NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

December 11, 2003

ADDENDUM NUMBER 9 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. "AAL 587 Study of Aeroelastic Scenarios"

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TITRE : AAL587 Investigation : Study of Aeroelastics scenarios

AUTEUR(S) :

RESUME :

The aim of this document is to provide for different initial failure scenarios an aeroelastic analysis, which could help to determine in which conditions dynamic loads induced by the aeroelastic behaviour added to steady loads could participate to the AAL587 investigation.

In a preliminary part a presentation of used data and nominal aeroelastic behaviour is shown.

The second part investigates different scenarios :

- S1 : Failures of all servo-controls leading to a rudder free to rotate
- S2 : Split of the rudder in two parts with a separation occurring above the servo-controls
- S3 : S2 plus the loss of the rudder bottom part

For each scenario an aeroelastic analysis is performed.

MOTS CLES : AEROELASTICITY

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1. INTRODUCTION

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In a preliminary part a presentation of used data and nominal aeroelastic behaviour is shown.

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For each scenario an aeroelastic analysis is performed.

2. INPUT DATA

The aeroelastics analysis presented in this document are based on an Aircraft Rear Part Nastran Finite Element Model (FEM) including Rear Fuselage, Vertical Tailplane+Rudder and Horizontal Tailplane+Elevator. Such model is fully adapted to the studied aeroelastic mechanisms.

The unsteady aerodynamic model is based on Doublet Lattice Method and includes an adjustment of control surfaces hinge moments.

Flutter calculations are performed with 1% of modal damping and the equation is solved using p-k method.

3. NOMINAL AEROELASTIC BEHAVIOUR

A modal analysis, using NASTRAN solver, of the Aircraft Rear Part FEM in nominal configuration was performed giving :

- A Fin Bending Mode at 6.62Hz
- A Rudder Rotation Mode at 12.58Hz.

A flutter calculation was performed using the first 39 flexible modes with unsteady airloads at Mach 0,38. No instability and no loss of damping with speed increasing is shown.

4. AEROELASTIC INVESTIGATIONS ON DIFFERENTS SCENARIOS

Three scenarios are studied :

- S1 : Failures of all servo-controls leading to a rudder free to rotate
- S2 : Split of the rudder in two parts with a separation occurring above the servo-controls
- S3 : S2 plus the loss of the rudder bottom part

The objective of this chapter is not to explain in which conditions such scenarios could occur but, taking as initial hypothesis each one, to study the induced aeroelastic behaviour.

4.1 S1 : FAILURES OF ALL SERVO-CONTROLS LEADING TO A RUDDER FREE TO ROTATE

This scenario considers the rudder as free in rotation after the failure of all servocontrols.

In such conditions the modal analysis shows :

- A Rudder Rotation Mode at 0Hz
- A Fin Bending Mode at 7.06Hz. Compared to the nominal configuration a small increase in frequency is noticed and, concerning the mode shape, we can observe that the rudder rotates in opposition to the fin bending, which is characteristic for an unbalanced control surface behaviour.

A flutter calculation was performed using the first 39 flexible modes with unsteady airloads at Mach 0,38. A coupling appears between Rudder Rotation and Fin bending modes : the aircraft remains stable with a minimum damping around 1.2% at 360kts CAS.

4.2 S2 : SPLIT OF THE RUDDER IN TWO PARTS

This scenario considers the rudder as splitted in two parts with a separation occurring above the servo-controls.

In such conditions the modal analysis shows :

- A Rudder Upper Part Rotation Mode at 0Hz.
- A Fin Bending Mode at 7.17Hz. Compared to the nominal configuration a small increase in frequency is noticed and, concerning the mode shape, we can observe that the rudder upper part rotates in opposition to the fin bending, which is characteristic for an unbalanced control surface behaviour.
- A Rudder Lower Part Rotation Mode at 14.64Hz.

A flutter calculation was performed using the first 39 flexible modes with unsteady airloads at Mach 0,38. A coupling appears between Rudder Upper Part Rotation and Fin bending modes : the aircraft is unstable with a critical flutter speed at 240kts CAS and a damping loss gradient around 2%/10kts.

4.3 S3 : SPLIT OF THE RUDDER IN TWO PARTS PLUS LOSS OF RUDDER LOWER PART

This scenario considers the rudder as splitted in two parts with a separation occurring above the servo-controls as in scenario S2 but with additionally the loss of the Rudder Lower Part.

In such conditions the modal analysis shows :

- A Rudder Upper Part Rotation Mode at 0Hz.
- A Fin Bending Mode at 7.26Hz. Compared to the nominal configuration a small increase in frequency is noticed and, concerning the mode shape, we can observe that the rudder upper part rotates in opposition to the fin bending. But this opposite rotation of the Rudder Upper Part is significantly reduced compared to S2 scenario.

A flutter calculation was performed using the first 39 flexible modes with unsteady airloads at Mach 0,38. A coupling appears between Rudder Upper Part Rotation and Fin bending modes : the aircraft is unstable with a critical flutter speed at 235kts CAS and a damping loss gradient around 2%/10kts. Compared to S2 scenario behaviour the coupling appears slightly worse with a loss of 5kts in flutter critical speed.

5. CONCLUSIONS

Aeroelastic analysis was performed at mach 0.38 to identify potential flutter issues from initial failure hypothesis in the context of AAL587 investigation. This study performed on a A300 Rear Part Aeroelastic Model demonstrates that :

- In case of servo-controls failures leading to a rudder free to rotate, the aircraft remains free of flutter. A Lateral Fin bending and Rudder Rotation modes coupling appears with sufficient margins and an acceptable minimum damping at very high speed (360kts CAS).

With a Rudder split in two parts upside the upper servocontrol, combined or not with the loss of the Rudder Lower Part, a strong instability appears at 240kts CAS from the coupling of Rudder Upper Part free Rotation and Lateral Fin Bending modes.