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4th NASA/SAE/DLR Aircraft Interior Noise Workshop
Friedrichshafen, Germany
May 19 - 20, 1992

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Vibro-acoustic FE analyses of the Saab 2000 Aircraft

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- 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

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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.

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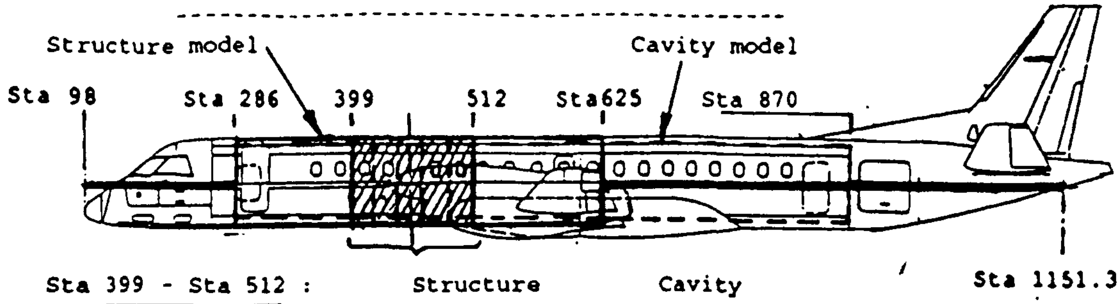
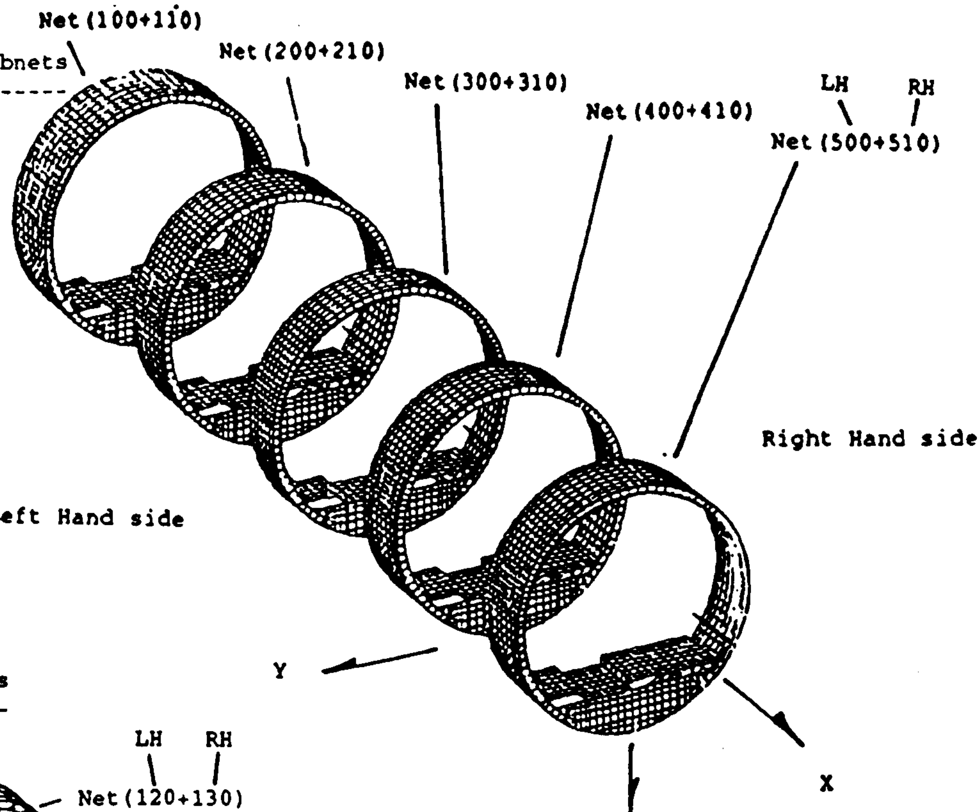
SAAB 2000 COUPLED STRUCTURE-CAVITY FE MODEL



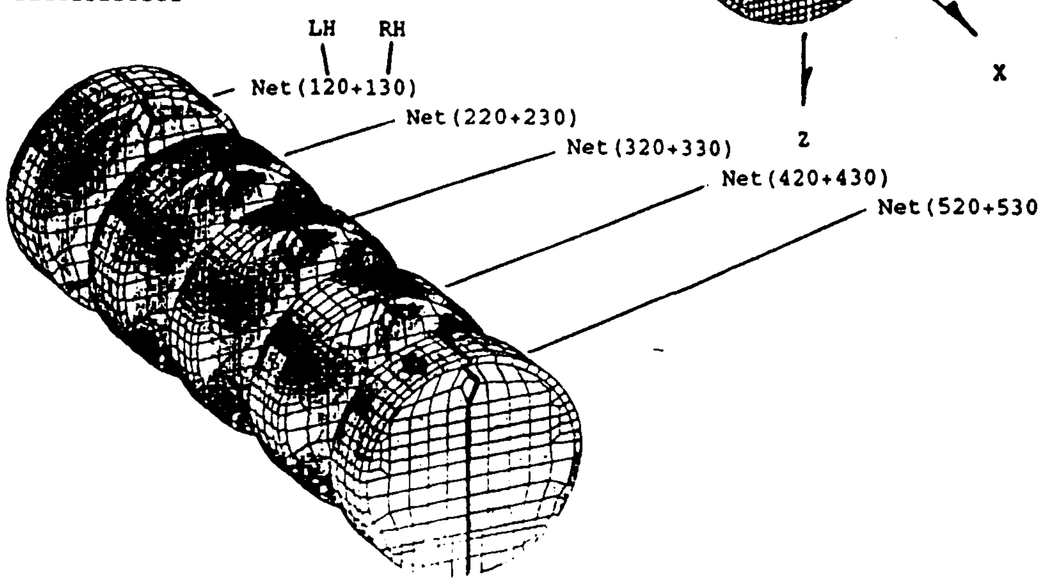
Sta 399 - Sta 512 :	Structure Main Net 290	Cavity
Number of Nodal points :	22681	62118
Number of Elements :	10153	3599
Number of Substructures:	10	10

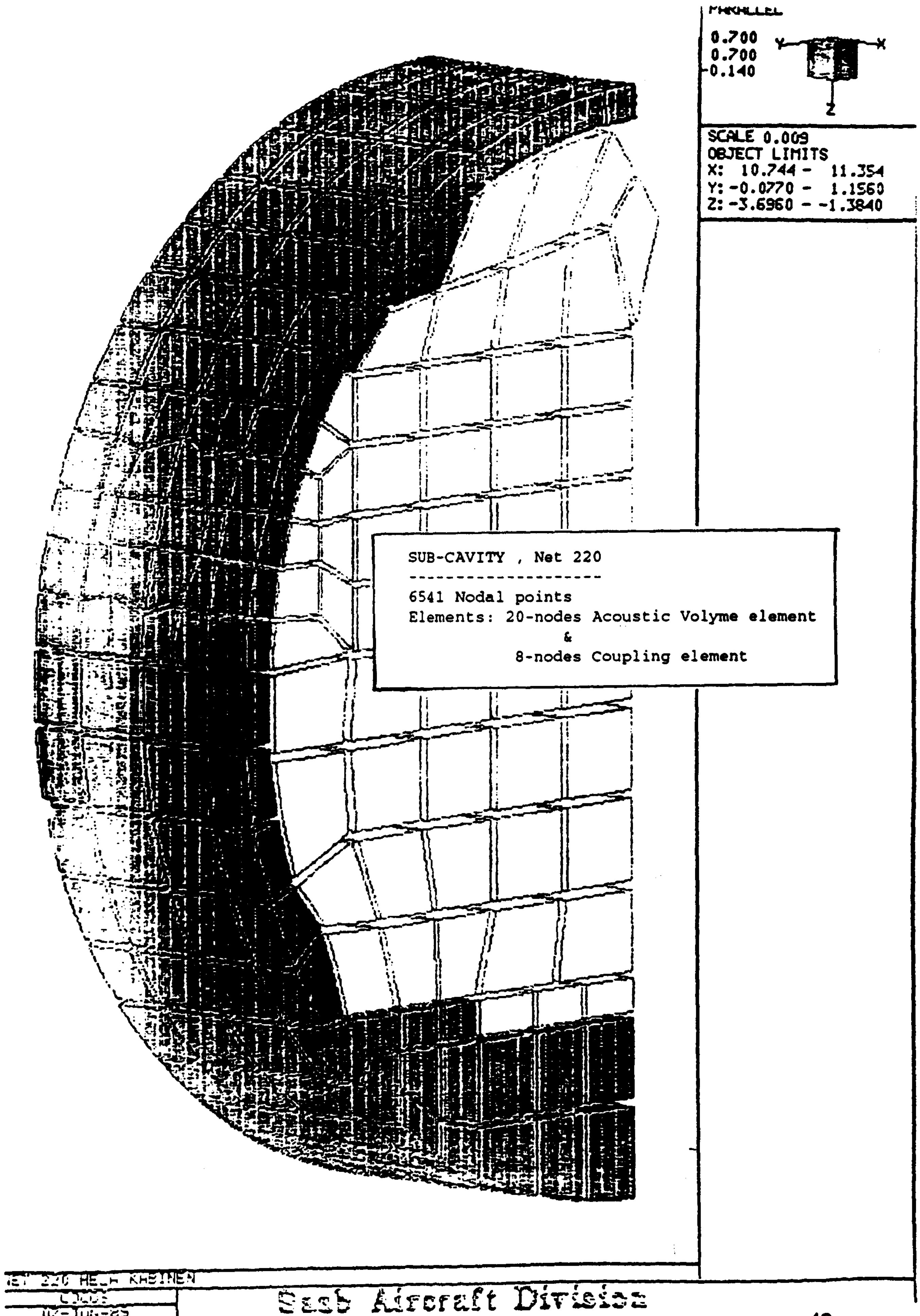
Database from
Eigenvalue analysis :720 eigenvalues (11.2-342.5 Hz)

Structure Subnets



Acoustic Nets




PARALLEL
0.700
0.700
-0.140
Y
X
Z
SCALE 0.009
OBJECT LIMITS
X: 10.744 - 11.354
Y: -0.0770 - 1.1560
Z: -3.6960 - -1.3840
SUB-CAVITY , Net 220
6541 Nodal points
Elements: 20-nodes Acoustic Volyme element
&
8-nodes Coupling element
Saab Aircraft Division

