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

December 5, 2003

ADDENDUM NUMBER 7 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 TEST REQUIREMENT

1. *"Test program Rear Main Fitting A300-600R (Lug Test #1)"*

AIRBUS

Test Requirement

Department: ESGE	Report No.: 32 X 029 K4 804 P34	
Typ: A300-600R		

Title:

AAL 587 Airbus Structure Investigation
Test program Rear Main Fitting A300-600R (Lug Test#1)

Summary:

The test component is a LH-side rear main attachment lug from an A310 CFRP fin box panel. The test shall demonstrate the behavior of the lug under load conditions to which the fin of AA flight 587 has been exposed during the accident. The load conditions are derived from DFDR-data and structural analysis by FEM.

Date:
08.12.2003

Distribution	Issue	Date	Page	Modified pages	Valid for:
Public Docket	1	10.11.03	23		A300-600R
	2	05.12.03	23	Format change from DIN A4 to LETTER	
	3	08.12.03	23		

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1. Introduction

The test component is a LH-side rear main attachment lug from an A310 CFRP fin box panel. This panel originally represents a manufacturing test and has been used to demonstrate the interior quality. For this reason a large sample has been cut out of the panel above rib4 and between rear spar and stringer 7 (fig.9.1). The remaining part (fig 9.2) is prepared for clamping to the test rig by removal of the stringer run outs (webs and inboard flange) and reinforcement by additional plies (fig 9.3/4).

2. Test objective

The test shall demonstrate the behavior of the lug under tensile load condition to which the fin of AA flight 587 has been exposed during the accident. The load condition is derived from DFDR-data and structural analysis by FEM.

3. Test component

The removal of the stringer webs and inboard flanges and the reinforcing plies for bolting of the component is shown on the figure 9.4.

4. Environmental conditions

The tests will be carried out at ambient temperature (RT). The component will be tested in an ‘as received ‘ condition.

5. Test setup

The test specimen will be fixed to the test rig (fig 9.5/6) at the upper end (parallel to rib 4), at the rear spar, parallel to stringer 6 and at rib 1. The loads will be introduced in the global coordinate system by 3 servo-hydraulic-jacks. The lateral loads in Y-direction are introduced in line with the axis of the connecting pin.

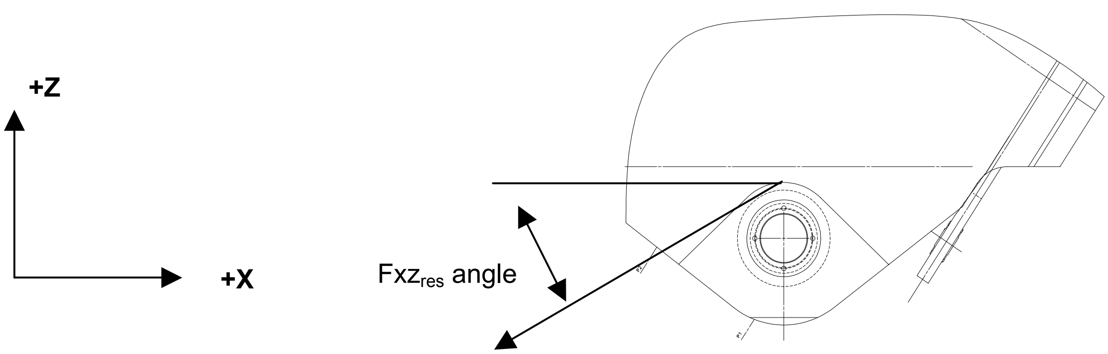
The loads in X- and Z-direction are applied by two rods each which are adjustable in their length by turnbuckles (see chapter 9.6). Therefore the turnbuckles can be used to preadjust an initial local lug moment Mx and Mz, before applying the test load vector.

The original fin/fuselage connecting pin has to be used. The fitting is attached to a fork-end lug (representing the fuselage attachment fitting) made from high strength aluminum alloy with similar dimensions as the original fuselage fitting for stiffness reason.

6. Load case

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 target condition includes a preadjusted local lug moment Mx of 2400Nm, which has to be introduced with the turnbuckles.

NASA W375-Mod							
	Fx	Fy	Fz	Fres	Mx	Mz	Angle Xzplane
	[kN]	[kN]	[kN]	[kN]	[Nm]	[Nm]	[°]
W375-Mod	-400	-42	-864	953	6300	-1600	65



7. Measurement plan

Figure 9.7/8 shows the strain gauge positions and the orientation. Displacement measurement positions are shown in the fig. 9.9. The reference for the displacements is the support plate of the upper boundary of the test component.

8. Test procedure

8.1 Basic inspections

After reinforcement of the test specimen a visual and ultrasonic inspection has to be done to document the quality and condition.

A second inspection (visual and US) has to be carried out after installation into the test rig before starting the test.

8.2 Load case application

The forces are then applied in the following load steps:

Fx	Fy	Fz	Fres	Load step
With turnbuckles preadjusted Mx of 2400Nm				0
-20	-2	-43	48	10
-30	-3	-65	71	15
-40	-4	-86	95	20
-50	-5	-108	119	25
-60	-6	-130	143	30
-68	-7	-147	162	35
-78	-8	-168	186	40
-88	-9	-190	210	45
-98	-10	-212	233	50
-108	-11	-233	257	55
-118	-12	-255	281	60
-128	-13	-276	305	65
-138	-14	-298	329	70
-148	-16	-320	353	75
-158	-17	-341	376	80
-168	-18	-363	400	85
-178	-19	-384	424	90
-188	-20	-406	448	95
-196	**-21**	**-423**	**467**	**100**
-206	-22	-445	491	105
-216	-23	-467	515	110
-226	-24	-488	538	115
-236	-25	-510	562	120
-246	-26	-531	586	125
-256	-27	-553	610	130
-266	-28	-575	634	135
-276	-29	-596	658	140
-286	-30	-618	681	145
-296	**-31**	**-639**	**705**	**150**
-300	-32	-648	715	152
-304	-32	-657	724	154
-308	-32	-665	734	156
-312	-33	-674	743	158
-316	-33	-683	753	160
-400	**-42**	**-864**	**953**	**203**
Fx	Fy	Fz	Fres	Load step

Limit Load level (load step 100)

Ultimate Load level (load step 150)

NASA W375-Mod load vector (load step 203)

All force values are kN

Definition of load step:

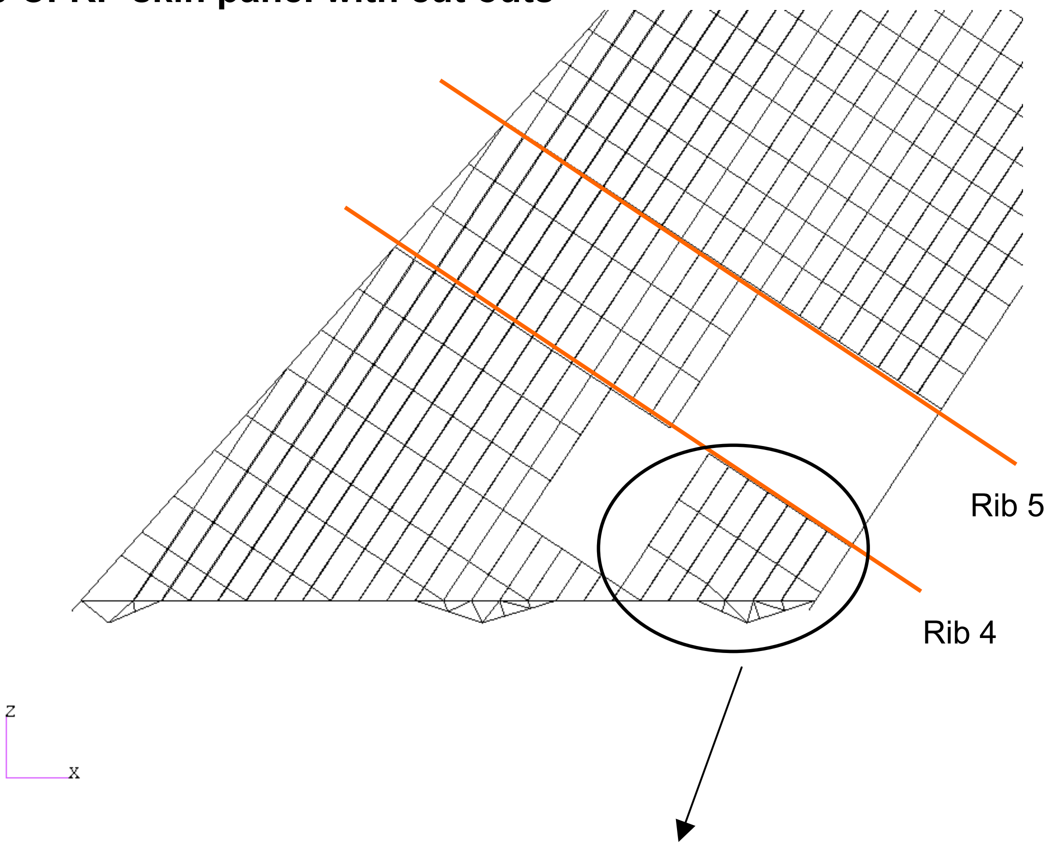
Load step 100 is defined as 100% of Limit Load of the design gust case (BI17) with Fres=469kN.

From load step 160 (160% of Limit Load) the test is pursued by continuous proportional load increase up to the failure.

At each load step strain gauges, displacements and load cell values (see 7.) have to be recorded. After measuring the load step 160 all measurements are recorded continuously up to failure.

