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

September 14, 2004

ADDENDUM NUMBER 18 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. "Flight AA587 Accident Investigation, Load Summary for Rear Main Lug"

AIRBUS	**Technical Note**	

Report Nr.: TN – ESGE – 0003/04

Author:

Department.:

Title

Flight AA587 Accident Investigation

Load Summary for Rear Main Lug

Date: 10.09.2004

Summary:

In the course of the flight AA587 accident investigation rear main lug forces were calculated with different FE-analysis models and compared with the results from the residual strength test on the FST and static tests on components.
In this report the loads resultants Qy, MxQ and MzQ for several load cases / conditions are related to the A300-600R relevant design load case.
For the corresponding rear main lug forces for the tension side which were obtained from FE-analysis a 'lug load factor' is calculated which defines the ratio between rear main lug forces obtained from the various accident condition analyses and the force at the lug resulting from L.L. of the relevant design load case.

Public Docket	Issue	Date	No. of page	Revised pages	Valid from/for
	2	10.09.2004	22		

Table of contents

References

	Report No.	Title
[1]	TN-ESGC-1017/03 Is3	AAL587 Airbus Structure Investigation Accident Analysis - FEM Global model - VTP & Rudder
[2]	TN-ESGC-1018/03 Is3	AAL587 Airbus Structure Investigation Accident Analysis - FEM RHS local rear lug model
[3]	TN-ESGC-1019/03 Is3	AAL587 Airbus Structure Investigation FEM Global to Local model analysis details
[4]	TN-ESGC-1020/03 Is3	AAL587 Airbus Structure Investigation LHS Lug sub-component test#1 FEM analysis
[5]	TN-ESGC-1021/03 Is4	AAL587 Airbus Structure Investigation Lug sub component test#1 – Results - Test / FEA Comparison
[6]	TN-ESGC-1020/04 Is2	AAL587 Airbus Structure Investigation Lug Test#2 – Results Test / FEA Comparison
[7]	TN-ESGC-1021/04 Is2	AAL587 Airbus Structure Investigation Lug Test#3 – Results Test / FEA Comparison
[8]	TN-ESGE-0003/03 Is2	AAL 587 Airbus Structure Investigation A300 / A310 Composite Fin Box / Rear Fin Box Attachment - Subcomponent Test Summary
[9]	TN-ESGE-0004/03 Is2	AAL 587 Airbus Structure Investigation A300 / A310 Composite Fin Box / Full Scale Certification Test Summary
[10]	TN-ESGE-0002/04 Is1	Flight AA587 Structure Accident Investigation Validation of Subcomponent Test Principles

Abbreviations

CSF	Correlated Shear Force Diagram
FST	A310 CFRP VTP Full Scale Test from 1985
DLG	Discrete Lateral Gust
CFD	Computational Fluid Dynamics
RT	Ambient Temperature (reference 20°C)
L.L.	Limit Load
U.L.	Ultimate Load (1.5xL.L.)
TS	Test Specimen

1. Introduction

In the course of the flight AA587 accident investigation rear main lug forces were calculated with different FE-analysis models and compared with the results from the residual strength test on the FST and static tests on components.
The tensile load on the rear lug Fxz is the resultant of the horizontal force Fx (x-axis in aircraft coordinate system) an the vertical force Fz (z-axis in aircraft coordinate system). For rear lug load conditions of interest (high strain level at the pin hole) Fxz is dominated by the vertical force Fz,which is driven by the bending moment MxQ resulting from aerodynamic- and mass-loads acting on the vertical fin and rudder.
For a given bending moment MxQ the variation of MzQ has little effect on the rear lug force resultant and produces only small changes in the resultant force attack angle. For this reason the stresses around the pin hole are insensitive to MxQ/MzQ -ratios given by the load case 'Discrete Lateral Gust' and the accident case W375 .
In this report the loads resultants Qy, MxQ and MzQ for several load cases / conditions are related to the A300-600R design load case ‘Discrete Lateral Gust’.
For the corresponding rear main lug forces for the tension side which were obtained from FE-analysis a ‘lug load factor’ is calculated which defines the ratio between rear main lug forces obtained from the various accident condition analyses and the force at the lug at L.L. DLG.
Both loadcases produce similar stresses in the lug which has been calculated by FEM-analysis and verified during component tests and for this reason the 'Discrete Lateral Gust' condition was chosen for comparative puposes in this Technical Note. Furthermore a direct comparison is not possible, because a condition with a similar correlation MxQ/MzQ is not available outside of the design calculations.

2. Analysis Models

During the flight AA587 Accident Investigation different FEM structure analysis models were developed. This chapter give an overview over all these different models. Detailed Information can be found in the specific technical reports [1 to 10].

2.1 VTP Finite Element Model 1985

The structural analyses for certification of the A310-300 and A300-600R CFRP VTP were done in 1985 with a Finite Element Model which is shown in Figure 2.1.

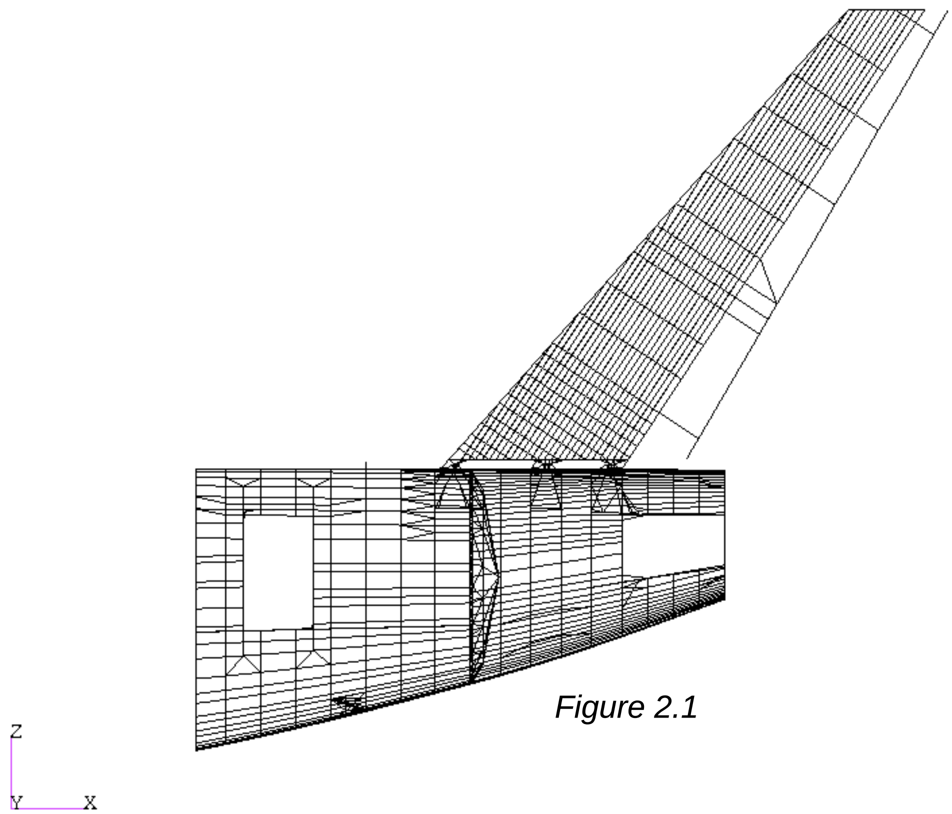


Figure 2.1

2.2 Global NASTRAN VTP Model used for Accident Investigation

For the Accident Investigation [1] the VTP Model from 1985 was remeshed/ refined and modelled with more details in specific areas. Figure 2.2 shows this Global NASTRAN VTP Model.

