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

December 3, 2003

ADDENDUM NUMBER 10 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. "AAL587 Investigation – Study on potential effect of rudder delamination"

AIRBUS

DEPARTEMENT : -------- SECTION : 529 GO : PROGRAMME : A300-600 OU AFFAIRE : DATE : 12/11/2003	REFERENCE : A0030D03020335 EDITION : 01 PROJET : REF. PROJET : O.F. : ATA : - - CLIENT :	TOME : REV :	
TITRE : AAL587 Investigation - Study on potential effect of Rudder Delamination			
AUTEUR(S) :			

RESUME :

The purpose of the present note is to deliver results on potential effect of delaminated Rudder on dynamic and flutter behaviour.

This analysis has been performed on three Rear Part Models (S19 + Fin + Rudder) delivered by AI-G Stress Office :

- Model with nominal Rudder,
- First model with partially delaminated Rudder skin.
- Second model with second partially delaminated Rudder skin (zone with delamination is more important).

Comparisons have been done on Modal Schema (frequencies and modal shapes) and flutter.

The study demonstrates a negligeable influence on dynamic and flutter behaviour of both partial Rudder skin delamination :

- Less than 0.4 % on frequencies up to 40 Hz for first model with partially delaminated Rudder skin
- Less than 1% on frequencies up to 25Hz and 4% up to 40Hz for second model with delamination,
- No noticeable modifications of Modal shapes up to 40 Hz,
- No impact on flutter analysis results.

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1. INTRODUCTION

This note provides the results of flutter analysis performed on a rear part of A300-600 in order to assess the influence of delamination of rudder above hinge 4. The flutter behaviour is compared to the nominal case (without delamination).

2. DYNAMIC MODEL

The analysis has been performed on three Rear Part Models (S19 + Fin + Rudder) of A300-600 delivered by AI-G Stress Office :

- Model with nominal rudder,
- Model with partially delaminated rudder skin
- Model with partially delaminated rudder skin, to simulate a greater reduced stiffness.

The structural models are defined in right aircraft coordinate system : x backwards, y on the right, z upwards. These models are NASTRAN finite elements models of the Vertical Tail Plane and Rear fuselage of A300-600 delivered by AIRBUS Germany. The first model has a nominal rudder, while the others have a partially delaminated rudder skin, derived from the delamination pattern observed after the AAL accident. Third model has a reduced stiffness aera between hinge arm 4 and 5 according to the observations made after the accident of MSN420.

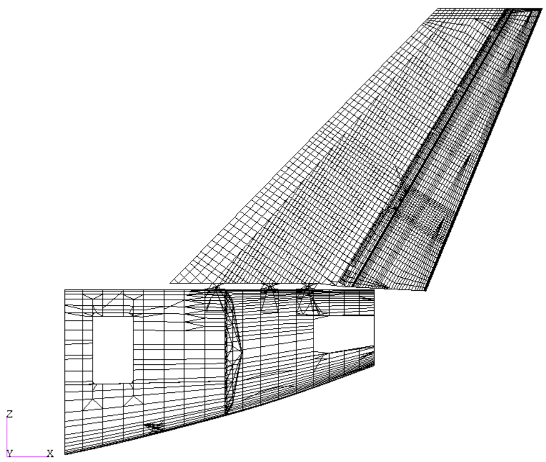
A lumped mass model was connected with the Finite Element Model in order to get a dynamic model.

3. MAIN MODAL SHAPES

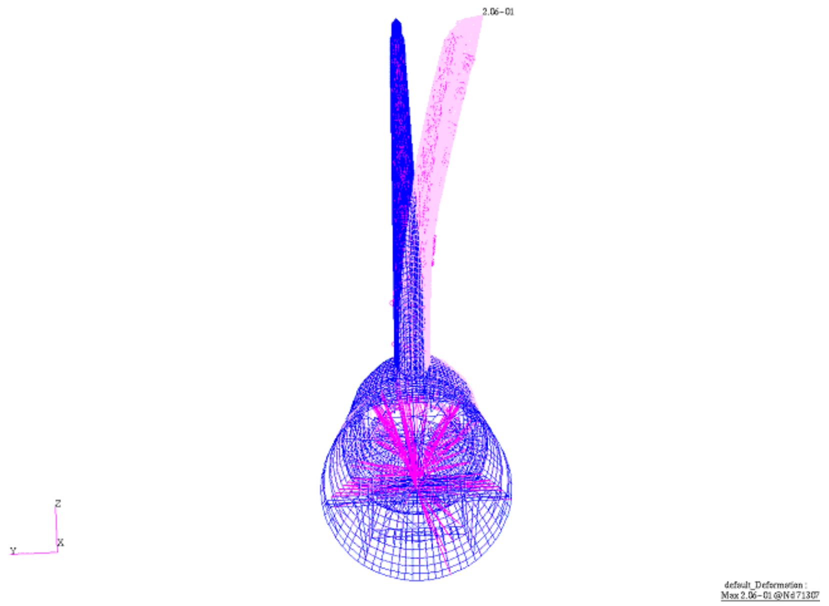
Modes are computed with MSC/NASTRAN v70.5. The eigenvalues are computed up to 40Hz, and associated modal shapes are determined. Lanczos method was chosen to extract modes. We show the 5 first modal shapes for the three models.

3.1 NOMINAL RUDDER

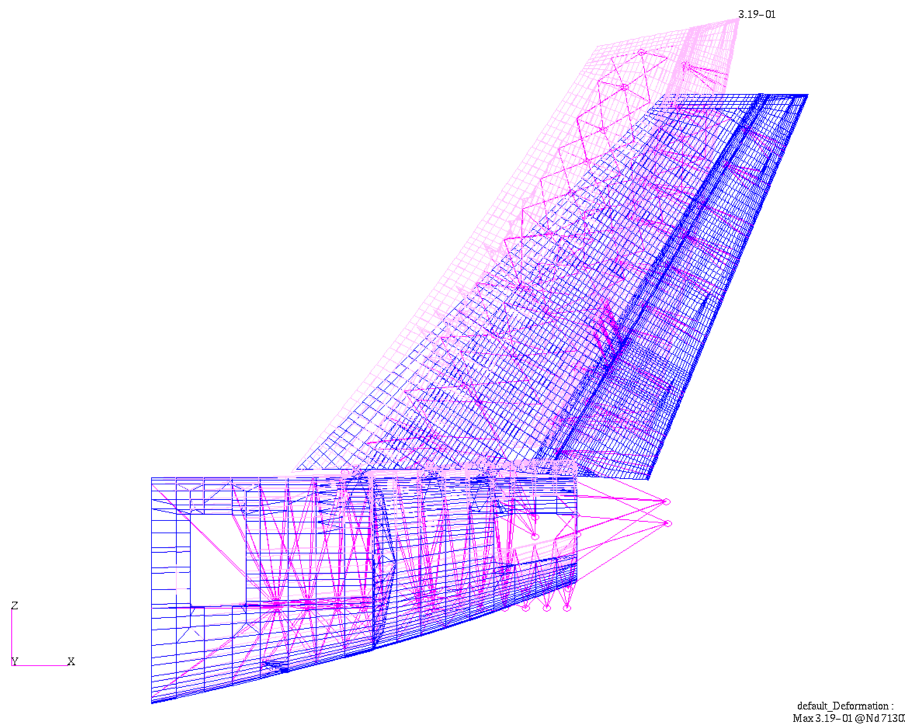
This model consists of Rear fuselage and Vertical Tail Plane (VTP). VTP is composed of a Box and a nominal Rudder.



