

New

**Docket No. SA-522**

**Exhibit No. 7-CC**

**NATIONAL TRANSPORTATION SAFETY BOARD**

**Washington, D. C.**

Structural Analysis and Evaluation for the Airbus A300-  
600R/MSN420 VTP and rudder for the accident flight AA587  
Part 1 : Calculation of the Load Levels experienced by the VTP & rudder during  
the accident

(18 Pages)

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## Technical Note

Project / accounting / project order no.:

Copy to (\* = only this coversheet)

Order-No.:

Preparation:

During:

Report Nr.: TN – ----- – 13/2002

Author: -----

Department: -----

Title

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

#### Part I: Calculation of the load levels experienced by the vertical stabilizer and rudder during the accident

Date:

Summary:

Key Words (Retrieval Terms):

	Issue	Date	No. of page	Revised pages	Valid from/for
	1	16.10.02	28		

Name:	prepared -----	checked	approved	signed	released
Date:	16.10.02				
Signum:					

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## 1. Introduction

This report describes the basic part of structural analysis for the Airbus A300-600R vertical stabilizer and rudder subjected to the accident during flight AA 587.

The finite element method is applied to calculate the structural behaviour for the 3 load peaks prior to the accident and 2 sizing load cases for the attachment lugs and the rudder with its supporting structure. Analysis results are supplied for the vertical stabilizer fuselage attachment lugs, rudder hinge line forces and rudder hinge fitting attach bolt loads to provide answers for major concerns which are the vertical stabilizer attachment rupture and the damages to the rudder and the rudder hinge line. The experienced load levels at the lugs and the rudder hinges in terms of L.L. – requirements given for the sizing load cases are summarized.

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### 3. Analysed load cases

The loads are calculated using the flight data recordings up to the accident.

The loads are provided as forces acting on both surfaces of the vertical stabilizer and rudder at the grid points of the analysis model.

The three most significant load cases with the reference

CRSHNBT1P2 238 D01ICCF0T YM-8026 (designation in this report K238)

CRSHNBT1P2 316 D01ICCF0T YM-8026 (designation in this report K316)

CRSHNBT1P2 376 D01ICCF0T YM-8026 (designation in this report Y376)

from the bending moment history prior to the accident were selected (see figure 4).

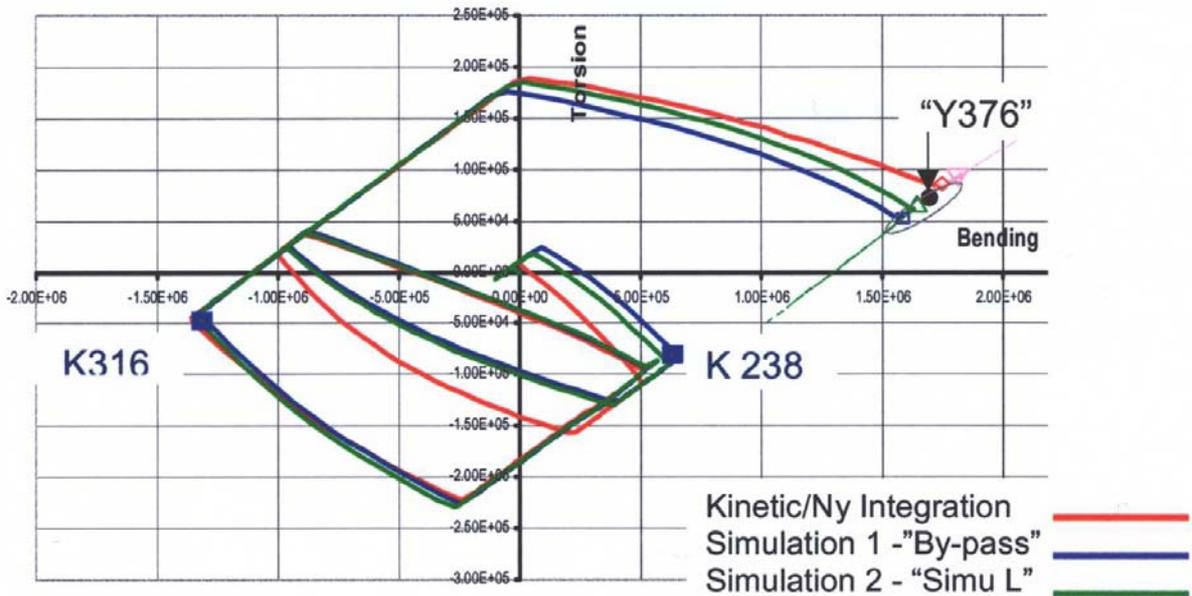


Figure 4

The correlated loads lateral shear  $Q_y$ , the bending moment  $M_{xQ}$  and the torsional moment  $M_{zQ}$  at the root of the vertical stabilizer are listed in figure 5 with the rudder deflection angle and hinge moment belonging to it.