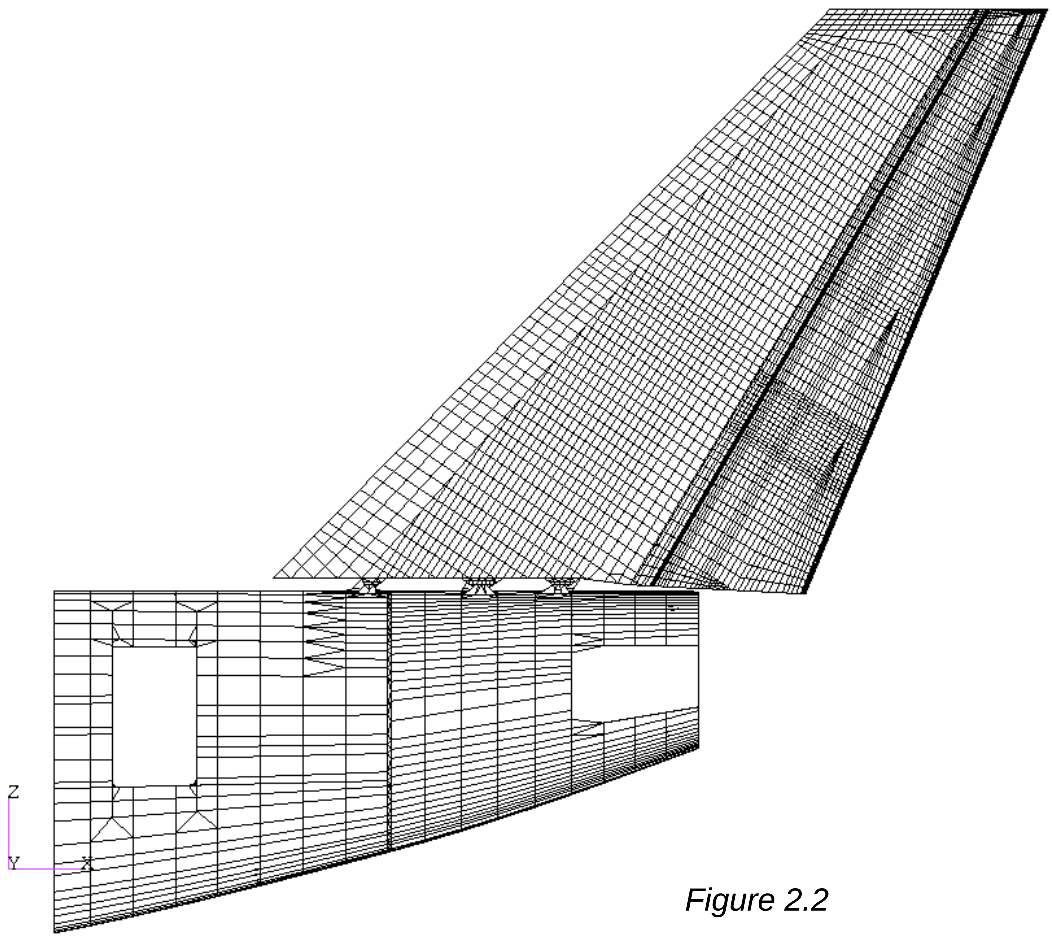


Figure 2.2

2.3 Global VTP NASTRAN Model with embedded RHS and LHS 3D rear main lugs

For detailed investigation of the rear main lug behaviour [4-7] 3D solid models from the LHS and RHS rear main attachment area are embedded into the Global NASTRAN VTP Model (Figures 2.3 to 2.5).

