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NATIONAL TRANSPORTATION SAFETY BOARD

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Structural Analysis and Evaluation for the Airbus A300-600R/MSN420 VTP and rudder for the accident flight AA587

Part 3: Analysis of the rupture sequence of the rudder following the accident

(24 Pages)

AIRBUS	**Technical Note**	

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Structural Analysis and evaluation for the Airbus A300-600R vertical stabilizer and rudder subjected to the accident during flight AA587

Part III: Analysis of the rupture sequence of the rudder following the accident

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Contents

1. Introduction

This report describes the rupture sequence of the rudder following the accident during flight AA587. FEM analysis and test results are provided to give evidence for the damages observed at the rudder structure.
In part I of this report the load level experienced by the rudder prior to the accident has been calculated (see part 1, figure 20, 21).
It is significantly lower than the load level demonstrated for certification of the rudder which corroborates that the observed rudder damages are due to a post-accident event.

2. Strength test for rudder hinge fitting BR3 attachment on RHS rudder panel

On the RHS of the rudder the hinge fittings BR2, BR3 and BR4 attachments ruptured by shear failure in the fitting flanges and due to bolt fracture (see figure 1).

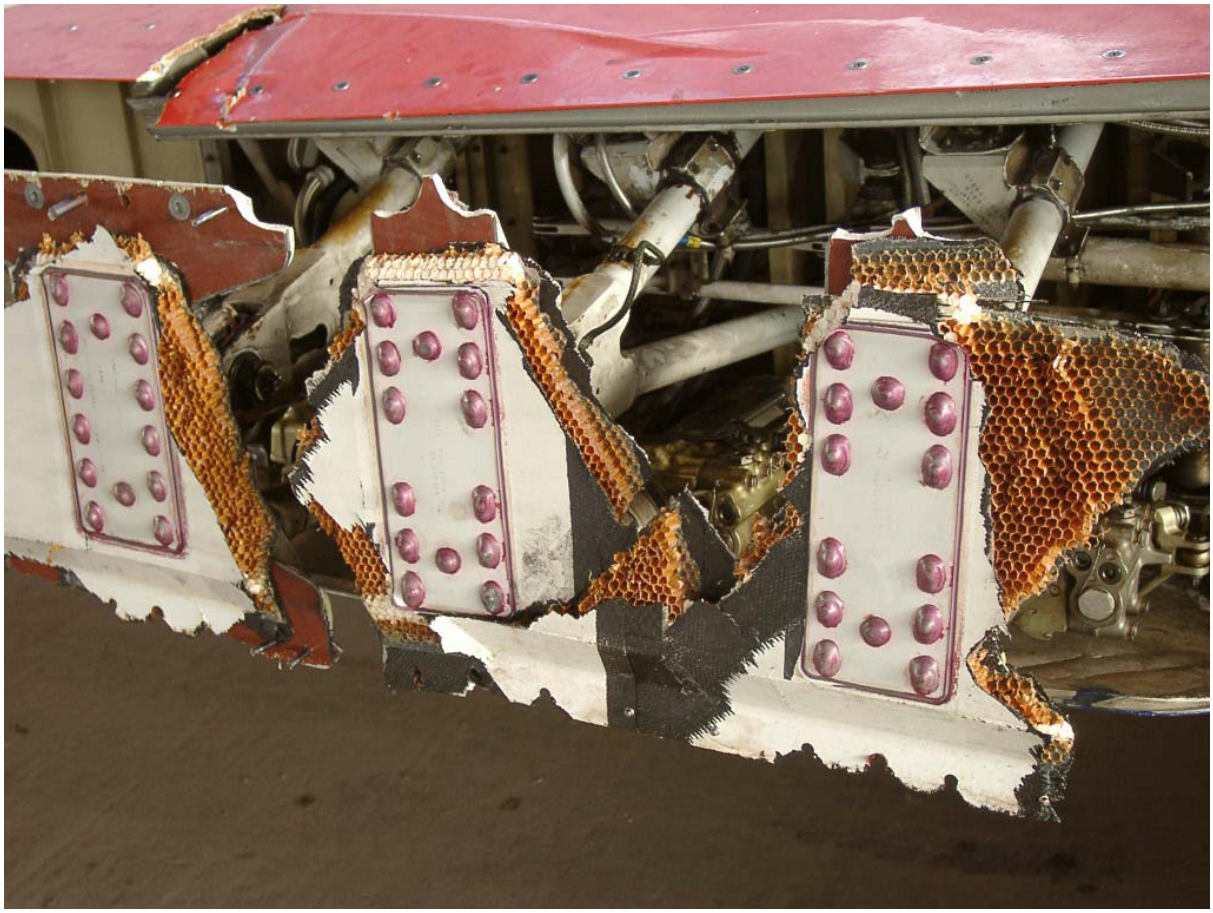


Figure 1

To establish the fitting damages test have been performed on 3 original fittings BR3 including the attach bolts as used on the rudder (see figure 2, 3).

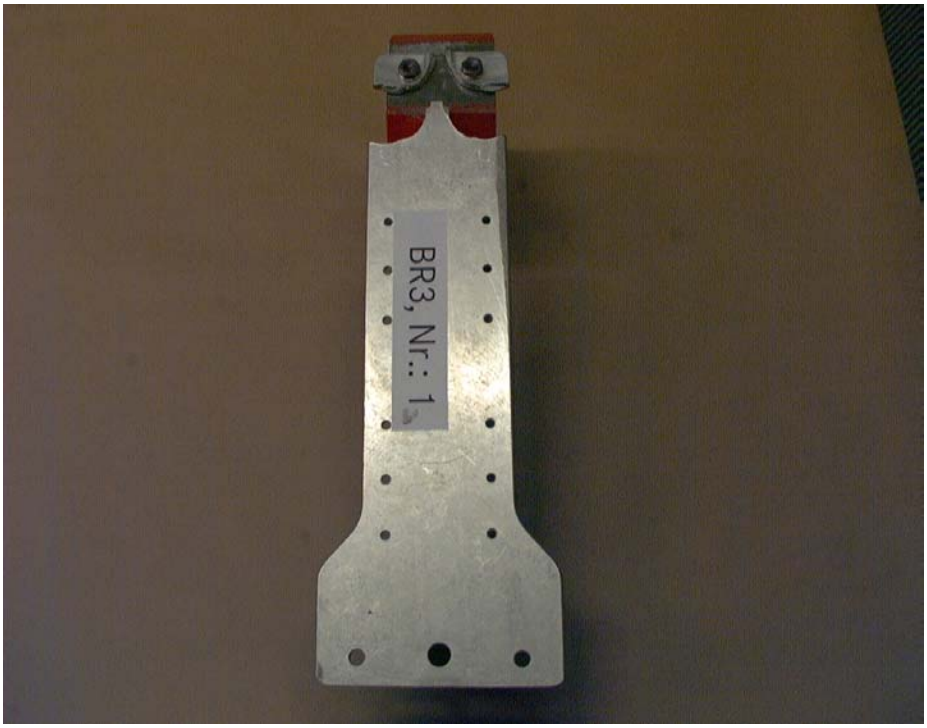


Figure 2

Figure 3

The test results are listed in figure 4.