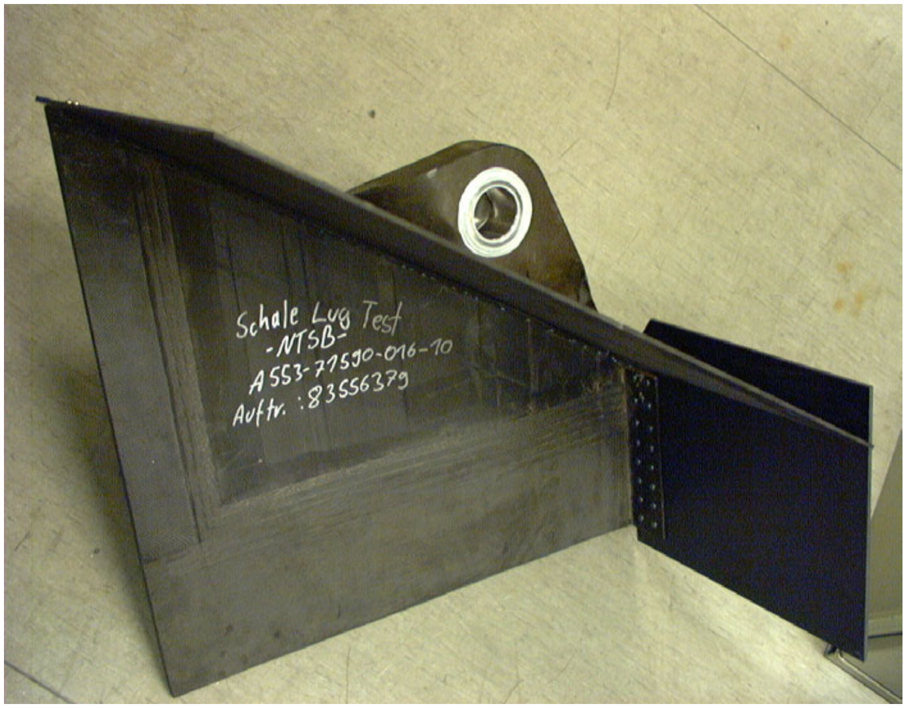
9. Figures

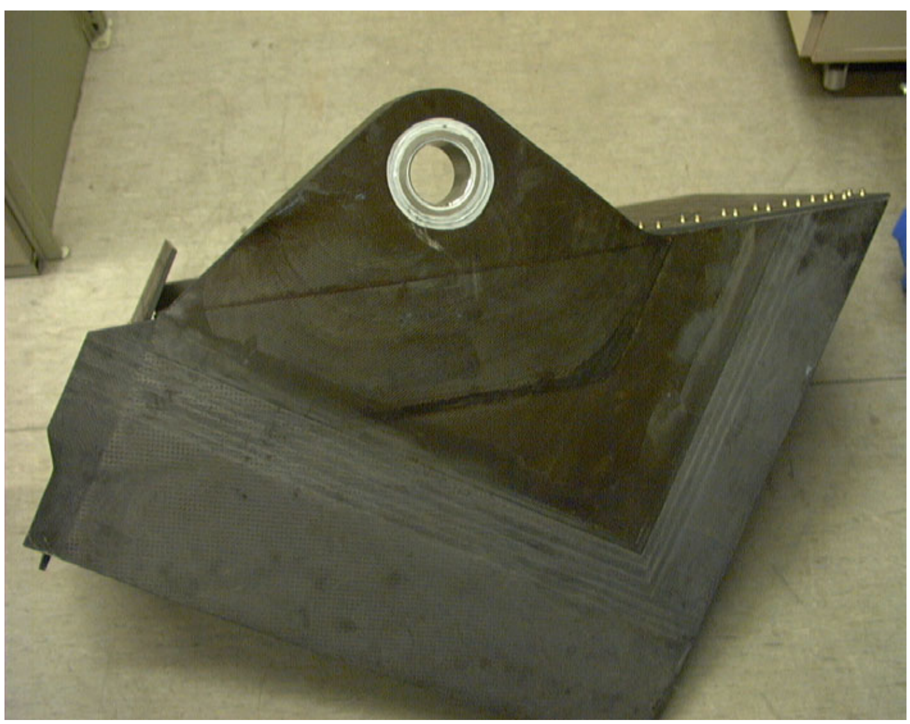
9.1 A310 CFRP skin panel with cut outs



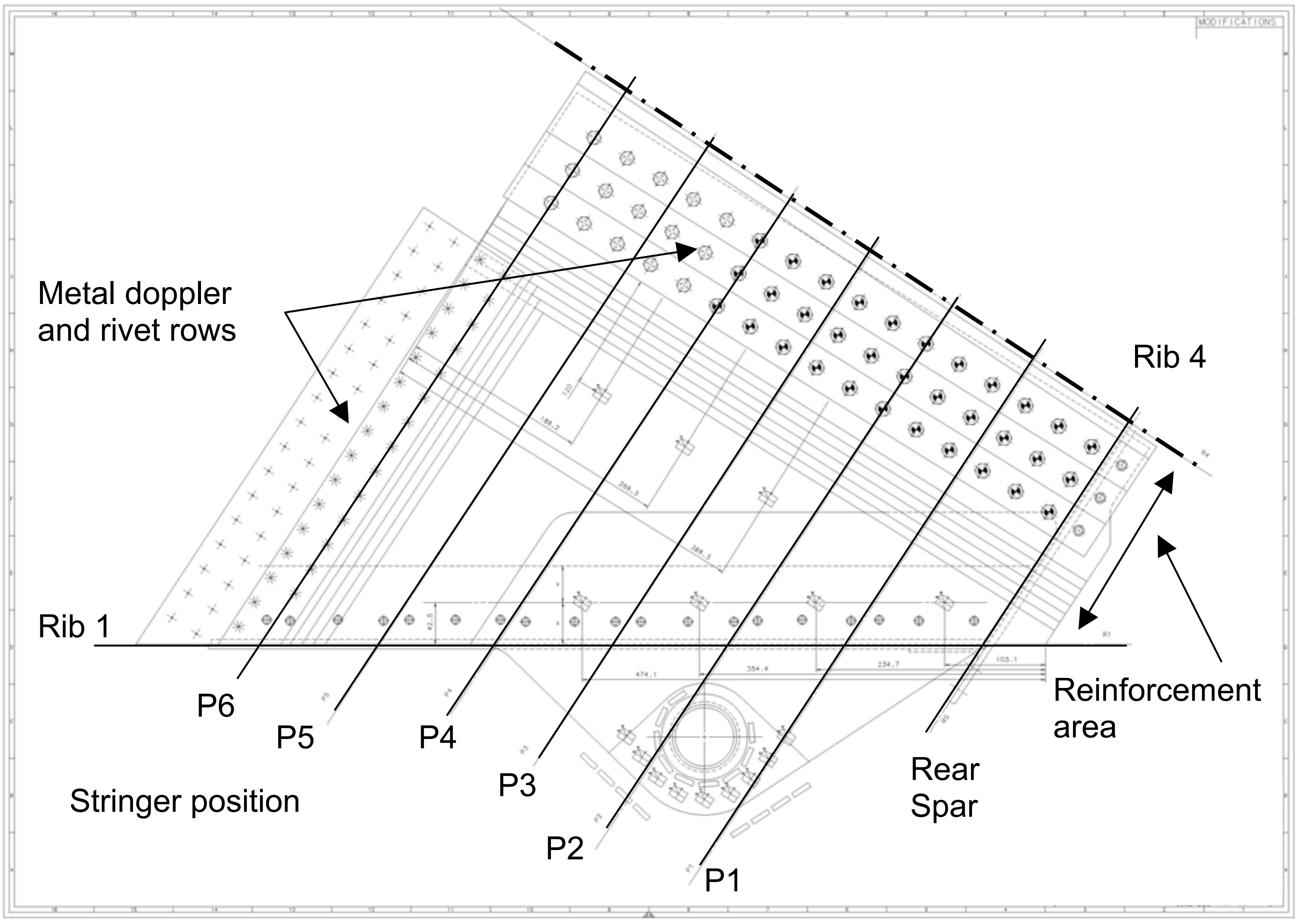
9.2 Rear Main Lug part of the side shell available for test