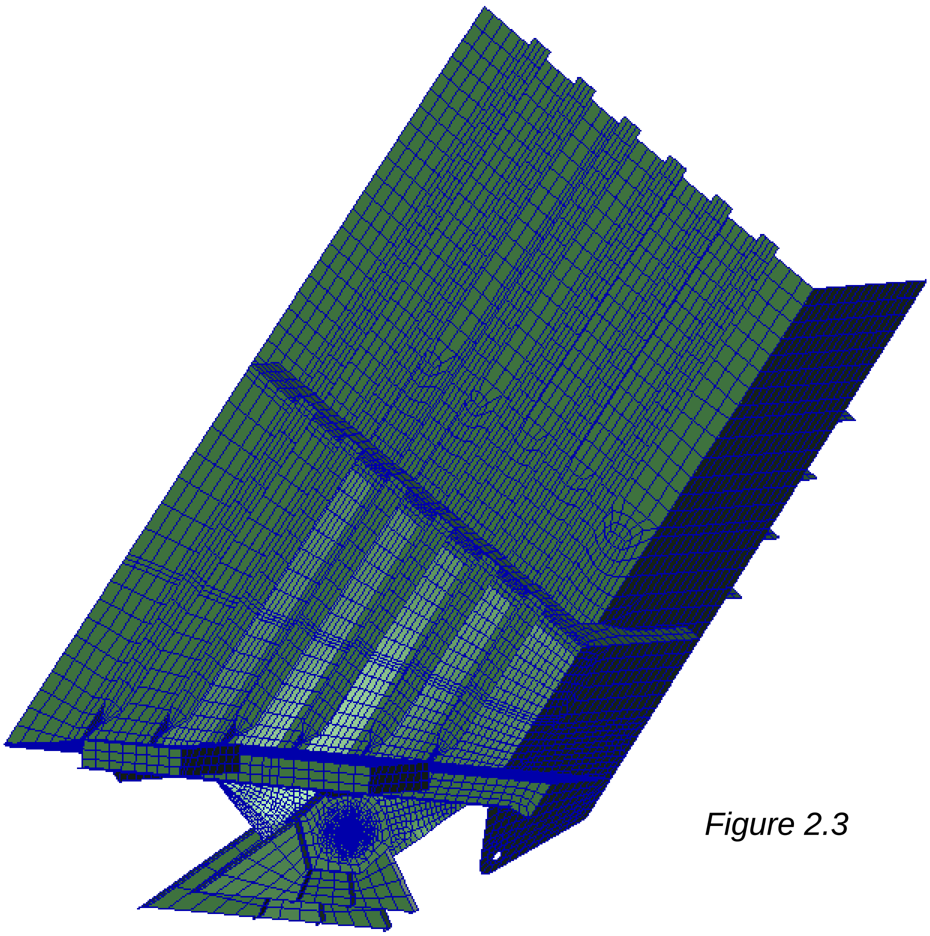


Figure 2.3

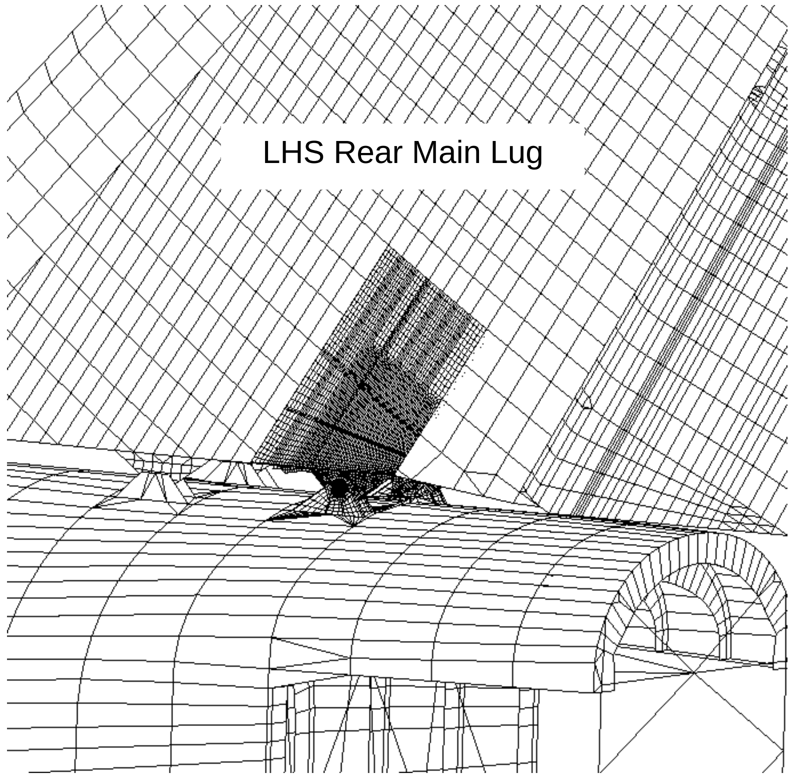


Figure 2.4

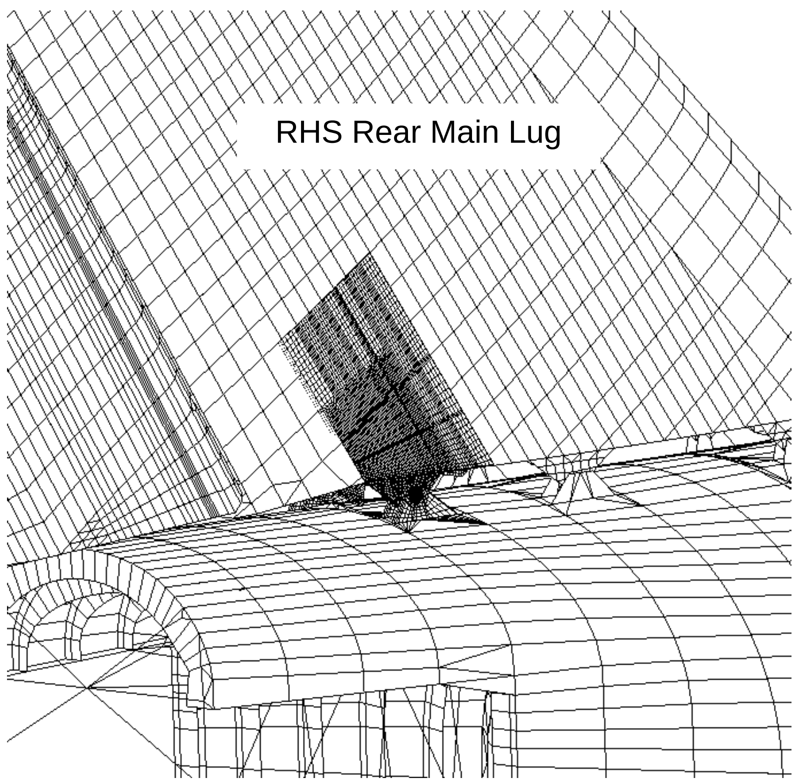


Figure 2.5

2.4 3D Rear Main Fitting ANSYS nonlinear contact Models

The boundary displacements from the Global NASTRAN Model with embedded 3D Rear Main Lug (Chapter 2.4) are applied on the ANSYS nonlinear contact model shown in figure 2.6.

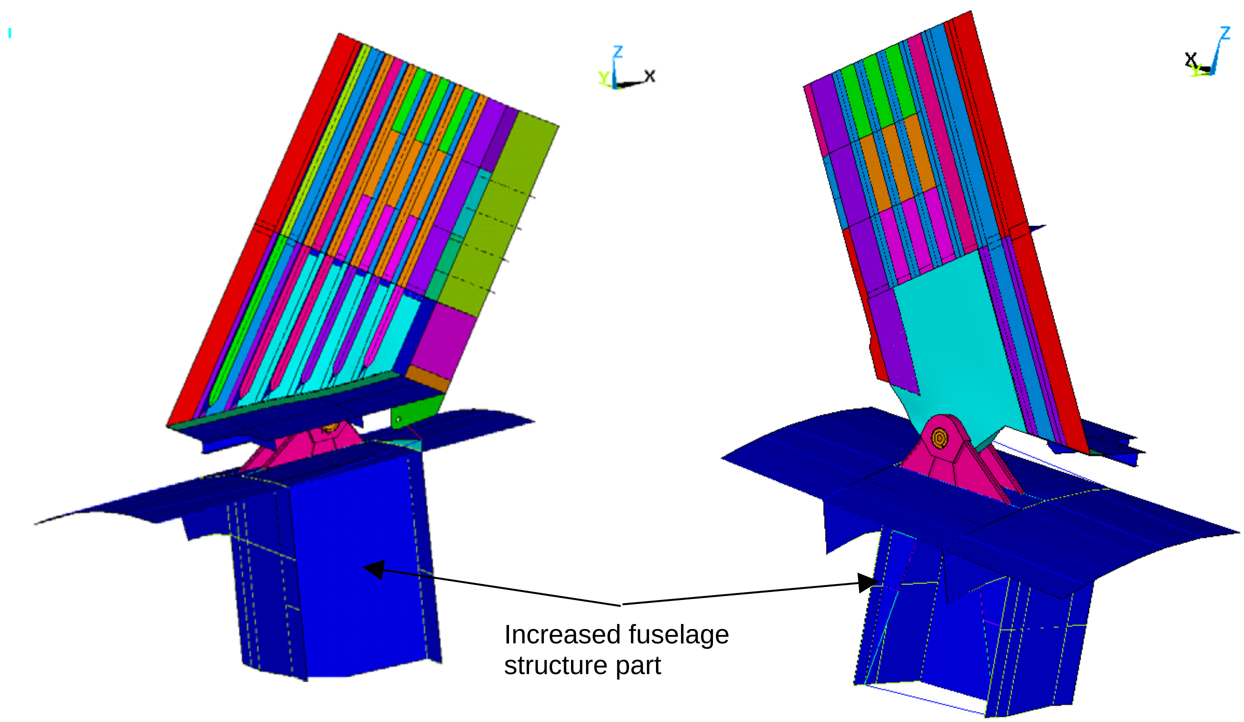


Figure 2.6

The flexible pin idealisation with all contact surfaces and bolt pre-stressing condition in all ANSYS models represents the best approach to account for the real bolt behaviour (figure 2.7).