Test no.	BR3 rupture load [N]
1	107 400
2	109 100
3	111 100

Figure 4

The failure modes are identical to the observed ones at the fittings BR2, BR3 of the accident rudder (see figure 1).

3. Strength of hinge arm attach fittings

The strength of the hinge arm attach fittings (see figure 5, 6) has been tested during the certification program of the vertical stabilizer for fittings no. 1, 3, 4, 6 and 7.

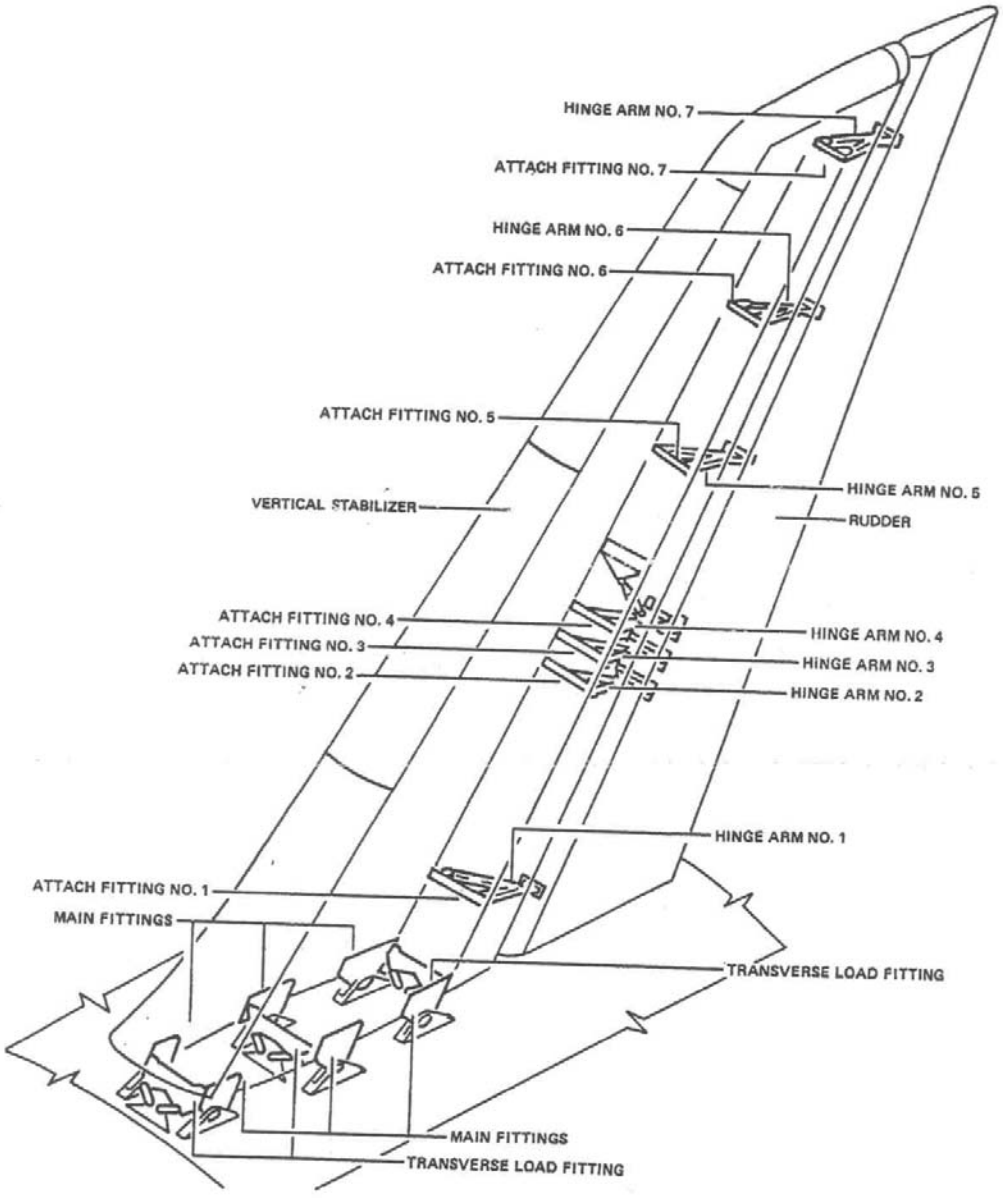


Figure 5

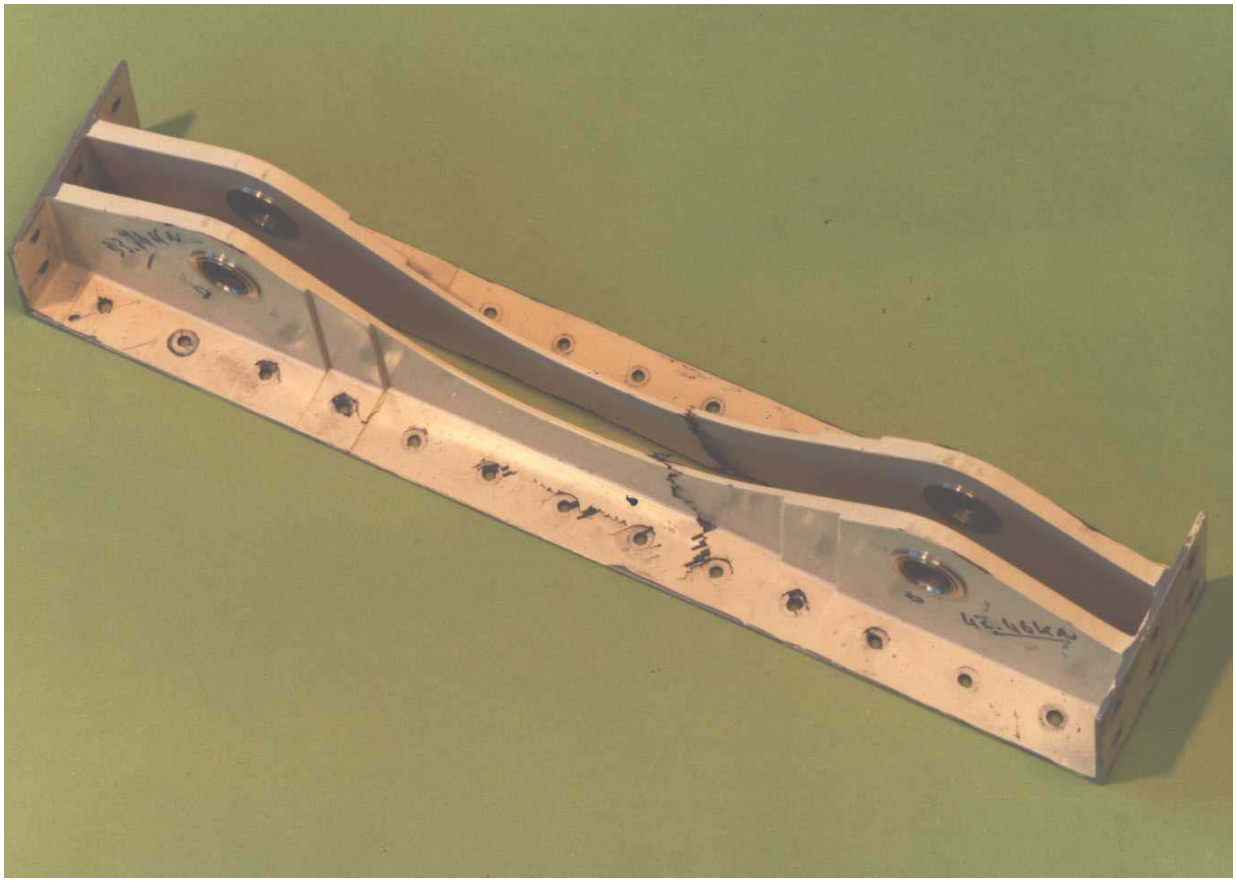


Figure 6

The strength values are listed in figure 7.

Attach fitting no.	Tension strength [N]	Compression strength [N]
1	80 480	-
3	337 000	337 000
4	326 400	326 000
6	42 460	-
7	54 240	-

Figure 7

The failure mode of hinge fitting no. 6 in the test is similar to the observed damage at the accident rudder (see figure 8).

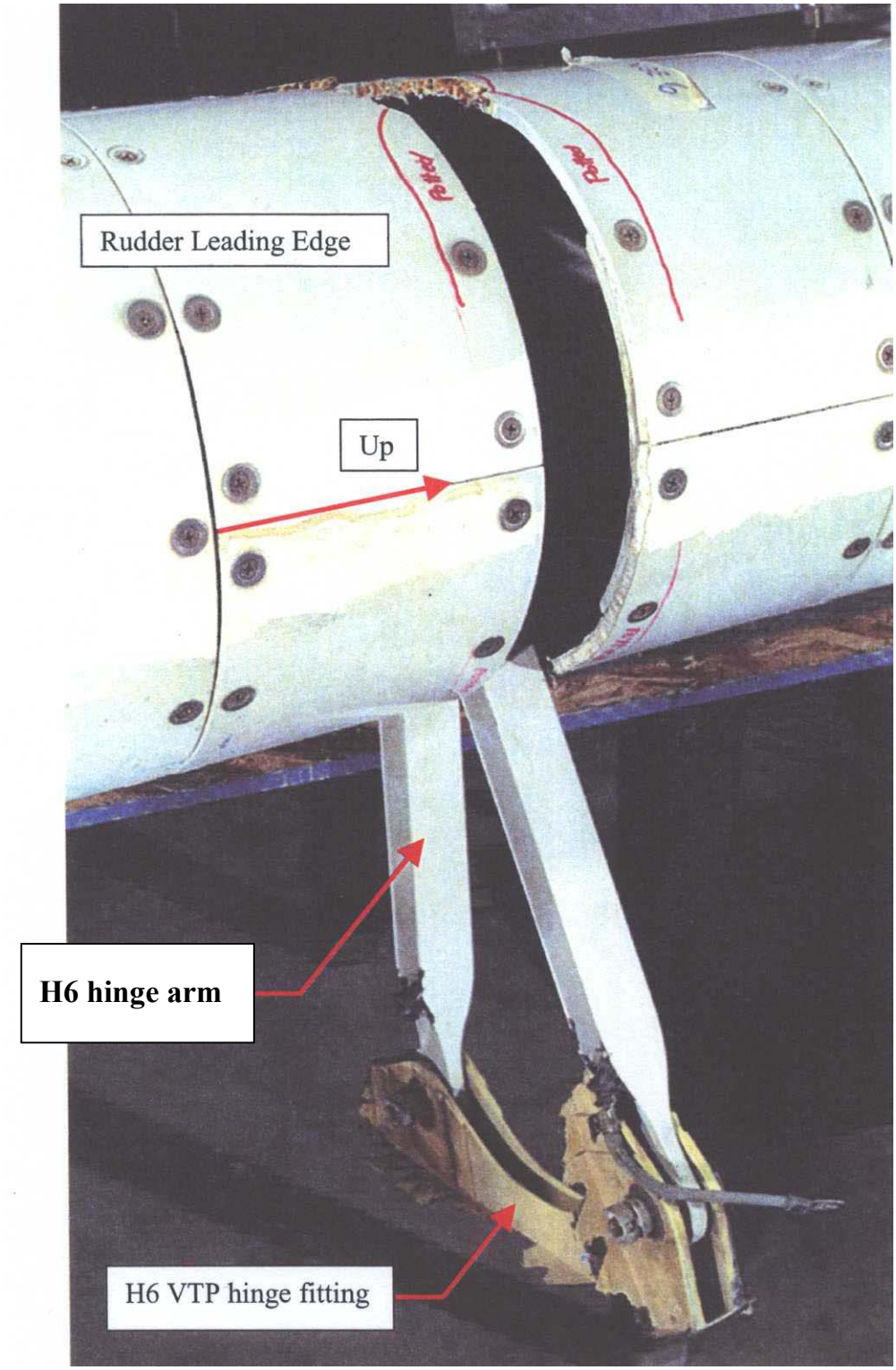


Figure 8

4. Analysed load cases

The damages observed on the rudder and hinge line can be reproduced by analysis applying a large hinge moment and normal force on the RHS rudder surface.
The magnitude of the hinge moment and normal force cannot be achieved by the rudder deflected to the maximum angle of 30° during the accident.
As a likely scenario a counter clockwise rotation of the structure into the airstream following the detachment from the aircraft is considered.
The structure is hit by the dynamic pressure. The lateral load and the corresponding hinge moment is listed in figure 9.

Load case	Normal load [N]	Hinge moment [Nm]
Dynamic pressure	180 053	118 470

Figure 9

5. Finite element analysis

A FEM – analysis is performed with the vertical stabilizer and rudder loaded on the RHS by the dynamic pressure load case. The analysis is run in several steps according to the progressing rupture sequence.

5.1 Initial condition with rudder and rudder support intact

During the first FEM analysis the rudder and its supports to the vertical stabilizer are intact. The hinge arm forces (see figure 10) and the rudder hinge fitting attachment forces (see figure 11) are given in the hinge line coordinate system (see figure 12).

