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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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Title

Structural Analysis and evaluation for the Airbus A300-600R / MSN 420 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

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1. Introduction

This report describes the basic part of structural analysis for the Airbus A300-600R, MSN 420 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 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.

3. Analysed load cases

The loads are calculated using the flight data recordings up to the accident. They are reported in document ________________.

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.

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 4 with the rudder deflection angle and hinge moment belonging to it.

	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 4

The loads are given in the fin coordinate system (see figure 5).

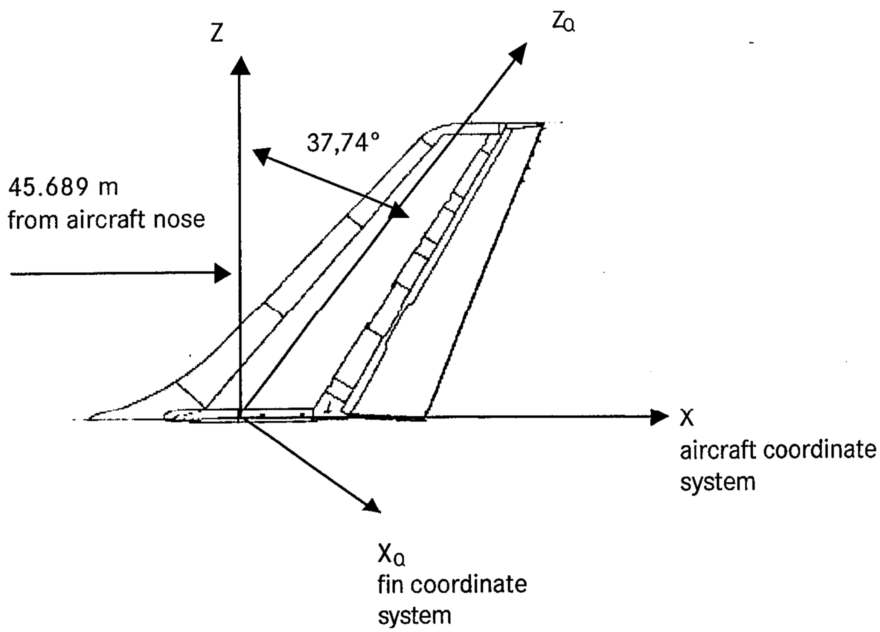

Figure 5

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 6) for the vertical stabilizer attachment lugs has been anew analyzed.

	Lateral gust, discrete A36RBI17 SD06 (limit load)
Qy [N]	-215 770
M_{xQ} [Nm]	861 650
M_{zQ} [Nm]	150 410

Figure 6

For the analytical investigation of the rudder the load case with the maximum hinge moment (figure 7) 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 7).

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

Figure 7

4. Analysis results

4.1 Vertical stabilizer reaction loads

The results are given as reaction forces in the aircraft coordinate system (see figure 5) at the main lugs and the lateral yokes, which are attached to the transverse load fittings (see figure 8 - 11).

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 8

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 9

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_x	241 154	-254 033	228 468	-233 066	387 676	-379 764
F_y	10 521	11 139	33 342	33 825	43 950	43 696
F_z	290 117	-307 792	640 708	-641 682	820 805	-796 830
F_{res}	377 404	399 240	681 040	683 535	908 815	883 780
M_x [Nm]	-2 755	-2 844	-7 268	-7 367	-10 209	-9 958
M_z [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_x	-1 053	985	-590	488	-9 192	9 470
F_y	14 171	13 261	8 068	6 669	75 525	77 809
F_z	-1 199	1 121	- 899	743	-14 026	14 450
F_{res}	14 261	13 345	8 140	6 728	77 364	79 704

Figure 10

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
Fres	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 11

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 12.

