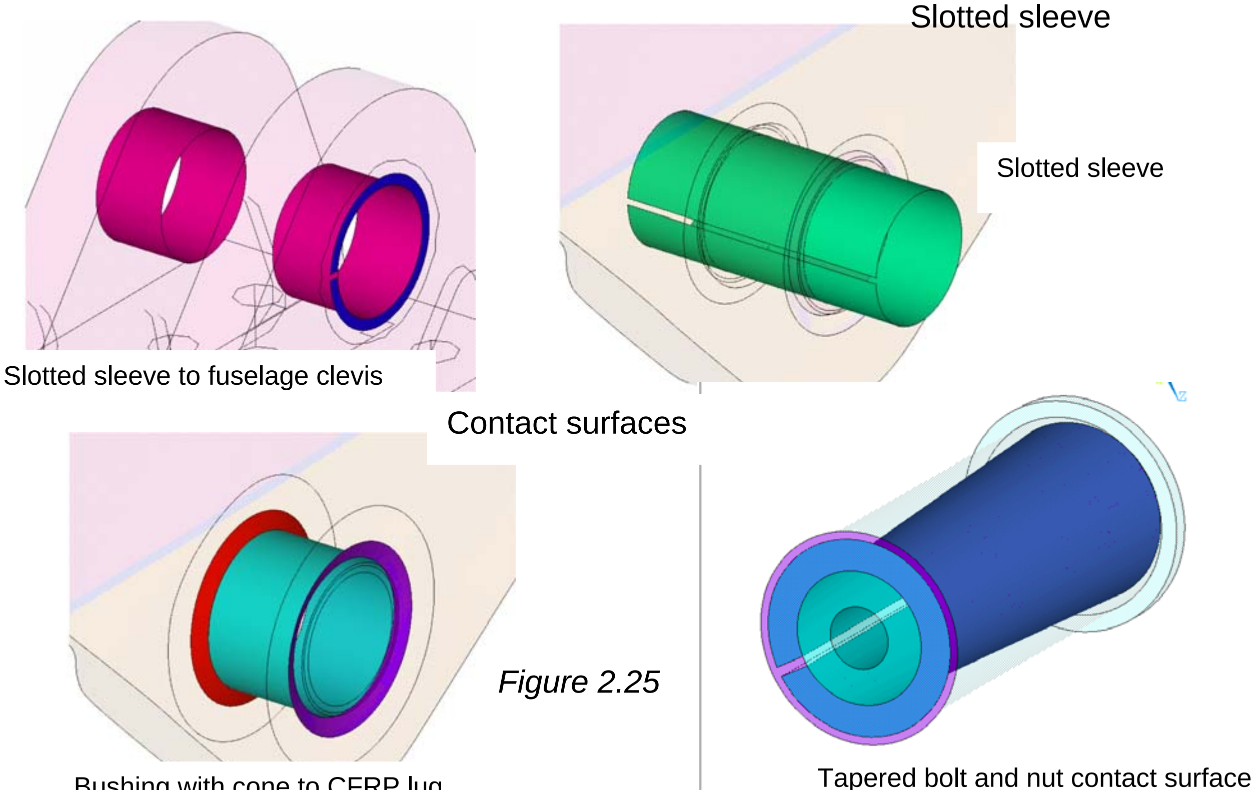


Figure 2.25

3. FE-Analysis loading conditions for comparison with the test

The following FEA-models are used for the comparison between FEA-results and the Lug Test#2:

I. RHS ANSYS rear main lug nonlinear contact model with the boundary displacement conditions from 2D global model with embedded 3D rear main lugs
II. LHS ANSYS Lug Test#2 nonlinear contact model with pre-adjusted bolt rotation of RX=0.45°

3.1 NASA W375 MOD load vector for the Lug Test#1 and #2

The load vector for the Lug Test#2 was the same as agreed for the Lug Test#1. In a meeting at Airbus Hamburg on the 12th of August 2003, it was agreed on by NTSB, NASA, American Airlines and Airbus to select the NASA W375 MOD load vector for the Lug Test#1.
The NASA W375 MOD load vector (see table 3.1) was used for the Lug Tests and all ANSYS test specimen FEA-analysis.

Table 3.1

NASA W375 MOD load vector			
Fx	Fy	Fz	Fres
[kN]	[kN]	[kN]	[kN]
-400	-42	-864	953

The bolt rotation was introduced in the test rig with the turnbuckles of the Z1 and Z2 main rods.

For the Lug Test#2 it was agreed by NTSB, NASA and Airbus to change the Fy lateral load introduction from force controlled to displacement controlled.
Also for the Lug Test#2 it was agreed to use a pre-adjusted local bolt rotation of Rx=0.45°.

3.2 RHS ANSYS contact 3D model W375

The loading condition for the RHS ANSYS model is derived from the Global NASTRAN model. The boundary displacements were applied in 7 steps and the analysis delivers the lug reaction forces as given in table 3.2

Table 3.2

Fres	**FX**	**FY**	**FZ**	**MX**	**MZ**
[kN]	[kN]	[kN]	[kN]	[Nm]	[Nm]
5	1	0	5	20	12
153	-66	6	-138	-1100	179
302	-127	11	-273	-2006	366
452	-188	16	-411	-2865	545
605	-248	22	-551	-3694	714
761	-309	28	-694	-4501	876
919	-371	34	-841	-5281	1032

For comparison with the LHS model the lateral force Fy and the local lug moments Mx and Mz the signs have to be reversed.

3.3 LHS ANSYS contact Lug Test#2 NASA W375 MOD Rx=0.45°

The ANSYS nonlinear contact model includes the following Analysis sequences:

- Pre-stressing the bolt
- Pre-adjust the bolt Rx-rotation of Rx=0.45°
- Applying the W375 MOD load vector

The applied load vector for the LHS ANSYS Lug Test#2 nonlinear contact analysis is shown in table 3.3.

Table 3.3

Fres	**FX**	**FY**	**FZ**
[kN]	[kN]	[kN]	[kN]
0	0	0	0
159	-67	-7	-144
318	-133	-14	-288
477	-200	-21	-432
635	-267	-28	-576
794	-333	-35	-720
953	-400	-42	-864

4. Lug Test#2 NASA W375 MOD Rx=0.45° loading condition

The load vector for the Lug Test#2 was the same as agreed for the Lug Test#1 with a pre-adjusted bolt rotation of Rx=0.45°.
Also for the Lug Test#2 it was agreed by NTSB, NASA and Airbus to change the Fy lateral load introduction from force controlled to displacement controlled.

To change the lateral load introduction the following test procedure was carried out:

Determination of Wy-displacement vector

- Pre-adjust the bolt rotation of Rx=0.45° with the turnbuckles of the Z1 and Z2 main rods
- Apply the force controlled (Fx,Fy and Fz) W375 MOD load vector up to Fres=400kN
- The measured lateral displacement Wy caused by the lateral force input was extrapolated linearly up to Fres=953kN
- This lateral Wy-displacement relationship was used as input for the Wy-displacement controlling.

Checking of Fy-force caused by the introduced Wy-displacement vector

- Pre-adjust the bolt rotation of Rx=0.45° with the turnbuckles of the Z1 and Z2 main rods
- Apply the force controlled (Fx and Fz) and Wy-displacement W375 MOD load vector up to Fres=400kN
- Compare the Fy-force with the initial Fy-force input vector

Residual strength test Lug Test#2

- Pre-adjust the bolt rotation of Rx=0.45° with the turnbuckles of the Z1 and Z2 main rods
- Apply the force controlled (Fx and Fz) and Wy-displacement W375 MOD load vector up to failure

For the Lug Test#2 it was decided to demonstrate first the lug capability up to ultimate load of the design lateral gust condition BI17 (A36RBI17 SD06). After that test the NASA W375 MOD load vector was applied up to failure. The following tables 4.1 show the applied load vectors and for the NASA W375 MOD condition the max. Wy-displacement.

Table 4.1

NASA W375 MOD						
	Fx	Fy	Fz	Fres	Bolt Rx rotation	Angle Xzplane
	[kN]	[-]	[kN]	[kN]	[°]	[°]
BI17 Ultimate Load	-256	-29 kN	-637	687	+0.3	68
W375-MOD	-400	-42 kN ≈ -1.95mm	-864	953	+0.45	65

Wy=-1.95mm total Y-displacement

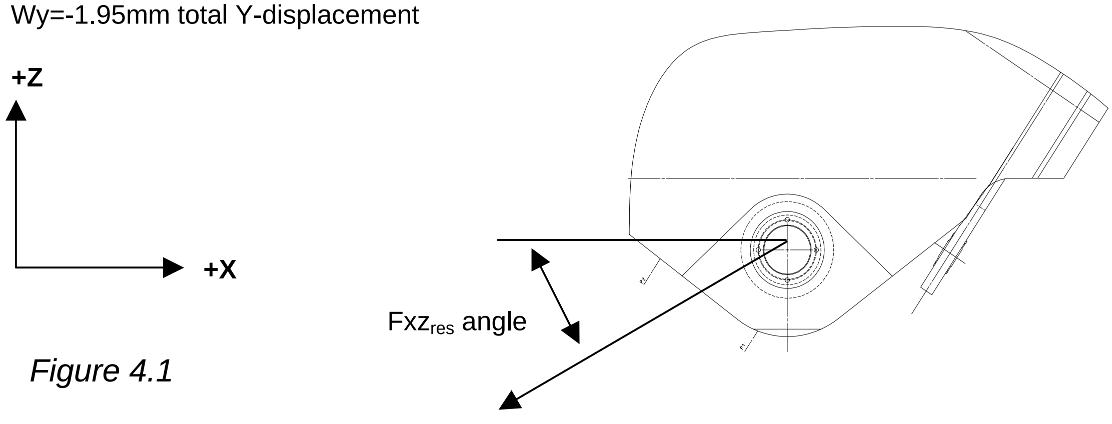


Figure 4.1

The forces were applied in the following load / displacement steps:

Table 4.2

Fx	Wy	Fz	Fres	Load step
[kN]	[mm]	[kN]	[kN]	[-]
With turnbuckles pre-adjusted Rx=+0.45°				0
0	+0.40	0	0	1
-10	+0.37	-21	23	5
-19	+0.33	-41	46	10
-29	+0.30	-62	69	15
-38	+0.27	-83	91	20
-48	+0.23	-104	114	25
-58	+0.20	-124	137	30
-67	+0.16	-145	160	35
-77	+0.11	-166	183	40
-86	+0.05	-187	206	45
-96	0.00	-207	229	50
-106	-0.08	-228	252	55
-115	-0.13	-249	274	60
-125	-0.18	-270	297	65
-134	-0.23	-290	320	70
-144	-0.27	-311	343	75
-154	-0.32	-332	366	80
-163	-0.36	-353	389	85
-173	-0.41	-373	412	90
-182	-0.46	-394	435	95
-192	**-0.51**	**-415**	**457**	**100**
-202	-0.56	-435	480	105
-211	-0.61	-456	503	110
-221	-0.65	-477	526	115
-230	-0.70	-498	549	120
-240	-0.75	-518	572	125
-250	-0.80	-539	595	130
-259	-0.85	-560	618	135
-269	-0.89	-581	640	140
-278	-0.94	-601	663	145
-288	**-0.99**	**-622**	**686**	**150**
-400	**-1.55**	**-864**	**953**	**208**
[kN]	[mm]	[kN]	[kN]	[-]
Fx	Wy	Fz	Fres	Load step

Limit Load Level (load step 100)

Ultimate Load Level (load step 150)

NASA W375-MOD load vector (load step 208)

All force values are kN

5. Strain gauge numbering system

All strain gauges are installed on both sides (inboard and outboard) of the test speci-men (see figure 5.1 to 5.5). The table 5.1 shows the numbering system with the gauge type, orientation and the location.

Table 5.1

No.	Inboard / Outboard	Strain Gauge Type	Orientation [°]			Location
			0	45	90	
E1-9	i/o	Unidirectional	A			around the lug
R10-18	i/o	Rosette	C	B	A	around the lug
E20-27		Unidirectional	A			Outer border of the lug
R30-38	i/o	Rosette	C	B	A	Skin panel
E40-41	i/o	Unidirectional	A			Stringer P1 and P3
FC01-08	i/o	Unidirectional	A			Fuselage clevis

