NASA/CR-2007-214898

Finite Element Development and Specifications of a Patched, Recessed Nomex Core Honeycomb Panel for Increased Sound Transmission Loss

Ferdinand W. Grosveld
Lockheed Martin Engineering and Sciences Company, Hampton, Virginia

September 2007

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

Prepared for Langley Research Center
under Contract NAS1-00135B

September 2007

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SUMMARY

This informal report summarizes the development and the design specifications of a recessed nomex core honeycomb panel in fulfillment of the deliverable in Task Order 13RBE, Revision 10, Subtask 17. The honeycomb panel, with 0.020-inch thick aluminum face sheets, has 0.016-inch thick aluminum patches applied to twenty-five, 6 by 6 inch, quarter inch thick recessed cores. A 10 dB higher transmission loss over the frequency range 250 – 1000 Hz was predicted by a MSC/NASTRAN finite element model when compared with the transmission loss of the base nomex core honeycomb panel. The static displacement, due to a unit force applied at either the core or recessed core area, was of the same order of magnitude as the static displacement of the base honeycomb panel when exposed to the same unit force. The mass of the new honeycomb design is 5.1% more than the base honeycomb panel. A physical model was constructed and is being tested.

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SCOPE

The goal of this subtask was to determine optimum configurations using finite element analysis of voided and recessed core design honeycomb laminate aircraft sidewall structures and use the results to show that the panel has improved acoustic performance and meets structural requirements.

TECHNICAL APPROACH

- Basic honeycomb, voided core and recessed core honeycomb finite element models were developed using metric units specified in the International System of Units (SI).
- Structural and acoustic performance parameters (including panel geometry, resonances, response functions, static/dynamic loading, boundary conditions, acoustic radiation parameters) were characterized.
- Design concepts were investigated meeting the structural/acoustic requirements suitable for fabrication of a prototype panel.

FINITE ELEMENT MODELS

Twenty-two different finite element models were developed using the pre/post processor MSC/PATRAN 2005 and were analyzed with different solution methods in MSC/NASTRAN 2005. The models are listed in Table 1 and their file name notations are explained in Table2. Sketches of the voided and recessed areas for the different panel configurations are shown in Figures 1-6. Many of the twenty-two models were used in additional finite element analyses with different material properties, boundary conditions, finite element solutions and resin/adhesive applications. Modal analyses (Solution 103) were performed to obtain the modal characteristics of the base honeycomb panel, the honeycomb panels with voided and recessed cores and the honeycomb panel with an aluminum plate inside the core. Frequency response functions were computed for all twenty-two models and derived configurations for excitation by 10 sets of random amplitude and random angle of incidence sound fields. The MSC/NASTRAN frequency response function computations took about two hours on average to complete for one set of random sound excitation. All bulk data files, database, journal, punch, f06, f04 and xdb files are archived on a Government workstation and available upon request.

MATLAB COMPUTATIONS

MATLAB was used, under the Windows operating system, to compute the acoustic pressures from the panel velocity distribution obtained by the frequency response functions in the finite element analysis (punch files) and to propagate the resulting pressures into the acoustic far field. The sound transmission loss was computed and averaged for ten excitation fields. Data were converted to one-third octave bands and 5 Hz wide narrow bands to allow comparisons between experimental, analytical and finite element predicted results. Experimental data was obtained from NASA for transmission loss measurement results of several aluminum and honeycomb panels in the Structural Acoustics Loads and Transmission facility (SALT). The file names are listed in Table 1. Analytical data were obtained using transmission loss calculations proposed by Davy, Sharp and Beranek. Plots were generated to show the trends and differences. All mat, workspace and figure files were archived on a Government workstation and are available upon request.

PRELIMINARY STUDIES

Voided honeycomb core composite structural design concepts were investigated for their transmission loss characteristics. Dispersion theories for acoustic radiation from flat and curved panels were studied. A finite element model of a honeycomb composite panel was developed which has voids cut into the honeycomb. Existing finite element bulk data files, MATLAB files, and other pertinent scripts were installed on a workstation and were analyzed. MSC/NASTRAN and MSC/PATRAN programs, documentation, and manuals were installed on the workstation. A number of analytical methods, describing the theoretical predictions of the effective elasticity moduli, shear moduli, and Poisson's ratios of honeycomb type cores, were reviewed. The mechanical properties for the current core configuration were predicted for several aluminum and aramid fiber core materials (Table 3). Calculations of the core mechanical properties included elasticity modulus, shear moduli and Poisson ratios from the honeycomb core geometry and material properties. Resulting characteristics agreed well with properties provided by the manufacturer. In addition, new modulus values were calculated that were lacking from the manufacturer specifications. The base, "solid", core nomex honeycomb finite element model was updated with the new material properties. The new model also included the steel frame supporting the test panel. The honeycomb panel design parameters were calculated including static flexural rigidity, material wave speeds, panel flexural wave speed, core shearing wave speed, face sheet flexural wave speed, the critical frequencies and the coincidence frequencies as function of angle of incidence. (Table 4). The material properties used in the finite element analyses are listed in Table 5 for aluminum steel and air and in Table 6 for the nomex (Nomex 1) and aluminum cores. The critical and the fundamental resonance frequencies were calculated for a simply supported honeycomb panel. The critical and fundamental resonance frequencies were calculated for simply supported, 0.020-inch (AS) and 0.040-inch thick (2AS) aluminum panels. The mass-air-mass resonances (Sharp and Davy), the critical frequency, the acoustic cavity resonance frequency and the limiting frequency based on the panel spacing were computed for two 0.020-inch thick aluminum face sheets in a double wall configuration (Table 7). The sound transmission loss for this arrangement was calculated as function of one-third octave band frequency using Davy's theory. The calculated transmission loss for the 0.020 inch thick aluminum panel (AS), the 0.040 inch thick panel (A2) and the two 0.020 inch thick panels in a double wall configuration with (DA abs) and without absorption (DA no) is shown in Figure 7. The transmission loss was also calculated using the approaches by Sharp (Figure 8) and Beranek for field, random and other angles of incidence.

MODAL ANALYSES

Modal analyses (Solution 103) were performed for the base honeycomb panel, the honeycomb panels with voided and recessed cores and the honeycomb panel with an aluminum plate inside the core. Modal analyses results are presented for finite element models of the two aluminum panels (AS and 2AS), the base nomex core honeycomb (SNC) panel and the base honeycomb panel featuring the 0.016 inch thick, 45 by 45 inch aluminum panel (ASNC). The modal displacements are shown in Figures A1-A80 of Appendix A. The first 20 modes of the aluminum panels are listed in Table 8. The first 18 modes of the two configurations of the base nomex core honeycomb panel are summarized in Table 9. Table 9 indicates if the modes are predominantly panel modes (negligible displacement of the steel frame) or frame+ modes where the combination of panel and supporting frame are in resonance. The modal analysis showed a low modal density (30 modes below 1000 Hz). The structural modes were well separated. The modal analysis of the honeycomb panel with “subpanels” covering the 10 by 10 inch voids showed a high modal density (53 modes below 120 Hz, 200 modes below 388 Hz). Figure 9 shows examples of the subpanel modes superimposed on the global panel modes for the voided nomex core honeycomb panel. The modes formed clusters of resonances covering frequency regions rather than single frequencies. The first cluster of 18 (1,1) subpanel modes, superimposed on 9 global panel modes (face sheets in-phase, then out-of-phase), occurred between 53.3 and 56.9 Hz.

SOUND TRANSMISSION LOSS RESULTS

The analytical sound transmission loss was calculated for single and double mass aluminum panels, and a double wall structure consisting of two single mass aluminum panels separated by the same distance as the honeycomb face sheets. Honeycomb experimental transmission loss data, obtained in the Structural Acoustics Loads and Transmission facility (SALT), were received from NASA. Experimental, predicted and calculated sound transmission loss data for the aluminum panel AS are compared in Figure 10, while Figure 11 shows the finite element predictions and analytical calculation results for the AS, 2AS, and AD2 configurations.

Updated values were obtained from NASA for the core and the resin/adhesive mass used in the manufacturing of the honeycomb panels. The new mass and mass distribution were incorporated in the finite element panel models. To strengthen the recessed core panels models were designed having an aluminum plate covering the exposed core areas. To save weight new models were developed having aluminum patches on the recessed honeycomb. Plots were generated to show the trends and differences for all twenty-two finite elements models and experimental transmission loss data. The results are presented in Figures 12-38.

The thickness, area, and volume parameters for the twenty-two panel configurations are listed in Table 10 for English units and in Table 11 for metric units. The total mass of each configuration is calculated in Table 12 and presented as the difference in percentage from the mass of the base nomex core honeycomb panel. The models were also excited by a static force at two different locations (nodes 769 and 433) on each panel. The nodal locations are indicated in Figure 1. The panel displacements due to the unit static force are listed in Table 13 for all finite element single aluminum and honeycomb panel configurations. The aluminum panel finite element model 3AS was included as its thickness was chosen such that its total mass was equal to the total mass of the base nomex core honeycomb panle. A total mass comparison is included in Table 13.

Several parameters, including structural damping of the core, the face sheets and the steel frame, and the fluid damping of the air in the voids between the face sheets, were investigated to determine their effect on the predicted transmission loss. Lower transmission loss was associated with lesser damping of the fluid (air). Mesh density variation was used as a parameter for the air space of the double wall and voided honeycomb panels to determine the effect on sound radiation. No differences were found for the various mesh densities, even when non-matching meshes were used for the interface between the fluid and the structure. Other parameters, including the core elasticity modulus, the core shear moduli, panel boundary conditions, and damping coefficients were investigated to determine their effect on the predicted transmission loss. The three-dimensional anisotropic material properties on the MAT9 entries of the aluminum (VAC10) and nomex core (VNC) honeycomb panels with the nine 10 by 10 inch voids, and the nomex core base panels (SNC) are tabulated in Table 14..The two aluminum sheets in the double wall configuration were modeled to couple with the ambient air on the outside of each panel. It was concluded that the structural-acoustic coupling could be ignored, even at the mass-air-mass resonance frequencies, as the results indicated no change in the sound radiation prediction. Plots were generated to show the trends and differences of these parameters on the transmission loss data. The results are shown in Figures 39-56.

FURTHER IMPROVEMENT OF THE SOUND TRANSMISSION LOSS

The transmission loss of the honeycomb panel with 0.016-inch thick aluminum patches covering the recessed core is being measured by NASA in the SALT facility. A perforated plate is being designed to replace the patch on the recessed core. Absorption material is added to the interior air cavity to improve transmission loss at the higher frequencies as suggested by the analytical calculations. The perforated plates will serve as a Helmholtz cavity resonator adding low-frequency t to the design. Nomex core panels with different numbers of voids and voids of different sizes are being modeled to investigate the effects of these parameters on the TL.

CONCLUSIONS

A nomex recessed core honeycomb panel was designed for high transmission loss. The panel, with 0.020-inch thick aluminum face sheets, has 0.016-inch thick aluminum patches applied to twenty-five, 6 by 6 inch, quarter inch thick recessed cores. A 10 dB higher transmission loss over the frequency range 250 – 1000 Hz was predicted by a MSC/NASTRAN finite element model when compared with the transmission loss of the base nomex core honeycomb panel (Figure 37). The static displacement, due to a unit force applied at either the core or recessed core area, was of the same order of magnitude as the static displacement of the base honeycomb panel when exposed to the same unit force. The mass of the new honeycomb design is 5.1% more than the base honeycomb panel. A physical model was constructed and is being tested. Parameter studies did not reveal significant advantages of changing structural or fluid damping factors.

TABLES

Table 1. Twenty-two finite element models used in the current study

Finite element analyses	SALT transmission loss measurements
AQRNC10	
ARNC10	
ASNC	
QRNC10	
QRNC10patch	
QRNC25-06	
QRNC25-06patch	
QRNC25-06patch_C	
RNC10	TL_RNC10_exp
SNC	TL_SNC_exp
VAC10	TL_VAC10_exp
VNC06	TL_VNC06_exp
VNC08	
VNC10	TL_VNC10_exp
VNC12	
VNC14	
VNC25-06	
AS	TL_AS_exp
2AS	
ADgap4	TL_AD2_gap1000
ADgap7	TL_AD2_gap1750
3AS	

Table 2. File name notations

Symbol	Description
A	Aluminum panel at 0.25 in from one of the face sheets covering the recessed core (if applicable); dimensions: 0.016 in by 45 in by 45 in
Q	Quarter inch recessed core; 0.25 in thick
R	Recessed core; 0.5 in thick
N	Core material N: Nomex; A: Aluminum
C10	Dimensions of the 9 square void or recessed areas; C10: 10 in; C06: 6 in; C08: 8 in; C12: 12 in; C14: 14 in; C25-06 indicates 25 square void or recessed areas with dimensions of 6 in
patch	Aluminum panel patches covering the recessed core
_C	Clamped edge conditions
AS	Aluminum panel
AD	Aluminum panels in a double wall configuration
gap	Airspace; gap4: 1.00 in; gap7 1.75 in

Table 3. Calculations of the core mechanical properties including elasticity modulus, shear moduli and Poisson ratios from the honeycomb core geometry and material properties.

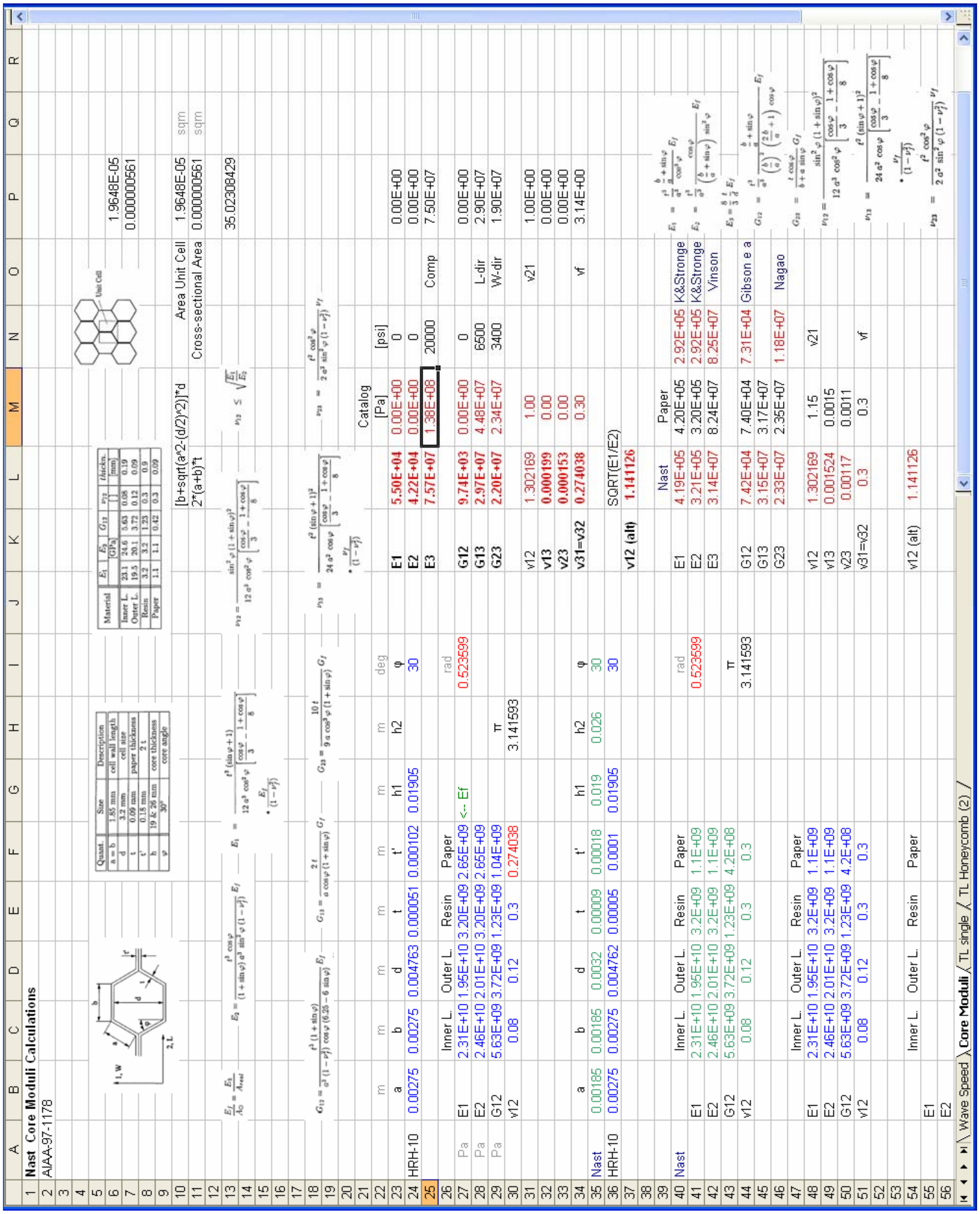

Table 4. Calculations of the honeycomb panel design parameters including static flexural rigidity, material wave speeds, panel flexural wave speed, core shearing wave speed, face sheet flexural wave speed, the critical frequencies and the coincidence frequencies as function of angle of incidence.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Honeycomb panel design**			**Davis**														
2	AIAA-99-1917																	
3																		
4	**Upper Face Sheet**										**90**	<- degrees	1	<- sin				
5		weight	t	nu	B	rho	m	E	etha	pi	rho	c	theta					
6	Aluminum	1.95	0.0005	0.33	0.9	2700	1.37	7.10E+10	0.01	3.141593	1.21	343	1.570796					
7		kg	m		kgm^2/sec	kg/cum	kg/sqm	N/sqm			kg/cum	m/sec	radians	a	b			
8	**Lower Face Sheet**													1.1938	1.1938			
9	Aluminum	1.95	0.0005	0.33	0.9	2700	1.37	7.10E+10	0.01	3.141593	1.21	343	1.570796	m	m			
10														47.00	47.00			
11	**Core**													in	in			
12		weight	tc	nuc	Bc	rhoc	mc	Gc	etha	pi	rho	c						
13	Nomex	0.87	0.01905	0.274	15.6	32.037	0.61	2.50E+07	0.01	3.141593	1.21	343						
14		kg	m		kgm^2/sec	kg/cum	kg/sqm	N/sqm			kg/cum	m/sec						
15																		
16	**Honey**	weight	th			rhoh	mh											
17		4.78	0.02007			167.12	3.35											
18																		
19	**Panel**					**Davis**												
20																		
21	fc=c^2/(2pi*SIN(theta))*SQRT(m/B)					Static flexural rigidity			$D_{static}=\frac{E_f t_f (t_c+t_f)^2}{2(1-\nu^2)}$									
22																		
23	Critical freq.		**23504.5**			Dstat	7741.3											
24																		
25	Coincidence freq:		**23504.5**			Material wave speeds			$c_{mL}=\sqrt{\frac{E_f}{\rho_f(1-\nu^2)}}$		$c_{ml}=\sqrt{\frac{G}{\rho_c}}$							
26																		
27	fss=pi/2*SQRT(B/m[i^2/a^2+j^2/b^2])					cml	5432.3		cms	883.4								
28																		
29			i	j		Full panel flexural wave speed - cb				$c_b=\left[\frac{\omega^2 t_f^2(1+t_c/t_f)^2}{4(1+\rho_c t_c/2\rho_f t_f)}\left(\frac{E_f}{\rho_f(1-\nu^2)}\right)\right]^{1/4}$								
30			1	1														
31																		
32	Simply supported		1.5							63	125	250	500	1000	2000	4000	8000	16000
33						g1	0.000078		cb	137.9	194.3	274.7	388.5	549.4	777.0	1098.9	1554.0	2197.8
34									Mach	0.4	0.6	0.8	1.1	1.6	2.3	3.2	4.5	6.4
35	**Honeycomb**		Bh	7743.052			f<	39.3										
36				kgm^2/sec^2														
37	Bh=1/3*(2*E*/(1-nu^2)*(3/4*tc^2*t+3/2*tc*t^2+t^3))					Core shearing wave speed - cs												
38										$c_s=\left[\frac{1}{(1+2\rho_f t_f/\rho_c t_c)}\left(\frac{G}{\rho_c}\right)\right]^{1/2}$								
39	fc=c^2/(2pi*SIN(theta))*SQRT(mh/Bh)																	
40																		
41	Critical freq.		**389.7**			g2	0.181990		cs	376.8	376.8	376.8	376.8	376.8	376.8	376.8	376.8	376.8
42									Mach	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
43	Coincidence freq:		**389.7**															
44																		
45	fss=pi/2*SQRT(Bh/mh[i^2/a^2+j^2/b^2])					Face sheet flexural wave speed - cf				$c_f=\left[\frac{\omega^2 t_f^2}{24(1+\rho_c t_c/2\rho_f t_f)}\left(\frac{E_f}{\rho_f(1-\nu^2)}\right)\right]^{1/4}$								
46																		
47			i	j														
48			1	1														
49						g3	8.796E-09		cf	14.2	20.0	28.3	40.0	56.6	80.0	113.2	160.0	226.3
50	Simply supported		**89.4**						Mach	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.5	0.7
51							f>	3701.5										

Wave Speed / Core Moduli / TL single / TL Honeycomb (2)

Table 5. Material properties used in the finite element analyses.

	Aluminum	Steel	Air
Elasticity modulus	7.1+10	1.95+11	
Poisson ratio	0.33	.28	
Density	2700	7700	1.21
Speed of sound			344

Table 6. Core material stiffness and density properties used in the finite element analyses.

	Nomex 1	Nomex 2	Aluminum
Stiffness 11	55000.	13790	5000
Stiffness 22	42200.	13790	5000
Stiffness 33	7.57+07	1.379E+08	5.17E+08
Stiffness 44	9740	1378	5000
Stiffness 55	2.97+07	4.754+07	3.10E+08
Stiffness 66	2.2+07	2.487+07	1.52E+08
Density	32.0369	48.0554	49.6572

Table 7. Modal analysis predicted frequencies for base nomex core honeycomb panel and the base nomex core honeycomb panel strengthened with a 45 inch by 45 inch by 0.016 inch aluminum panel, each mounted in the steel frame of the transmission loss window in SALT.

Resonance	Descriptor	Dimension [m]	Frequency [Hz]
Cavity	length	1.1684	146.8
	width	1.1684	146.8
	depth	0.01905	9002.6
	10"	0.254	675.2
	6"	0.1524	1125.3
Limiting	depth	0.01905	2865.6
Mass-air-mass	Sharp		703.5
	Davy		524.3
Critical	AS		23490.8
	2AS		11745.4
Critical/2	AS		11745.4
	2AS		5872.7
Fundamental	AS		1.8
	2AS		3.7
frame+	SNC		84.4
frame+	ASNC		72.9
	SNC		165.9
	ASNC		164.5

Table 8. Modal analysis predicted frequencies for 0.020 inch (AS) and 0.040-inch thick (2AS) aluminum panels mounted in the steel frame of the transmission loss window in SALT.

Mode number m	Mode number n	Modal frequency AS [Hz]	Modal frequency 2AS [Hz]
1	1	1.83	3.67
2	1	4.59	9.17
1	2	4.59	9.17
2	2	7.33	14.7
2	2	9.19	18.4
2	2	9.19	18.4
3	1		
1	3		
3	2	11.9	23.9
2	3	11.9	23.9
3	3	16.5	33.0
4	1	15.7	31.3
1	4	15.7	31.3
4	2	18.4	36.8
2	4	18.4	36.8
4	3	23.0	45.9
3	4	23.0	45.9
4	4	29.4	58.8
5	2	26.8	53.5
2	5	26.8	53.5

Table 9. Modal analysis predicted frequencies for base nomex core honeycomb panel and the base nomex core honeycomb panel strengthened with a 45 inch by 45 inch by 0.016 inch aluminum panel, each mounted in the steel frame of the transmission loss window in SALT.

Mode number m	Mode number n	Modal frequency SNC [Hz]	Modal frequency ASNC [Hz]	Resonating structure
1	1	84.4	72.9	frame+
2	1	136.9	130.2	frame+
1	2	137.3	131.1	frame+
2	2	151.6	153.2	frame+
1	1	165.9	164.5	panel
2	1	204.7	181.7	panel
1	2	211.2	187.0	panel
2	2	246.2	221.8	frame+
2	3	282.7	277.1	frame+
3	2	282.8	276.7	frame+
2	2	308.1	286.4	panel
3	1	337.0	285.4	panel
1	3	360.3	305.8	panel
3	3	393.9	382.1	frame+
3	2	407.4	348.7	panel
2	3	422.9	361.7	panel
4	1	477.0	397.6	panel
1	4		433.8	panel

Table 10. Thickness, area, and volume parameters for twenty-two panel configurations in English units.

050620_final_honeycomb_index.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**File Format:**	**final_VNC10_050601_PHat_Run1.bdf**													
2										adhesive	adhesive	adhesive	adhesive	adhesive	adhesive
3	**Configuration:**				Area [sq in]	Vol [cu in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]	Area [sq in]
4															
5	**#**	**Name**			**core_hon**	**core_alum**	**SFS**	**RFS**	**Patch**	**SFS_hon**	**SFS_alum**	**RFS_hon**	**RFS_alum**	**P_hon**	**P_alum**
6	14	AQRNC10			1216	225	2116	2116	1936	1216		1216	900	1036	900
7	13	ARNC10			1216	450	2116	2116	1936	1216		1216	900	1036	900
8	12	ASNC			2116		2116	2116	1936	2116		2116		2116	
9	10	QRNC10			1216	225	2116	2116		1216		1216	900		
10	11	QRNC10patch			1216	225	2116	2116	900	1216		1216	900		900
11	15	QRNC25-06			1216	225	2116	2116		1216		1216	900		
12	16	QRNC25-06patch			1216	225	2116	2116	900	1216		1216	900		900
13	17	QRNC25-06patch_C			1216	225	2116	2116	900	1216		1216	900		900
14	9	RNC10			1216	450	2116	2116		1216		1216	900		
15	1	SNC			2116		2116	2116		2116		2116			
16	8	VAC10		alum core	1216		2116	2116		1216		1216			
17	3	VNC06			1792		2116	2116		1792		1792			
18	5	VNC08			1540		2116	2116		1540		1540			
19	2	VNC10			1216		2116	2116		1216		1216			
20	6	VNC12			820		2116	2116		820		820			
21	7	VNC14			352		2116	2116		352		352			
22	4	VNC25-06			1216		2116	2116		1216		1216			
23	18	AS					2116								
24	19	2AS					2116								
25	20	ADgap4					2116	2116							
26	21	ADgap7					2116								
27	22	3AS					2116								
28															
29				Thickness [in]	0.75		0.02	0.02	0.016						
30				Thickness [in]	(Configurations 18)		0.02								
31				Thickness [in]	(Configurations 19)		0.04								
32				Thickness [in]	(Configurations 20, 21)		0.02	0.032							
33				Thickness [in]	(Configurations 22)		0.05871								
34				Density [lb/cu ft]	3	3									
35				Density [kg/cu m]			2700	2700	2700						
36				Mass/area [kg/sq m]						0.1837		0.1837	0.1837	0.3674	0.1837

Mass / Sheet2 / Sheet3

Table 11. Thickness, area, and volume parameters for twenty-two panel configurations in metric units.

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
37															
38	**Configaration:**				Area [sq m]	Vol [cu m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]	Area [sq m]
39															
40	**#**	**Name**			**core_hon**	**core_alum**	**SFS**	**RFS**	**Patch**	**SFS_hon**	**SFS_alum**	**RFS_hon**	**RFS_alum**	**P_hon**	**P_alum**
41	14	AQRNC10			0.7845	0.0037	1.3652	1.3652	1.2490	0.7845		0.7845	0.5806	0.6684	0.5806
42	13	ARNC10			0.7845	0.0074	1.3652	1.3652	1.2490	0.7845		0.7845	0.5806	0.6684	0.5806
43	12	ASNC			1.3652		1.3652	1.3652	1.2490	1.3652		1.3652		1.3652	
44	10	QRNC10			0.7845	0.0037	1.3652	1.3652		0.7845		0.7845	0.5806		
45	11	QRNC10patch			0.7845	0.0037	1.3652	1.3652	0.5806	0.7845		0.7845	0.5806		0.5806
46	15	QRNC25-06			0.7845	0.0037	1.3652	1.3652		0.7845		0.7845	0.5806		
47	16	QRNC25-06patch			0.7845	0.0037	1.3652	1.3652	0.5806	0.7845		0.7845	0.5806		0.5806
48	17	QRNC25-06patch_C			0.7845	0.0037	1.3652	1.3652	0.5806	0.7845		0.7845	0.5806		0.5806
49	9	RNC10			0.7845	0.0074	1.3652	1.3652		0.7845		0.7845	0.5806		
50	1	SNC			1.3652		1.3652	1.3652		1.3652		1.3652			
51	8	VAC10		alum core	0.8107		1.3652	1.3652		0.7845		0.7845			
52	3	VNC06			1.1561		1.3652	1.3652		1.1561		1.1561			
53	5	VNC08			0.9935		1.3652	1.3652		0.9935		0.9935			
54	2	VNC10			0.7845		1.3652	1.3652		0.7845		0.7845			
55	6	VNC12			0.5290		1.3652	1.3652		0.5290		0.5290			
56	7	VNC14			0.2271		1.3652	1.3652		0.2271		0.2271			
57	4	VNC25-06			0.7845		1.3652	1.3652		0.7845		0.7845			
58	18	AS					1.3652								
59	19	2AS					1.3652								
60	20	ADgap4					1.3652	1.3652							
61	21	ADgap7					1.3652								
62	22	3AS					1.3652								
63															
64				Thickness [m]	0.01905		0.000508	0.000508	0.0004064						
65				Thickness [m]	(Configuration 18)		0.000508								
66				Thickness [m]	(Configuration 19)		0.001016								
67				Thickness [m]	(Configurations 20, 21)		0.000508	0.0008128							
68				Thickness [in]	(Configurations 22)		0.00149123								
69				Density [kg/cu m]	48.06	48.06	2700	2700	2700						
70				Mass/area [kg/sq m]						0.1837		0.1837	0.1837	0.3674	0.1837
71															

Mass / Sheet2 / Sheet3

Table 12. Calculations of the total mass for twenty-two panel configurations.

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Mass [kg]:

#	Name	Unit Force x 10^(-06) 769_disp	Unit Force x 10^(-06) 433_disp	% SNC	Total	core_hon	core_alum	SFS	RFS	Patch	SFS_hon	SFS_alum	RFS_hon	RFS_alum	P_hon	P_alum
14	AQRNC10	4	4	23.0	6.7579	0.7182	0.1772	1.8725	1.8725	1.3705	0.1441		0.1441	0.1067	0.2456	0.1067
13	ARNC10	3	2	26.2	6.9351	0.7182	0.3544	1.8725	1.8725	1.3705	0.1441		0.1441	0.1067	0.2456	0.1067
12	ASNC	3	2	34.1	7.3683	1.2497		1.8725	1.8725	1.3705	0.2508		0.2508		0.5016	
10	QRNC10	4	462	-8.4	5.0352	0.7182	0.1772	1.8725	1.8725		0.1441		0.1441	0.1067		
11	QRNC10patch	4	4	5.1	5.7790	0.7182	0.1772	1.8725	1.8725	0.6371	0.1441		0.1441	0.1067		0.1067
15	QRNC25-06	180	175	-8.4	5.0352	0.7182	0.1772	1.8725	1.8725		0.1441		0.1441	0.1067		
16	QRNC25-06patch	6	4	5.1	5.7790	0.7182	0.1772	1.8725	1.8725	0.6371	0.1441		0.1441	0.1067		0.1067
17	QRNC25-06patch_C	5	3	5.1	5.7790	0.7182	0.1772	1.8725	1.8725	0.6371	0.1441		0.1441	0.1067		0.1067
9	RNC10	4	457	-5.2	5.2124	0.7182	0.3544	1.8725	1.8725		0.1441		0.1441	0.1067		
1	SNC	3	2	0.0	5.4962	1.2497		1.8725	1.8725		0.2508		0.2508			
8	VAC10	2	466	-13.1	4.7753	0.7421		1.8725	1.8725		0.1441		0.1441			
3	VNC06	3	177	-4.9	5.2280	1.0584		1.8725	1.8725		0.2124		0.2124			
5	VNC08	4	306	-8.7	5.0195	0.9095		1.8725	1.8725		0.1825		0.1825			
2	VNC10	4	468	-13.6	4.7513	0.7182		1.8725	1.8725		0.1441		0.1441			
6	VNC12	6	663	-19.5	4.4236	0.4843		1.8725	1.8725		0.0972		0.0972			
7	VNC14	5280	1550	-26.6	4.0362	0.2079		1.8725	1.8725		0.0417		0.0417			
4	VNC25-06	183	179	-13.6	4.7513	0.7182		1.8725	1.8725		0.1441		0.1441			
18	AS	14600	6670	-65.9	1.8725			1.8725								
19	2AS	1820	834	-31.9	3.7449			3.7449								
20	ADgap4			-11.4	4.8684			1.8725	2.9959							
21	ADgap7			-65.9	1.8725			1.8725	0.0000							
22	3AS	578	264	0.0	5.4966			5.4966								

Format:

AQRNC10	A	Aluminum panel at 0.25 in from one of the face sheets covering the recessed core (if applicable); dimensions: 0.016 in by 45 in by 45 in
	Q	Quarter inch recessed core; 0.25 in thick
	R	Recessed core; 0.5 in thick
	N	Core material N: Nomex; A: Aluminum
	C10	Dimension of the square void or recessed are; C10: 10 in; C06: 6 in; C08: 8 in; C12: 12 in; C14: 14 in
QRNC25-06patch_C	patch	Aluminum panel patches covering the recessed core
	_C	Clamped edge conditions

Mass / Sheet2 / Sheet3

Table 13. Displacement due to a unit [N] static force at two different node locations for several finite element honeycomb panel configurations.

Panel Configuration	Displacement due to unit force at node 769	Displacement due to unit force at node 433	Mass	Difference with mass of SNC panel
	[x 10^{-6} m]	[x 10^{-6} m]	[kg]	[%]
AQRNC10	4	4	6.7579	23.0
ARNC10	3	2	6.9351	26.2
ASNC	3	2	7.3683	34.1
QRNC10	4	462	5.0352	-8.4
QRNC10patch	4	4	5.7790	5.1
QRNC25-06	180	175	5.0352	-8.4
QRNC25-06patch	6	4	5.7790	5.1
QRNC25-06patch_C	5	3	5.7790	5.1
RNC10	4	457	5.2124	-5.2
SNC	3	2	5.4962	0.0
VAC10	2	466	4.7753	-13.1
VNC06	3	177	5.2280	-4.9
VNC08	4	306	5.0195	-8.7
VNC10	4	468	4.7513	-13.6
VNC12	6	663	4.4236	-19.5
VNC14	5280	1550	4.0362	-26.6
VNC25-06	183	179	4.7513	-13.6
AS	14600	6670	1.8725	-65.9
2AS	1820	834	3.7449	-31.9
ADgap4			4.8684	-11.4
ADgap7			1.8725	-65.9
3AS	578	264	5.4966	0.0

Table 14. Three-dimensional anisotropic material properties on the MAT9 entries of the aluminum (VAC10) and nomex core (VNC) honeycomb panels with the nine 10 by 10 inch voids, and the nomex core base panels (SNC).

Number	Designation	Core material properties
1	VAC10_aver	MAT9 3 5000. 5000. 5.17+8 5000. 3.1+8 1.52+8 49.6572 .05
2	VAC10_G13E9_G23E9	MAT9 2 5000. 5000. 5.17+8 5000. 3.1+9 1.52+9 49.6572 .05
3	VNC10_aver	MAT9 2 13790. 13790. 1.379+8 1378. 4.754+7 2.487+7 48.0554 .05
4	VNC10_5000	MAT9 2 5000. 5000. 1.379+8 5000. 4.754+7 2.487+7 48.0554 .05
5	VNC10_E3	MAT9 2 13790. 13790. 5.17+8 1378. 4.754+7 2.487+7 48.0554 .05
6	VNC10_G13_G23	MAT9 2 13790. 13790. 1.379+8 1378. 3.1+8 1.52+8 48.0554 .05
7	VNC10_G13	MAT9 2 13790. 13790. 1.379+8 1378. 3.1+8 2.487+7 48.0554 .05
8	VNC10_G23	MAT9 2 13790. 13790. 1.379+8 1378. 4.754+7 1.52+8 48.0554 .05
9	SNC_core1 and SNC_1core	MAT9 2 13790. 13790. 1.379+8 1378. 4.754+7 2.487+7 43.235 .0065
10	SNC_core	MAT9 2 55000. 42200. 7.57+7 9740. 2.97+7 2.2+7 32.0369 .00065

FIGURES

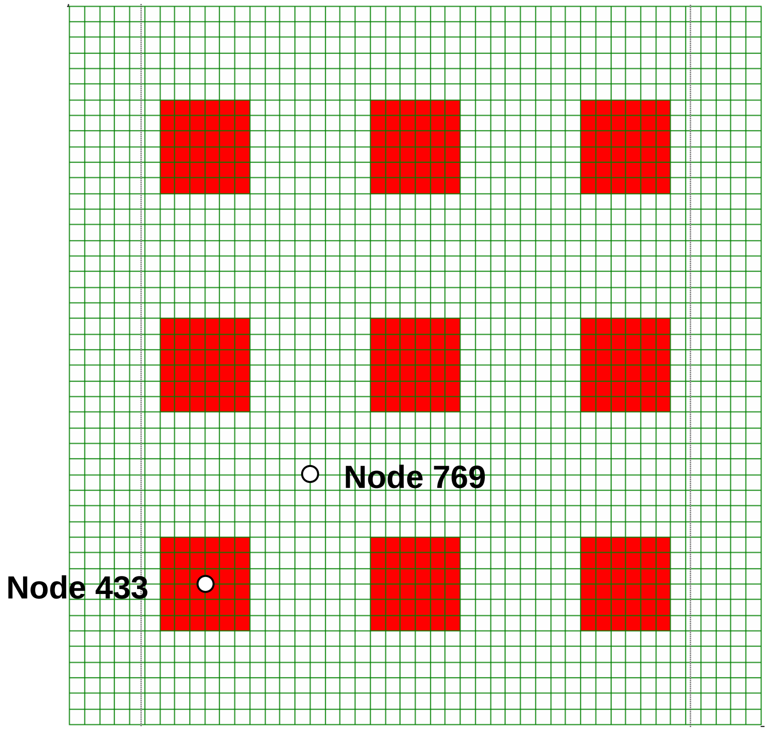


Figure 1. Panel with nine 6 inch by 6 inch voids. The nodes indicate the two locations at which a static unit force was applied. The same locations were used for all panel configurations.

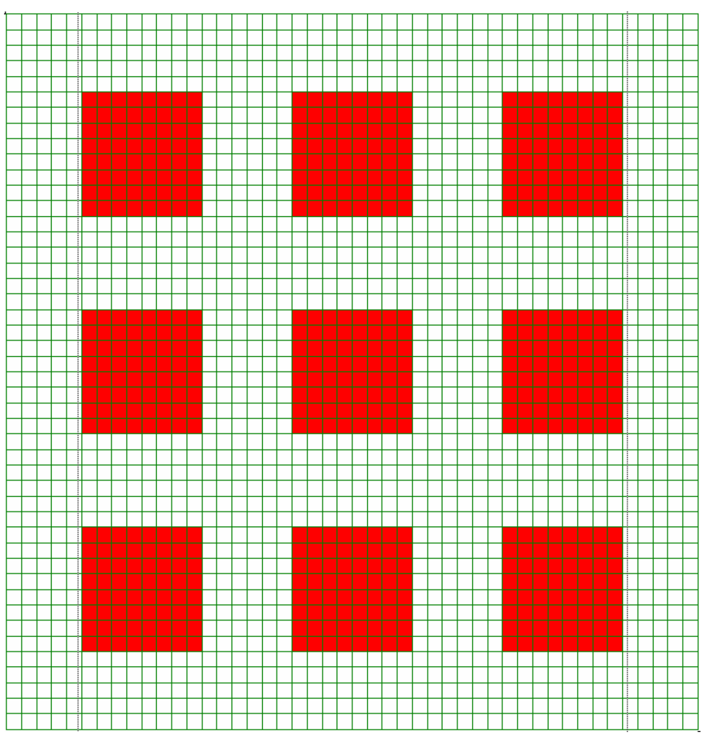


Figure 2. Panel with nine 8 inch by 8 inch voids.

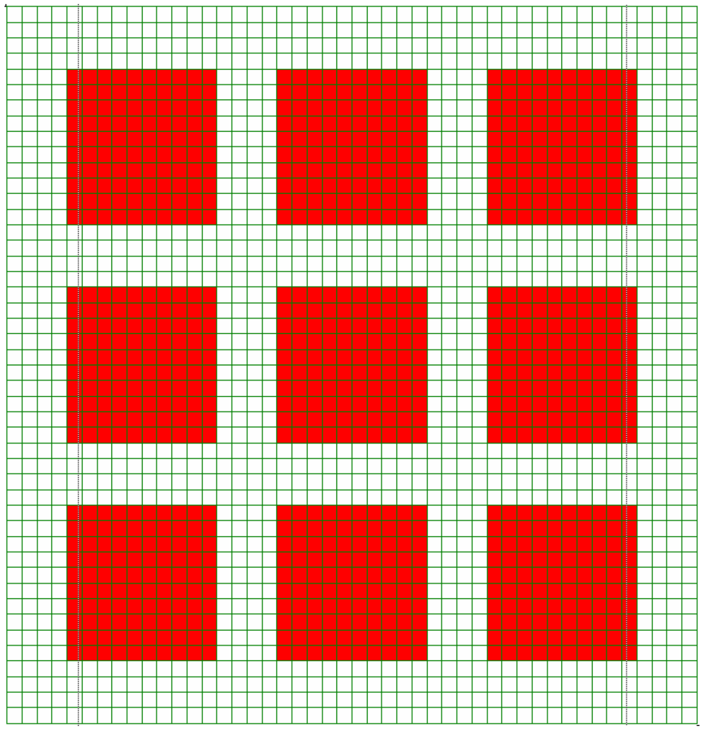


Figure 3. Panel with nine 10 inch by 10 inch voids.

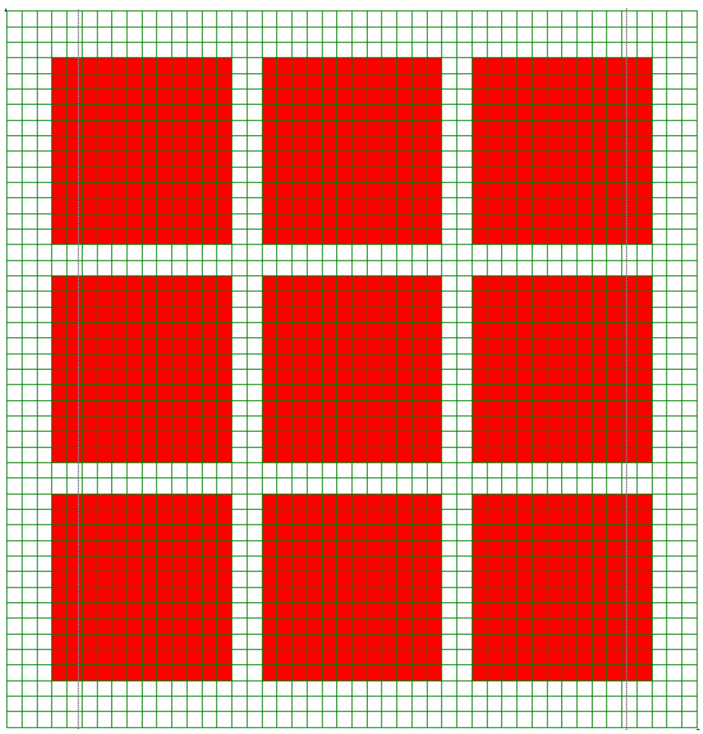


Figure 4. Panel with nine 12 inch by 12 inch voids.

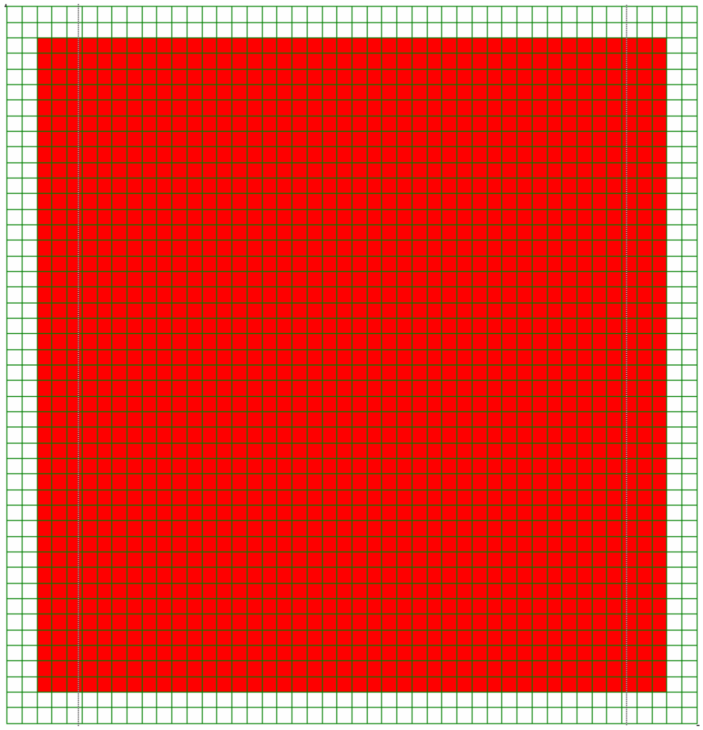


Figure 5. Panel with nine 14 inch by 14 inch voids.

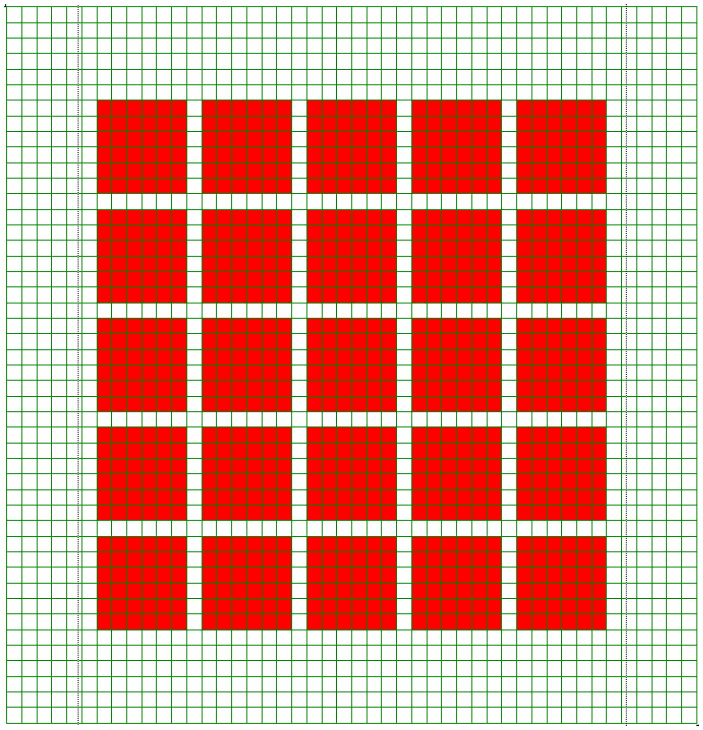


Figure 6. Panel with twenty-five 6 inch by 6 inch voids.

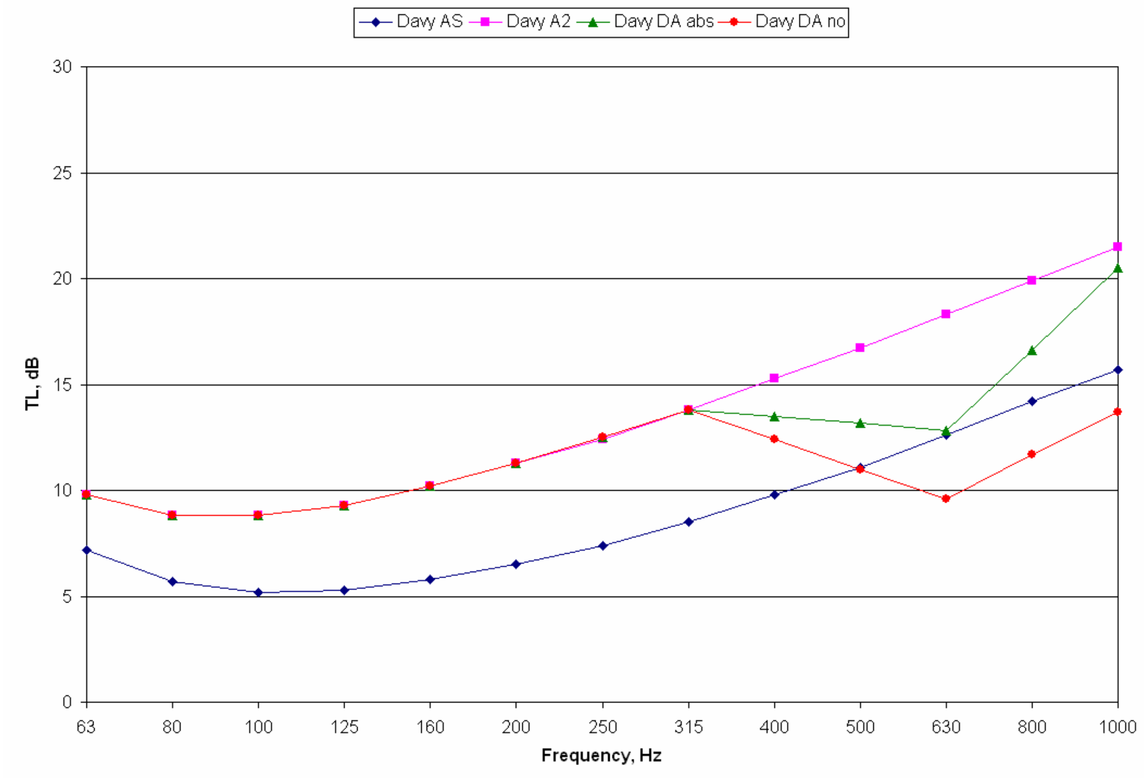


Figure 7. Calculated transmission loss for a 0.020 inch thick aluminum panel (AS), a 0.040 inch thick panel (A2) and two 0.020 inch thick panels in a double wall configuration with (DA abs) and without absorption (DA no) using Davy predictions.