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	K238	K316	Y376
$Q_y$ [N]	-107 990	291 470	-378 590
$M_{xQ}$ [Nm]	564 140	-1 313 960	1 689 880
$M_{zQ}$ [Nm]	-87 060	-41 720	71 050
Rudder hinge moment [Nm]	13 041	-17 116	21 610
Rudder deflection angle [°]	-10.56	9.95	-11.47

Figure 5

The loads are given in the fin coordinate system (see figure 6).

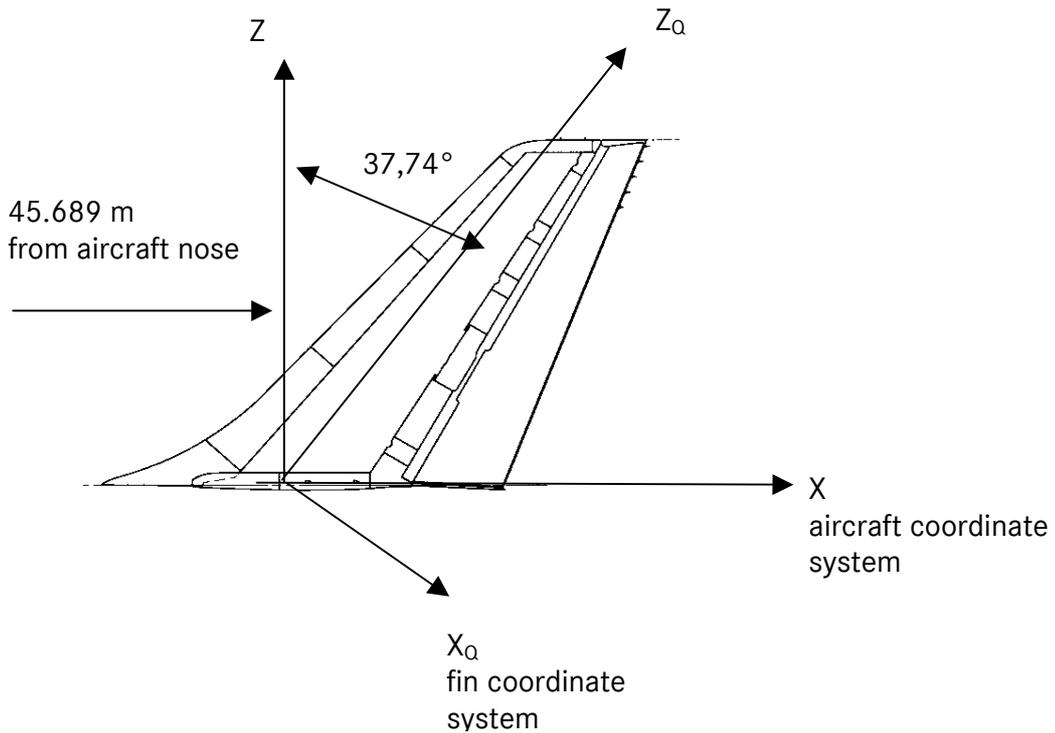


Figure 6

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To compare the load level experienced during the accident with the loads demonstrated for certification according to FAR25 requirements, the sizing load case (see figure 7) for the vertical stabilizer attachment lugs has been anew analyzed.

	Lateral gust, discrete A36RBI17 SD06 (limit load)
Q <sub>y</sub> [N]	-215 770
M <sub>xQ</sub> [Nm]	861 650
M <sub>zQ</sub> [Nm]	150 410

Figure 7

For the analytical investigation of the rudder the load case with the maximum hinge moment (figure 8) has been used to calculate hinge line forces and hinge fitting attach forces. The load level experienced by the rudder and its supports during the accident is calculated by comparing the hinge moment limit load requirement for the A300-600R and the hinge moment demonstrated by test during the certification (see figure 8).

	Lateral maneuver A36RLA38 <b>limit load</b>	Certification tests, static <b>limit load</b>	Y376
Hinge moment [Nm]	-17 250	33 910	21 610
Rudder deflection [°]	25.43		-11.47

Figure 8

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### 4. Analysis results

#### 4.1 Vertical stabilizer reaction loads

The results are given as reaction forces in the aircraft coordinate system (see figure 6) at the main lugs and the lateral yokes, which are attached to the transverse load fittings (see figure 9 - 12). A negative sign for  $F_z$  indicates tension at the main lugs.