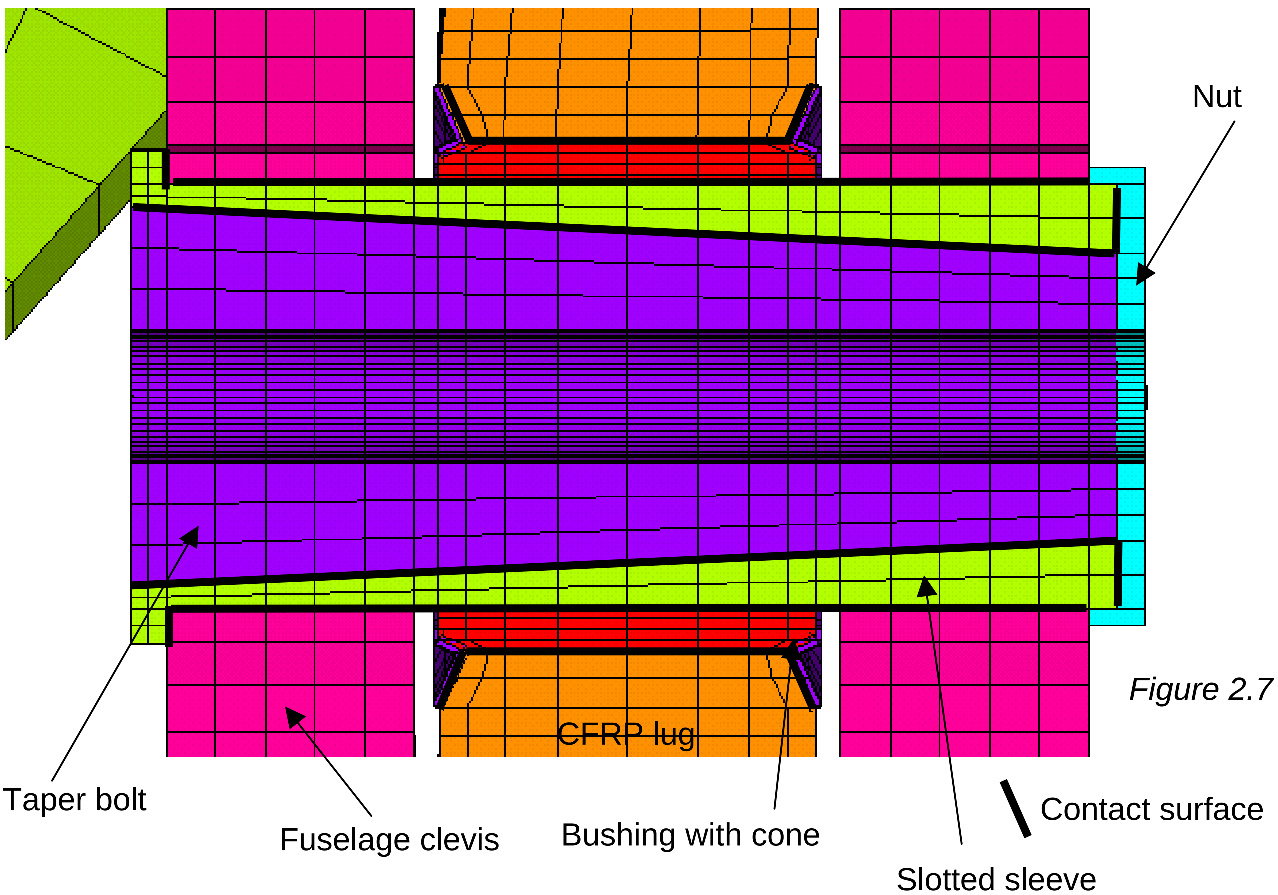


Figure 2.7

To verify the three lug tests detailed ANSYS nonlinear contact models with the test component/ load introduction and support are created. One of this FE-Models is shown in figure 2.8.

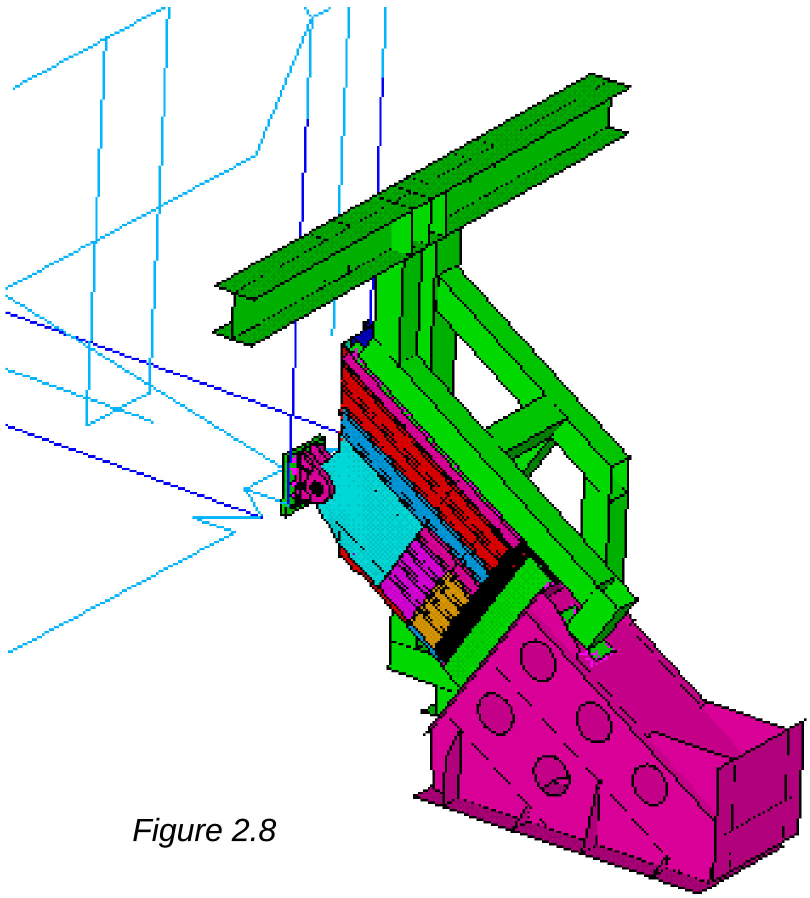


Figure 2.8

3. Test components

3.1 A310-300 Full Scale Test 1985

The test principle is shown on figure 3.1. The vertical stabilizer box is inside of an environmental chamber. The fuselage attachment lugs are connected to clevises which are mounted on long beams from steel. These beams provide the fuselage reactions to the fin loads thru a static determinated support by 6 rods equipped with load cells and 11 force controlled hydraulic actuators.