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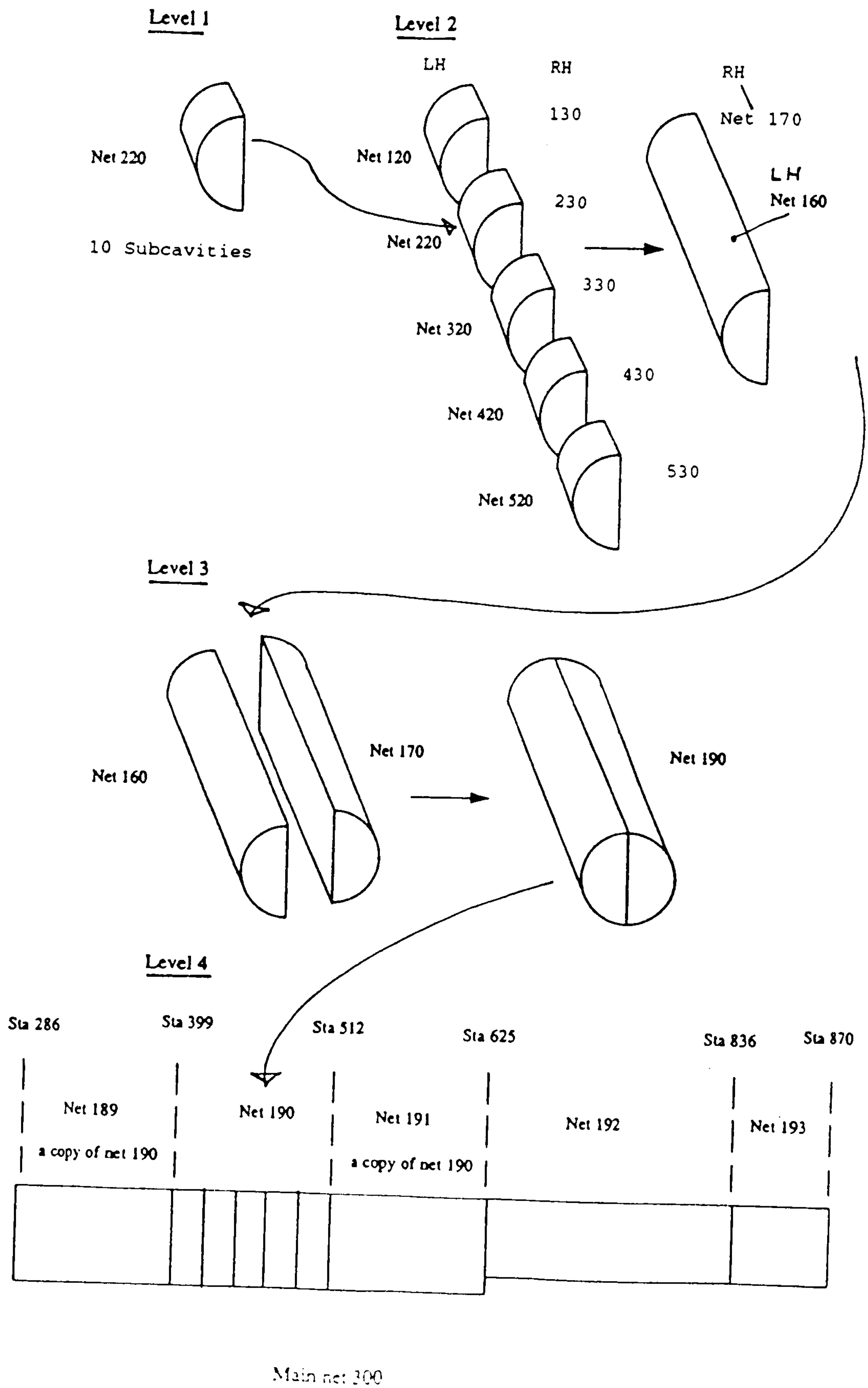
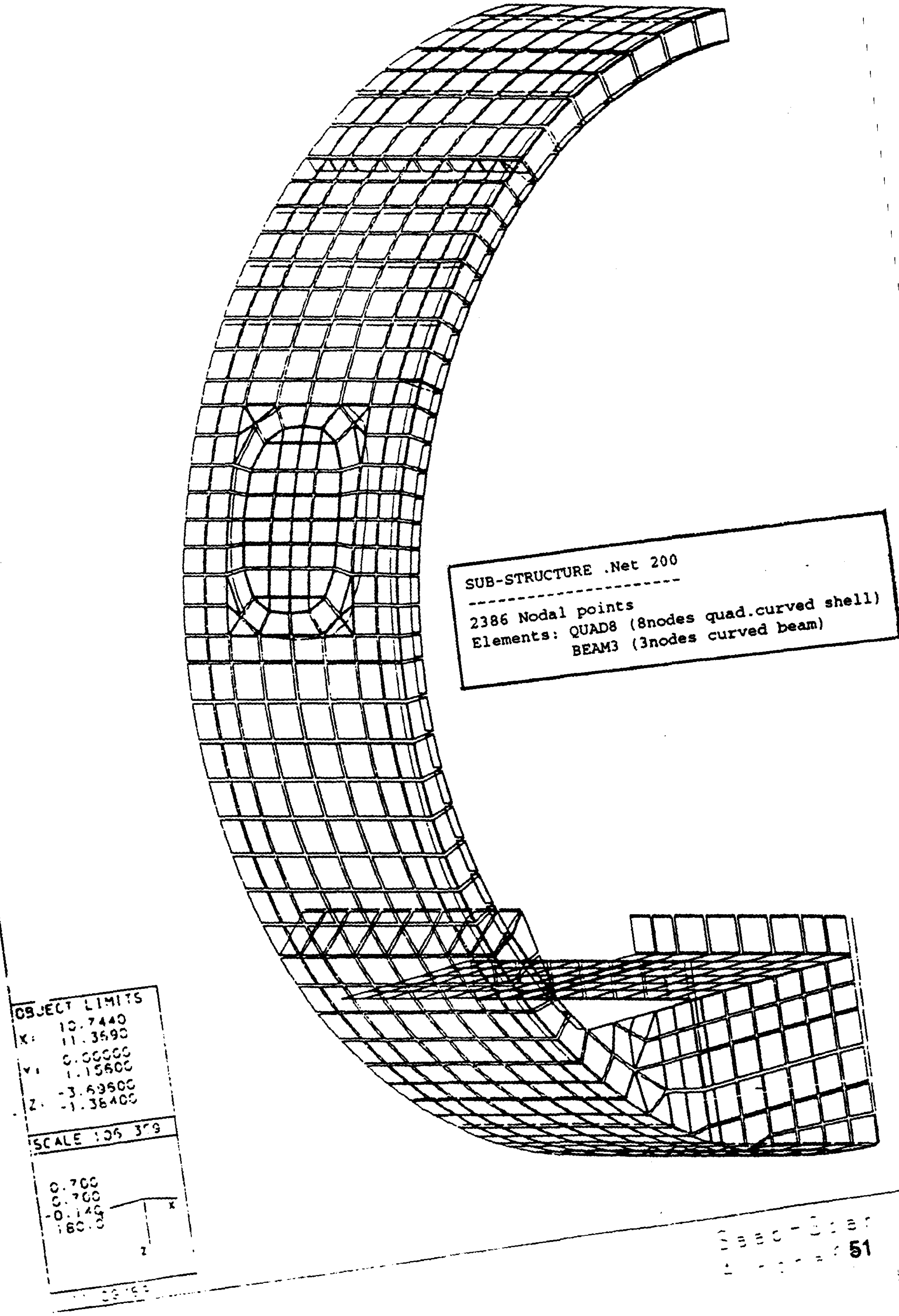
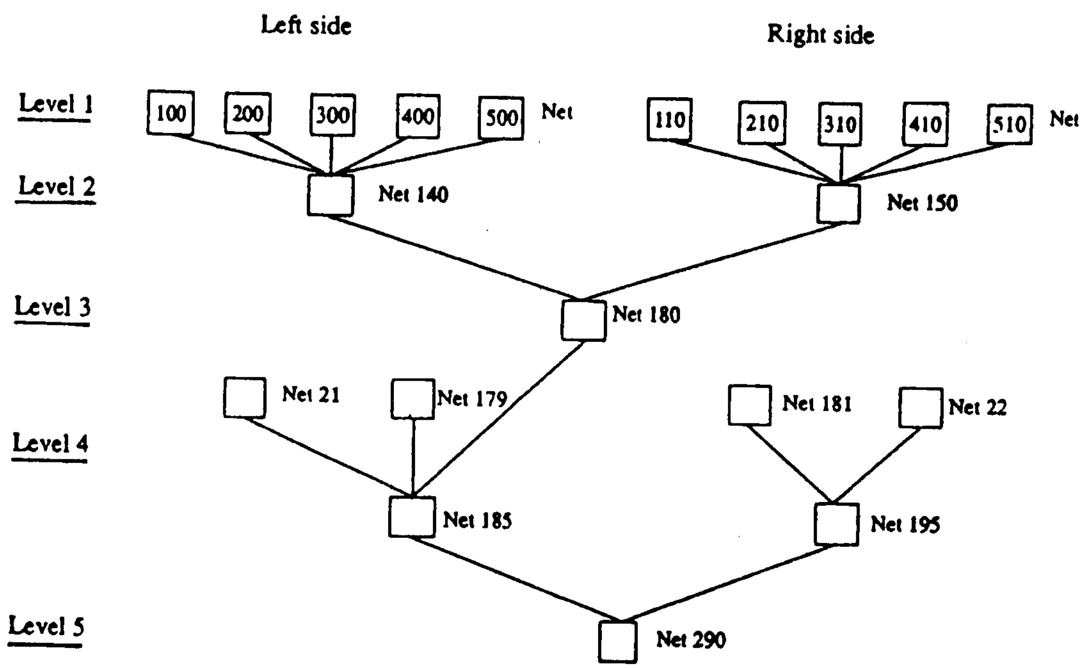
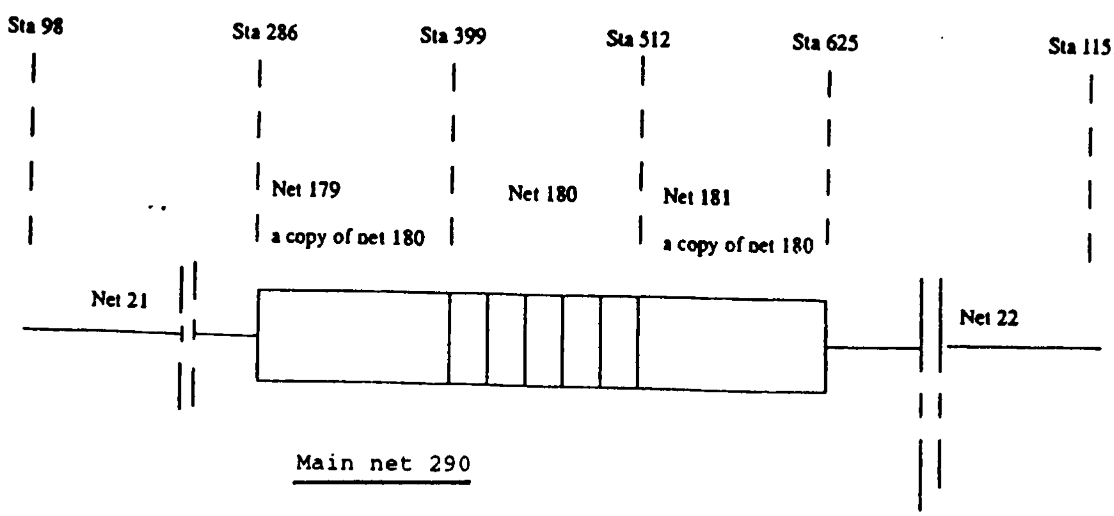
ACOUSTIC MODEL




SUB-STRUCTURE .Net 200
2386 Nodal points
Elements: QUAD8 (8nodes quad.curved shell)
BEAM3 (3nodes curved beam)
OBJECT LIMITS
X: 10.7440
11.3690
Y: 0.00000
1.15600
Z: -3.69600
-1.38400
0.700
0.700
-0.149
180.0
X
Z

STRUCTURAL MODEL





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.