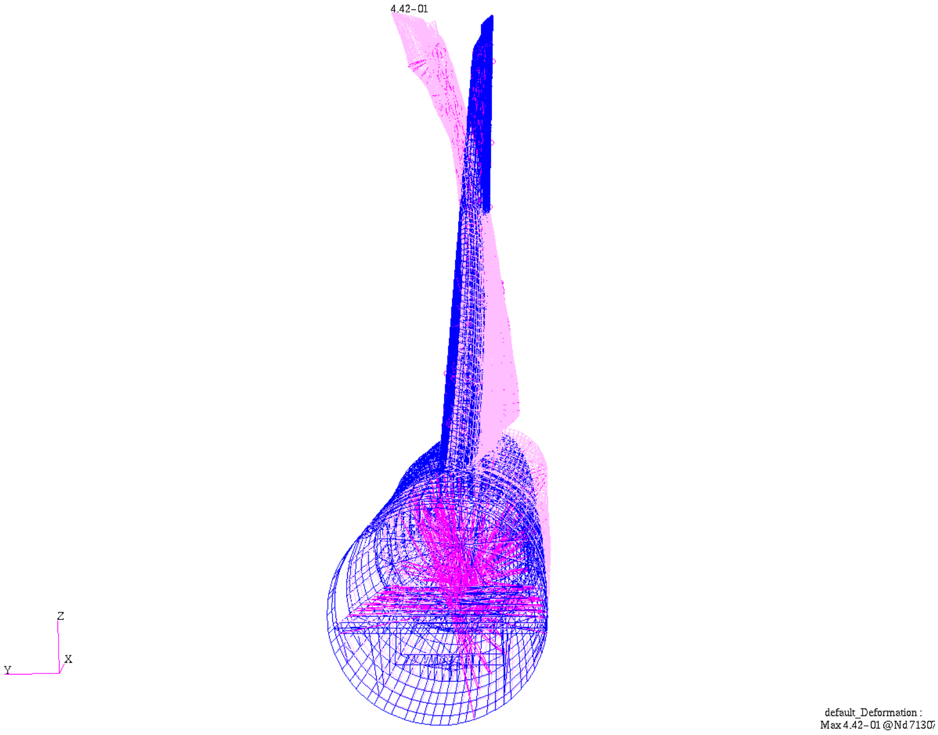
First VTP Bending Mode



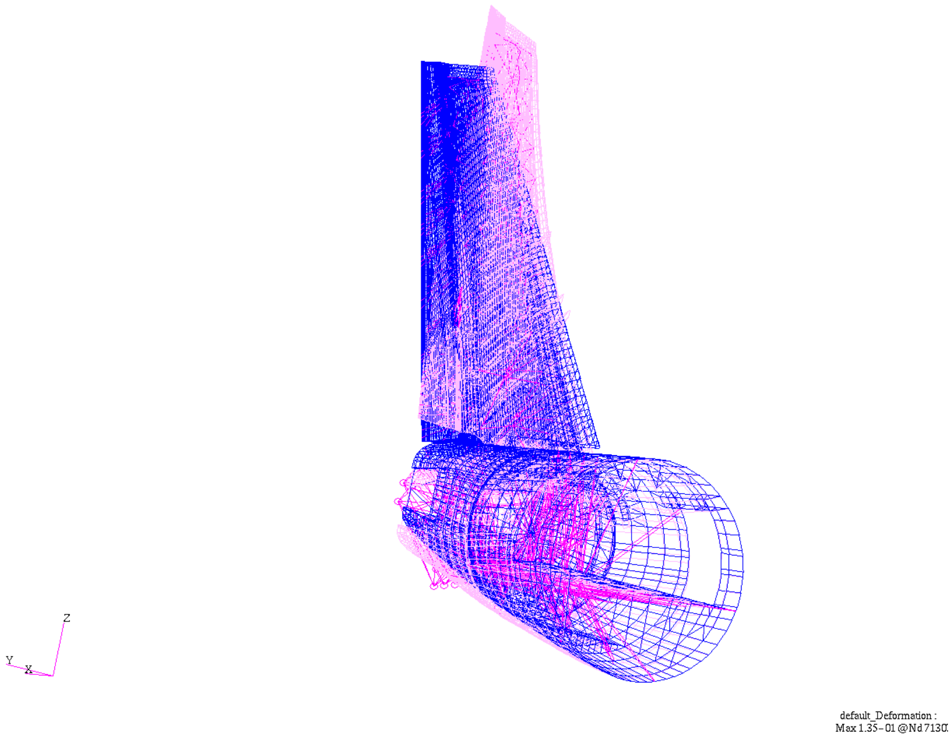
VTP Fore and Aft Mode



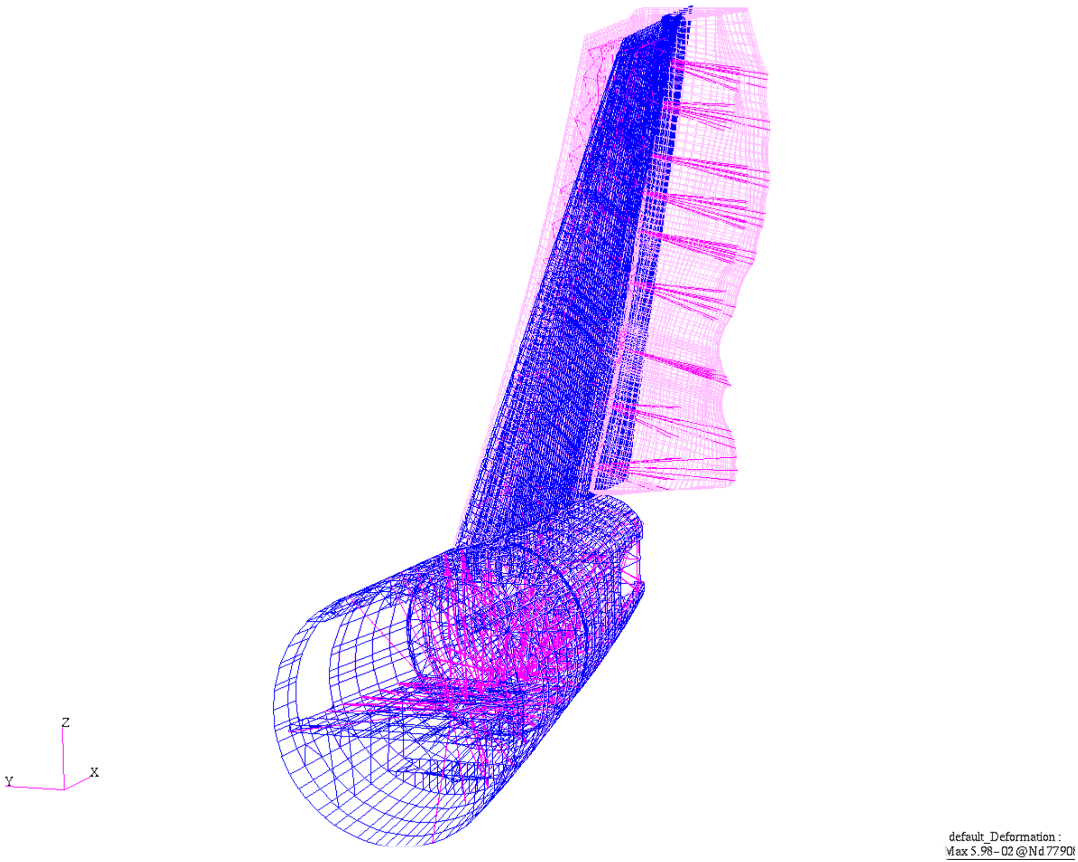
Second VTP Bending Mode



Rear Fuselage Lateral Bending Mode



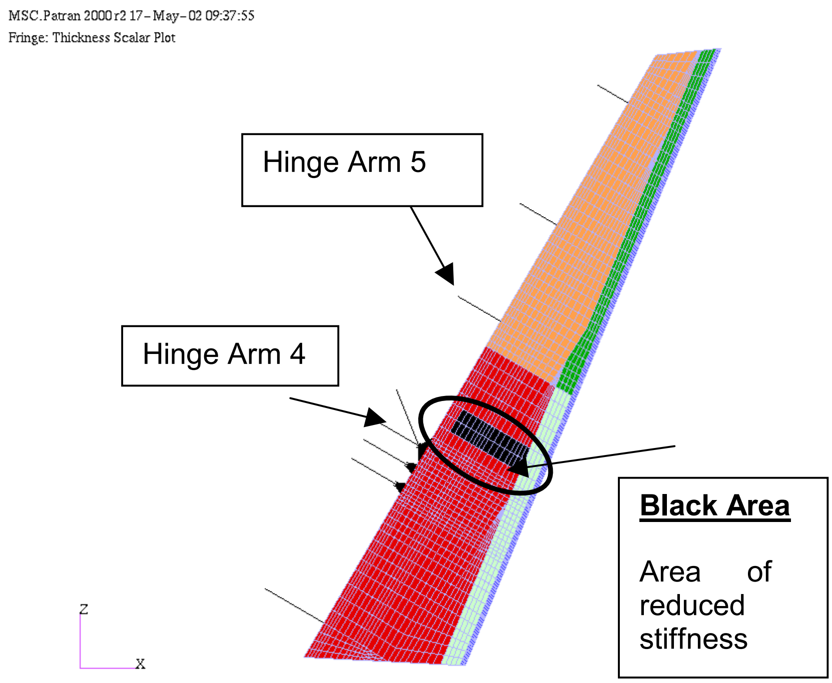
Rudder Rotation Mode



3.2 FIRST PARTIALLY DELAMINATED RUDDER SKIN