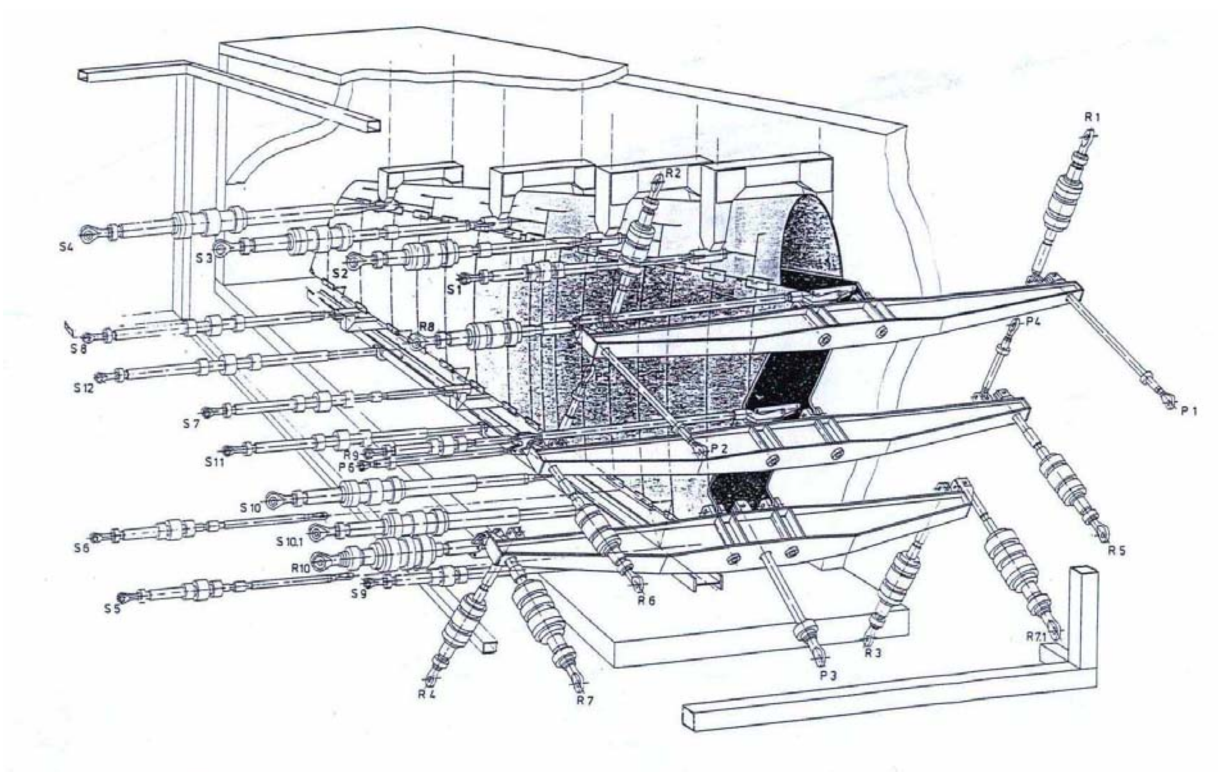


Figure 3.1

The fin lateral loads are applied by loading trees thru 13 force controlled hydraulic actuators. For these discrete lateral forces, the balancing fuselage reactions are calculated by a FEM analysis of the fin and the rear fuselage structure. The calculated reactions are used as input loads for the fuselage reaction actuators and for control of the forces in the support rods. Parallel to this procedure the relative displacements at the attachment lugs have been measured to check for correct stiffness of the real structure relative to the analysis model.

3.2 Rear Lug Tests

On fig. 3.2 to 3.4 the rear main lug components are shown ready to be mounted into the test rig.

LHS Lug Test#1 specimen

Figure 3.2

LHS Lug Test#2 specimen

Figure 3.3

RHS Lug Test#3 specimen

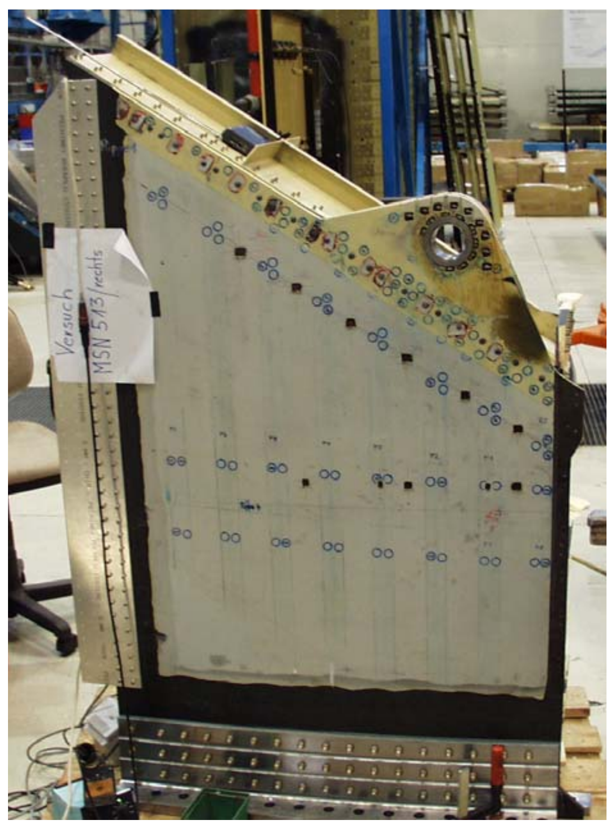


Figure 3.4

4. A300-600R Loads Envelope

The L.L. Envelope is shown in Diagram 4.1. Additionally the design case A300-600R discrete lateral gust (DLG) L.L. and U.L. condition is included with W375 Is18 and FST Rupture condition.