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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)

LEVEL	TOTAL NUMBER UNCONSTRAINED DOF	TOTAL NUMBER NORMAL MODES	TOTAL CPU-TIME IN CRAY (SEC)
1	30300	268	8000
2	3200	284	5700
3	2100	295	7800
4	4000	596	10500

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

LEVEL	TOTAL NUMBER UNCONSTRAINED DOF	TOTAL NUMBER NORMAL MODES	TOTAL CPU-TIME IN CRAY (SECS)
1	117000	913	44000
2	6860	776	22800
3	2610	720	16000
4	3524	1029	3700
5	2025	720	7250

- 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)

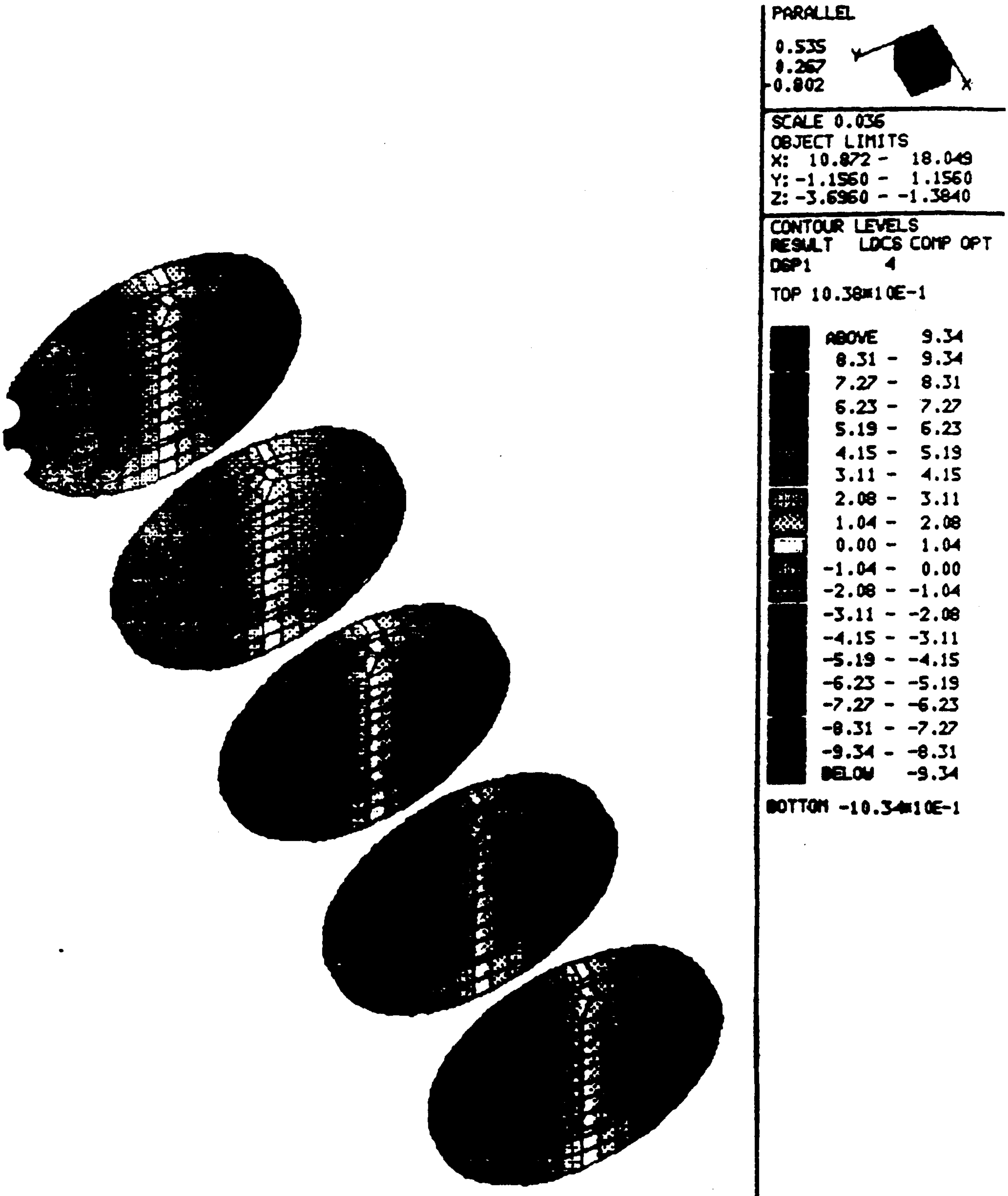


Fig ACOUSTIC SIDE-SIDE MODE AT 85.3 Hz

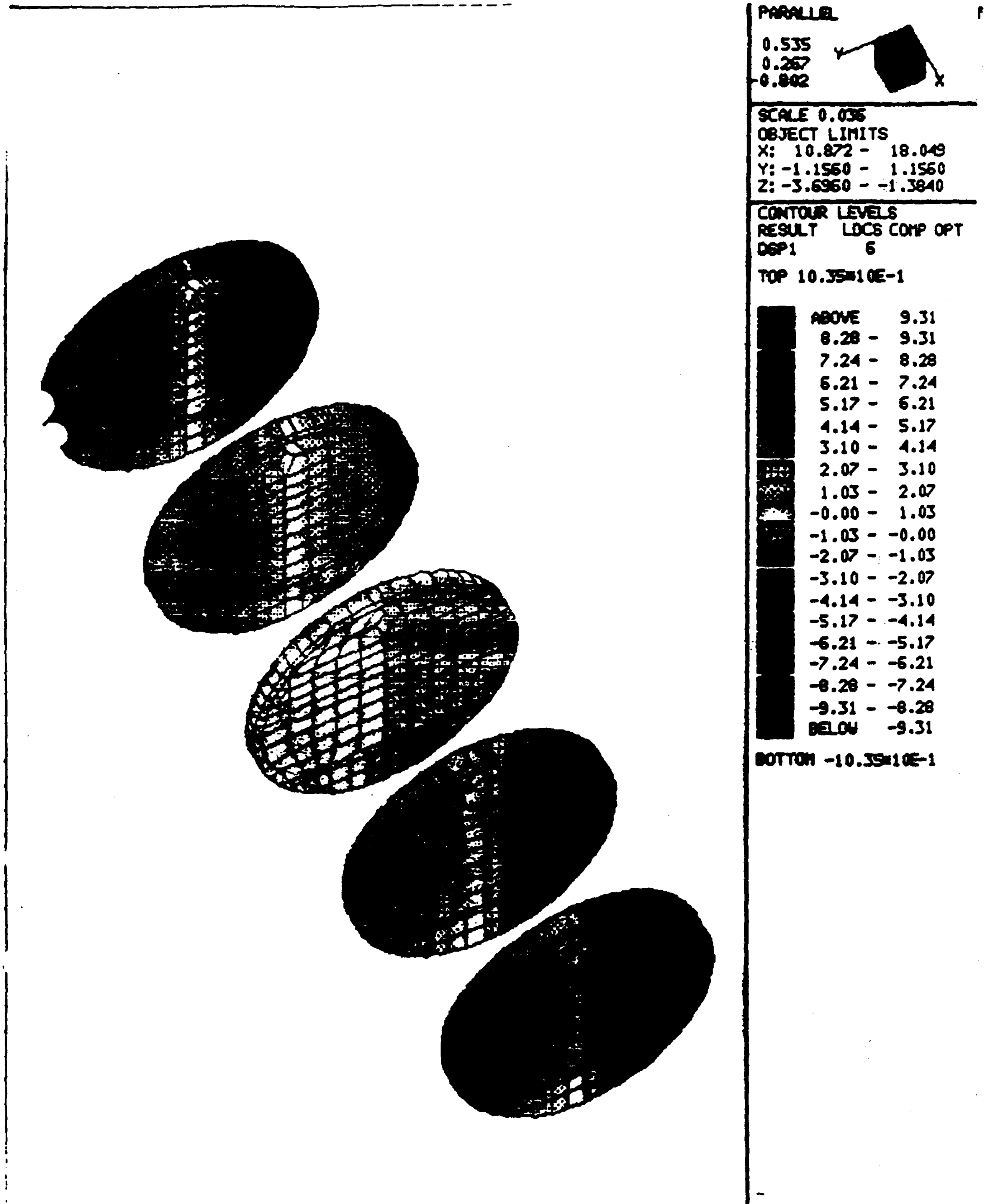
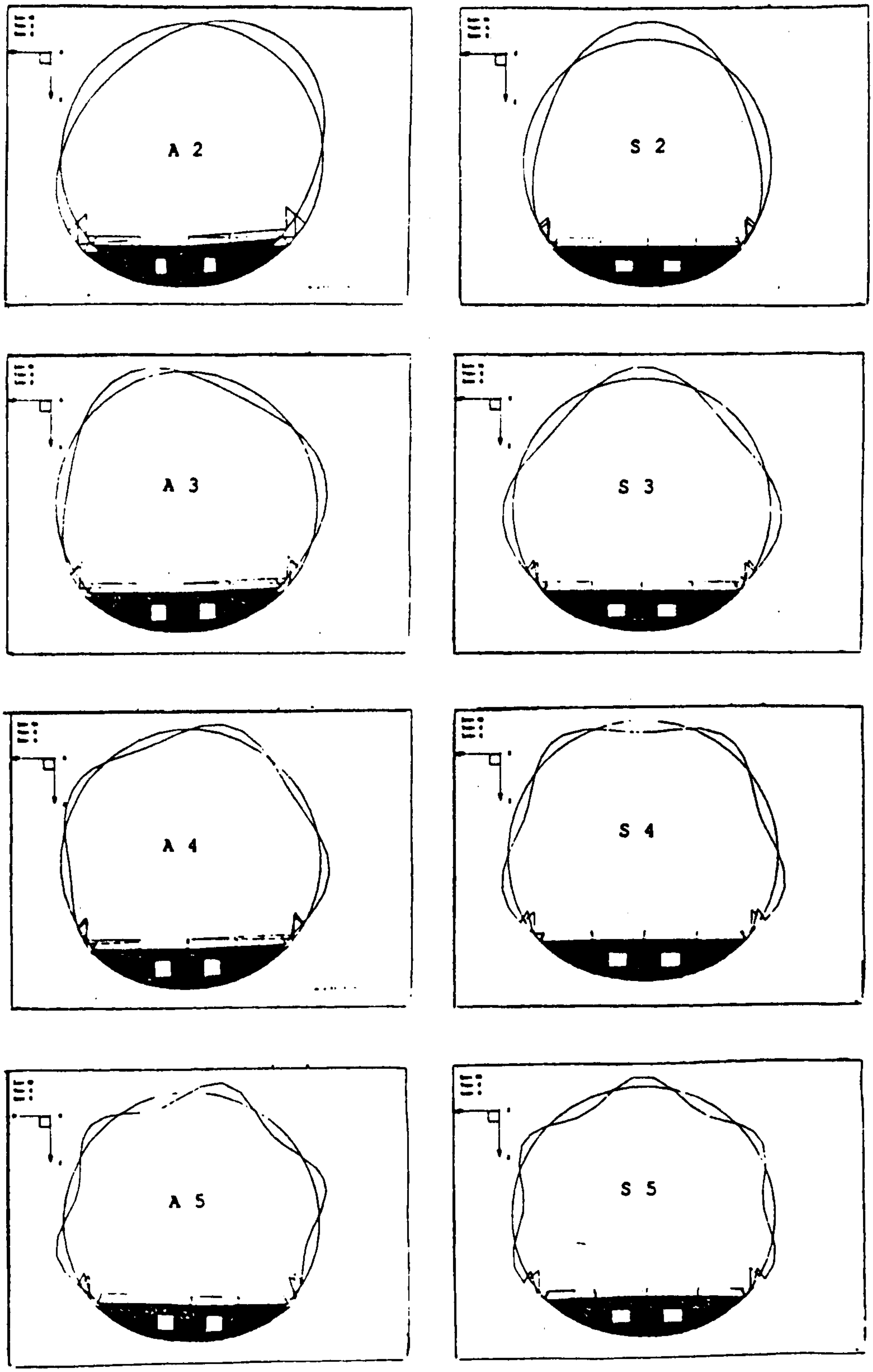