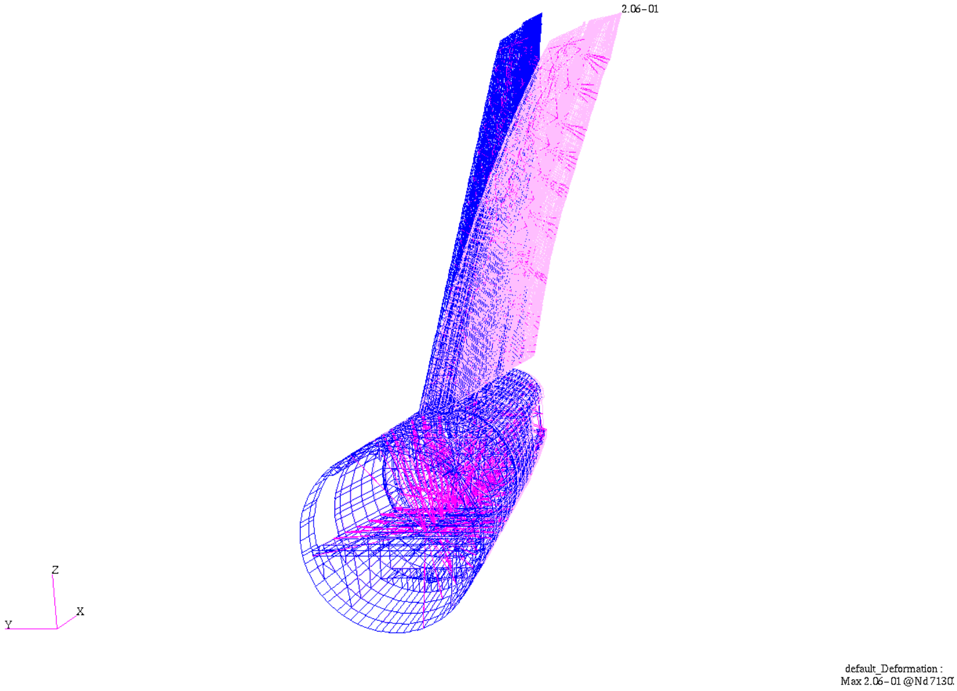
This model consists of Rear fuselage and Vertical Tail Plane (VTP). VTP is composed of a box and a partially delaminated Rudder skin.

The stiffness of the RHS rudder shell between hinge arm 4 and 5 (see picture 1) has been reduced within an area of A=0.38m² (350mm x 1075mm).