Hinge arm attach fitting no.		Hinge arm force [N]
1	LHS	-10 070
	RHS	18 087
2	LHS	134 100
	RHS	125 204
3	LHS	138 471
	RHS	121 002
4	LHS	157 828
	RHS	147 679
5	LHS	-26 332
	RHS	33 068
6	LHS	-44 312
	RHS	**44 828**
7	LHS	-46 009
	RHS	41 665

Figure 10

		F_x [N]	F_y [N]
BR1	LHS	6432	-6470
	RHS	2147	-3074
BR2/AC1	LHS	-99201	-30678
	RHS	84868	24732
BR3/AC2	LHS	-100268	-31237
	RHS	87722	26512
BR4/AC3	LHS	-116368	-39458
	RHS	109851	14745
BR5	LHS	9529	-10175
	RHS	-2489	-6955
BR6	LHS	10525	-11097
	RHS	-9982	-10362
BR7	LHS	12885	-13111
	RHS	-17445	-13589

Figure 11

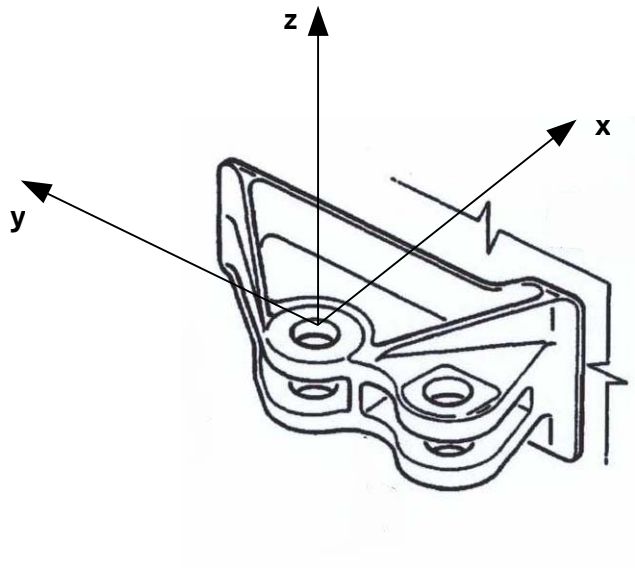


Figure 12

The analysis results indicate that hinge arm fitting no. 6 has exceeded its tension strength on RHS (see figure 7, 10, 13).

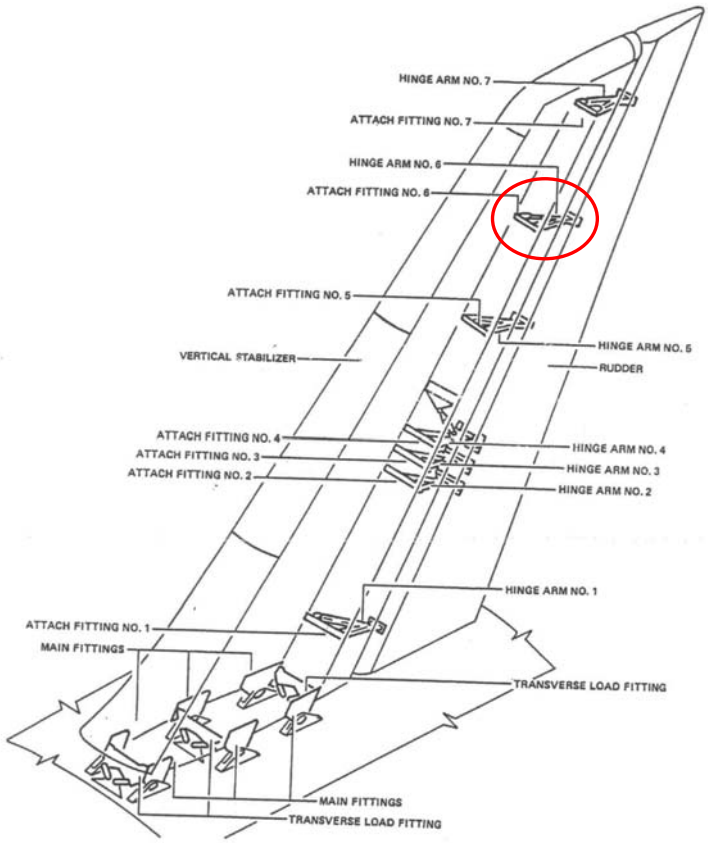


Figure 13

5.2 Analysis for the rupture sequence of the rudder

The second FEM analysis takes into account that hinge arm fitting no. 6 has ruptured on RHS. The forces are redistributed to hinges no. 5 and 7. The hinge fitting attachment forces (connection between rudder hinge fitting and rudder skin panels, see figure 14) are listed in figure 15.