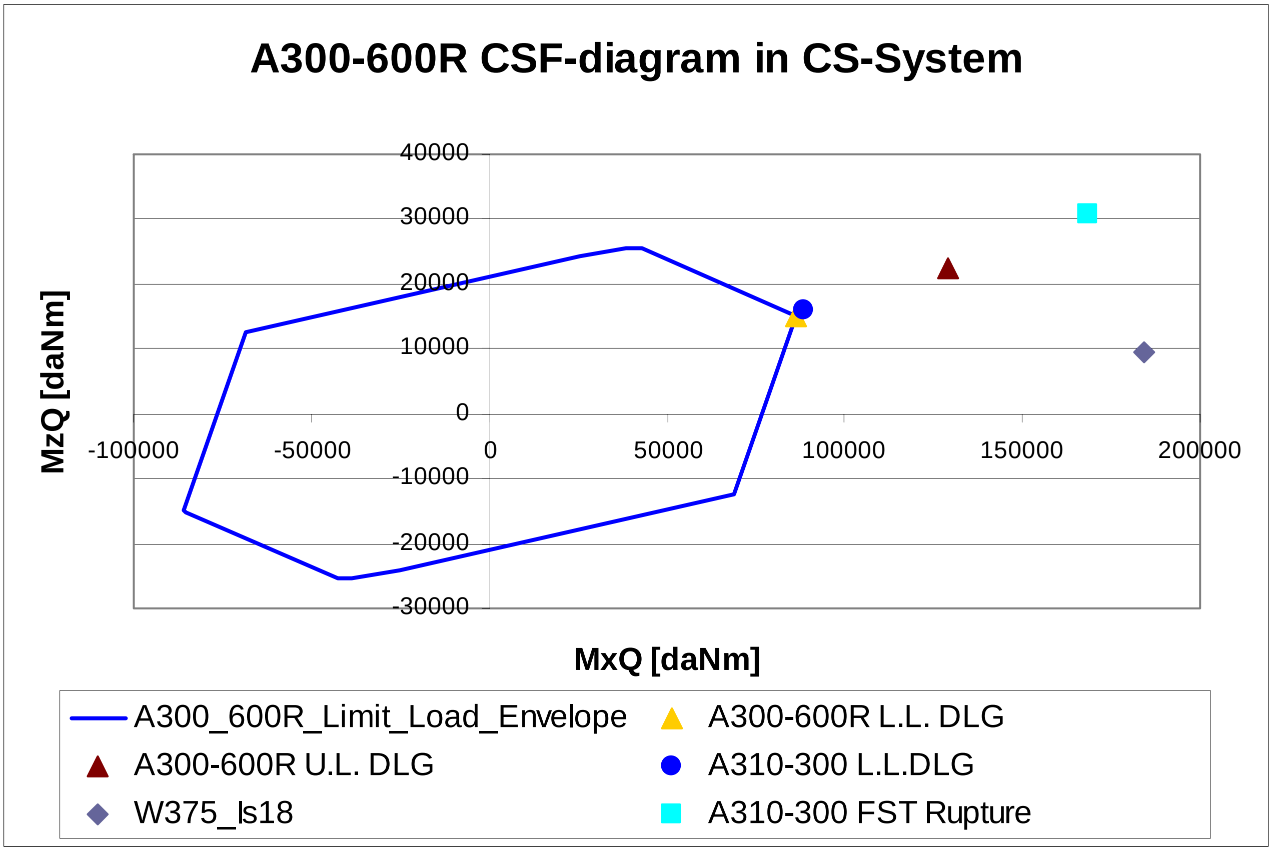


Diagram 4.1 CSF-Diagram [Limit Load / MzQ vs. MxQ]

The load resultants for the A300-600R DLG are shown in table 4.1.

	Discrete Lateral Gust Envelope (L.L.)	%-difference to A310-300 DLG Envelope
F_y [N]	-215 800	-3.4
M_x [Nm]	861 650	-2.4
M_z [Nm]	152 680	-5.2

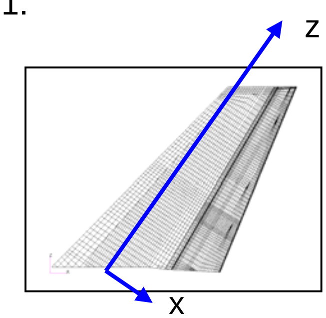


Table 4.1

5. Residual strength test of A310-300 FST

The residual strength test was performed after completion of the fatigue test at 120 000 simulated flights which corresponds to a minimum of 3 lives.
The structure was loaded with the negative lateral gust case (tension on the LHS) including the thermal loads at 70°C from CTE-effects under hot/wet conditions (70°C / 90% laminate moisture content measured by re-drying of the reference laminates from HEXCEL material).

Main Fitting Forces at U.L. are based on the A310-300 FE-Model from 1985 (see table 5.1).

Load case: Lateral discrete gust (+) A310-300

	Front spar		Center spar		Rear spar	
	LHS [N]	RHS [N]	LHS [N]	RHS [N]	LHS [N]	RHS [N]
F_x	205 900	-208 700	166 900	-168 800	280 400	-279 000
F_y 1)	12 858		48 770		39 499	
F_y 2)	75 732		50 660		107 041	
F_z	296800	-299400	573000	-573000	671500	-666700

1) force at main lugs / 2) force at spar web lugs

Table 5.1 (ultimate loads at RT)

The lateral loads reactions at the fuselage attachment lugs were combined with thermal loads resulting from CTE-effects between the fuselage (aluminium) and the fin box (carbon/epoxy) under worst hot/wet conditions (see table 5.2).

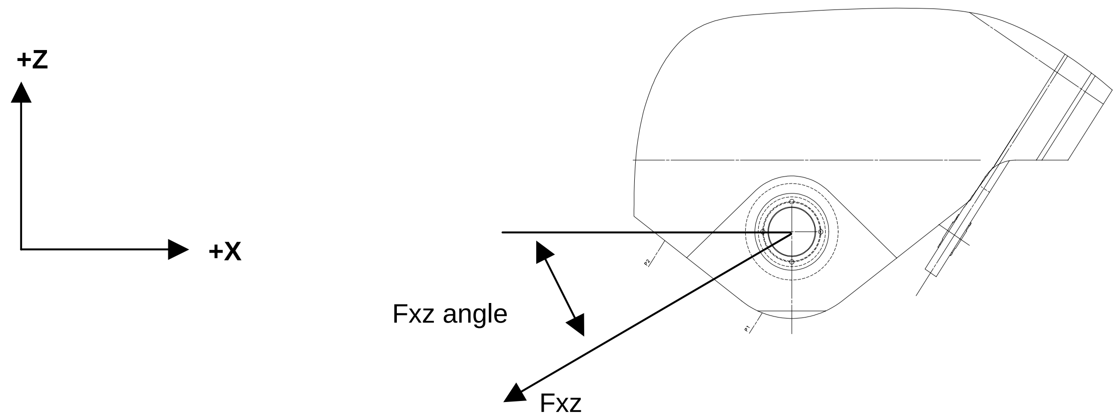
Load case: Temperature +70°C

	Front spar		Center spar		Rear spar	
	LHS [N]	RHS [N]	LHS [N]	RHS [N]	LHS [N]	RHS [N]
F_x	-55 360	-55 470	-10 010	-9 850	65 380	65 310