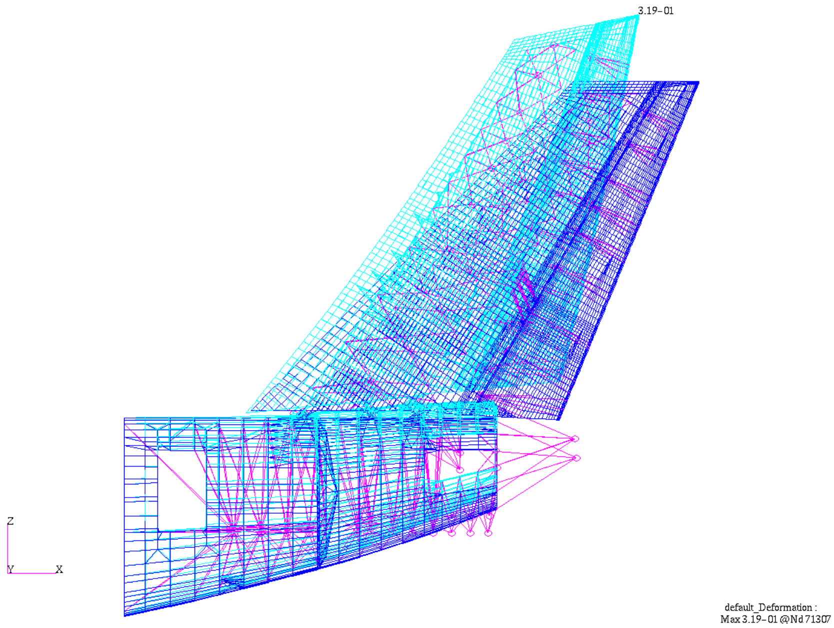


picture 1

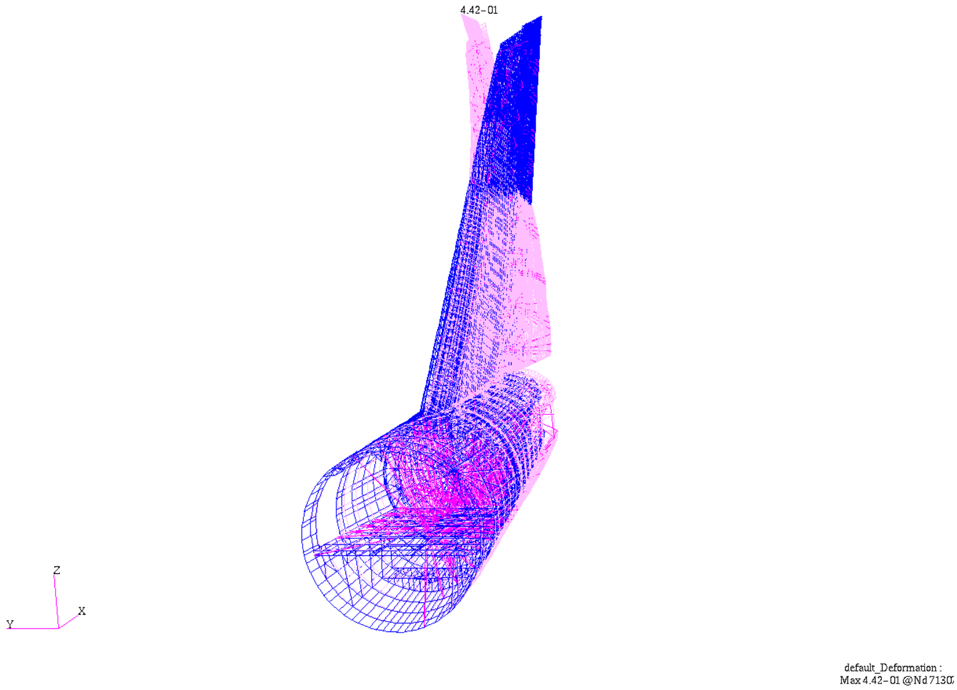
First VTP Bending Mode



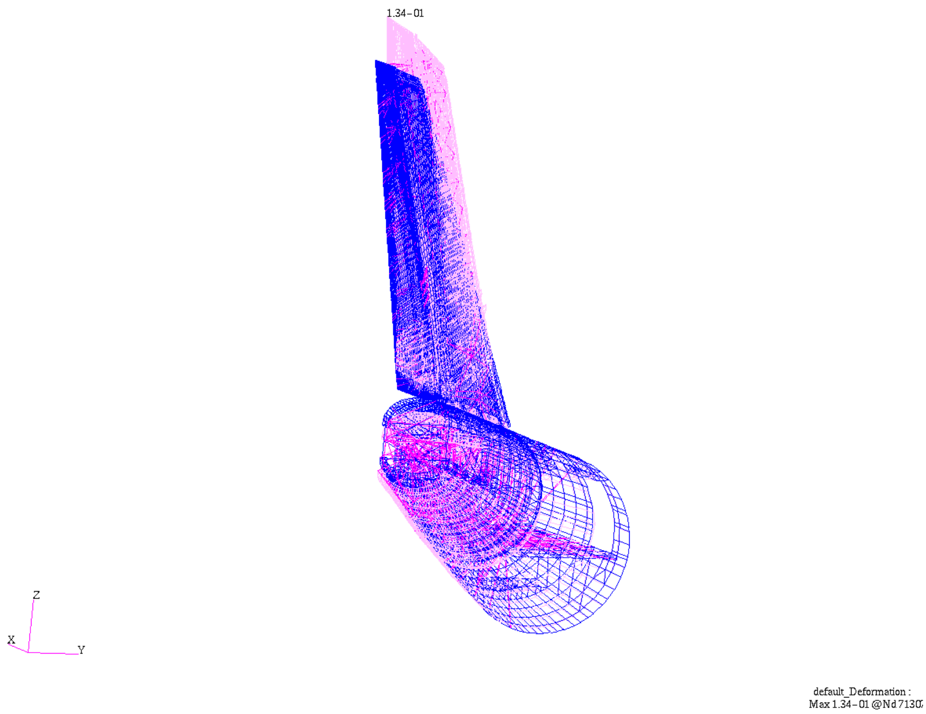
VTP Fore and Aft Mode



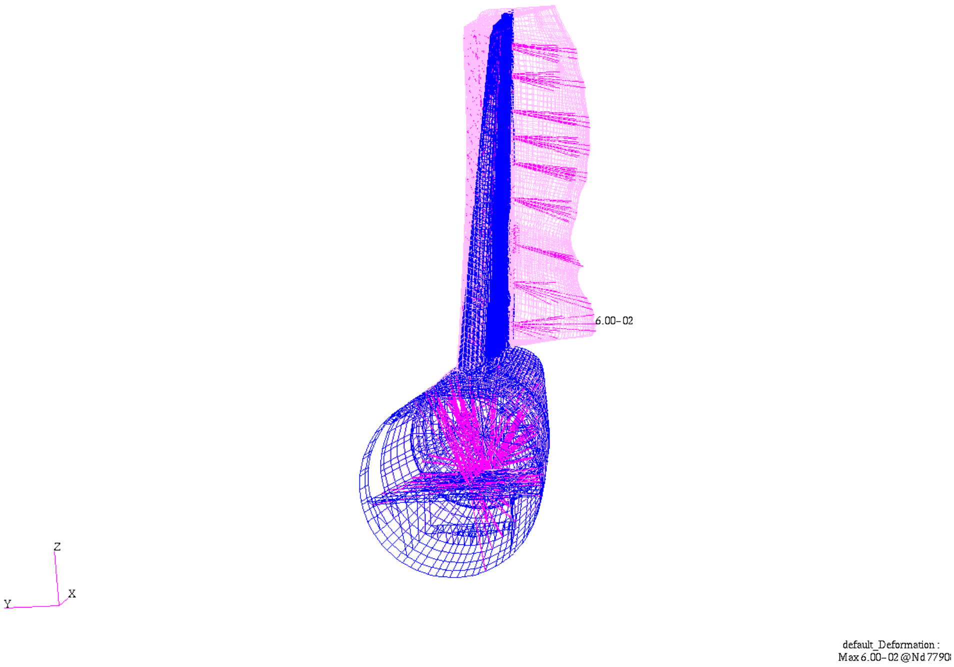
Second VTP Bending Mode



Rear Fuselage Lateral Bending Mode



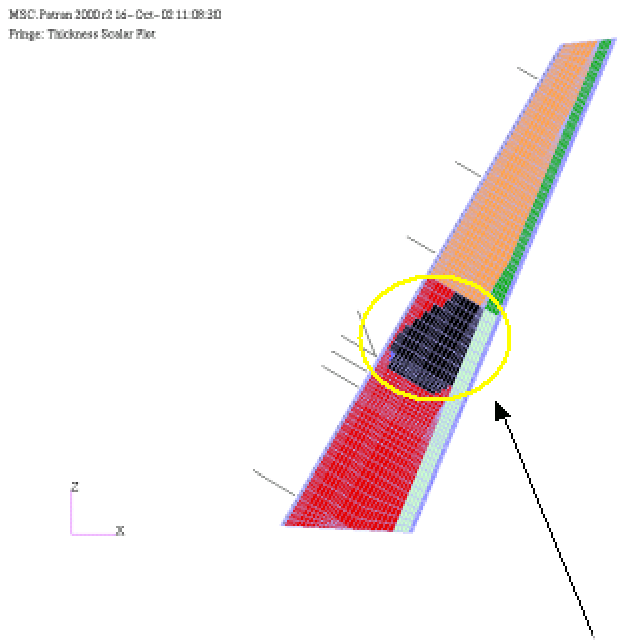
Rudder Rotation Mode



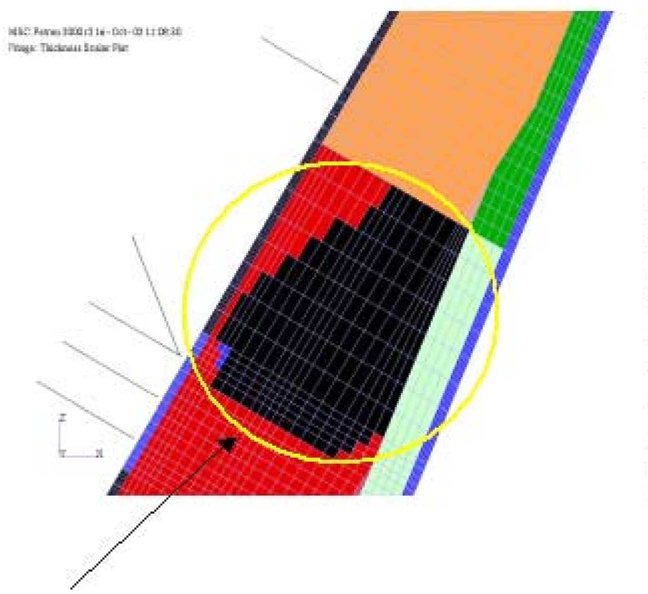