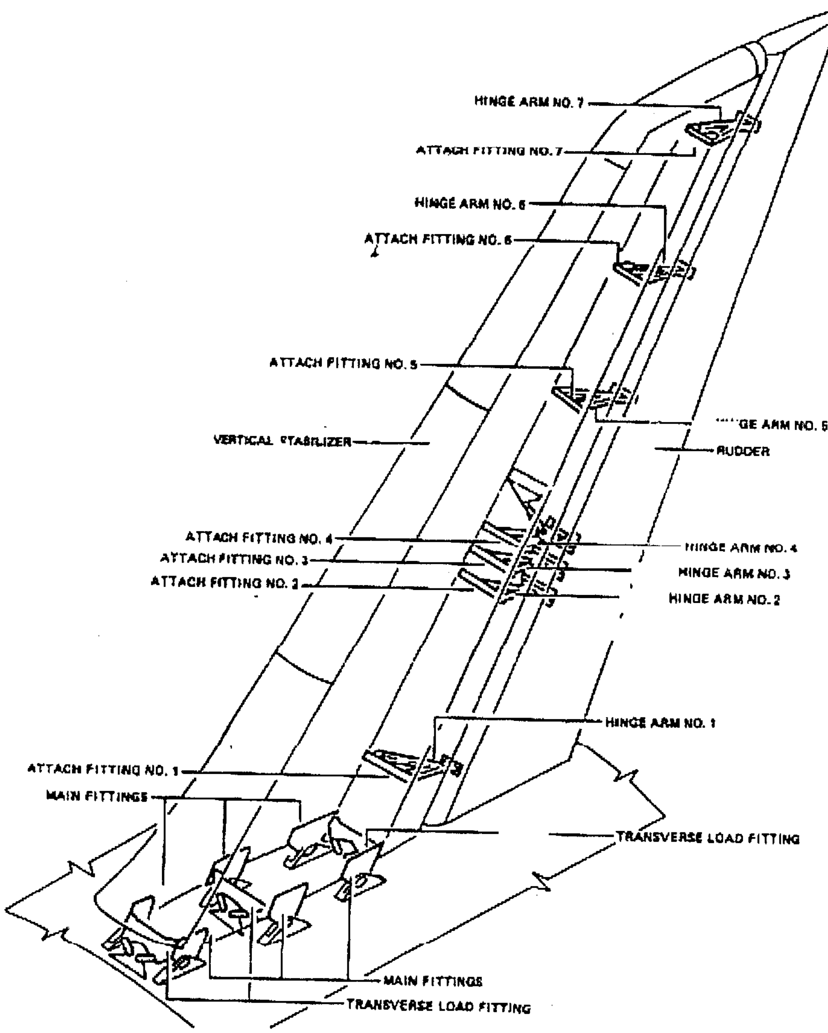

Figure 12

The forces at the hinge line of the rudder for fittings BR1 to BR7 are given in the hinge line coordinate system (see figure 13) and are listed in figure 14 and 15.

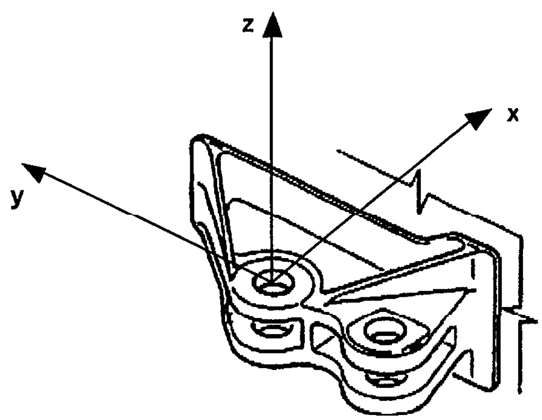

Figure 13

	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 14

	Load case Lateral Maneuver A36RLA38 **limit load**		
	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 15

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 main lugs of the vertical stabilizer for the load cases K238, K316 and Y376 (see fig. 8 to 10) with the resultant forces at limit load for the sizing load case “lateral gust, discrete A36RBI17” (see figure 11).
The equivalent load levels based on L.L. of the lateral gust load case are listed in figure 24.

Case	Experienced load level (x L.L.)		
	FS	CS	RS
K238	0.48	0.53	0.60
K316	1.27	1.39	1.51
Y376	1.70	1.80	1.91

Figure 24

5.2 Load level at the rudder hinge line

The rudder hinge line forces from load case Y376 (see figure 14) are compared with the sizing load case "lateral maneuver" (see figure 15) for each hinge separately in figure 25.

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 25

5.3 Strain levels in the vertical stabilizer skin panels

The strain distributions for both load cases are similar especially for the component ? 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 26).

	Lateral gust **limit load** A36RBI1 7	Y376	Experienced strain level (x L.L.)
Min. principal	-1 503	-3 210	2.13

Figure 26

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 1.91 x L.L. – level and exceeds U.L. – requirement significantly by 27 %.

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 2.13 x L.L. from the lateral gust case.