9.3 Reinforced test specimen with part of rib1 and the rear spar

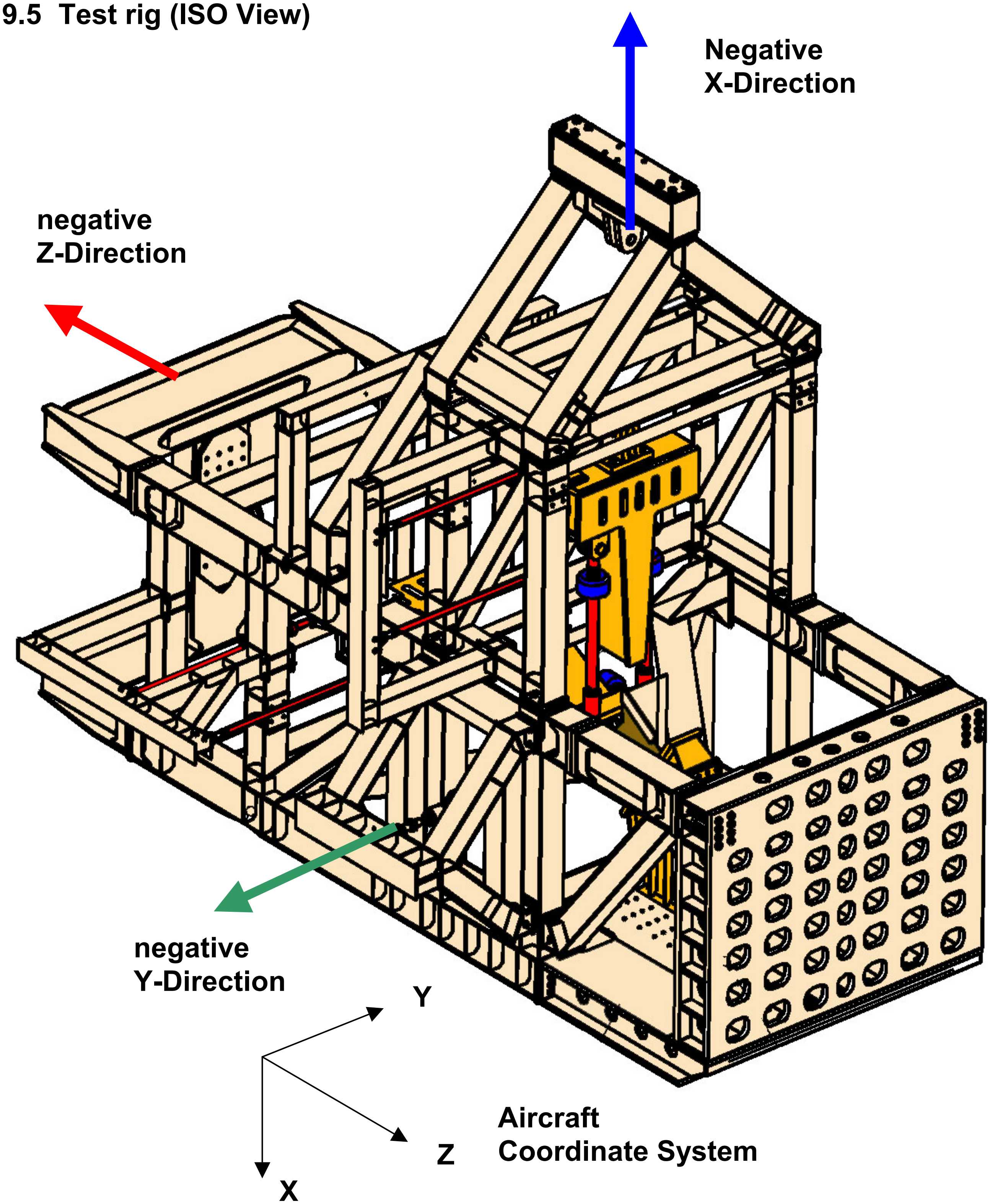




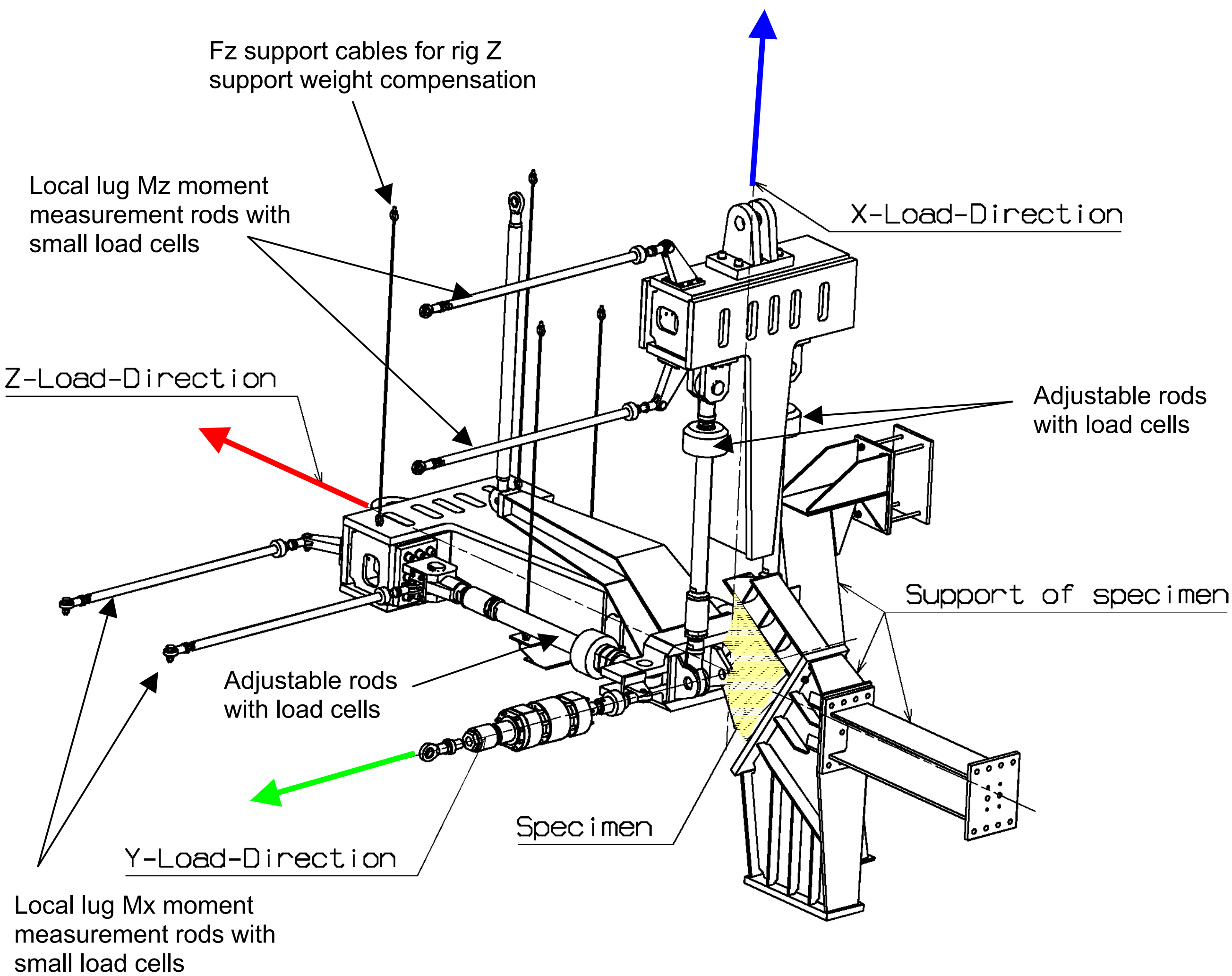
9.4 Rear main lug remaining part and reinforcement



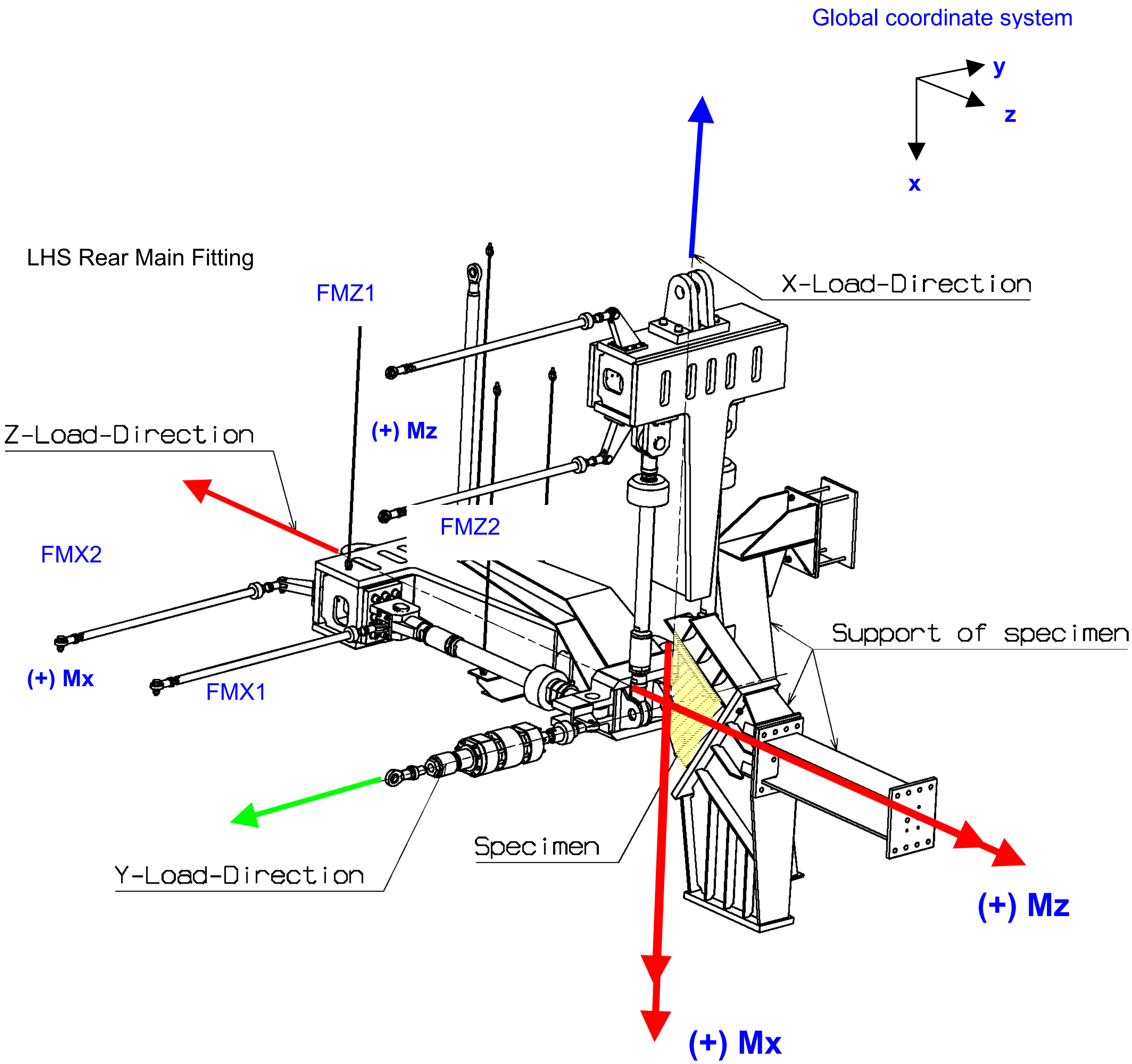
9.5 Test rig (ISO View)