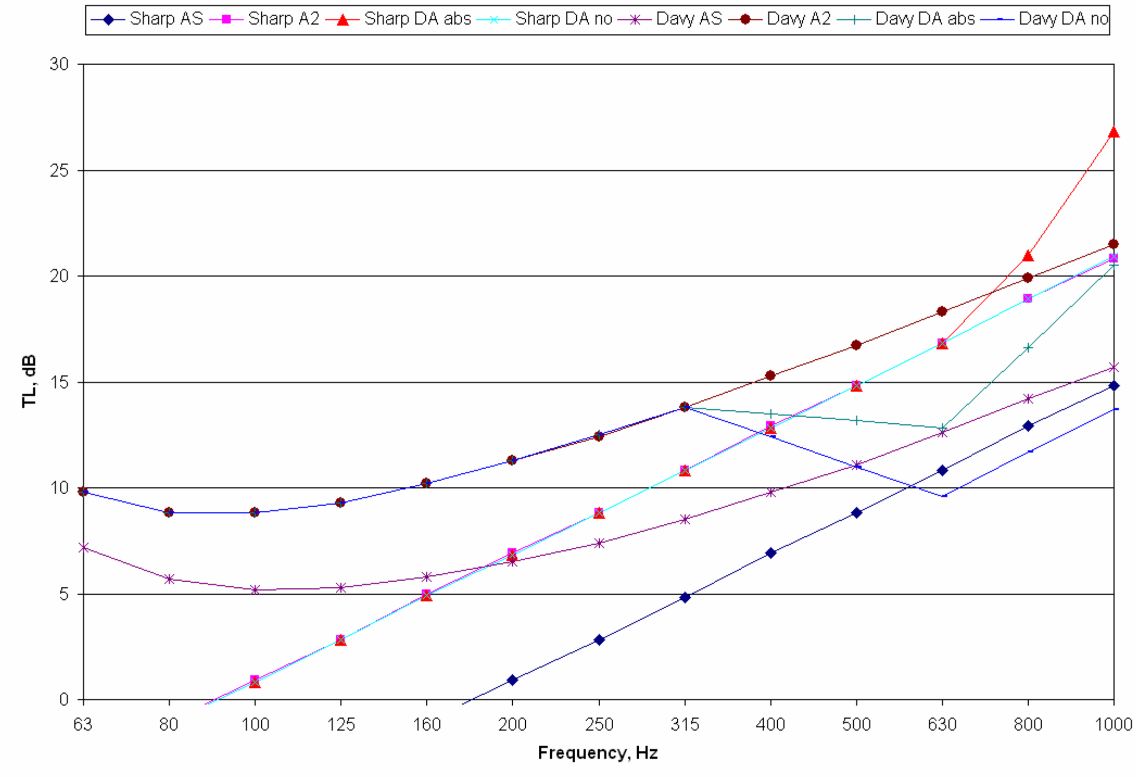
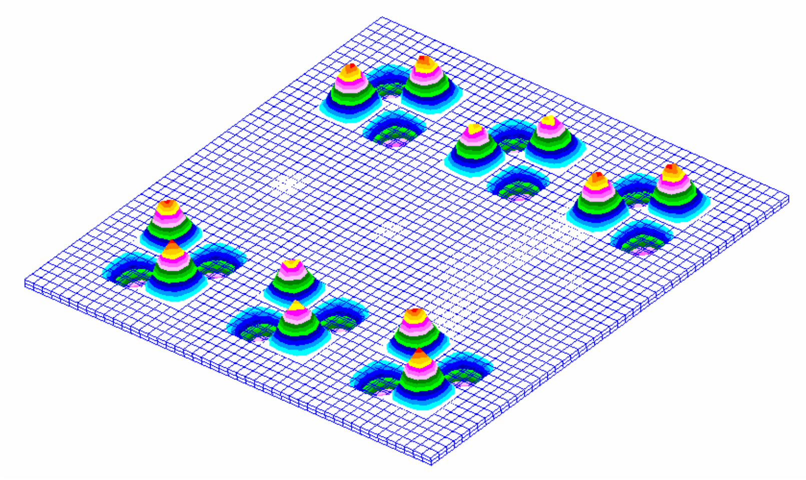
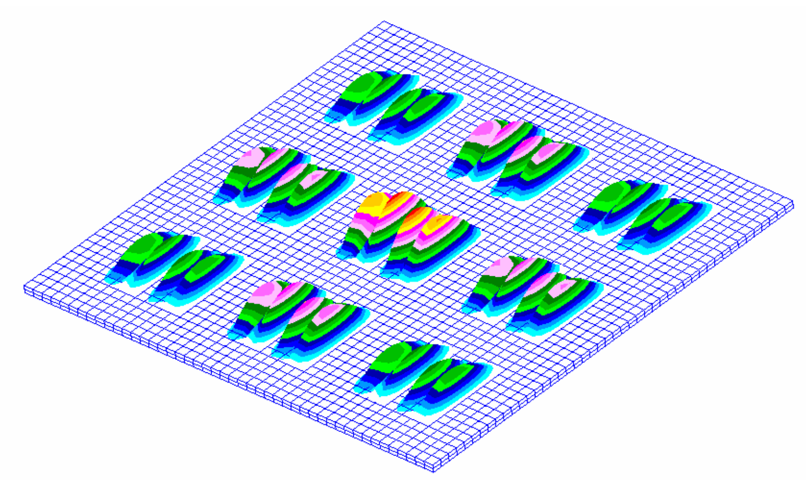


Figure 8. Calculated transmission loss for a 0.020 inch thick aluminum panel (AS), a 0.040 inch thick panel (A2) and two 0.020 inch thick panels in a double wall configuration with (DA abs) and without absorption (DA no) using Sharp and Davy predictions.



a) (2,2) subpanel mode on global (1,2) mode at 178.3 Hz



b) (4,1) subpanel mode on global (3,3) mode at 383.9 Hz (face sheets out-of-phase)

Figure 9. Examples of subpanel modes superimposed on the global panel modes for the voided nomex core honeycomb panel.

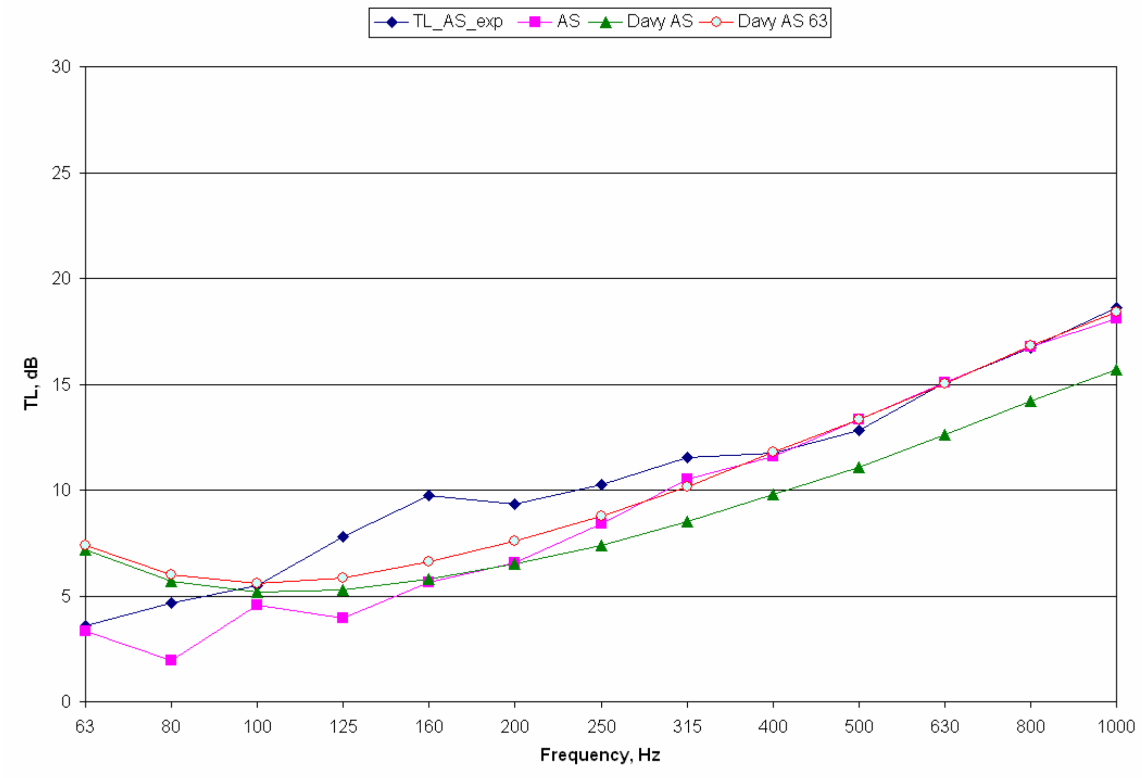


Figure 10. Experimental (TL_AS_exp), predicted (AS), and calculated (Davy AS) random transmission loss for a 0.020 inch thick aluminum panel. The calculated transmission loss curve for a sound incidence angle of 63 degrees from the normal (Davy AS 63) is also indicated in the figure.

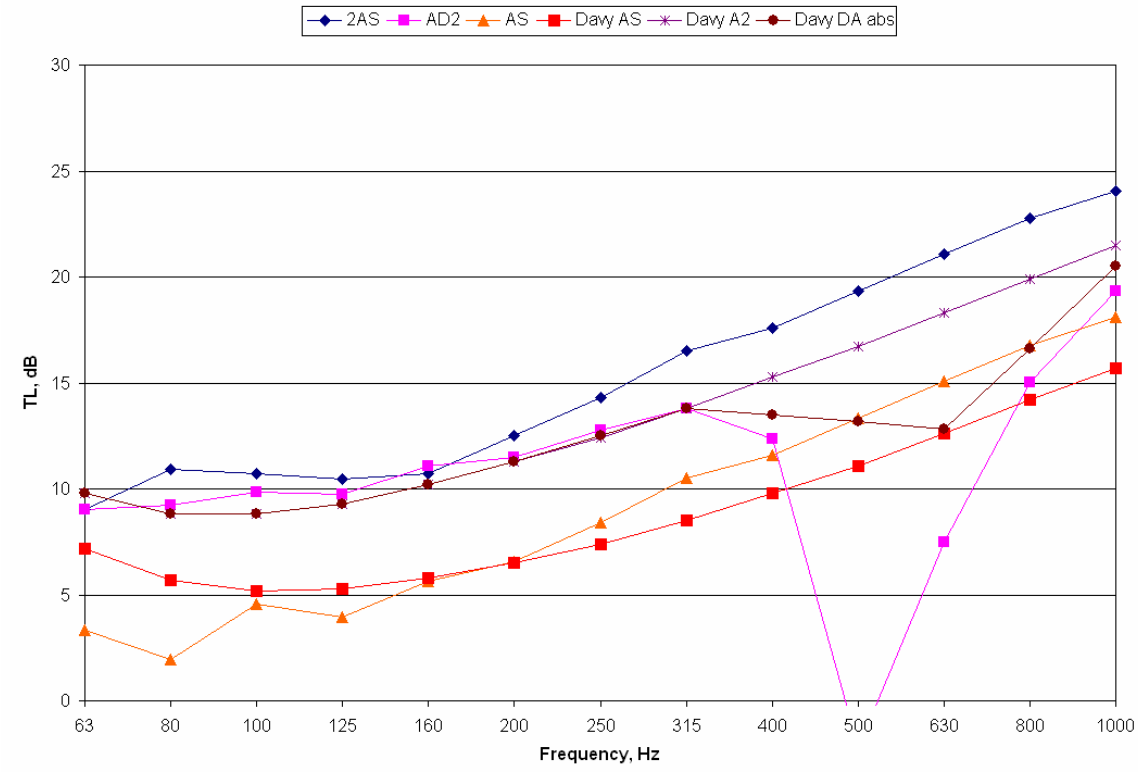


Figure 11. Predicted (AS) and calculated (Davy AS) single mass (0.020-inch thick) panel sound transmission loss, predicted (2AS) and calculated (Davy A2) double mass transmission loss and the predicted (AD2) and calculated (Davy DA abs) transmission loss of two single mass panels in a double wall configuration.

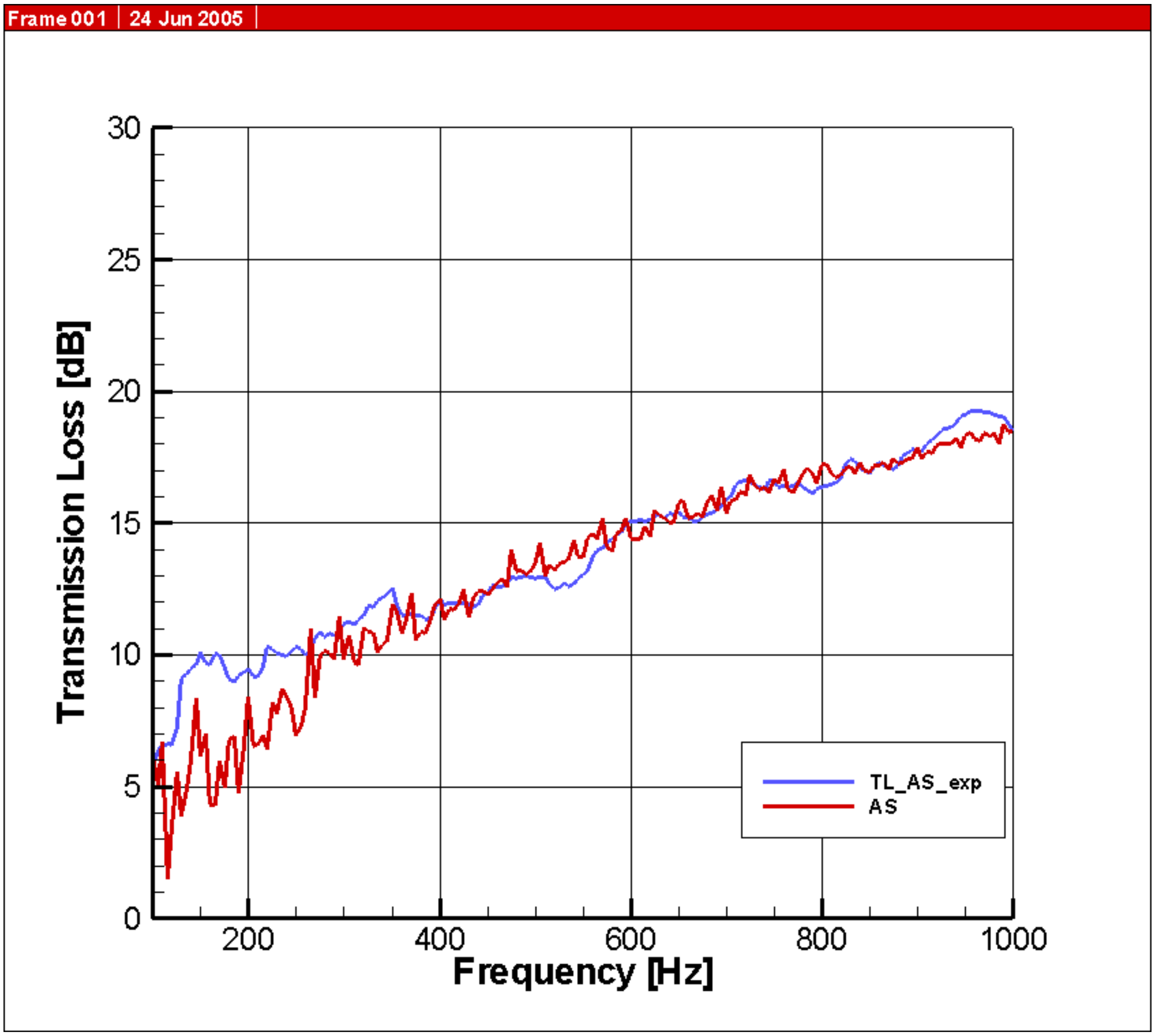


Figure 12. Experimental (TL_AS_exp) and predicted (AS) transmission loss of a single 0.020 inch thick aluminum panel.

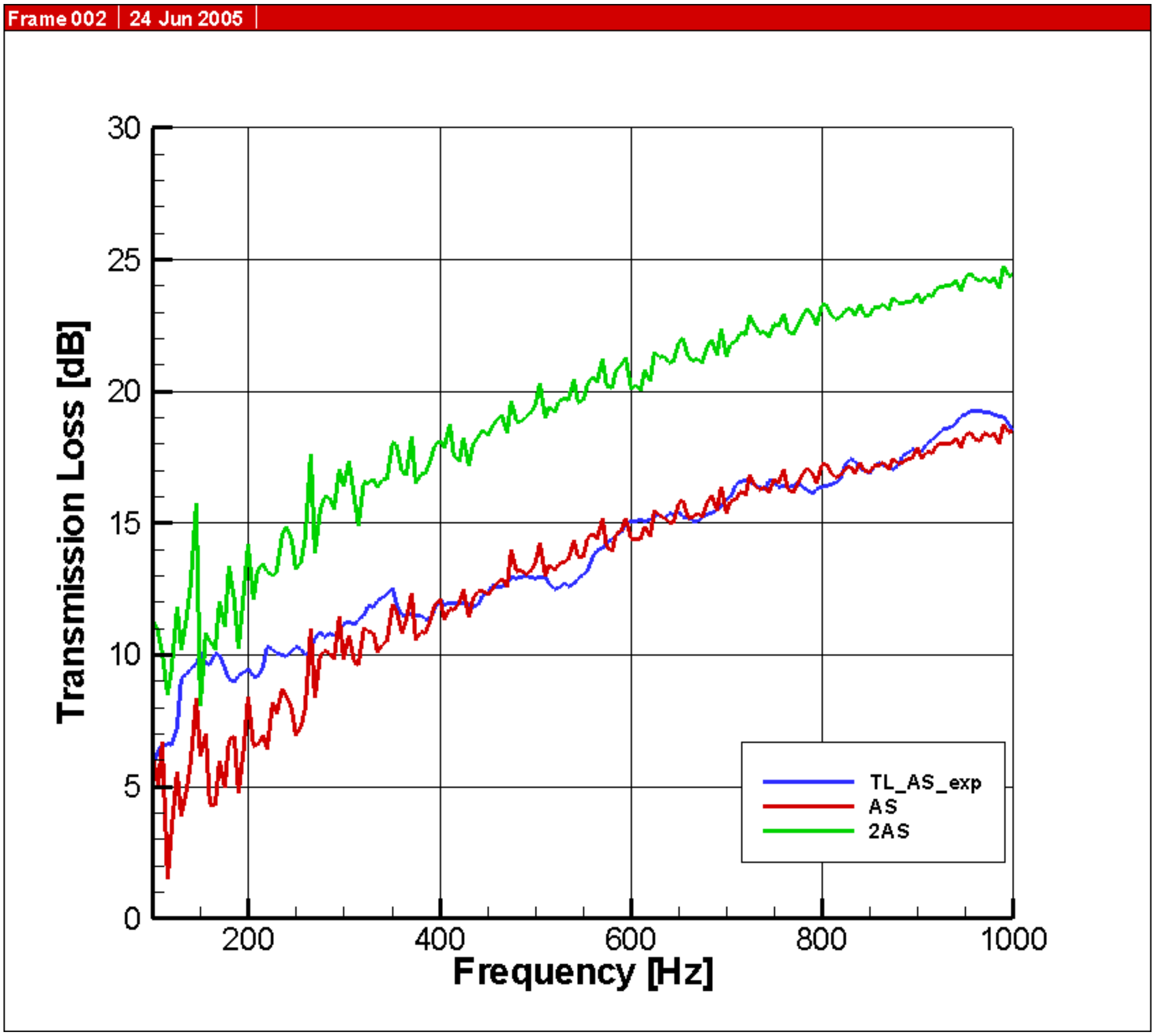


Figure 13. Experimental (TL_AS_exp) and predicted (AS) transmission loss of a single 0.020 inch thick aluminum panel and the predicted (2AS) transmission loss of a 0.040 inch thick panel.

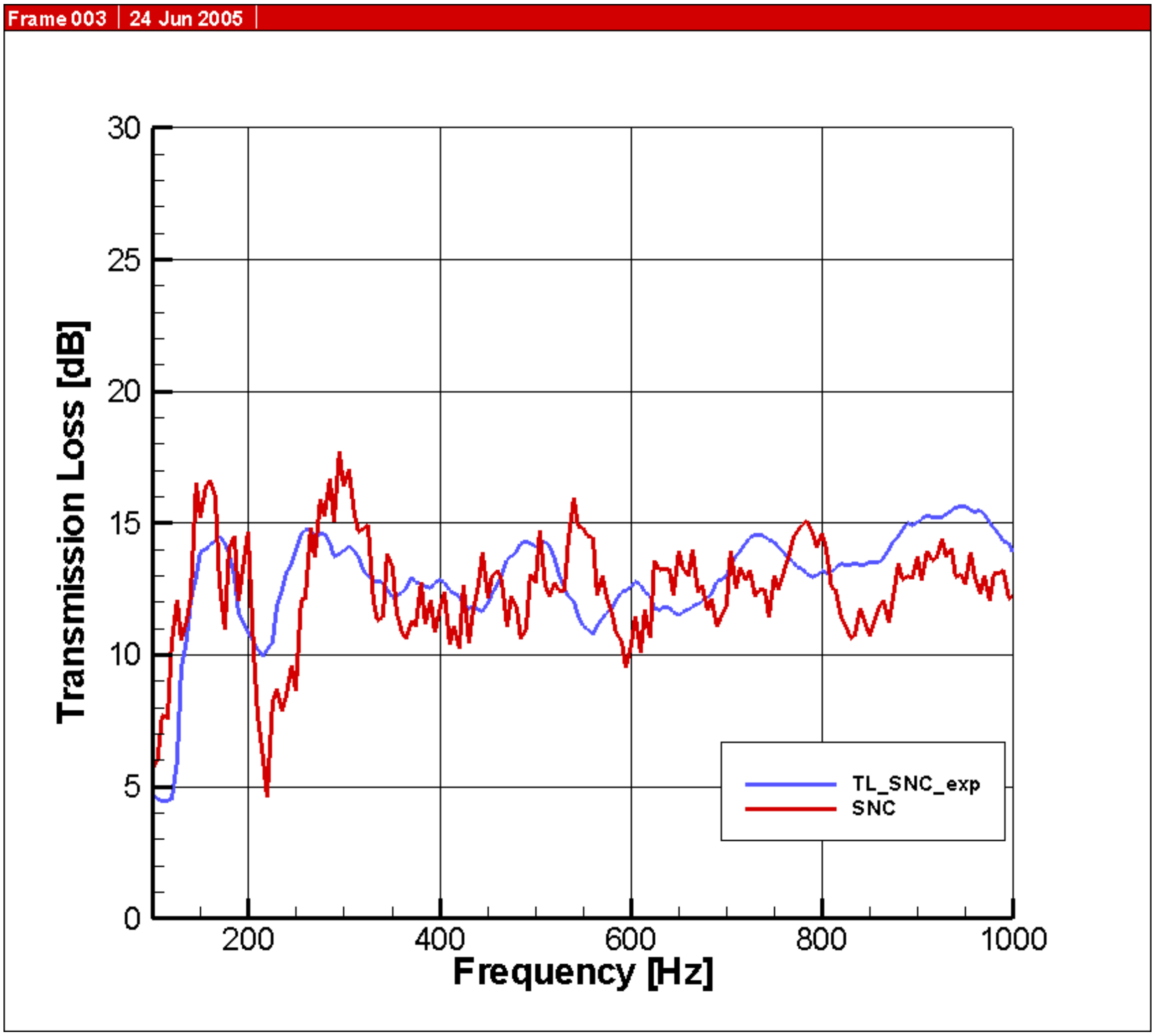


Figure 14. Experimental (TL_SNC_exp) and predicted (SNC) transmission loss of the base honeycomb panel.

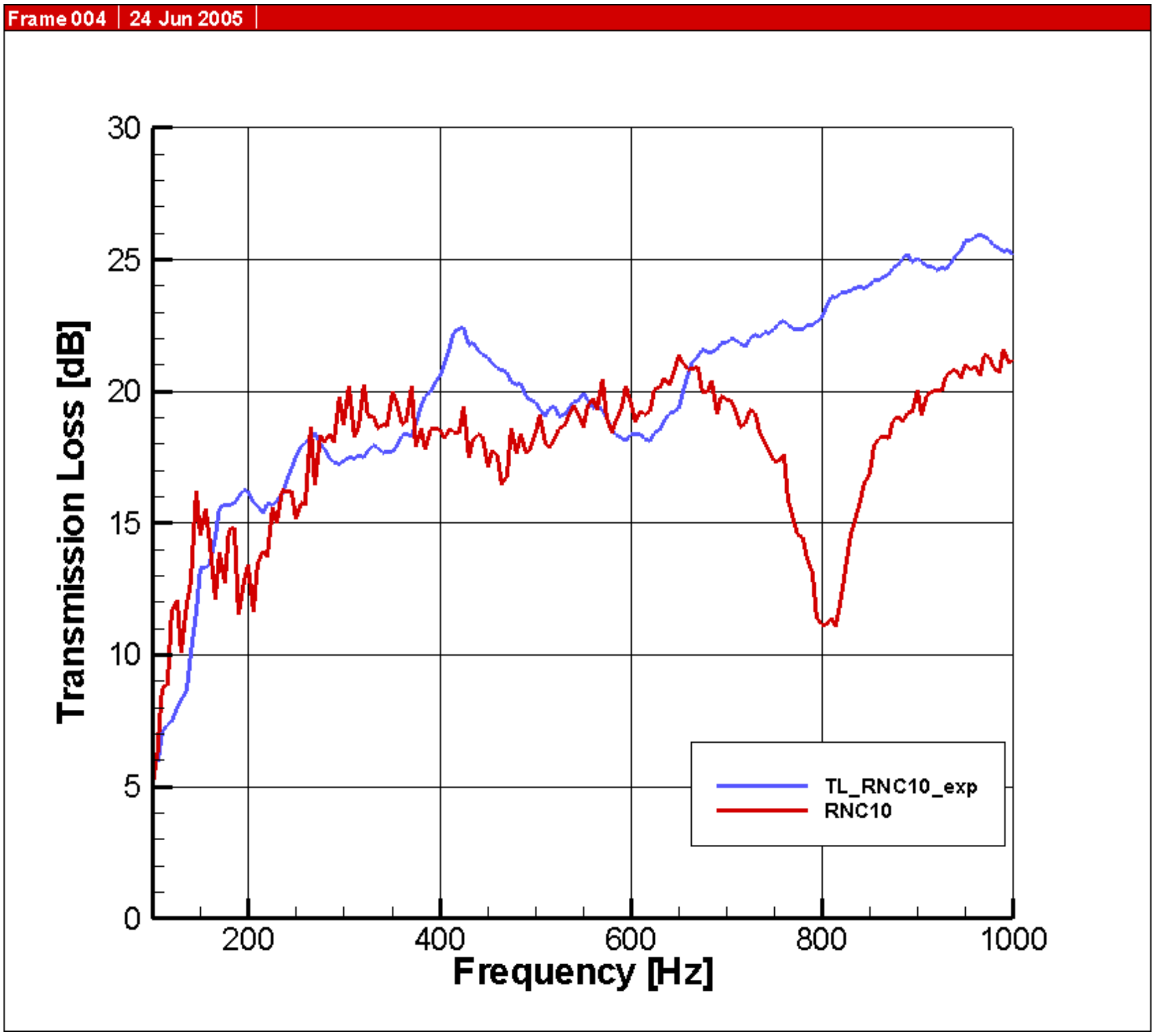


Figure 15. Experimental (TL_RNC10_exp) and predicted (RNC10) transmission loss of the recessed nomex core honeycomb panel.

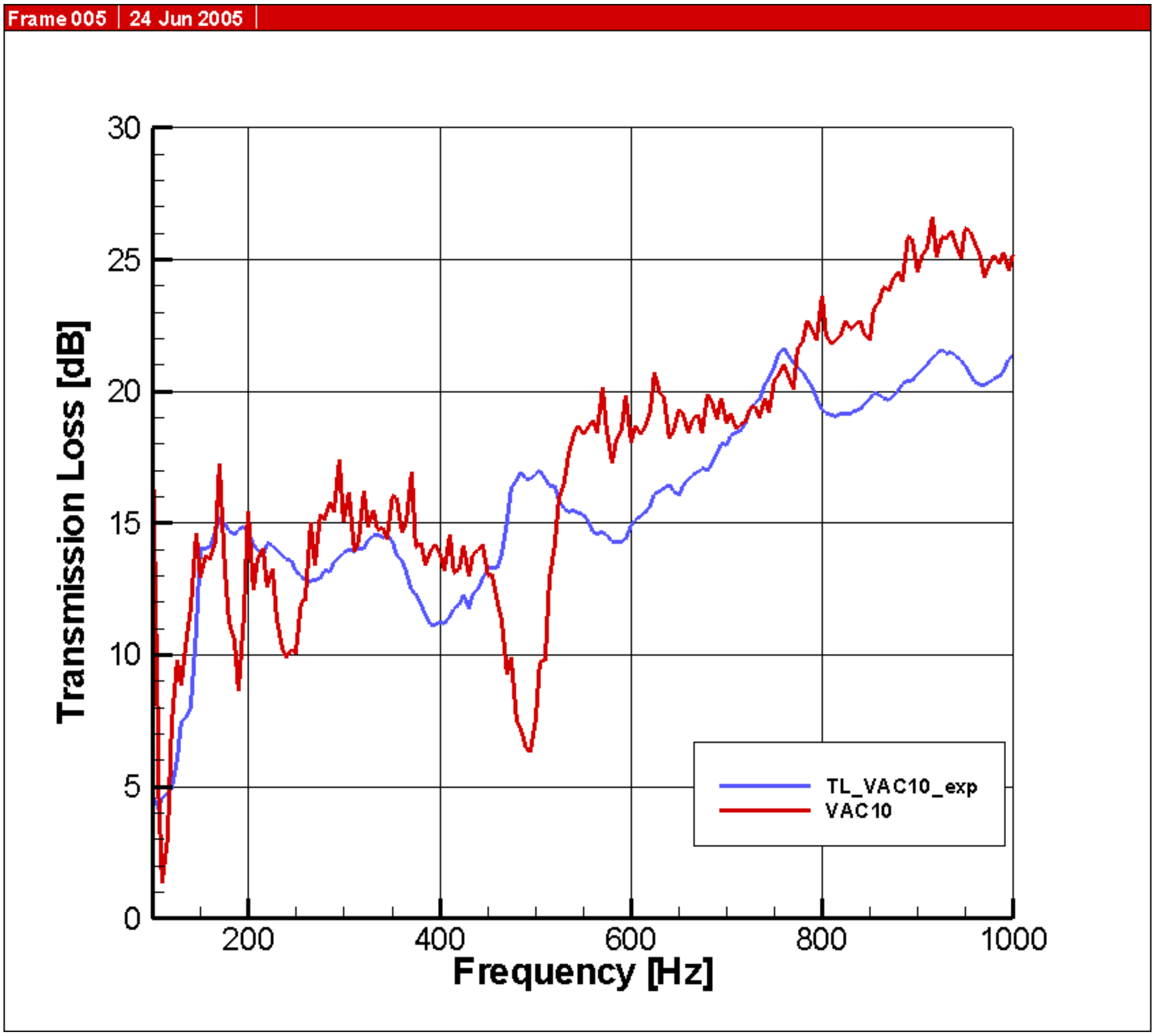


Figure 16. Experimental (TL_VAC10_exp) and predicted (VAC10) transmission loss of the aluminum core voided honeycomb panel.

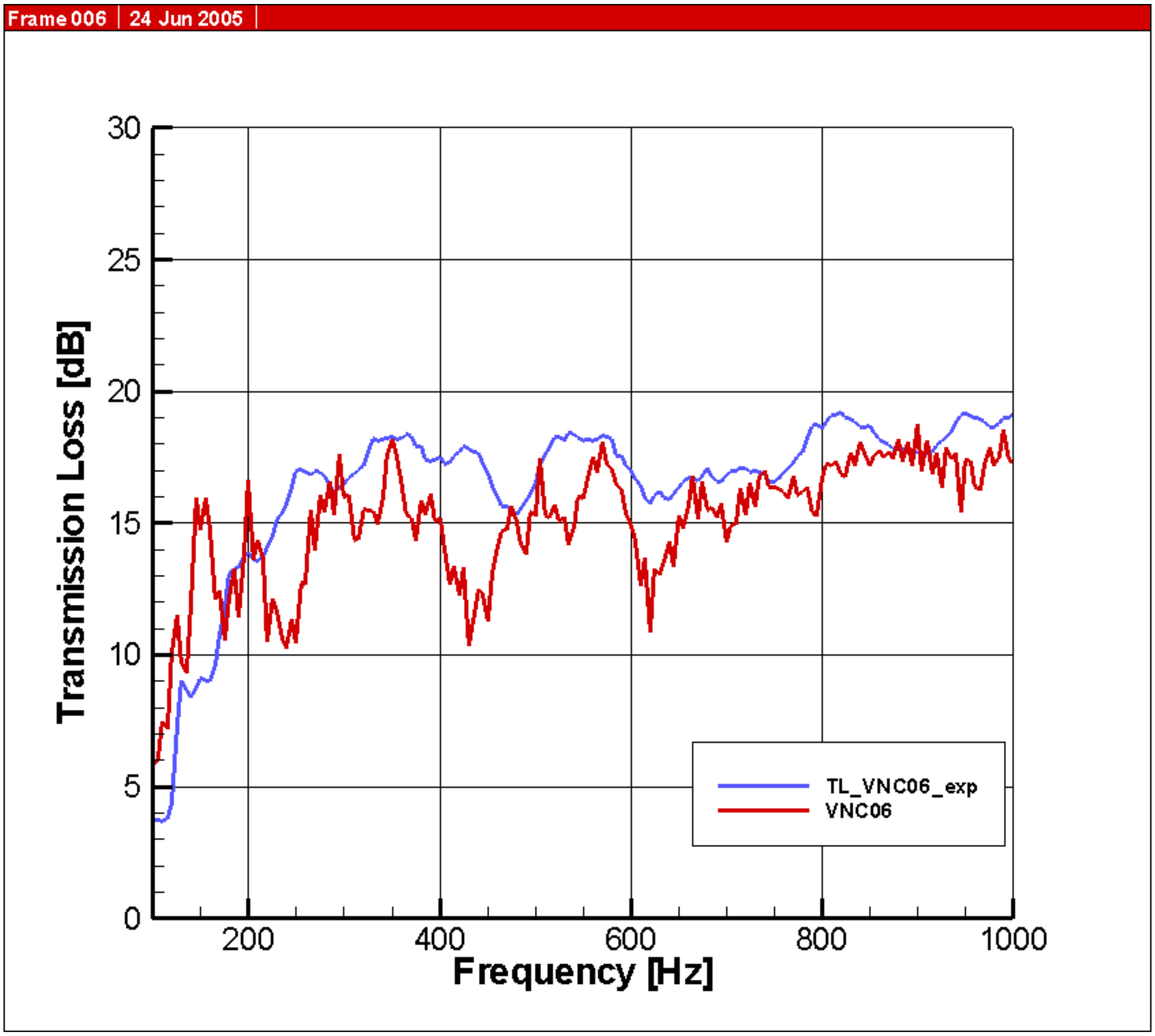


Figure 17. Experimental (TL_VNC06_exp) and predicted (VNC06) transmission loss of the nomex core, 6 by 6 inch, voided honeycomb panel.

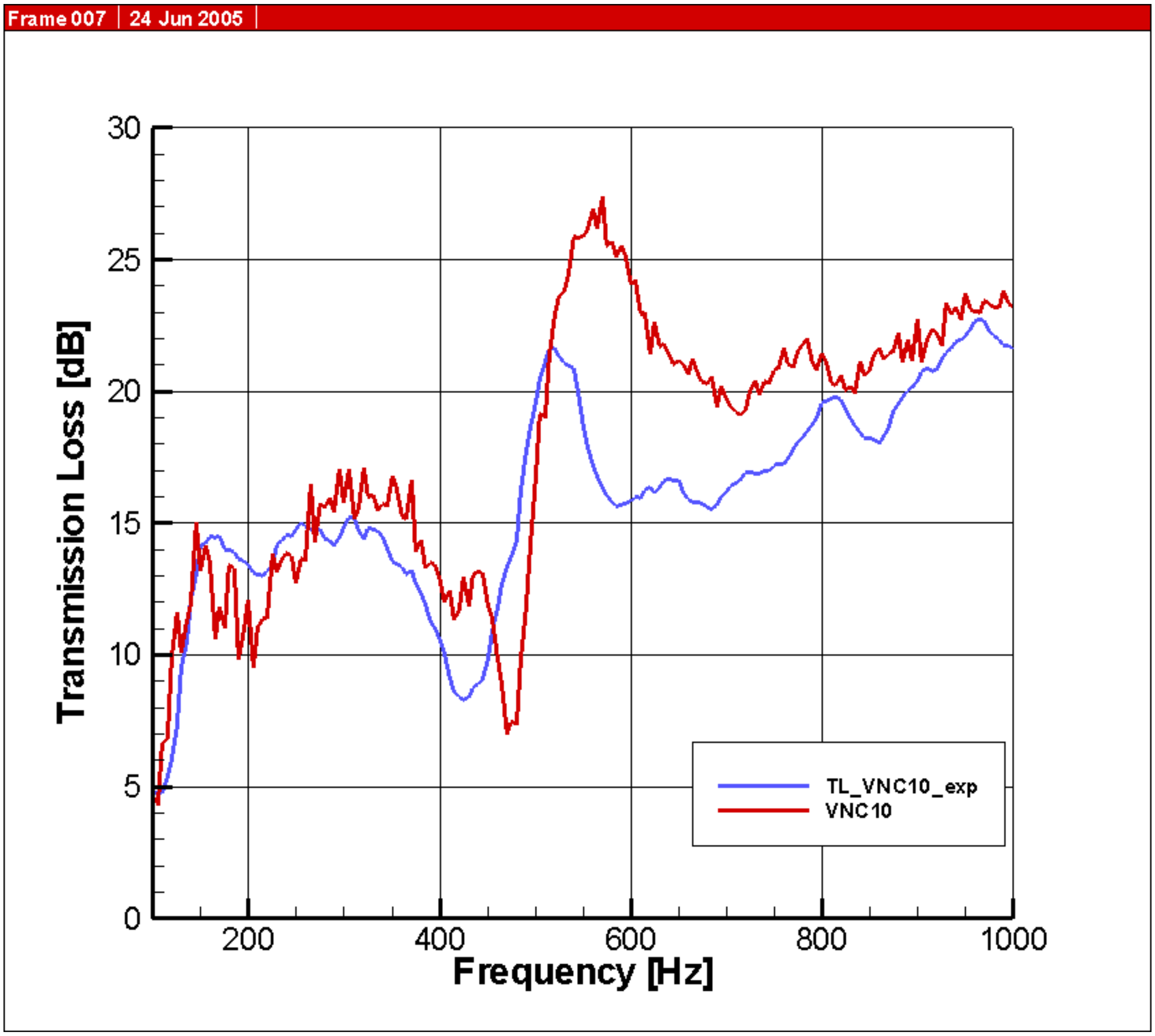


Figure 18. Experimental (TL_VNC10_exp) and predicted (VNC10) transmission loss of the nomex core voided honeycomb panel.

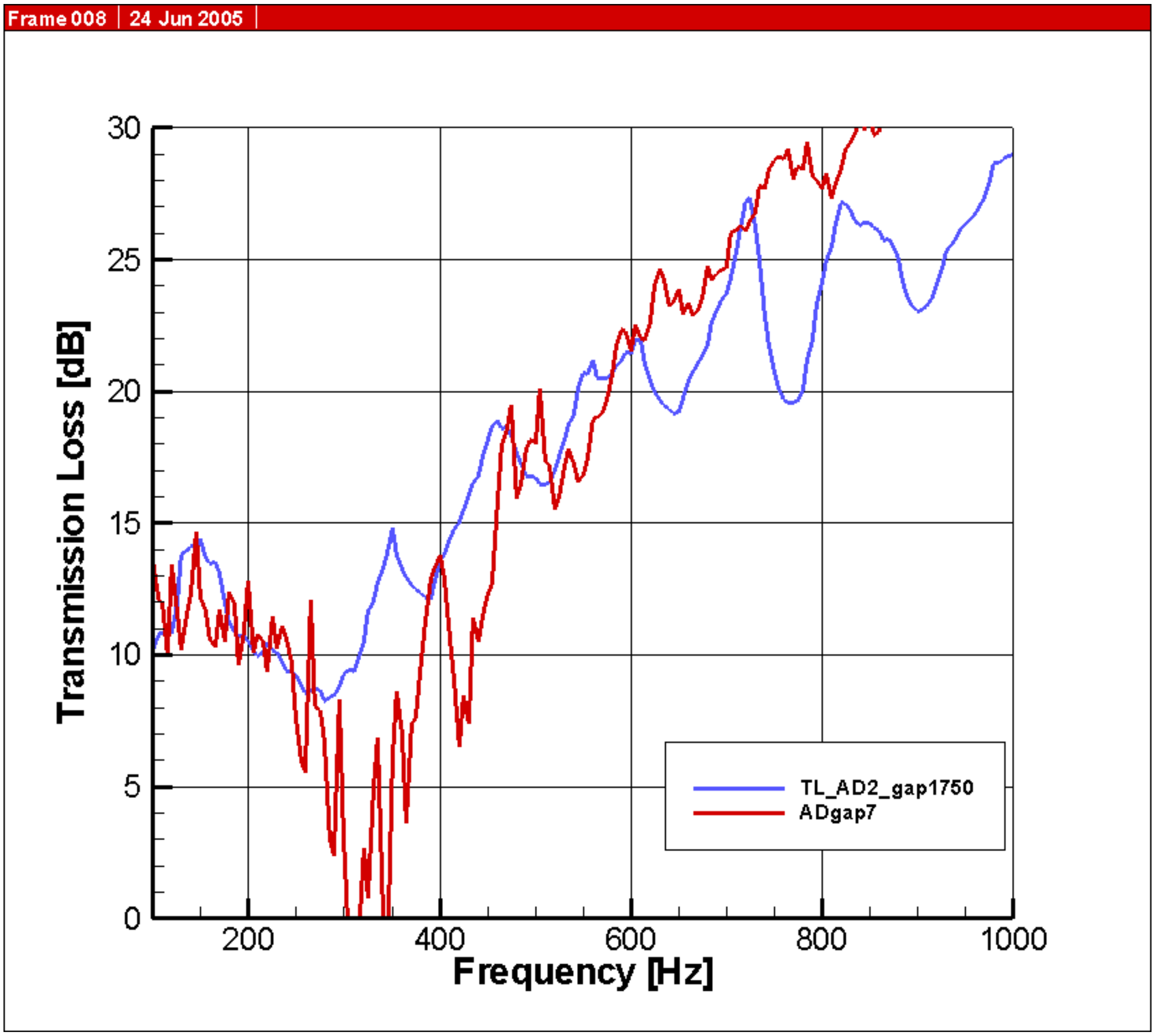


Figure 19. Experimental (TL_AD2_gap1750) and predicted (ADgap7) transmission loss of a double wall configuration of 0.020 and 0.032 inch thick aluminum panels separated by a distance of 1.75 inches.

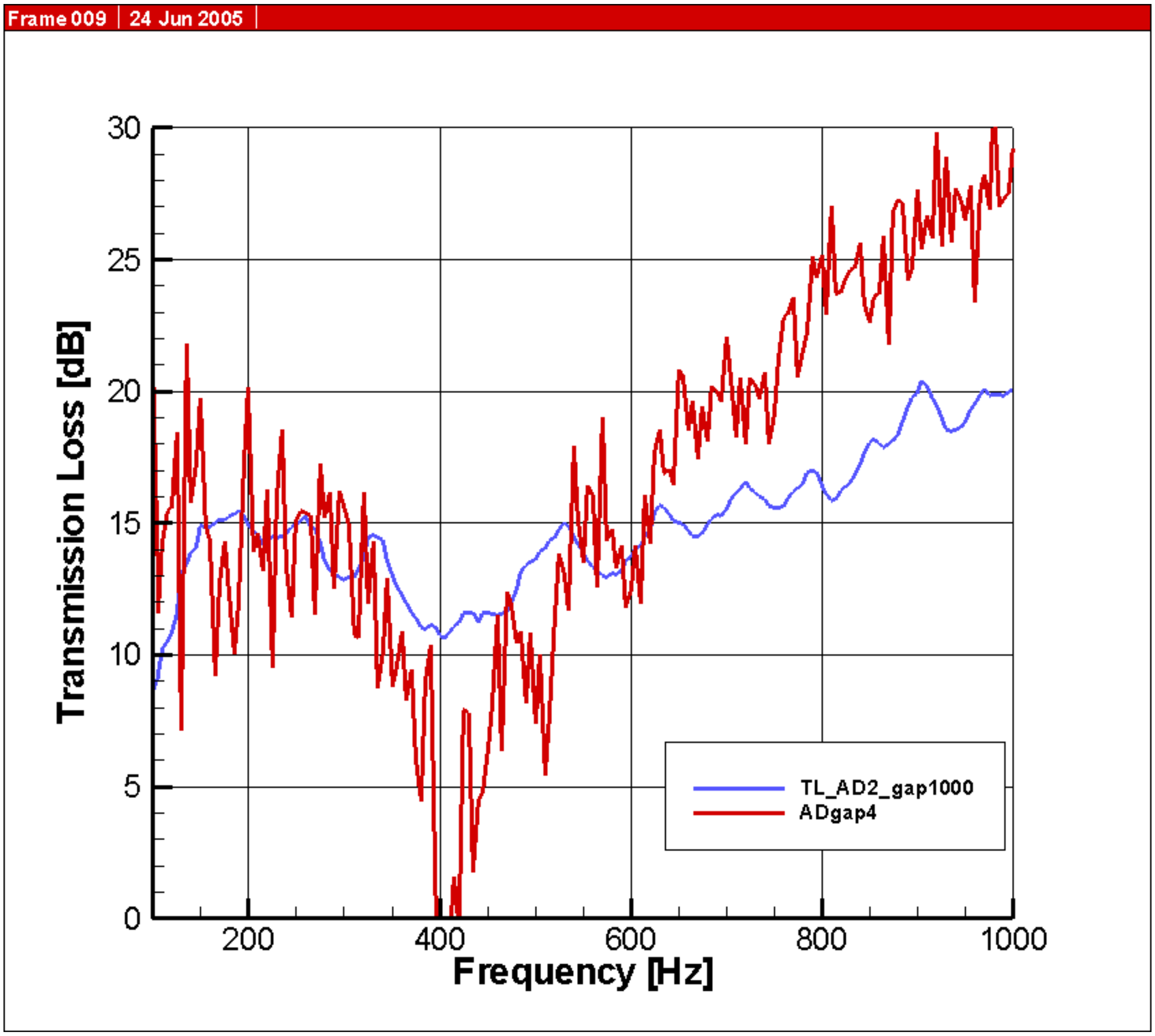


Figure 20. Experimental (TL_AD2_gap1000) and predicted (ADgap4) transmission loss of a double wall configuration of 0.020 and 0.032 inch thick aluminum panels separated by a distance of 1.0 inch.

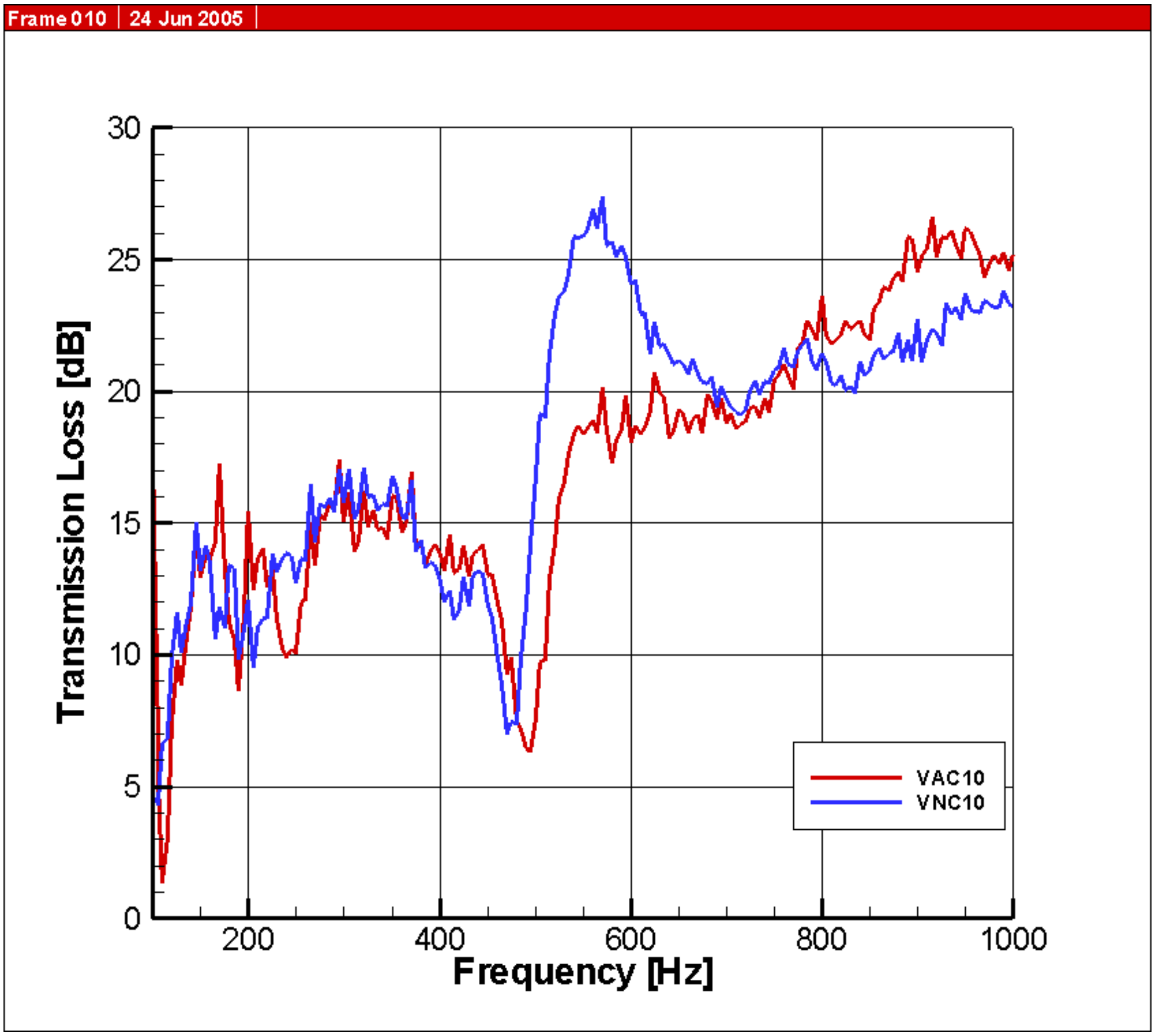


Figure 21. Predicted transmission loss of the aluminum core (VAC10) and nomex core (VNC10) voided honeycomb panels.

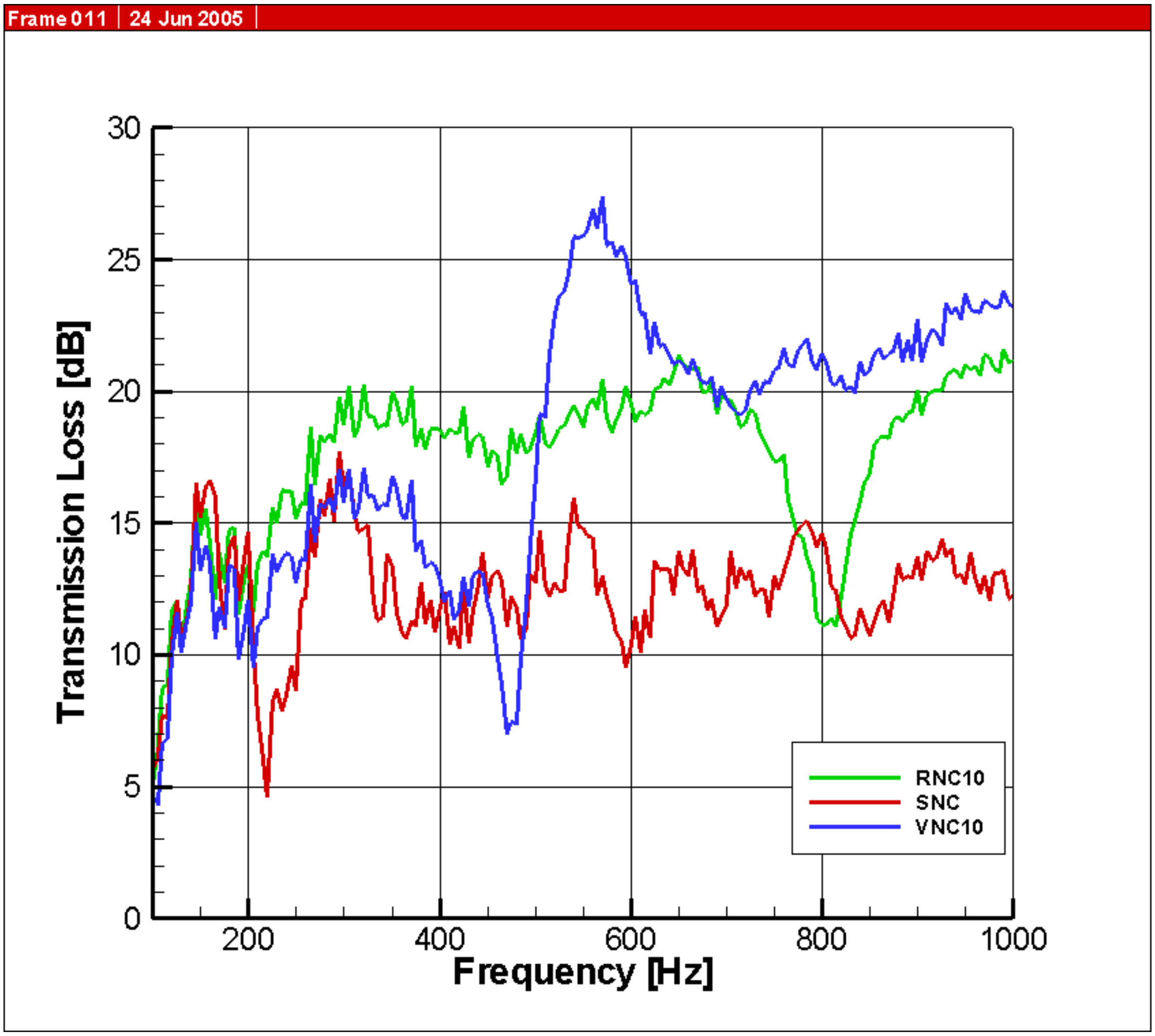


Figure 22. Predicted transmission loss of the base (SNC), the voided (VNC10) and the recessed (RNC10) honeycomb panels.

