Vibro-acoustic FE analyses of the Saab 2000 Aircraft

- Coupled acoustic/structural aircraft FE-model
- Creation of modal database
- BPF pressure field excitation
- Frequency response analyses
- Model validation analysis
- Planned analyses
- Model development
Vibro-acoustic FE analyses of the Saab 2000 Aircraft

• Coupled acoustic/structural aircraft FE-model
  - Acoustic model
  - Structural model
  - Coupled Acoustic-Structural model

• Creation of modal database
  - Substructuring/Modal synthesis
  - Acoustic eigenmodes
  - Structural eigenmodes
  - Coupled eigenmodes

• BPF pressure field excitation
  - Cruise flight nearfield BPF noise prediction
  - Inclusion of fuselage scattering
• Frequency response analyses
  - Scheme of computation
  - Modal contribution to BPF response
  - Structural response (Operating deflection shape)
  - Cabin cavity response (Pressure field in dB)

• Model validation analysis
  - Experimental modal analysis, Fuselage Test Rig
  - Fuselage Rig shaker test simulation

• Planned analyses
  - Tuned Damper installation and optimization
  - Structure-borne path identification
  - Active Vibration Control analyses

• Model development
  - Fuselage sections with interior
  - Active Noise Control analyses
VIBRO-ACOUSTIC FE ANALYSES OF THE SAAB 2000 AIRCRAFT

SUMMARY

FE-models of the Saab 2000 fuselage structure and the interior cavity have been created in order to compute the noise level in the passenger cabin due to propeller noise (page 1).

The FE-system ASKA was used for these analyses. The total number of degrees of freedom (dof) for the models is over 400000. To make the analysis possible substructuring was used in addition to several levels of “midnets” and modal component synthesis. This way the number of dof at each level was reduced to give acceptable computer times (page 2 - 6).

Examples are shown of Acoustic modes (page 7 - 8) and dominant structure modes (page 9 - 10) from the modal database.

BPF pressure field at cruise flight was predicted and applied to the aircraft (page 11 - 12).

Scheme of computations (Normal mode analysis and Frequency response analysis) are outlined in page 13.

From the frequency response analysis, modal contribution (page 14), structural response (page 15) and cabin cavity response (page 16) are shown.

From Fuselage Test Rig modal analysis a first validation of the FE-model is made (page 17).

Validation with the Frequency Response Function method is under way (page 18 - 19).

Planned analyses with the Saab 2000 AFEM model is shown in page 20 and proposed model development in page 21.
SAAB 2000 COUPLED STRUCTURE-CAVITY FE MODEL

Sta 399 - Sta 512:

<table>
<thead>
<tr>
<th>Structure</th>
<th>Cavity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta 90</td>
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<tr>
<td>Sta 286</td>
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</tr>
<tr>
<td>Sta 399</td>
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<td>Sta 512</td>
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</tr>
<tr>
<td>Sta 625</td>
<td></td>
</tr>
<tr>
<td>Sta 870</td>
<td></td>
</tr>
</tbody>
</table>

Number of Nodal points:
- Structure: 22681
- Cavity: 62118

Number of Elements:
- Structure: 10153
- Cavity: 3599

Number of Substructures:
- Structure: 10
- Cavity: 10

Database from Eigenvalue analysis: 720 eigenvalues (11.2 - 342.5 Hz)

Right Hand side:
- Net (100 + 110)
- Net (200 + 210)
- Net (300 + 310)
- Net (400 + 410)
- Net (500 + 510)

Left Hand side:
- Net (120 + 130)
- Net (220 + 230)
- Net (320 + 330)
- Net (420 + 430)
- Net (520 + 530)
SUB-CAVITY, Net 220

6541 Nodal points
Elements: 20-nodes Acoustic Volume element
&
8-nodes Coupling element
Level 1
Net 220
10 Subcavities

Level 2
LH
Net 120
Net 220
Net 320
Net 420
Net 520
RH
Net 170
RH
Net 160

Level 3
Net 160
Net 170
Net 190

Level 4
Sta 286 Sta 399 Sta 512 Sta 625 Sta 836 Sta 870
Net 189 Net 190 Net 191 Net 192 Net 193
a copy of net 190 a copy of net 190