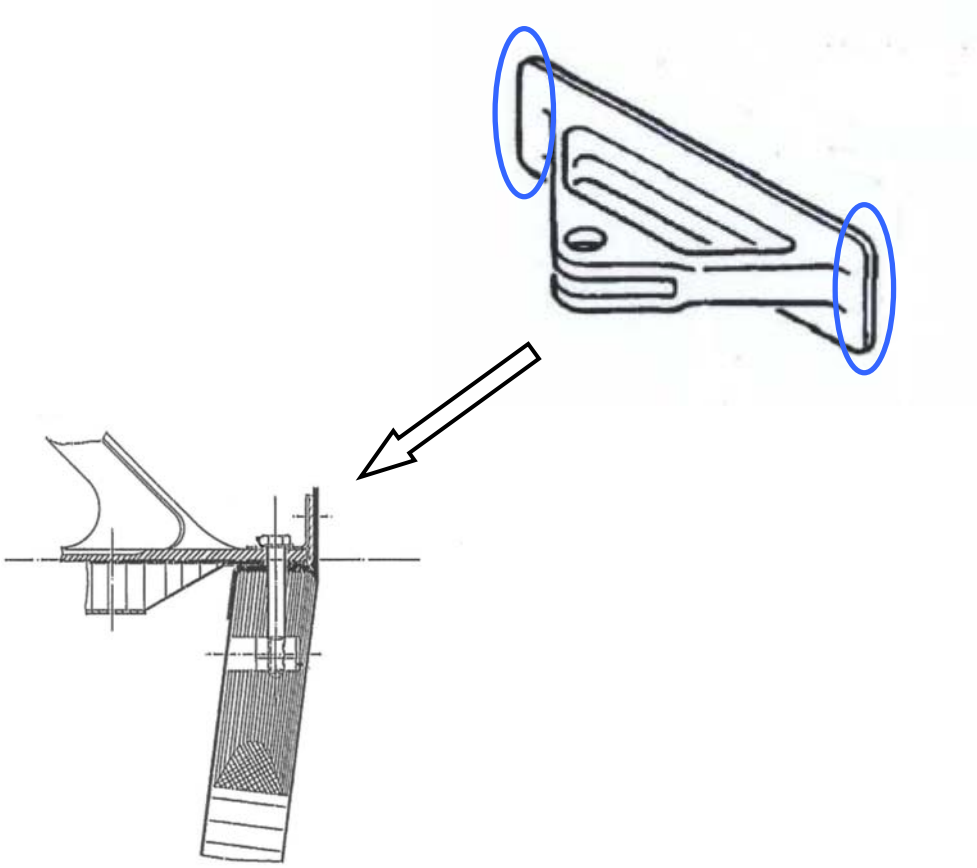
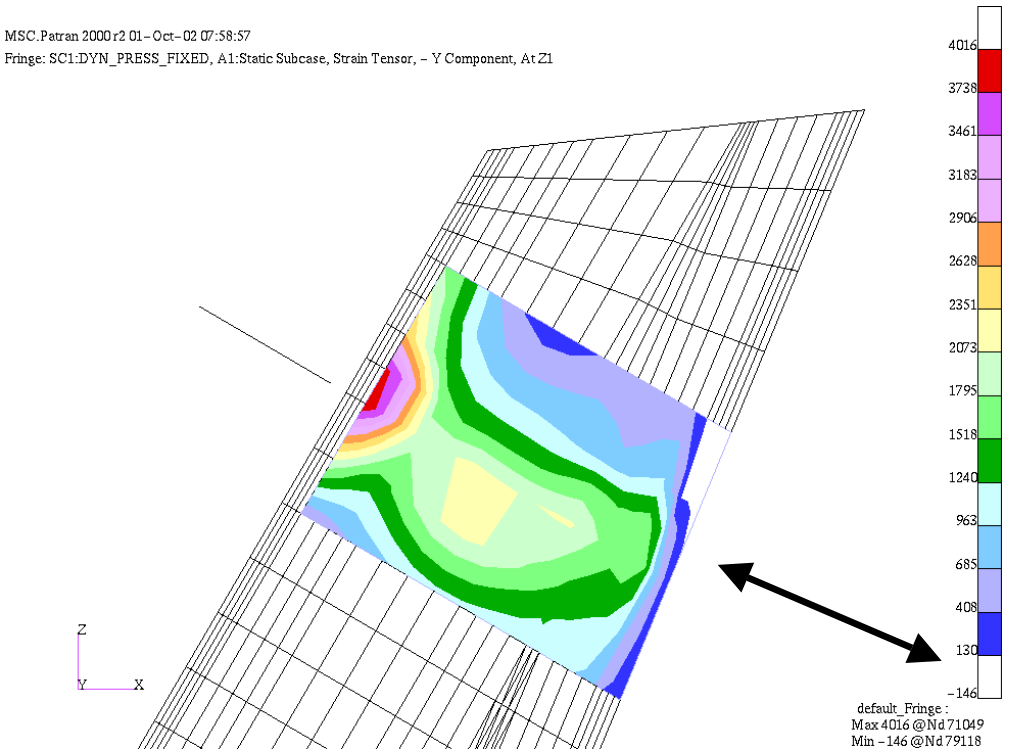


Figure 14

		F_x [N]	F_y [N]
BR1	LHS	4 229	-5 268
	RHS	203	-3 696
BR2/AC1	LHS	-101 892	-29 963
	RHS	84 560	24 576
BR3/AC2	LHS	-99 619	-31 034
	RHS	88 837	26 491
BR4/AC3	LHS	-110 492	-39 549
	RHS	113 579	14 259
BR5	LHS	20 333	-18 762
	RHS	-1 093	-11 721
BR6	LHS	-10 154	-617
	RHS	-16 531	-5 502
BR7	LHS	21 360	-17 264
	RHS	-15 002	-14 751

Figure 15

The local strain distribution around the rudder hinge fitting BR7 (see figure 16 to 21) indicates the rupture of the skin panels in the vicinity of the fitting attachment.
The direction of x-component of strain is cordwise normal to the rudder spar plane and the y-component is spanwise.

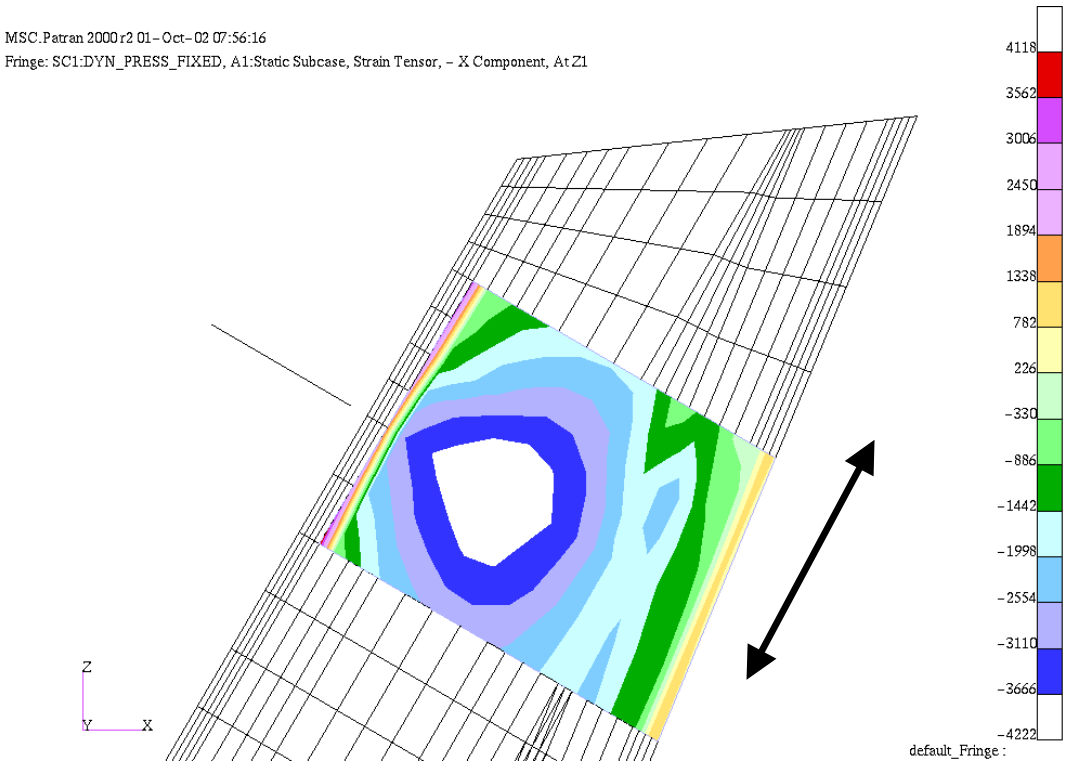


micro strain

[με]

Strain distribution in material coordinate system

Figure 16 (Strain ε_X LHS Rudder Shell)