Fig ACOUSTIC SIDE-SIDE MODE with LH/RH shift AT 101.6 Hz

Cross-sectional mode shapes (Frames).



8

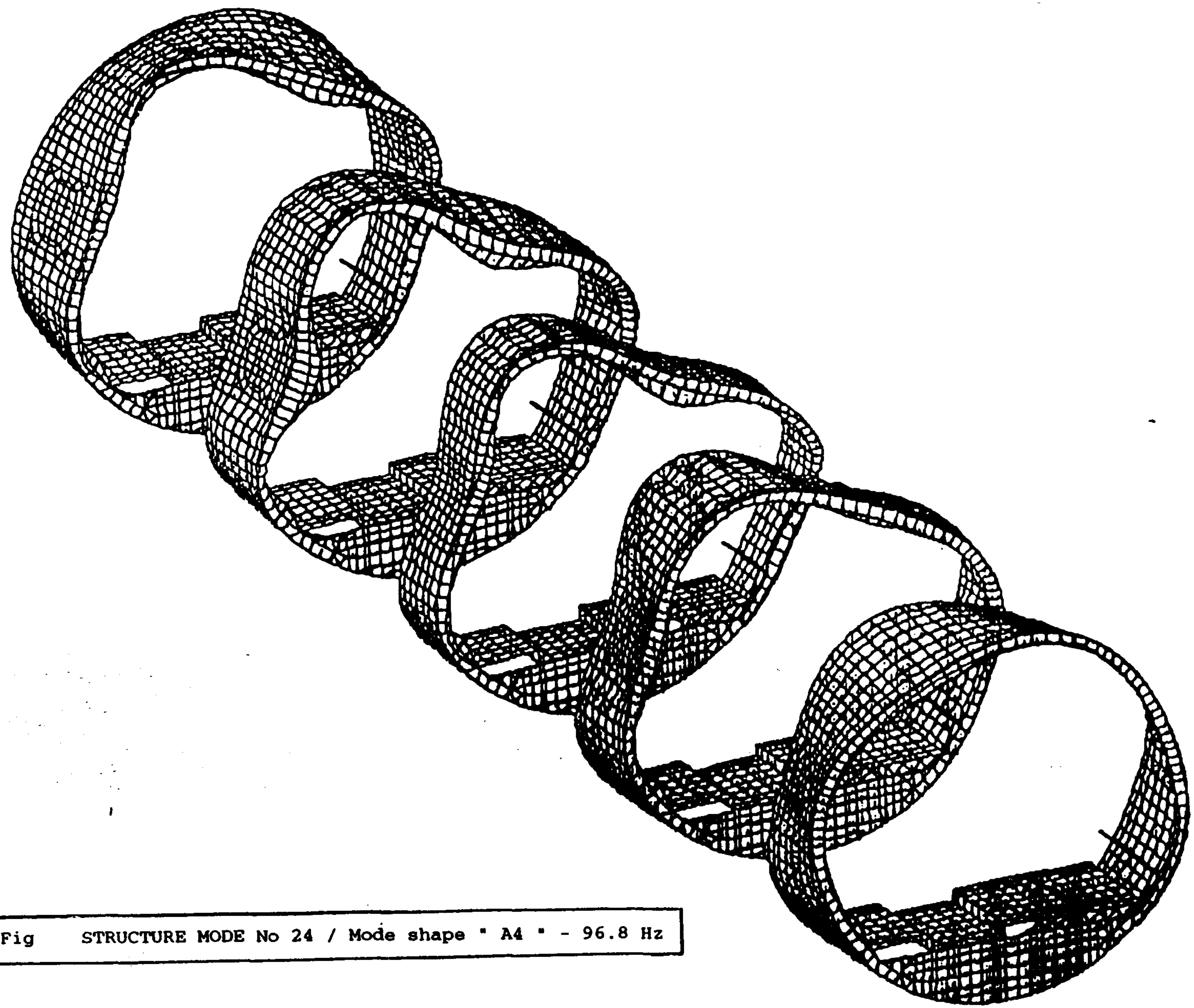


Fig STRUCTURE MODE No 24 / Mode shape " A4 " - 96.8 Hz

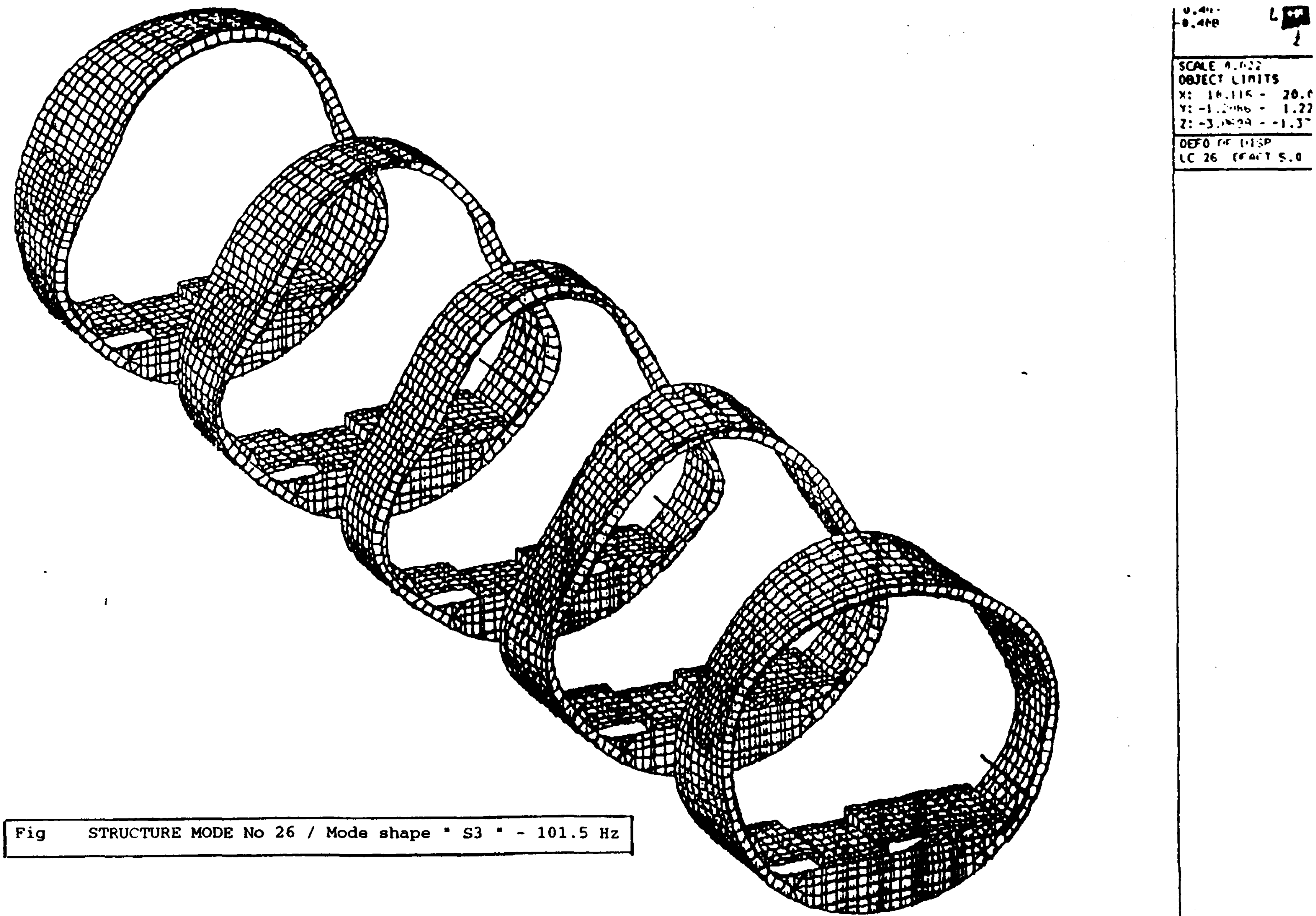


Fig   STRUCTURE MODE No 26 / Mode shape " S3 " - 101.5 Hz

- 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.