3.3 SECOND PARTIALLY DELAMINATED RUDDER SKIN

This model consists of Rear fuselage and Vertical Tail Plane (VTP). VTP is composed of a box and a partially delaminated Rudder skin.

Reduced stiffness area between hinge arm 4 and 5 according to the detected delaminated MSN420.

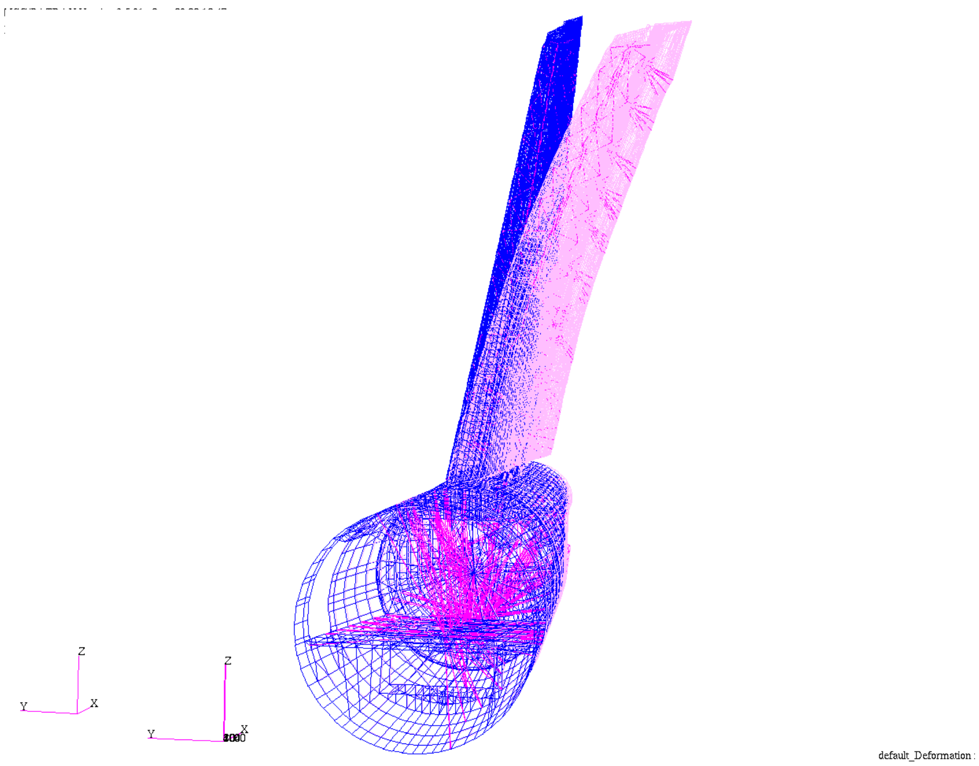


Reduced stiffness area (black)

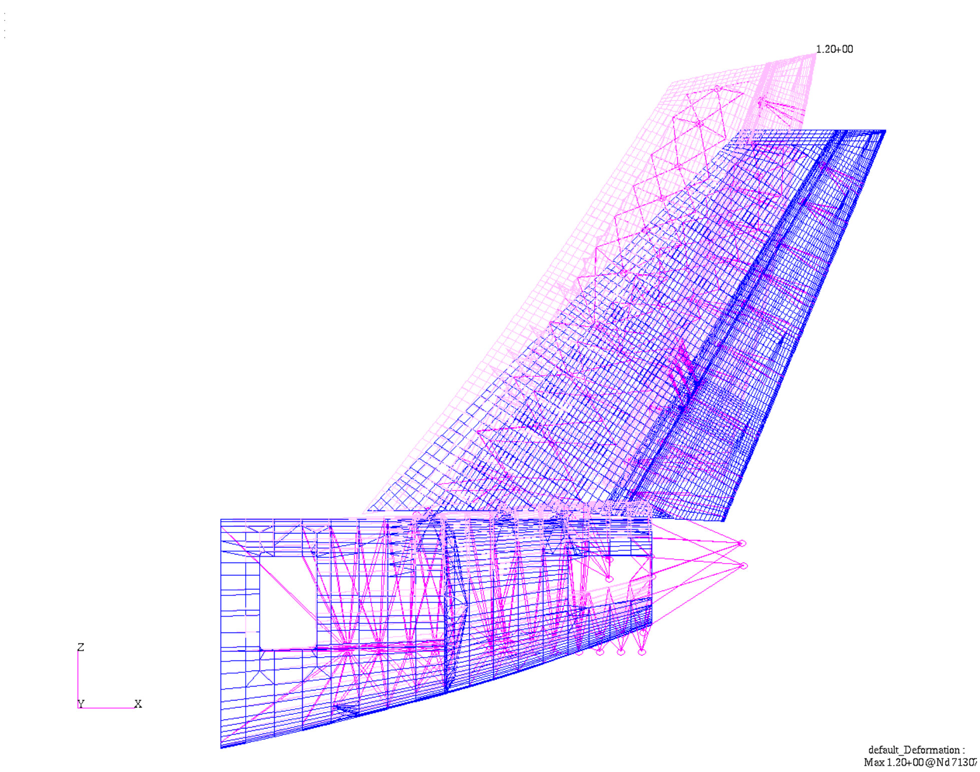


Reduced stiffness area (black)