1i= for the inboard strain gauge

1o= for the outboard strain gauge

Example: 16_i_B

No. 16 rosette round the lug, inboard and shear strain

Figure 5.1 **Strain Gauge locations around the lug area**

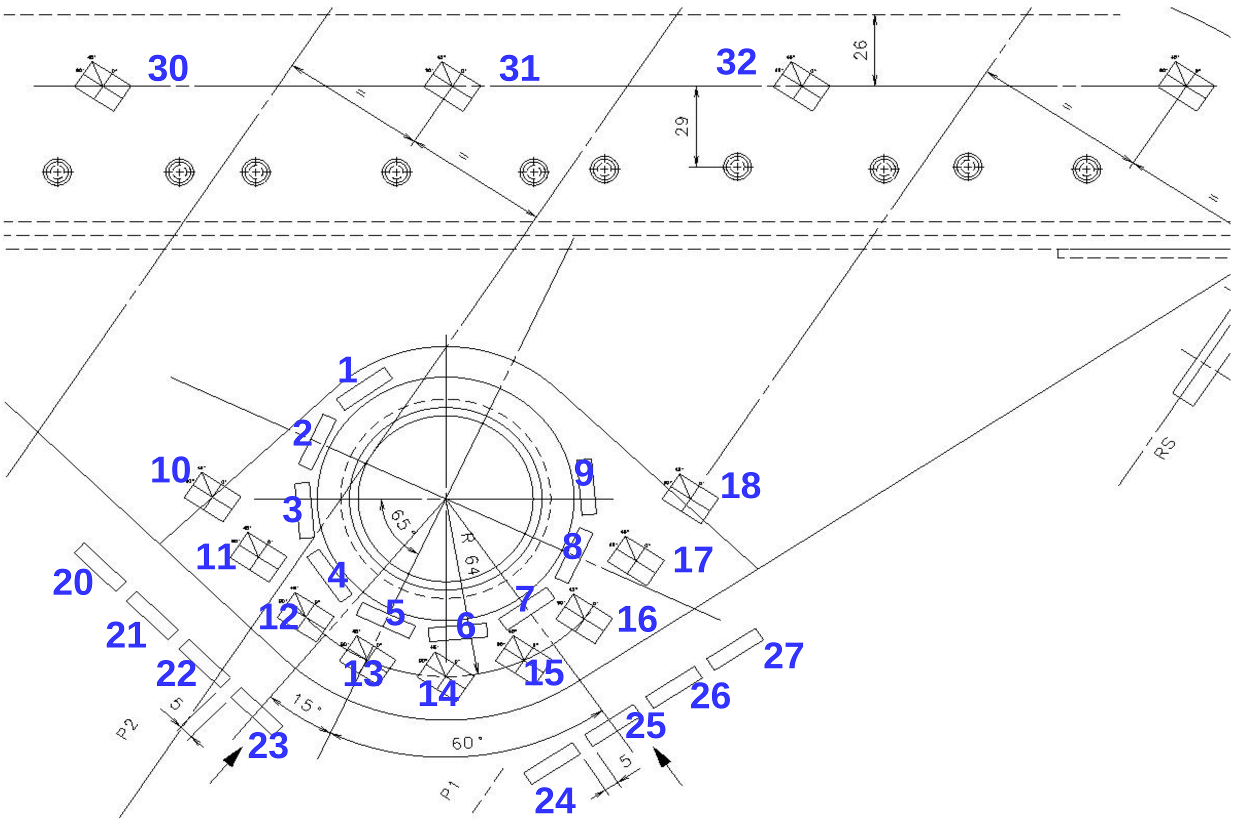
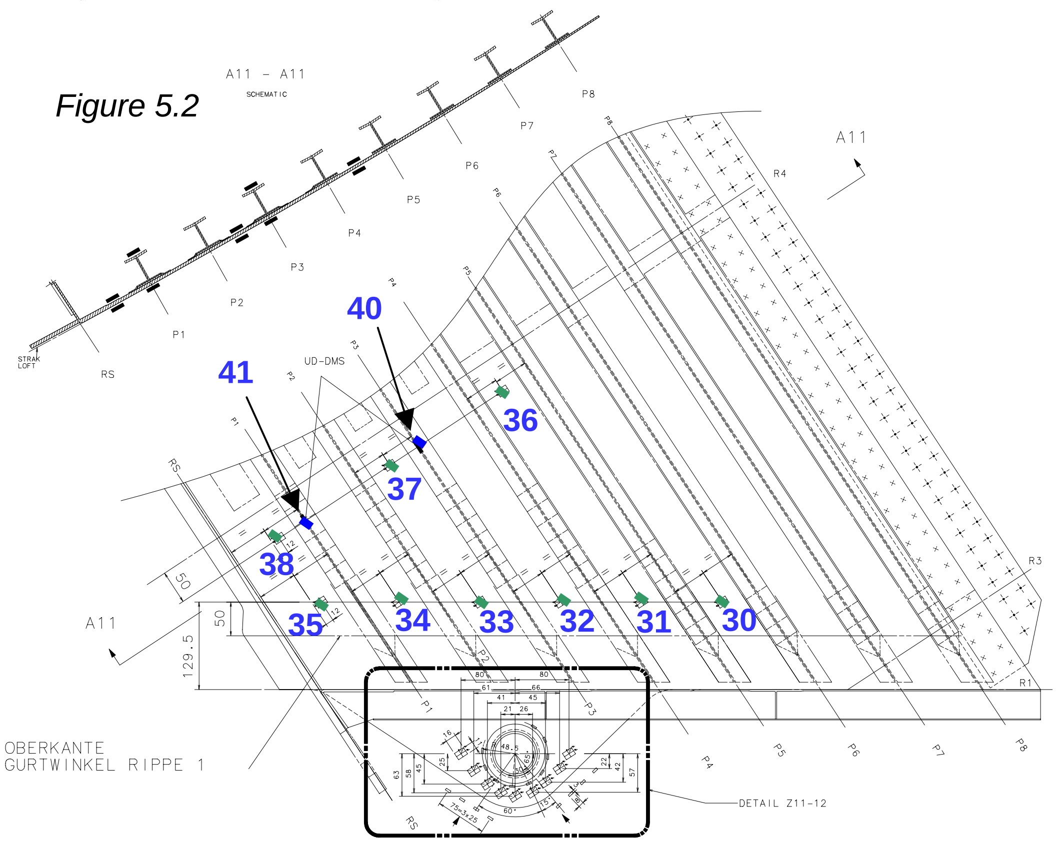


Figure 5.2



Test rig fuselage clevis strain gauge location

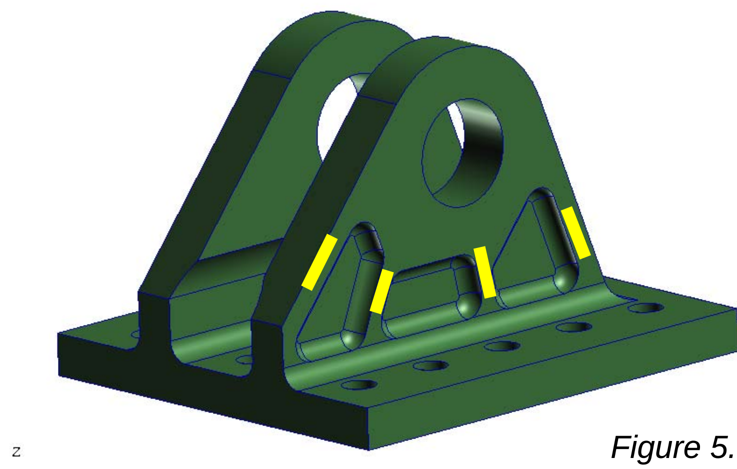


Figure 5.3

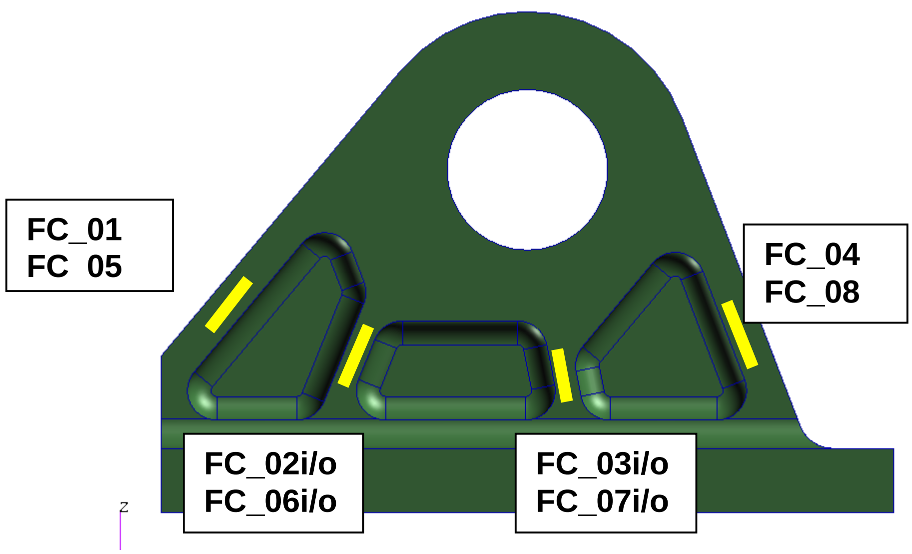


Figure 5.4

Outboard view of the test specimen Lug Test#2

Figure 5.5

6. FEA results

6.1 RHS ANSYS contact 3D model NASA W375

6.1.1 RHS rear main local lug forces & moments

Table 6.1

Fx [kN]	Fy [kN]	Fz [kN]	Fres [kN]	Mx [Nm]	Mz [Nm]	Rx [°]	Rz [°]
1	0	5	**5**	20	12	0	-0,001
-66	6	-138	**153**	-1100	179	-0,063	0,008
-127	11	-273	**302**	-2006	366	-0,132	0,018
-188	16	-411	**452**	-2865	545	-0,203	0,034
-248	22	-551	**605**	-3694	714	-0,275	0,05
-309	28	-694	**761**	-4501	876	-0,345	0,067
-371	34	-841	**919**	-5281	1032	-0,415	0,084

Rx/Rz bolt rotation in relation to rib 1

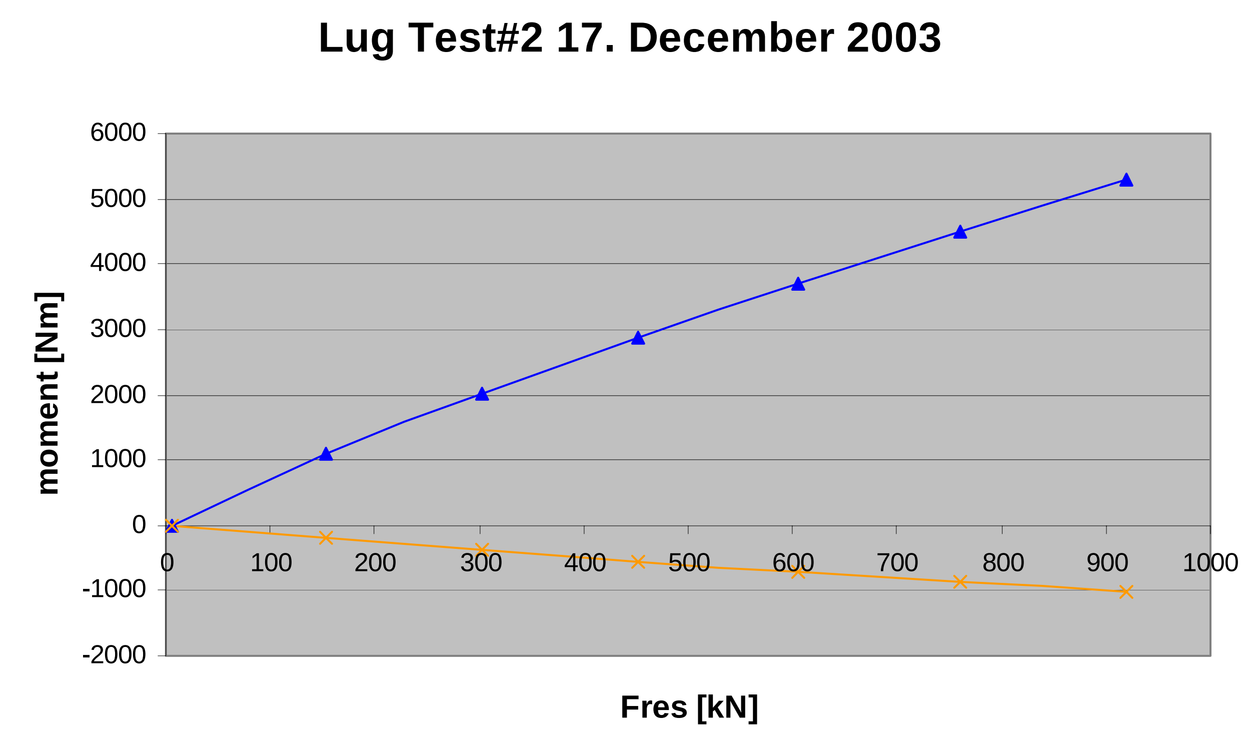


Diagram 6.1

6.1.2 Deformation & Rx bolt rotation

The cross section through the CFRP lug, the bolt and the fuselage fitting illustrate the connection bolt contact situation under max. applied loading condition (see figure 6.1 and 6.2). The color scale is von Mises equivalent stress distribution.

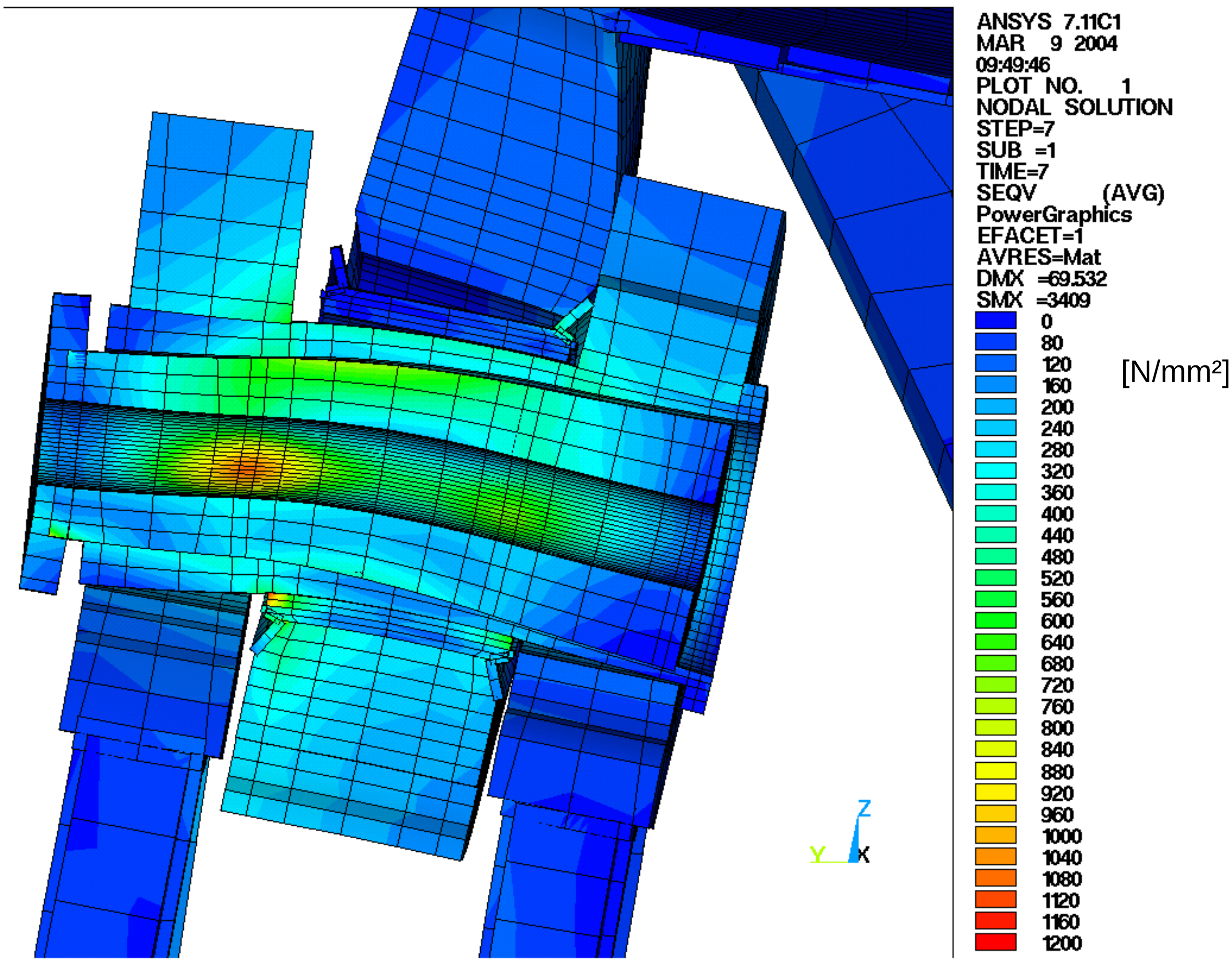


Figure 6.1

Deformations are scaled up for a better understanding of the structure behaviour!