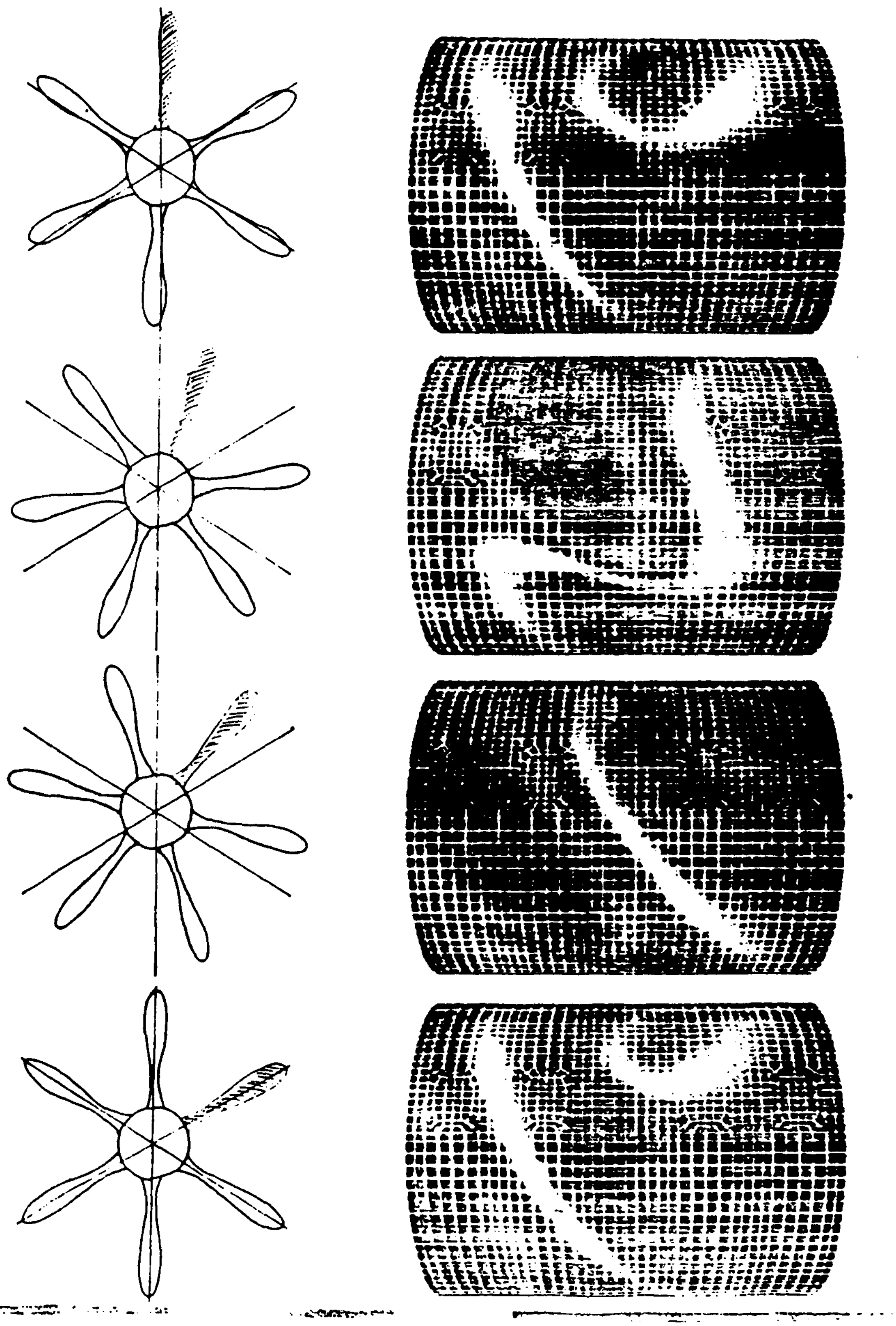


Figure Predicted pressure field on the lefthand side of the Saab 2000 at different time steps

- Scheme of computation

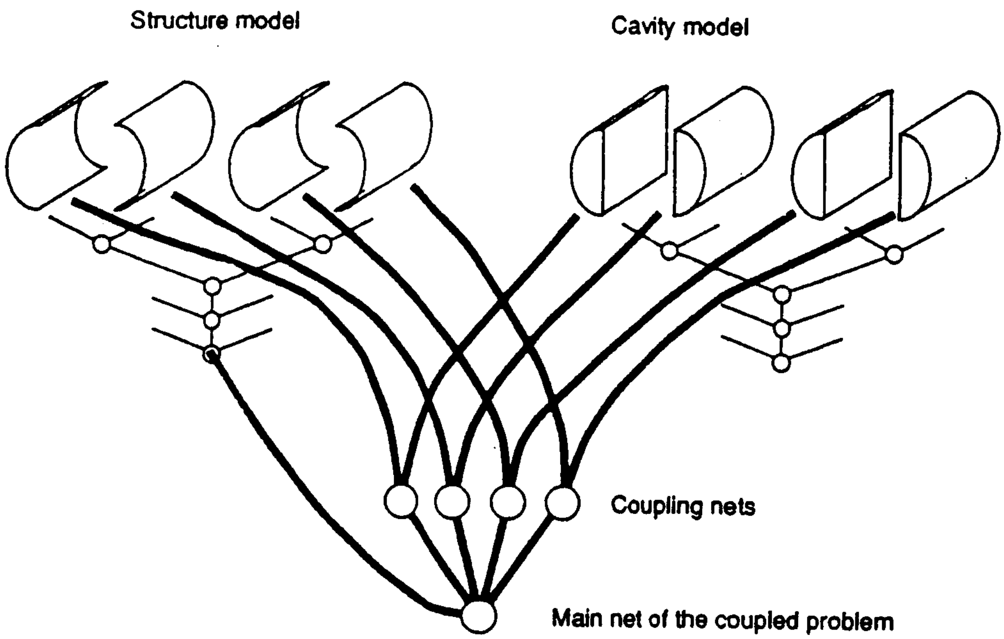


Figure . Natural mode flow of computation

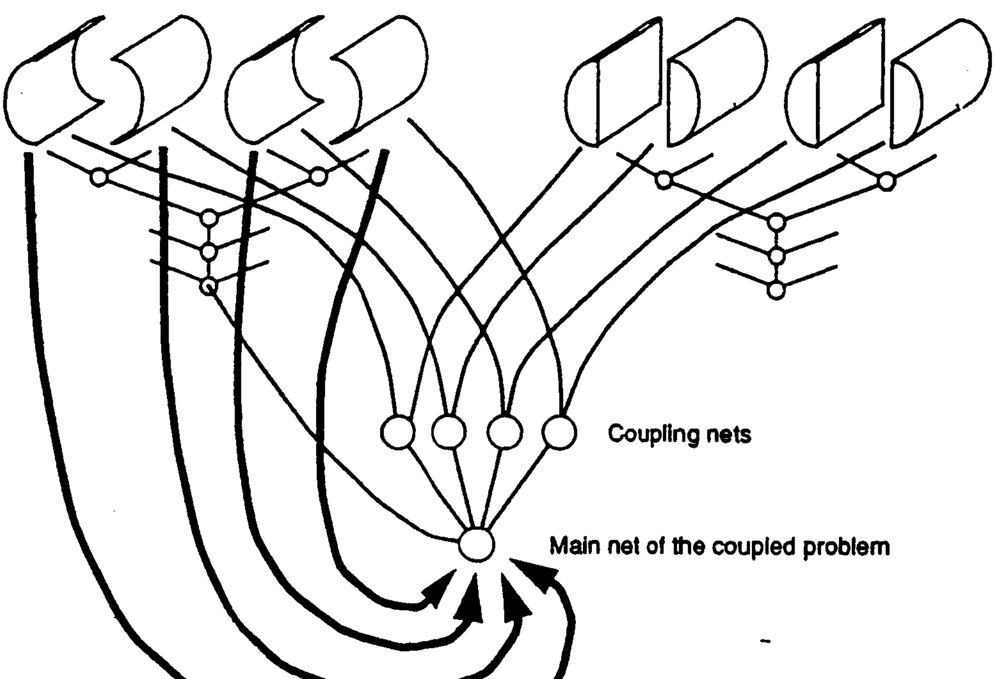
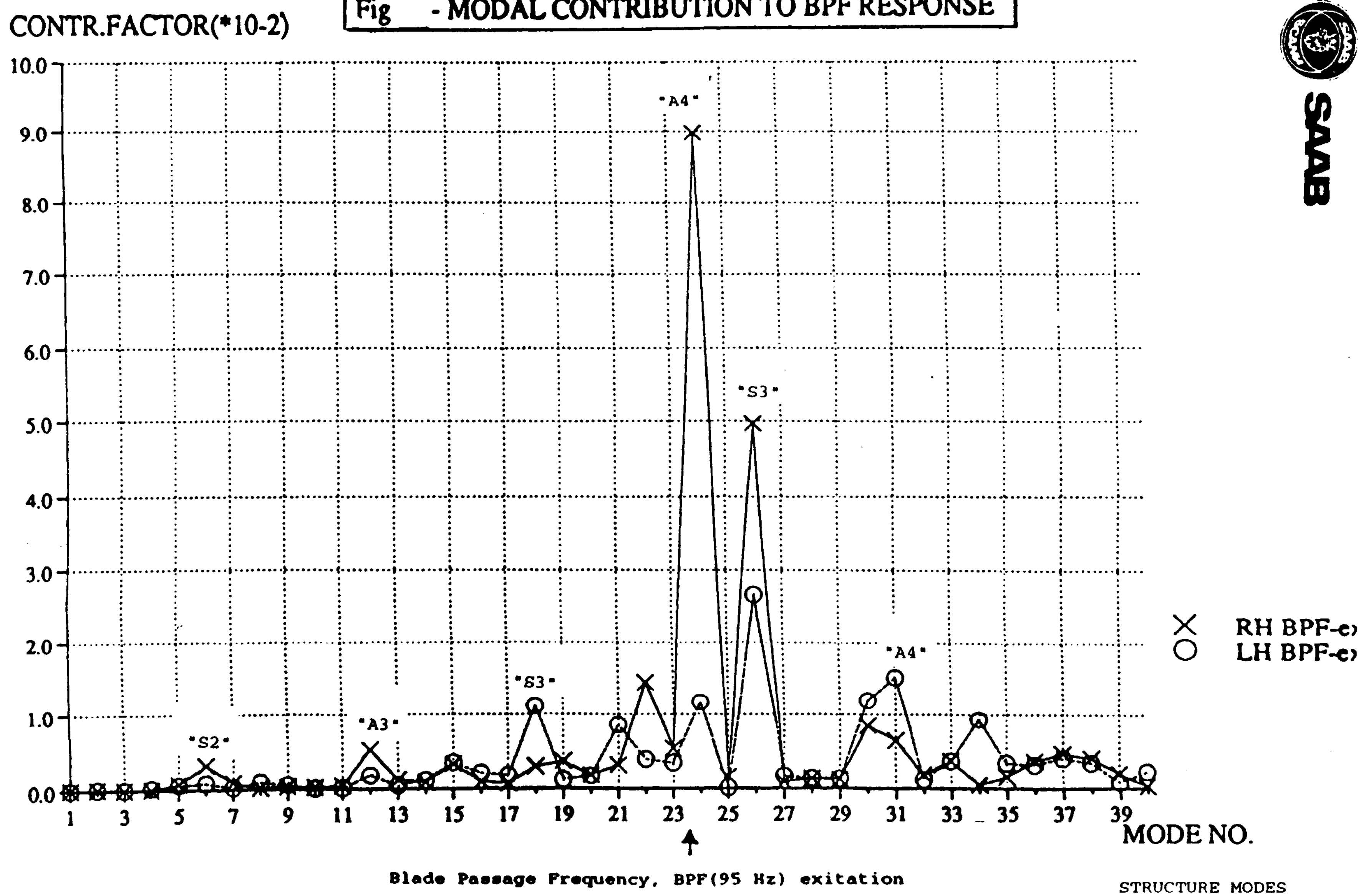
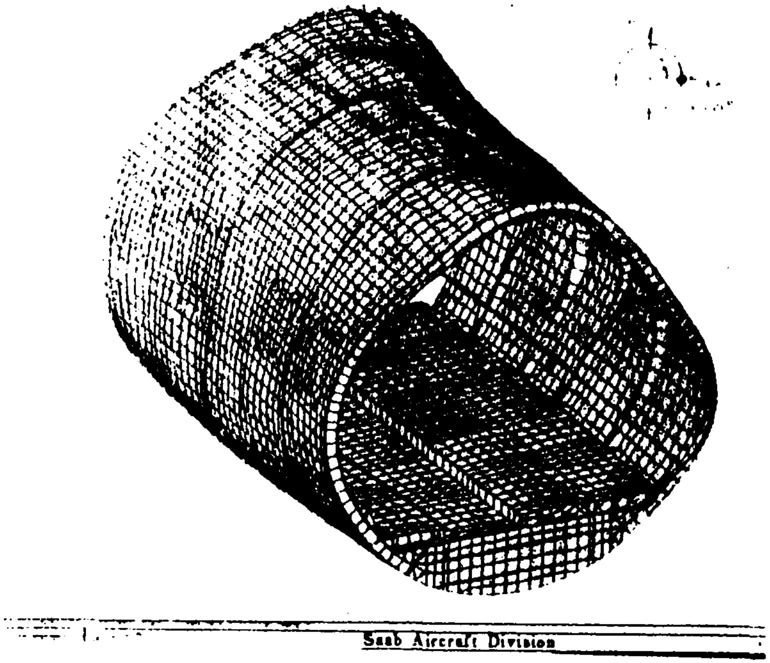