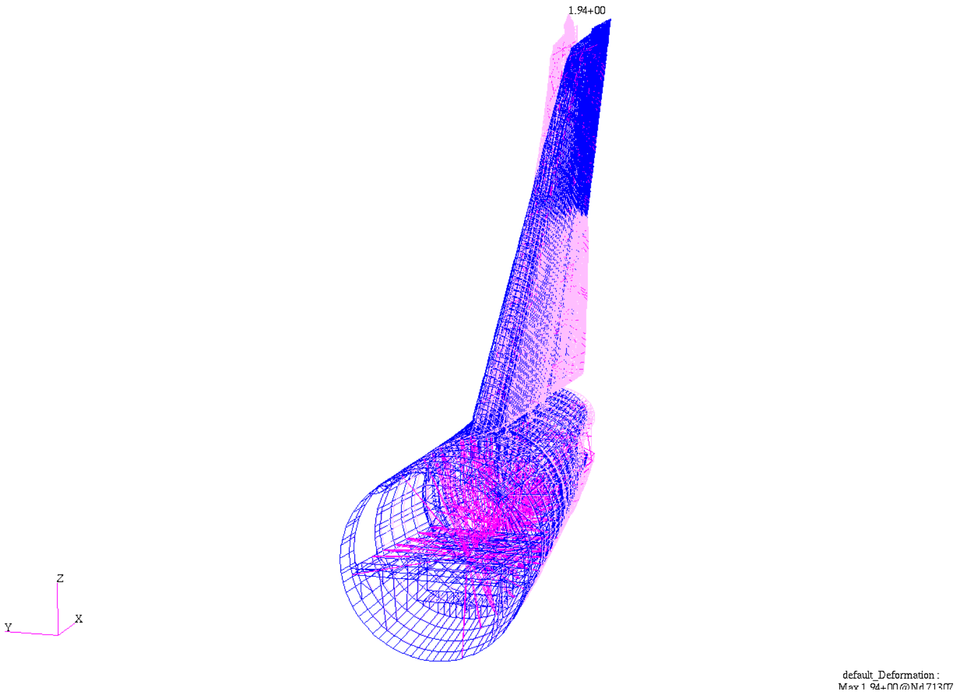
First VTP Bending Mode



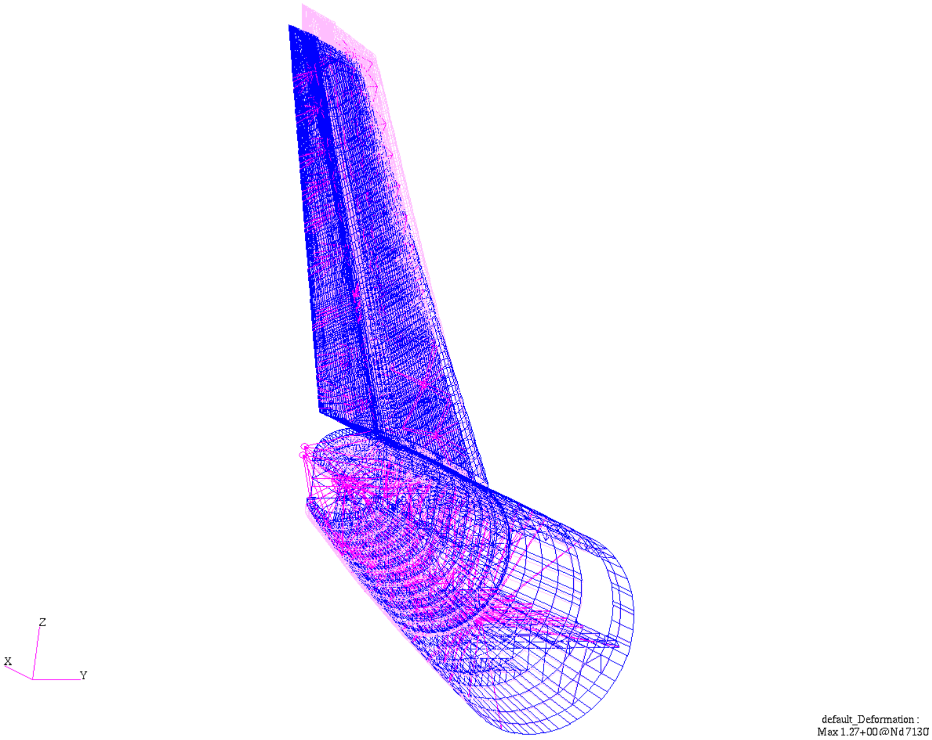
VTP Fore and Afte Mode :



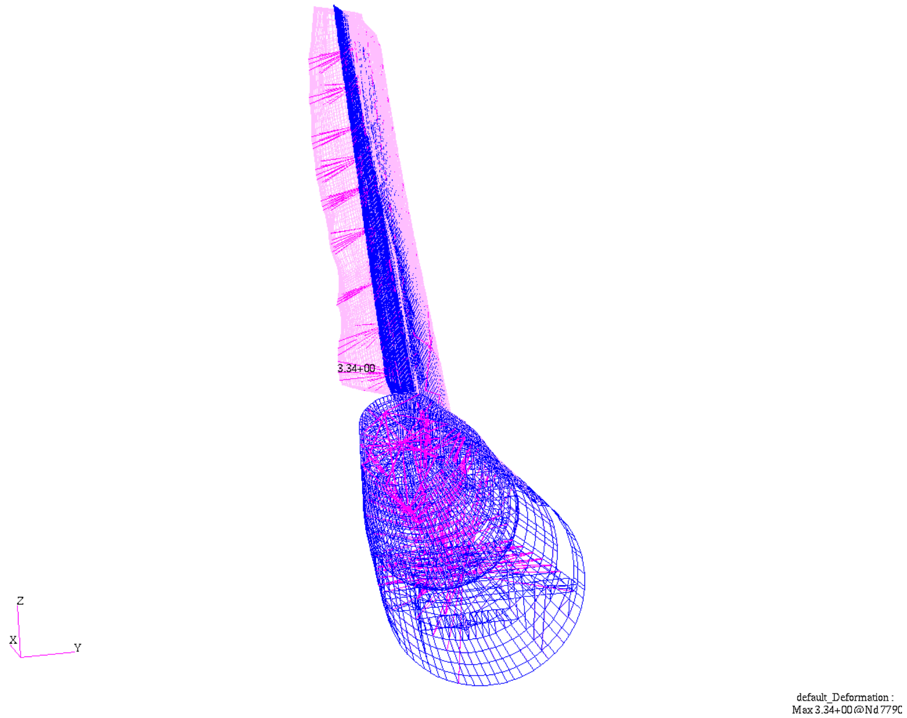
Second VTP Bending Mode



Rear Fuselage Lateral Bending Mode



Rudder’s Rotation Mode



3.4 MODAL COMPARISONS

The table below shows the impact of the first delamination on frequencies up to 40 Hz.

Mode n°	Frequency impact (%)
1	-0,01%
2	0,00%
3	0,00%
4	0,00%
5	-0,14%
6	0,00%
7	0,23%
8	0,00%
9	-0,01%
10	-0,31%
11	-0,11%
12	-0,01%
13	-0,38%
14	-0,08%
15	-0,04%
16	-0,01%
17	-0,01%

Table 1

Up to 40Hz (mode n°17), the frequency shift is smaller than 0.4%. The delaminated Rudder has no impact on the modal shapes.