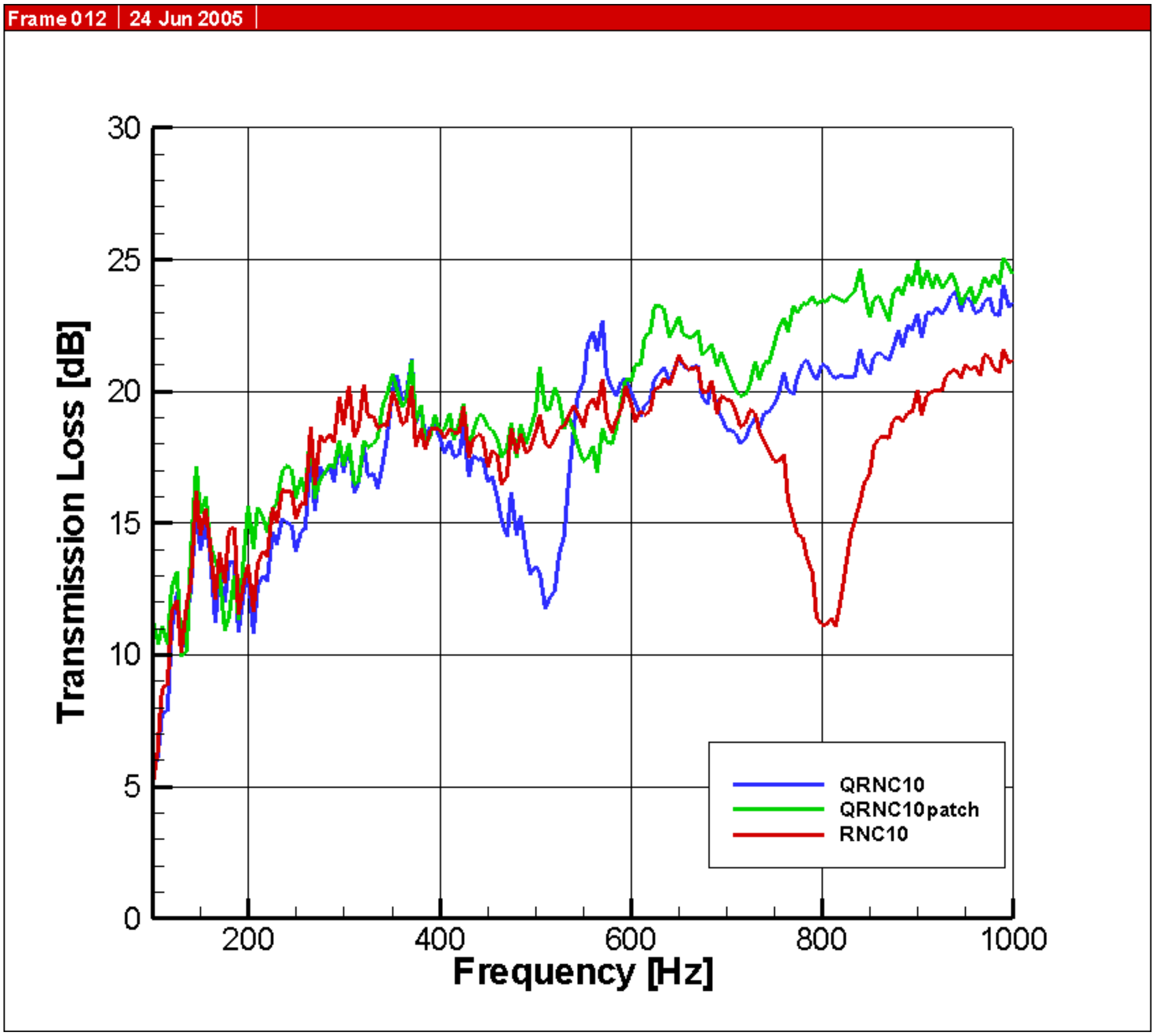


Figure 23. Predicted transmission loss of the recessed honeycomb panel with a half inch thick core (RNC10), the recessed honeycomb panel with a quarter inch thick core (QRNC10) and the quarter inch recessed honeycomb panel with a 0.016 inch thick aluminum patch applied to the recessed core (QRNC10patch).

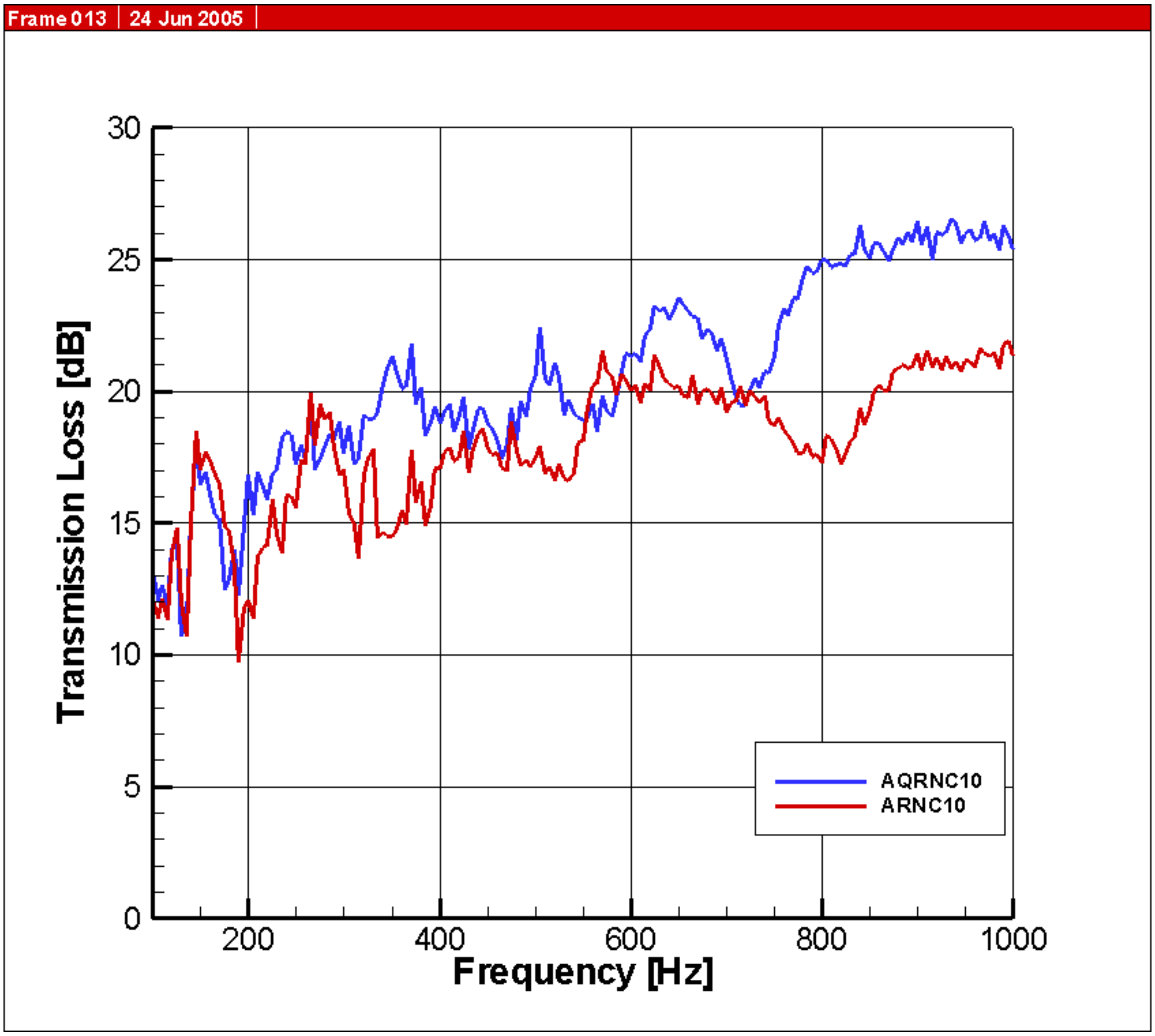


Figure 24. Predicted transmission loss of the honeycomb panels with half inch (ARNC10) and quarter inch (AQRNC10) thick recessed cores including a 0.016 inch thick, 45 by 45 inch aluminum panel covering the recessed cores.

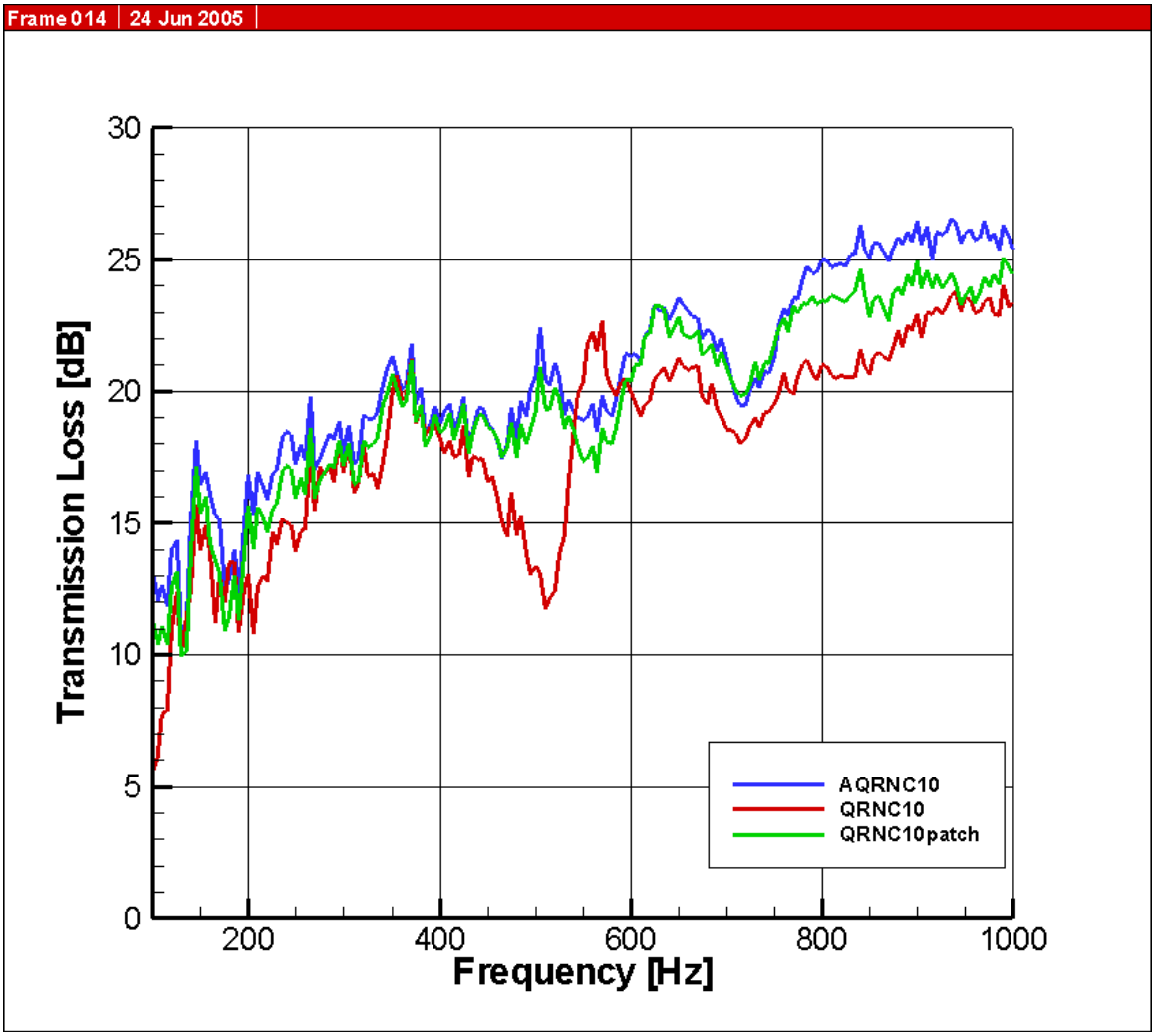


Figure 25. Predicted transmission loss of the honeycomb panels with quarter inch thick recessed cores without material covering the recessed core (QRNC10), with a 0.016 inch thick, 45 by 45 inch aluminum panel covering the recessed cores (AQRNC10) and with a 0.016 inch thick aluminum patch applied to the recessed cores (QRNC10patch).

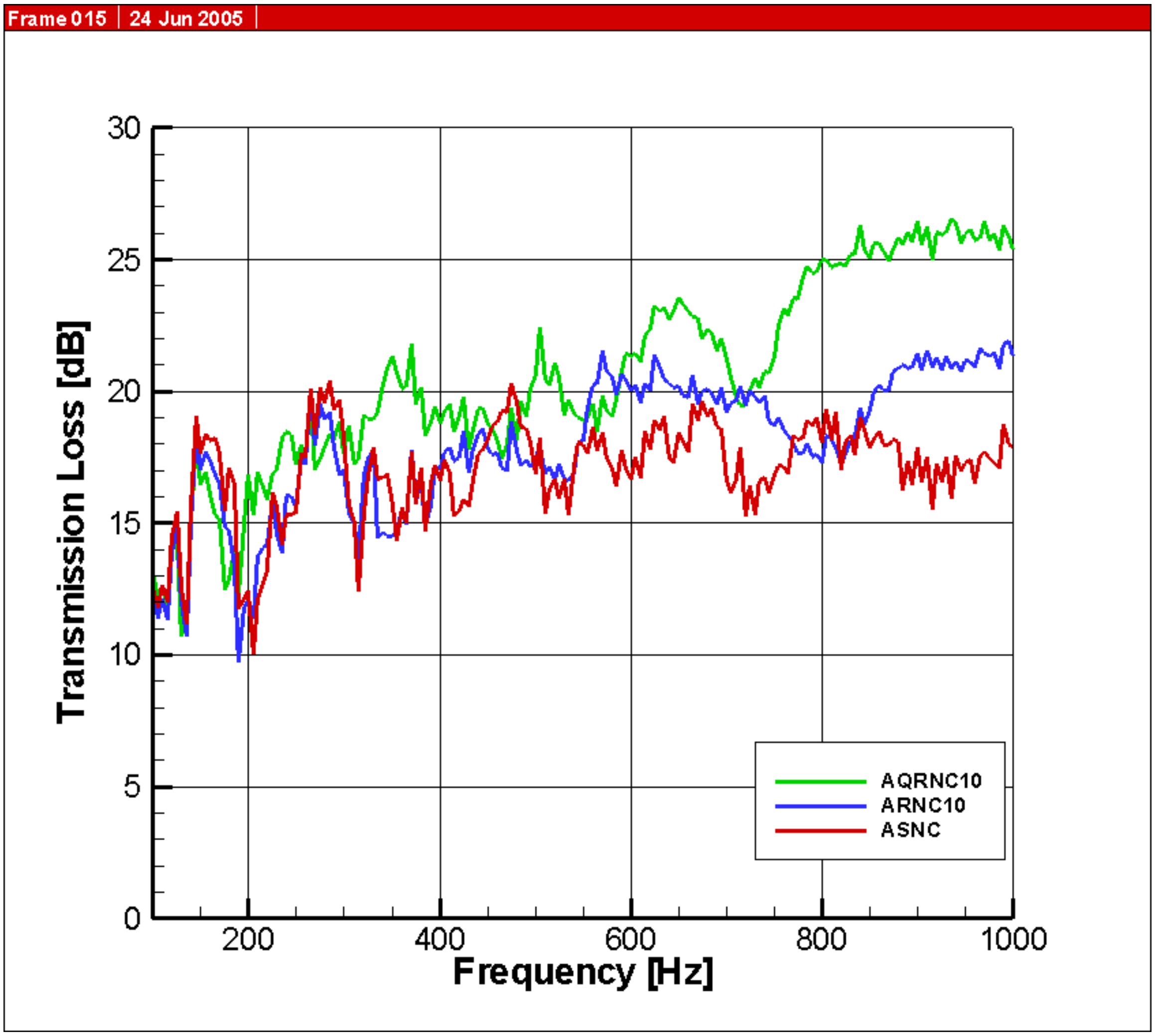


Figure 26. Predicted transmission loss of the half inch recessed core honeycomb panel (ARNC10) and the quarter inch (AQRNC10) honeycomb panels, both including a 0.016 inch thick, 45 by 45 inch aluminum panel covering the recessed cores. The panels are compared with the base honeycomb panel also featuring the 0.016 inch thick, 45 by 45 inch aluminum panel (ASNC),

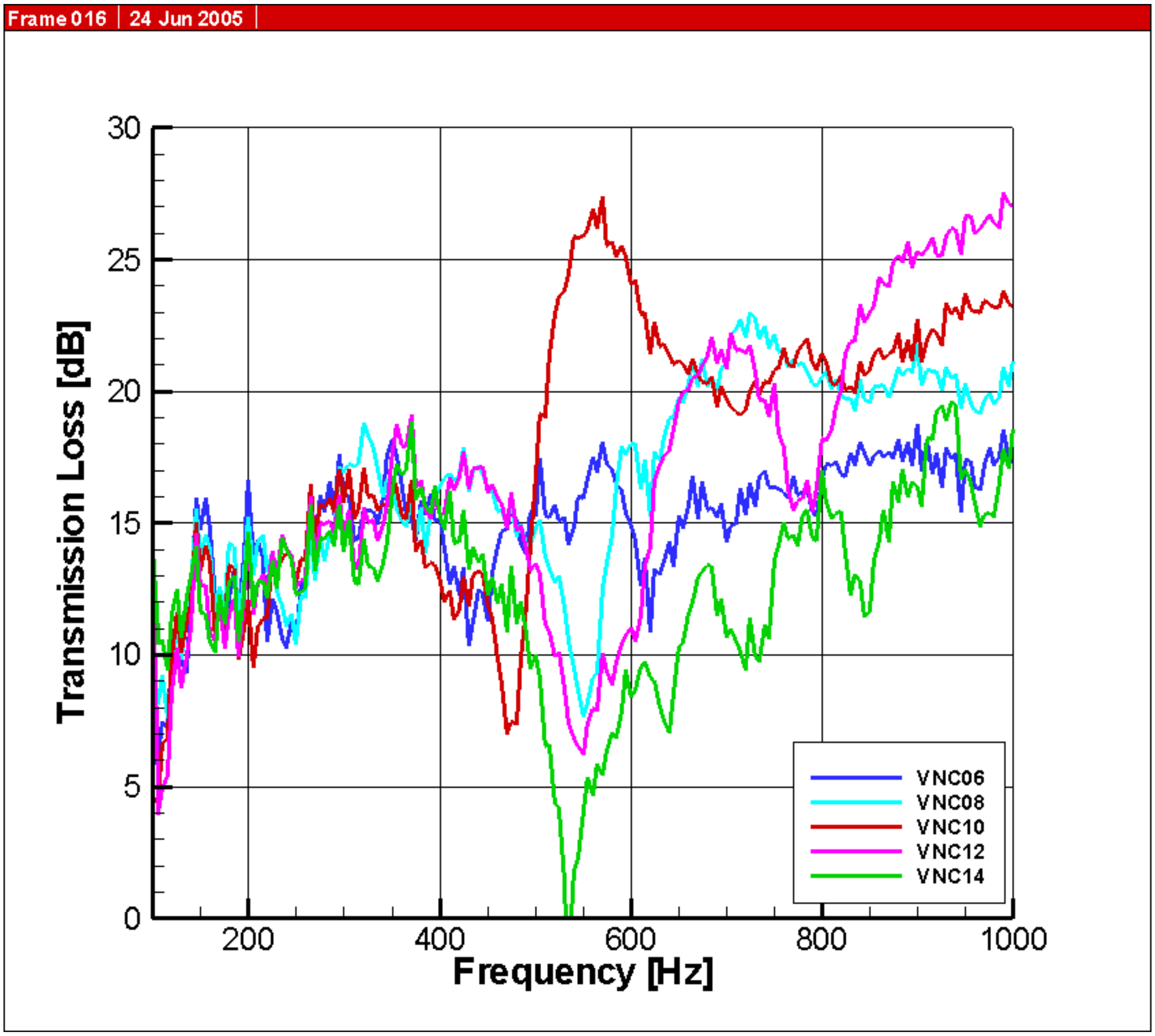


Figure 27. Predicted transmission loss of nomex core honeycomb panels having nine 6 by 6 (VNC06), 8 by 8 (VNC08), 10 by 10 (VNC10), 12 by 12 (VNC12), and 14 by 14 (VNC14) inch voids.

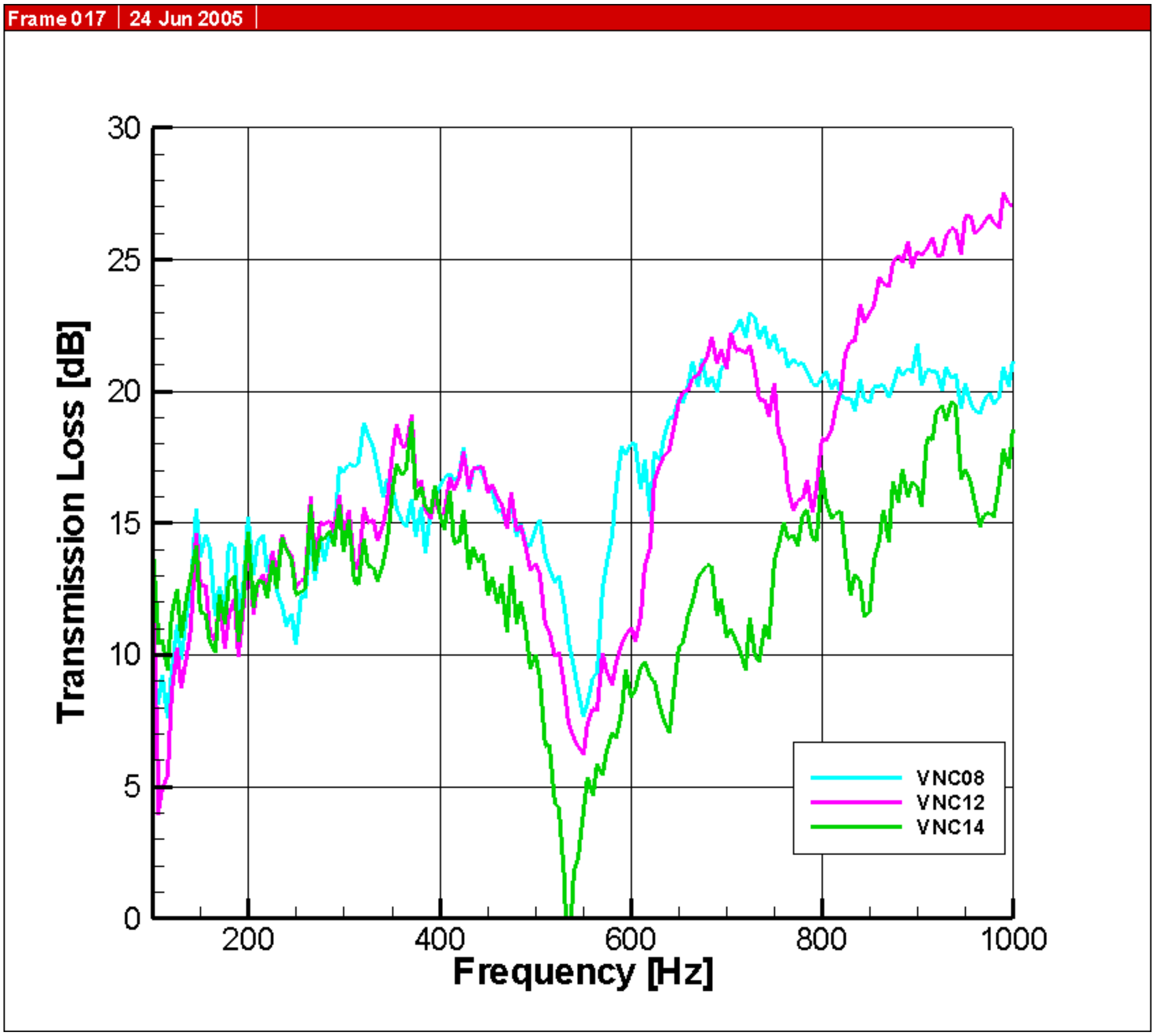


Figure 28. Predicted transmission loss of nomex core honeycomb panels having 8 by 8 (VNC08), 12 by 12 (VNC12), and 14 by 14 (VNC14) inch voids.

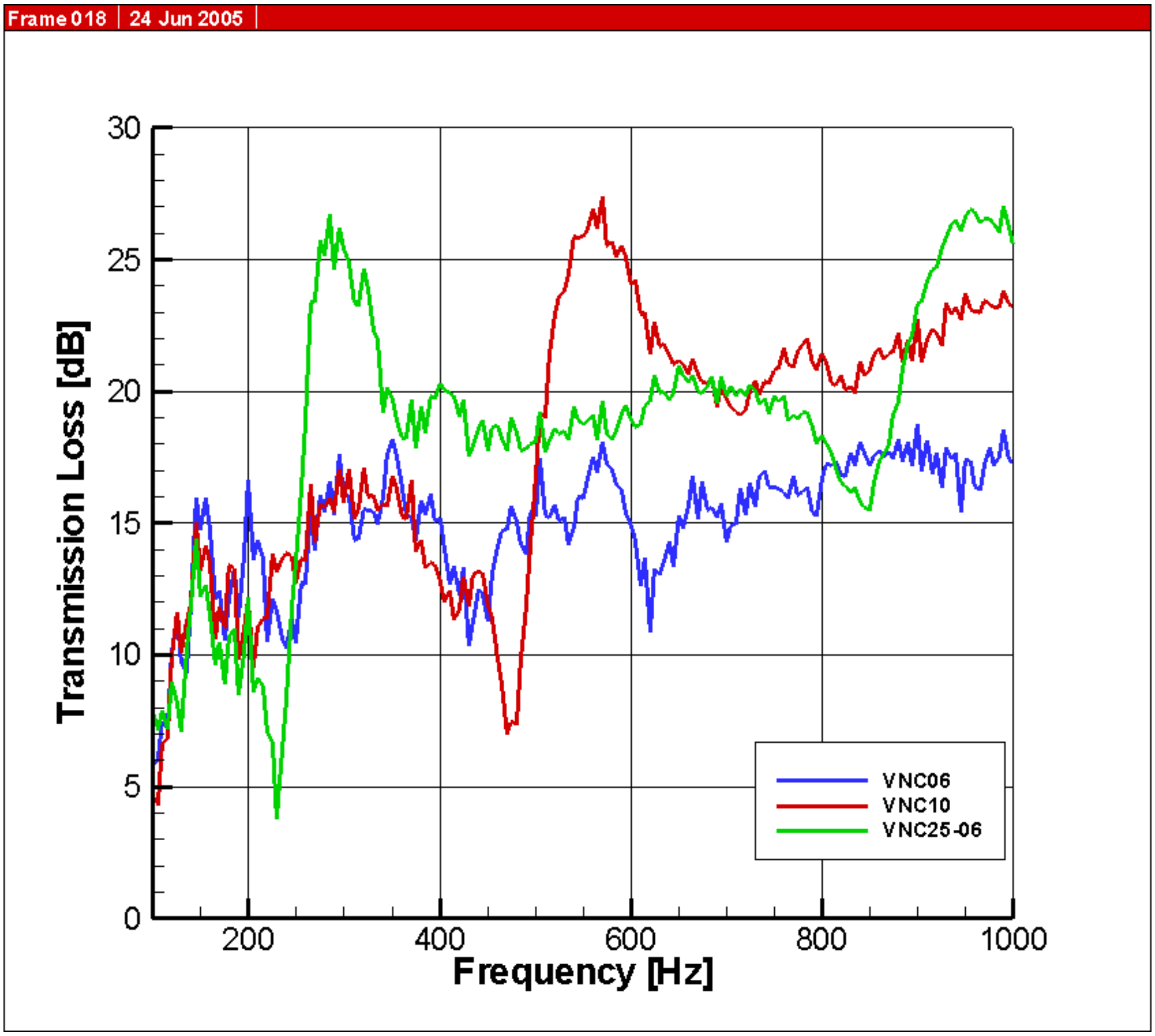


Figure 29. Predicted transmission loss of nomex core honeycomb panels having nine 6 by 6 (VNC06), nine 10 by 10 (VNC10), and twenty-five 6 by 6 (VNC25-06) inch voids.

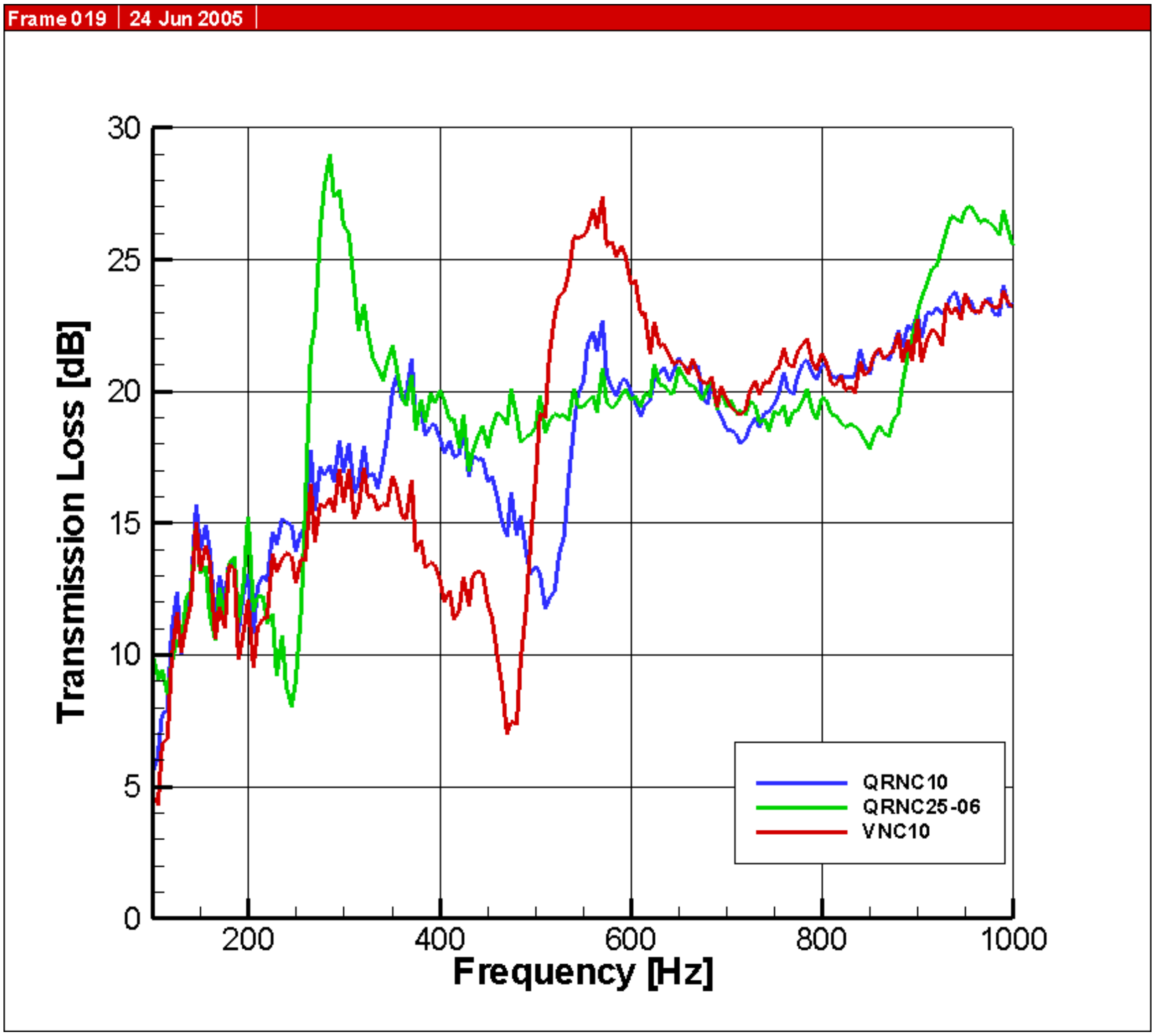


Figure 30. Predicted transmission loss of the honeycomb panels with nine 10 by 10 inch voids (VNC10), nine 10 by 10, quarter-inch recessed cores (QRNC10), and twenty-five 6 by 6, quarter-inch recessed cores (QRNC25-06).

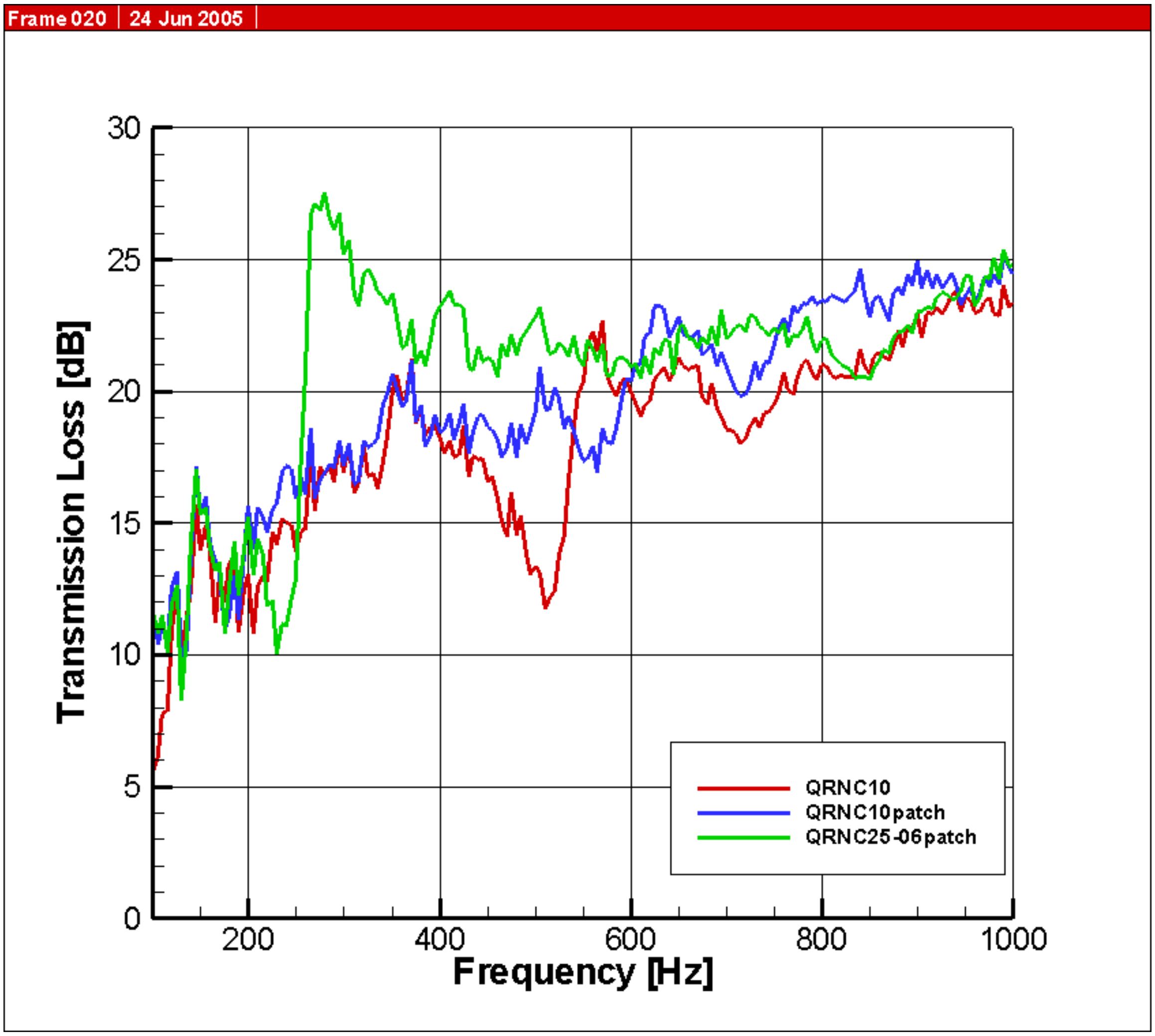


Figure 31. Predicted transmission loss of the quarter-inch recessed core honeycomb panels with nine 10 by 10 inch recessed cores (QRNC10), nine 10 by 10 recessed cores with 0.016 inch thick aluminum patches (QRNC10patch), and the panel with twenty-five 6 by 6 recessed cores including the aluminum patches (QRNC25-06patch).

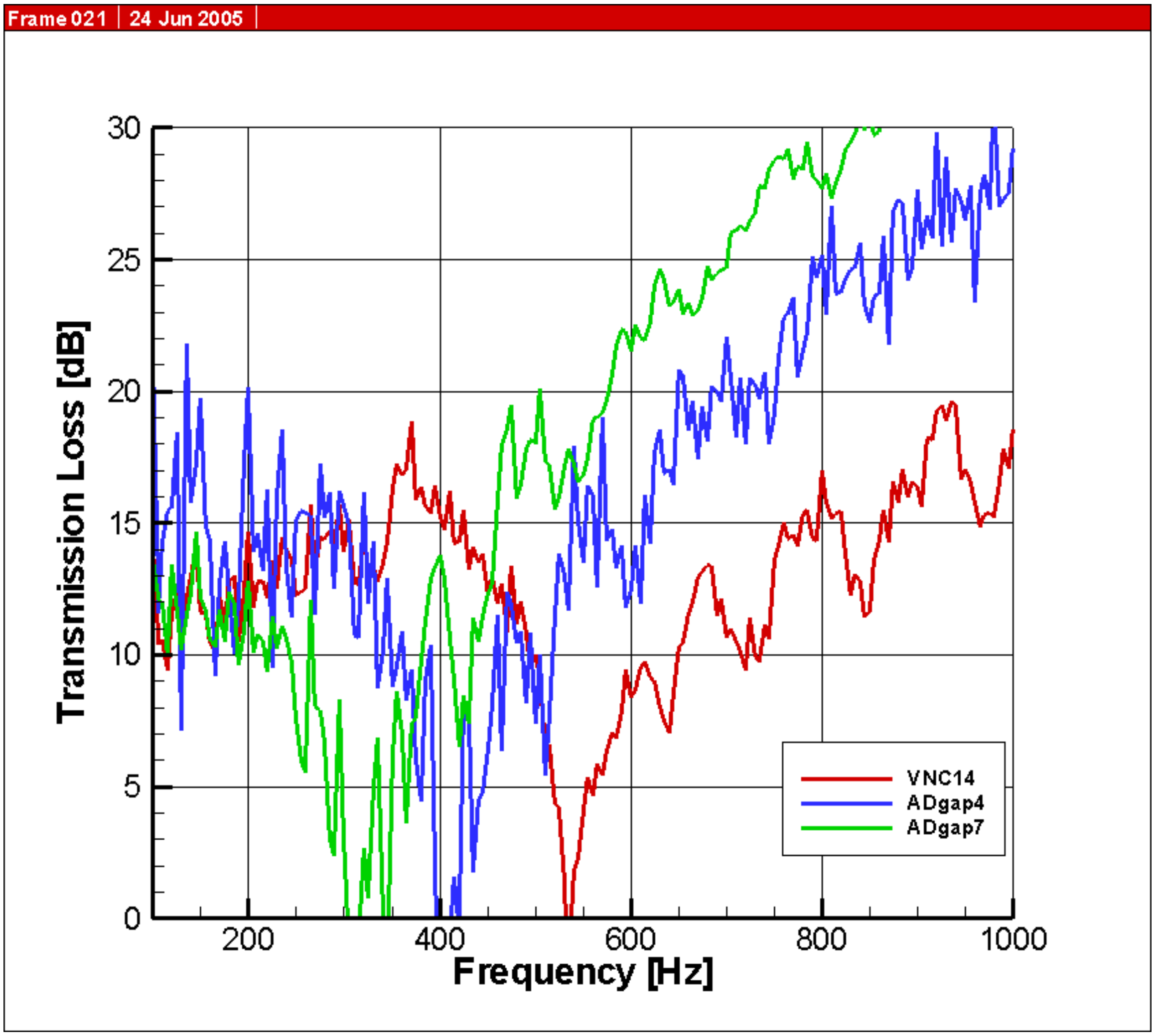


Figure 32. Predicted transmission loss of a double wall configuration of two 0.020 inch thick aluminum panels separated by a 0.75 inch air gap (VNC14), a double wall configurations consisting of a 0.020 inch thick and a 0.032 inch thick aluminum panel separated by 1.00 (ADgap4) and 1.75 inch (ADgap7) air gaps.

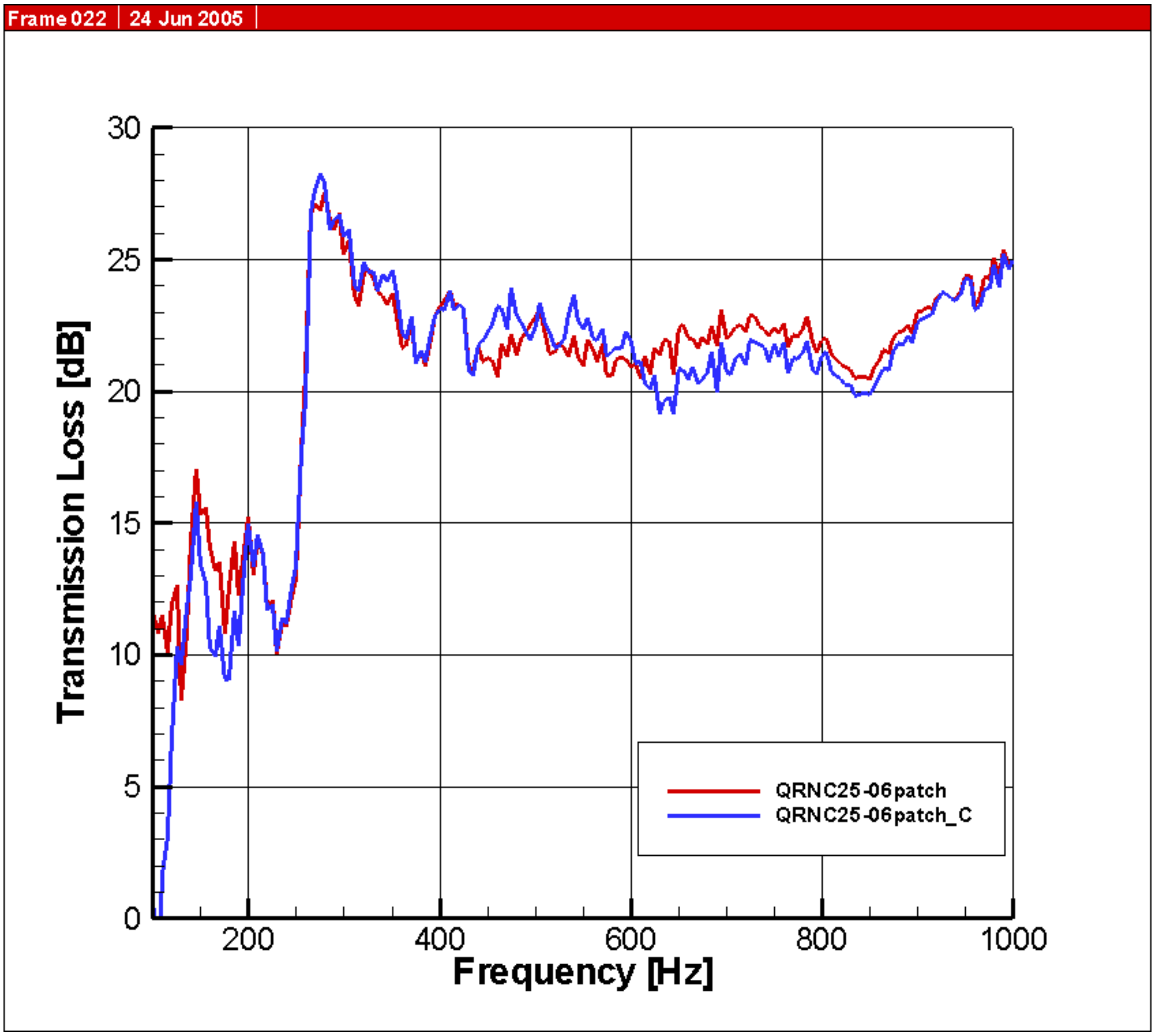


Figure 33. Predicted transmission loss of the honeycomb panel with twenty-five, 6 by 6 inch, quarter inch thick recessed cores with a 0.016 inch thick aluminum patch applied to the recessed cores. A comparison was made between the panel supported by its frame (QRNC10patch) and the panel constrained by clamped edge conditions for both its face sheets (QRNC10patch_C).

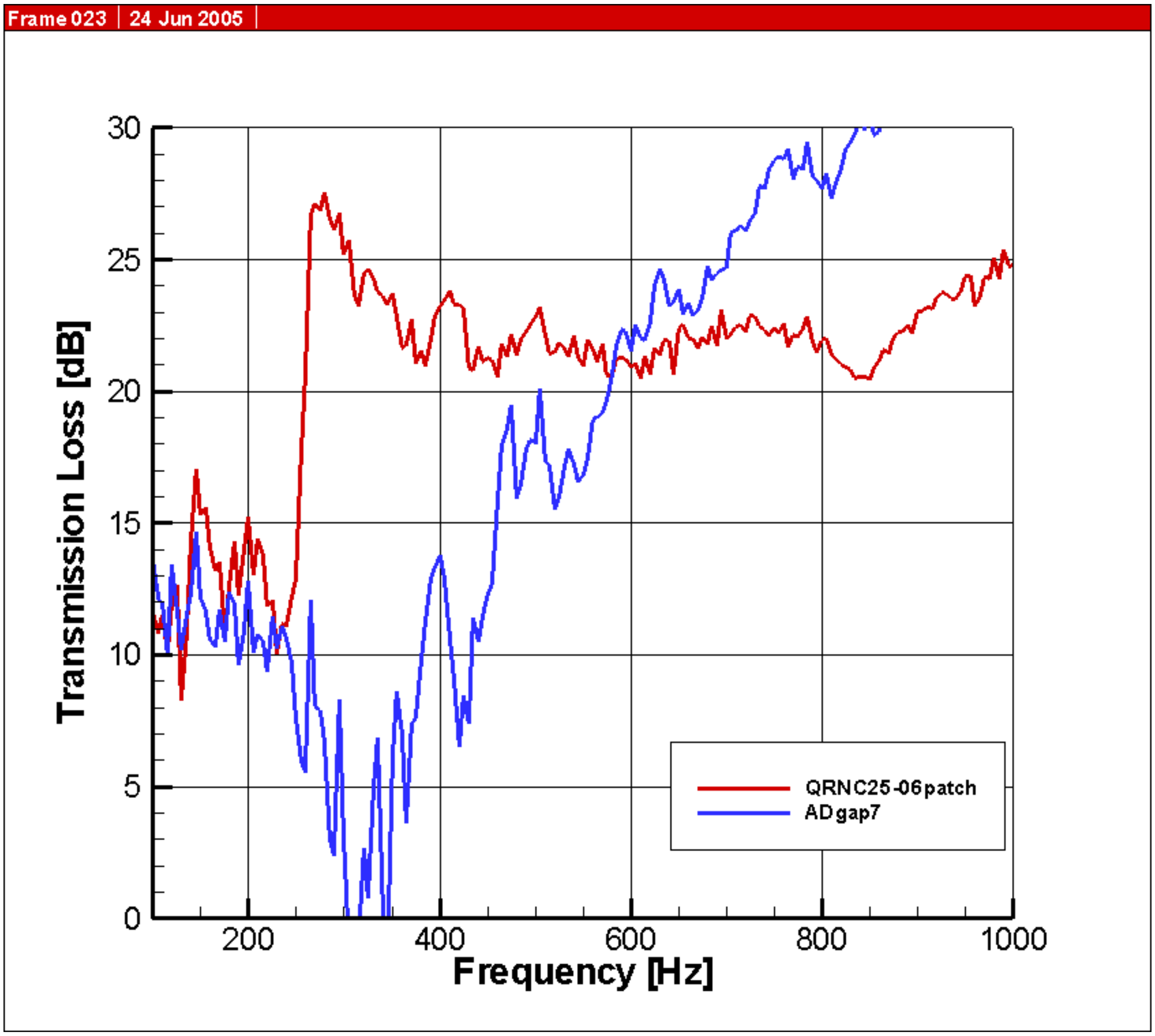


Figure 34. Predicted transmission loss of the honeycomb panel with twenty-five, 6 by 6 inch, quarter inch thick recessed cores with a 0.016 inch thick aluminum patch applied to the recessed cores (QRNC25-06) and the transmission loss of a double wall configuration consisting of 0.020 and 0.032 inch thick aluminum panels separated by a 1.75 inch air gap (ADgap7).

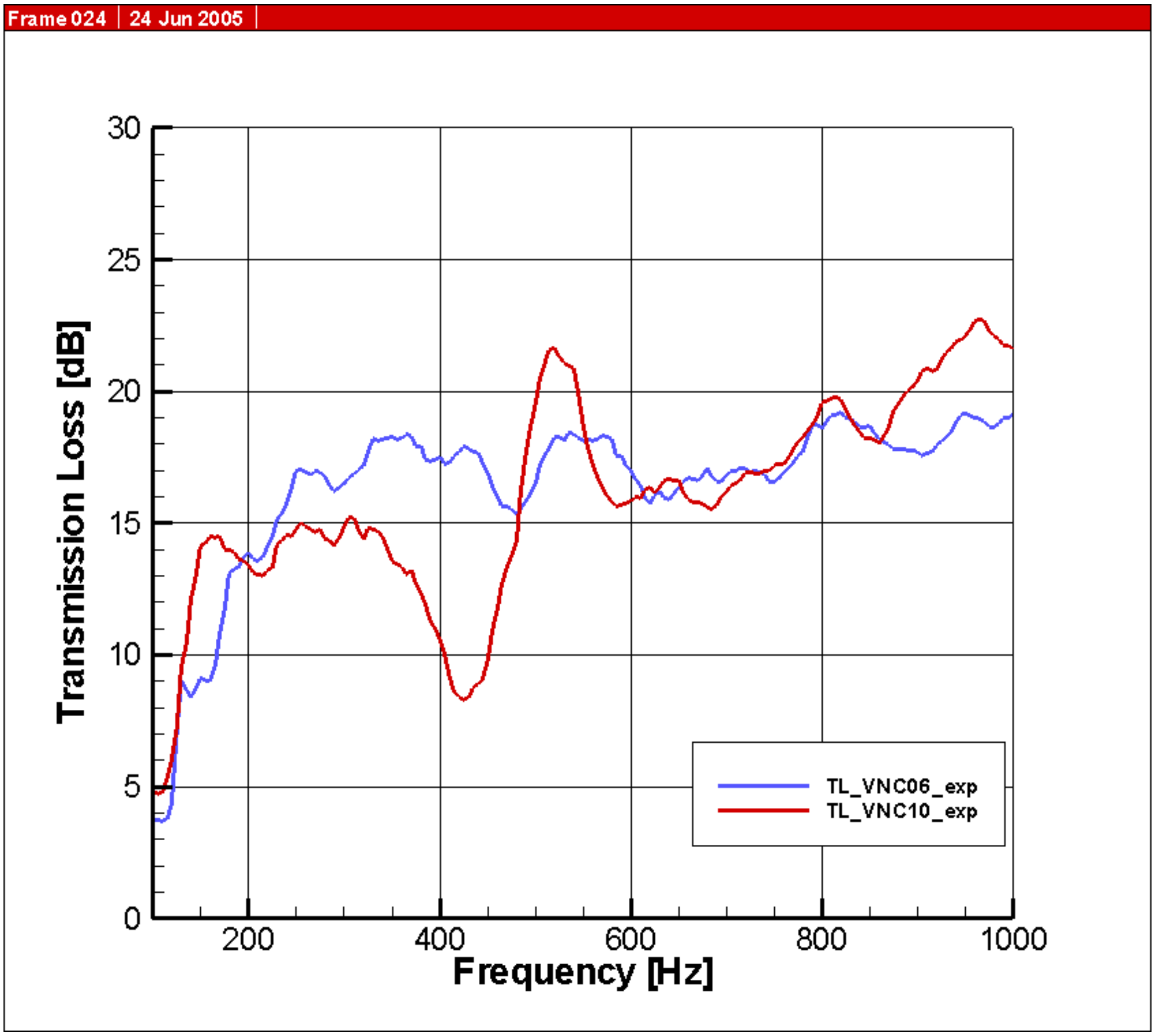


Figure 35. Experimental transmission loss of nomex core honeycomb panels with nine 6 by 6 inch (TL_VNC06_exp) and nine 10 by 10 inch voids (TL_VNC10_exp).