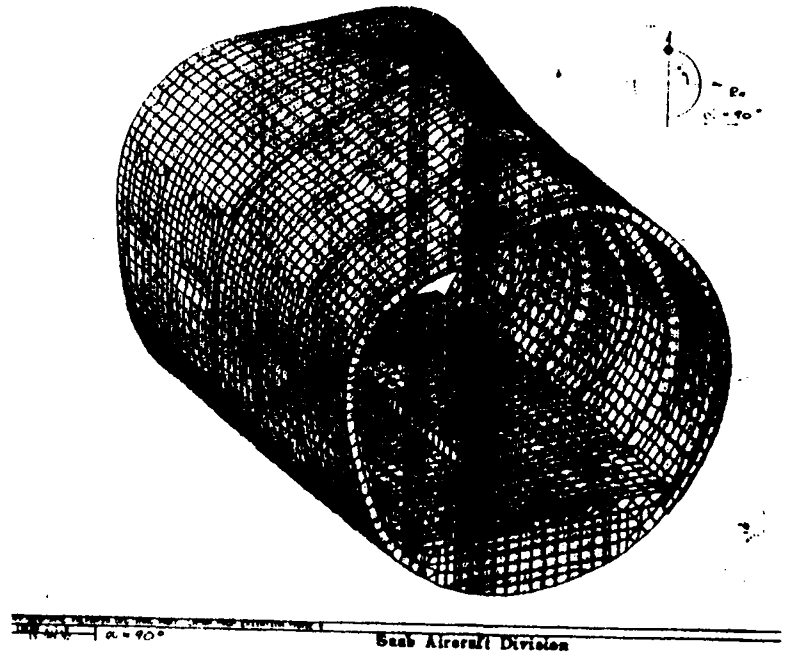
Figure . Frequency response flow of computation

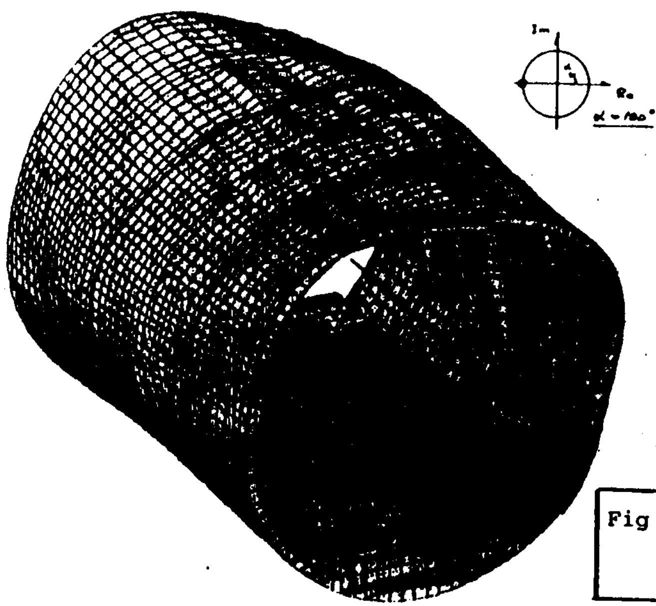
Fig - MODAL CONTRIBUTION TO BPF RESPONSE



Blade Passage Frequency, BPF(95 Hz) exitation







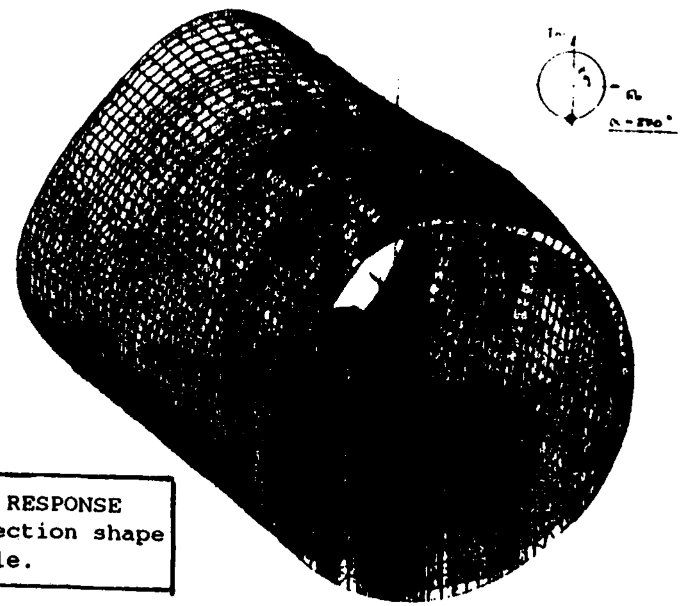
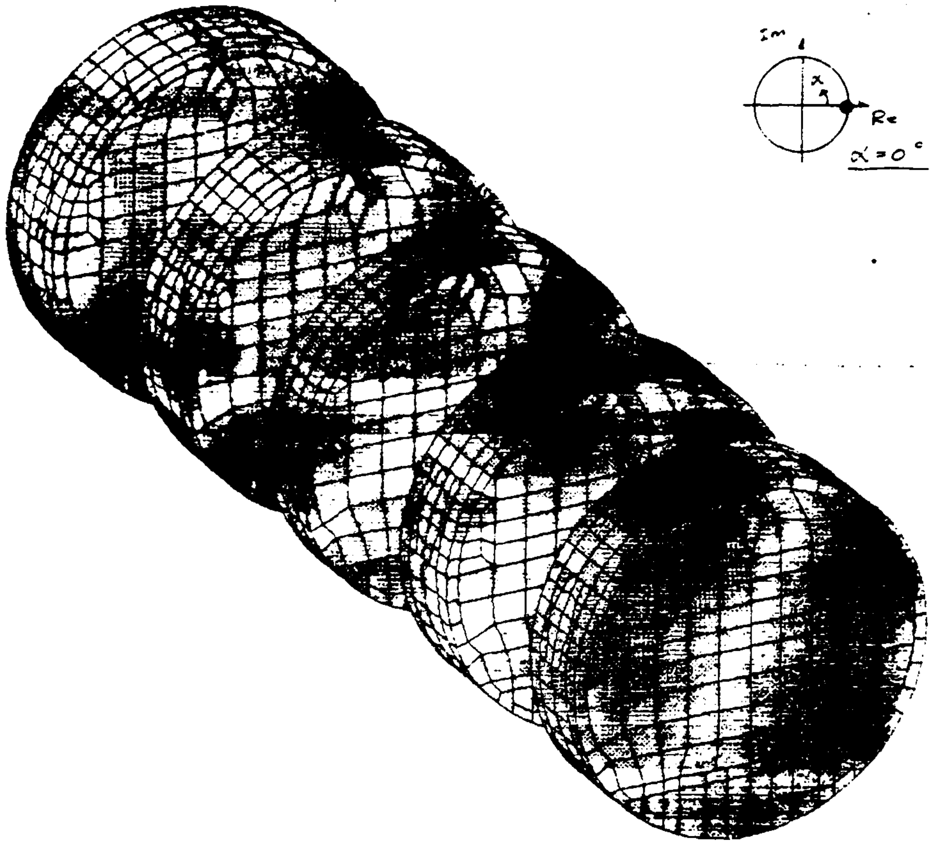


Fig STRUCTURAL BPF RESPONSE
Operating deflection shape
during one cycle.