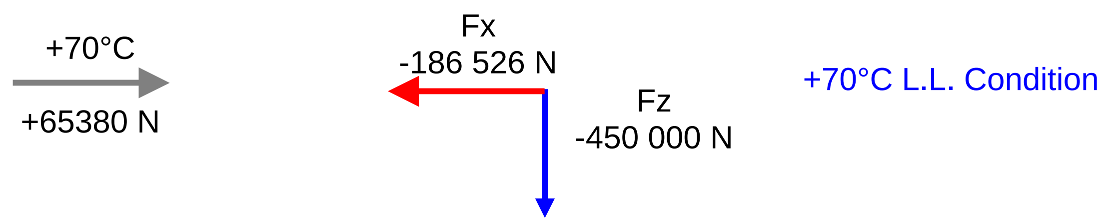
Table 5.2

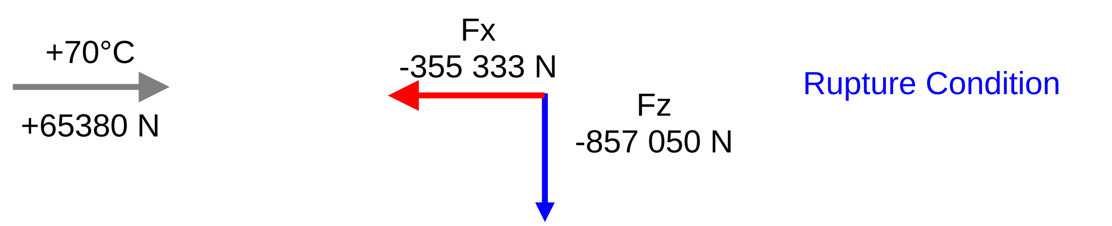
The structure failed at 1.905 x L.L. at the LHS rear main lug. The rupture load was 904.8 kN (see table 5.3).

LHS Rear Main Attachment Force



Temperature Component Airload and Mass Components





Condition	Temp in X	X	Xres	Y	Z	Fxz angle	Fxz	Fxyz
	[N]	[N]	[N]	[N]	[N]	[°]	[N]	[N]
+70°C L.L.	+65 380	-186 526	-121 146	13 167	-450 000	74.9	466 022	466 208
+70°C Rupture (1.905 L.L.)	+65 380	-355 333	-289 953	25 083	-857 050	71.3	904 769	905 117

Table 5.3 Reaction Forces L.L. based on A310-300 Load cases

6. L.L. exceedence of load case W375 ls18

In the CSF-diagram (see diagram 6.1) the flight AA587 Accident loading condition is compared to the A300-600R Limit Load Envelope (blue curve). The intersection point of the design envelope and the straight line from the origin to the accident condition defines the 100% Limit Load.

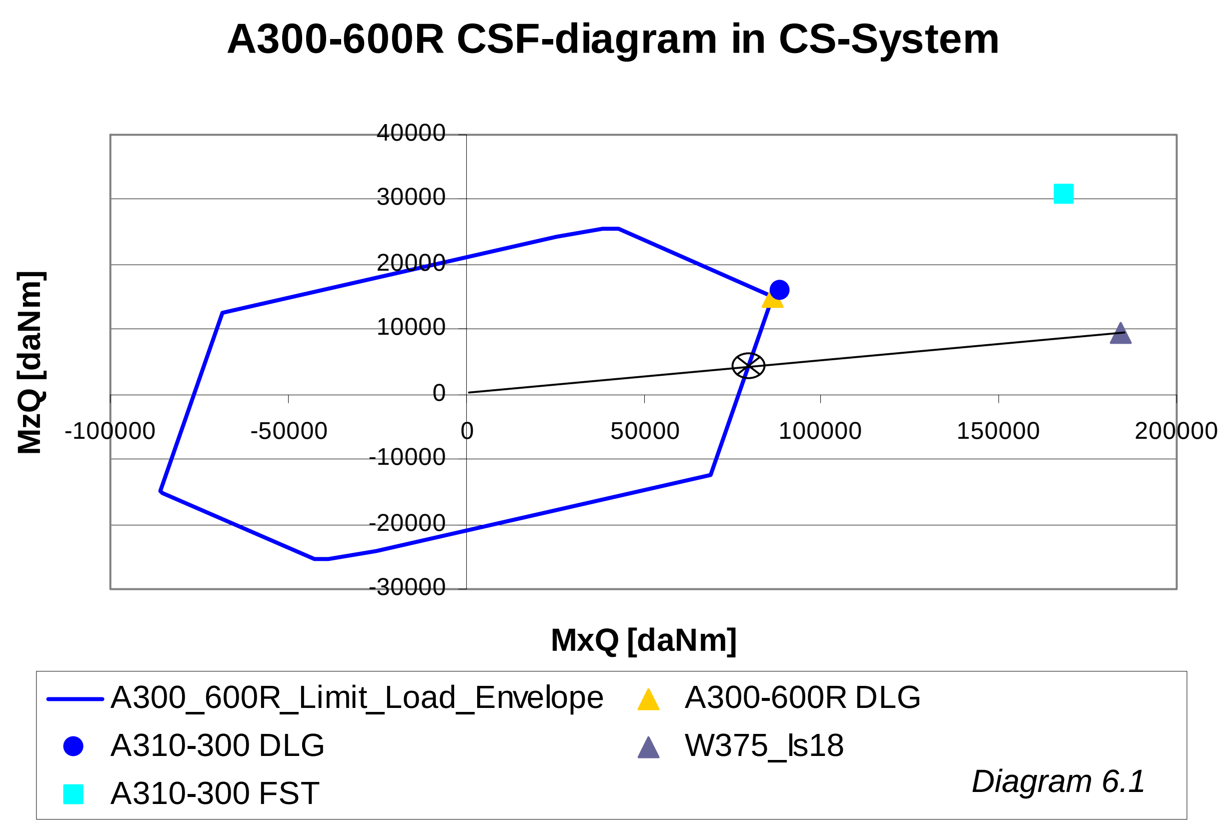


Diagram 6.1

The coordinates in the CSF-diagram of this intersection point are:

MxQ=79227 daNm and MzQ=4088 daNm

The Limit Load Exceedence relative to the Maneuver Design Envelope is given by:

$$L.L.Excc = \frac{184230 daNm}{79333 daNm} = 2.32$$

7. Summary

Abbreviation	Description
L.L. Factor	Fin load resultant factor Dividing actual MxQ-Values by the L.L. bending moment of DLG design.
Lug Load Factor	Rear Main Lug Load Factor Dividing actual Fxz by the L.L. DLG rear main lug Fxz including temperature effects.
Temp in X	Temperature Effect in X-Direction due to CTE of the fuselage

FE-Model	Description
1	VTP FE-Model from 1985
2	Scaled Values from FE-Model 1 / Scale Factor defined by 86165/88300=0,976
3	MSN420 Global NASTRAN FE-Model with 2 embbeded 3D Rear Main Lugs with flexible pin
4	RHS ANSYS Contact 3D-Model with boundary displacement
5	ANSYS Test Rig Model

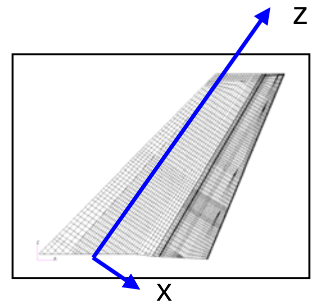
Load Case	Description
LC1	negative DLG A310-300 (positive Qy)
LC2	negative DLG A300-600R (positive Qy)
LC3	DLG Load case for A300-600R / Nodal Loads created during Accident Investigation. Slightly differences in the fin resultant load vector compared to LC2 vector due to Nodal Loads calculation process.
LC4	Flight AA587 Accident Loading Condition W375 Is18
LC5	By NTSB, NASA, AAL and Airbus agreed Load Vector for the flight AA587 accident condition

7.1 A310-300 Load and Rear Lug Forces

VTP Loading Condition at the fin root and values are given in the Component Coordinate-System. Loads and Fitting forces are based on the 1985 FE-Model calculations.