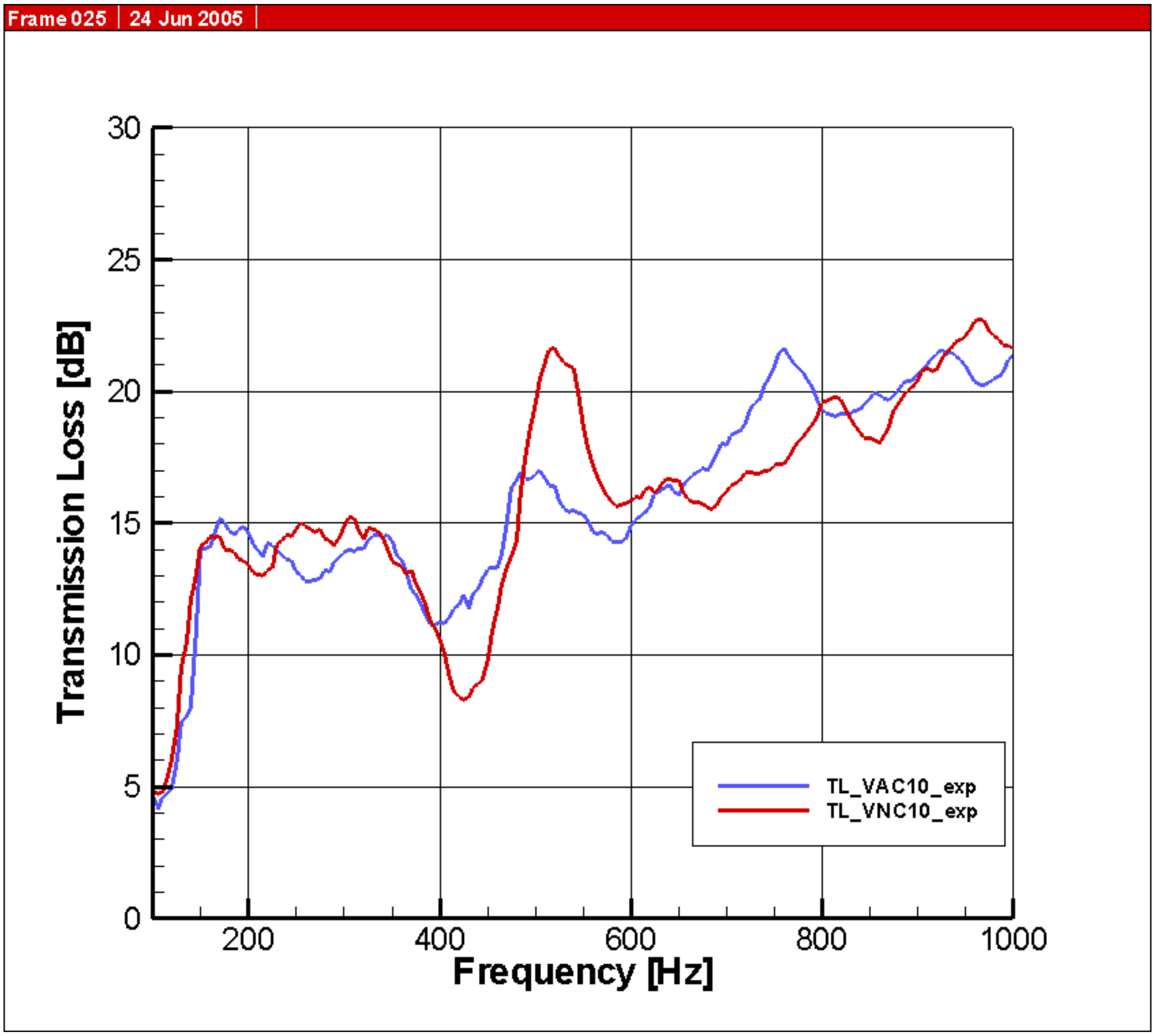


Figure 36. Experimental transmission loss of aluminum (TL_VAC10_exp) and nomex core honeycomb panels with nine 10 by 10 inch voids (TL_VNC10_exp).

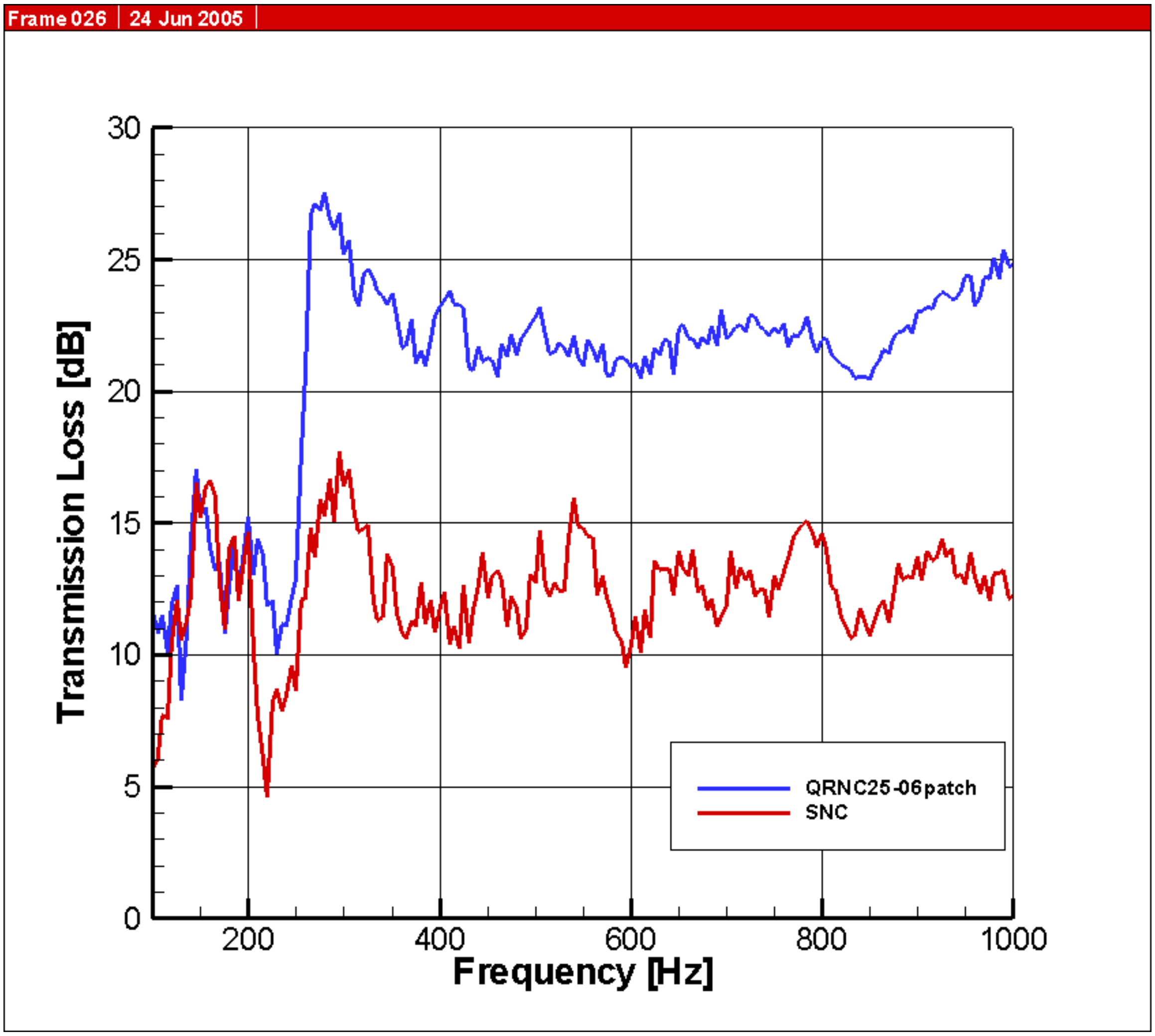


Figure 37. Predicted transmission loss of the honeycomb panel with twenty-five, 6 by 6 inch, quarter inch thick recessed cores with a 0.016 inch thick aluminum patch applied to the recessed cores (QRNC25-06) and the transmission loss of the base nomex core honeycomb panel (SNC).

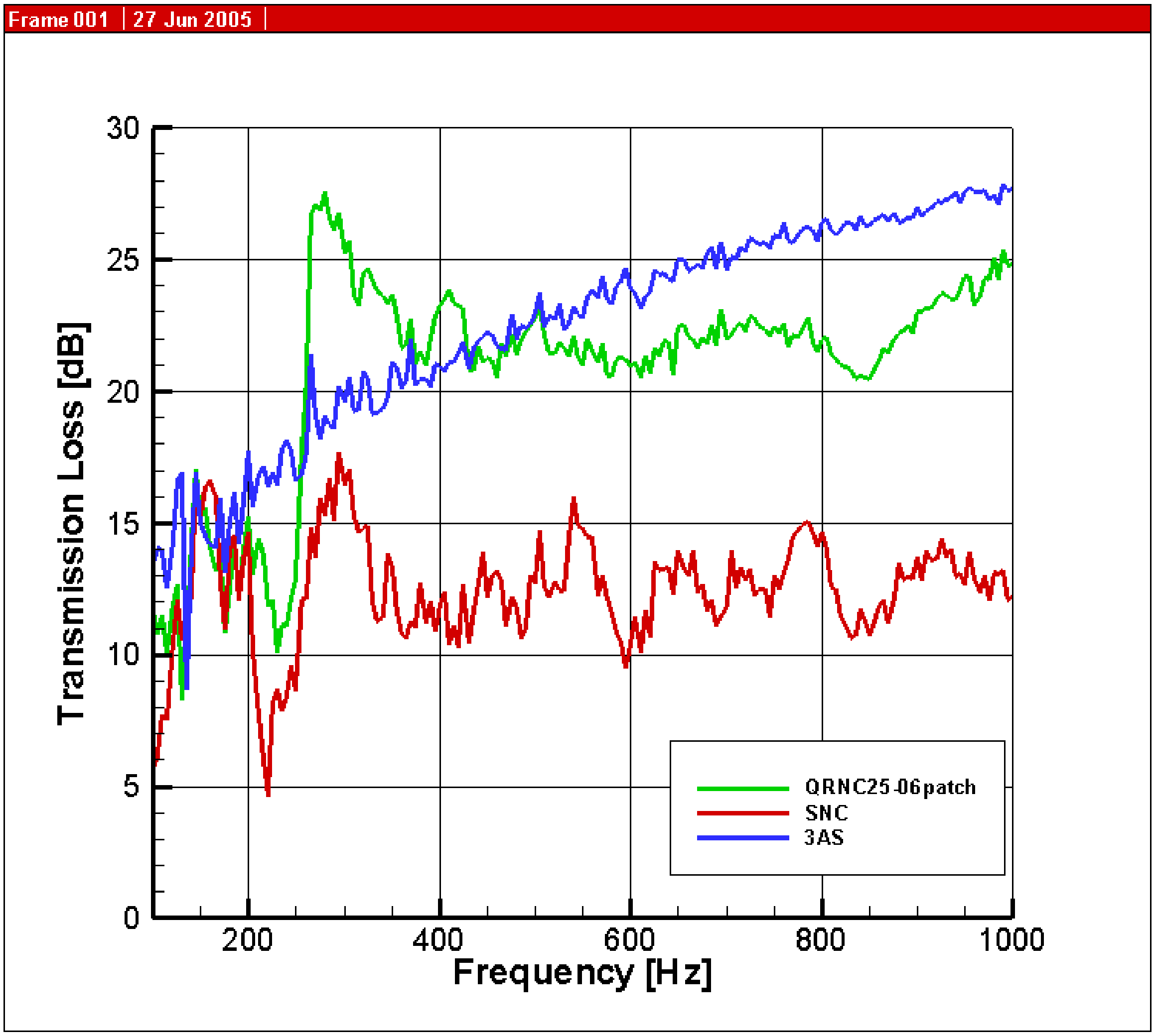


Figure 38. Predicted transmission loss of the honeycomb panel with twenty-five, 6 by 6 inch, quarter inch thick recessed cores with a 0.016 inch thick aluminum patch applied to the recessed cores (QRNC25-06) the transmission loss of the base nomex core honeycomb panel (SNC) and a single, 0.05871 inch thick aluminum panel (3AS) with the same total mass as the base honeycomb panel. The mass of the QRNC25-06patch panel is 5.1% more than the SNC or 3AS panels.

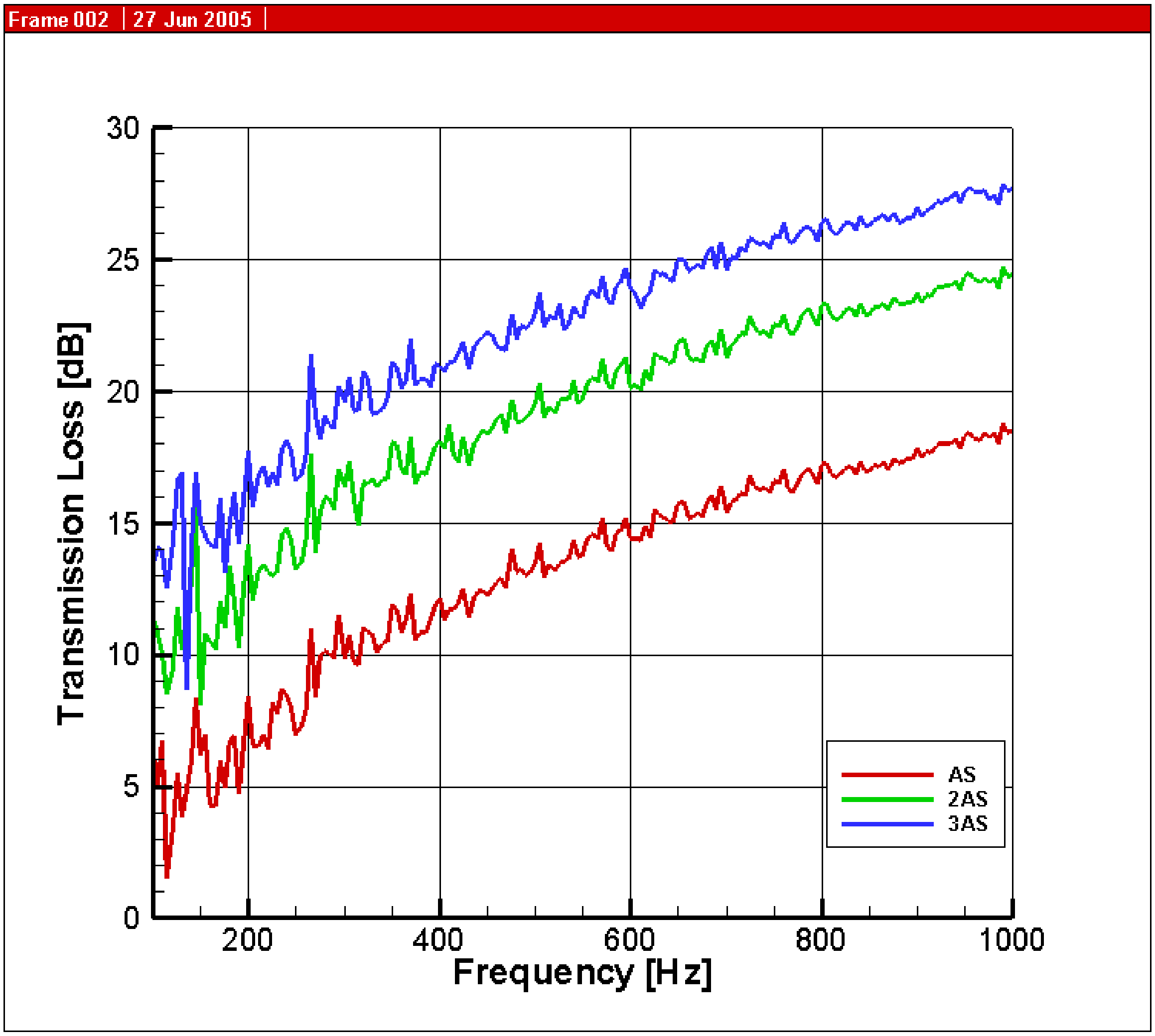


Figure 39. Predicted transmission loss of single 0.020 inch thick (AS), 0.040 inch thick (2AS), and 0.05871 inch thick (3AS) aluminum panels.

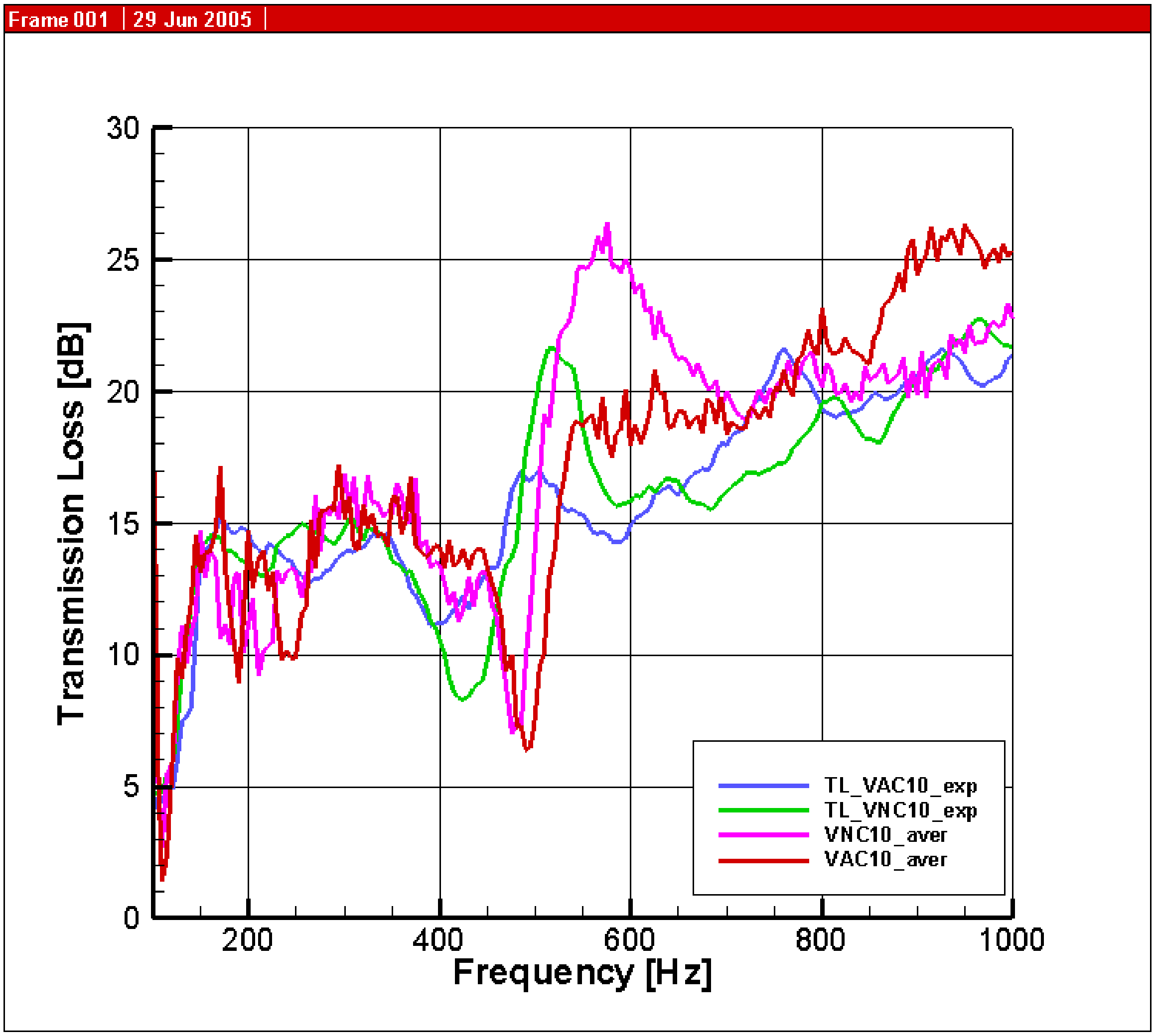


Figure 40. Experimental transmission loss of aluminum (TL_VAC10_exp) and nomex core honeycomb (TL_VNC10_exp) panels with nine 10 by 10 inch voids compared with predicted transmission loss for of aluminum (VAC10_aver) and nomex core honeycomb (VNC10_aver) panels with nine 10 by 10 inch voids.

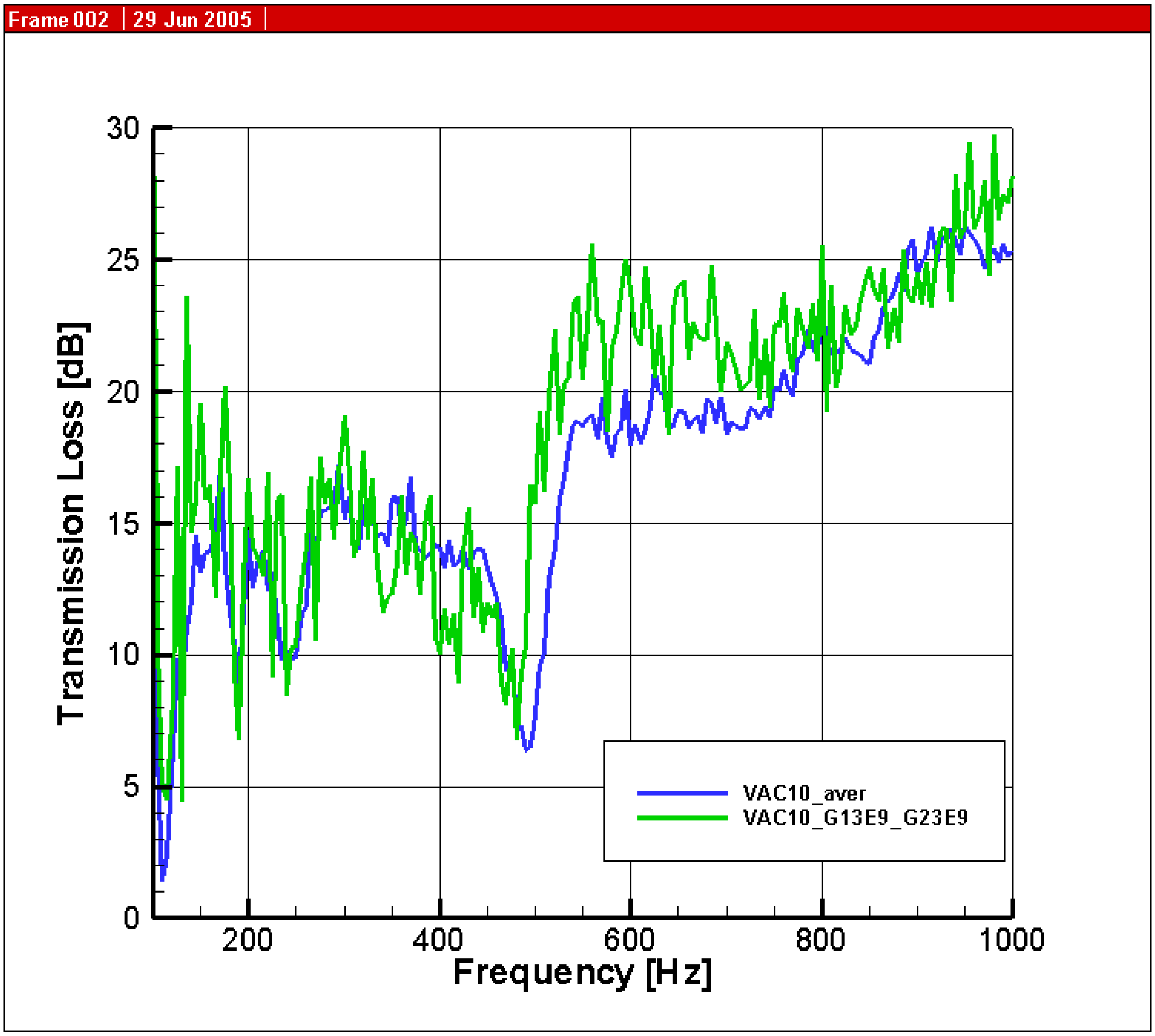


Figure 41. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for aluminum cores with MAT9 material properties listed in Table 1, showing the effect of different G13 and G23 shear moduli. The predicted transmission loss of the honeycomb panel VAC10_G13E9_G23E9 was for one set of random incident sound input parameters, while the transmission loss of VAC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

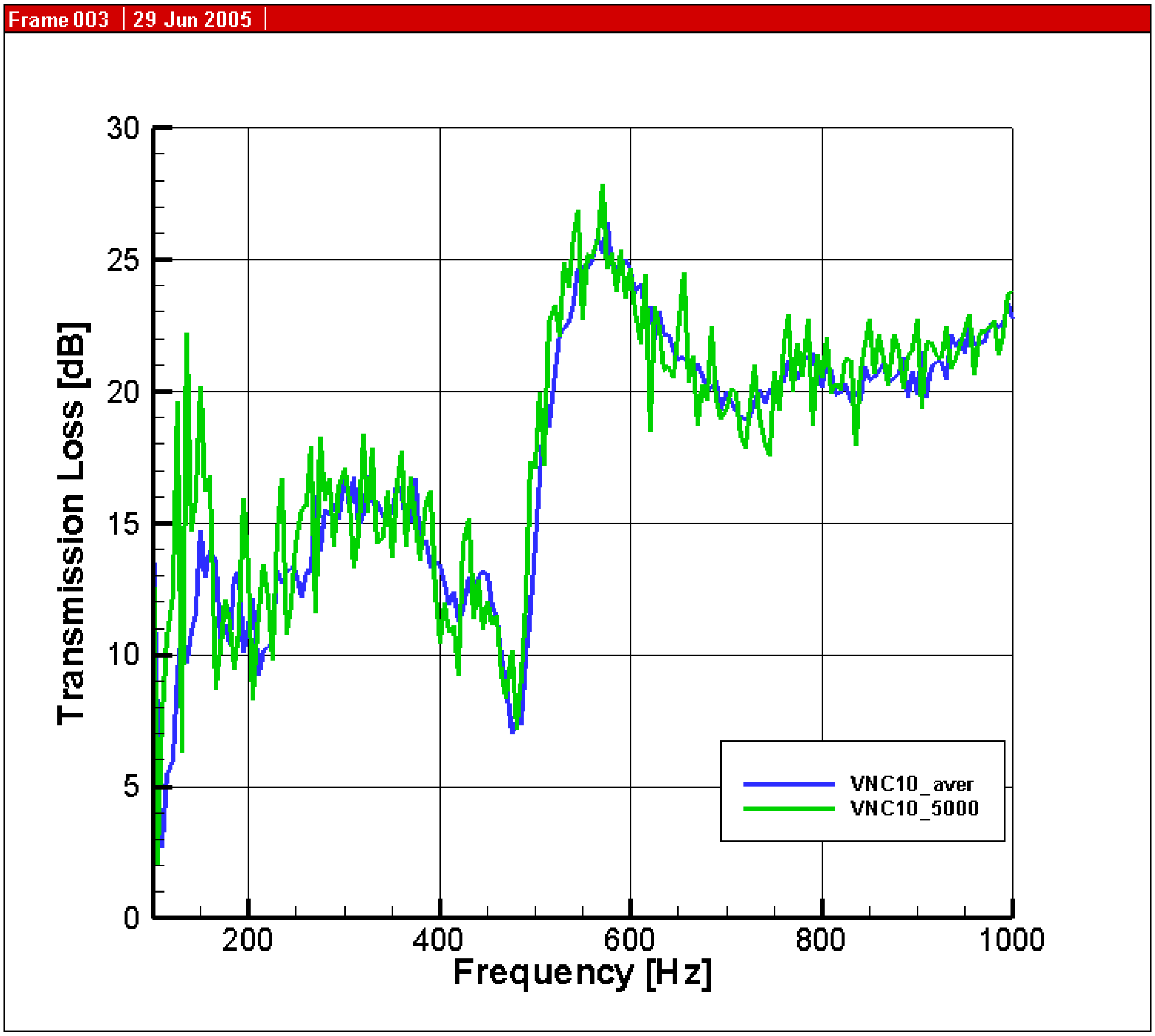


Figure 42. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with MAT9 material properties listed in Table 1, showing the effect of different core properties. The predicted transmission loss of the honeycomb panel VNC_5000 was for one set of random incident sound input parameters, while the transmission loss of VAC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

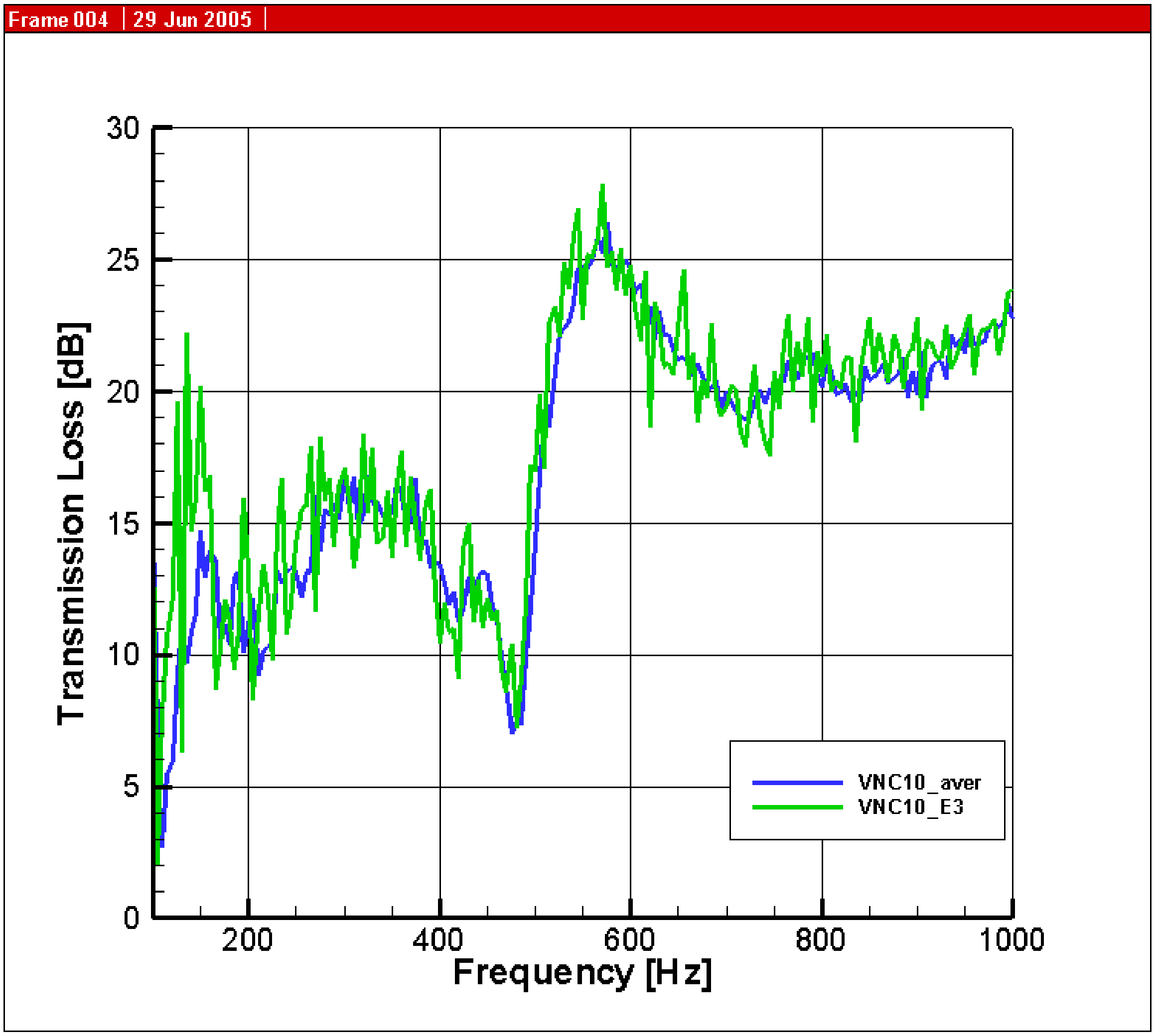


Figure 43. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with MAT9 material properties listed in Table 1, showing the effect of different E3 elasticity moduli. The predicted transmission loss of the honeycomb panel VNC10_E3 was for one set of random incident sound input parameters, while the transmission loss of VNC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

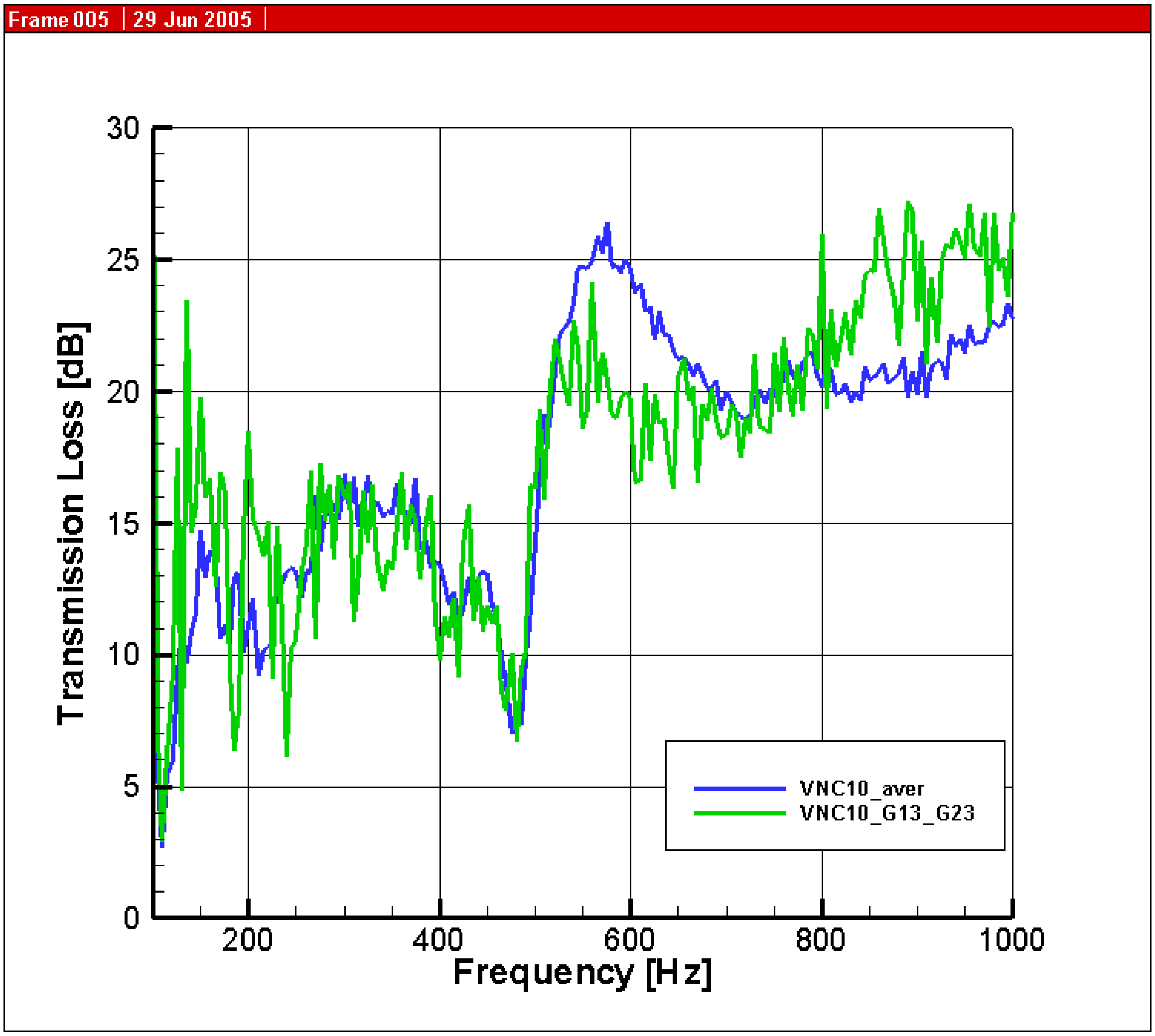


Figure 44. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with MAT9 material properties listed in Table 1, showing the effect of different G13 and G23 shear moduli. The predicted transmission loss of the honeycomb panel VNC10_G13_G23 was for one set of random incident sound input parameters, while the transmission loss of VNC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

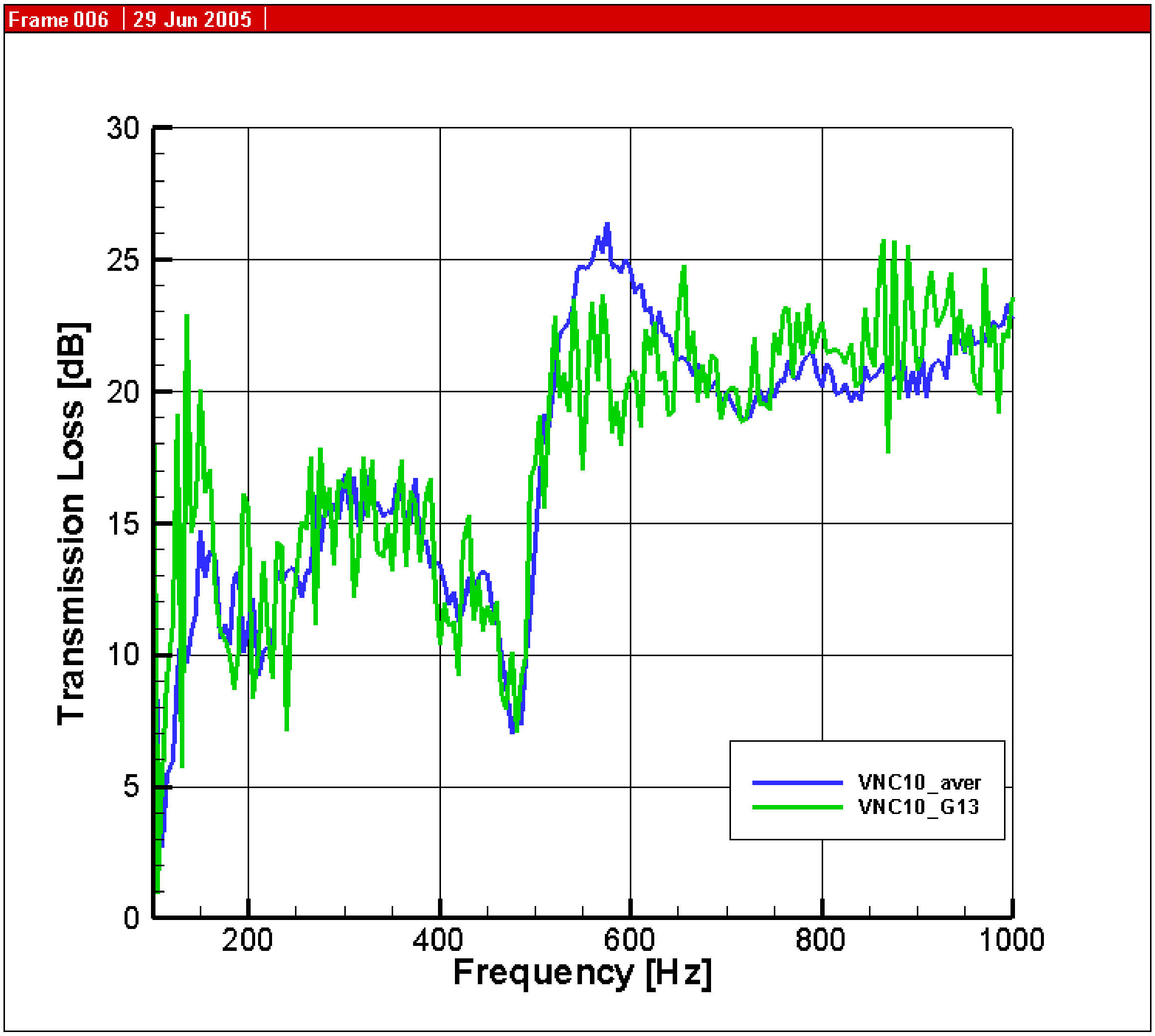


Figure 45. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with MAT9 material properties listed in Table 1, showing the effect of different G13 shear moduli. The predicted transmission loss of the honeycomb panel VNC10_G13 was for one set of random incident sound input parameters, while the transmission loss of VNC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

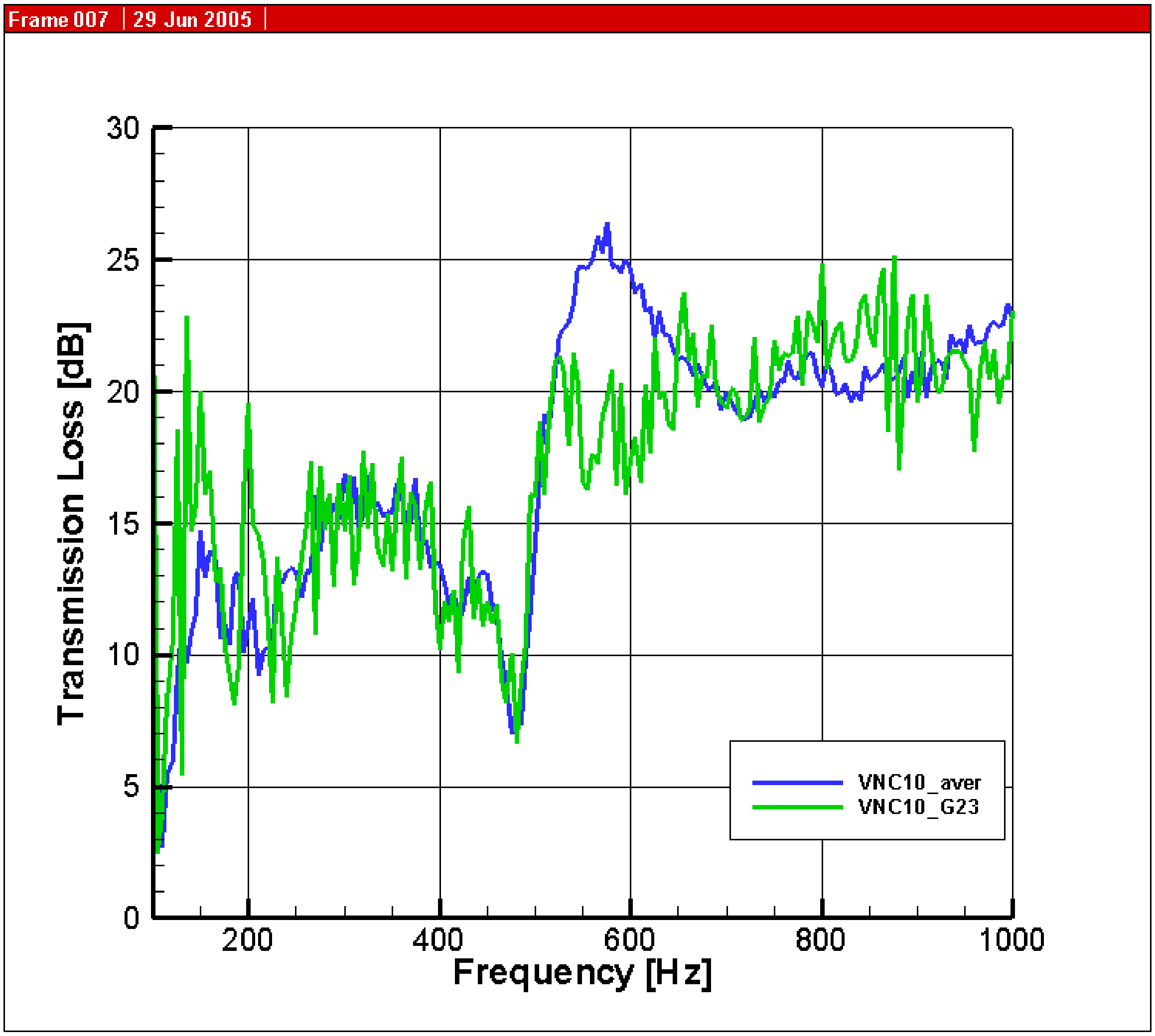


Figure 46. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with MAT9 material properties listed in Table 1, showing the effect of different G23 shear moduli. The predicted transmission loss of the honeycomb panel VNC10_G23 was for one set of random incident sound input parameters, while the transmission loss of VNC10_aver was averaged over the predictions for ten sets of random incident sound input parameters.

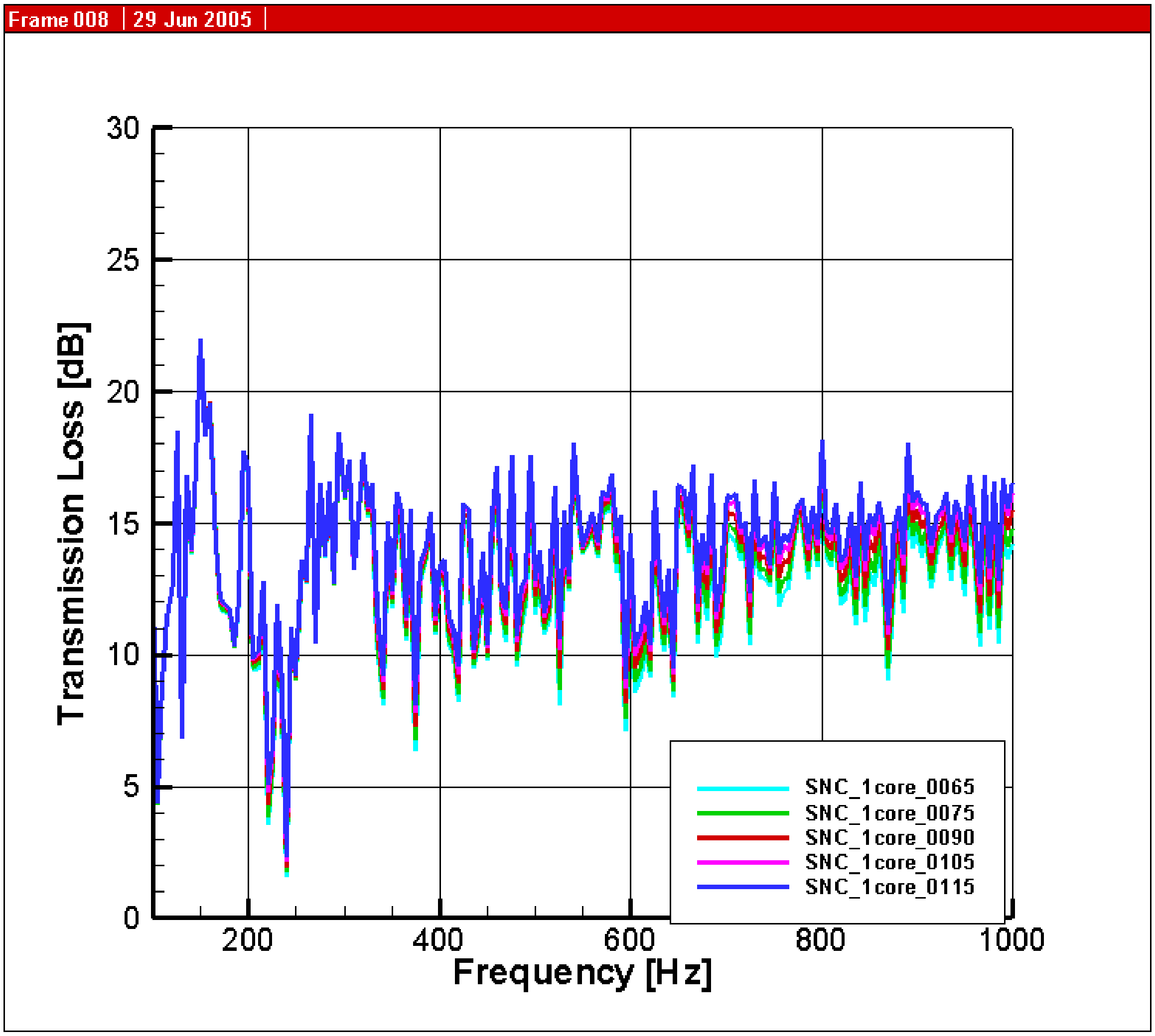


Figure 47. Transmission loss of nomex core honeycomb panels for core damping coefficients of 0.065, 0.075, 0.090, 0.105 and 0.115. The core material properties are listed in Table 1. Each transmission loss curve was predicted for one set of random sound incident input parameters.

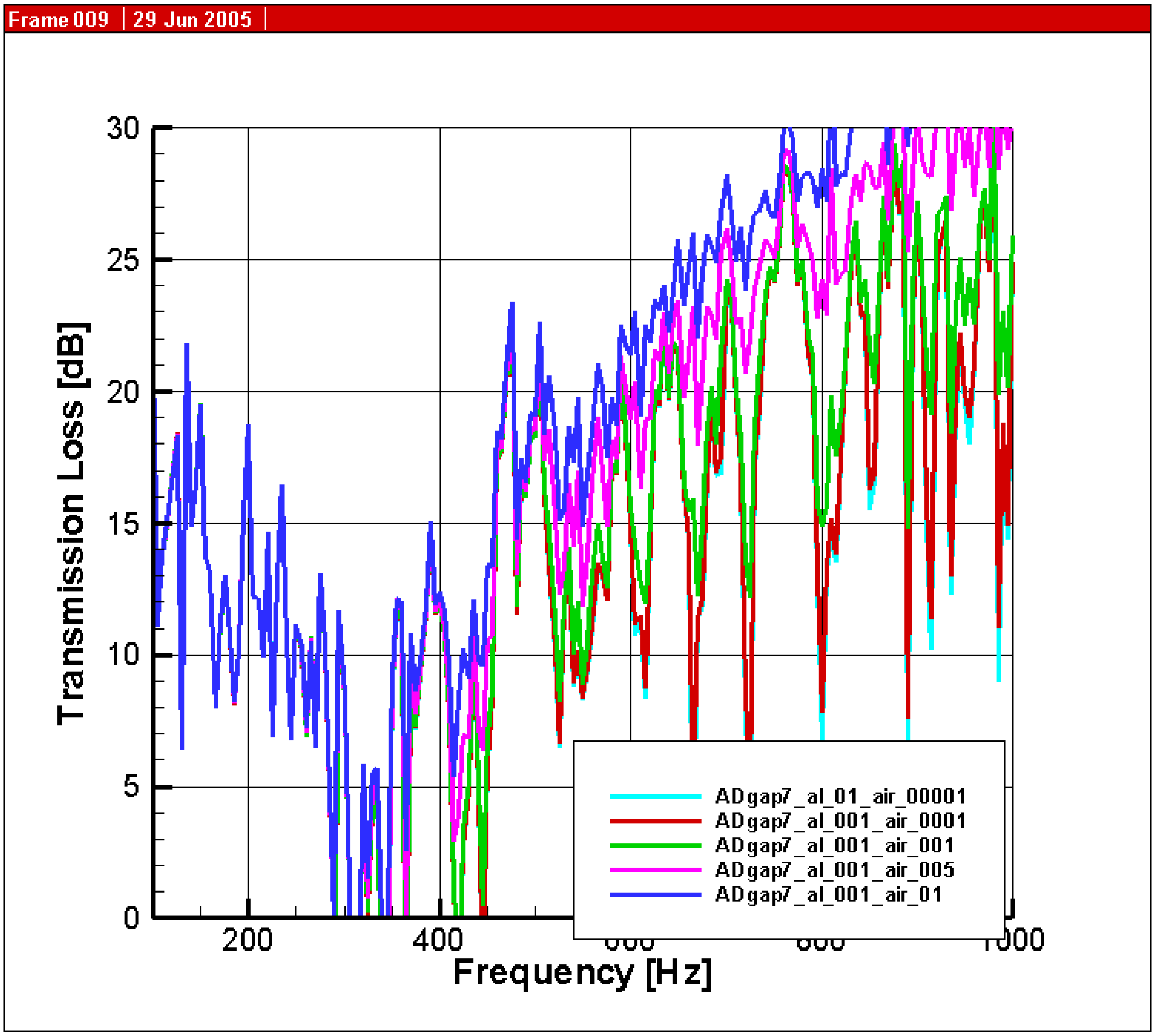


Figure 48. Transmission loss of a double wall configuration with 0.020 inch and 0.032 inch thick aluminum panels separated by an air gap of 1.75 inches having air damping coefficients of 0.0001, 0.001, 0.01, 0.05 and 0.1. The damping factor of the aluminum panels was 0.01 except for the air damping coefficient of 0.0001 for which case the aluminum panel damping coefficient equaled 0.1 Each transmission loss curve was predicted for one set of random sound incident input parameters.