Bolt Rx rotation

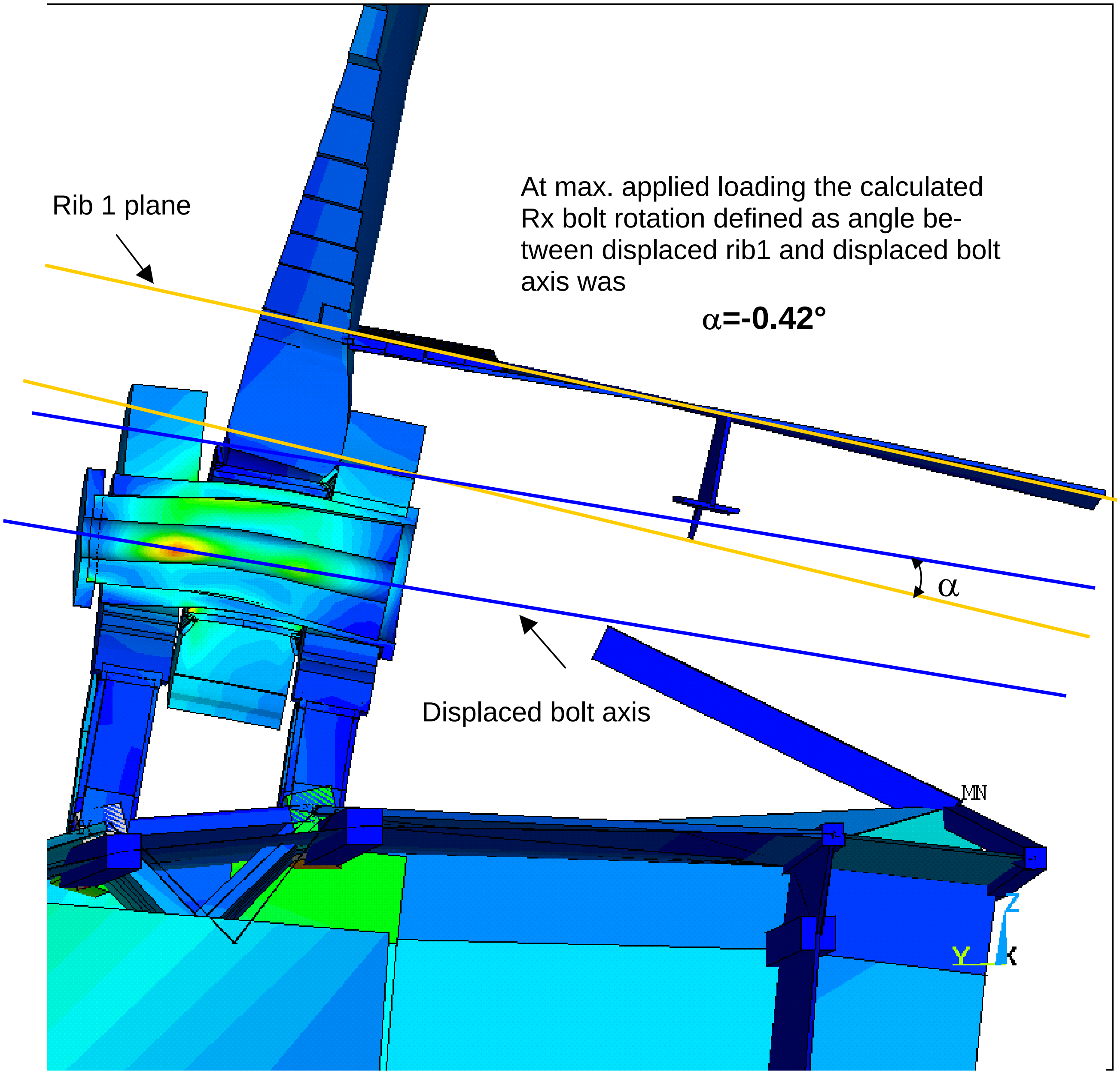
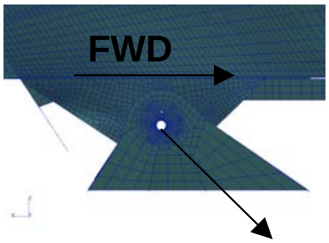


Figure 6.2

Deformations are scaled up for a better understanding of the structure behaviour.

6.1.3 Strain distribution at the pin hole



Fres=919kN

RHS model

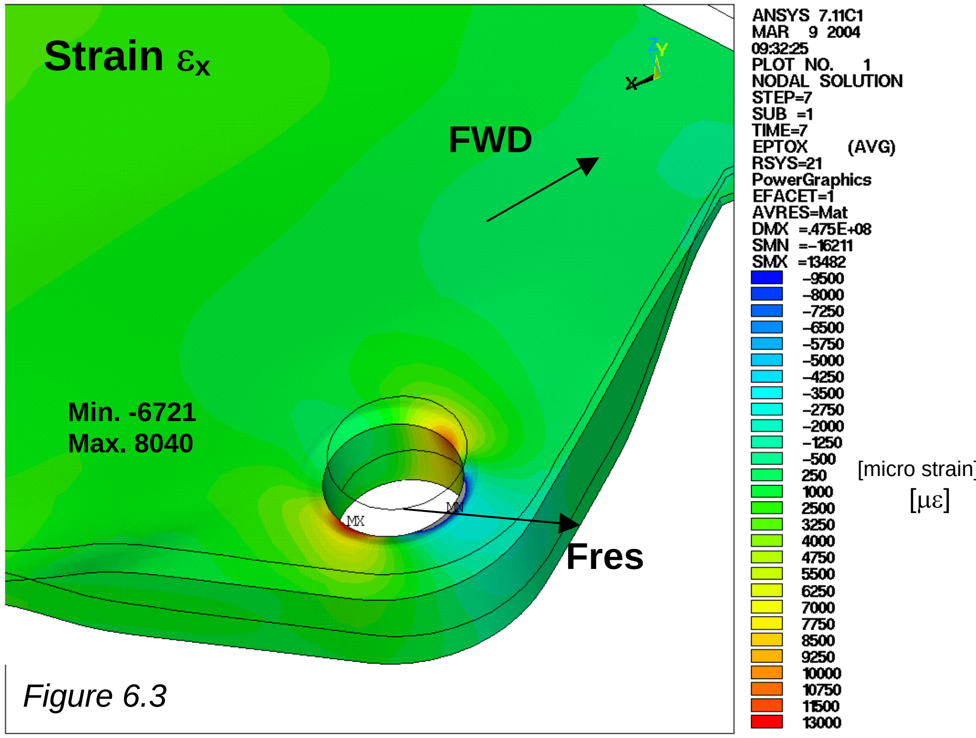


Figure 6.3

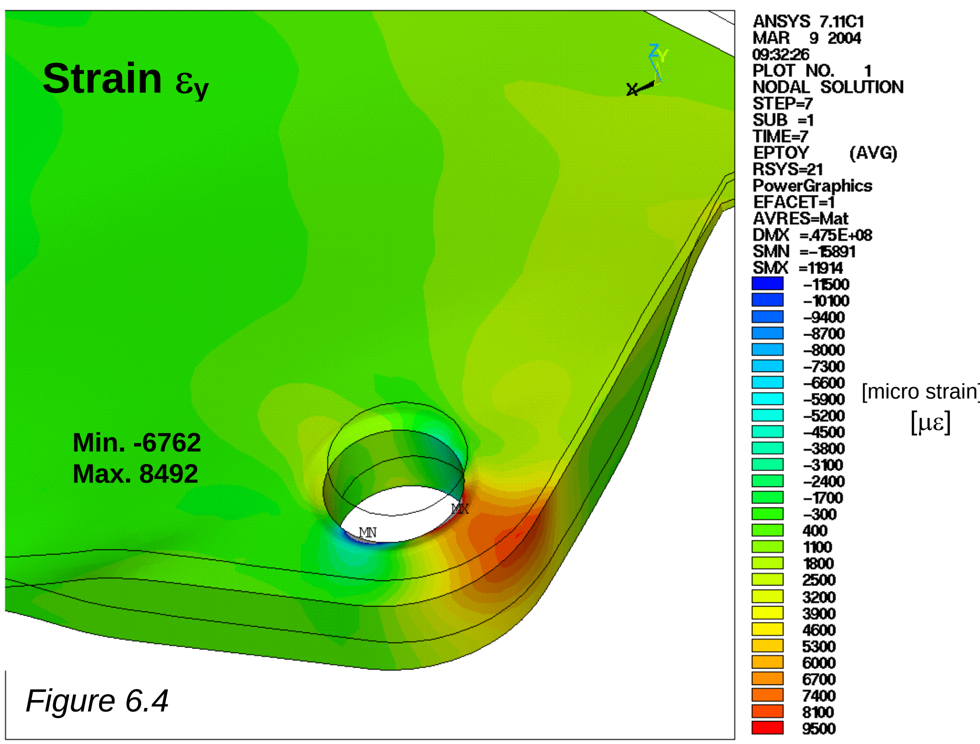
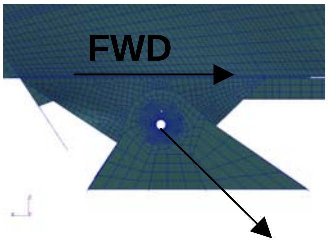


Figure 6.4

MIN / MAX strain values consider only the strain distribution outside the countersink area

All views from outboard
Strain distribution in material coordinate system



Fres=919kN

RHS model

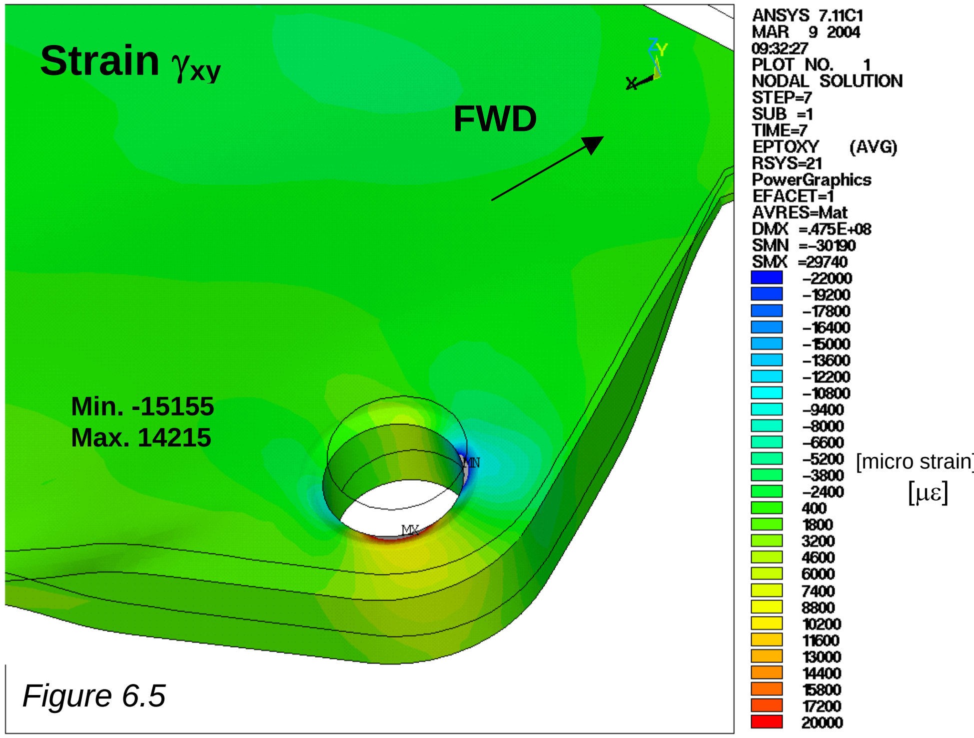


Figure 6.5

Strain$_{tangential}$
Cylinder coordinate system in the bolt axis

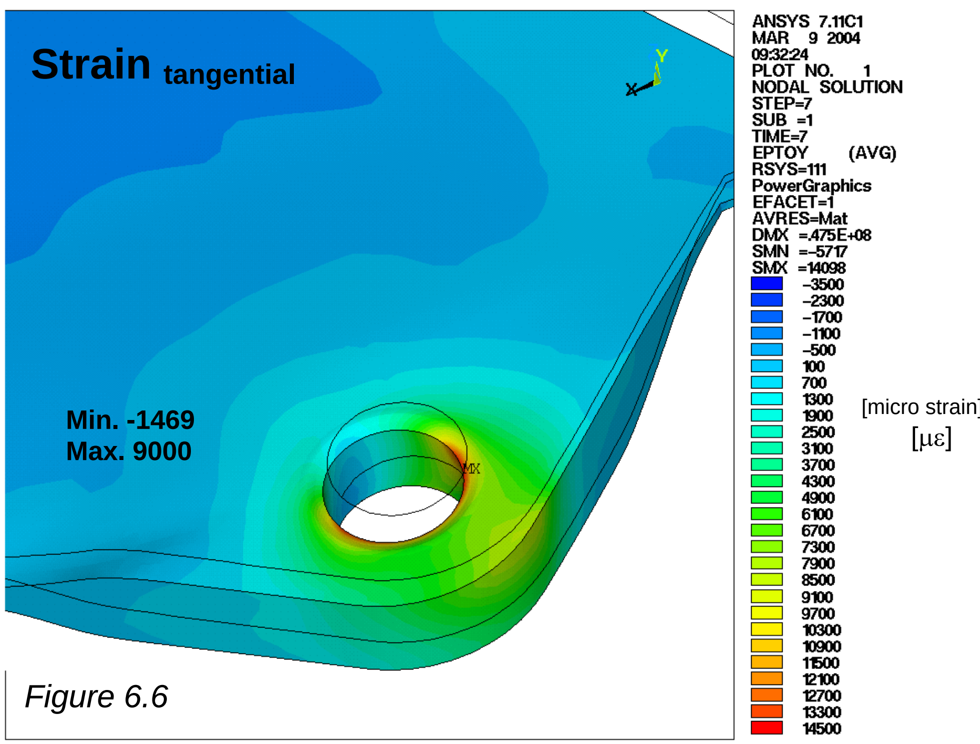


Figure 6.6

MIN / MAX strain values consider only the strain distribution outside the countersink area