9.6 Test rig load introduction and location of the test specimen

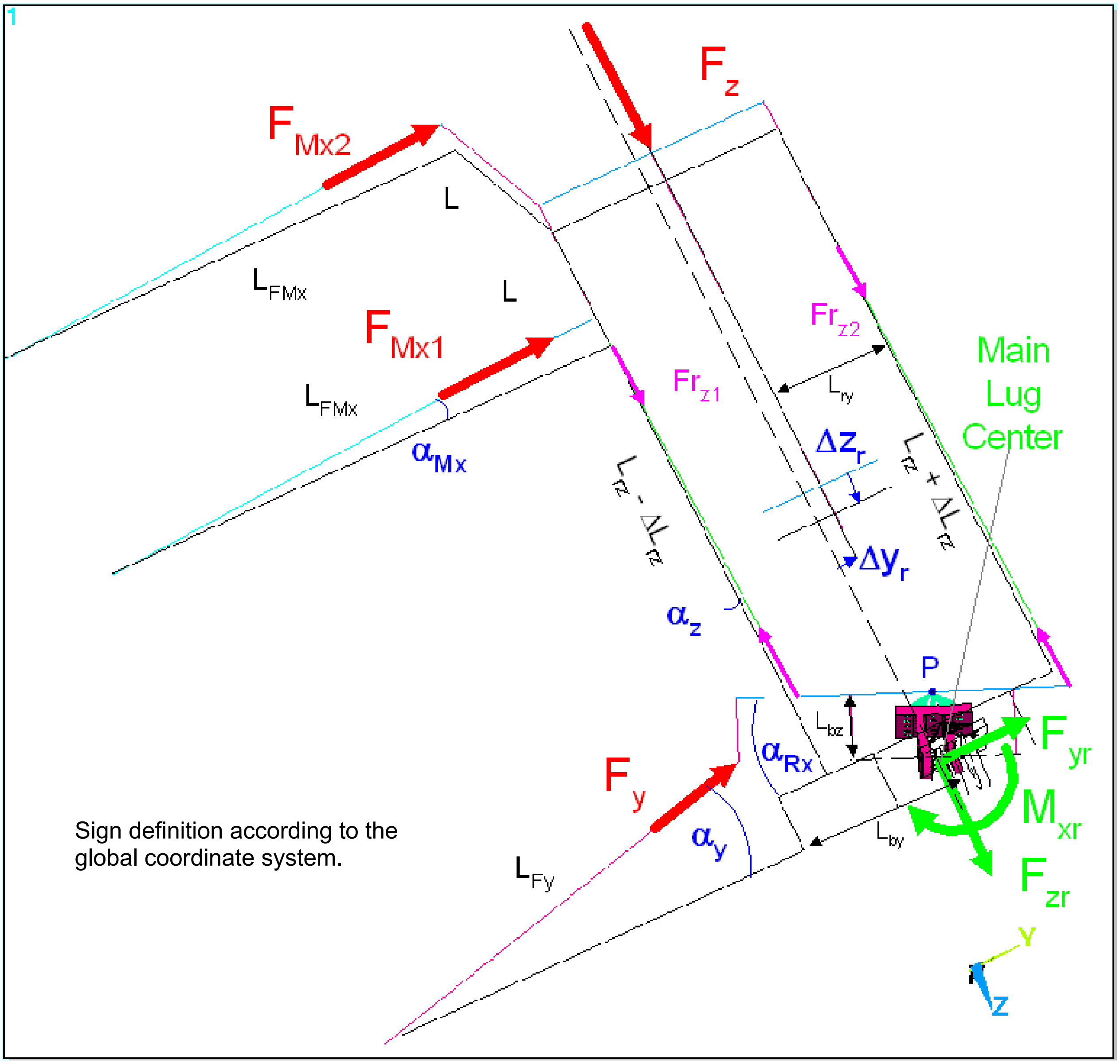


9.6.1 Test rig sign convention local lug reaction moments



9.6.2 Local lug moment Mx (Equation considers displacements in the yz-plane)

The equation represents the moment equilibrium at the displaced load introduction system due to the deformed test specimen (see figure below). The supports of the Fy- actuator and the rods ends of FMX1/2 are assumed to be fixed and the free play at all bearings and length deformation of the linkages are not taken into account.



For practical reasons, the reference for the displacement measurement is the test rig. This can also cause some errors in the measured values.

The figure shows the undeformed and deformed load introduction and the relevant dimension in the test rig.