##### 4.1.1 Load case K238

Reaction forces at main lugs

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	71 284	-80 322	86 157	-88 191	146 507	-141 788
$F_y$	872	1 180	9 127	9 338	15 975	15 715
$F_z$	63 025	-74 193	178 279	-179 470	257 154	-241 351
$F_{res}$	95 154	109 351	198 216	200 186	296 391	280 359
$M_x$ [Nm]	-527	-591	-2 001	-2 036	-3 161	-2 983
$M_z$ [Nm]	17	-4	372	340	1 394	1 290
angle [°]	41	43	64	64	60	60

Reaction forces at lateral load yokes

Load Component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	366	-409	209	-246	-4 204	4 401
$F_y$	-4 929	-5 505	-2 856	-3 369	34 541	36 162
$F_z$	417	-466	318	-375	-6 415	6 716
$F_{res}$	4 960	5 540	2 881	3 399	35 383	37 043

Figure 9

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**4.1.2 Load case K316**

Reaction forces at main lugs

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	-197 567	186 374	-181 140	180 842	-298 776	303 039
$F_y$	-8 334	-7 862	-25 857	-25 946	-33 907	-34 551
$F_z$	-235 674	223 400	-497 135	494 247	-618 701	637 490
$F_{res}$	307 643	291 040	529 739	526 932	687 901	706 697
$M_x$ [Nm]	2 169	2 124	5 623	5 673	7 724	7 942
$M_z$ [Nm]	-14	-57	-805	-753	-3 098	-3 059
angle [°]	50	50	70	70	64	65

Reaction forces at lateral load yokes

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	696	-744	371	-336	7 533	-7 248
$F_y$	-9 369	-10 021	-5 068	-4 592	-61 893	-59 552
$F_z$	792	-847	565	-512	11 494	-11 060
$F_{res}$	9 428	10 084	5 113	4 632	63 400	61 002

Figure 10

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**4.1.3 Load case Y376**

Reaction forces at main lugs

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
F <sub>x</sub>	241 154	-254 033	228 468	-233 066	387 676	-379 764
F <sub>y</sub>	10 521	11 139	33 342	33 825	43 950	43 696
F <sub>z</sub>	290 117	-307 792	640 708	-641 682	820 805	-796 830
F <sub>res</sub>	377 404	399 240	681 040	683 535	908 815	883 780
M <sub>x</sub> [Nm]	-2 755	-2 844	-7 268	-7 367	-10 209	-9 958
M <sub>z</sub> [Nm]	59	33	1 041	952	4 061	3 832
angle [°]	50	50	70	70	65	65

Reaction forces at lateral load yokes

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
F <sub>x</sub>	-1 053	985	-590	488	-9 192	9 470
F <sub>y</sub>	14 171	13 261	8 068	6 669	75 525	77 809
F <sub>z</sub>	-1 199	1 121	- 899	743	-14 026	14 450
F <sub>res</sub>	14 261	13 345	8 140	6 728	77 364	79 704

Figure 11

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**4.1.4 Load case Lateral Gust A36RBI17**

Reaction forces at main lugs

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	134 392	-133 432	105 747	-107 032	178 043	-177 638
$F_y$	8 392	8 429	19 324	19 451	21 014	21 317
$F_z$	186 089	-186 552	365 710	-364 532	433 075	-433 669
$F_{res}$	229 697	229 514	381 181	380 418	468 716	469 125
$M_x$ [Nm]	-1 806	-1 804	-4 193	-4 221	-5 485	-5 438
$M_z$ [Nm]	21	27	510	458	2 009	1 948
angle [°]	54	54	74	74	68	68

Reaction forces at lateral load yokes

Load component	Front [N]		Center [N]		Rear [N]	
	LHS	RHS	LHS	RHS	LHS	RHS
$F_x$	-1 262	1 261	-792	754	-3 613	3 573
$F_y$	16 987	16 970	10 828	10 310	29 685	29 356
$F_z$	-1 437	1 435	-1 207	1 149	-5 513	5 452
$F_{res}$	17 094	17 077	10 923	10 401	30 408	30 071

Figure 12

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### 4.2 Rudder hinge line forces

The rudder hinge line forces are listed only for the maximum load case Y376. The corresponding values for the load cases K238 and K316 are lower due to lower hinge moment and displacement of the supporting vertical stabilizer.