All views from outboard
Strain distribution in material coordinate system

6.2 LHS ANSYS contact Lug Test#2 NASA W375 MOD Rx=0.45°

6.2.1 Rear main local lug forces & moments

Table 6.3

Fx [kN]	Fy [kN]	Fz [kN]	Fres [kN]	Mx [Nm]	Mz [Nm]	Rx [°]	Rz [°]
0	0	0	**0**	1882	-124	0,445	0
-80	-8	-173	**191**	2239	-3	0,444	0
-160	-17	-346	**381**	2715	-70	0,442	-0,001
-240	-25	-518	**572**	3144	-101	0,441	-0,001
-320	-34	-691	**762**	3525	-124	0,44	-0,002
-400	-42	-864	**953**	3855	-140	0,44	-0,002

Rx/Rz bolt rotation in relation to rib 1

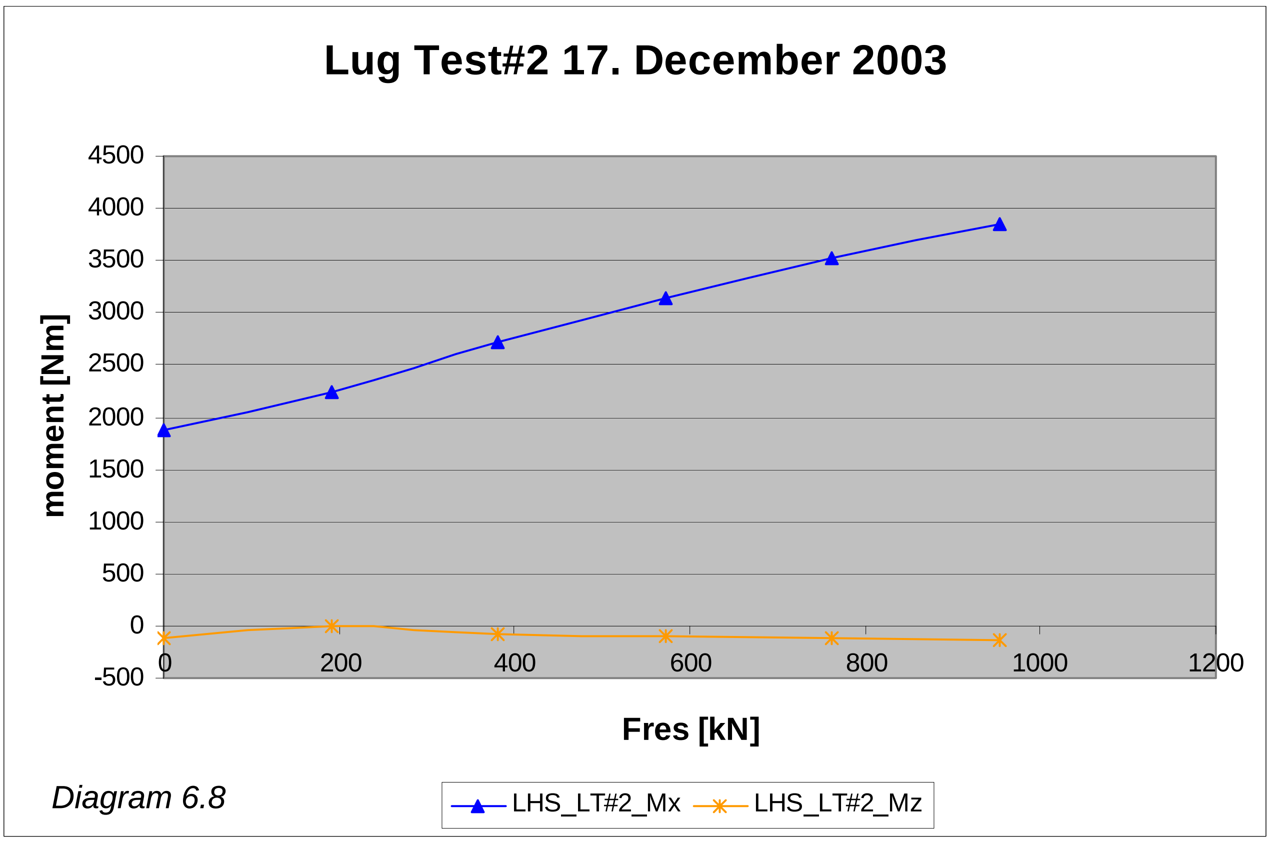


Diagram 6.8

6.2.2 Deformation & Rx bolt rotation

The cross section through the CFRP lug, the bolt and the fuselage fitting illustrate the connection bolt contact situation under max. applied loading condition (see figure 6.7 and 6.8). The color scale is von Mises equivalent stress distribution.

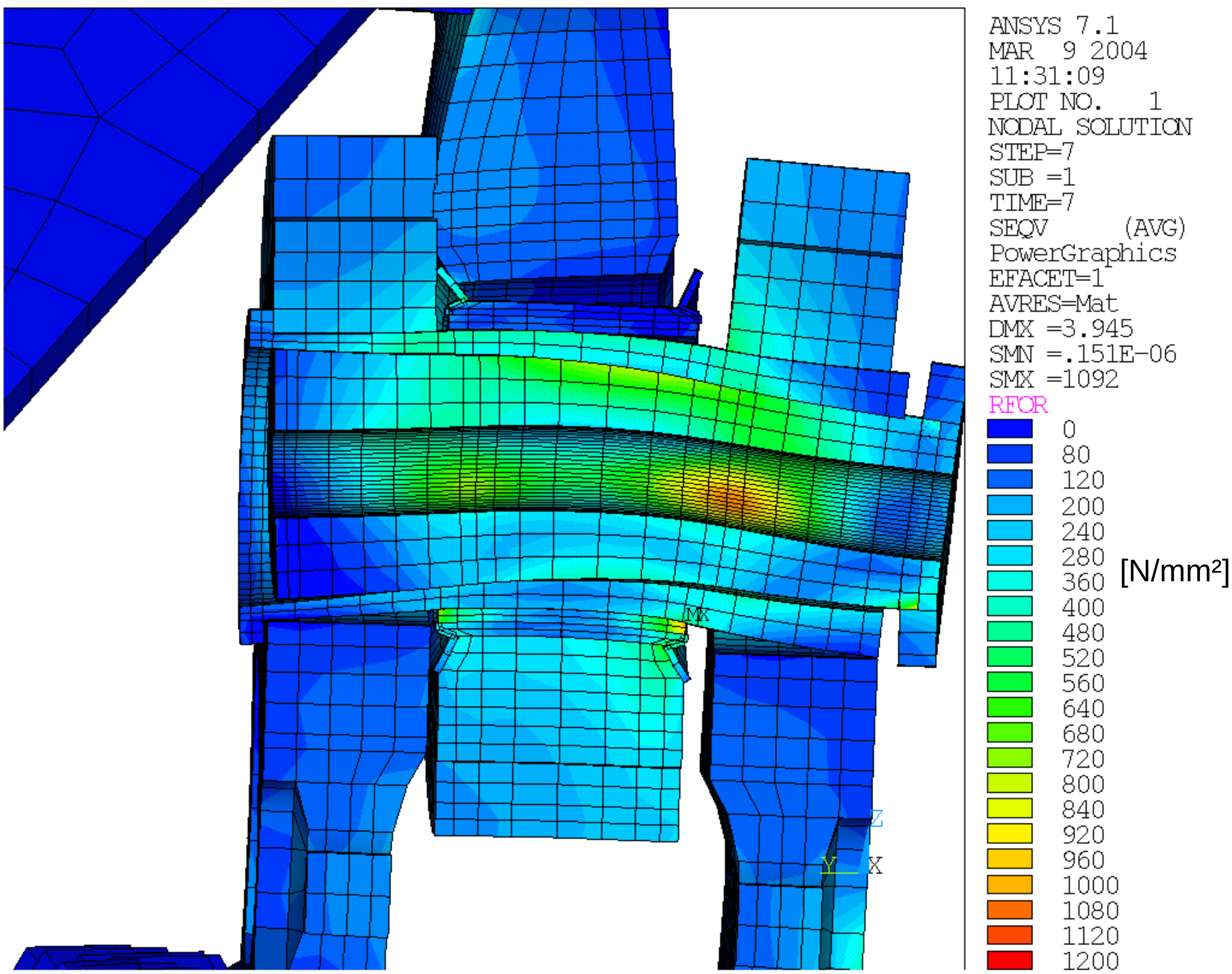


Figure 6.7

Deformations are scaled up for a better understanding of the structure behaviour.

Rx bolt rotation

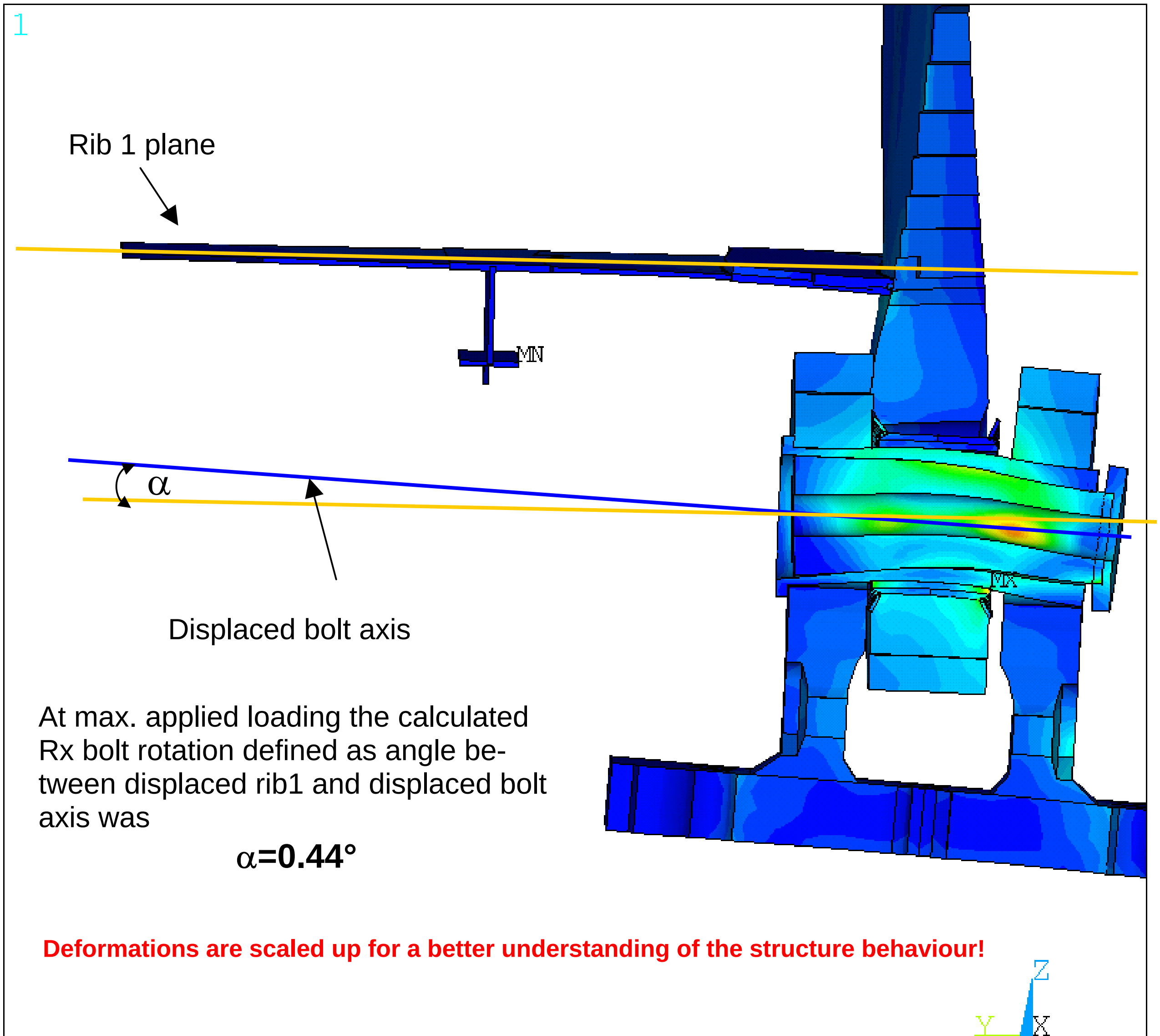
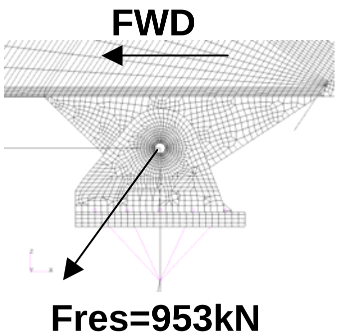