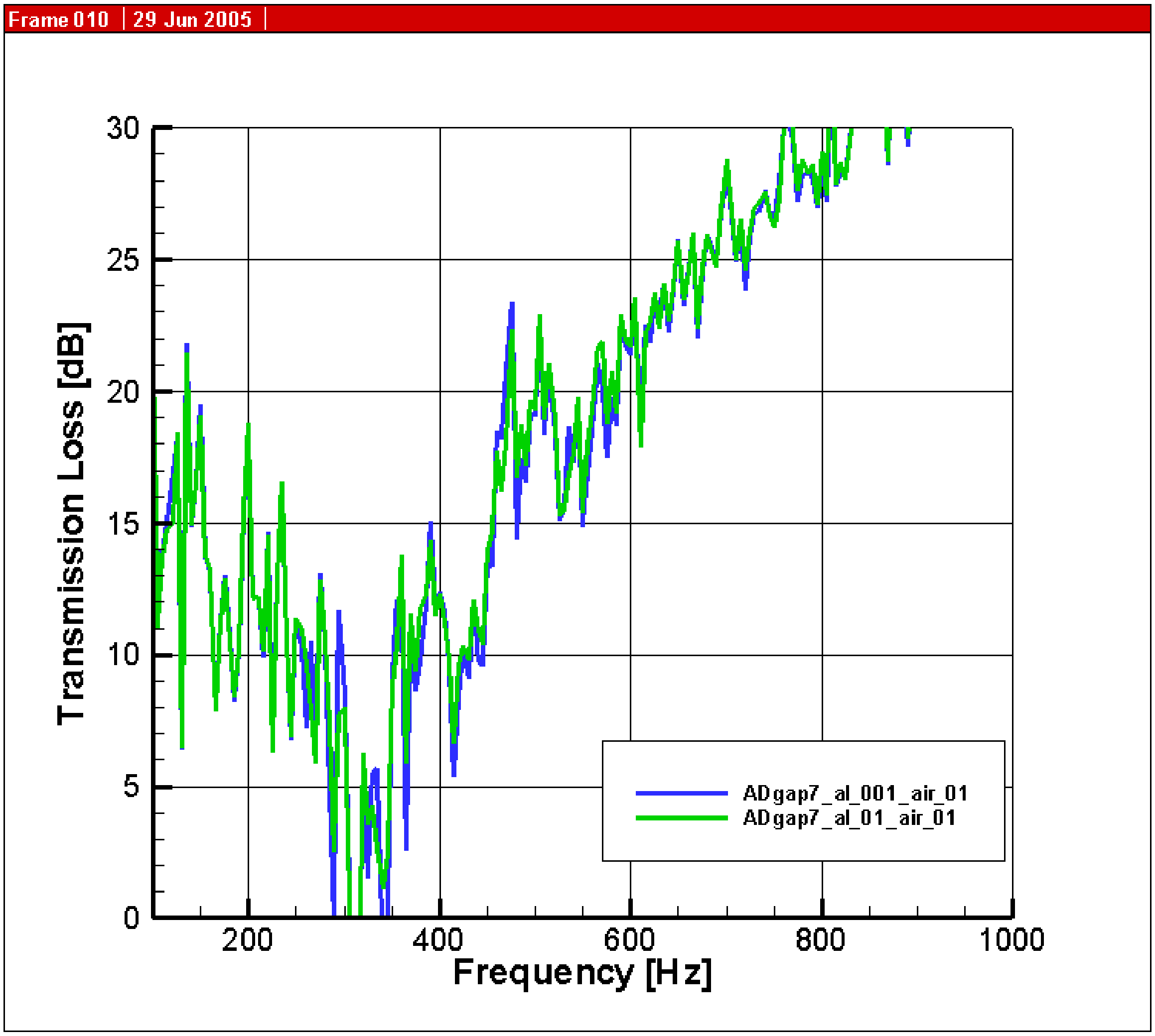


Figure 49. Transmission loss of a double wall configuration with 0.020 inch and 0.032 inch thick aluminum panels separated by an air gap of 1.75 inches having aluminum damping coefficients of 0.01 and 0.1. The air damping coefficient was 0.1. Each transmission loss curve was predicted for one set of random sound incident input parameters.

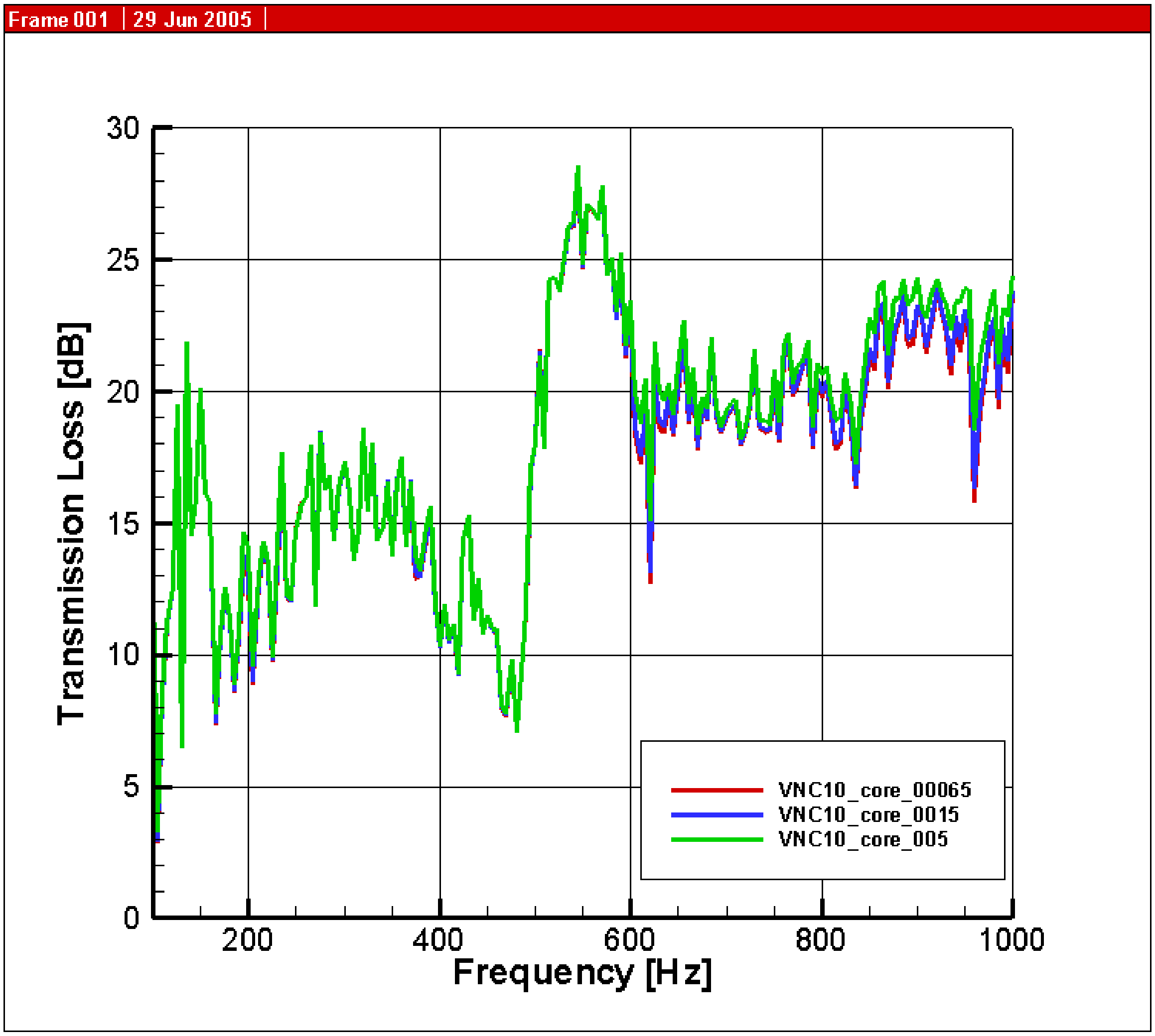


Figure 50. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with damping coefficients of 0.0065, 0.015 and 0.05. The core material properties are listed in Table 1. Each transmission loss curve was predicted for one set of random sound incident input parameters.

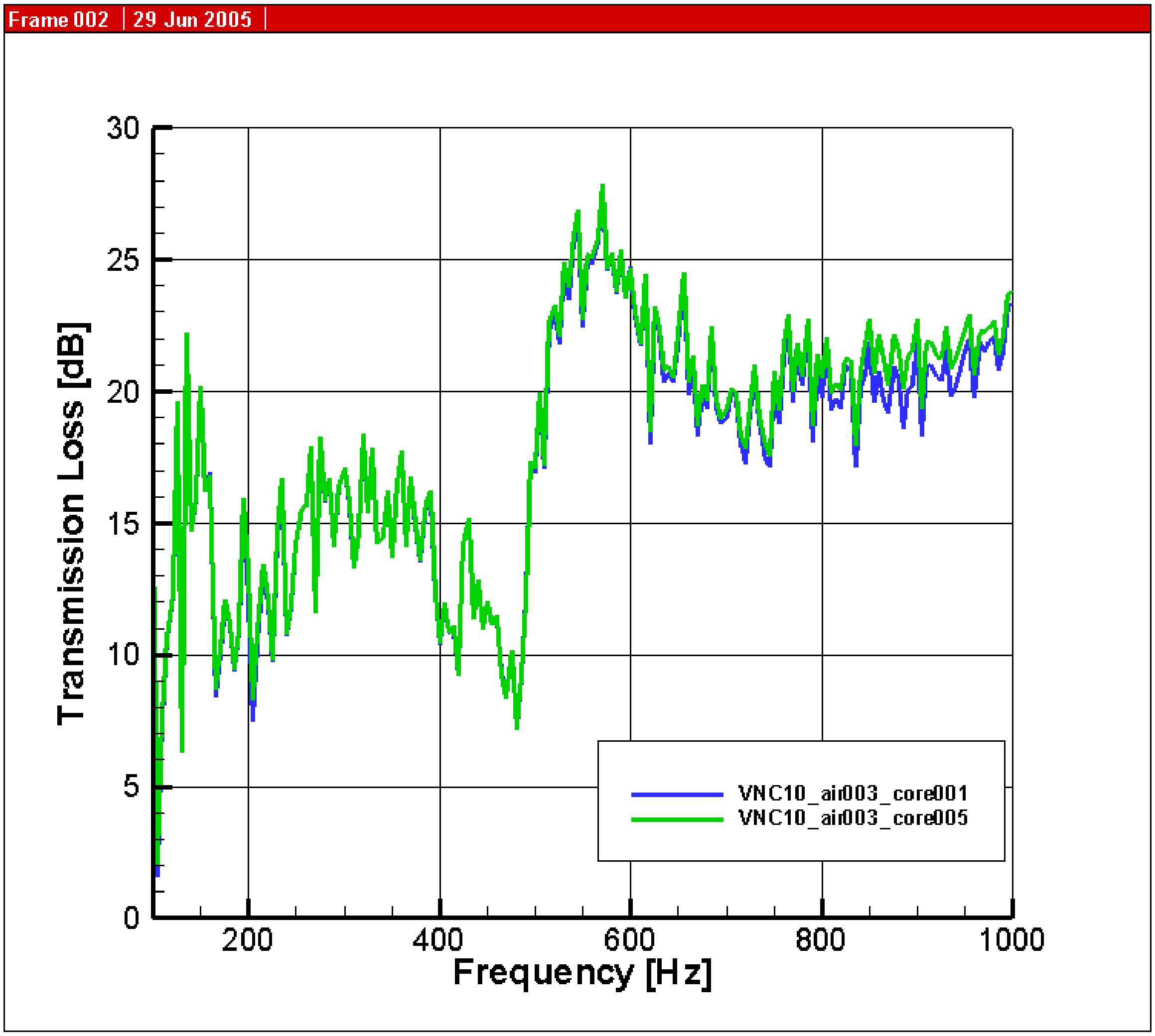


Figure 51. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with damping coefficients of 0.01, and 0.05. The air damping coefficient equaled 0.03. Each transmission loss curve was predicted for one set of random sound incident input parameters.

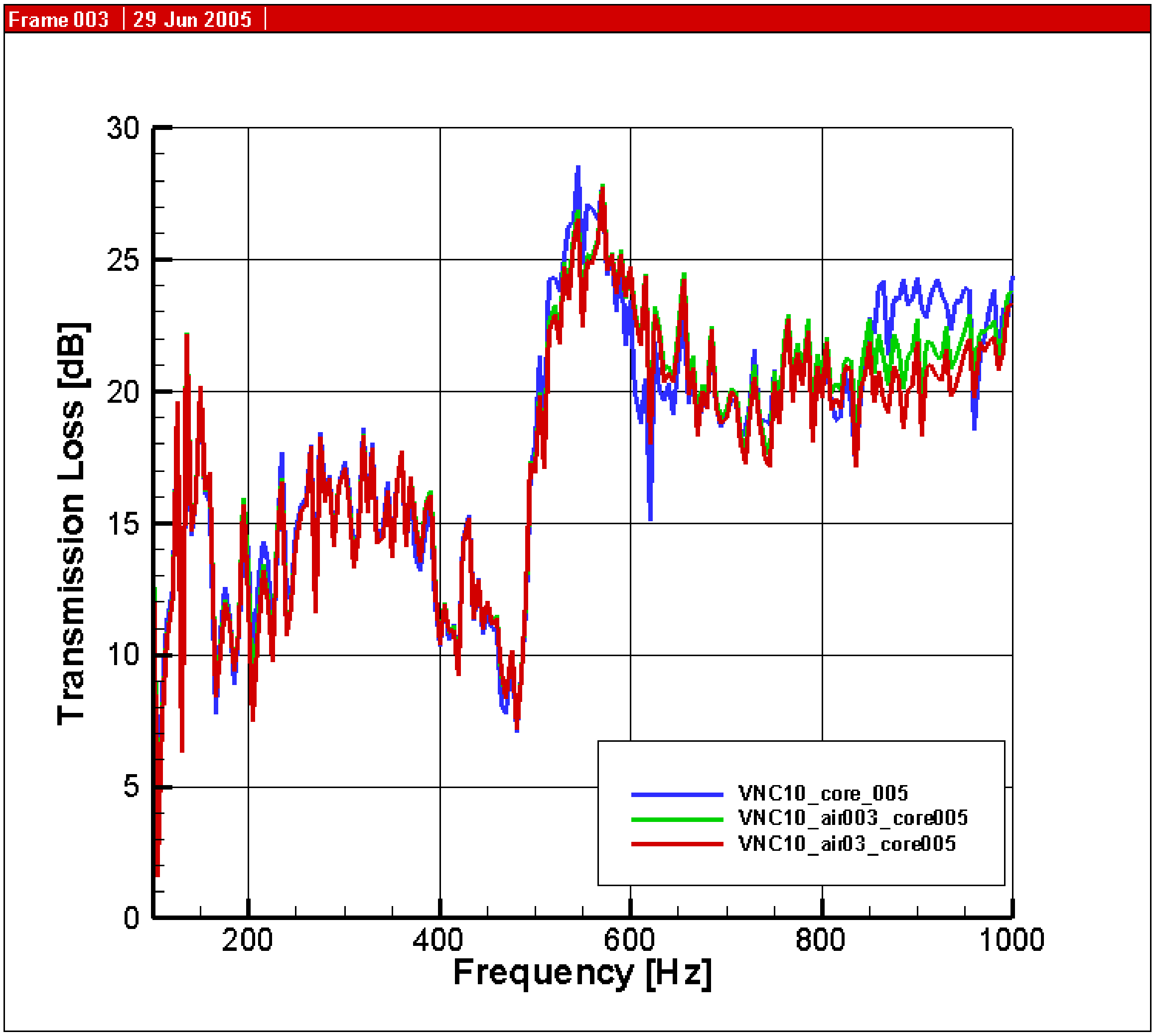


Figure 52. Transmission loss of honeycomb panels with nine 10 by 10 inch voids predicted for nomex cores with the same damping coefficient of 0.05 but different air damping coefficients of 0.03, 0.01 and 0.3. Each transmission loss curve was predicted for one set of random sound incident input parameters.

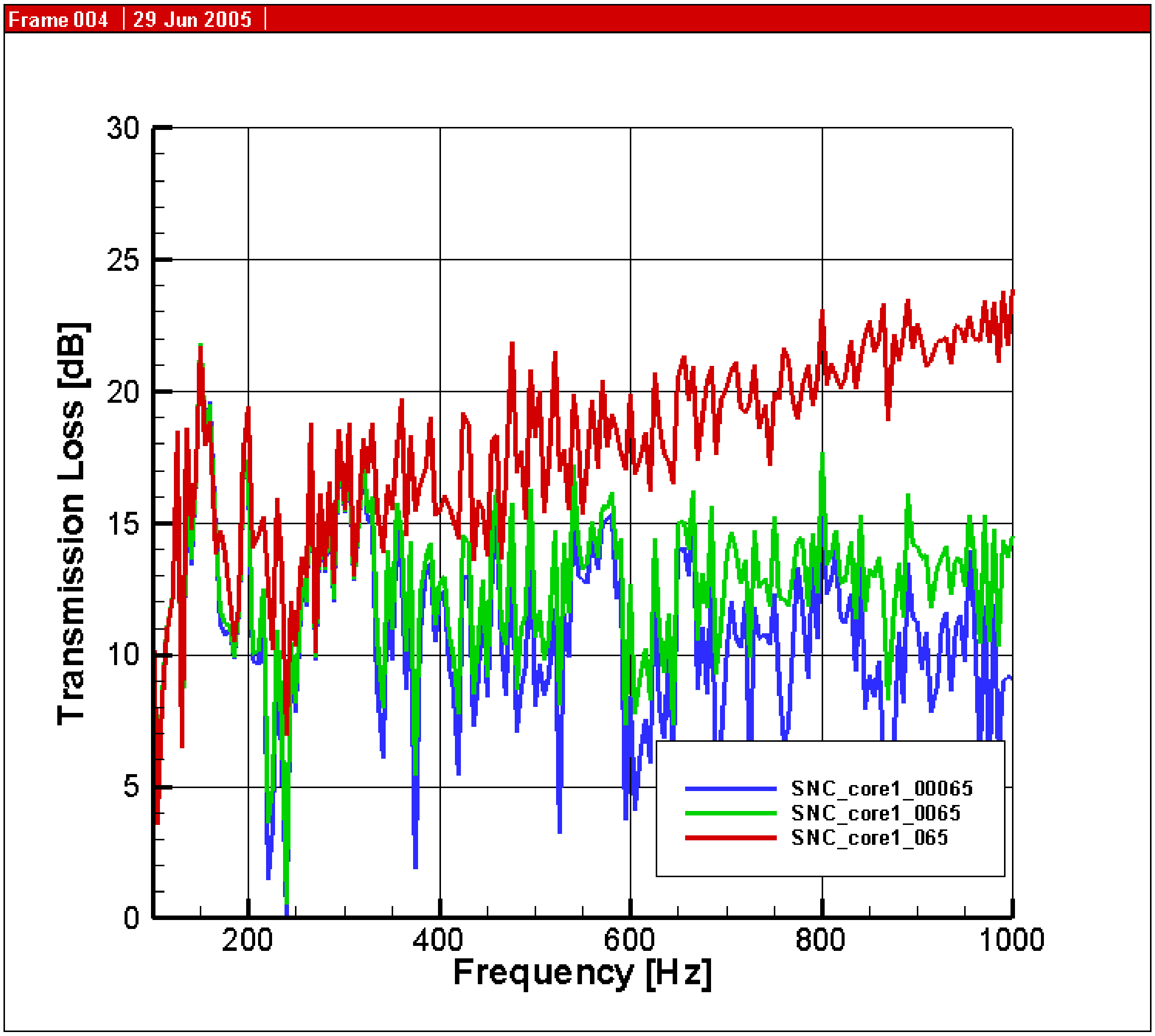


Figure 53. Transmission loss of nomex core honeycomb panels for core damping coefficients of 0.065, 0.065, and 0.65. The core material properties are listed in Table 1. Each transmission loss curve was predicted for one set of random sound incident input parameters.

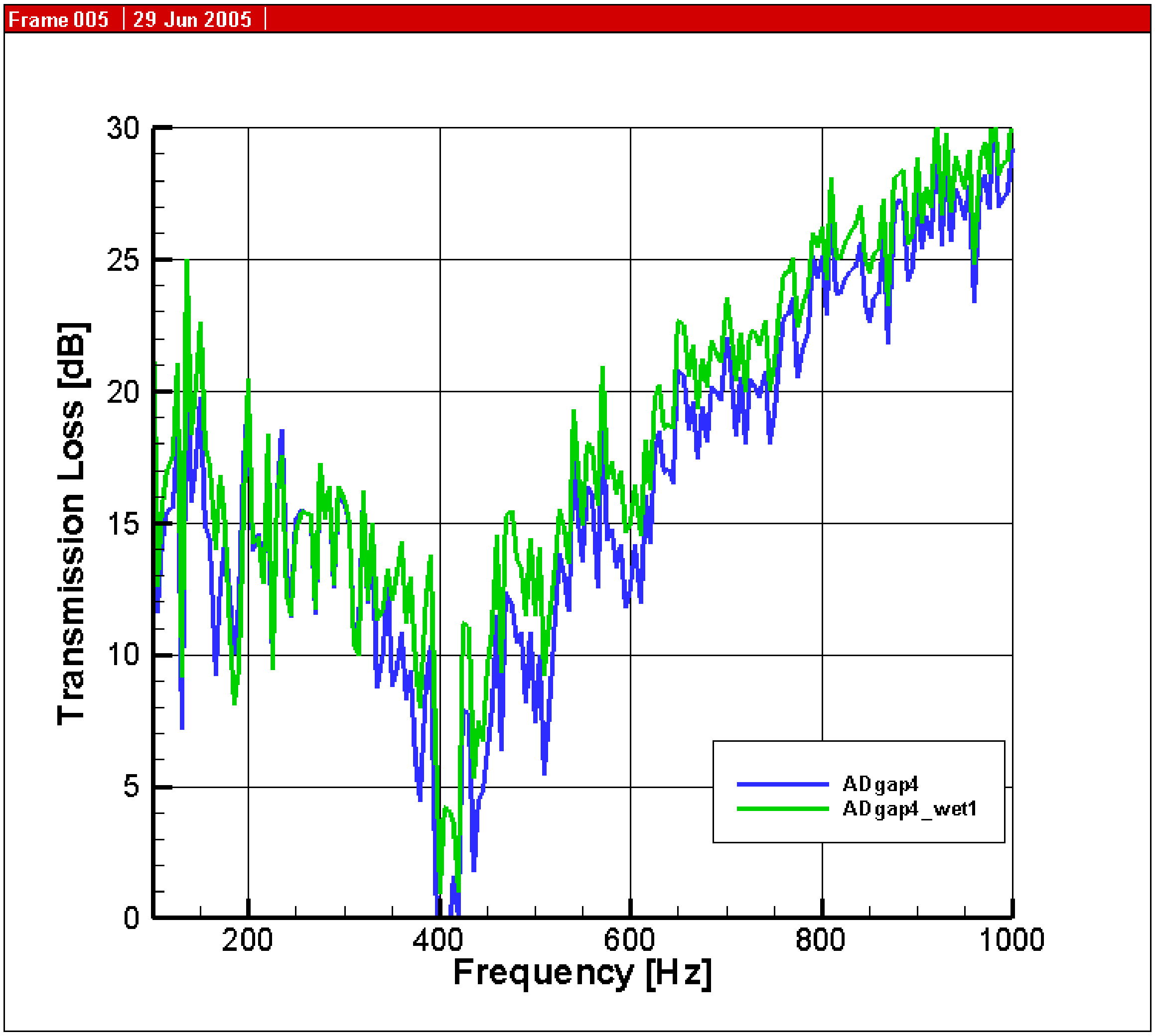


Figure 54. Transmission loss of a double wall configuration with 0.020 inch and 0.032 inch thick aluminum panels separated by an air gap of 1.00 inch for in-vacuo conditions on either side of the double panel and for layers of one meter thick air. Each transmission loss curve was predicted for one set of random sound incident input parameters.

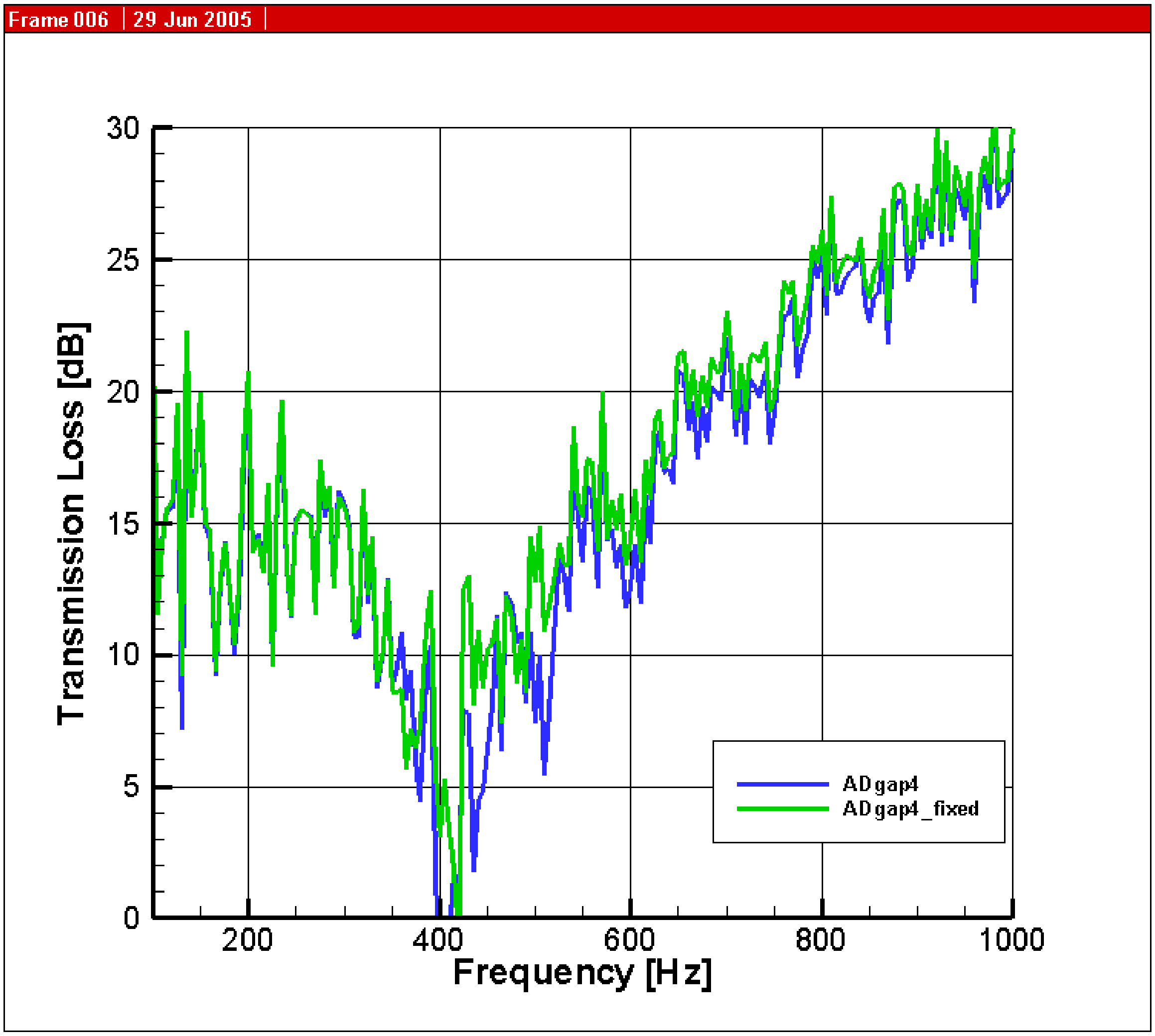


Figure 55. Transmission loss of a double wall configuration with 0.020 inch and 0.032 inch thick aluminum panels separated by an air gap of 1.00 inch for boundary conditions imposed by the steel frame compared to fixed boundary conditions imposed on both panels. Each transmission loss curve was predicted for one set of random sound incident input parameters.

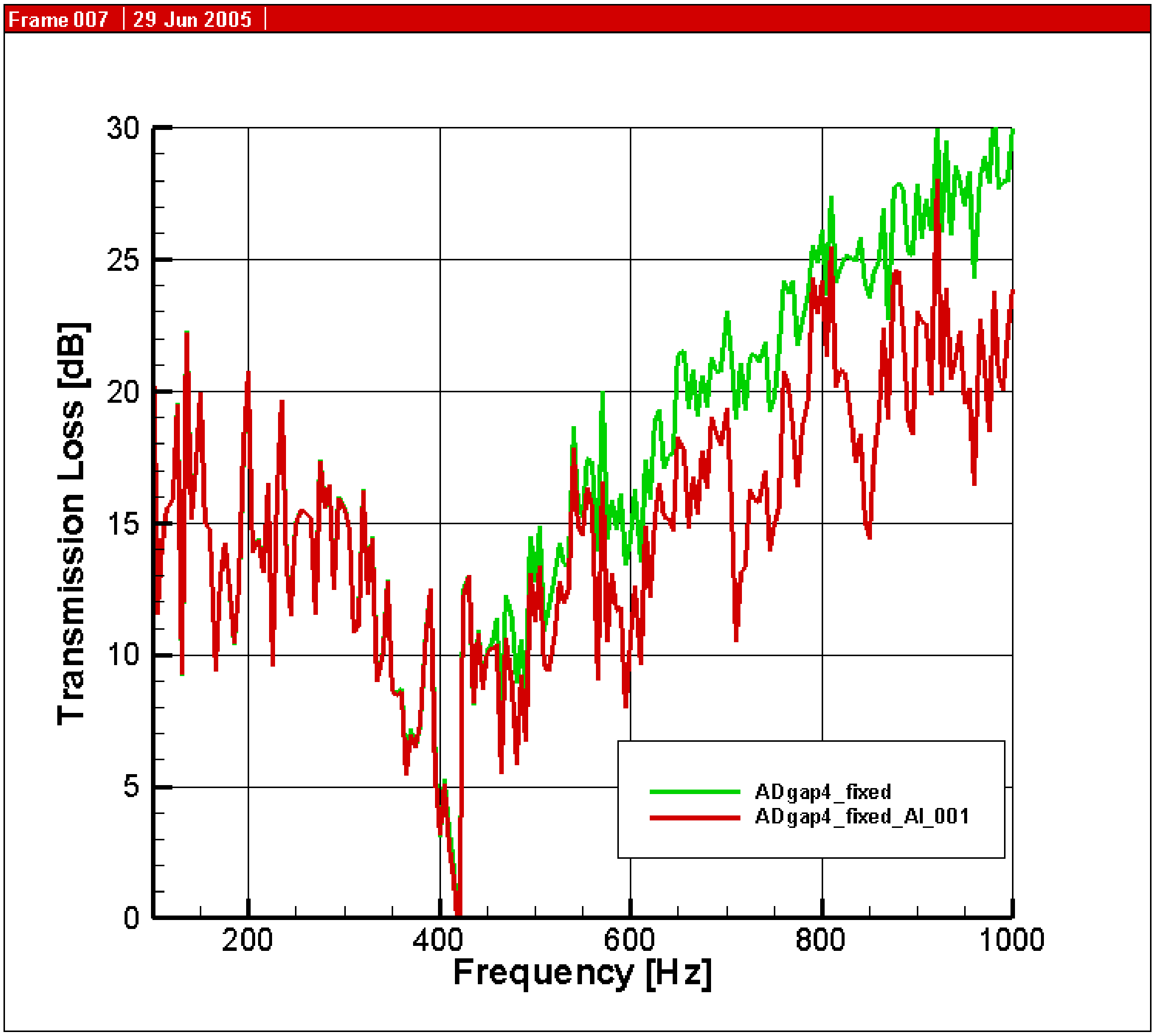


Figure 56. Transmission loss of a double wall configuration with 0.020 inch and 0.032 inch thick aluminum panels separated by an air gap of 1.00 inch for fixed boundary conditions imposed on both panels and aluminum damping coefficients of 0.1 and 0.01. Each transmission loss curve was predicted for one set of random sound incident input parameters.

APPENDIX A

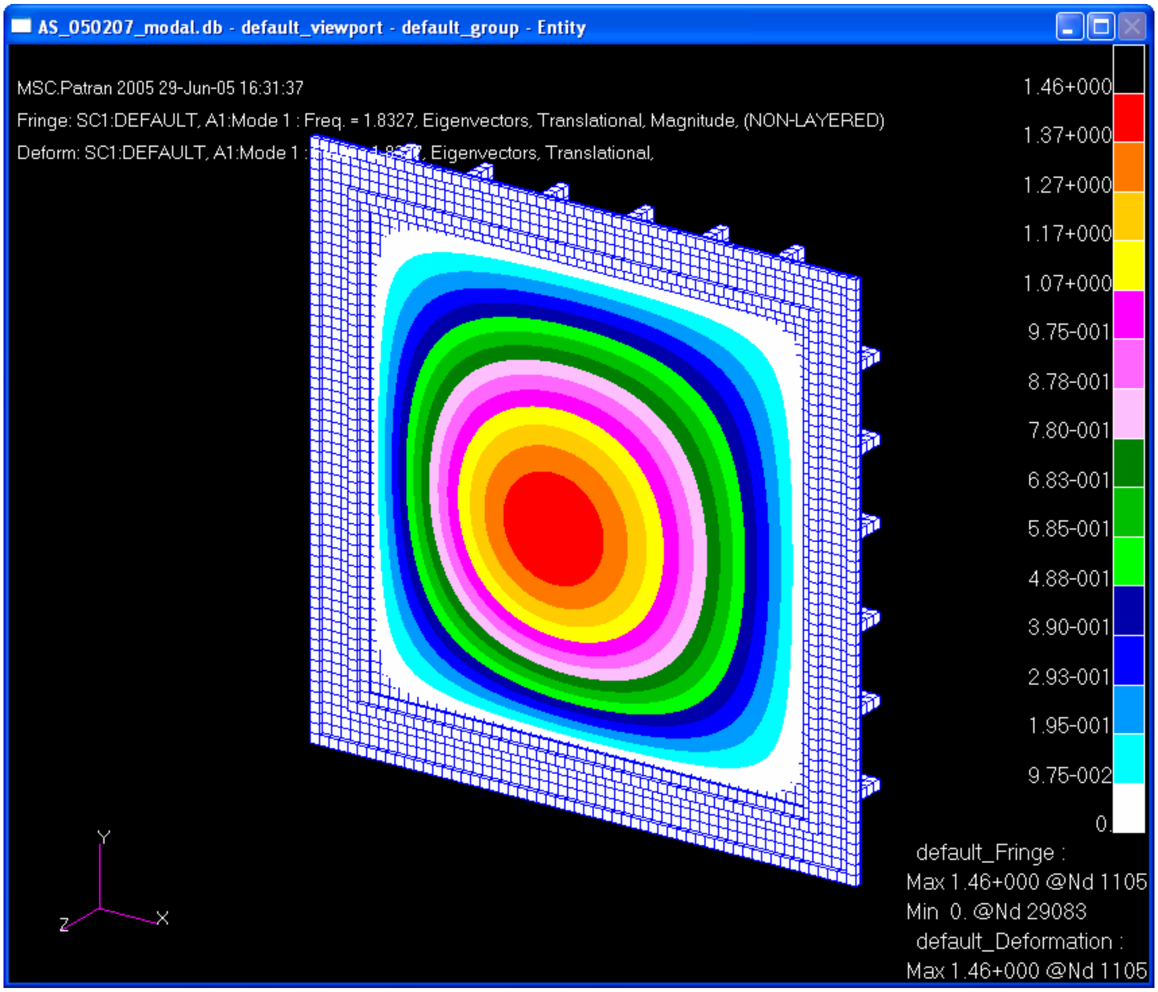


Figure A1. Modal analysis of a single aluminum panel, Mode 1.

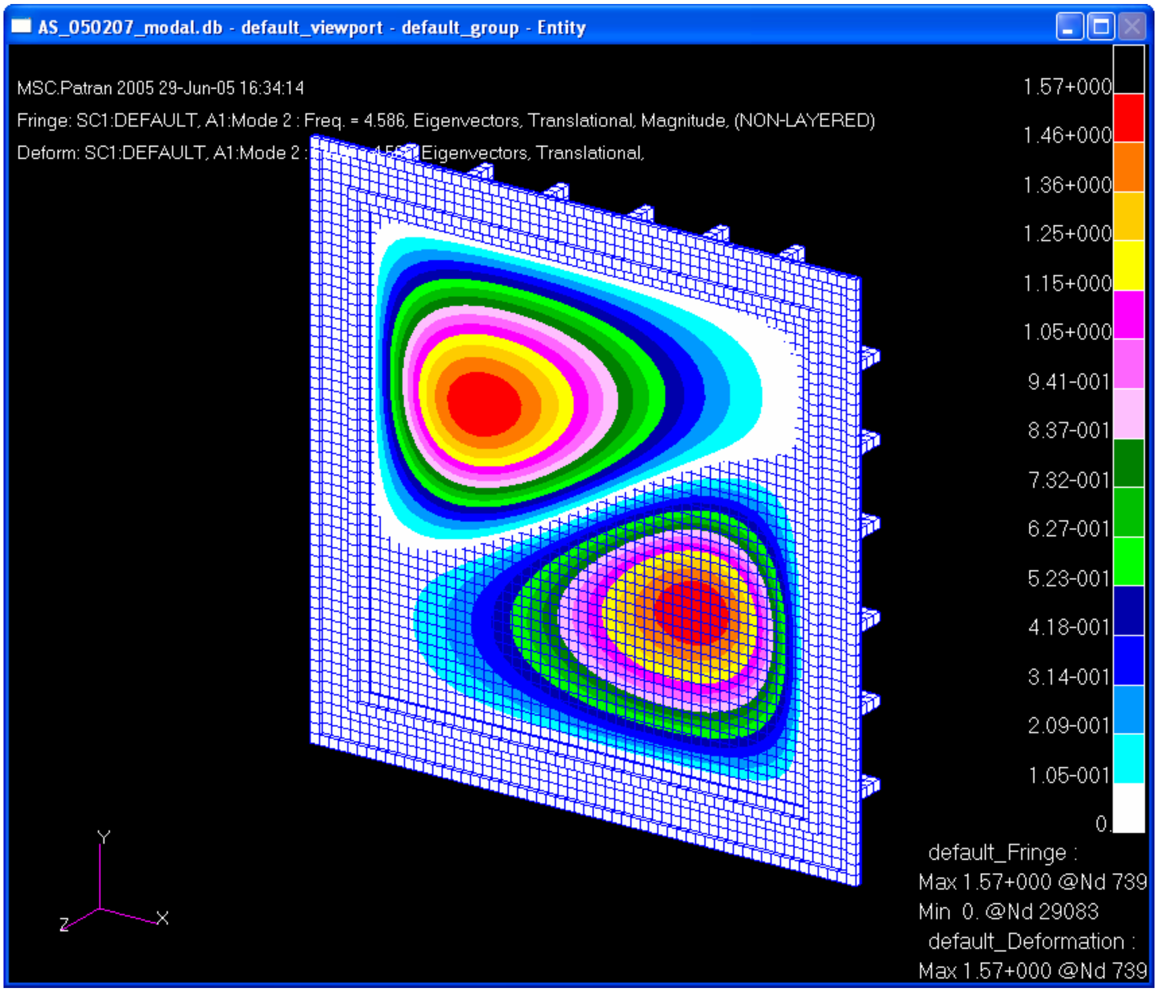


Figure A2. Modal analysis of a single aluminum panel, Mode 2.

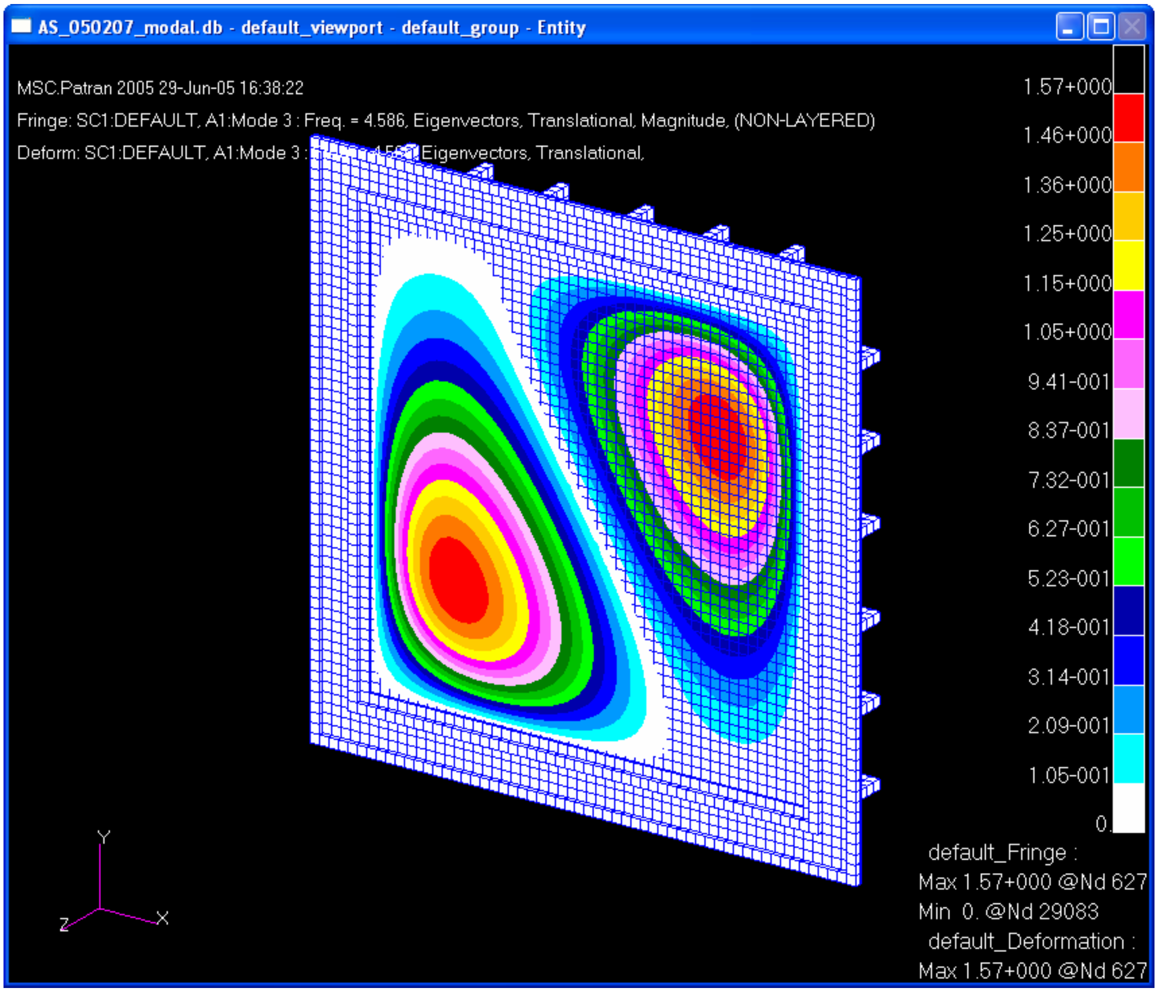


Figure A3. Modal analysis of a single aluminum panel, Mode 3.

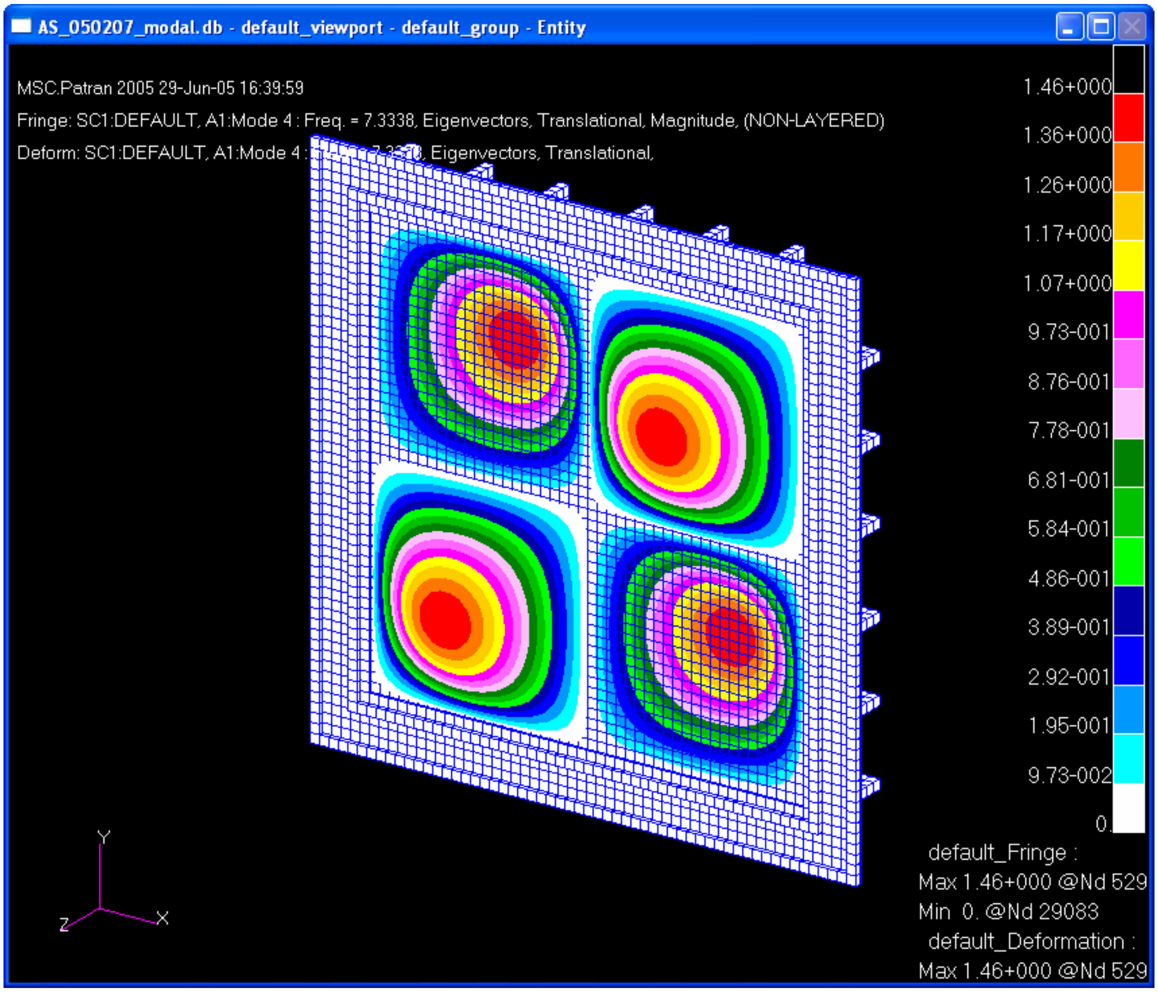


Figure A4. Modal analysis of a single aluminum panel, Mode 4.

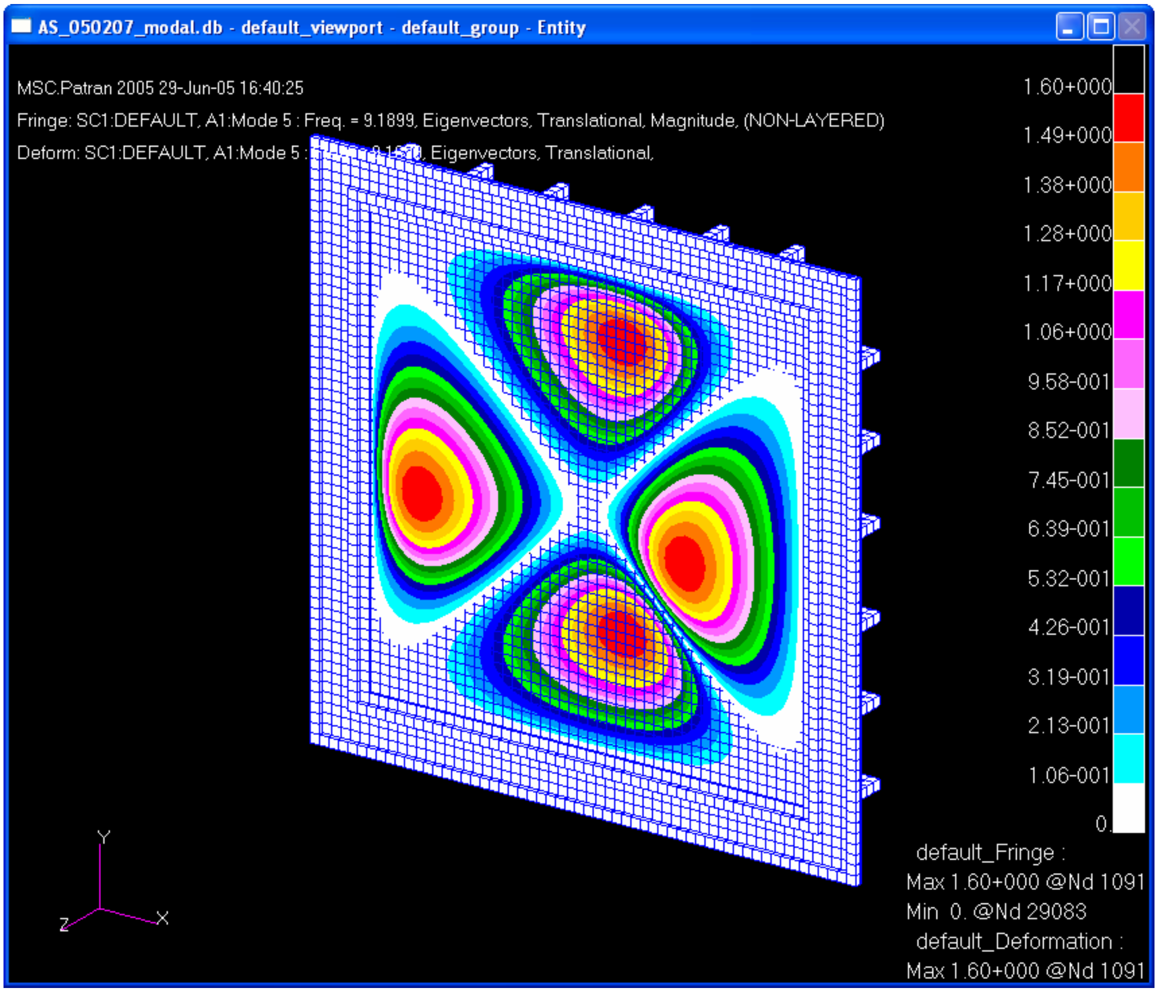


Figure A5. Modal analysis of a single aluminum panel, Mode 5.

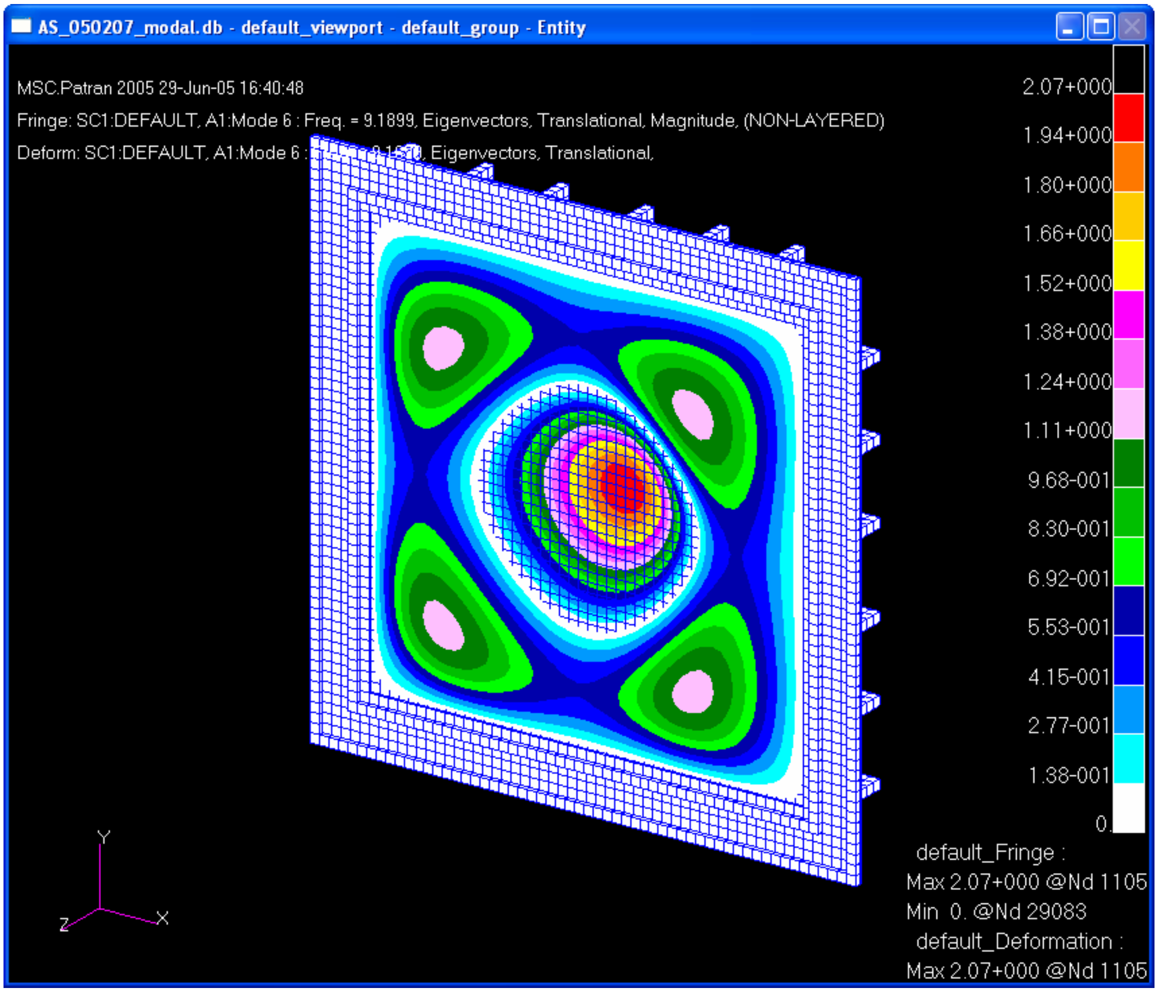


Figure A6. Modal analysis of a single aluminum panel, Mode 6.