Main net: 200
SUB-STRUCTURE .NET 200

2386 Nodal points
Elements: QUAD8 (8nodes quad.curved shell)
BEAM3 (3nodes curved beam)
STRUCTURAL MODEL

Left side

Level 1
100 200 300 400 500 Net

Level 2
Net 140

Level 3
Net 180

Level 4
Net 21 Net 179 Net 183

Level 5
Net 290

Right side

Level 1
110 210 310 410 510 Net

Level 2
Net 150

Level 3
Net 180

Level 4
Net 181 Net 22

Level 5
Net 195

Sta 98 Sta 286 Sta 399 Sta 512 Sta 625 Sta 1151

Net 179 Net 180 Net 181 a copy of net 180 a copy of net 180

Net 21

Main net 290

COUPLED ACOUSTIC-STRUCTURAL MODEL

Coupling only for the master sections Sta 399 - Sta 512:

Acoustic net 190 + Structure net 180

With rest of the models Main nets 300 and 290 uncoupled.
SAAB

2000 AFEM.
CREATION OF THE COUPLED ACOUSTIC-STRUCTURAL MODAL DATABASE.

ASKA analyses on CRAY X-MP/416

Total number of DOF's for the models: > 400000

Analyses performed with substructuring (Sub-, Mid- and Main nets) and modal component synthesis for reduction of the number of DOF's at each level.

- ACOUSTIC MODEL (Master section Sta 399-Sta 512)

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>TOTAL NUMBER UNCONSTRAINED DOF</th>
<th>TOTAL NUMBER NORMAL MODES</th>
<th>TOTAL CPU-TIME IN CRAY (SEC)</th>
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<tbody>
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<td>10500</td>
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</table>

- STRUCTURAL MODEL (Master section Sta 399-Sta 512)

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>TOTAL NUMBER UNCONSTRAINED DOF</th>
<th>TOTAL NUMBER NORMAL MODES</th>
<th>TOTAL CPU-TIME IN CRAY (SECS)</th>
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<td>720</td>
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<td>3524</td>
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<tr>
<td>5</td>
<td>2015</td>
<td>720</td>
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</tr>
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</table>

- COUPLED ACOUSTIC-STRUCTURAL MODEL (Master sections)

Number of Acoustic normal modes: 596 (10.9 - 400 Hz)
Number of Structural normal modes: 720 (11.2 - 342 Hz)
After the coupled analysis,

Number of coupled normal modes: 700 (9.6 - 288 Hz)
Fig 54 ACOUSTIC SIDE-SIDE MODE AT 85.3 Hz
Fig. ACOUSTIC SIDE-SIDE MODE with LH/RH shift AT 101.6 Hz
Cross-sectional mode shapes (Frames).

A 2

S 2

A 3

S 3

A 4

S 4

A 5

S 5
Fig STRUCTURE MODE No 24 / Mode shape * A4 * - 96.8 Hz
• BPF pressure field excitation
  - Cruise flight nearfield BPF noise prediction
  - Inclusion of fuselage scattering

• Propeller free field prediction program NOISEGEN developed at FFA.

• Program code based on a linearized version of Ffows-Williams-Howkings equation.

• Fuselage scattering and boundary layer effects added.

• Complex pressures converted to Real and Imaginary pressure fields (Load data).

• Load data applied to Structure Subnets.
Figure: Predicted pressure field on the lefthand side of the Saab 2000 at different time steps.
- Scheme of computation

Structure model

Cavity model

Coupling nets

Main net of the coupled problem

Figure . Natural mode flow of computation

Coupling nets

Main net of the coupled problem

Figure . Frequency response flow of computation
CONTR. FACTOR(*10-2) MODAL CONTRIBUTION TO BPF RESPONSE

Fig. - Modal contribution to BPF response

Blade Passage Frequency, BPF(95 Hz) excitation

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<th>MODE NO.</th>
<th>RH BPF-e</th>
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</tr>
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</table>

Structure Modes
STRUCTURAL BPF RESPONSE
Operating deflection shape during one cycle.
Fig 64: ACOUSTIC CABIN CAVITY RESPONSE
Pressure field in dB.
Acoustic Mockup shaker test simulation

* 16 shakers with simultaneously sinusoidal force (95 Hz) excitation.

* Force and phase distribution randomly chosen.

<table>
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<th>Shaker</th>
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<td>16</td>
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</tbody>
</table>
Planned analyses

- Tuned dampers

- Structure-borne path identification

- Active Vibration Control
• Model development
  - Fuselage sections with interior
  - Active Noise Control analyses