Test rig dimension:

Dimension			Description
L_{Fy}	[mm]	1783	Y-cylinder length from outer to inner bearing point
L_{by}	[mm]	720	Inner Y-cylinder bearing point to the lug reference point
L_{bz}	[mm]	245	Z-distance from lug reference point to the z-axis main rod bearing points
L_{ry}	[mm]	500	Half distance between the z-axis main rods Z1 and Z2
L_{rz}	[mm]	2000	Length of the main rods Z1 and Z2
L_{FMx}	[mm]	2000	Length of the moment measurement rods FMX1 and FMX2
L	[mm]	500	Half distance between FMX1 and FMX2

Equations to recalculate the local lug reactions with the measured data:

Assumptions:

1. Deformation of the test rig + fuselage clevis negligible
2. Only displacement in the yz-plane considered

Displacement:

$\Delta zP(\alpha Rx, \Delta zr) = \Delta zr + L_{bz}(1 - \cos(\alpha Rx))$ Z-Displacement in point P

$\Delta yP(\alpha Rx, \Delta yr) = \Delta yr + L_{bz} \cdot \sin(\alpha Rx)$ Y-Displacement in point P

$\Delta zsy(\alpha Rx, \Delta zr) = \Delta zr - L_{by} \cdot \sin(\alpha Rx)$ Z-Displacement sum Fy

Deformation angle:

$$\alpha Rx = \arcsin\left(\frac{Dz3 - Dz4}{600}\right) \text{ Rx bolt rotation}$$

$$\alpha_y(\alpha Rx, \Delta zr) = \arcsin\left(\frac{\Delta zsy(\alpha Rx, \Delta zr)}{L_{Fy}}\right)$$

$$\alpha_z(\alpha Rx, \Delta yr) = \arcsin\left(\frac{\Delta yP(\alpha Rx, \Delta yr) + L_{ry}(1 - \cos(\alpha Rx))}{L_{rz}}\right)$$

$$\alpha_{Mx}(\alpha Rx, \Delta zr) = \arcsin\left(\frac{\Delta zP(\alpha Rx, \Delta zr)}{L_{FMx}}\right)$$

Total moment of measurement rods:

$$M_{Mx}(\alpha Rx, \Delta zr) =$$

$$FMX1\left[\sin(\alpha_{Mx}(\alpha Rx, \Delta zr) \cdot L_{ry} + \cos(\alpha_{Mx}(\alpha Rx, \Delta zr)) \cdot (L_{rz}\cos(\alpha_z(\alpha Rx, \Delta yr)) + L_{bz})\right]$$
$$+ FMX2\left[\sin(\alpha_{Mx}(\alpha Rx, \Delta zr) \cdot L_{ry} + \cos(\alpha_{Mx}(\alpha Rx, \Delta zr)) \cdot (L_{rz}\cos(\alpha_z(\alpha Rx, \Delta yr)) + L_{bz} + 2L)\right]$$

Moment resulting from Fz and displacement Δyr

$$M_{xFz}(\Delta yr) = F_z \cdot \Delta yr$$

Moment resulting from Fy and displacement Δyr

$$M_{xFy}(\alpha Rx, \Delta zr) = F_y \cdot L_{by} \cdot (\sin(\alpha_y(\alpha Rx, \Delta zr) - \alpha Rx))$$

Total moments about the main lug center:

$$\sum Mx = 0 = -M_{xr} + M_{xFz} - M_{Mx} - F_y \cdot L_{by} \cdot \sin(\alpha_y(\Delta zr))$$

With the above mentioned equations the reaction moment Mxr is

$$M_{xr}(\alpha Rx, \Delta yr, \Delta zr) = -M_{xFz}(\Delta yr) - M_{Mx}(\alpha Rx, \Delta yr, \Delta zr) - M_{xFy}(\alpha Rx, \Delta zr)$$

9.6.3 Local lug moment Mz (Equation considers displacements in xy-plane)

Test rig dimension:

Dimension			Description
L_{Fy}	[mm]	1783	Y-cylinder length from outer to inner bearing point
L_{by}	[mm]	720	Inner Y-cylinder bearing point to the lug reference point
L_{bx}	[mm]	0	The bolt axis is aligned with the Y-cylinder axis
L_{xry}	[mm]	300	Half distance between the z-axis main rods X1 and X2
L_{rx}	[mm]	1990.6	Length of the main rods X1 and X2
L_{FMz}	[mm]	2000	Length of the moment measurement rods FMZ1 and FMZ2
L_{x}	[mm]	525	Half distance between FMZ1 and FMZ2

Equations to recalculate the local lug reactions with the measured data.

Deformation angle:

$$\alpha_y(\Delta xr) = \arcsin\left(\frac{\Delta xr}{L_{Fy}}\right) \qquad \alpha_x(\Delta yr) = \arcsin\left(\frac{\Delta yr}{L_{rx}}\right) \qquad \alpha_{Mz}(\Delta xr) = \arcsin\left(\frac{\Delta xr}{L_{FMz}}\right)$$

Total moment of measurement rods:

$$M_{Mz}(\Delta xr, \Delta yr) = (F_{Mz1} + F_{Mz2}) \cdot \left[\sin(\alpha_{Mz}(\Delta xr)) \cdot L_{xry} + \cos(\alpha_{Mz}(\Delta xr)) \cdot (L_{rx} \cdot \cos(\alpha_x(\Delta yr)) + L_{bx})\right] + \cos(\alpha M_z(\Delta xr)) \cdot F_{Mz1} \cdot 2 \cdot L_x$$

Moment resulting from Fx and displacement Δyr

$$M_{zFx}(\Delta yr) = -F_x \cdot \Delta yr$$

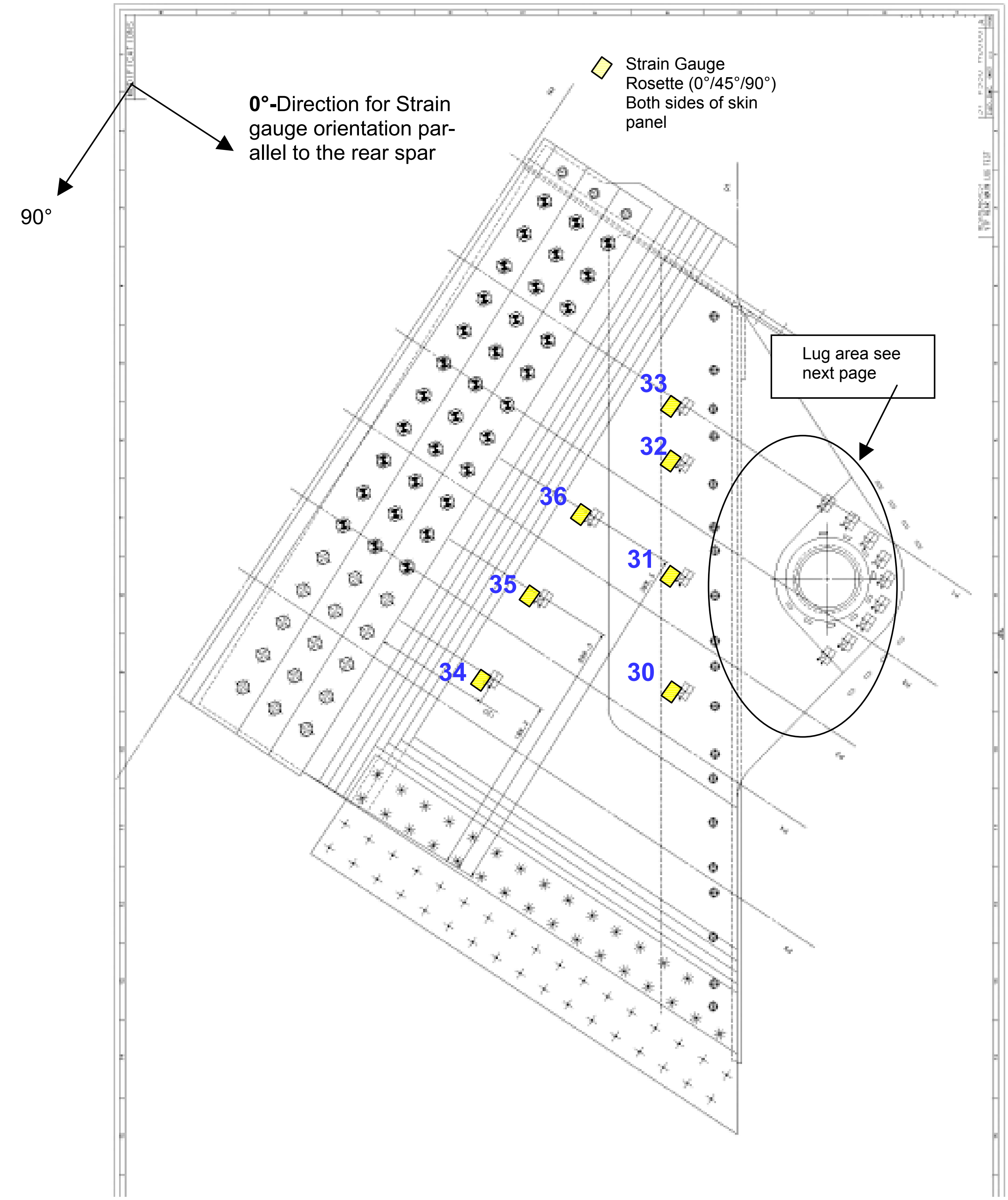
Moment resulting from Fy and displacement Δxr