For designation of the hinges see figure 13.

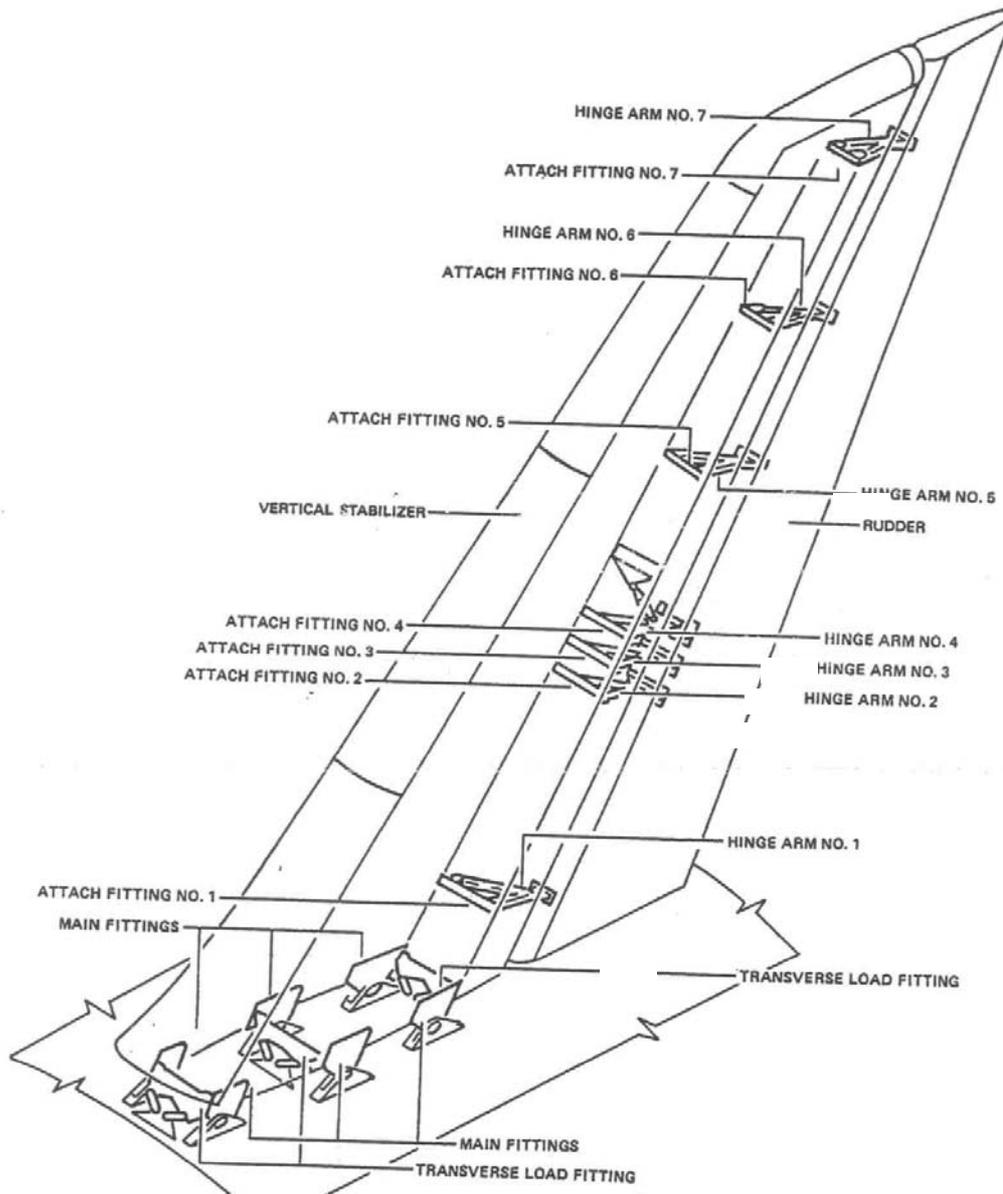


Figure 13

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The forces at the hinge line of the rudder for fittings BR1 to BR7 are given in the hinge line coordinate system (see figure 14) and are listed in figure 15 and 16.