Model Condition	Load case	**L.L. Factor**	Qy *)	MxQ	MzQ
	[-]	[-]	[daN]	[daNm]	[daNm]
A310-300 DLG					
RT L.L.	LC1	**1.000**	22339	**-88300**	-16100
+70°C L.L.	LC1	**1.000**	22339	-88300	-16100
+70°C FST Rupture	LC1	**1.905**	42556	-168212	-30671

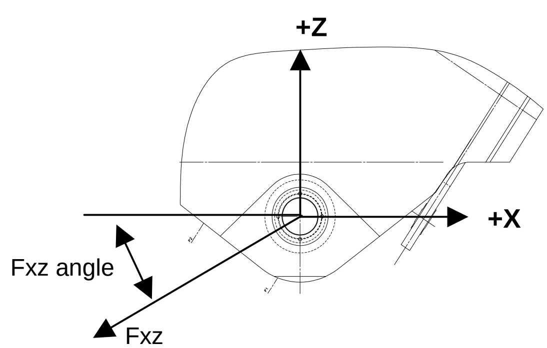
*) Fin Root values in CS-System



The Rear Main Lug Attachment Forces are Reaction Forces given in the Global Coordinate System

Model Condition	FE-Model	Side	Temp in X	X	Xres	Y	Z
	[-]	[-]	[N]	[N]	[N]	[N]	[N]
A310-300 DLG							
RT L.L.	1	LHS	0	-186526	-186526	13167	-450000
+70°C L.L.	1	LHS	65380	-186526	-121146	13167	-450000
+70°C FST Rupture	1	LHS	65380	-355333	-289953	25083	-857050

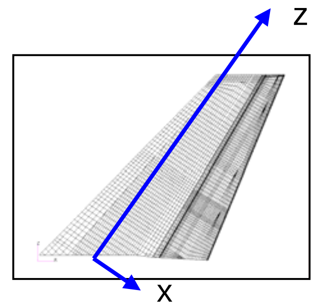
Model Condition	Fxz angle	Fxz	**Lug Load Factor**
	[°]	[N]	[-]
A310-300 DLG			
RT L.L.	67.5	487126	**1.05**
+70°C L.L.	74.9	**466022**	**1.00**
+70°C FST Rupture	71.3	904769	**1.94**



7.2 A300-600R Load and Rear Lug Forces

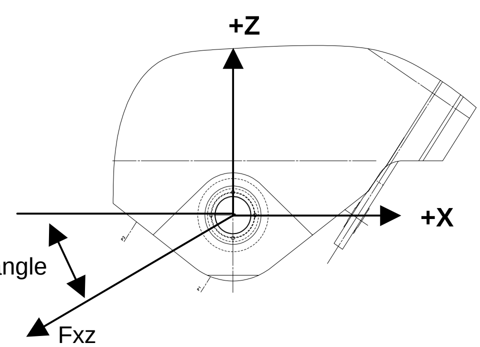
The following tables are scaled (with bending moment factor MxQ) from the A310-300 results in chapter 7.1

Model Condition	Load case	**L.L. Factor**	Qy	MxQ	MzQ
	[-]	[-]	[daN]	[daNm]	[daNm]
A300-600R DLG					
RT L.L.	LC2	**1.000**	21799	**-86165**	-15711
+70°C L.L.	LC2	**1.000**	21799	-86165	-15711
+70°C FST Rupture	LC1	**1.952**	42556	-168212	-30671



Model Condition	FE-Model	Side	Temp in X	X	Xres	Y	Z
	[-]	[-]	[N]	[N]	[N]	[N]	[N]
A300-600R DLG							
RT L.L.	2	LHS	0	-182016	-182016	12849	-439119
+70°C L.L.	2	LHS	65380	-182016	-116636	12849	-439119
+70°C FST Rupture	1	LHS	65380	-355333	-289953	25083	-857050

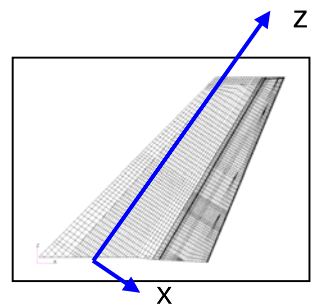
Model Condition	Fxz angle	Fxz	**Lug Load Factor**
	[°]	[N]	[-]
A300-600R DLG			
RT L.L.	67.5	475348	**1.05**
+70°C L.L.	75.1	**454346**	**1.00**
+70°C FST Rupture	71.3	904769	**1.99**



7.3 Flight AA587 Accident Investigation Load and Fitting Forces

Calculations done with FE-Model from 2002 used for the Accident Investigation see chapter 2.3.

Model Condition	Load case	**L.L. Factor**	Qy	MxQ	MzQ
	[-]	[-]	[daN]	[daNm]	[daNm]
Flight AA587 Investigation A300-600R					
L.L. DLG	LC3	**1.000**	-20595	**85697**	15804
W375 Is18	LC4	**2.147**	-41523	183985	9493
Lug Test Load Vector	LC5				
Lug Test#1	LC5				
Lug Test#2	LC5				
Lug Test#3	LC5				



Model Condition	FE-Model	Side	X	Y	Z
	[-]	[-]	[N]	[N]	[N]
Flight AA587 Investigation A300-600R					
L.L. DLG	3	RHS	-168744	15669	-420763
W375 Is18	4	RHS	-371000	34000	-841000
Lug Test Load Vector		RHS	-400000	42000	-864000
Lug Test#1	TS	LHS	-381600	-39100	-822500
Lug Test#2	TS	LHS	-373000	-25000	-811000
Lug Test#3	TS	RHS	-457500	35300	-992400

Model Condition	Fxz angle	Fxz	**Lug Load Factor**
	[°]	[N]	[-]
Flight AA587 Investigation A300-600R			
L.L. DLG	68.1	**453339**	**1.00**
W375 Is18	66.2	919196	**2.03**
Lug Test Load Vector	65.2	952101	**2.10**
Lug Test#1	65.1	906711	**2.00**
Lug Test#2	65.3	892665	**1.97**
Lug Test#3	65.3	1092778	**2.41**