The table 2 below shows the impact of the second delamination on frequencies up to 40 Hz.

Up to 25Hz (mode n°7), the difference of frequency is smaller than 1%. Up to 40Hz (mode n°17), the difference of frequency is smaller than 4%. The delaminated Rudder has no impact on the modal shapes.

Mode n°	**Frequency impact %**
1	0,01%
2	0,00%
3	0,01%
4	0,00%
5	-0,71%
6	0,10%
7	0,62%
8	-0,01%
9	-0,07%
10	-3,59%
11	-0,34%
12	-1,07%
13	-3,71%
14	-1,42%
15	-0,61%
16	-0,02%
17	-0,49%

Table 2

4. FLUTTER ANALYSIS

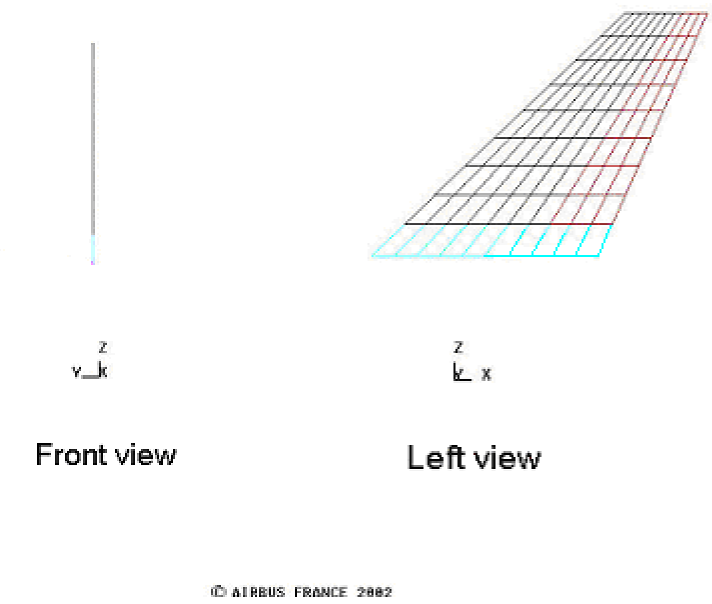
4.1 GENERALITIES

Aeroelasticity analysis are performed at Mach 0.4. Modal analysis are performed with NASTRAN rear part dynamic model. Flutter reponses are computed with an in house code using p-k method.

Flutter analysis uses modal bases computed with MSC/NASTRAN and matrix of aerodynamic influence coefficients computed with a Doublet Lattice Method in house software.

4.2 AERODYNAMIC DATA

View presented below shows the aerodynamic surfaces reference a300603mc used for the Doublet Lattice Method aerodynamic computation and for interpolation of modal shapes. Interpolation surfaces used in the calculations are VTP box and Rudder.