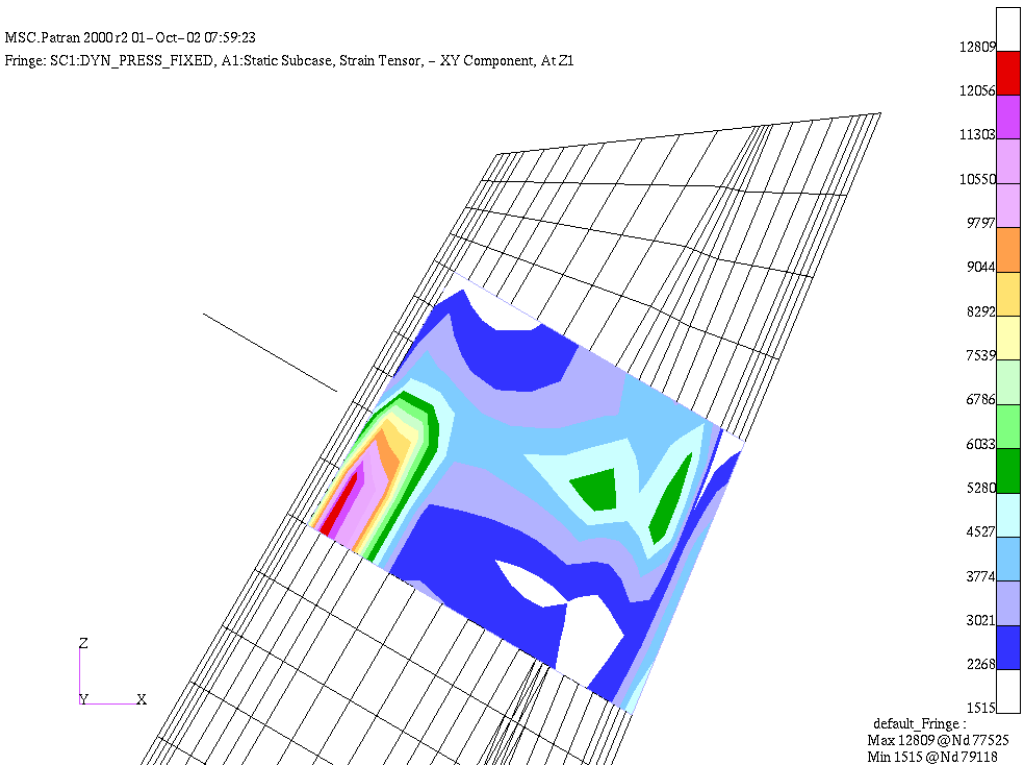


micro strain

[με]

Strain distribution in material coordinate system

Figure 17 (Strain ε_Y LHS Rudder Shell)

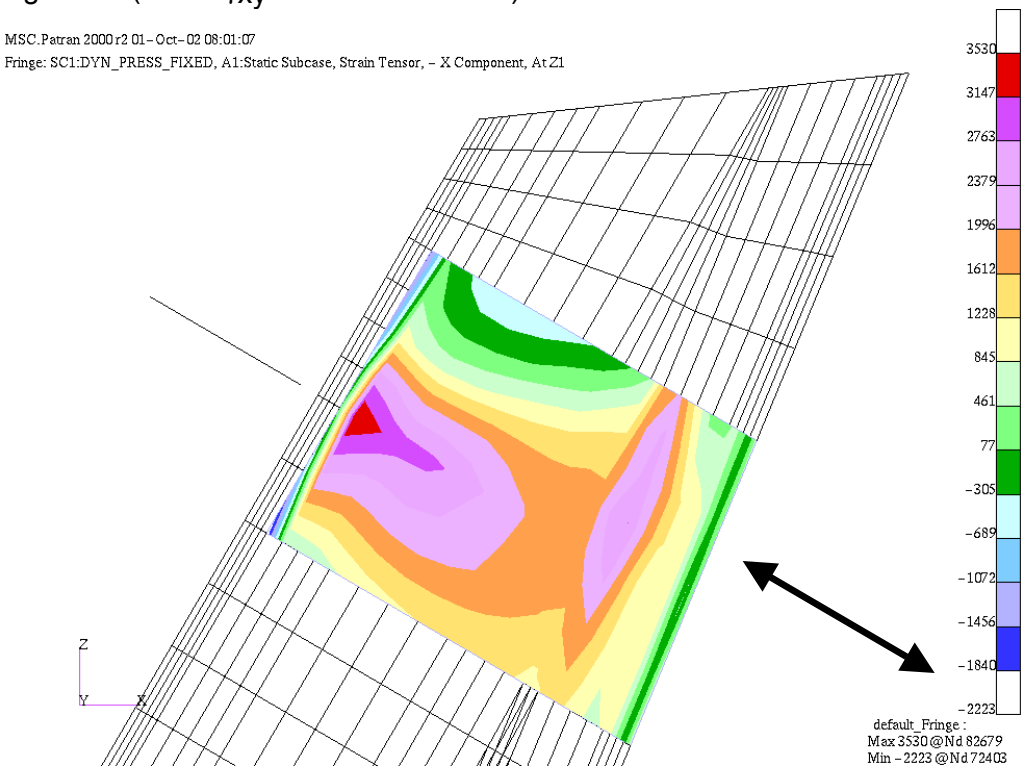


micro strain

[με]

Strain distribution in material coordinate system

Figure 18 (Strain γ_{xy} LHS Rudder Shell)

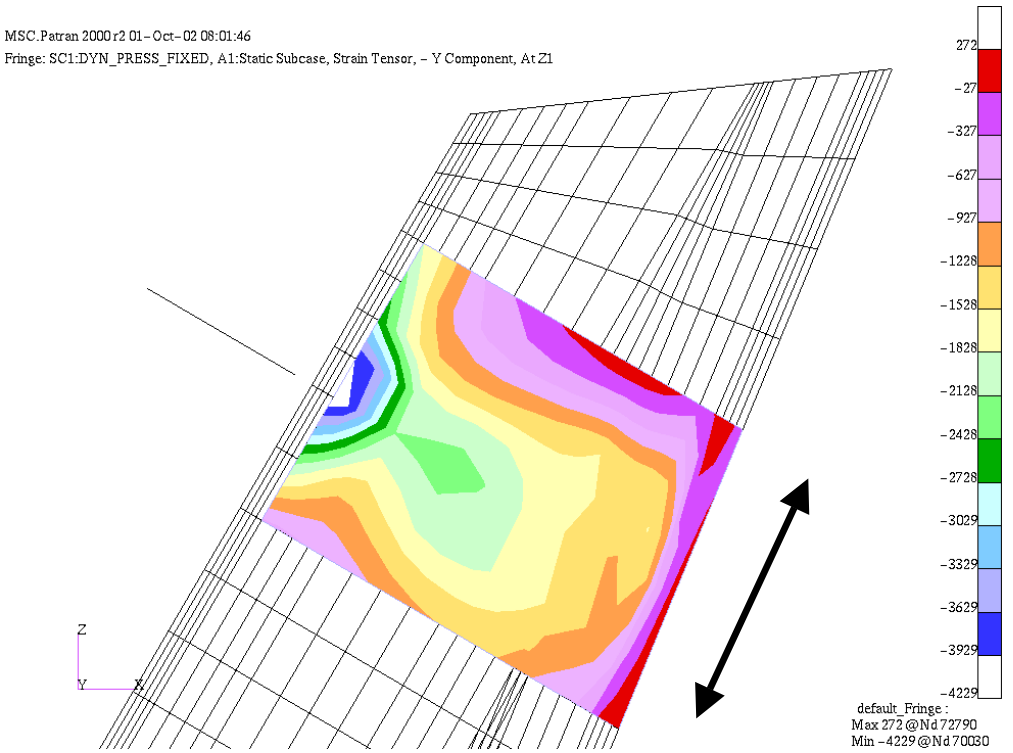


micro strain

[με]