$$M_{zFy}(\Delta xr) = F_y \cdot \Delta xr \cdot (\cos(\alpha_y(\Delta xr)) + \sin(\alpha_y(\Delta xr)))$$

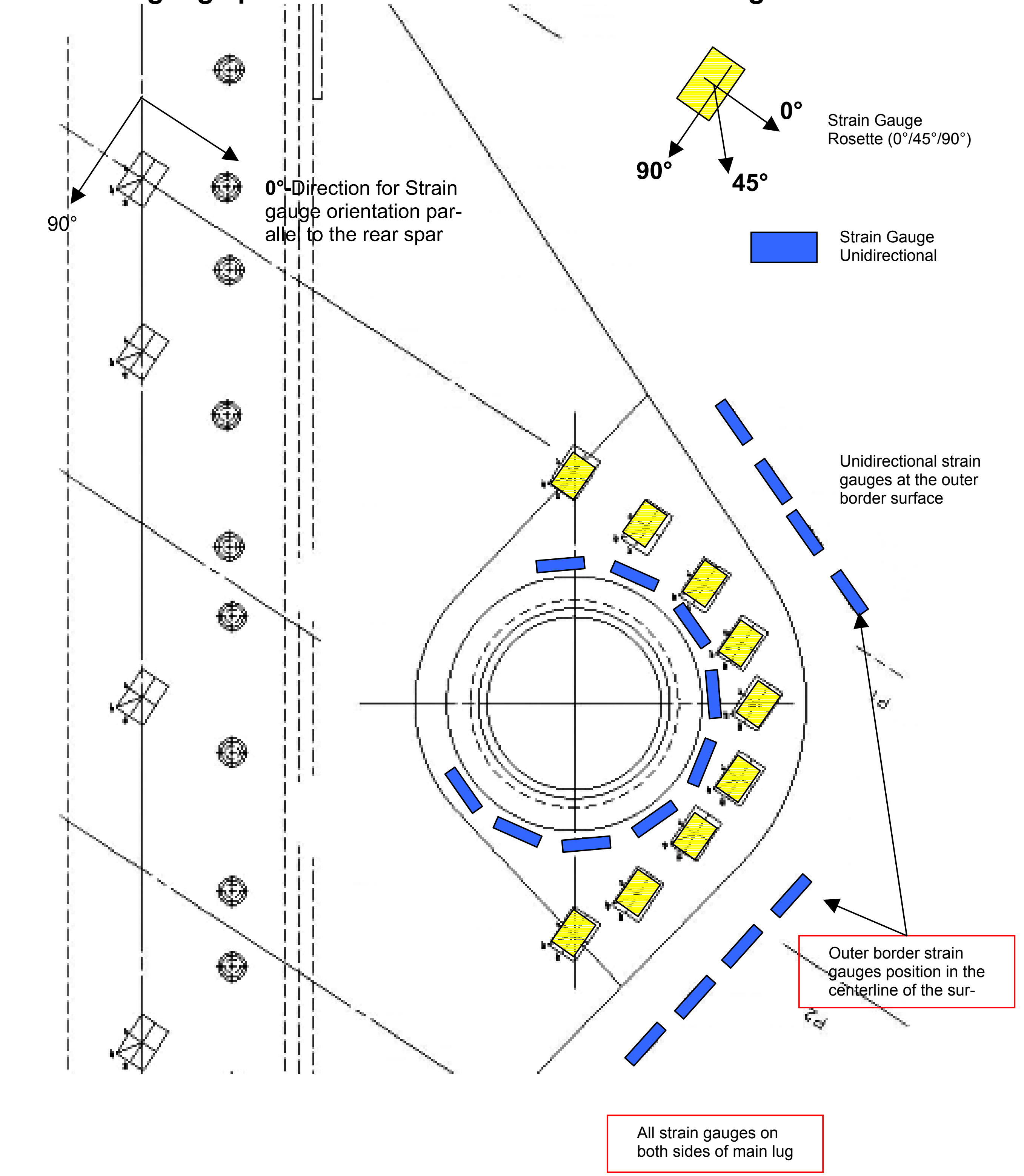
With the above mentioned equations the reaction moment Mzr is