Figure 6.8

6.2.3 Strain distribution at the pin hole



LHS model

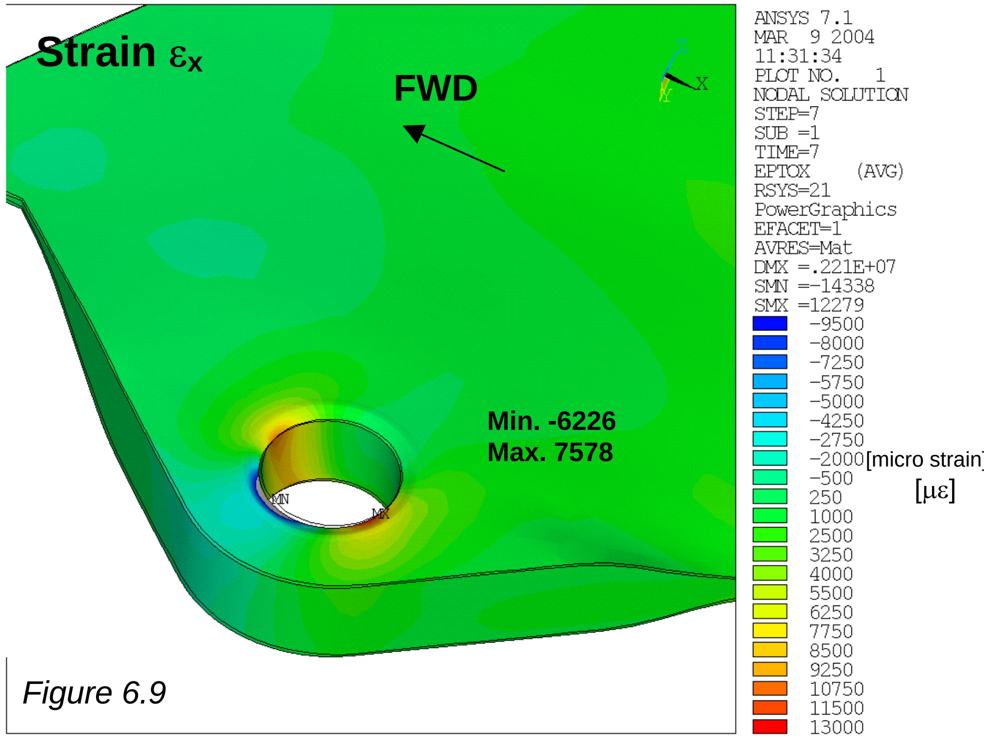


Figure 6.9

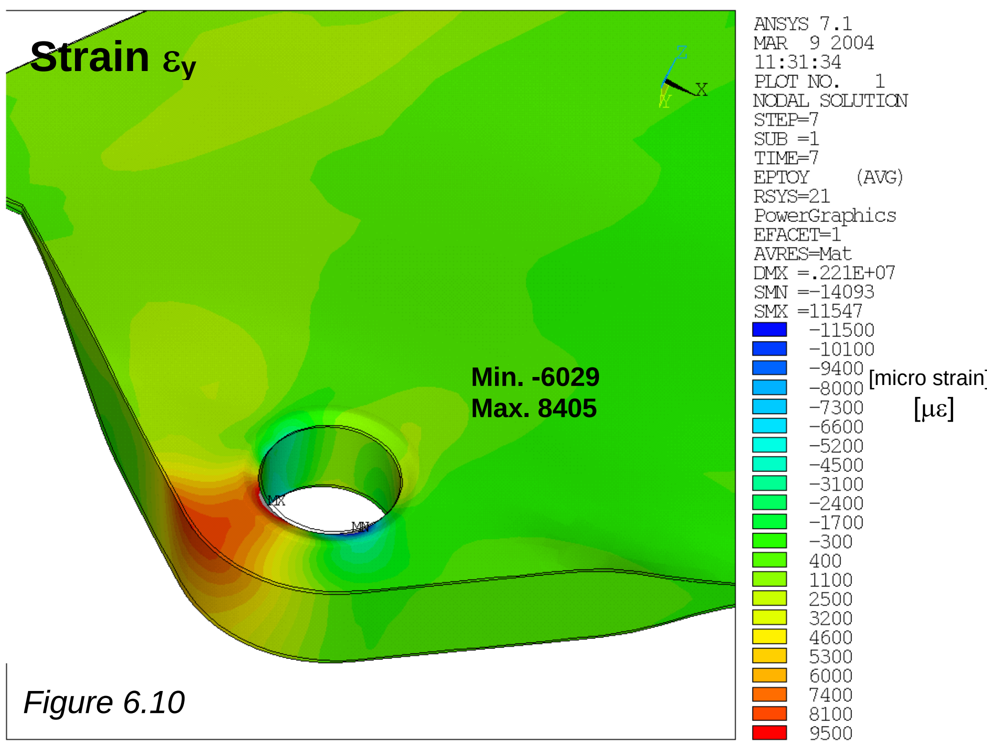
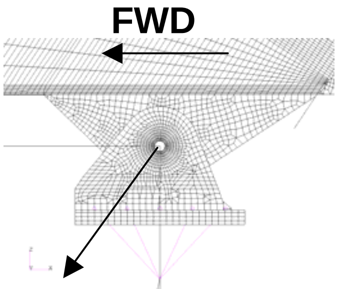


Figure 6.10

MIN / MAX strain values consider only the strain distribution outside the countersink area

All views from outboard
Strain distribution in material coordinate system



LHS model

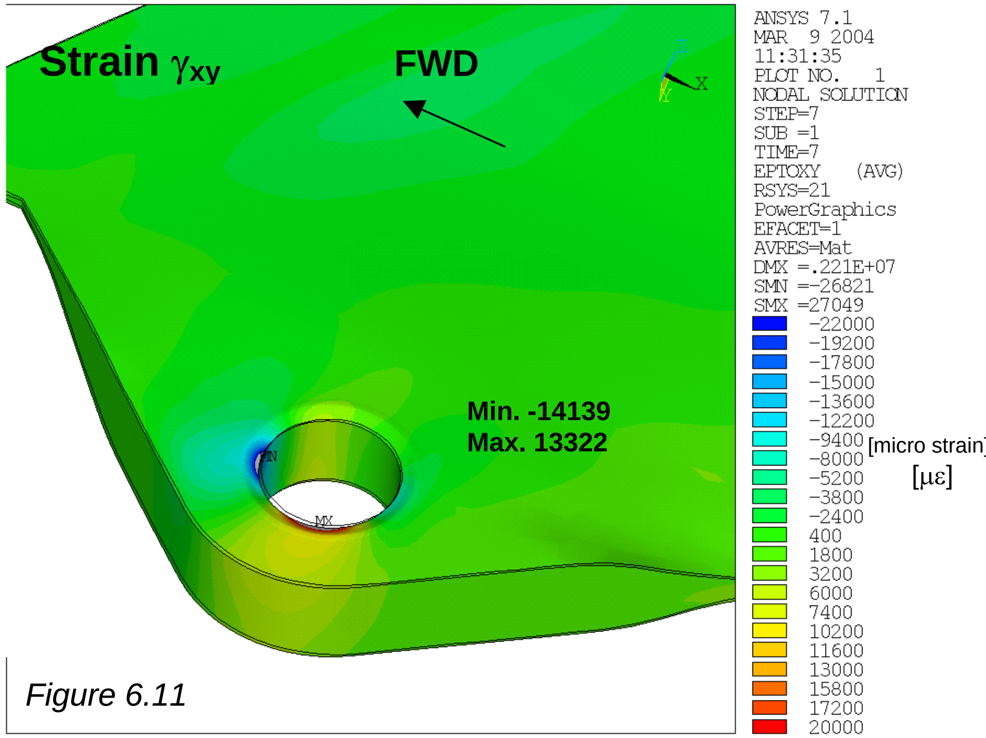


Figure 6.11

Strain$_{\textbf{tangential}}$
Cylinder coordinate system in the bolt axis

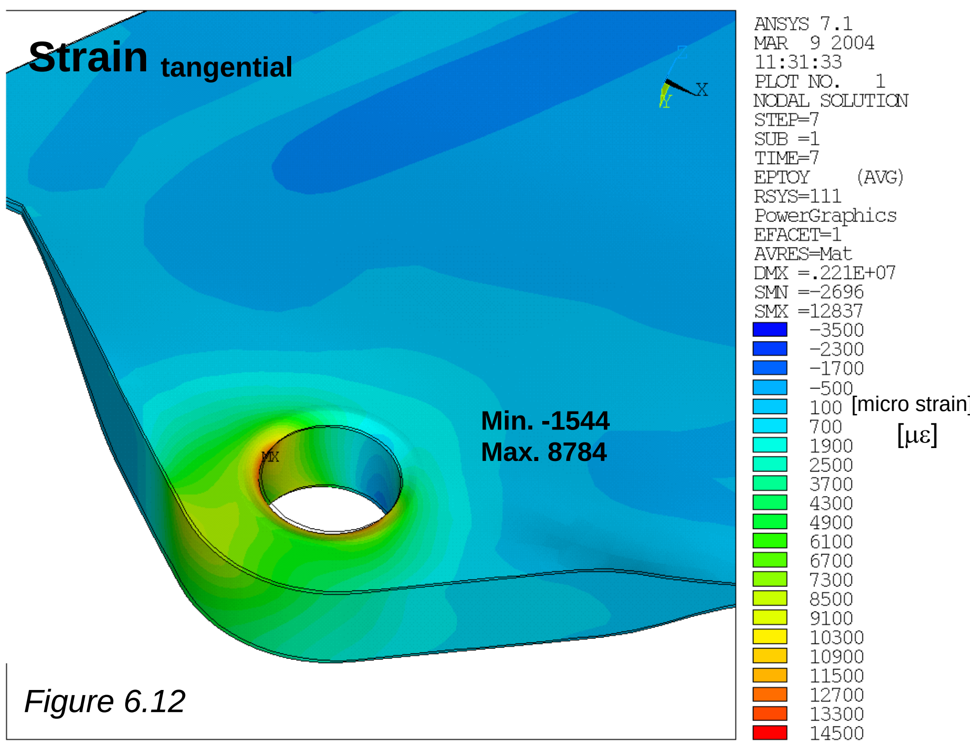


Figure 6.12

MIN / MAX strain values consider only the strain distribution outside the countersink area

All views from outboard
Strain distribution in material coordinate system

6.3 Comparison of the contact status & pressure between the two models

To compare the contact surfaces of the ANSYS analysis a settlement of the circumferential surface was chosen. The three main contact surfaces, bushing to CFRP and both fuselage clevis contact surfaces are shown.

The direction of the resultant force Fres is the start point for the settlement of the 2D-plots. From this line the 2D-plot is a settlement of 180°-degree in both direction. The following figures 6.13 to 6.19 illustrates the contact surface settlement.