Strain distribution in material coordinate system

Figure 19 (Strain ε_x RHS Rudder Shell)

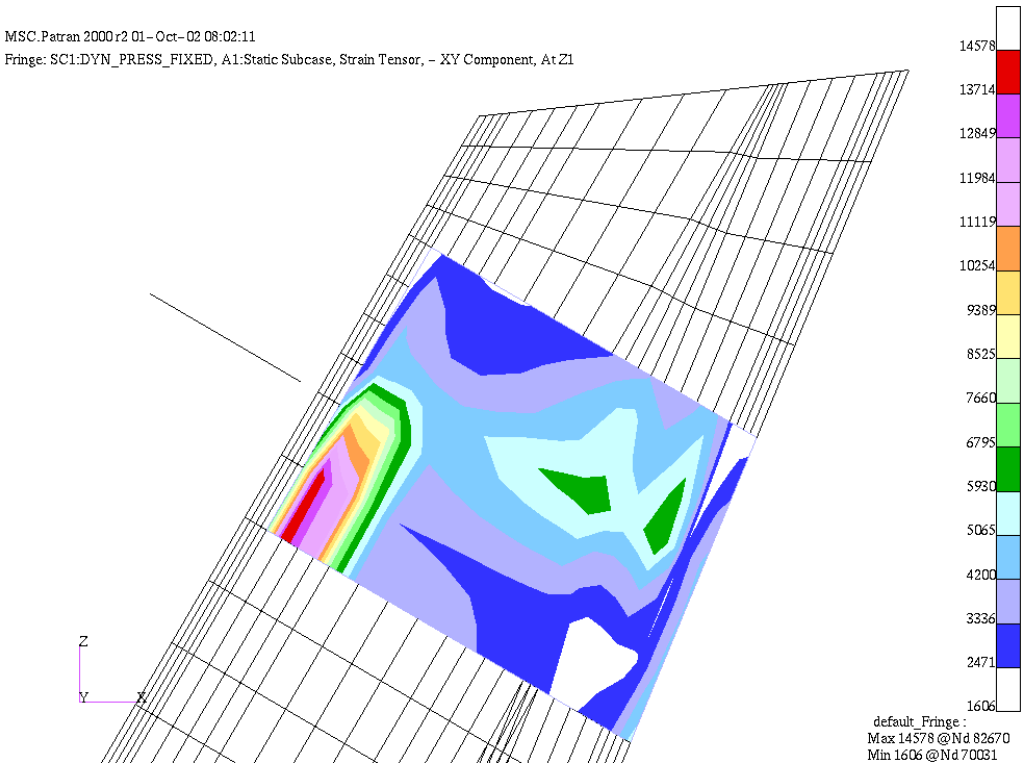


micro strain

[με]

Strain distribution in material coordinate system

Figure 20 (Strain ε_y RHS Rudder Shell)



micro strain

[με]

Strain distribution in material coordinate system

Figure 21 (Strain γ_{xy} RHS Rudder Shell)

The attachment forces of hinge fitting BR5 are on LHS and RHS in tension. The tension force (see figure 15) on LHS exceeds the strength of this fitting.

The third FEM analysis takes into account that a total disconnection at rudder hinge fitting BR7, a RHS rupture at the hinge arm fitting no. 6 and the LHS disconnection of the rudder hinge fitting BR5. For this condition the hinge fitting attachment forces are listed in figure 22.

		F_x [N]	F_y [N]
BR1	LHS	-44 163	19 074
	RHS	-44 764	-20 402
BR2/AC1	LHS	-161 757	-16 920
	RHS	77 284	19 707
BR3/AC2	LHS	-82 346	-28 364
	RHS	112 728	26 548
BR4/AC3	LHS	32 748	-39 834
	RHS	196 490	6 640
BR5	LHS	0	0
	RHS	-52 783	-85 647
BR6	LHS	-21 069	-1 816
	RHS	-34 584	-15 772
BR7	LHS	0	0
	RHS	0	0

Figure 22

At RHS of rudder hinge fitting BR3 and BR4 the attachment to the skin panels (see figure 23, 24) fails at this load level. Hinge fitting BR3 ruptures at RHS in the vicinity of the bolt holes (see figure 2 to 4) and at fitting BR4 five of six attach bolts rupture in tension (see figure 25).