α = 0° Saab Aircraft Division

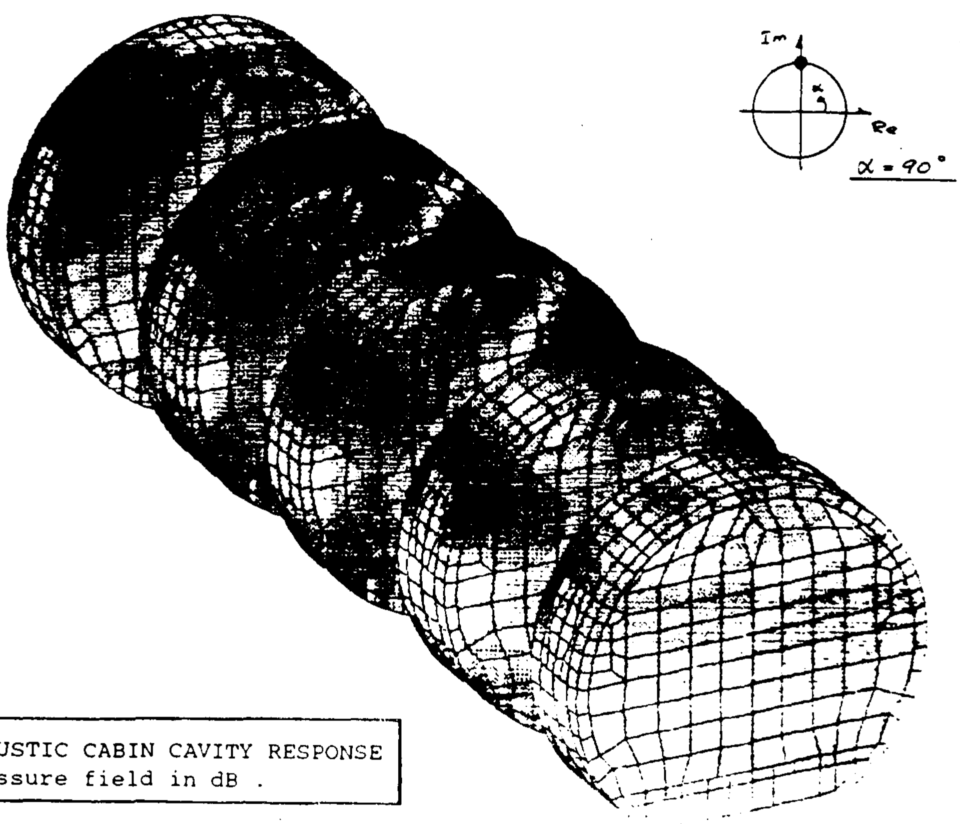
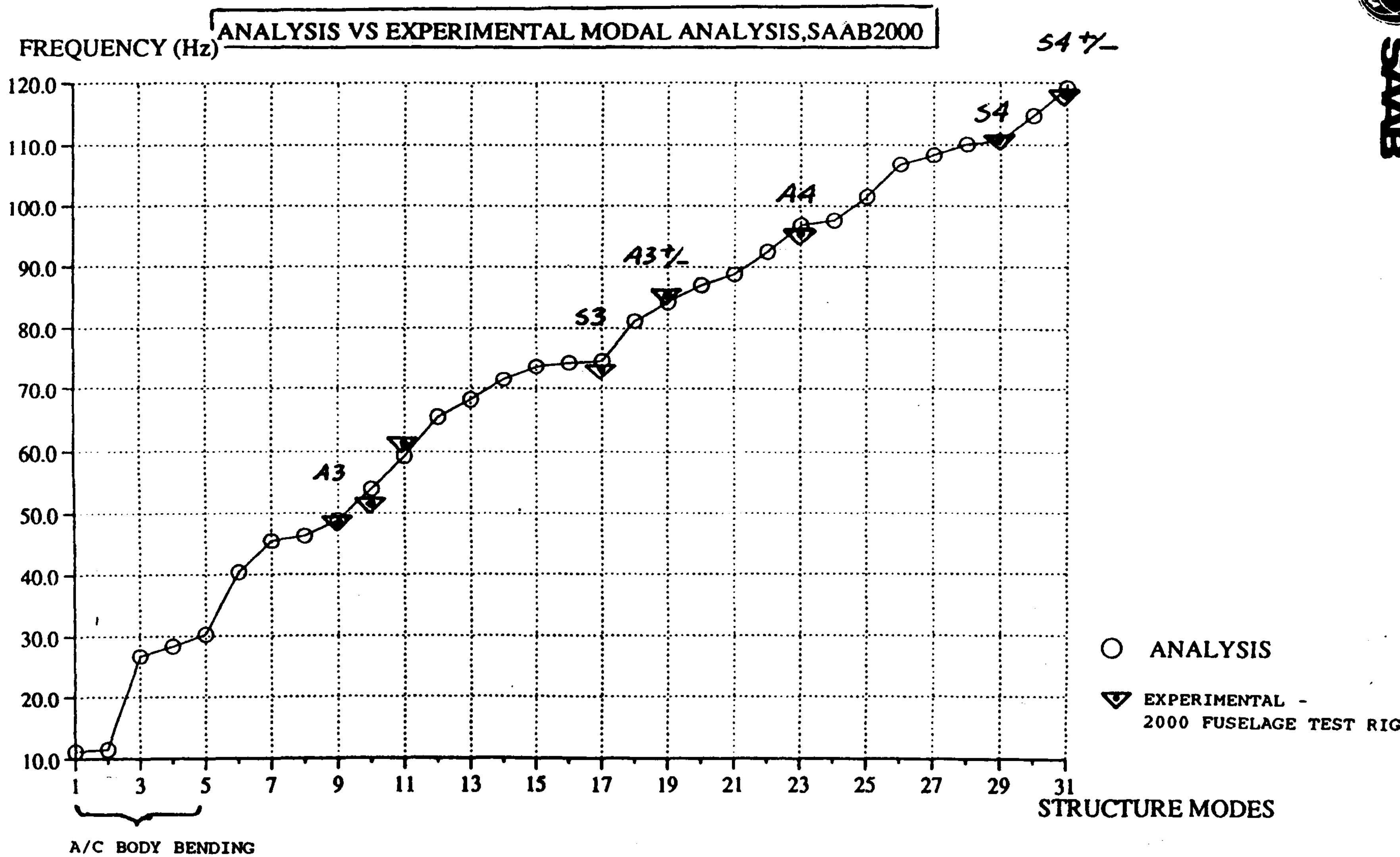


Fig ACOUSTIC CABIN CAVITY RESPONSE
Pressure field in dB .


ANALYSIS VS EXPERIMENTAL MODAL ANALYSIS,SAAB2000
FREQUENCY (Hz)
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
STRUCTURE MODES
A/C BODY BENDING
A3
S3
A3+/-
A4
S4
S4+/-
ANALYSIS
EXPERIMENTAL -
2000 FUSELAGE TEST RIG

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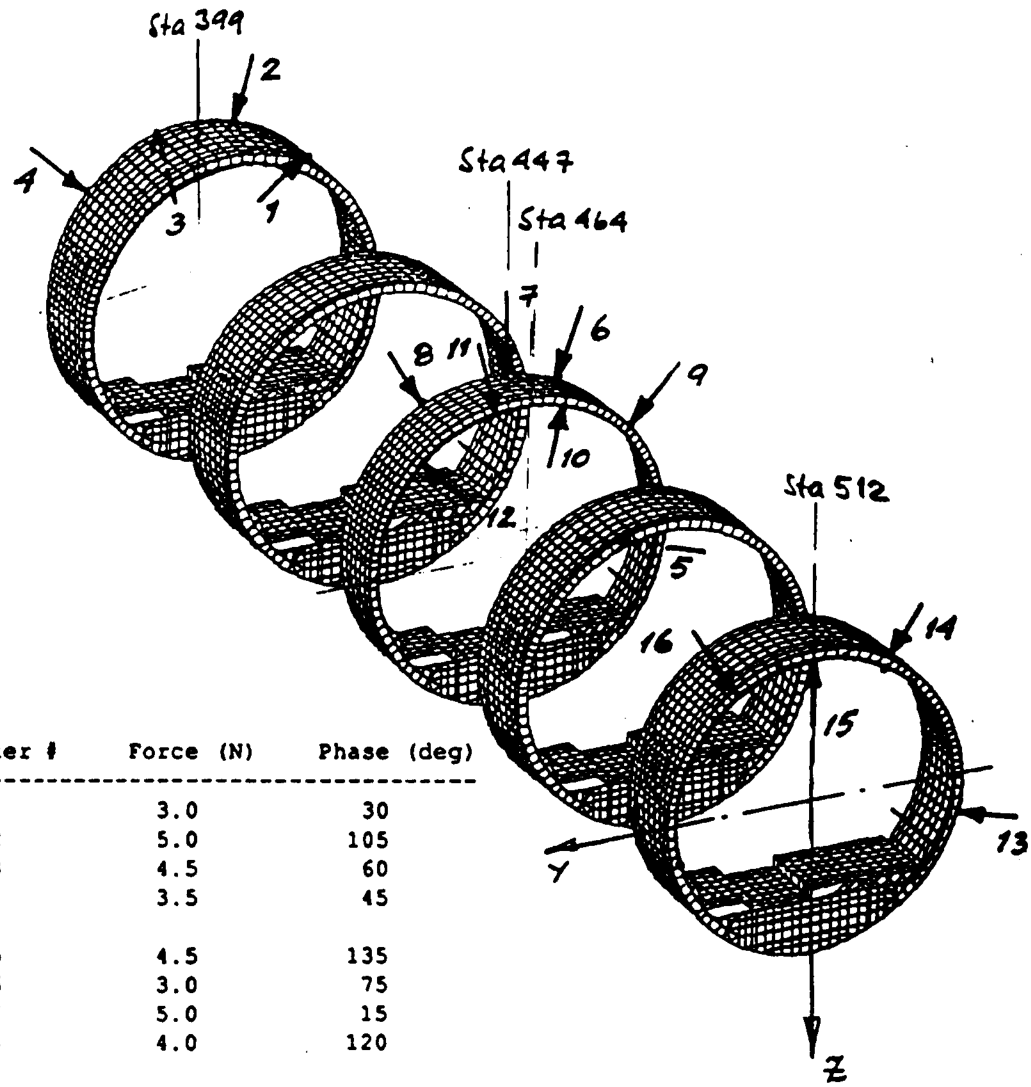
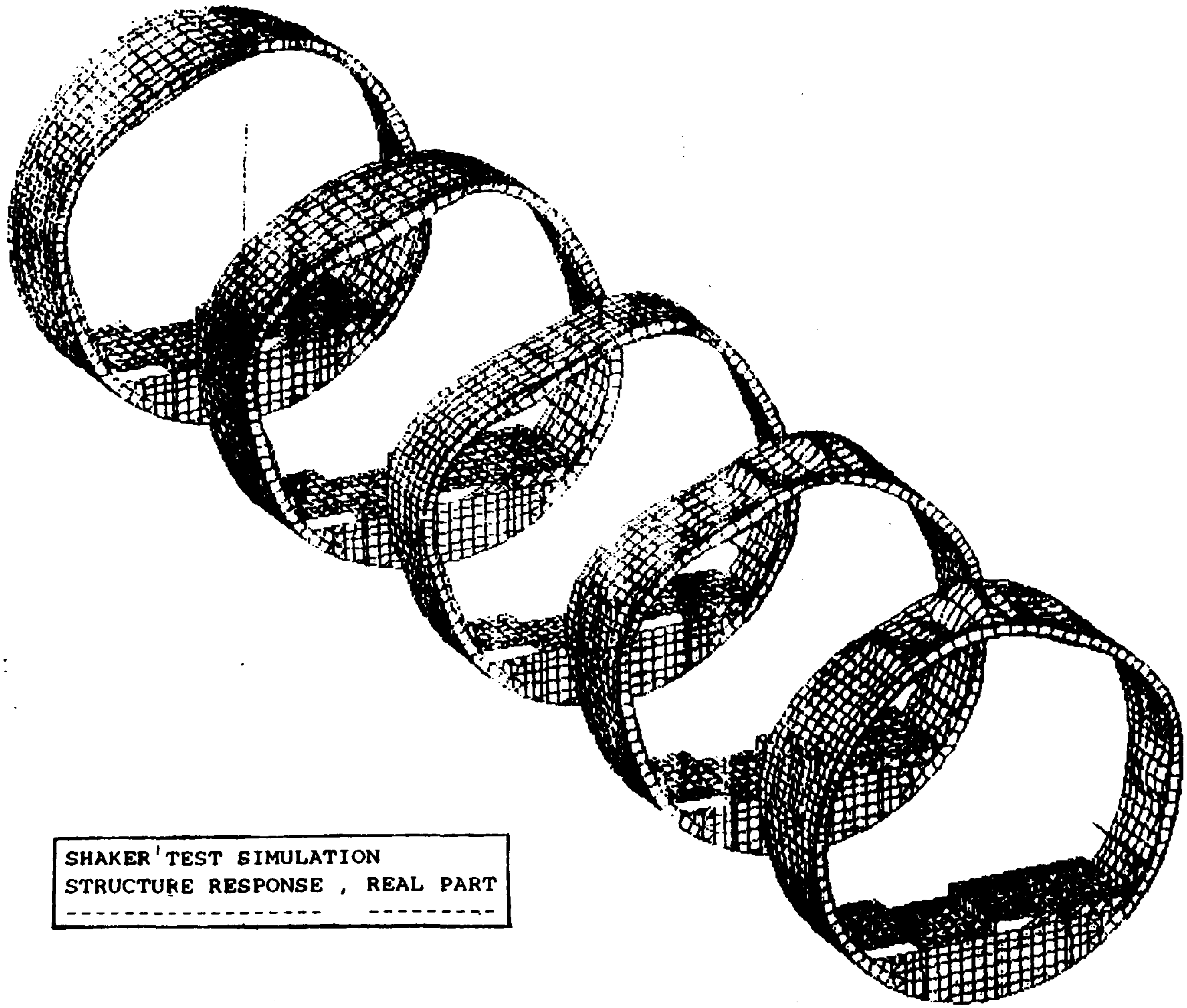
MODEL VALIDATION ANALYSIS