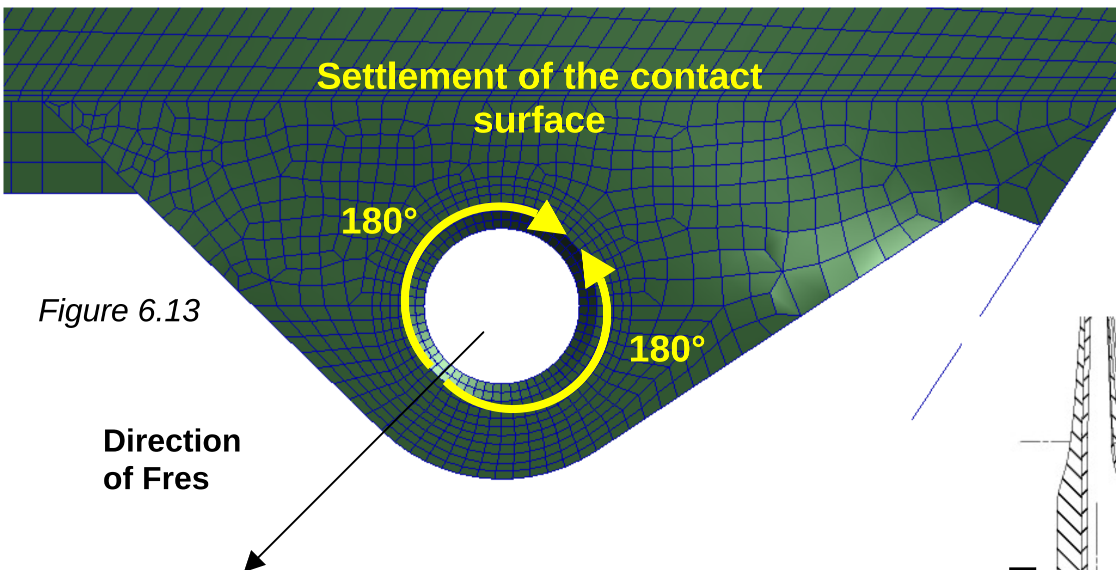


Figure 6.13

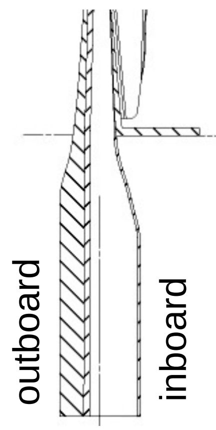


Figure 6.14

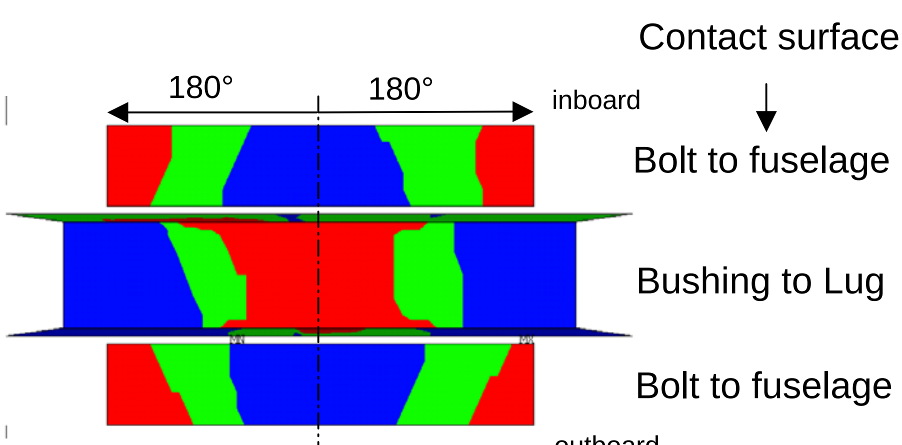


Figure 6.15

Contact Status for	RHS ANSYS contact 3D model NASA W375

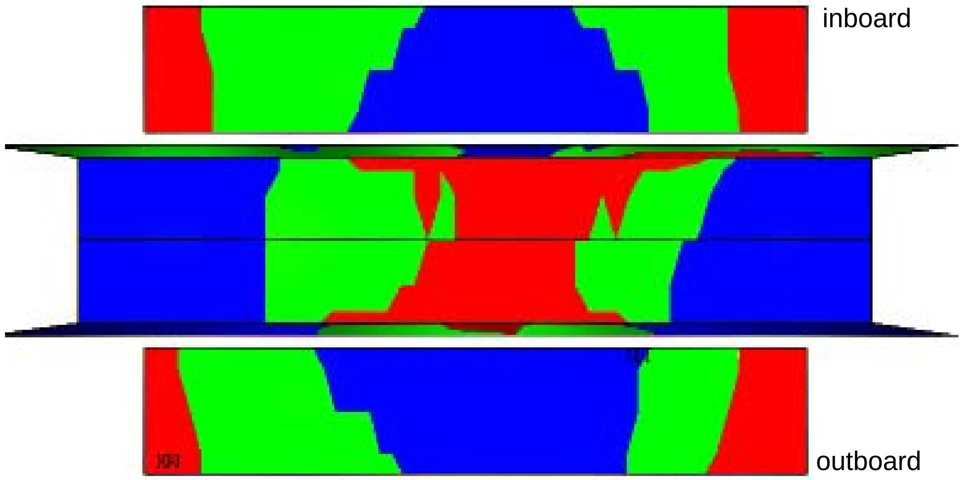
Contact surface

↓

Bolt to fuselage

Bushing to Lug

Bolt to fuselage



inboard

outboard

Figure 6.16

Contact Status for	LHS ANSYS contact Lug Test#2 NASA W375 MOD Rx=0.45°

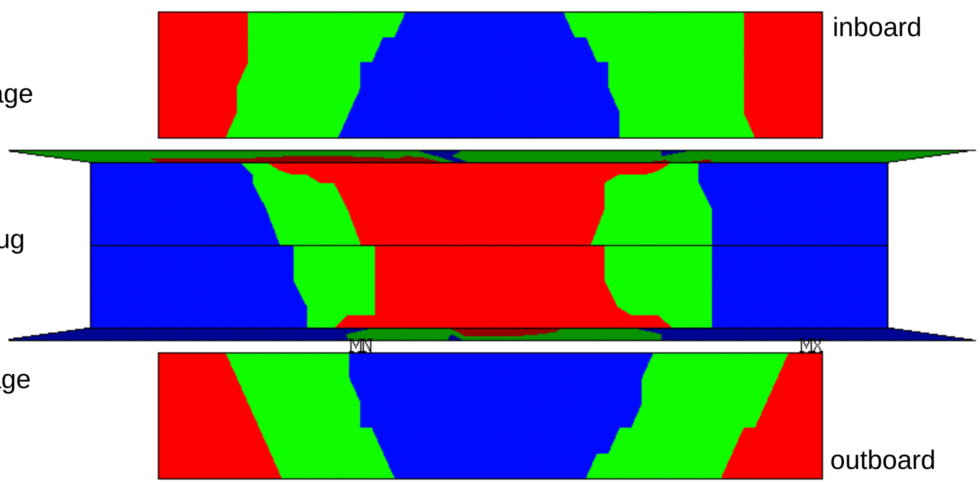
Contact surface

↓

Bolt to fuselage

Bushing to Lug

Bolt to fuselage



inboard

outboard

Figure 6.17

RED + **GREEN** = contact closed **BLUE** = gap

Contact Pressure for	RHS ANSYS contact 3D model NASA W375

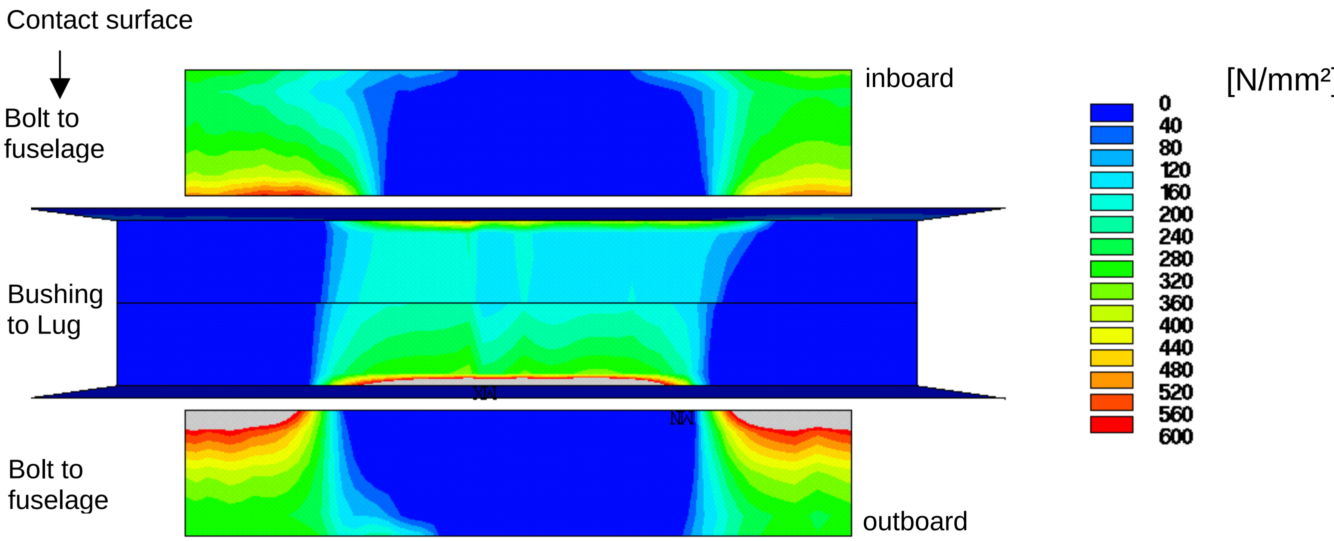


Figure 6.18

Contact Pressure for	LHS ANSYS contact Lug Test#2 NASA W375 MOD Rx=0.45°

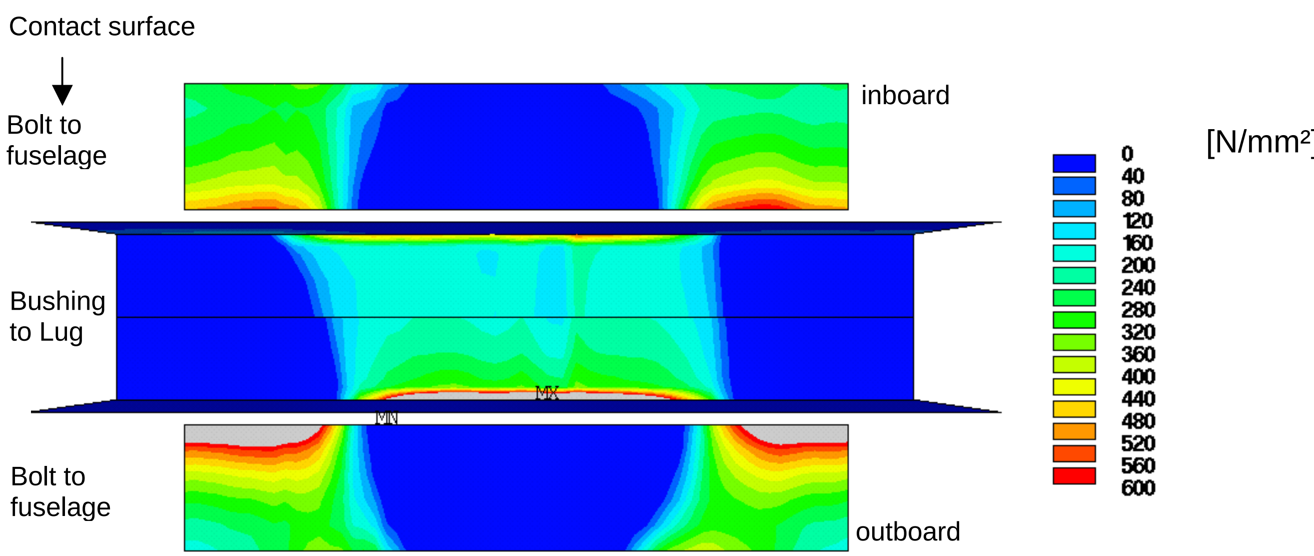


Figure 6.19

7. Test results Lug Test#2 W375 MOD Rx=0.45°

7.1 Lug Test#2 failure pictures

The figures 7.1 to 7.4 show the Lug Test#2 specimen after the test with all strain gauges removed and the fracture line is visible.

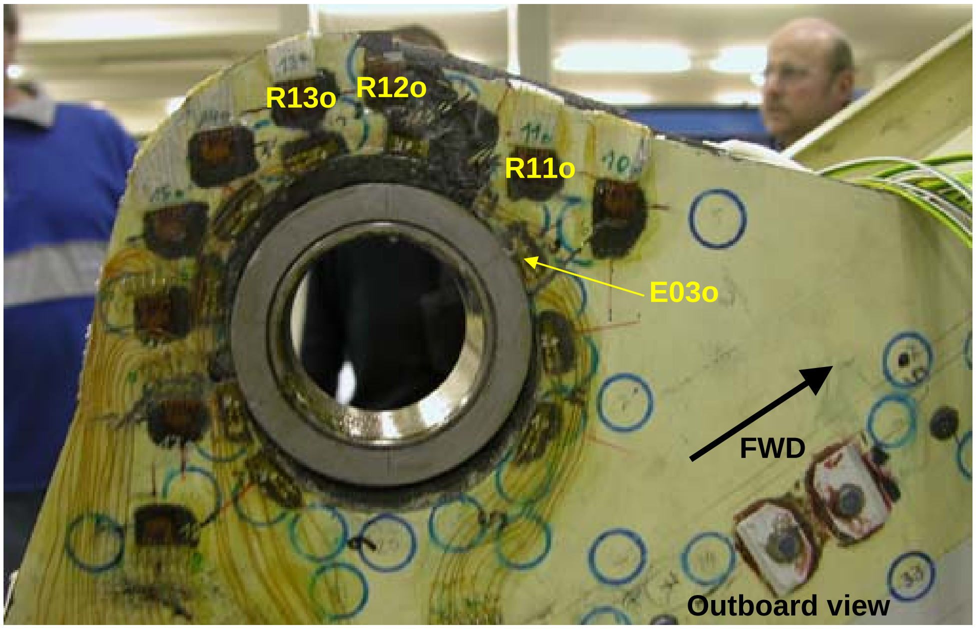


Figure 7.1

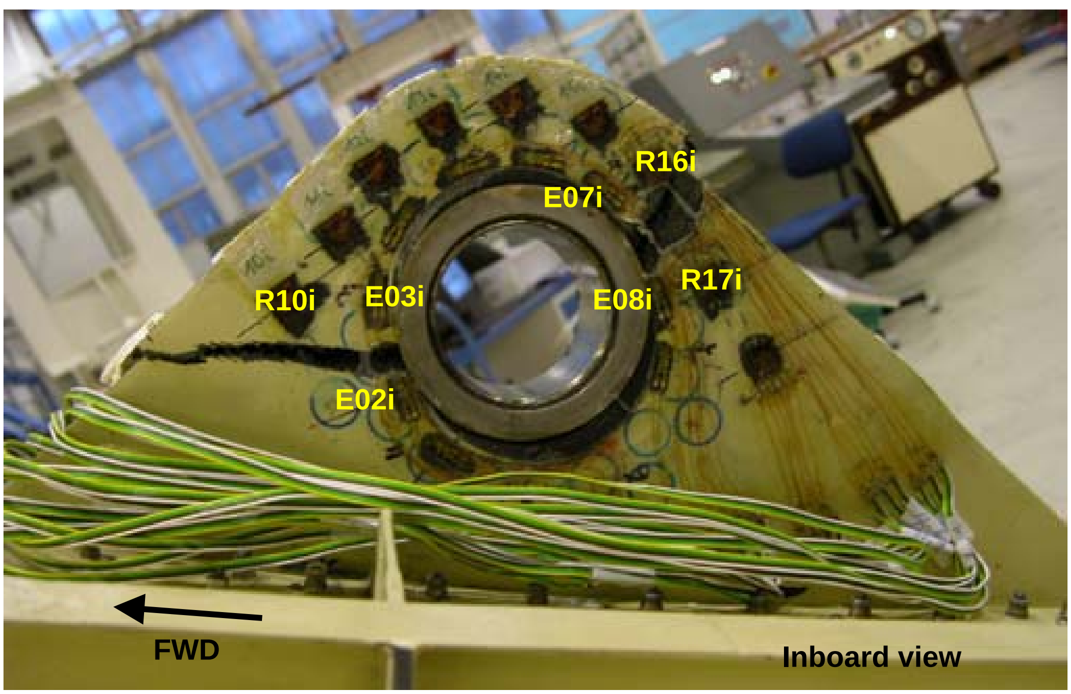


Figure 7.2

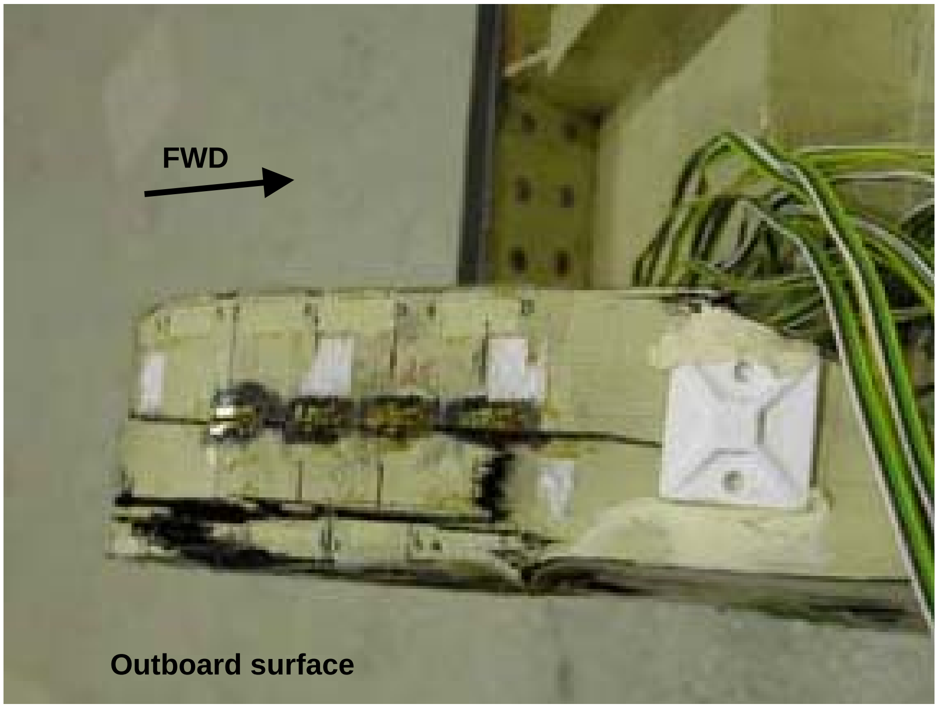


Figure 7.3

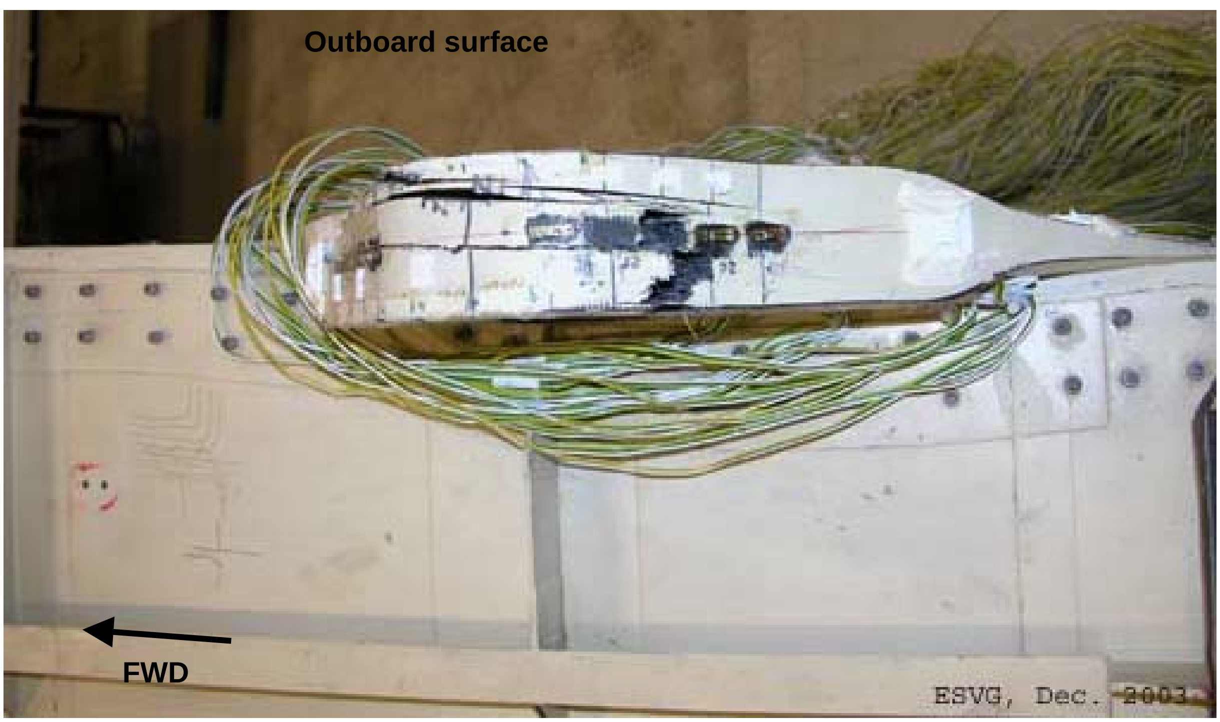


Figure 7.4

7.2 Lug Test#2 Failure load

The load vector according to chapter 4 was applied to the test specimen. After load step 150 the loads increased continuously and achieved a residual strength of Fres=893kN. The reached load level corresponds to 191 percent of the A300-600 limit load design gust vector BI17 (Basis was the Global FE-Model without embedded 3D rear main lugs Fres=469kN).
The max. load vector is shown in table 7.1.