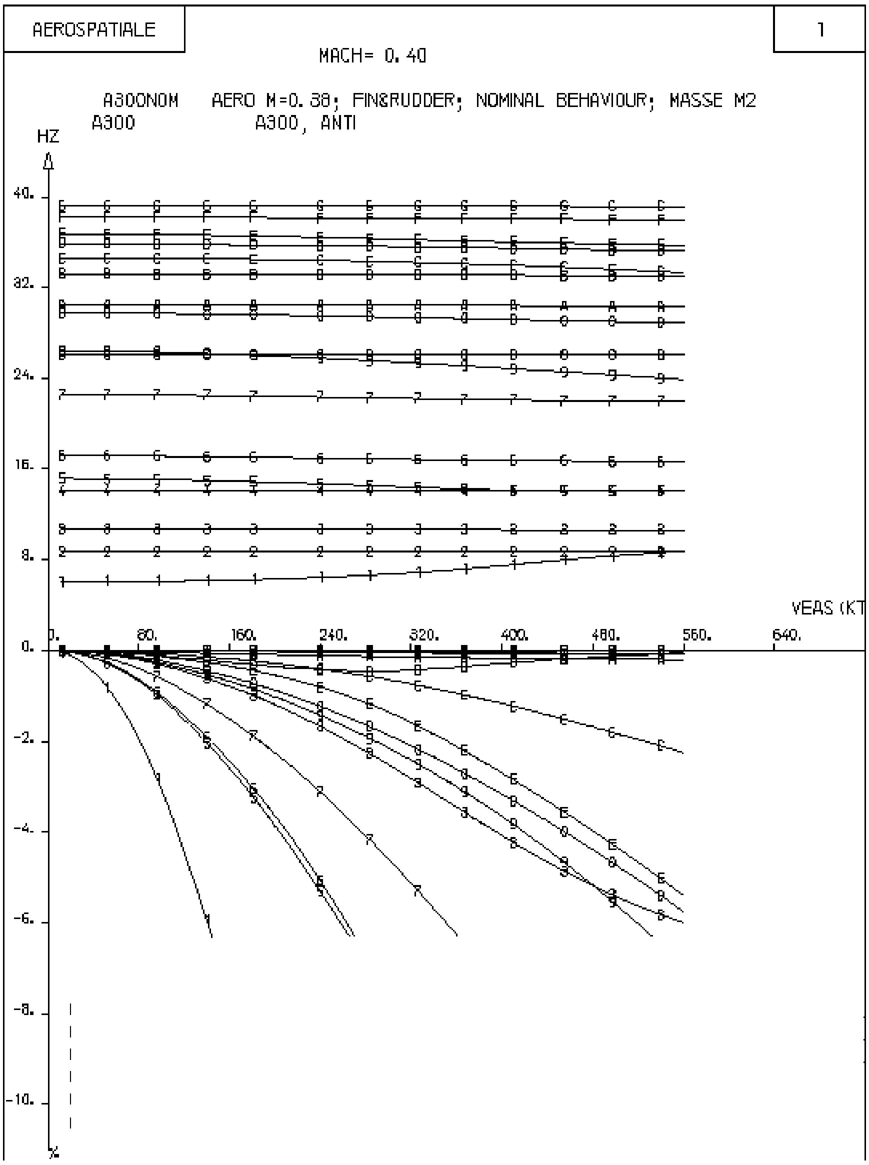


Asumptions

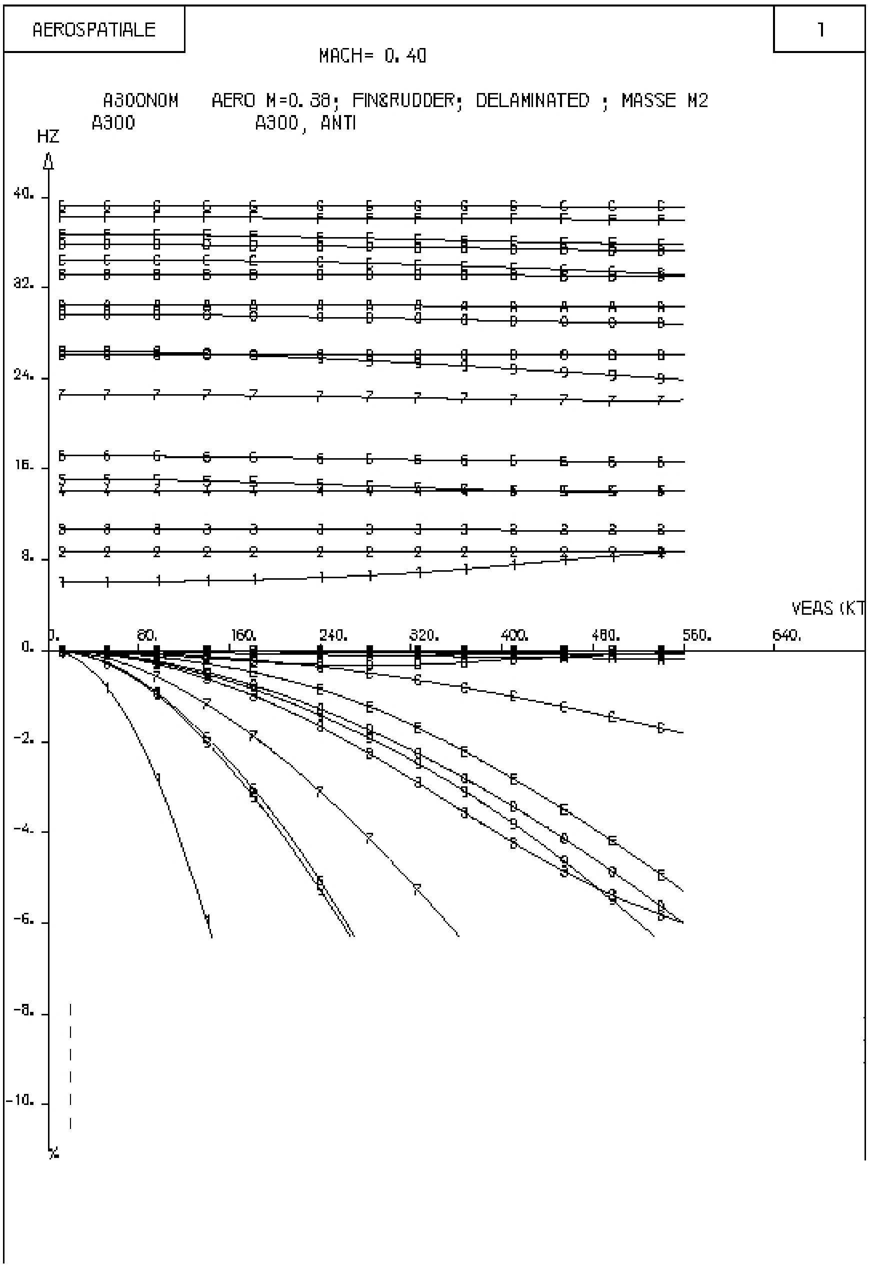
- unsteady aerodynamic : Hinge moment adjustment (on control surface),
- flutter curves are computed without structural damping,
- Values of reduced frequency are 0.002, 0.05, 0.1, 0.15, 0.3 and 0.6.

4.3 NOMINAL RUDDER

No or weak aeroelastic coupling for all modes.

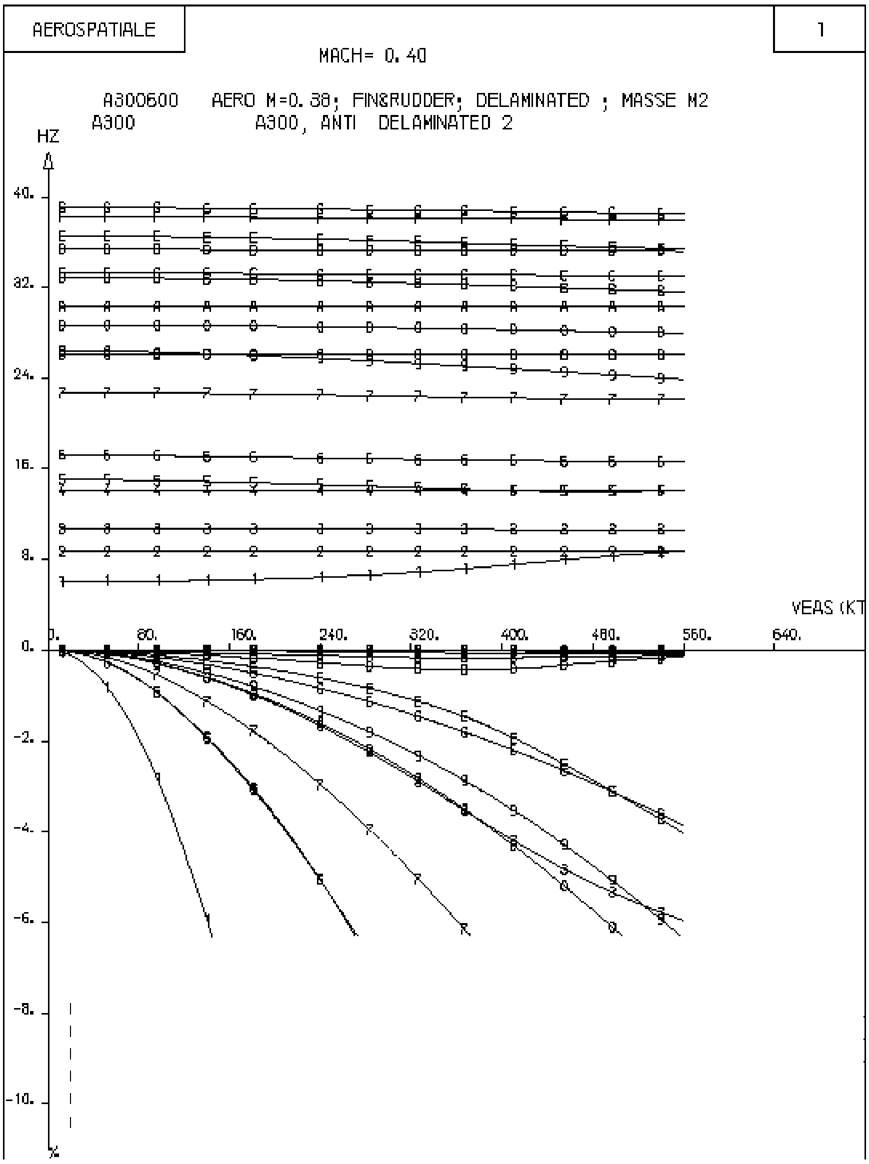


4.4 FIRST PARTIALLY DELAMINATED RUDDER SKIN



No or weak aeroelastic coupling for all modes.

4.5 SECOND PARTIALLY DELAMINATED RUDDER SKIN (ACCORDING MNS420)



No or weak aeroelastic coupling for all modes.

5. CONCLUSION

The first and second delaminated Rudder have no influence on the flexible modes. The modal shapes are similar between three models. Impact on freqencies are :

- less than 0.4% for frequencies up to 40Hz for first delamination,

- less than 1% up to 25Hz and less than 4% up to 40Hz for second model of Rudder's delaminated.

The both delaminated Rudder have no impact on flutter analys.

Modal and flutter behaviours are similar with both delaminated Rudder skin and with nominal Rudder. Effect of Rudder delamination above hinge 4, derived from observations after AAL accident, is negligeable for dynamic.