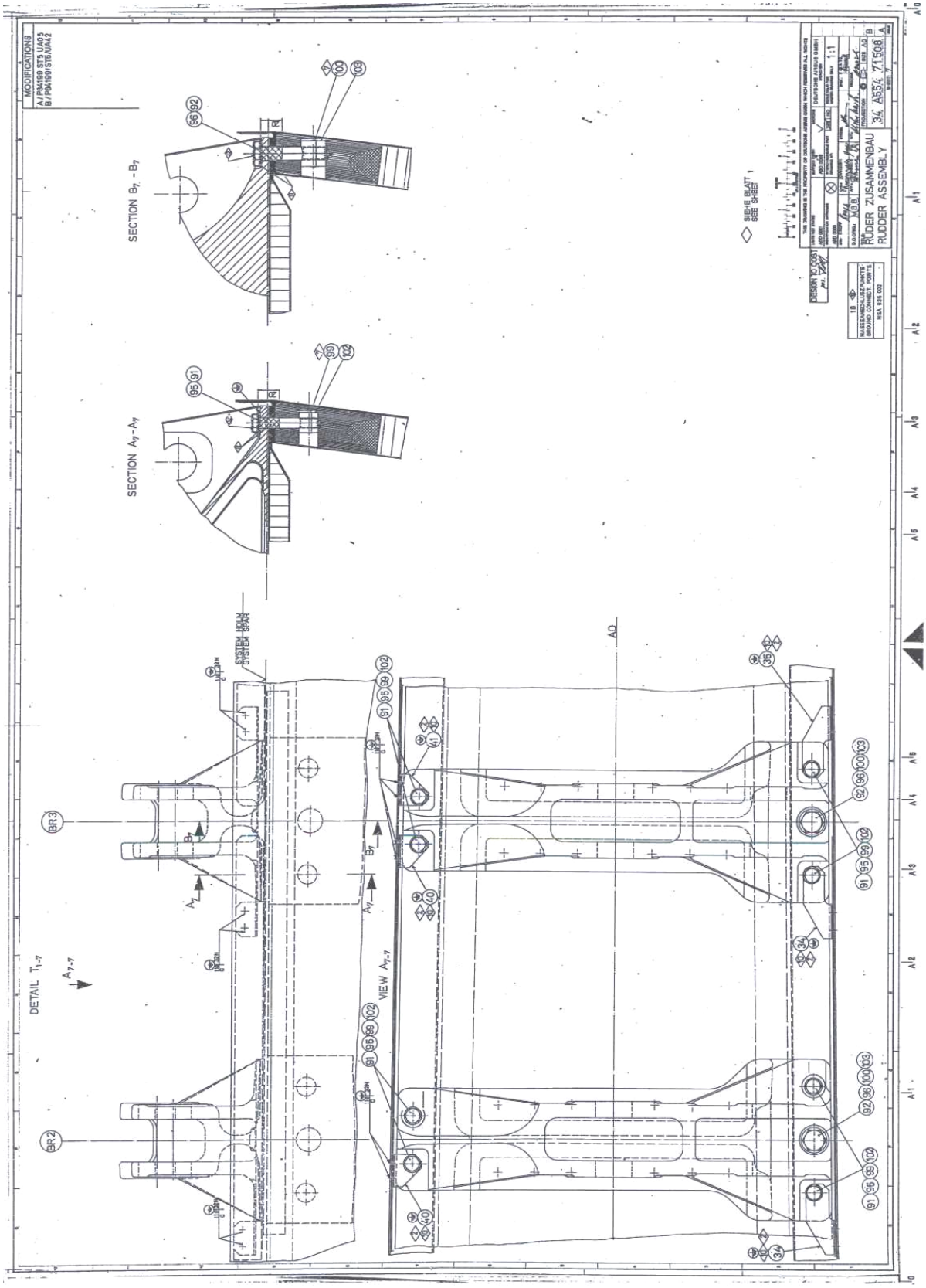


Figure 23

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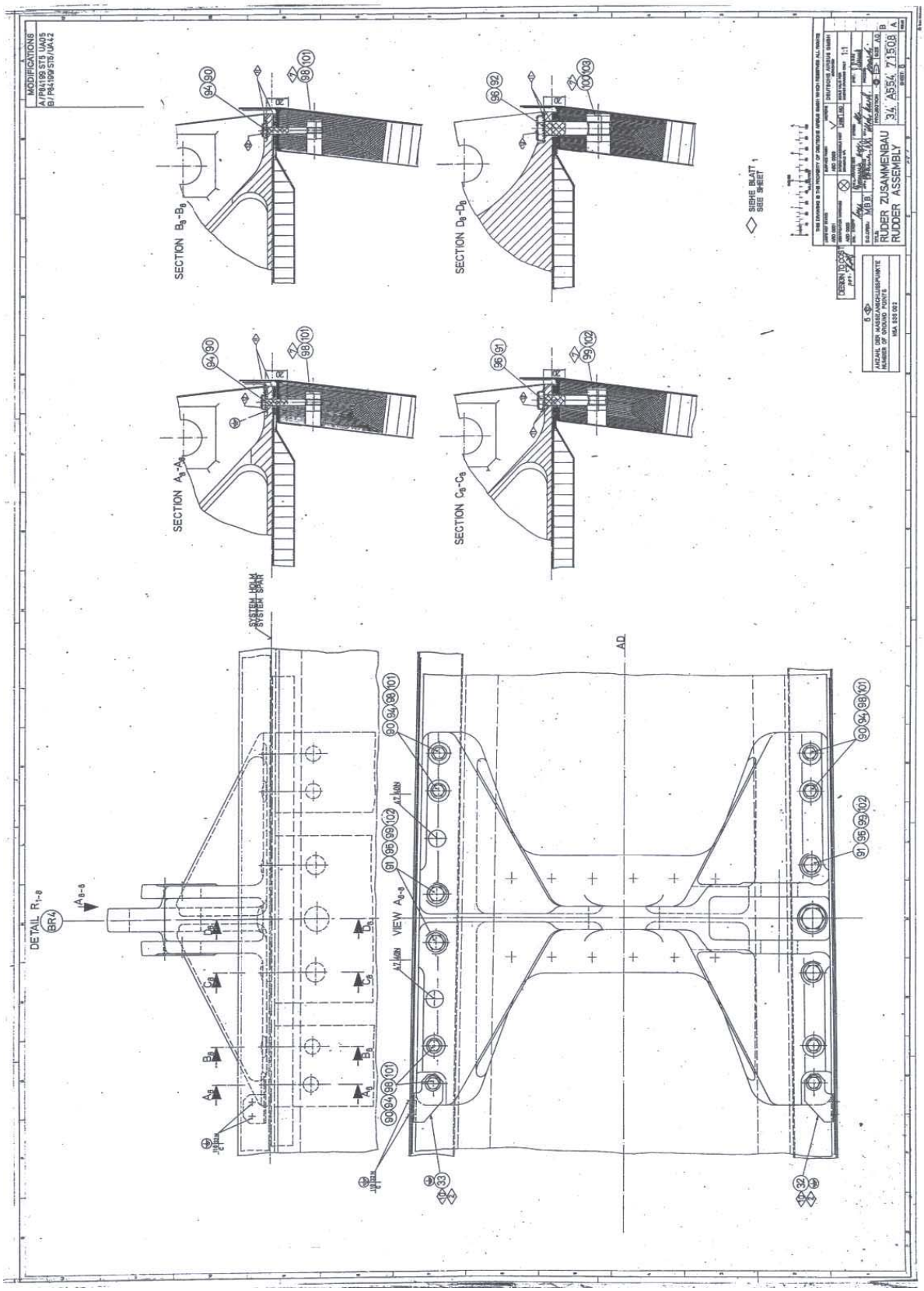

Figure 24

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	Date Prepared Approved	16.10.02 ----------				

				Thread	Tension strength [N]
95	Bolt, Hexagon-Head	ABS 0232-6-26		0.3750" - 24	67 610
95	Bolt, Hexagon-Head	A554-71515-202-00	NAS 670 6U28	0.3750" - 24	
99	Nut, Barrel	NAS 577-6A			75 620
94	Bolt, Hexagon-Head	ABS 0232-4-22		0,2500" - 28	28 780
94	Bolt, Hexagon-Head	A554-71515-204-00	NAS 670 4U25	0,2500" - 28	
98	Nut, Barrel	NAS 577-4A			32 030

Figure 25

As the consequence of the rupture at BR3 and BR4 the fitting BR2 ruptures next.

6. Summary

It has been shown by analysis and supported by test results that the rudder separation from the vertical stabilizer is a post-accident event.
The rupture sequence starts with the RHS hinge arm attach fitting no. 6 which is fixed to the upper rear spar of the vertical stabilizer.
The rupture progresses with the failure at the vicinity of hinge fitting BR7, the failure of the LHS hinge fitting BR5 and the failure of the RHS hinge fittings BR3, BR4 and BR2.
The sandwich structure disintegrates as a consequence of the hinge fitting ruptures.