Acoustic Mockup shaker test simulation

* 16 shakers with simultaneously sinusodial force (95 Hz) excitation.
* Force and phase distribution randomly choosen.



Shaker #	Force (N)	Phase (deg)
1	3.0	30
2	5.0	105
3	4.5	60
4	3.5	45
5	4.5	135
6	3.0	75
7	5.0	15
8	4.0	120
9	3.5	150
10	4.5	120
11	3.5	75
12	5.0	45
13	4.0	15
14	3.5	60
15	5.0	165
16	4.0	105


SHAKER TEST SIMULATION
STRUCTURE RESPONSE , REAL PART

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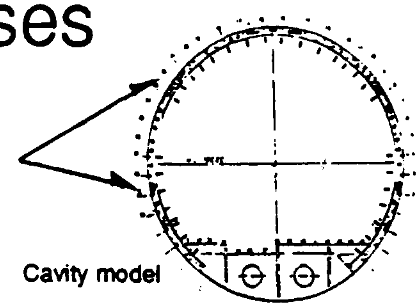
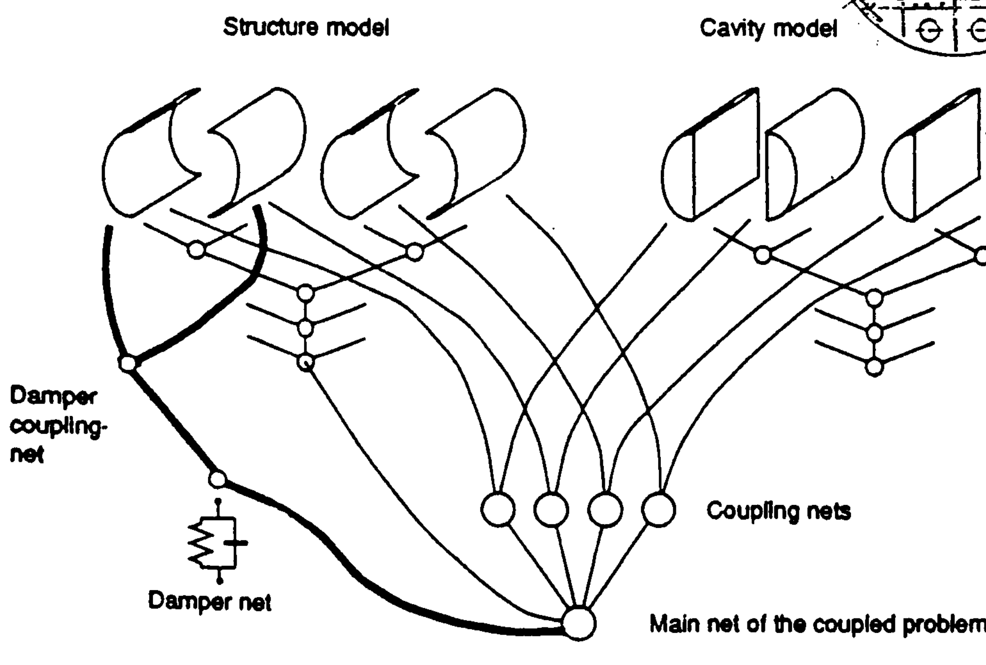
Planned analyses

- Tuned dampers





- Structure-borne path identification

- Active Vibration Control

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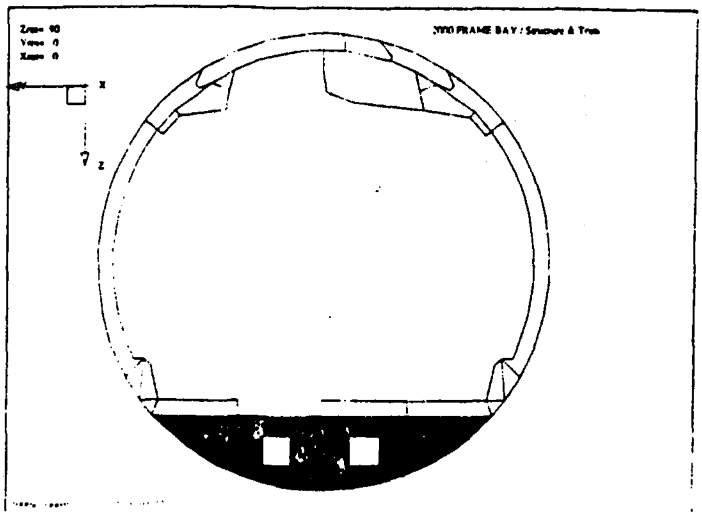
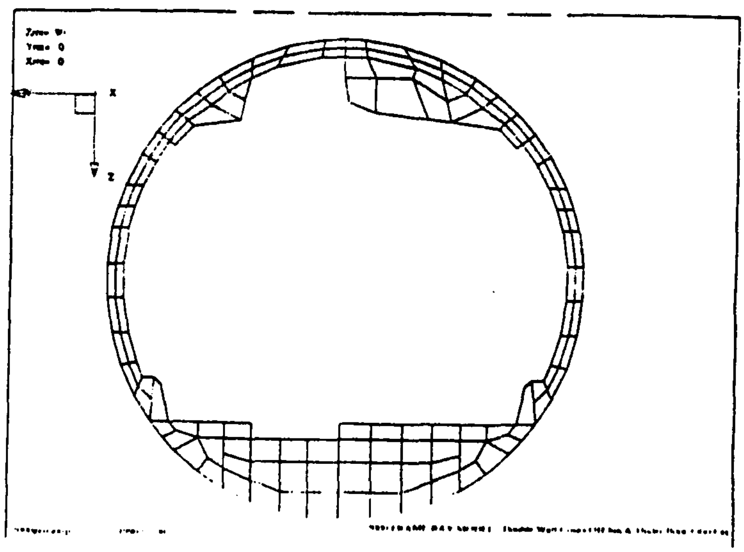
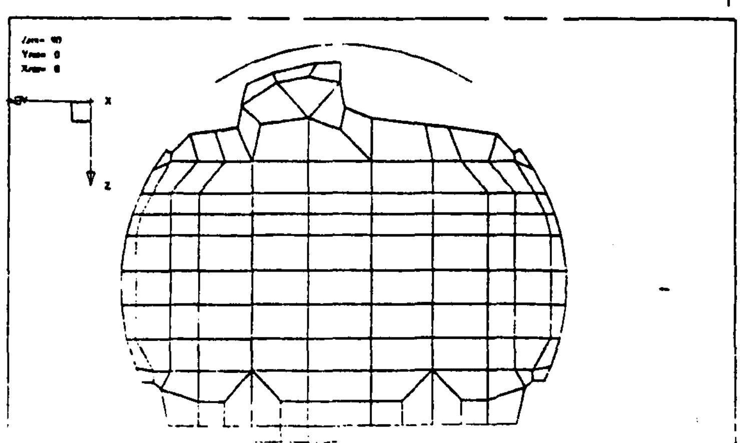
- # Model development
  - Fuselage sections with interior
  - Active Noise Control analyses







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