Table 7.1

Lug Test#2 (17. December 2003)		
Component		Rupture value
Fx	[kN]	-373
Fy	[kN]	-35
Fz	[kN]	-811
Fres	[kN]	**893**

7.3 Lug Test#1 Failure Load

Lug Test#1 (13. August 2003)		
Component		Rupture value
Fx	[kN]	-381.6
Fy	[kN]	-39.1
Fz	[kN]	-822.5
Fres	[kN]	**907**

7.4 Measured Forces

The measured forces (see diagram 7.1) from the Lug Test#2 load cells are identical to the applied forces of the FE-Analysis. In lateral direction a Wy displacement was applied during the test sequence as described in chapter 4. The Fy force represents the lateral reaction force generated by the Wy displacement.

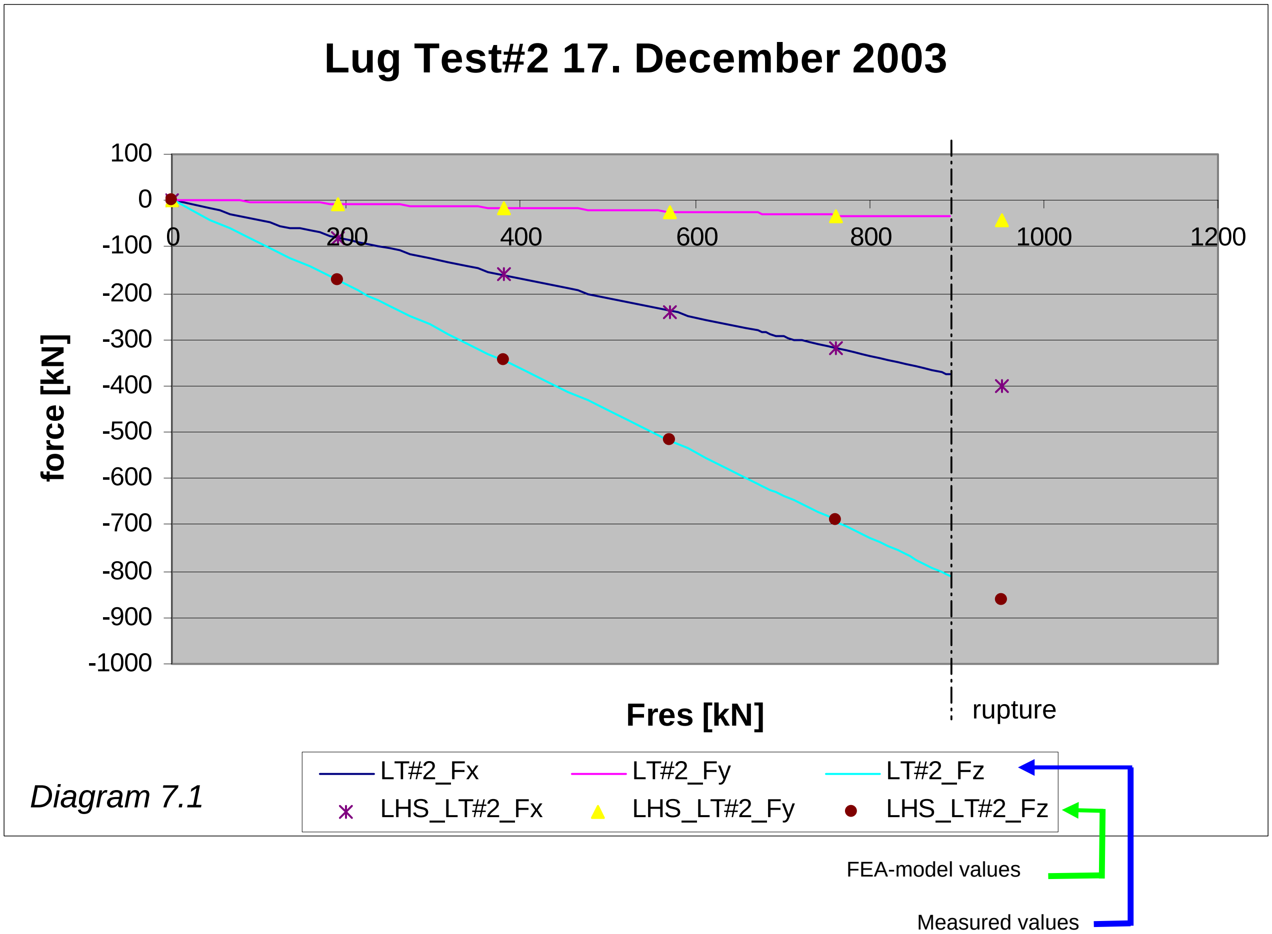


Diagram 7.1

8. Lug Test#2 Result Comparison

8.1 Local lug moments and bolt Rx rotation

The local lug moments Mx and Mz are calculated taking into account the equations described in chapter 2.3.

The calculated moments are shown in diagram 8.1.

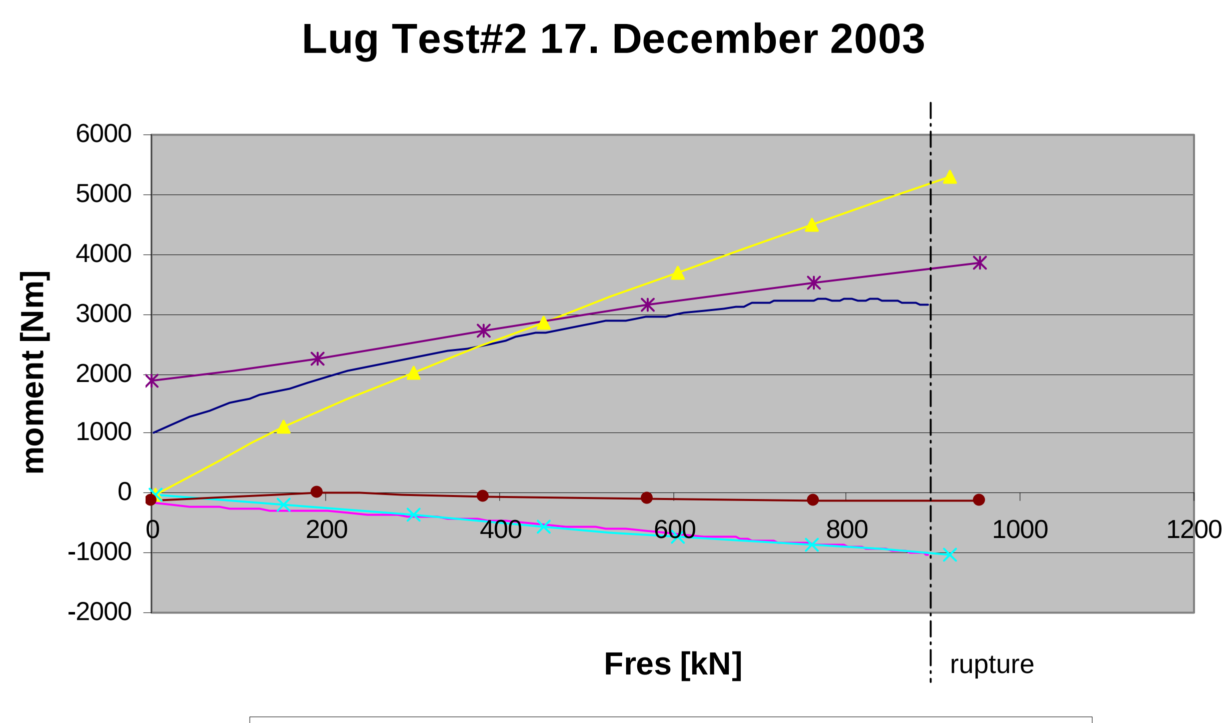


Diagram 8.1

The bolt Rx rotation shown in diagram 8.2 is calculated with the two displacement transducers DZ3/4 in z-direction behind the fuselage clevis test rig structure (Y=±300mm).

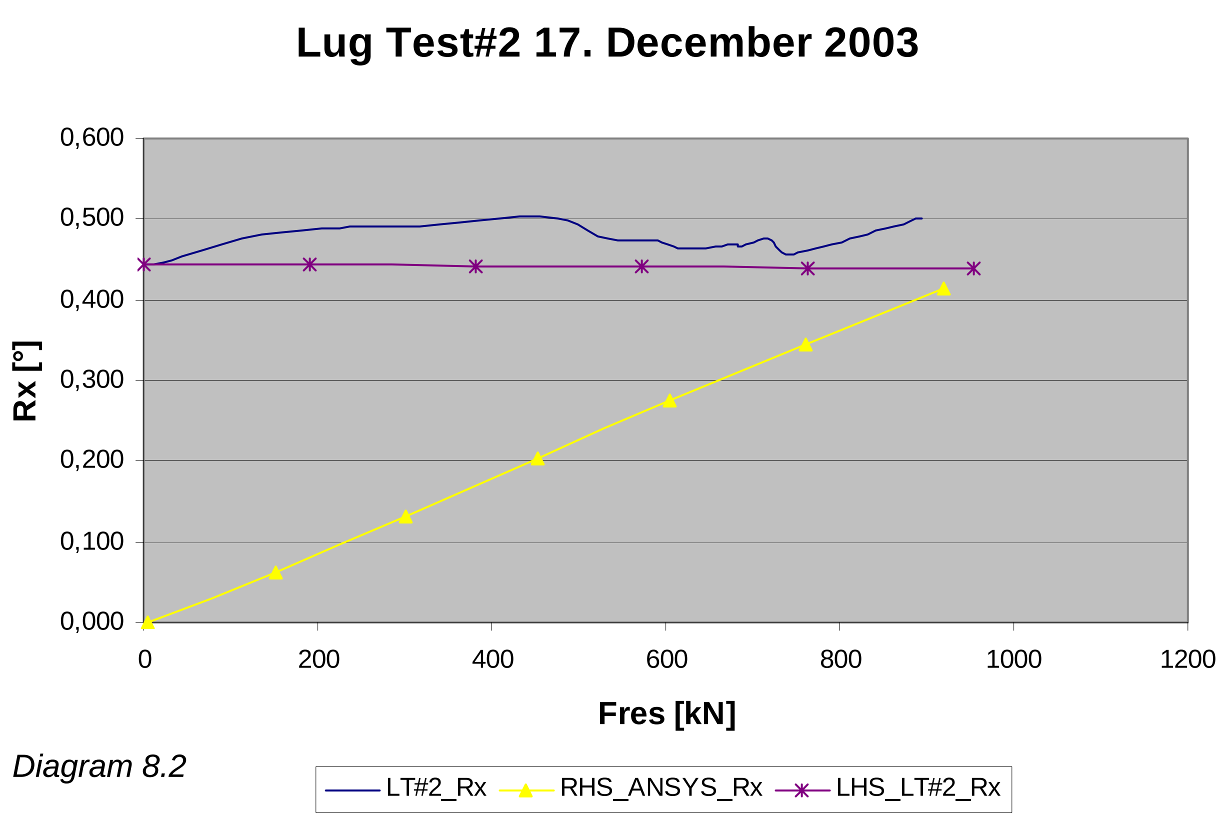
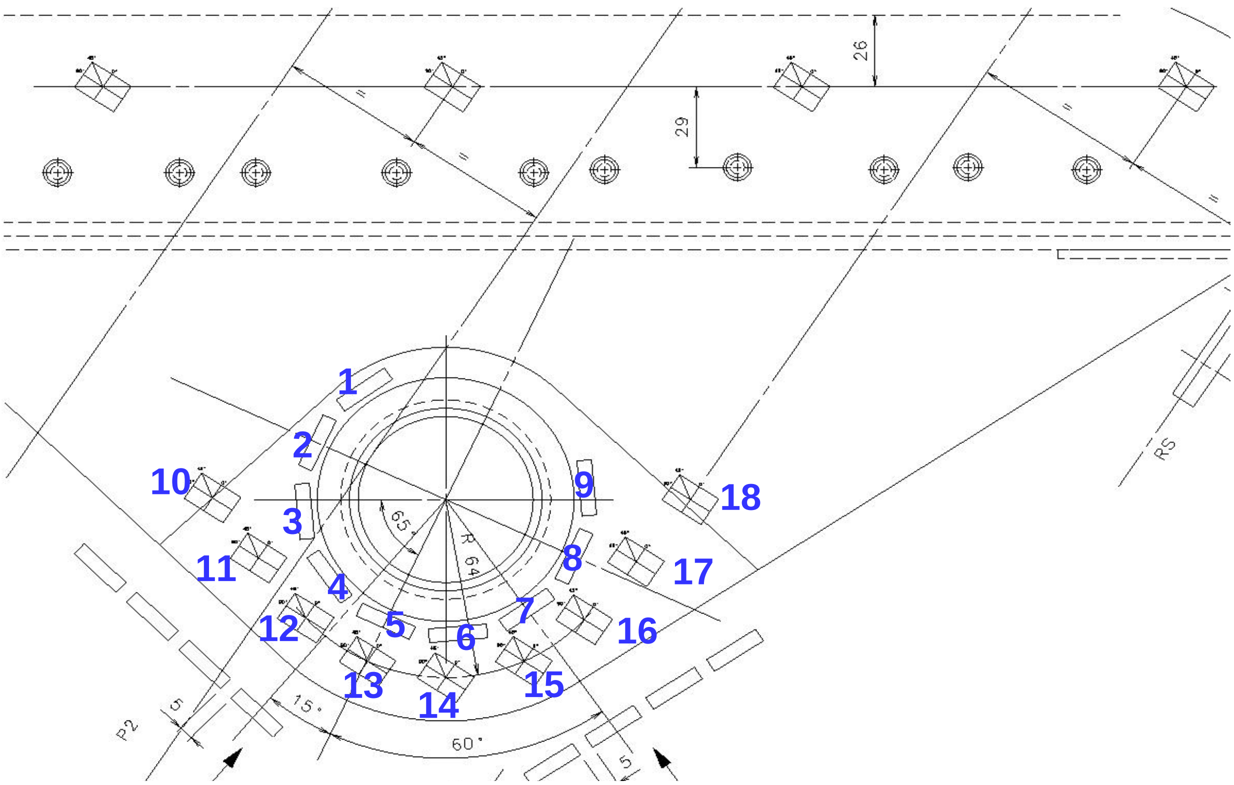


Diagram 8.2

8.2 Strain Result Comparison

For the inboard and outboard faces of the lug the tangential strains from the gauges E01 to E09 and the maximum principal strains from the rosettes R10 to R18 are plotted together with the calculated values from the LHS subcomponent test analysis in fig. 8.3 to 8.6 for a resultant load of Fres = 890 kN (the measured values are taken from the nearest load step and are not interpolated).