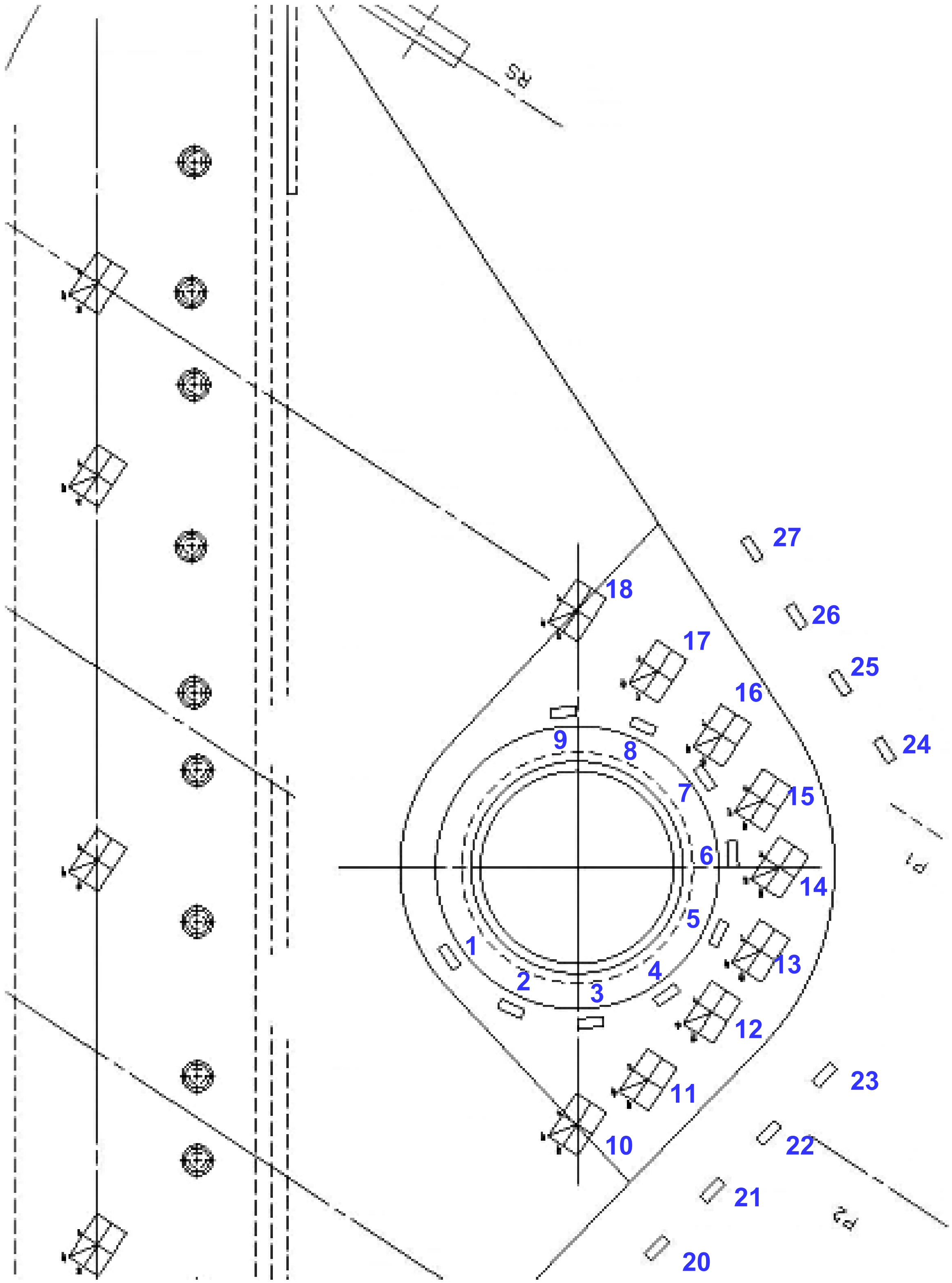
$$M_{zr}(\Delta xr, \Delta yr) = M_{zFx}(\Delta yr) + M_{Mz}(\Delta xr, \Delta yr) + M_{zFy}(\Delta xr)$$

9.7 Strain gauge plan and orientation



9.8 Strain gauge position and orientation in the main lug area

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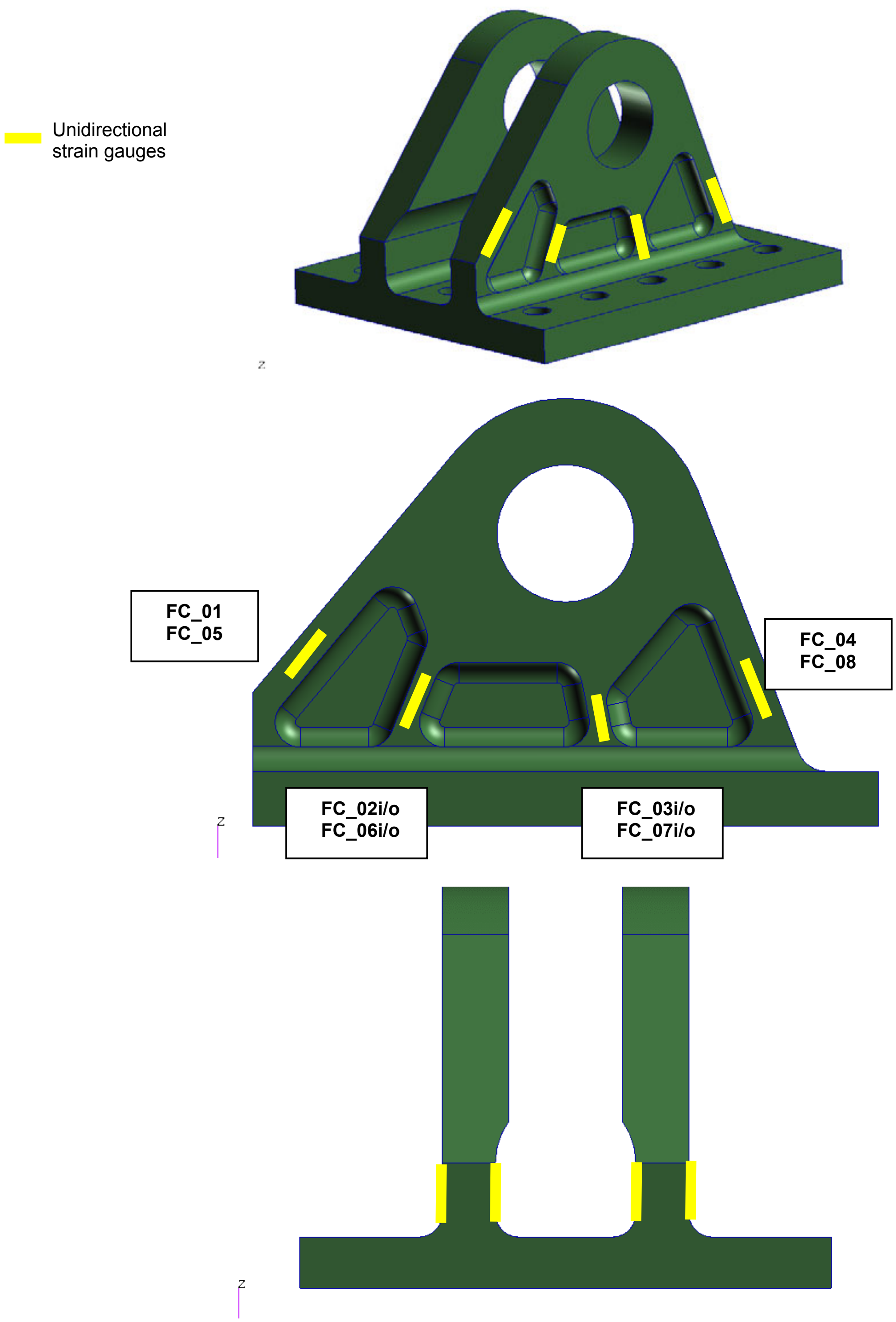
9.9 Strain gauge position on the fuselage clevis



9.10 Displacement measurement location