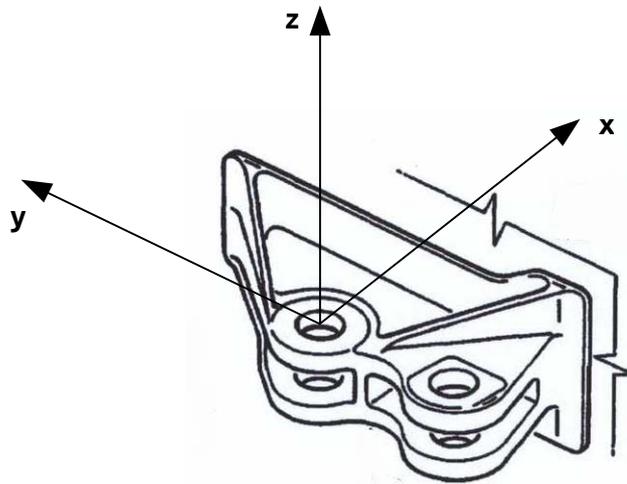


Figure 14

	Load case Y376		
	$F_x$ [N]	$F_y$ [N]	$F_{res}$ [N]
BR1	-11 743	1 857	11 889
BR2	-41 373	10 125	42 594
AC1	41 406	3 333	41 539
BR3	-40 079	7 937	40 857
AC2	43 542	3 583	43 689
BR4+Z-Force	-46 005	7 883	46 675
AC3	53 074	4 617	53 275
BR5	-2 345	5 270	5 768
BR6	-3 786	5 427	6 617
BR7	-3 640	3 922	5 351

Figure 15

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	Load case Lateral Maneuver A36RLA38 <b>limit load</b>		
	$F_x$ [N]	$F_y$ [N]	$F_{res}$ [N]
BR1	-9 491	-4 783	10 628
BR2	33 658	-5 176	37 021
AC1	-40 682	-3 771	40 856
BR3	37 934	-5 006	38 263
AC2	-38 919	-3 695	39 094
BR4 + Z-Force	44 855	-6 972	45 394
AC3	-42 844	-4 302	43 060
BR5	-2 092	-5 786	6 153
BR6	-4 152	-5 476	6 872
BR7	-4 189	-3 243	5 298

Figure 16

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**5. Evaluation of results**

**5.1 Loads level on the vertical stabilizer attachment lugs**

The load levels which have been experienced during the 3 last bending moment peaks before the accident are calculated by comparison of the resultant forces at the RHS main lugs of the vertical stabilizer for the load cases K238, K316 and Y376 (see fig. 9 to 11) with the resultant forces at limit load for the sizing load case “lateral gust, discrete A36RBI17” (see figure 12).

The equivalent load levels based on L.L. of the lateral gust load case are listed in figure 25.

Case	Experienced load level ( x L.L.)		
	FS	CS	RS
K238	0.48	0.53	0.60
K316 <sup>1)</sup>	1.27	1.39	1.51
Y376	1.74	1.80	1.88

<sup>1)</sup> For load case K316 RHS lugs are acting in compression

Figure 25

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**5.2 Load level at the rudder hinge line**

The rudder hinge line forces from load case Y376 (see figure 15) are compared with the sizing load case “lateral maneuver” (see figure 16) for each hinge separately in figure 26.

Hinge	Experienced load level (x L.L.)
BR1	1.12
BR2	1.15
BR3	1.07
BR4	1.03
BR5	0.94
BR6	0.96
BR7	1.01

Figure 26

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**5.3 Strain levels in the vertical stabilizer skin panels**

The strain distributions for both load cases are similar especially for the component  $\epsilon_x$ . The strain level which has been experienced during the accident is calculated from the minimum principal strain values of load case Y376 and load case A36RBI17 from the LHS compression panels (see figure 27).

	Lateral gust <b>limit load</b> A36RBI17	Y376	Experienced strain level ( x L.L.)
Min. principal	-1 503	-3 238	2.15

Figure 27

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### 6. Summary

The evaluation of analysis results demonstrates, that concerning the vertical stabilizer attachment lugs

- case K238 is significantly below L.L. – requirement,
- case K316 is at 1.51 x L.L. – level
- and case Y376 is at 1.88 x L.L. – level and exceeds U.L. – requirement significantly by 26 %.

The load level at the rudder hinge line is 1.15 x L.L. at maximum relative to the rudder maneuver load case required by FAR25 for A300-600R.

In relation to the static load case demonstrated for certification the experienced hinge moment is equivalent to 42.5%.

The damages at the rudder hinge line and the sandwich structure itself is not caused by the loads acting on the rudder or due to interface loads between vertical stabilizer and rudder from deformation prior to the accident.

The maximum strain values in the skin panels of the vertical stabilizer are equivalent 2.15 x L.L. from the lateral gust case.

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