The measured strain values of the **Lug Test#2 specimen** are compared to

- Lug Test#1 specimen
- RHS ANSYS nonlinear contact model (Vertical stabilizer attached to the fuselage)
- LHS ANSYS nonlinear contact Lug Test#2 Rx=0.45°

The appendix of this report includes diagrams for all the strain gauges in the Lug Test#2 which are compared to the above mentioned FEA models.

Diagram 8.3 **E01o to E09o (Unidirectional / Outboard)**

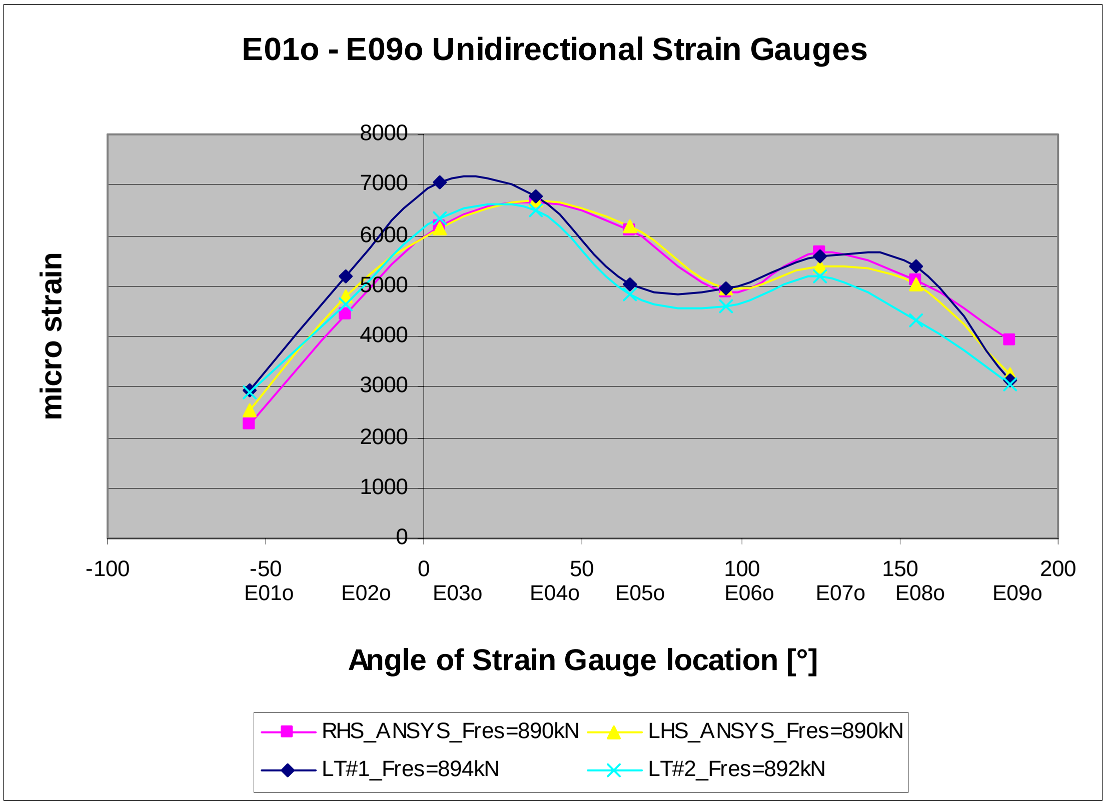


Diagram 8.4 **E01i to E09i (Unidirectional / Inboard)**

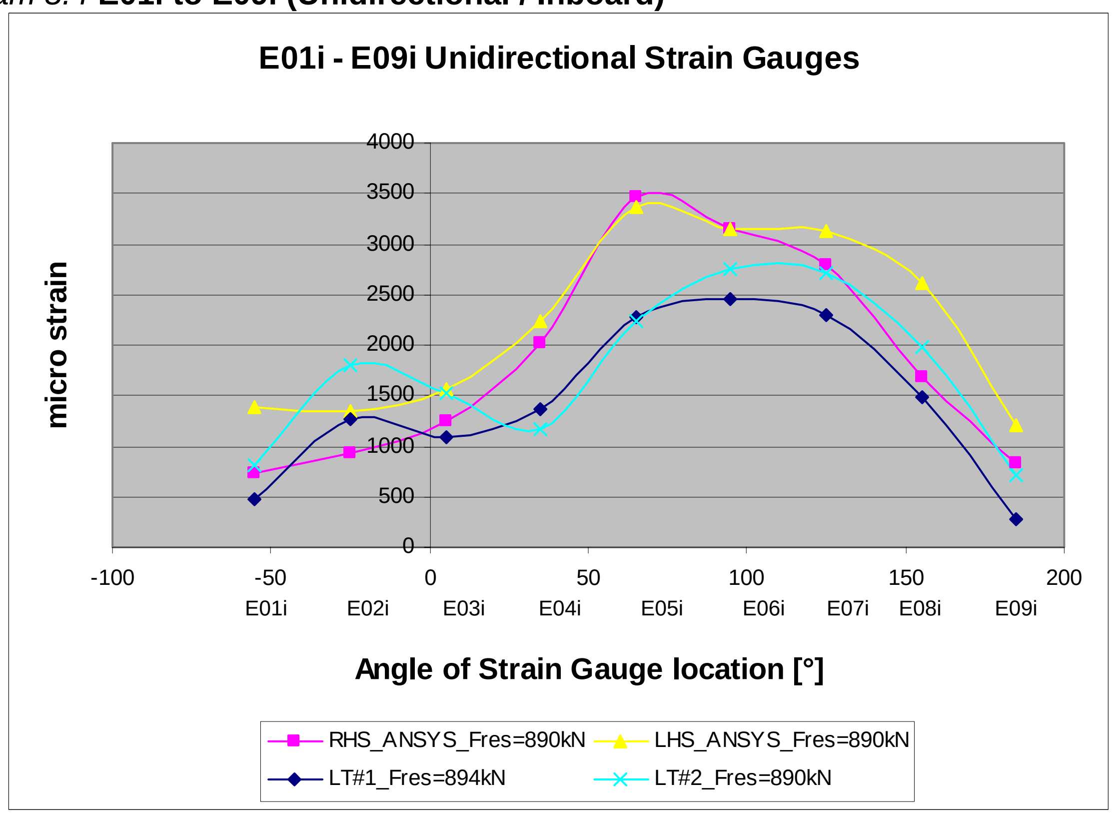


Diagram 8.5 **R10o to R18o (Rosettes / SN1 principle strain / outboard)**

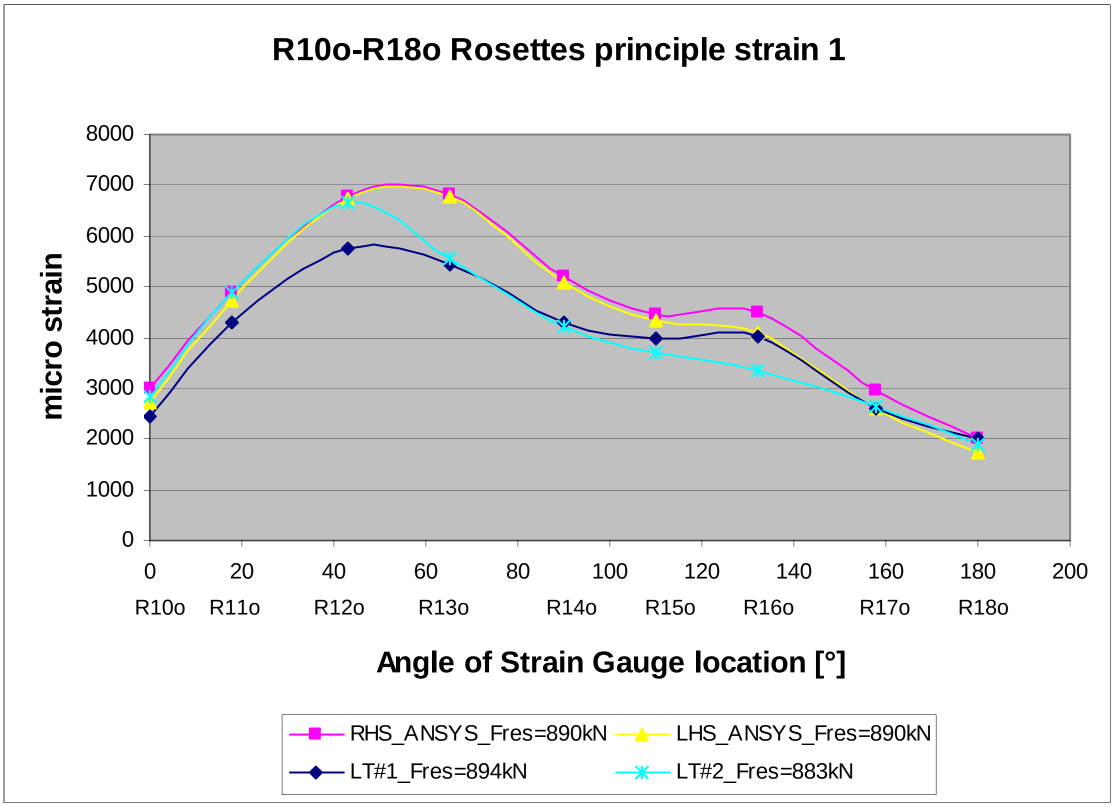
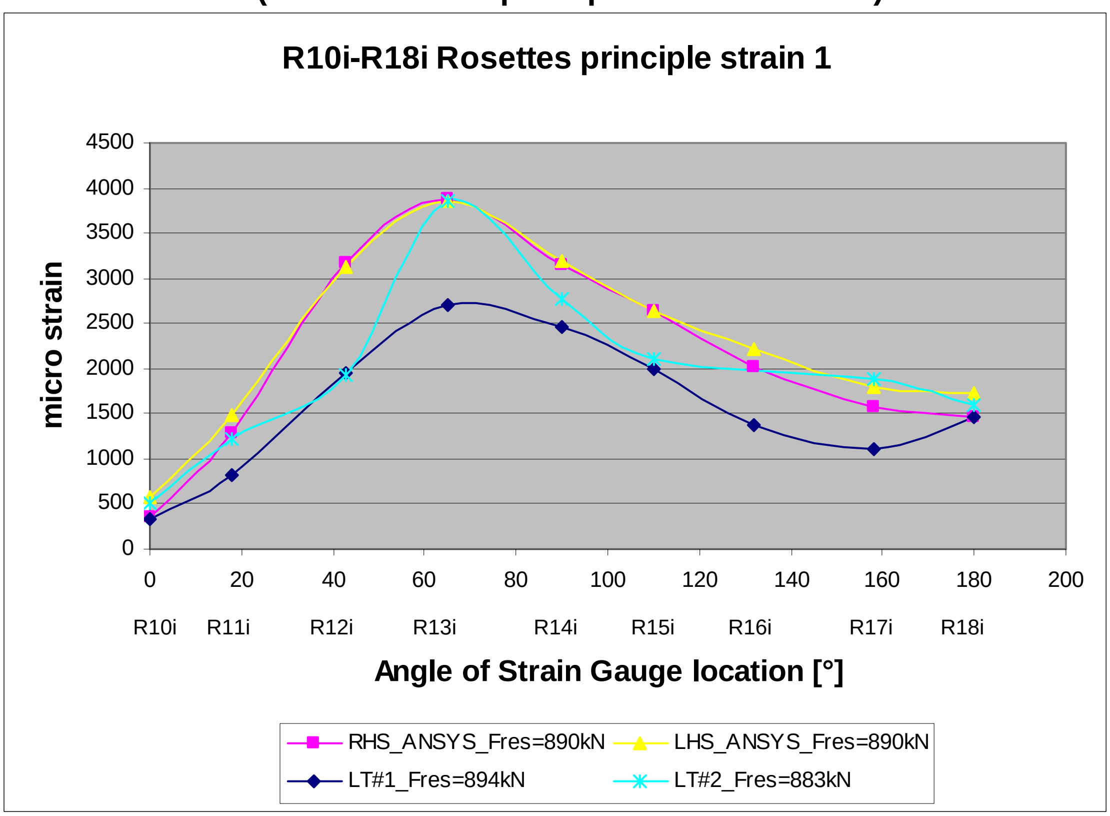


Diagram 8.6 **R10i to R18i (Rosettes / SN1 principle strain / inboard)**



9. Summary

The objective of this report is to demonstrate, that the test principles which are applied to the subcomponent tests are suitable to represent the behaviour of the RHS rear lug during the accident of flight AAL587.

This has been shown by validation of the subcomponent test analysis model results with the measured strains from the tested lugs and the comparison of the calculated strains from the global/local FEA.

The calculated strains are in good agreement with the measurements from strain gauges applied to the test parts around the pin hole.