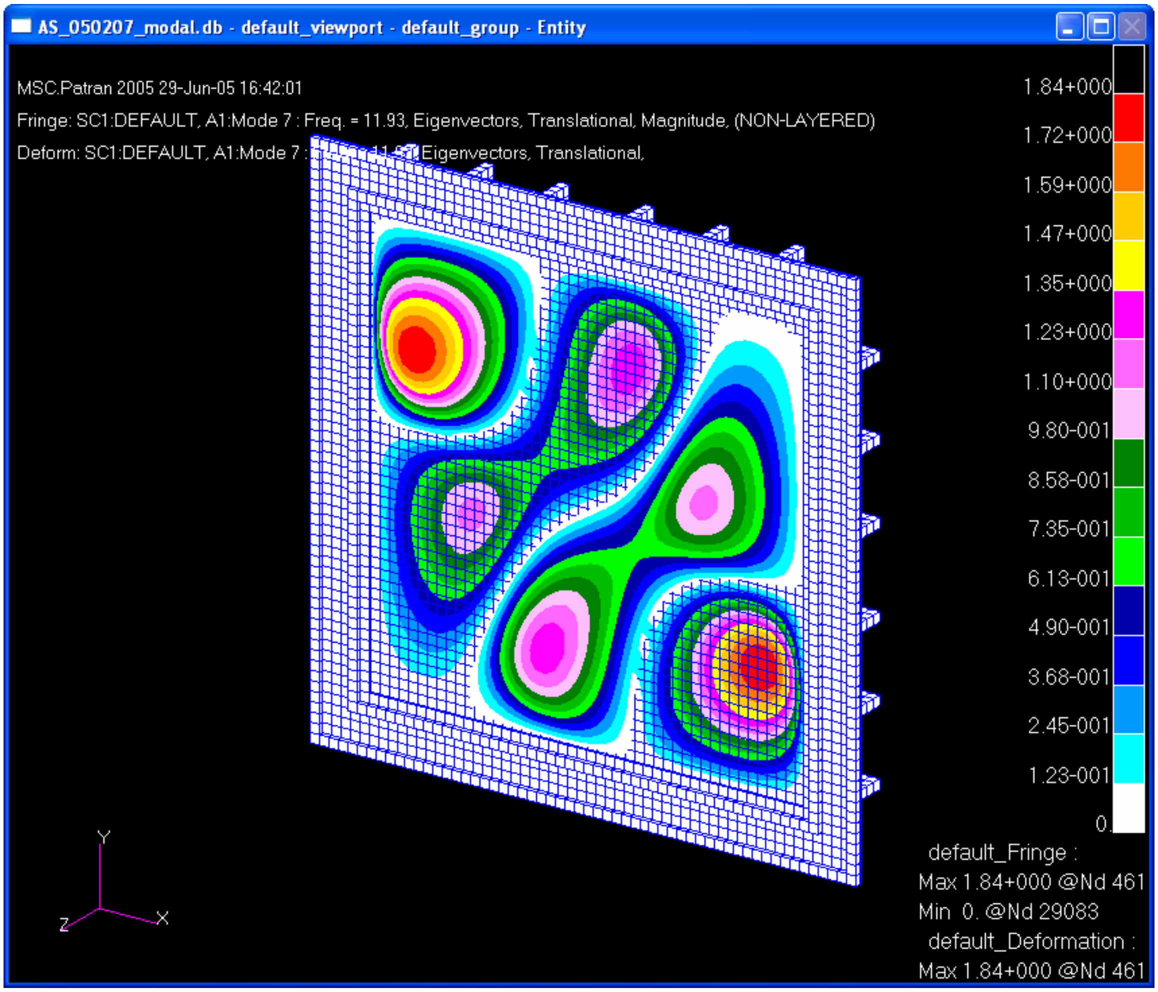


Figure A7. Modal analysis of a single aluminum panel, Mode 7.

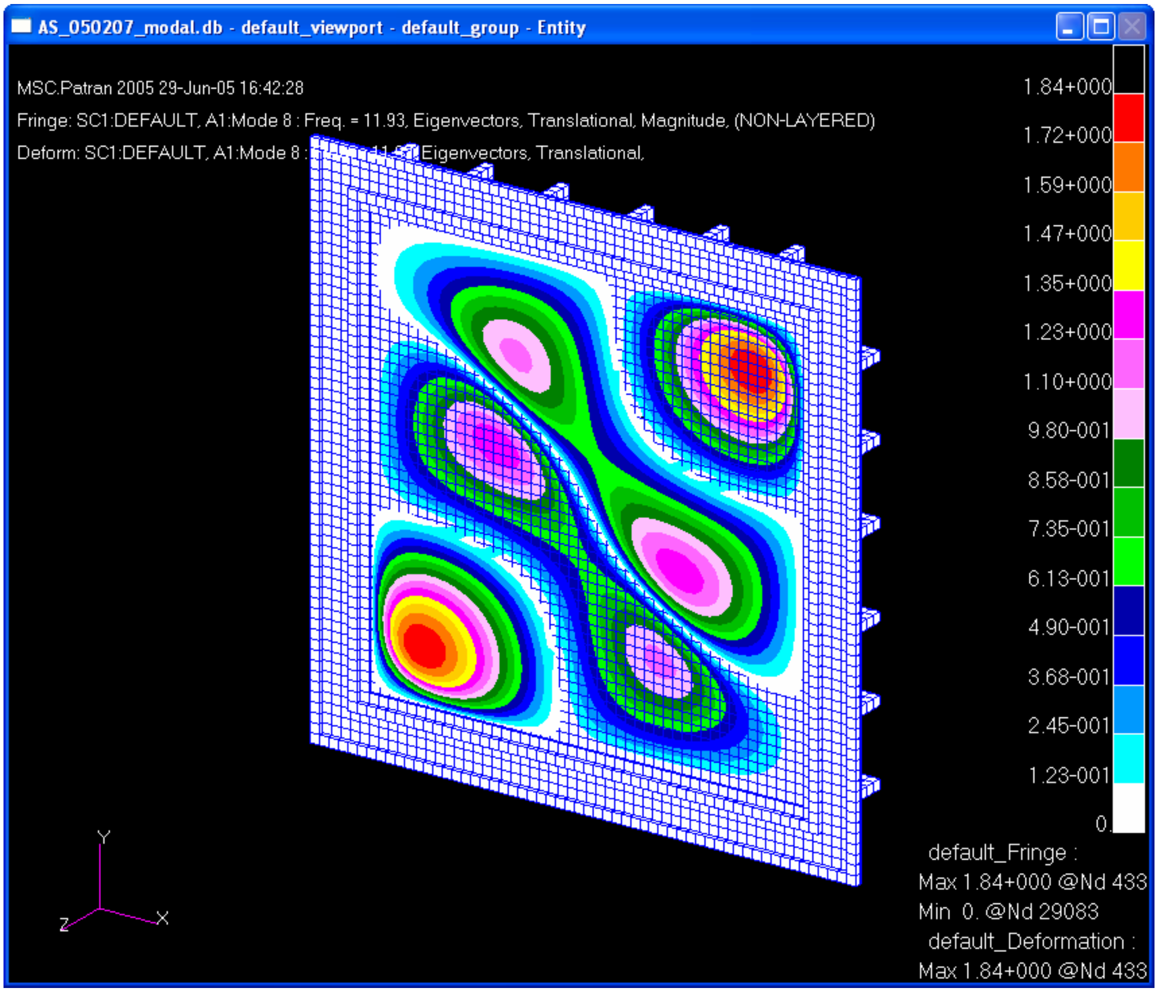


Figure A8. Modal analysis of a single aluminum panel, Mode 8.

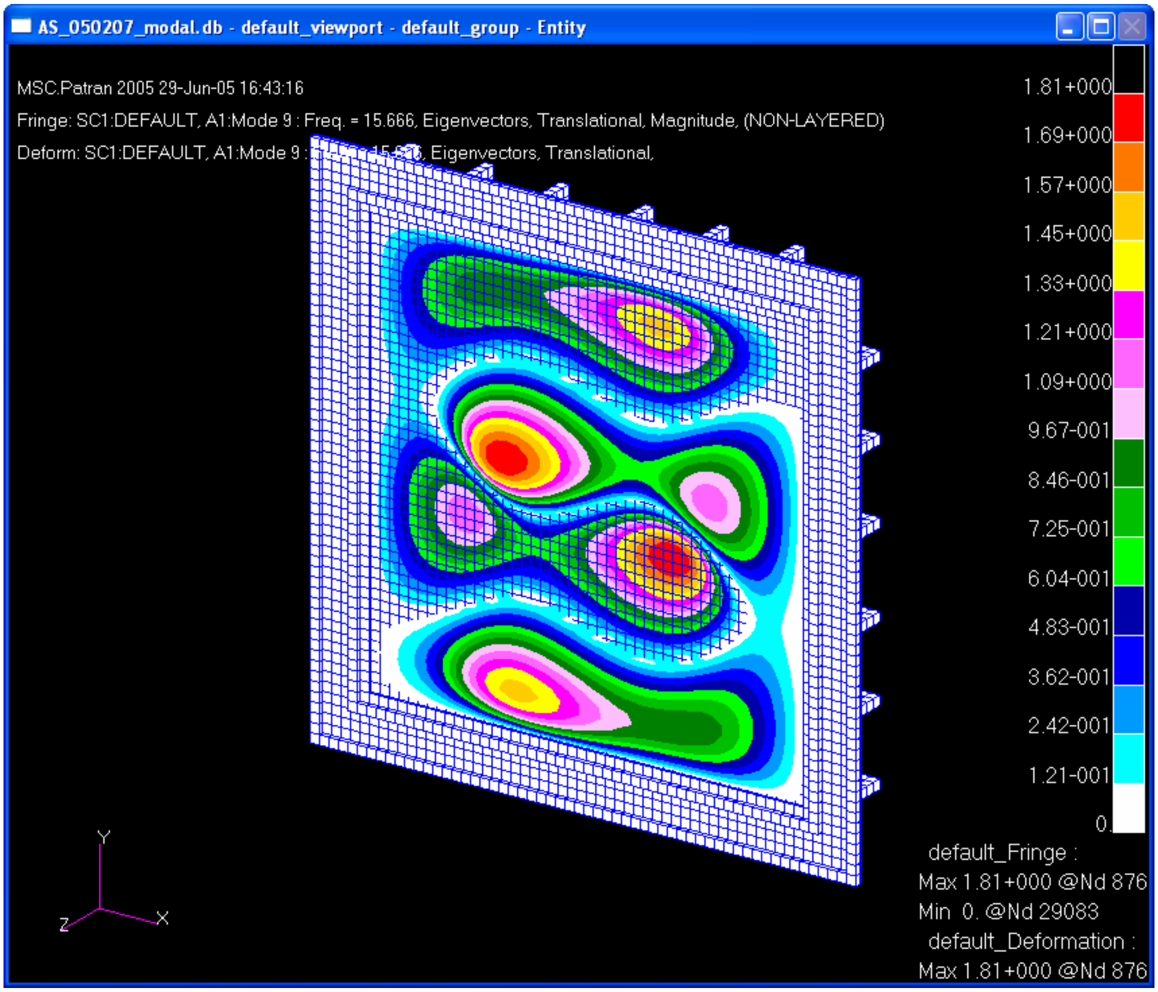


Figure A9. Modal analysis of a single aluminum panel, Mode 9.

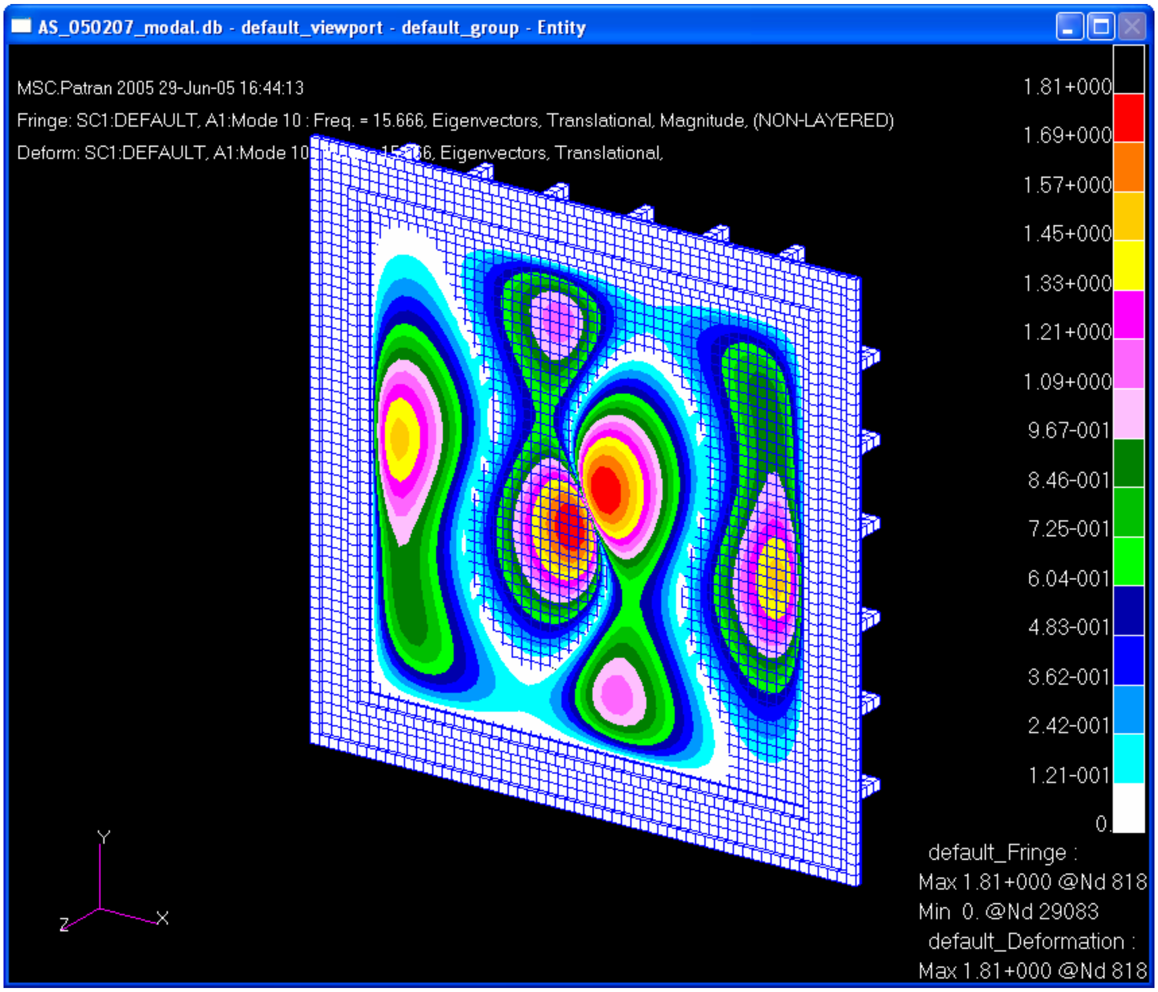


Figure A10. Modal analysis of a single aluminum panel, Mode 10.

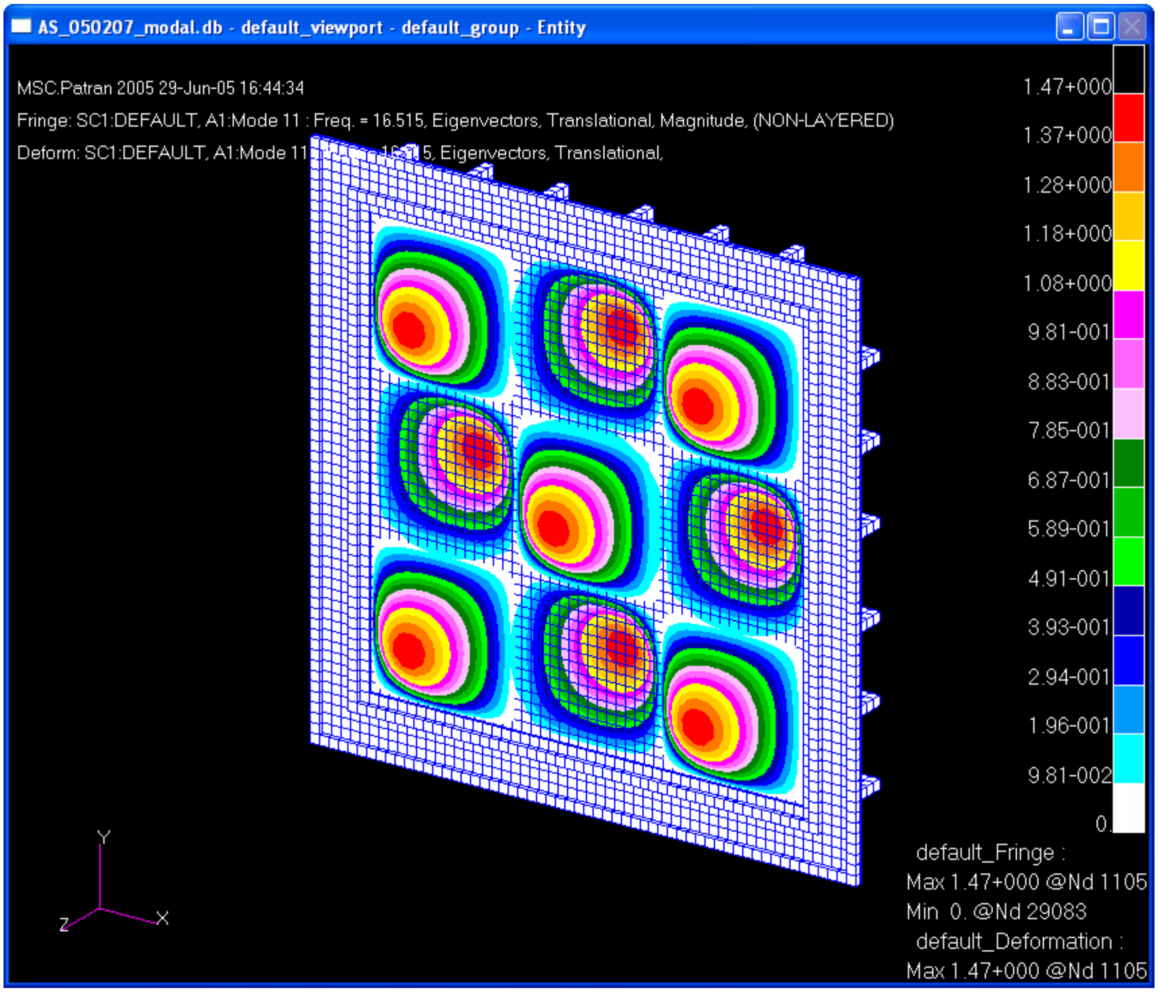


Figure A11. Modal analysis of a single aluminum panel, Mode 11.

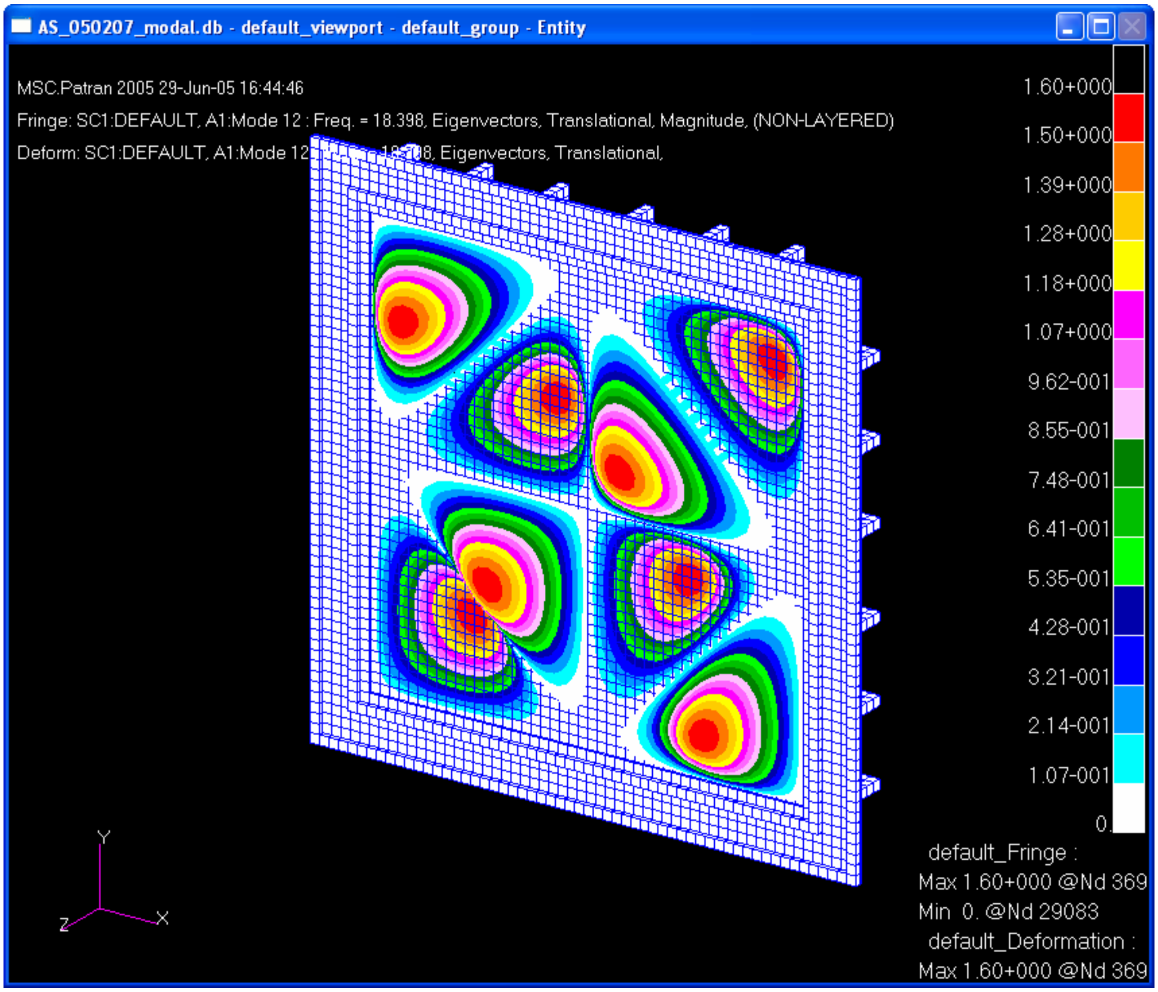


Figure A12. Modal analysis of a single aluminum panel, Mode 12.

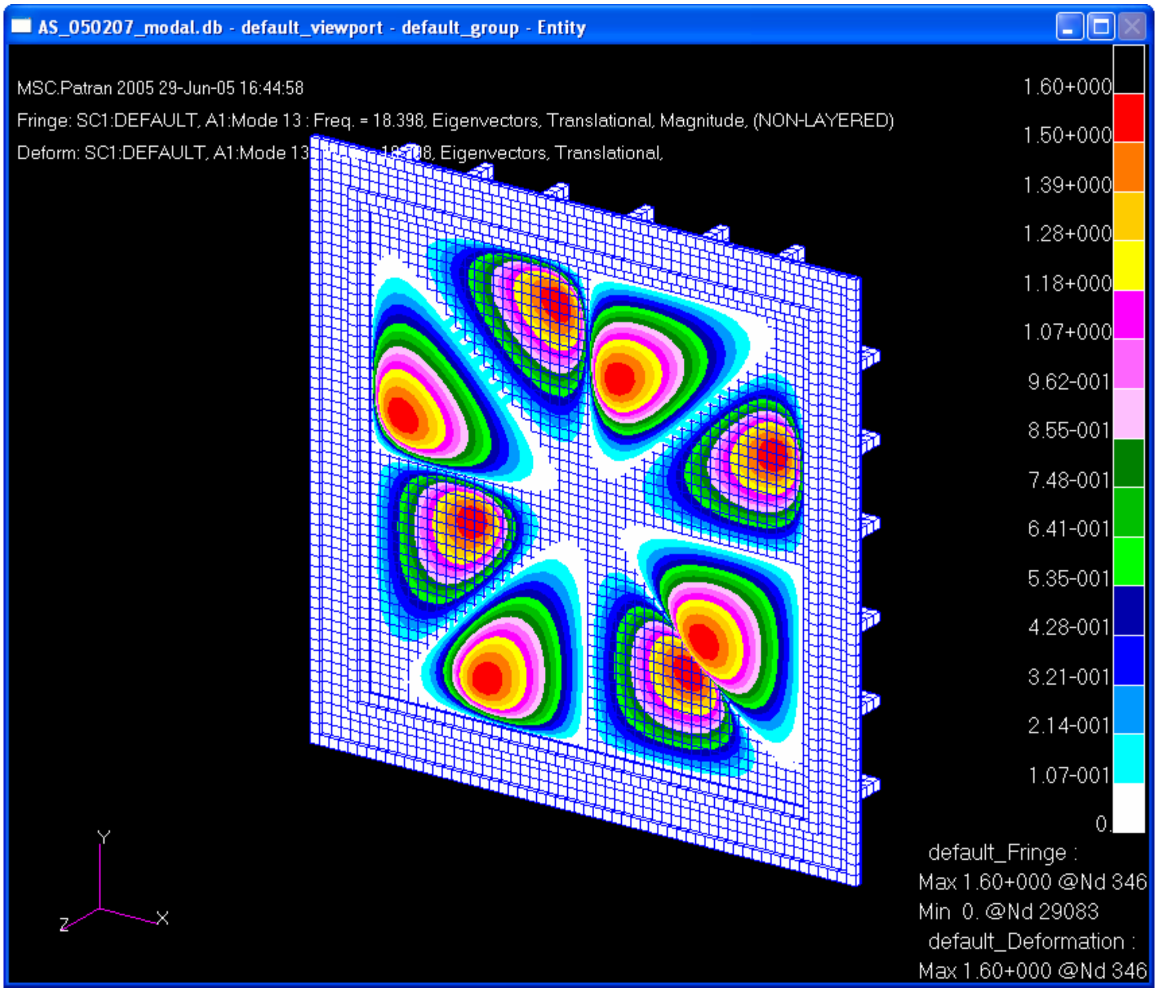


Figure A13. Modal analysis of a single aluminum panel, Mode 13.

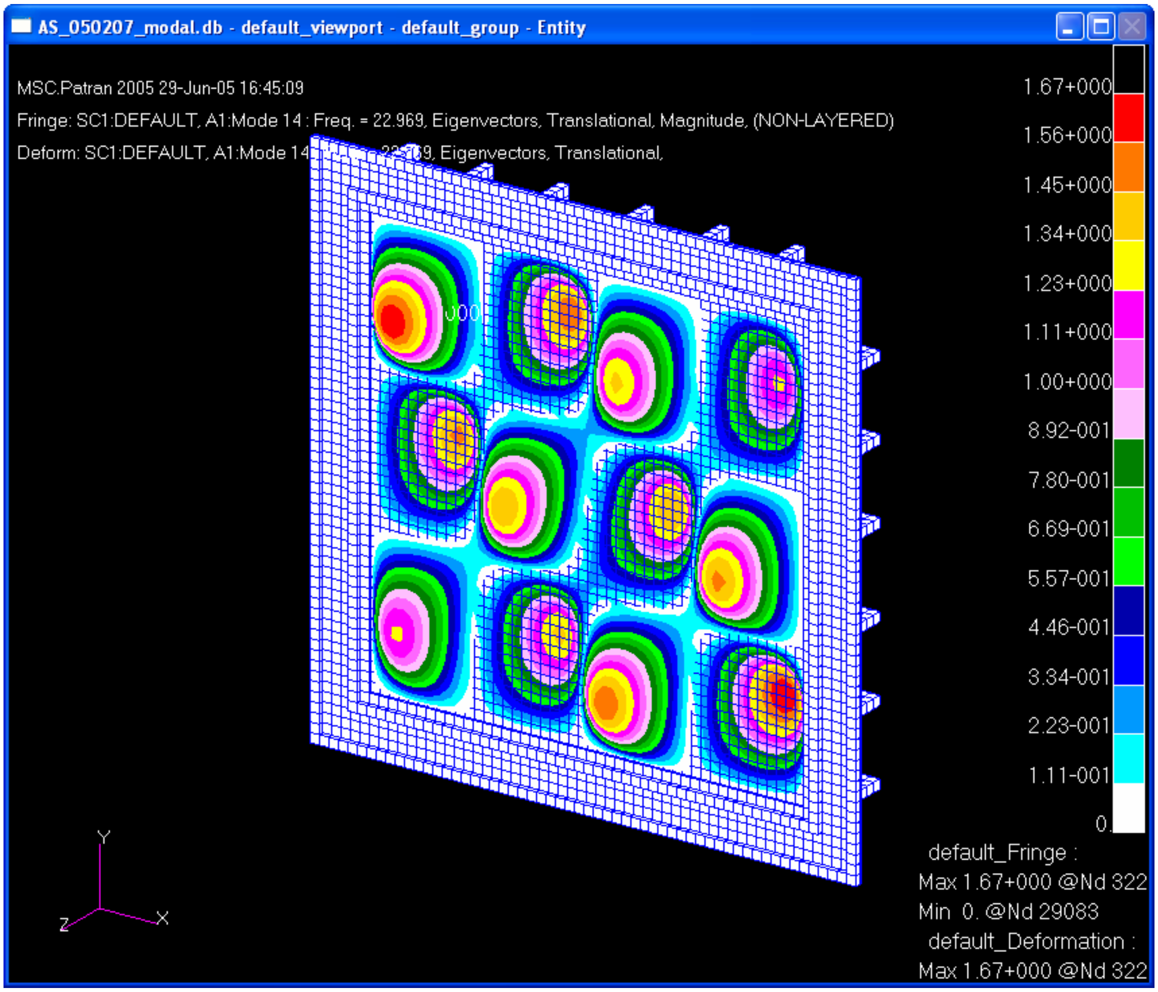


Figure A14. Modal analysis of a single aluminum panel, Mode 14.

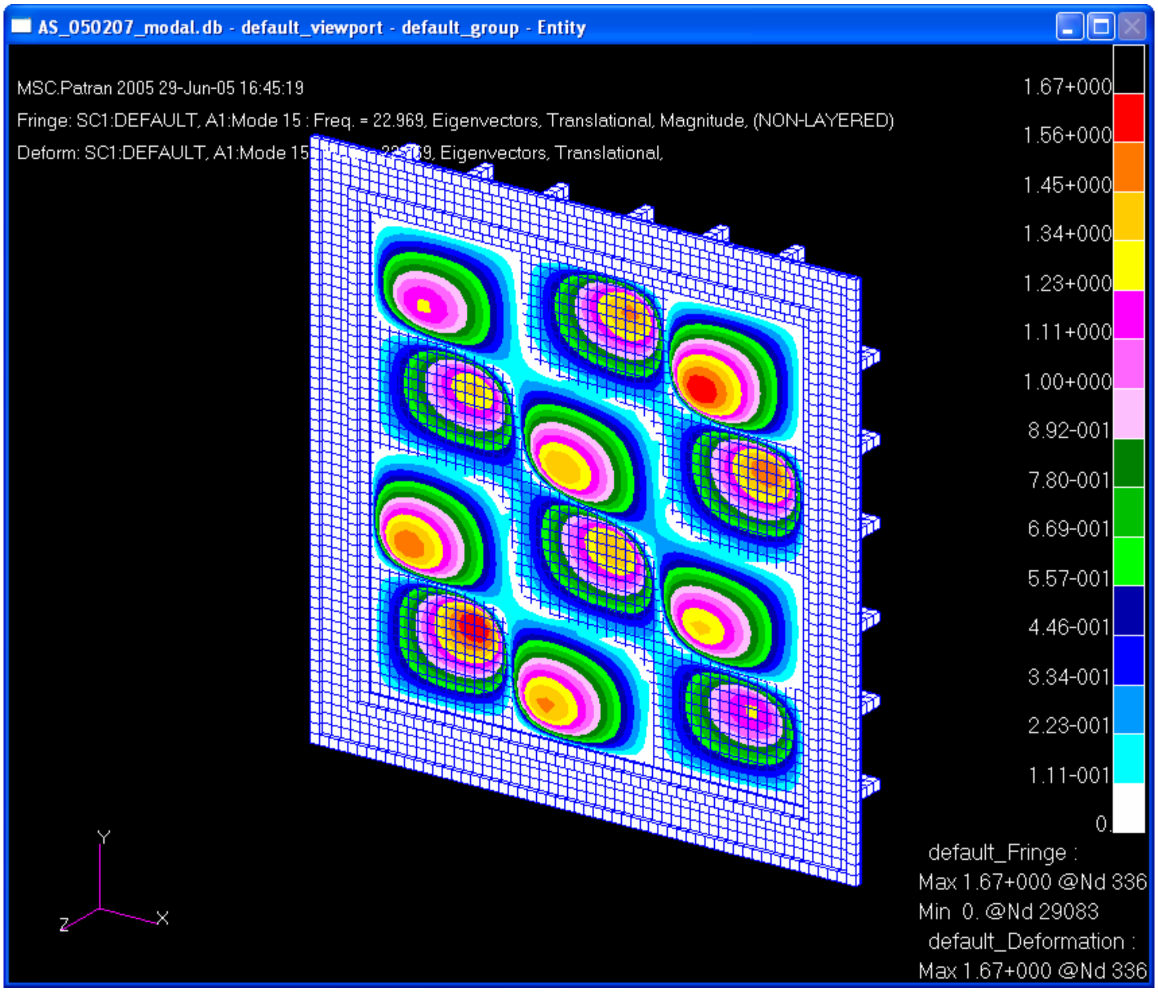


Figure A15. Modal analysis of a single aluminum panel, Mode 15.

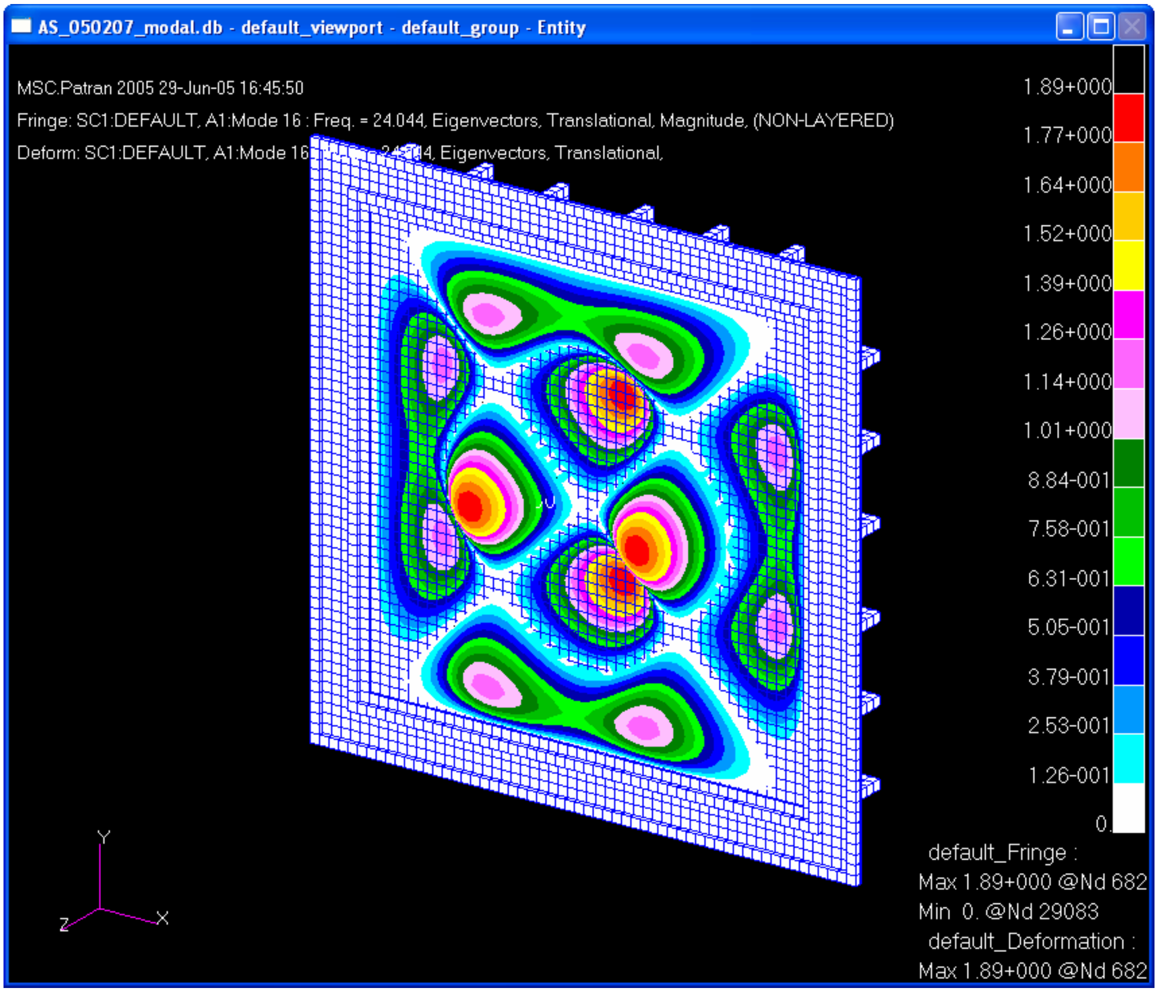


Figure A16. Modal analysis of a single aluminum panel, Mode 16.

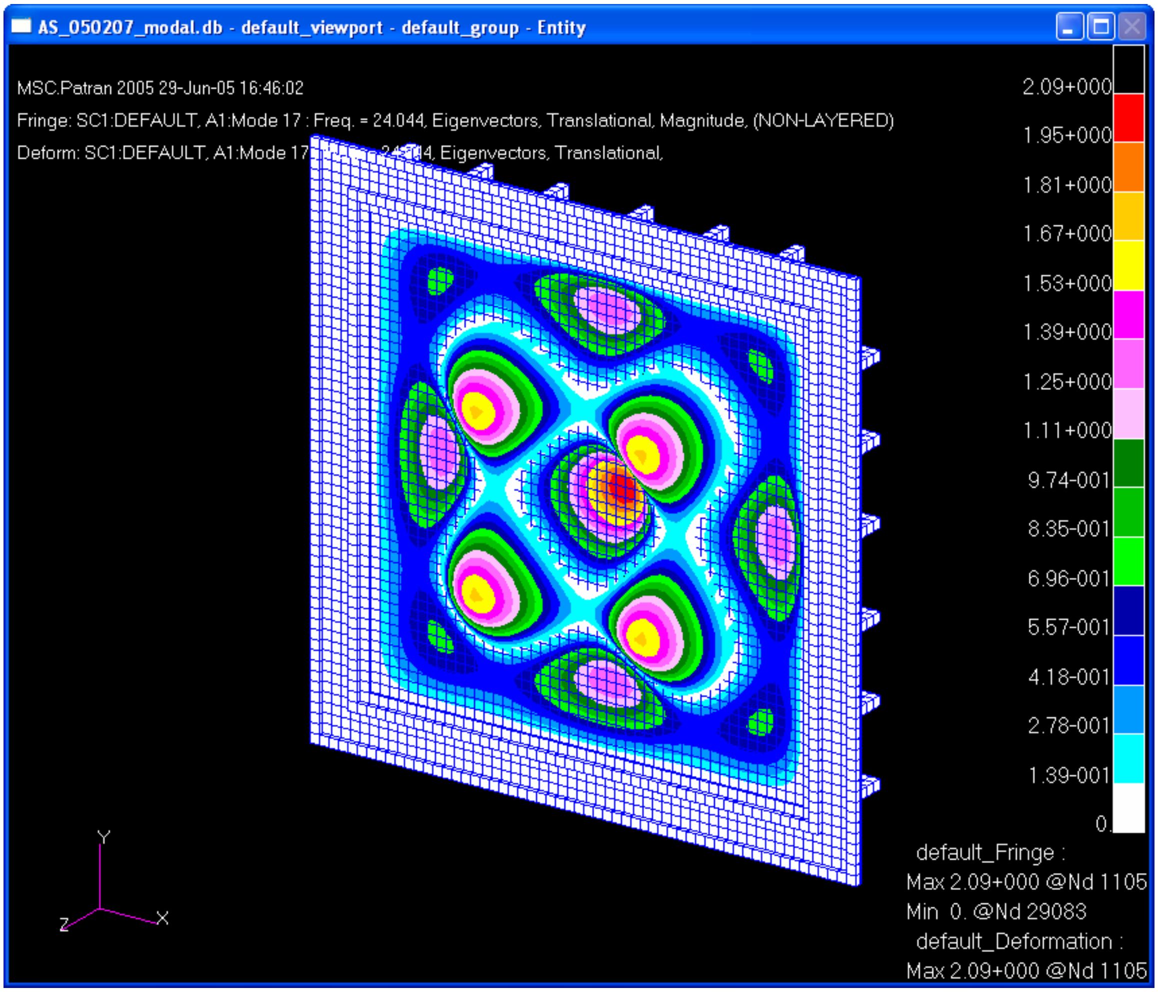


Figure A17. Modal analysis of a single aluminum panel, Mode 17.

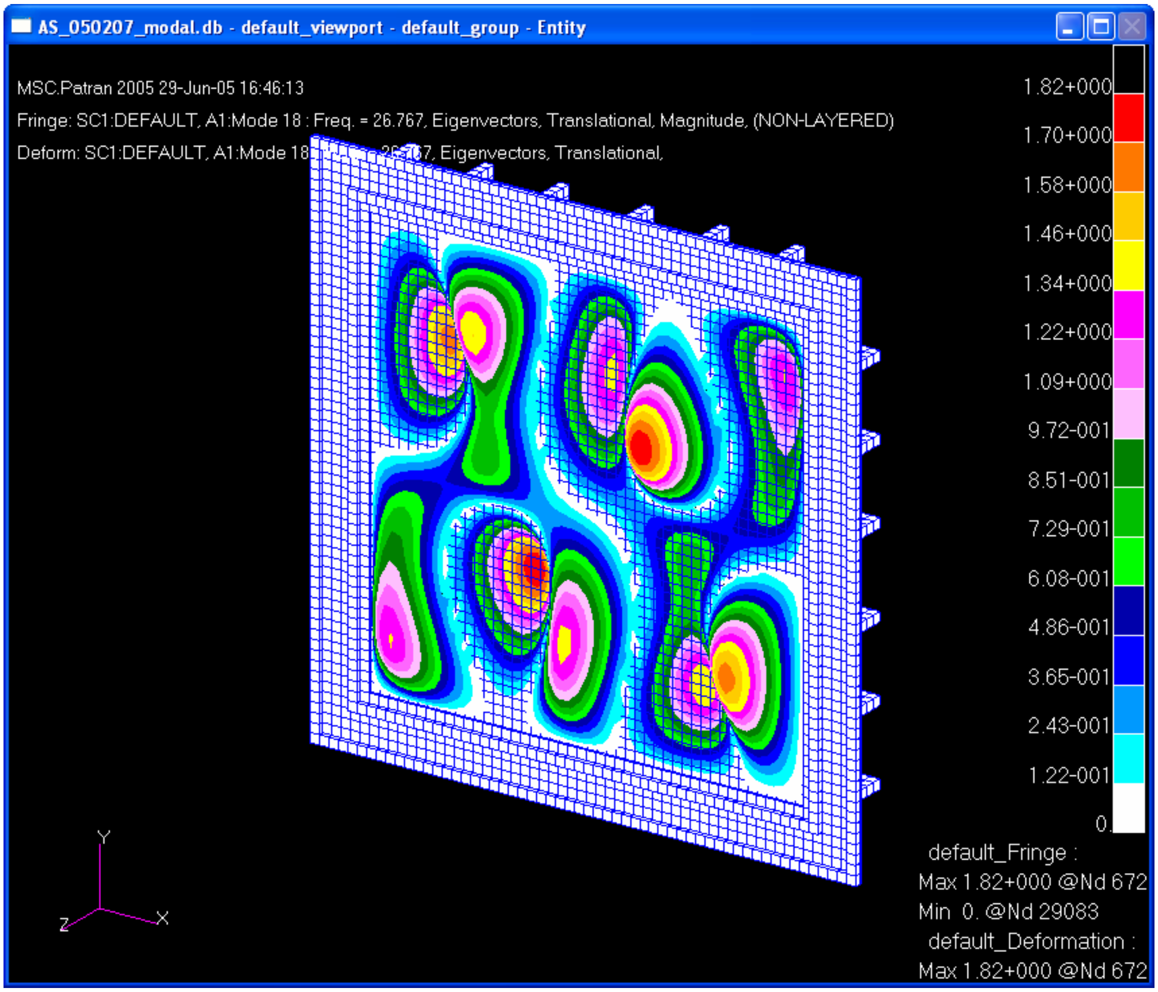


Figure A18. Modal analysis of a single aluminum panel, Mode 18.

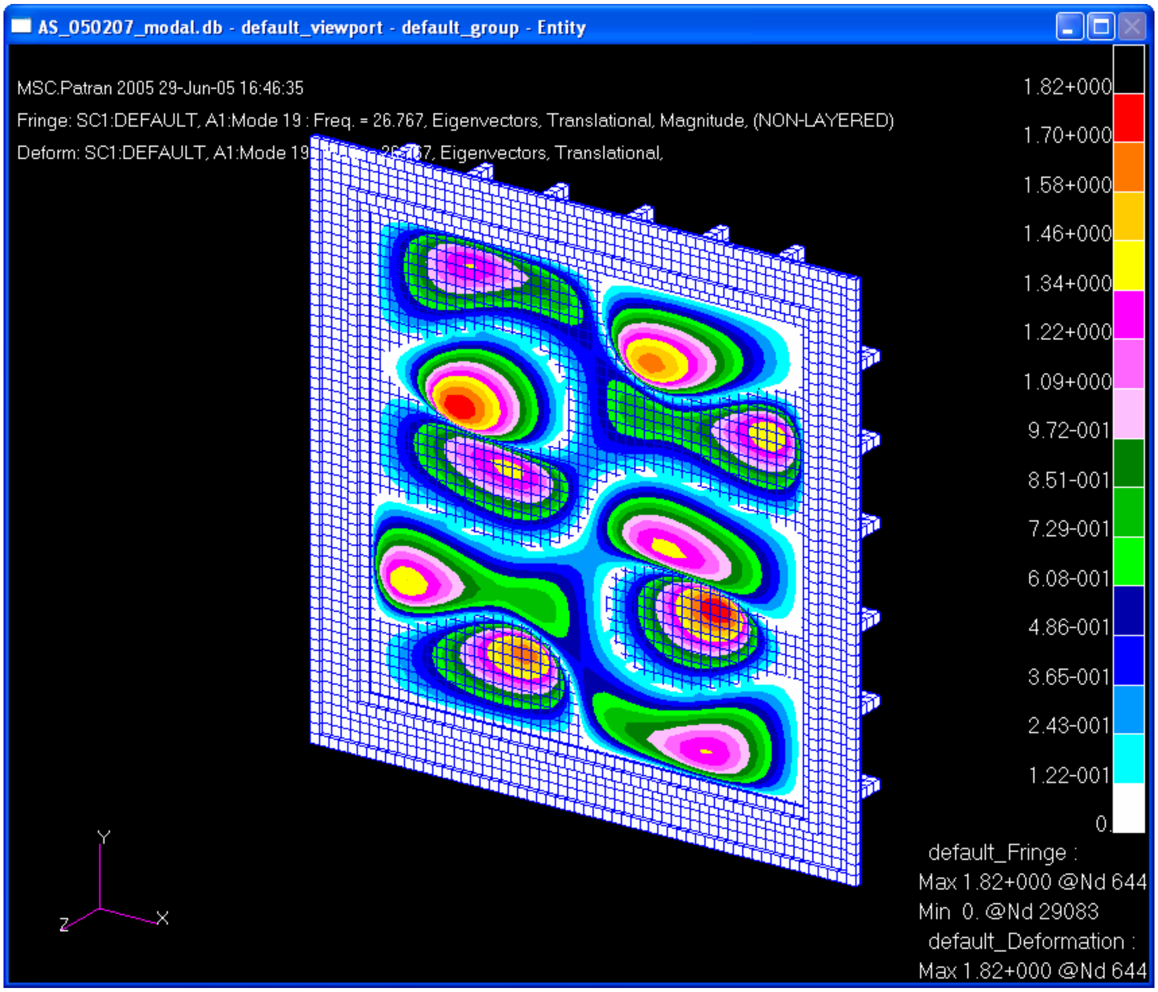


Figure A19. Modal analysis of a single aluminum panel, Mode 19.

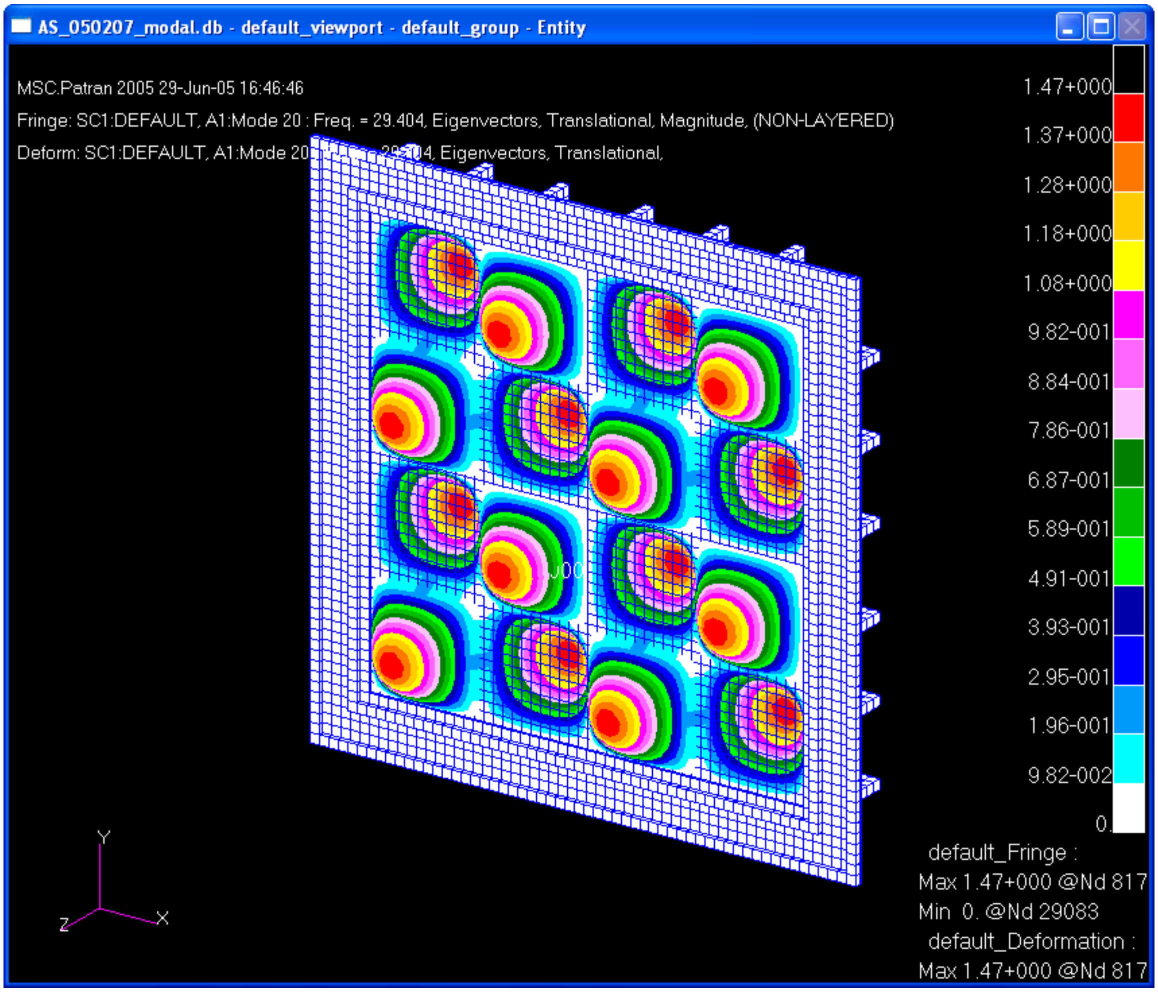


Figure A20. Modal analysis of a single aluminum panel, Mode 20.

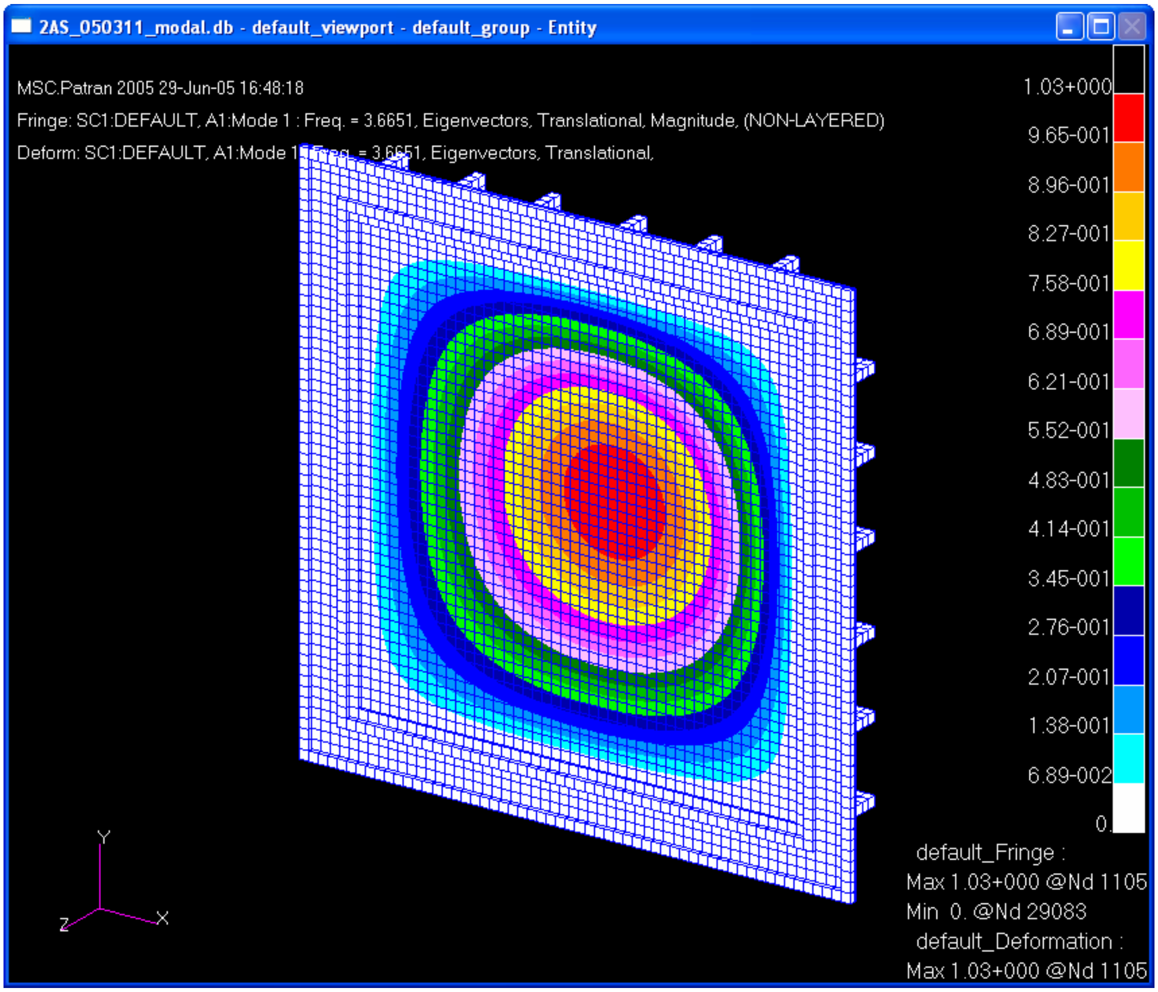


Figure A21. Modal analysis of a single aluminum panel with twice the mass, Mode 1.

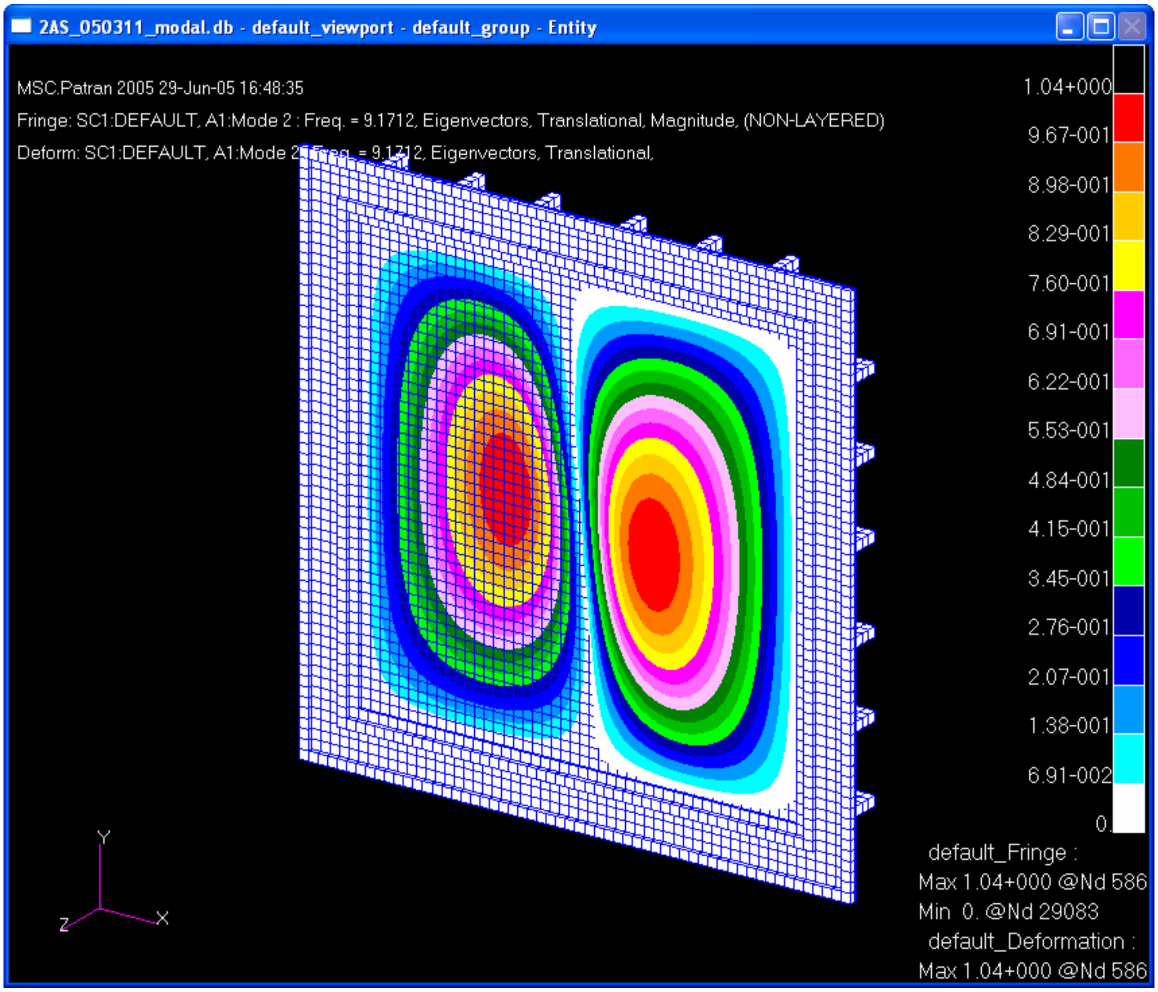
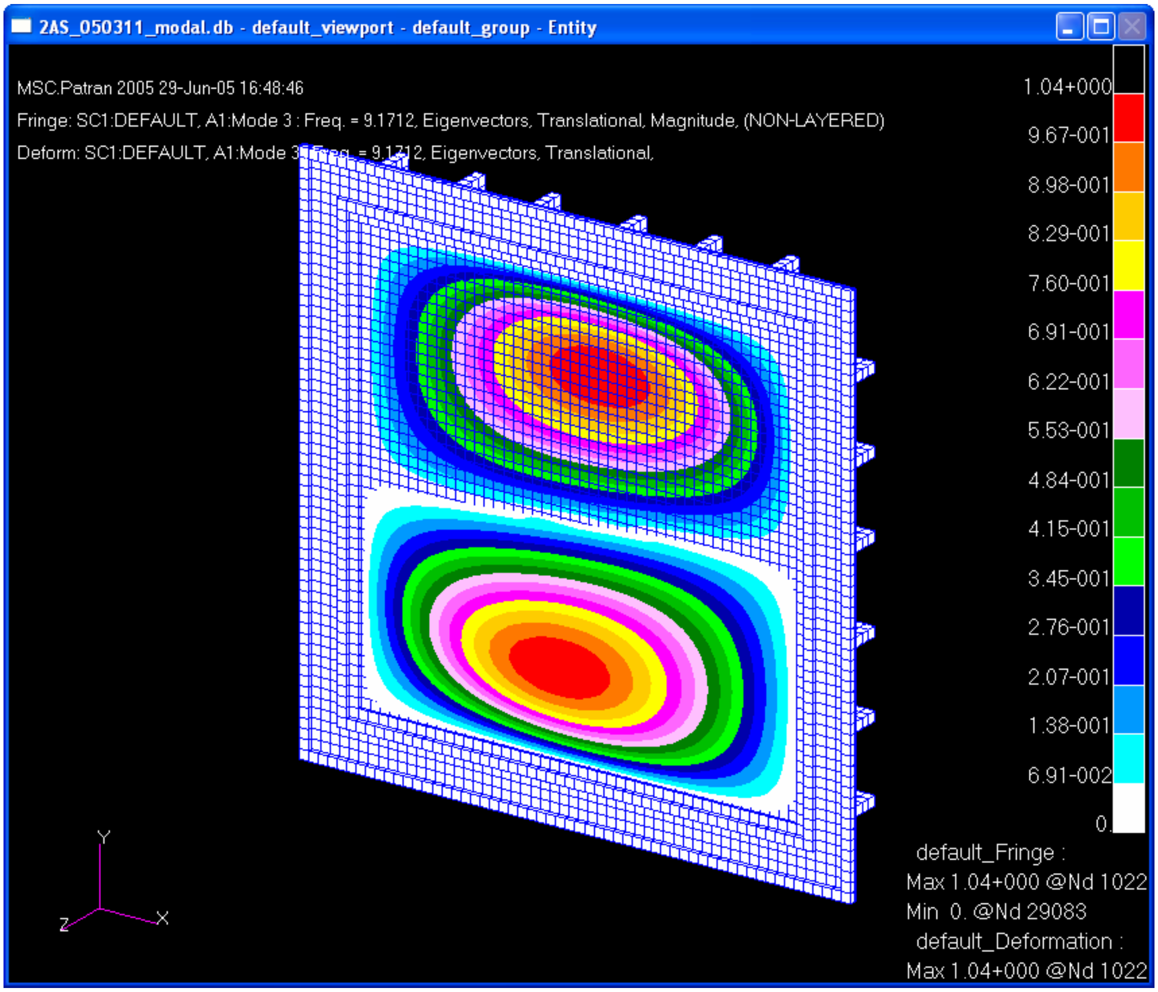


Figure A22. Modal analysis of a single aluminum panel with twice the mass, Mode 2.



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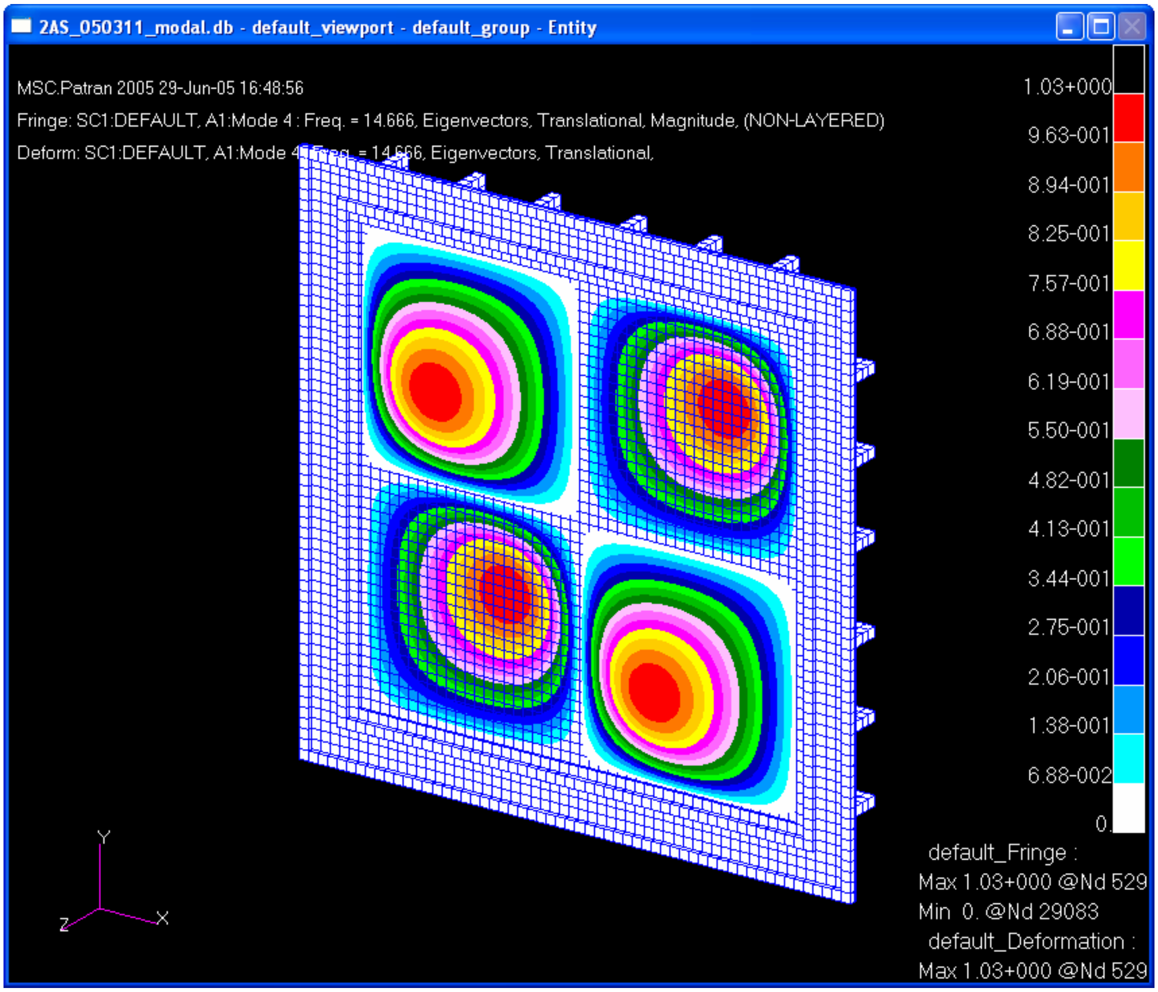

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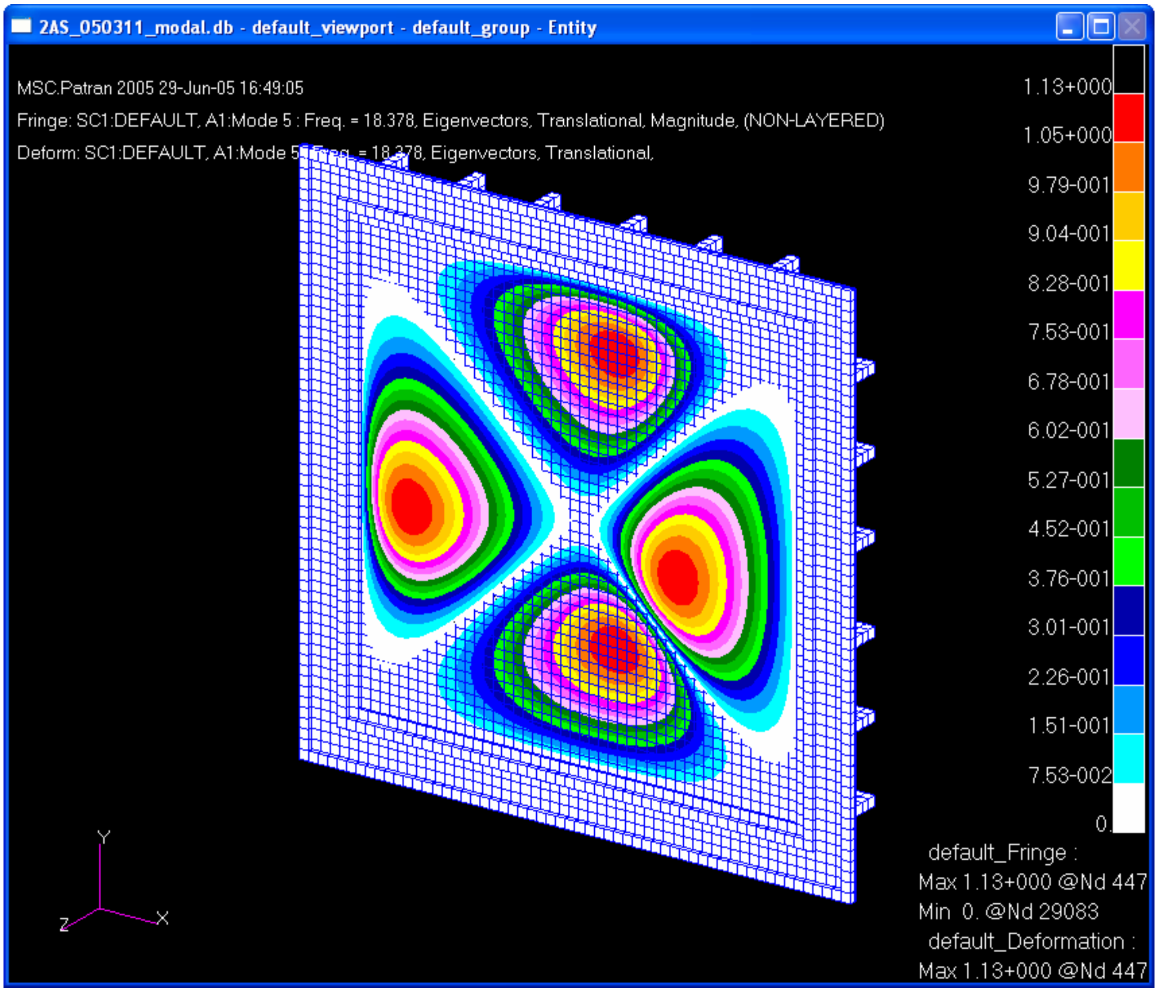

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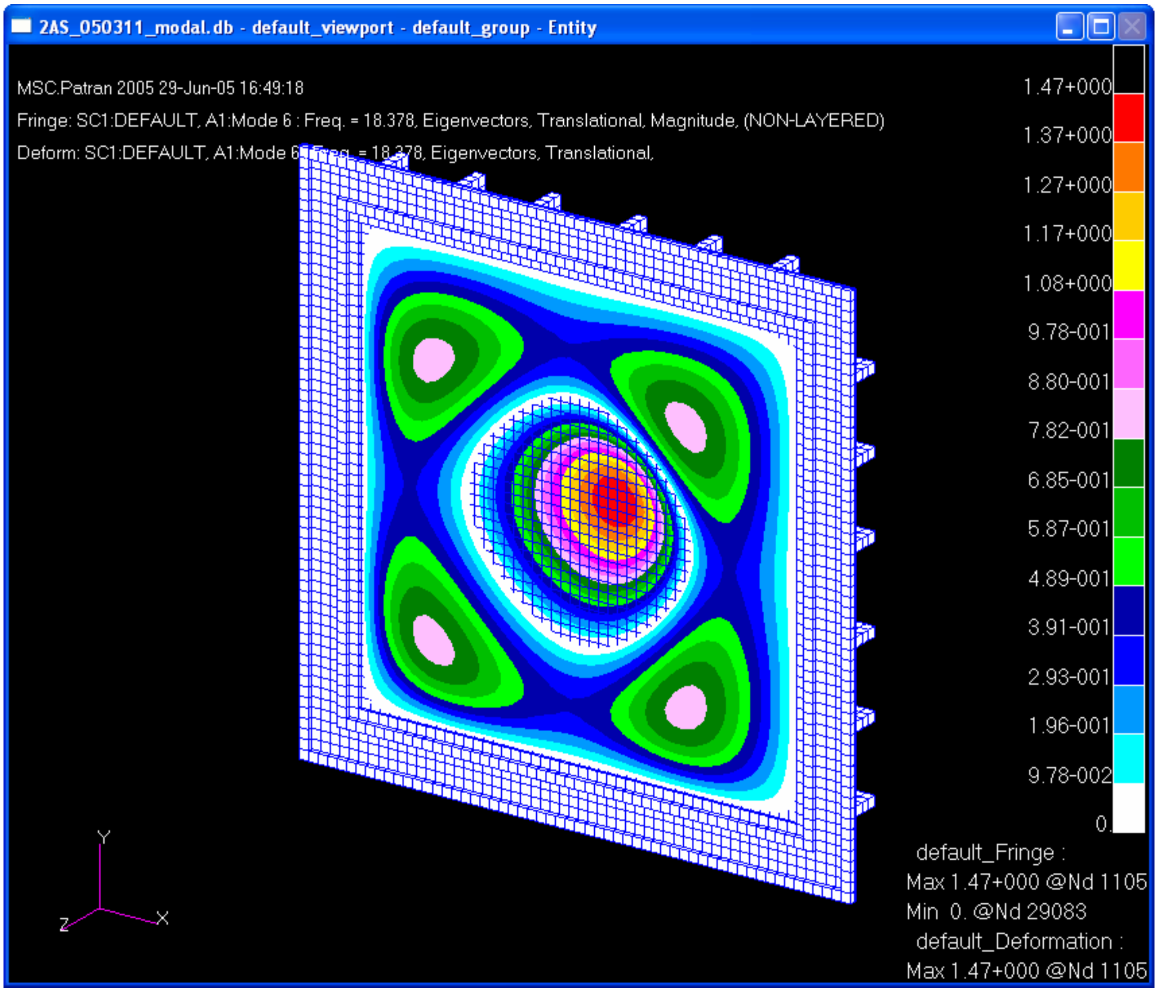

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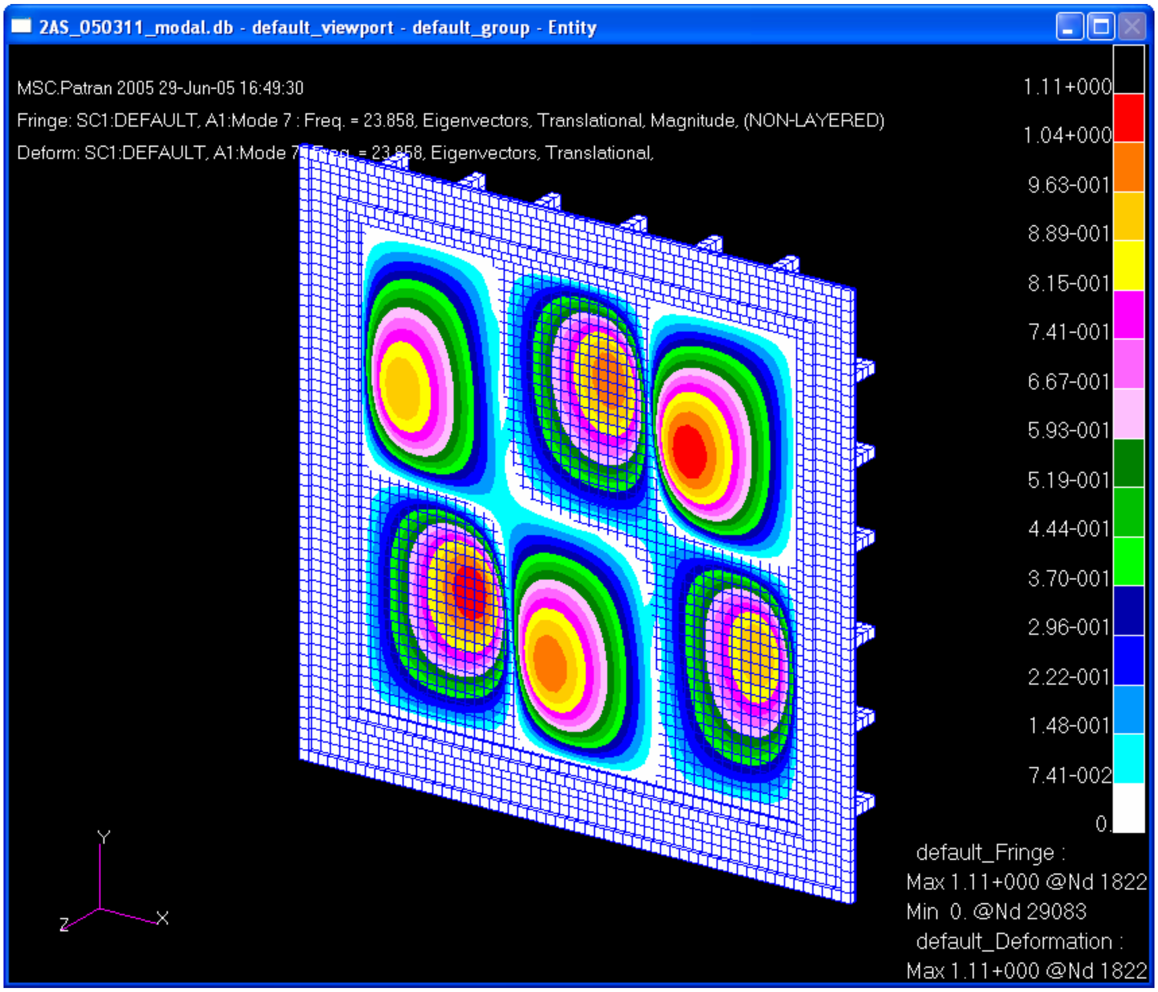

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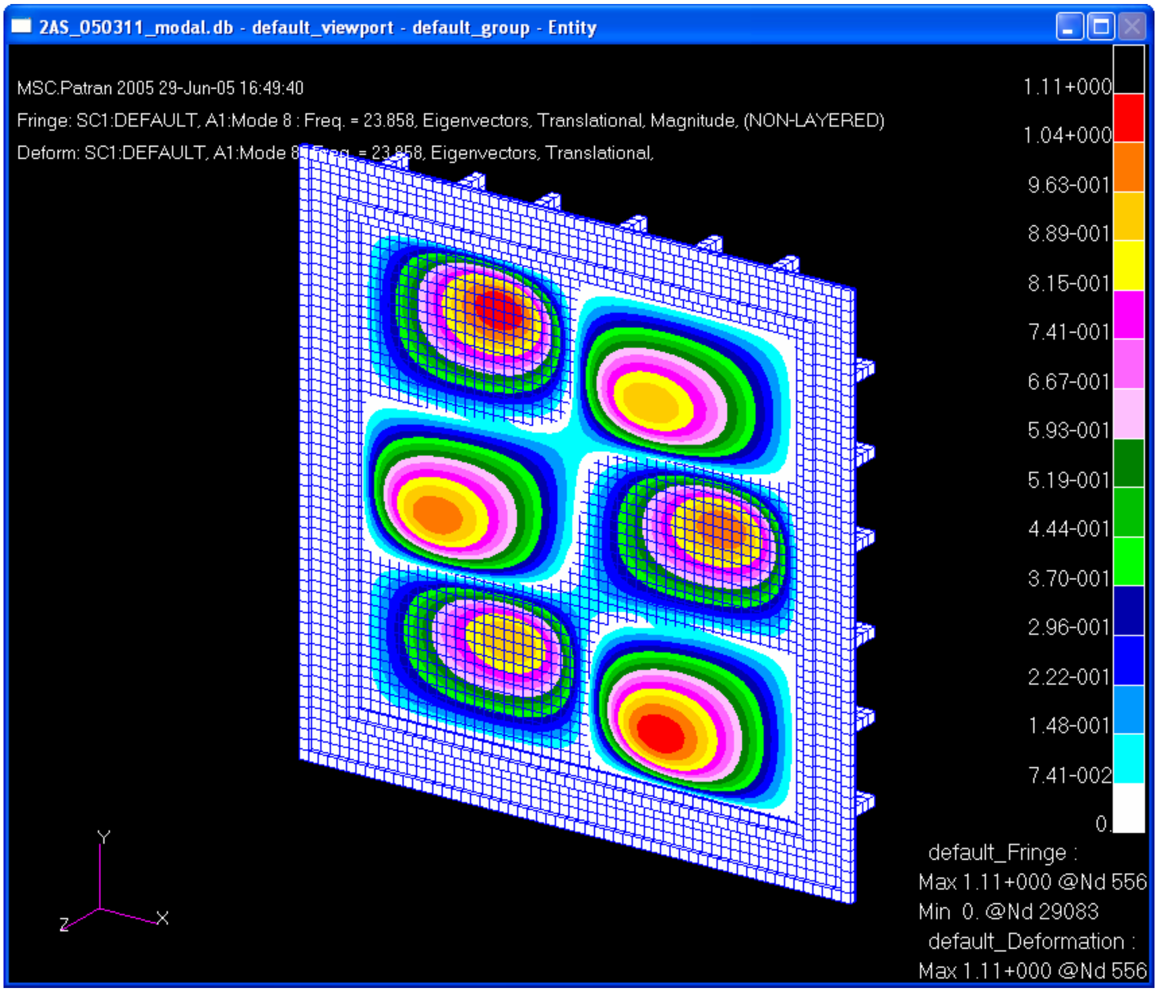

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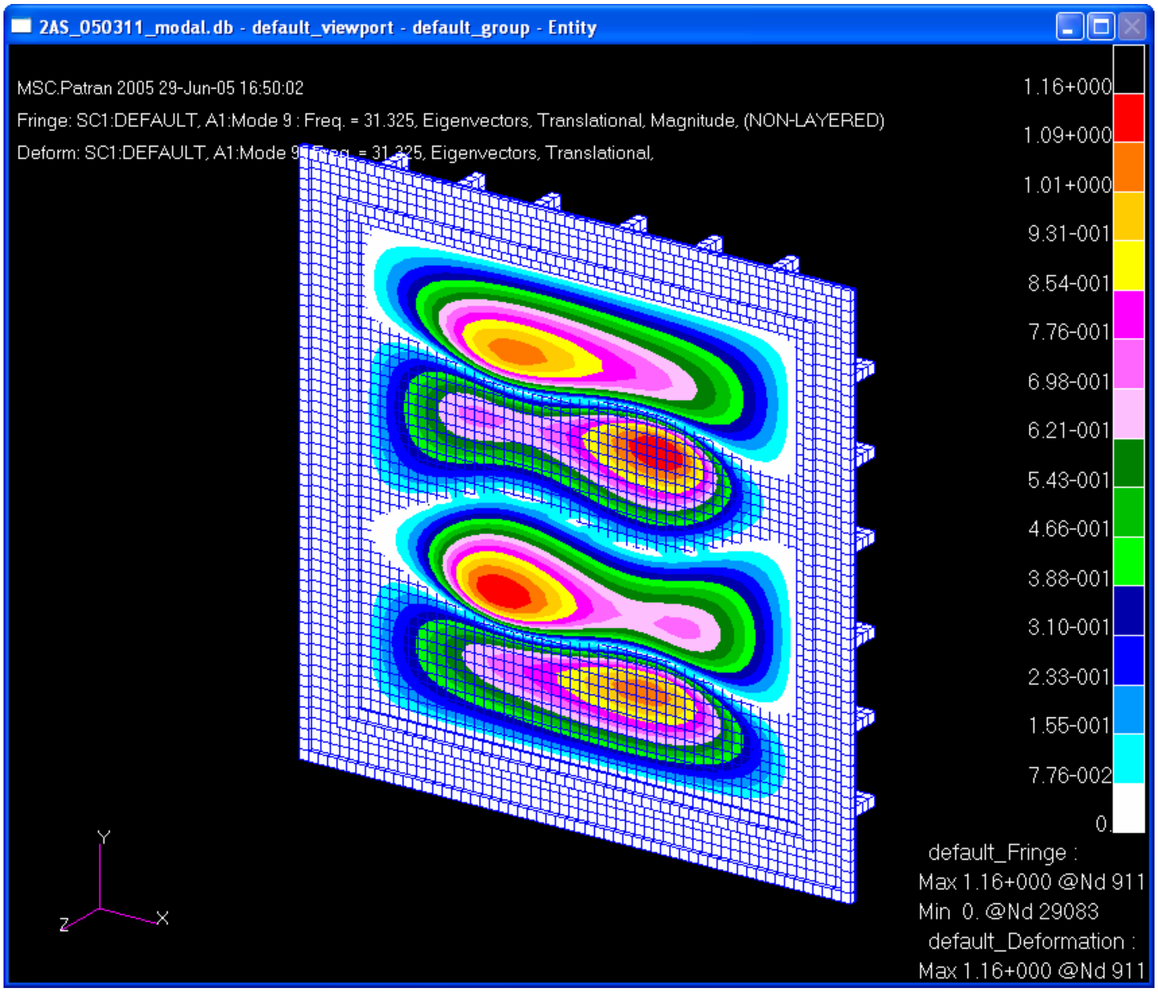

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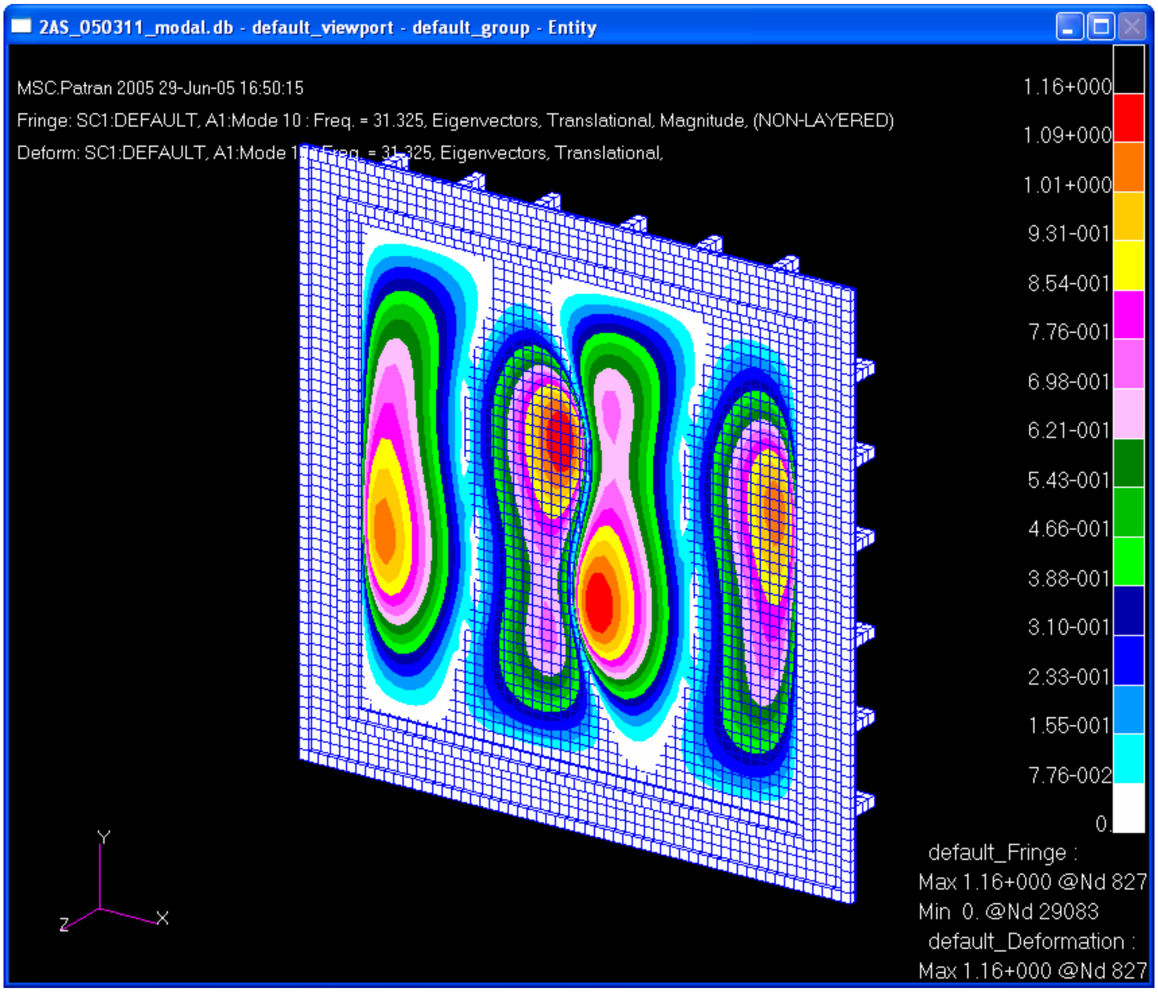

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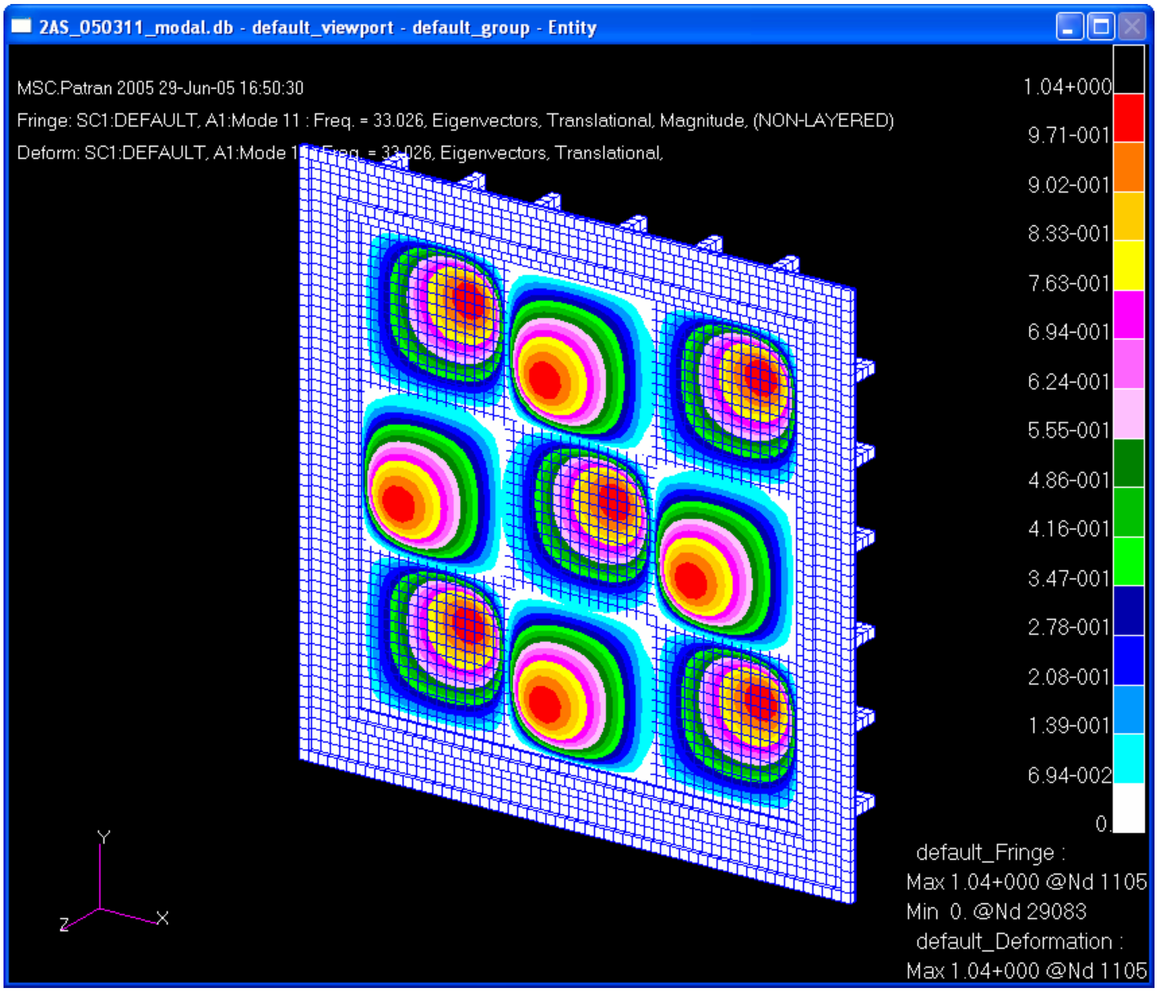

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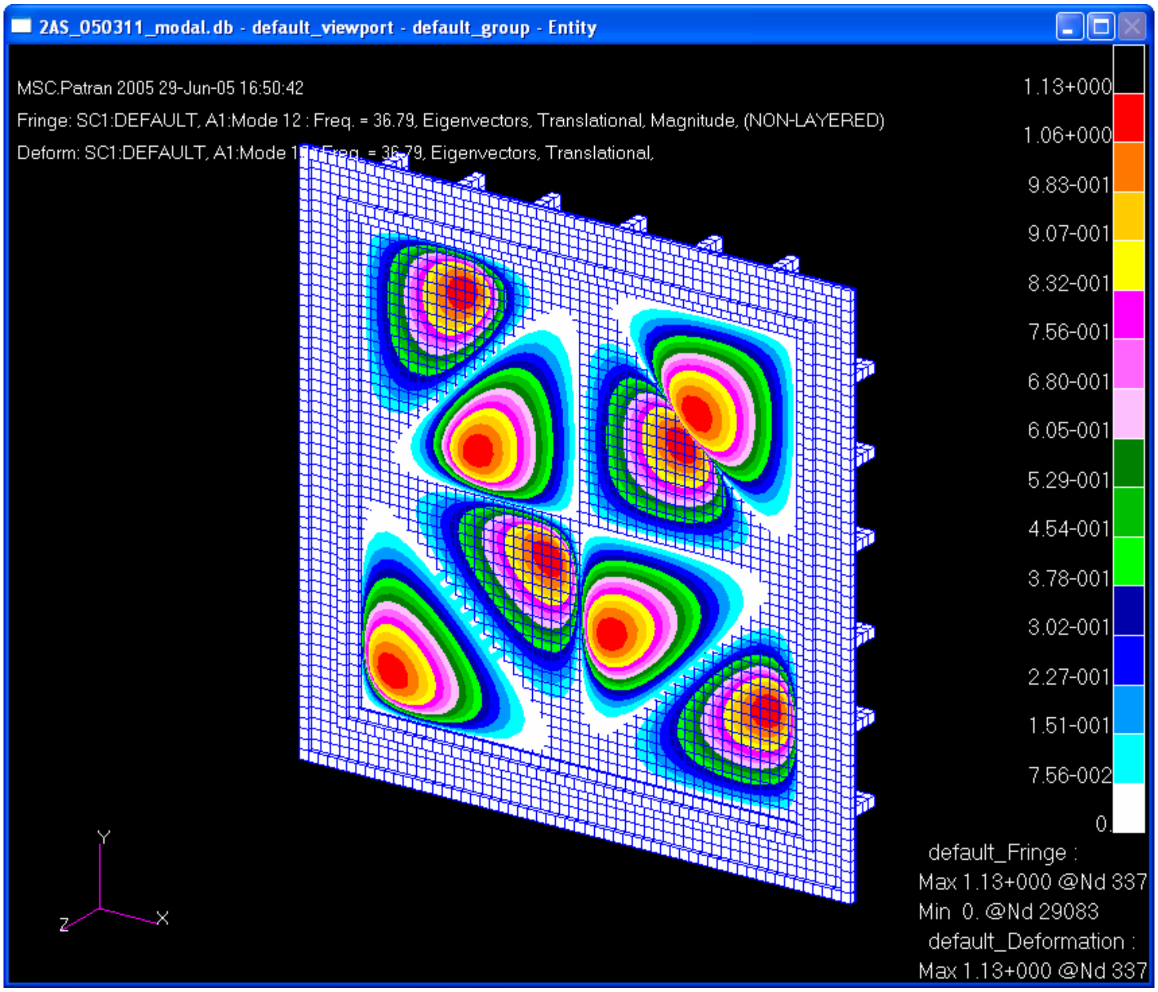

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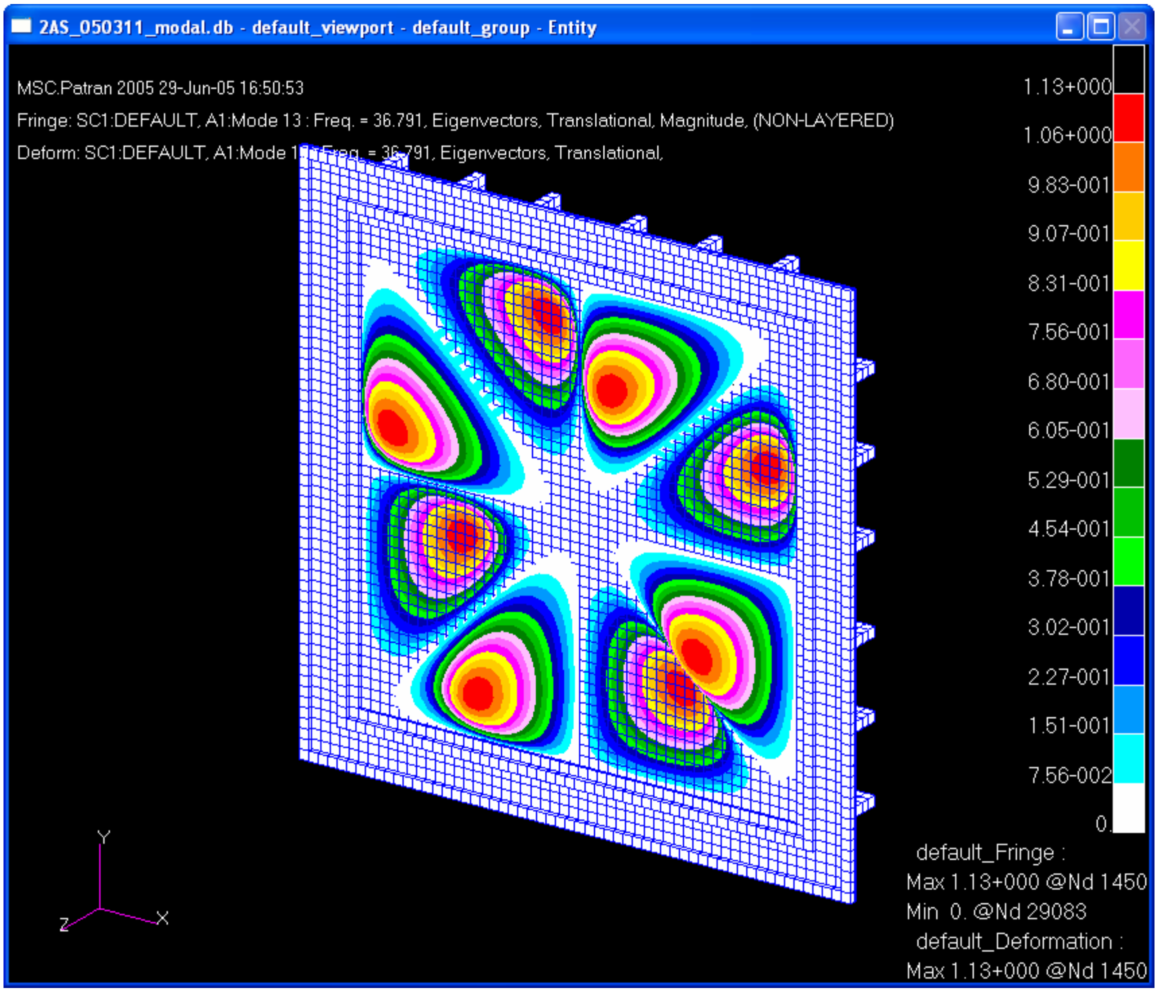

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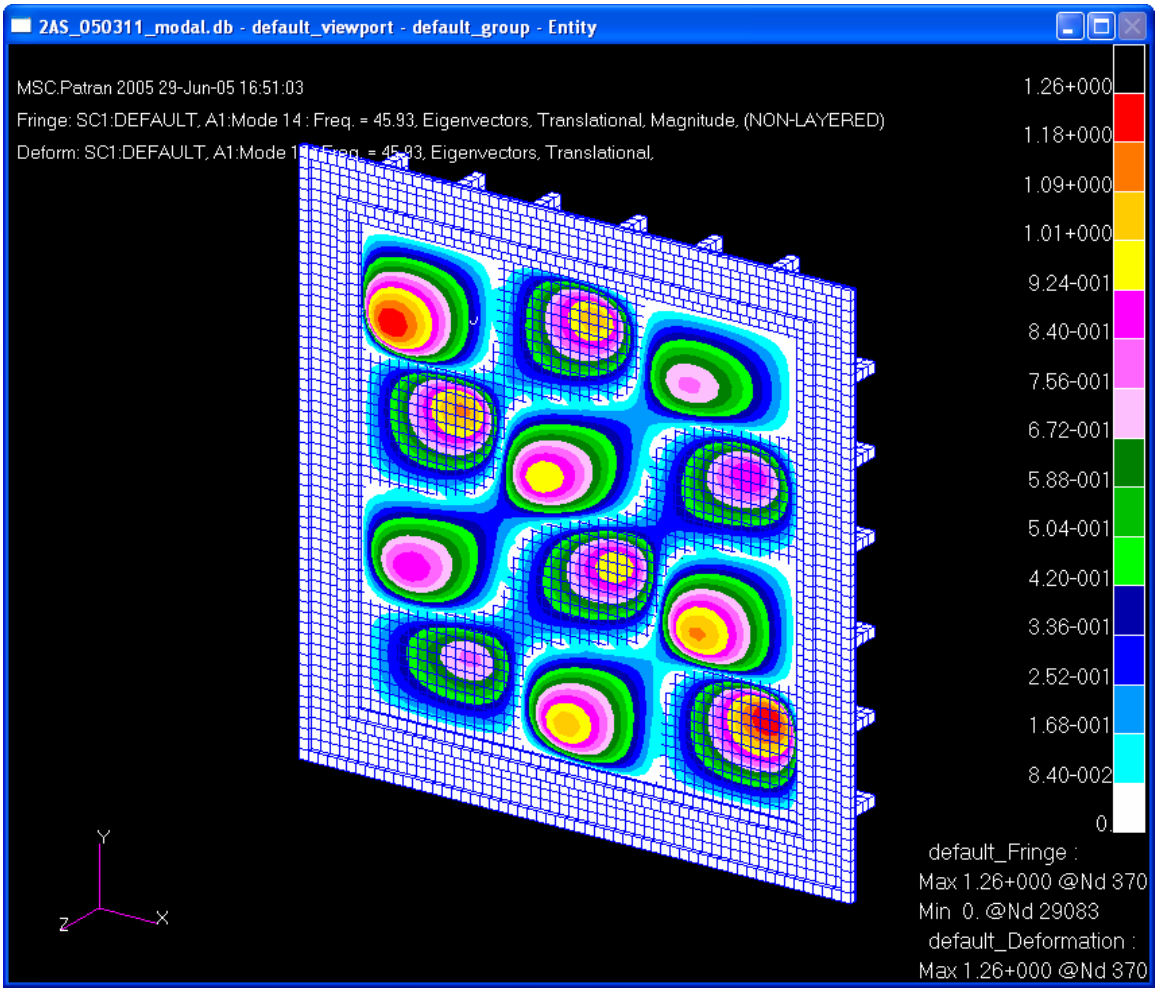

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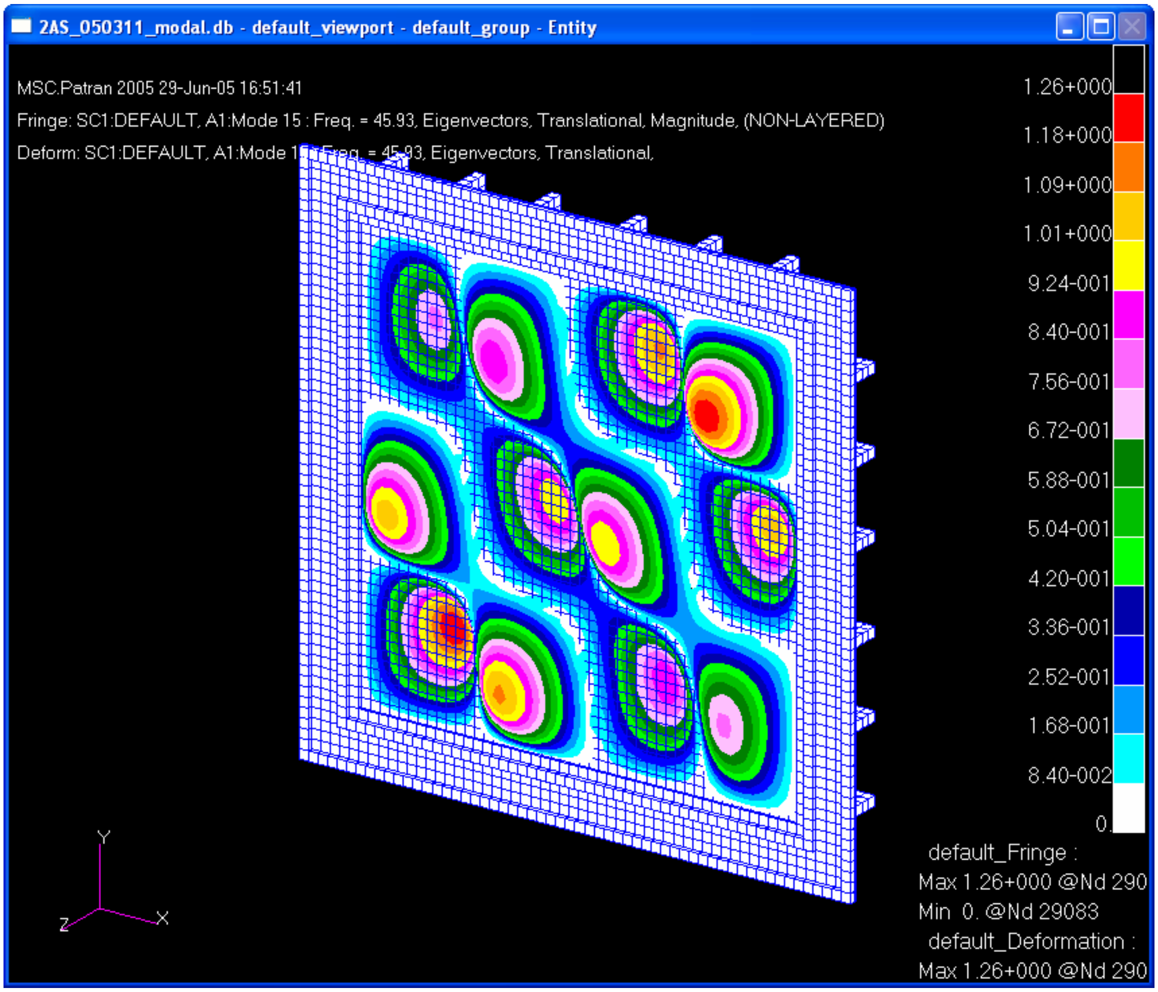

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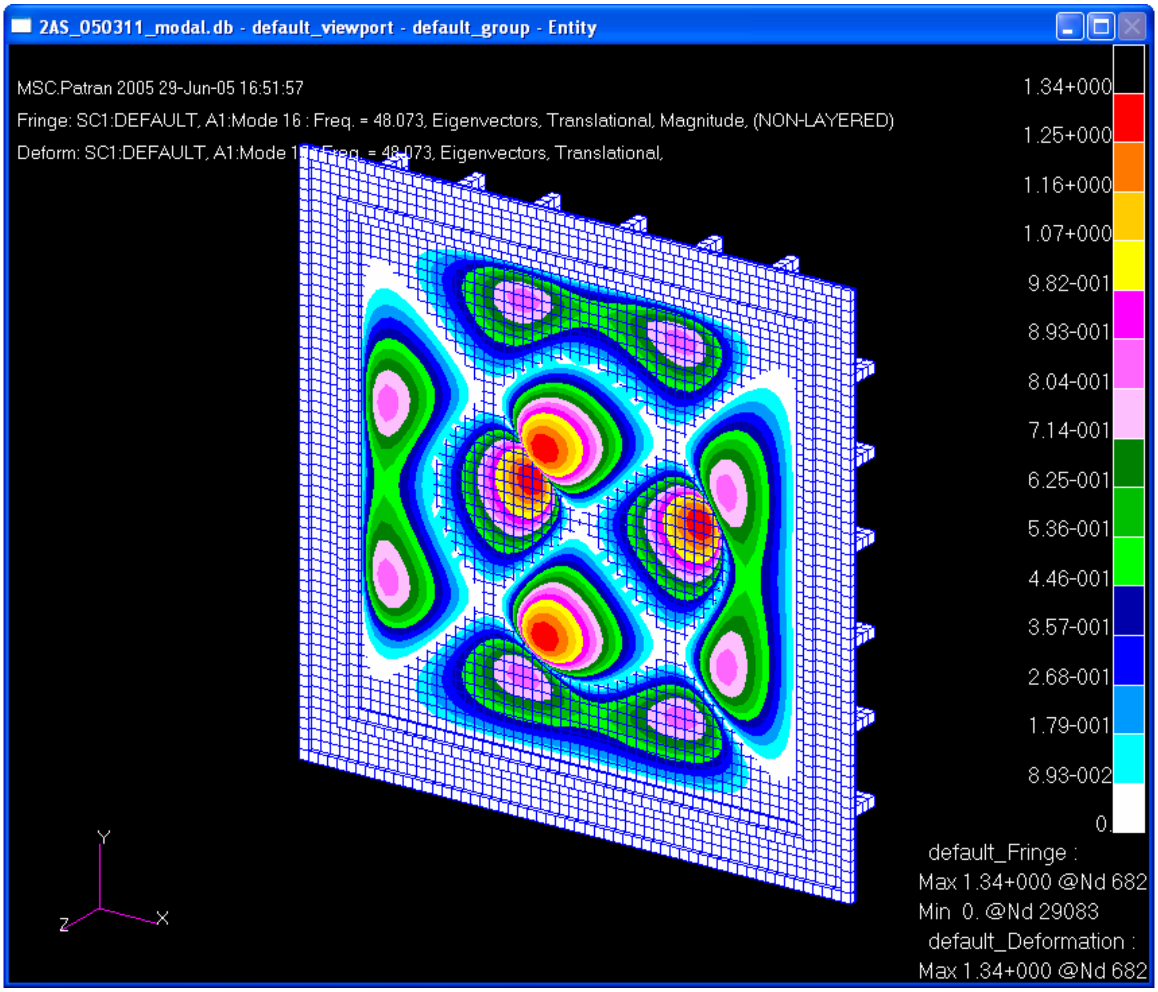

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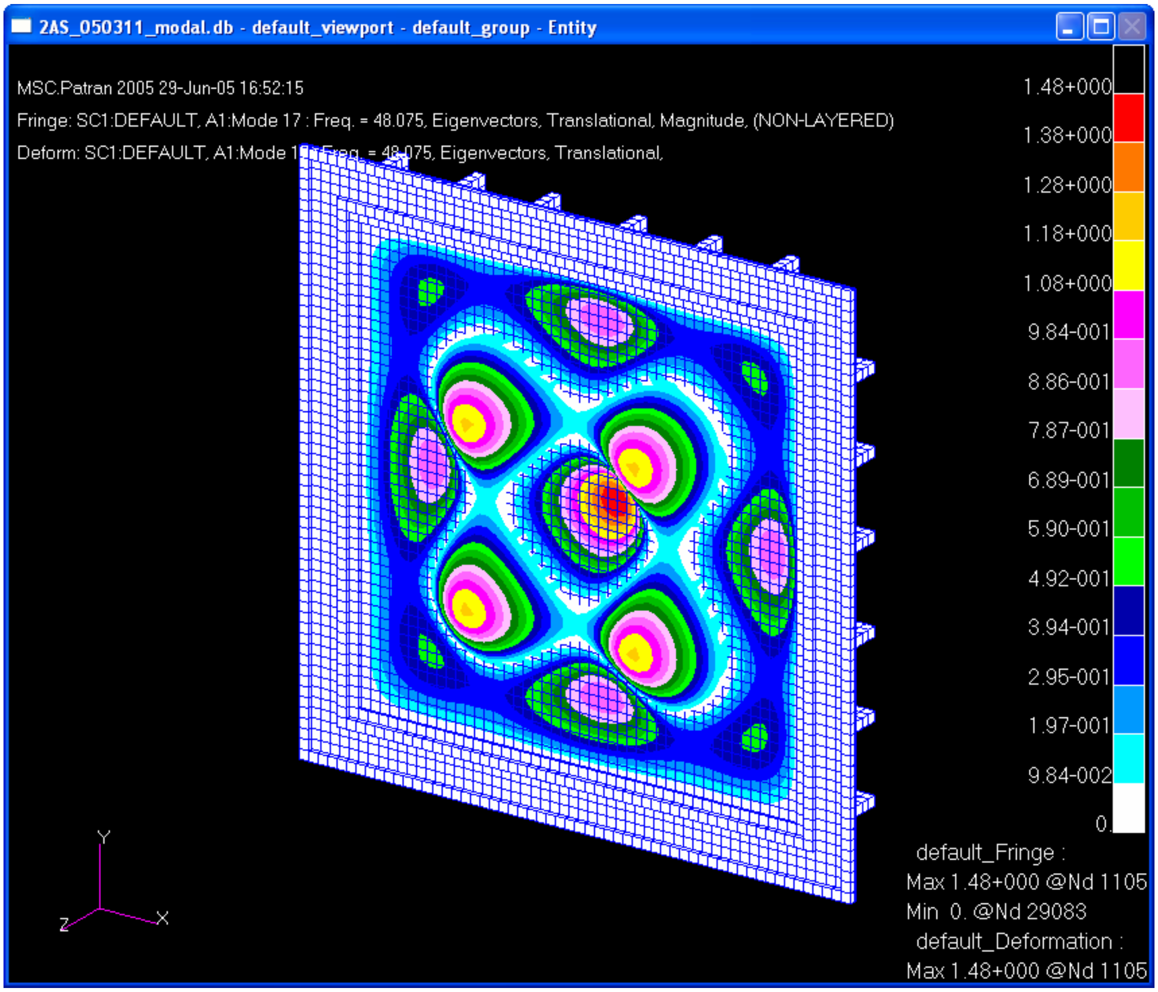

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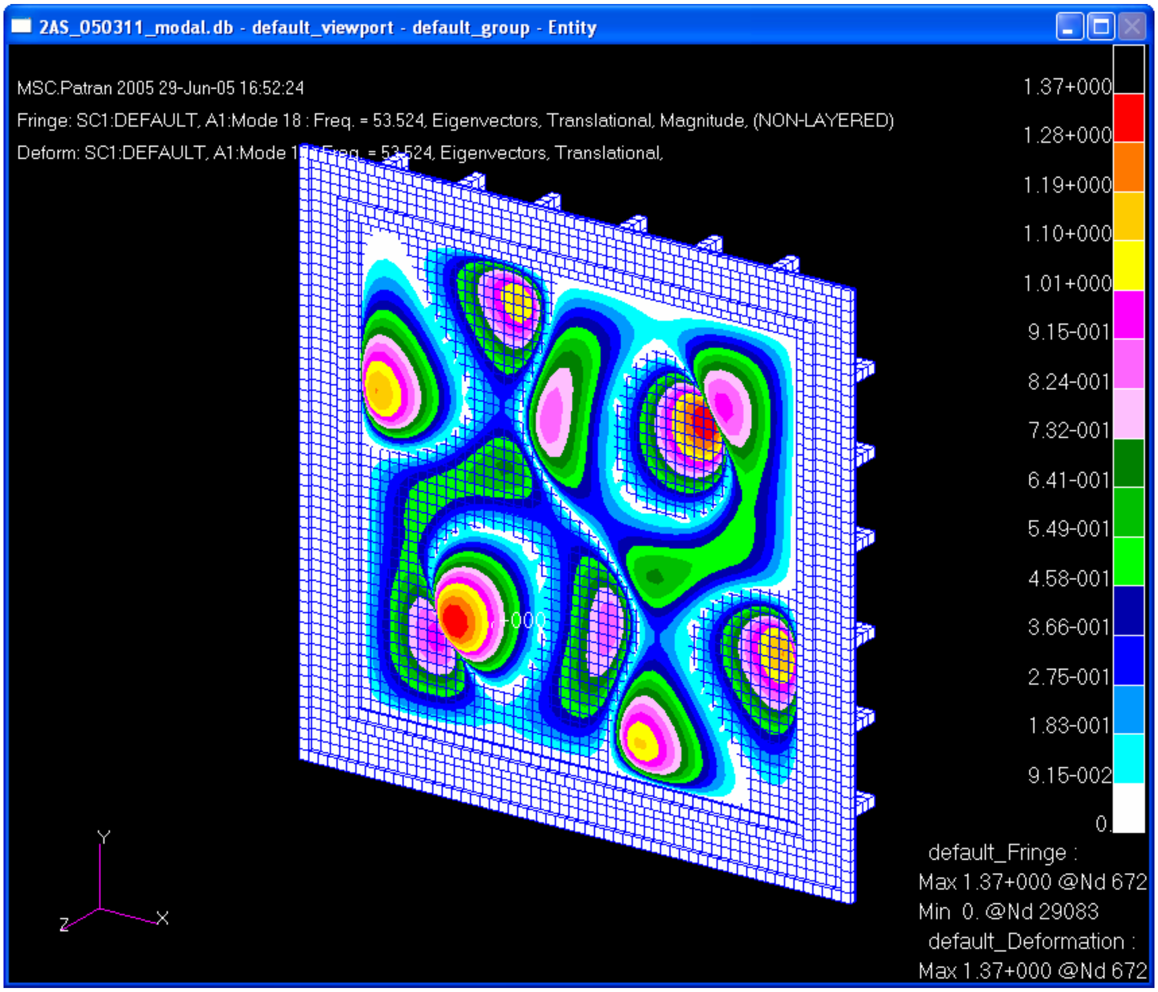

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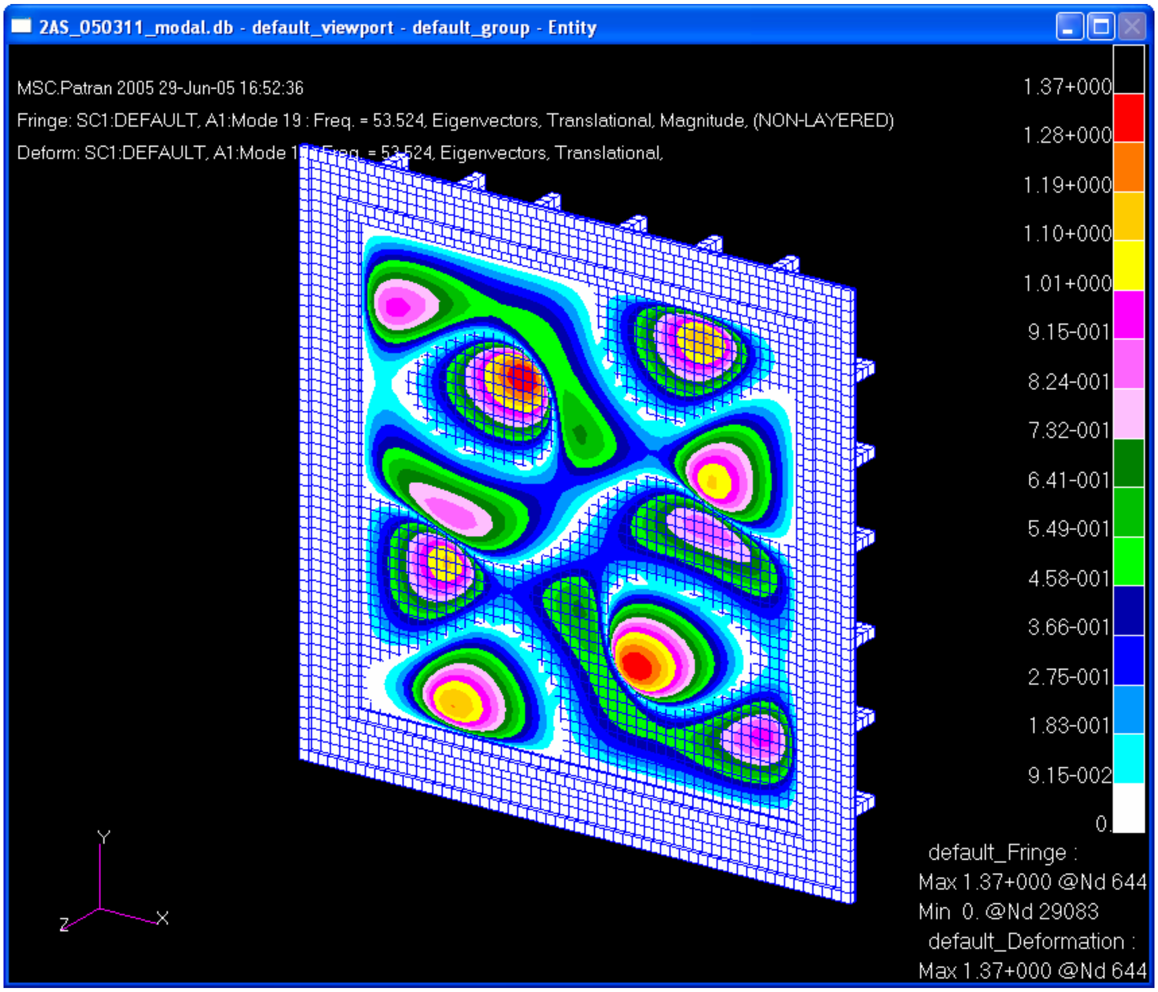

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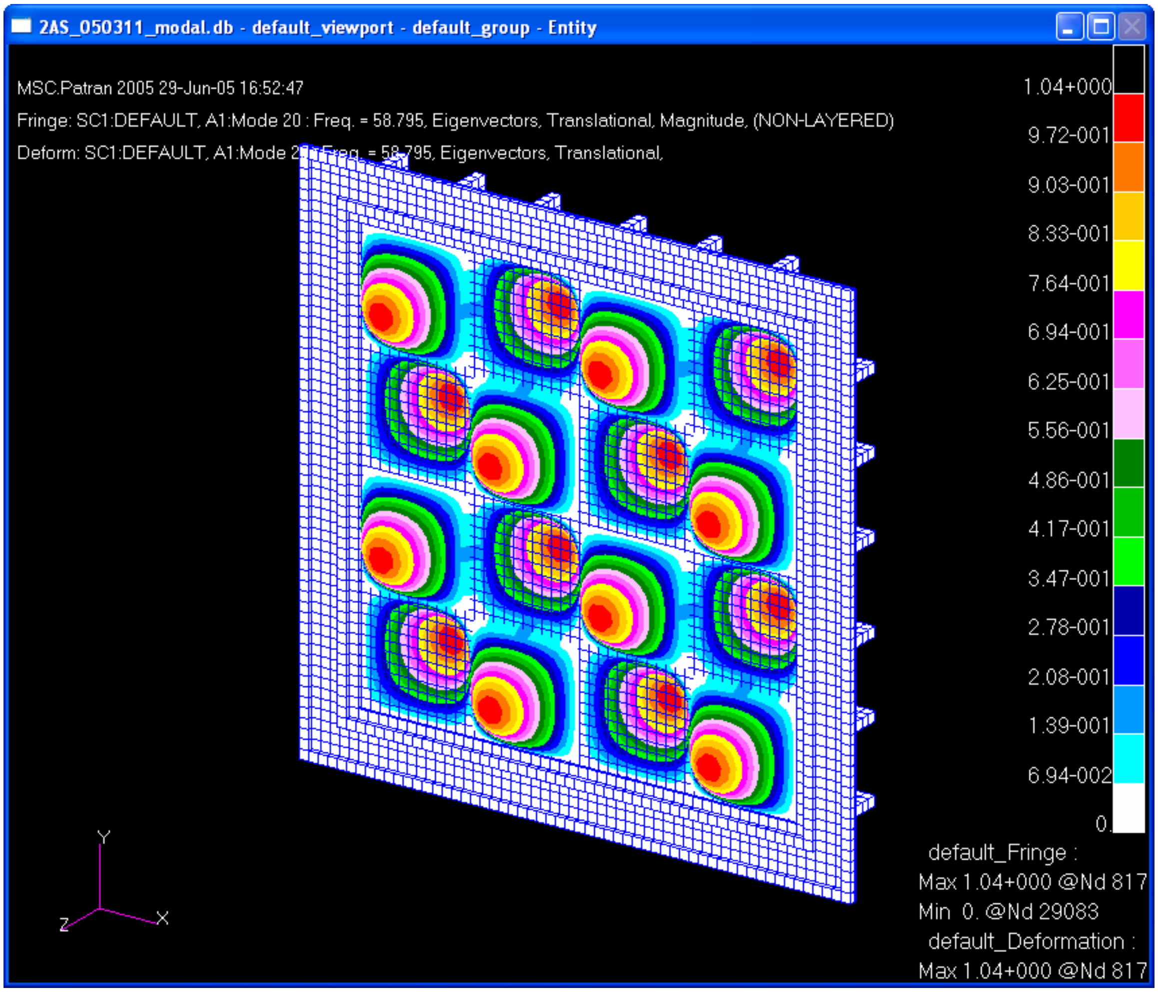

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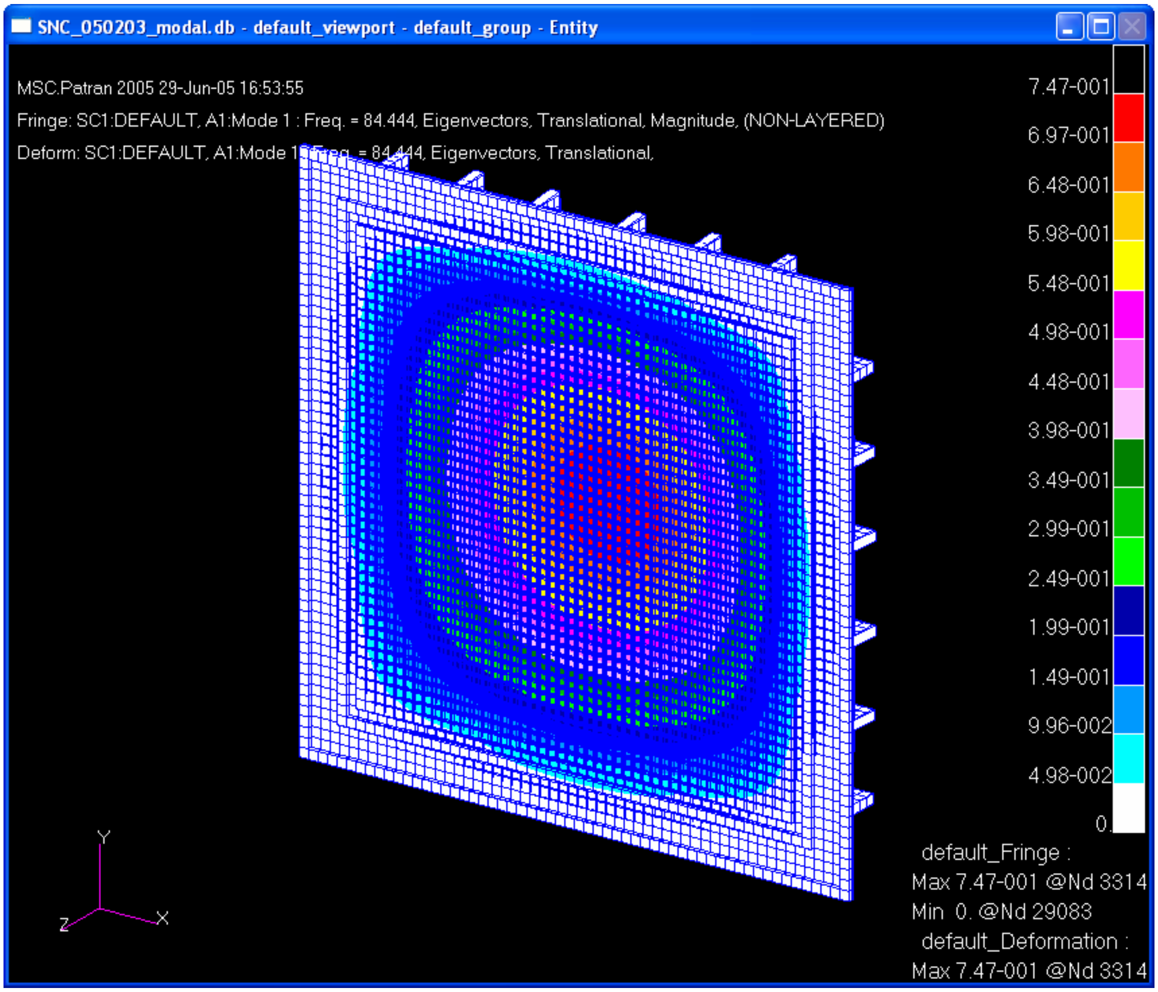
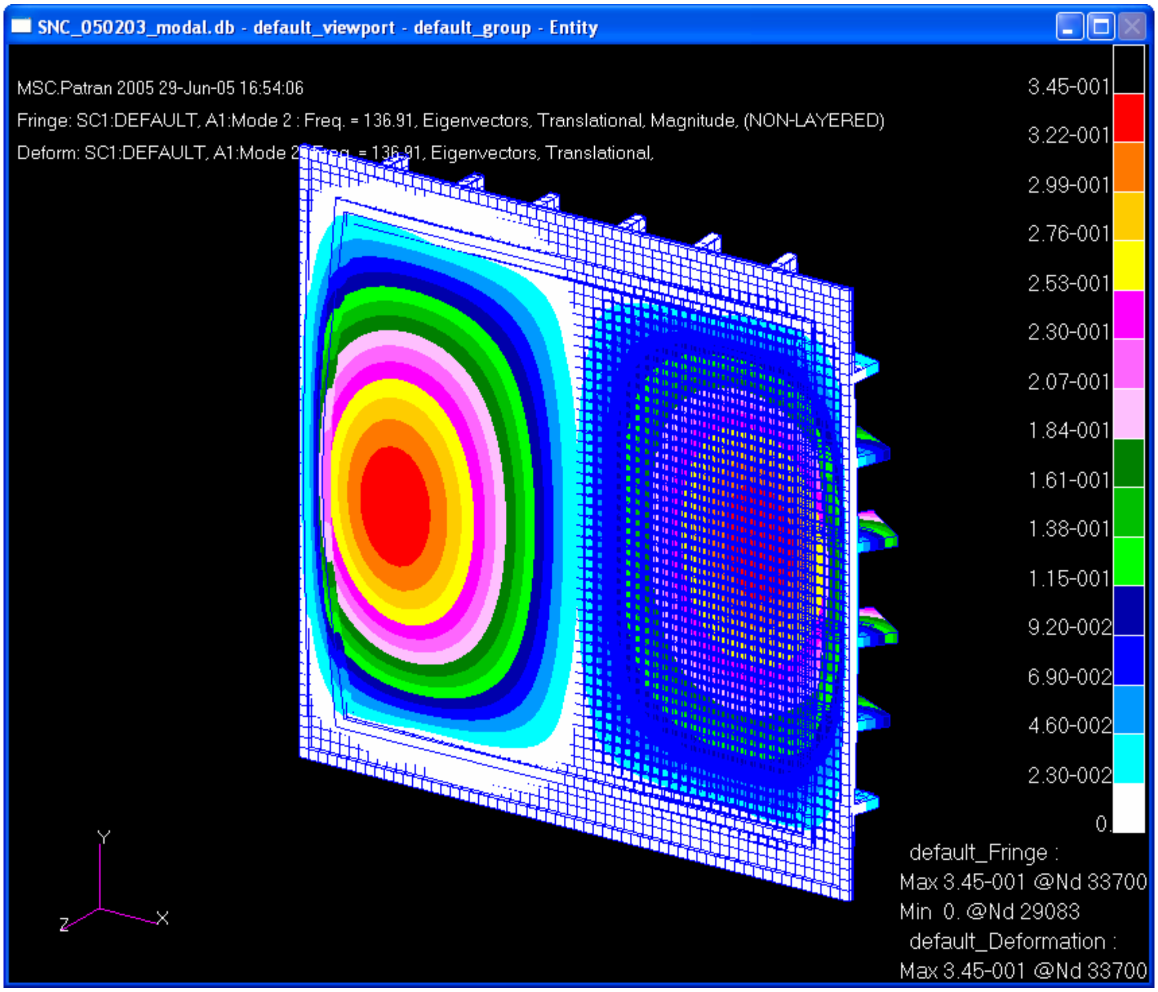


Figure A41. Modal analysis of a nomex core honeycomb panel, Mode 1.



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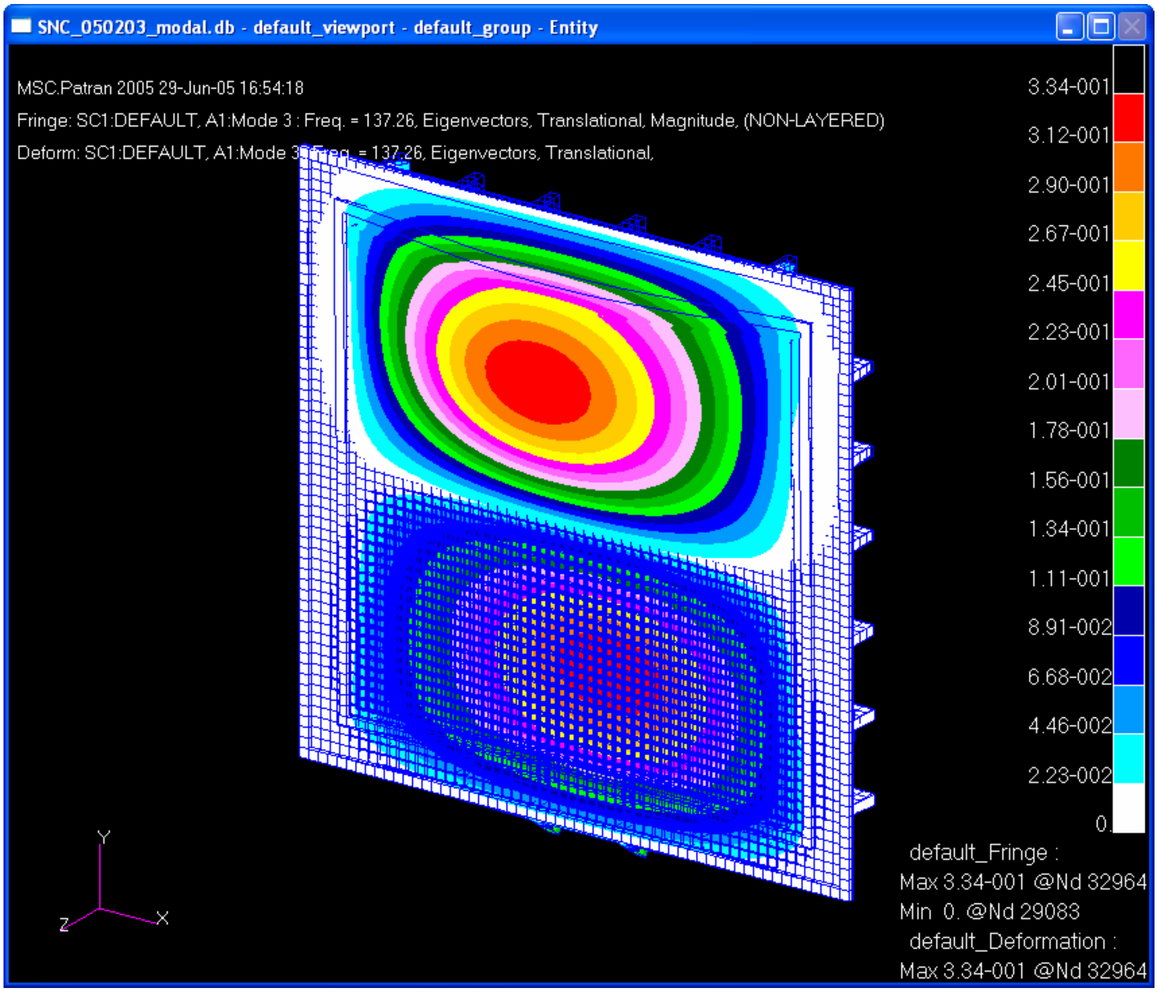

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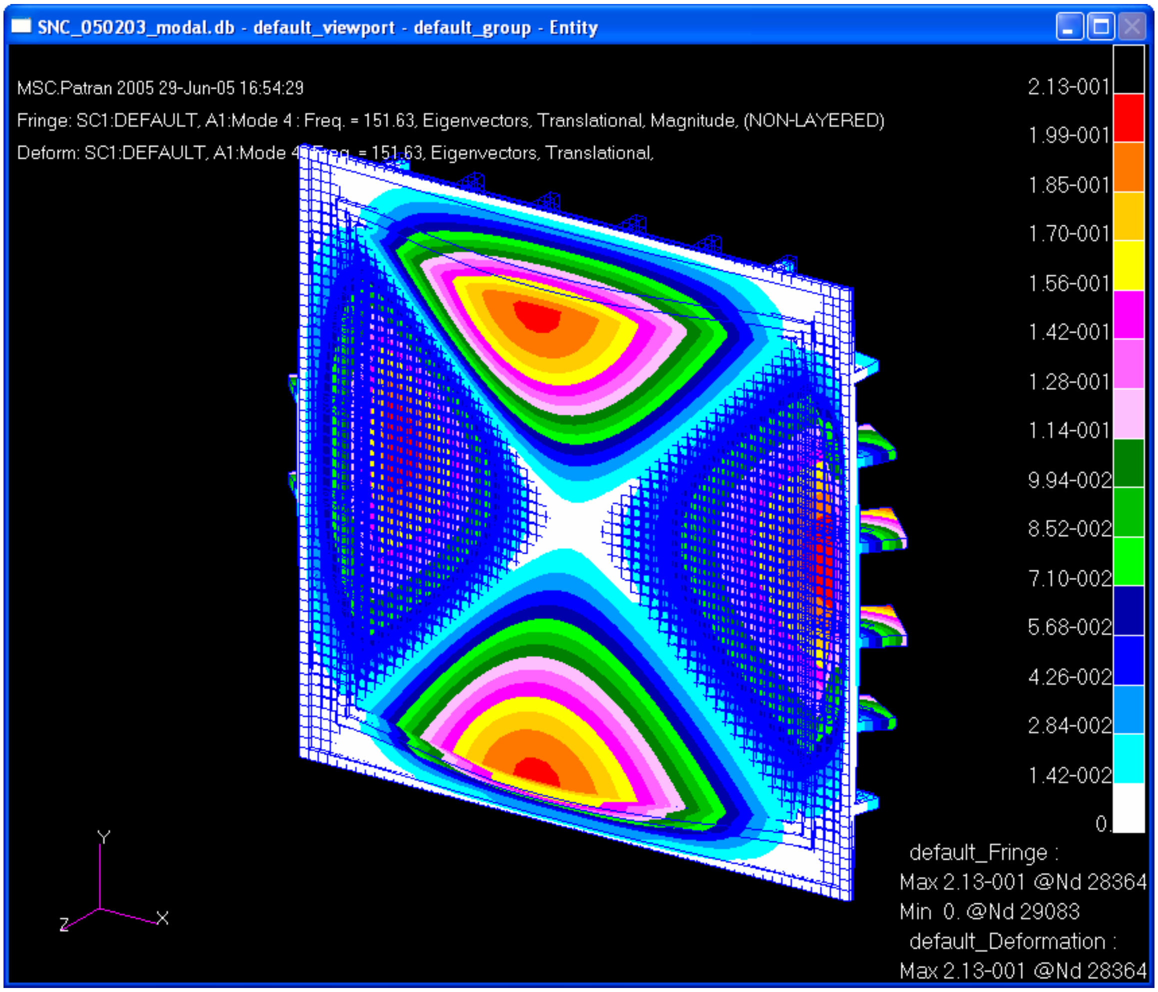

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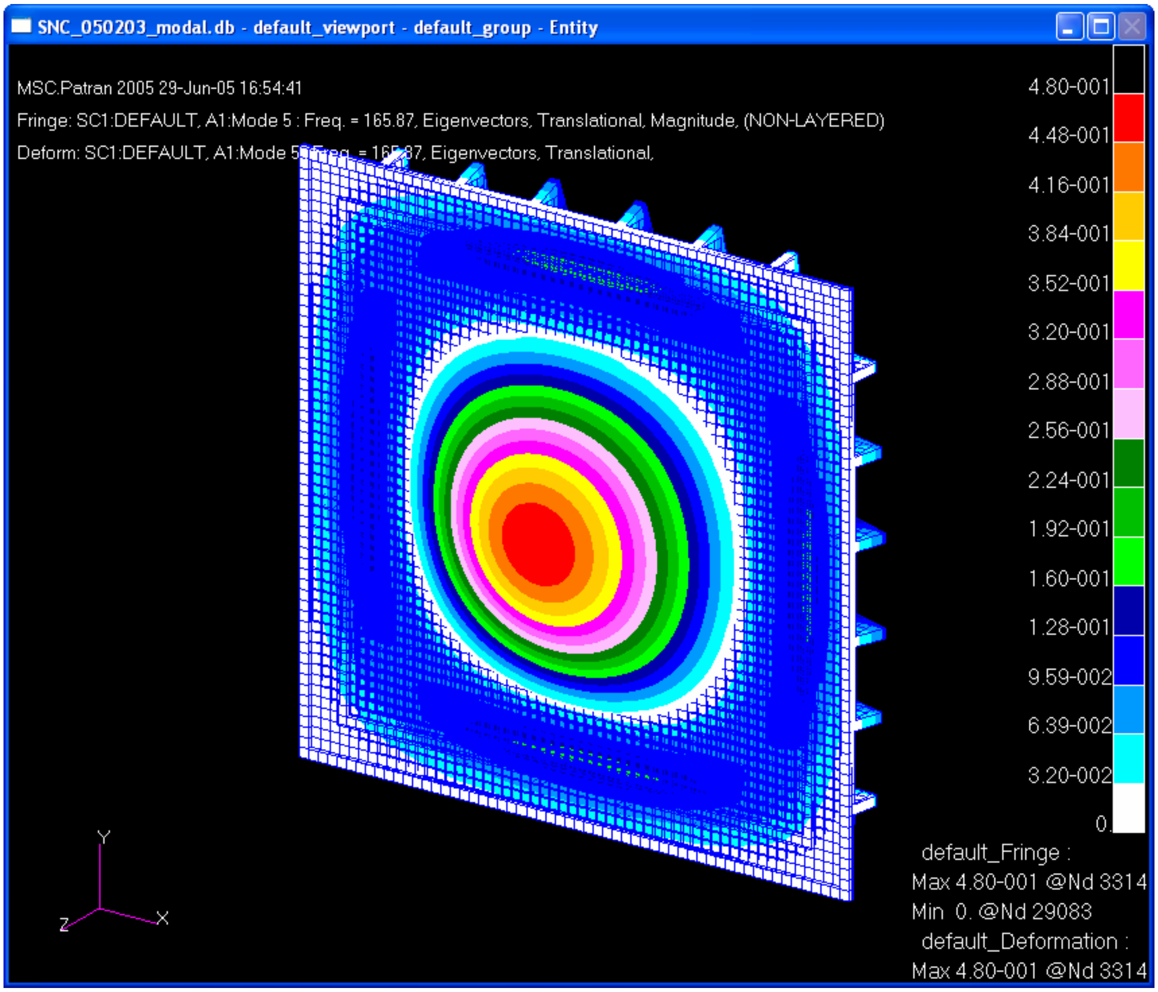

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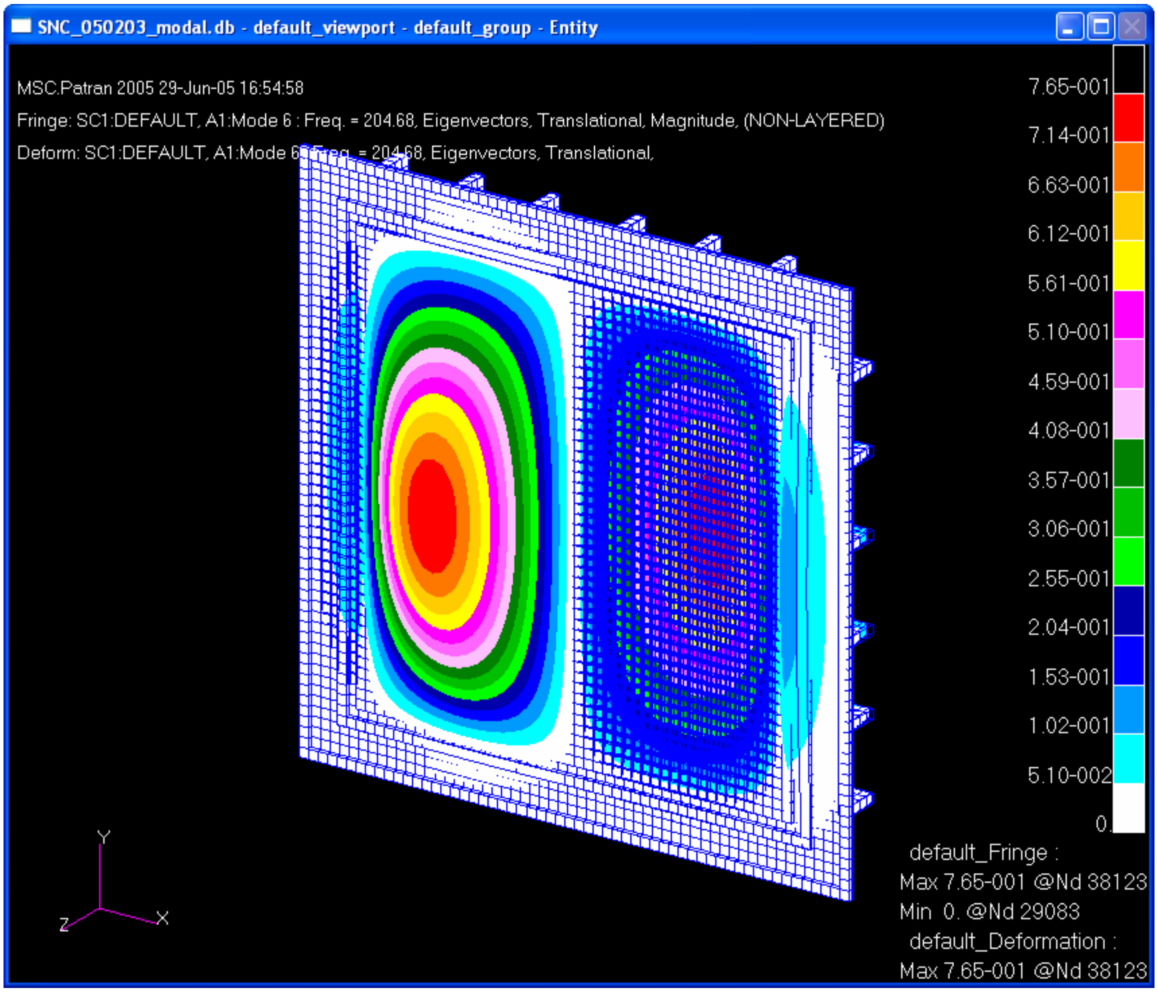

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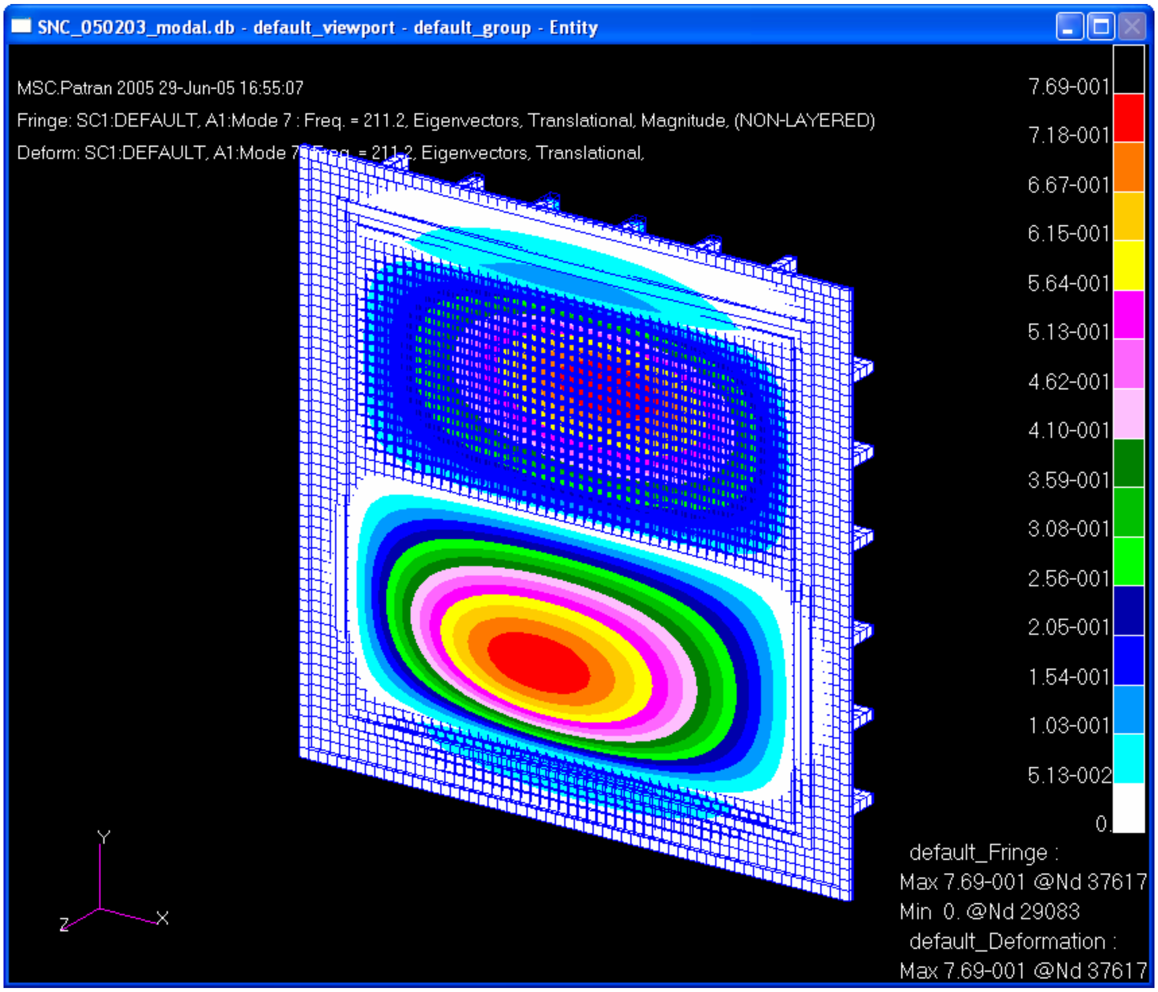

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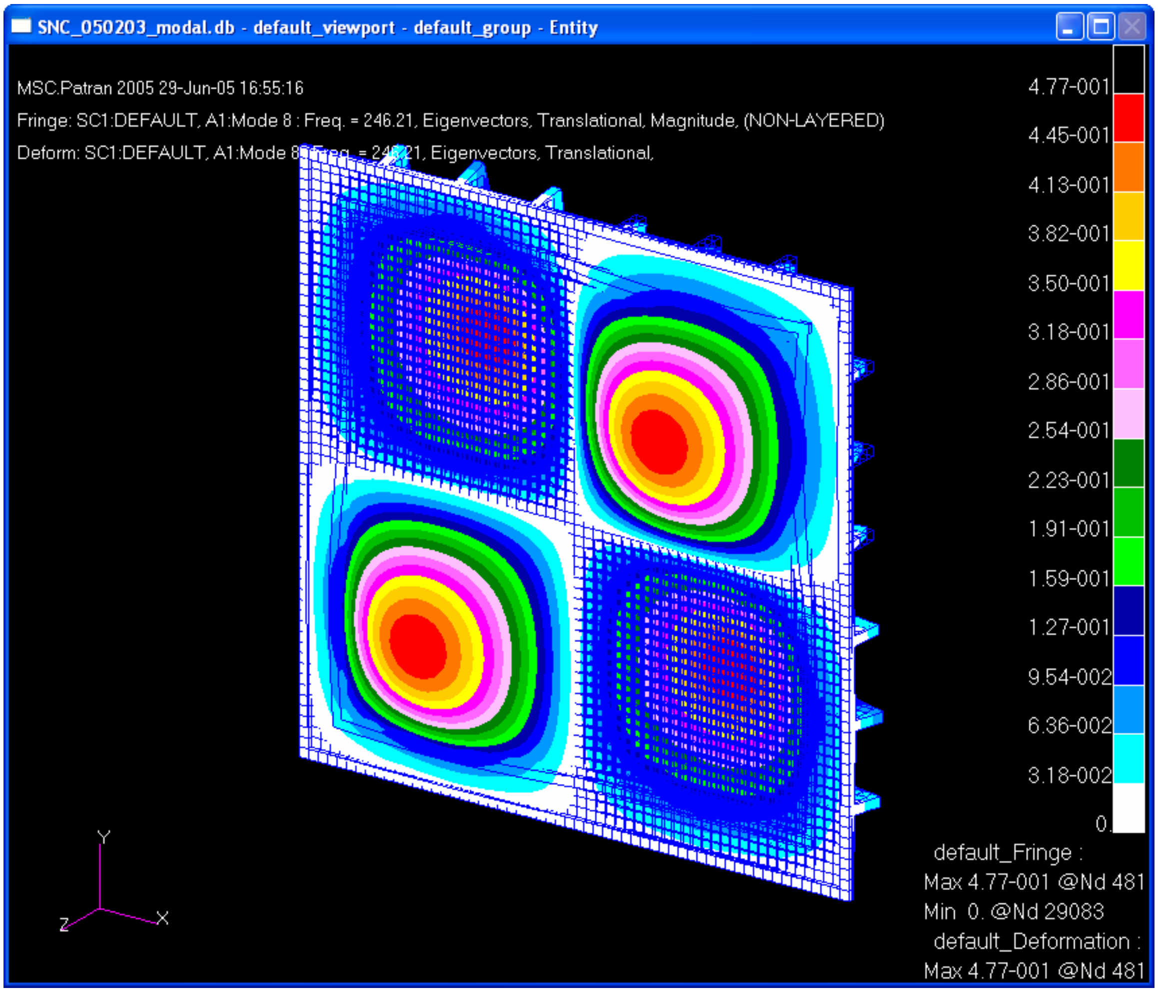

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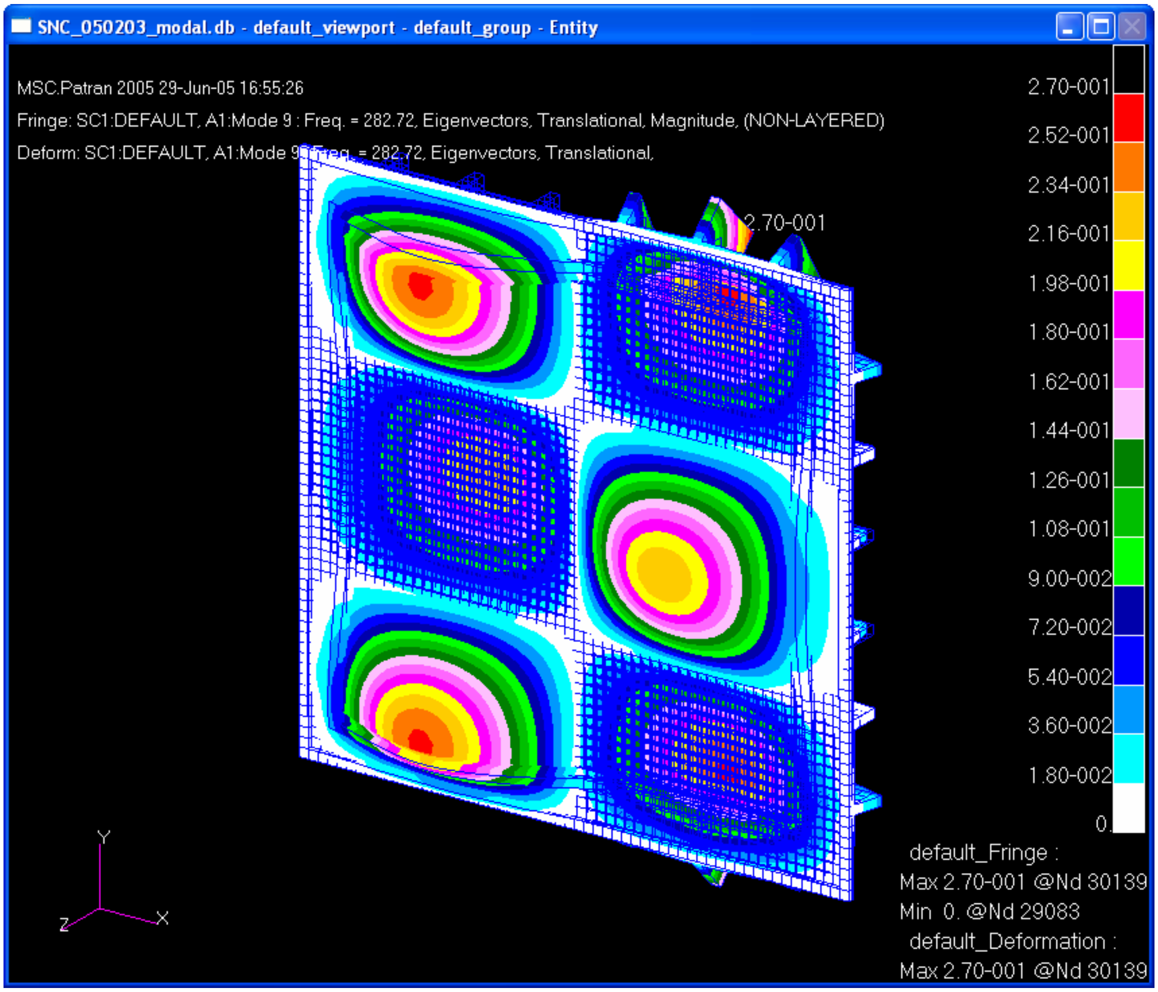

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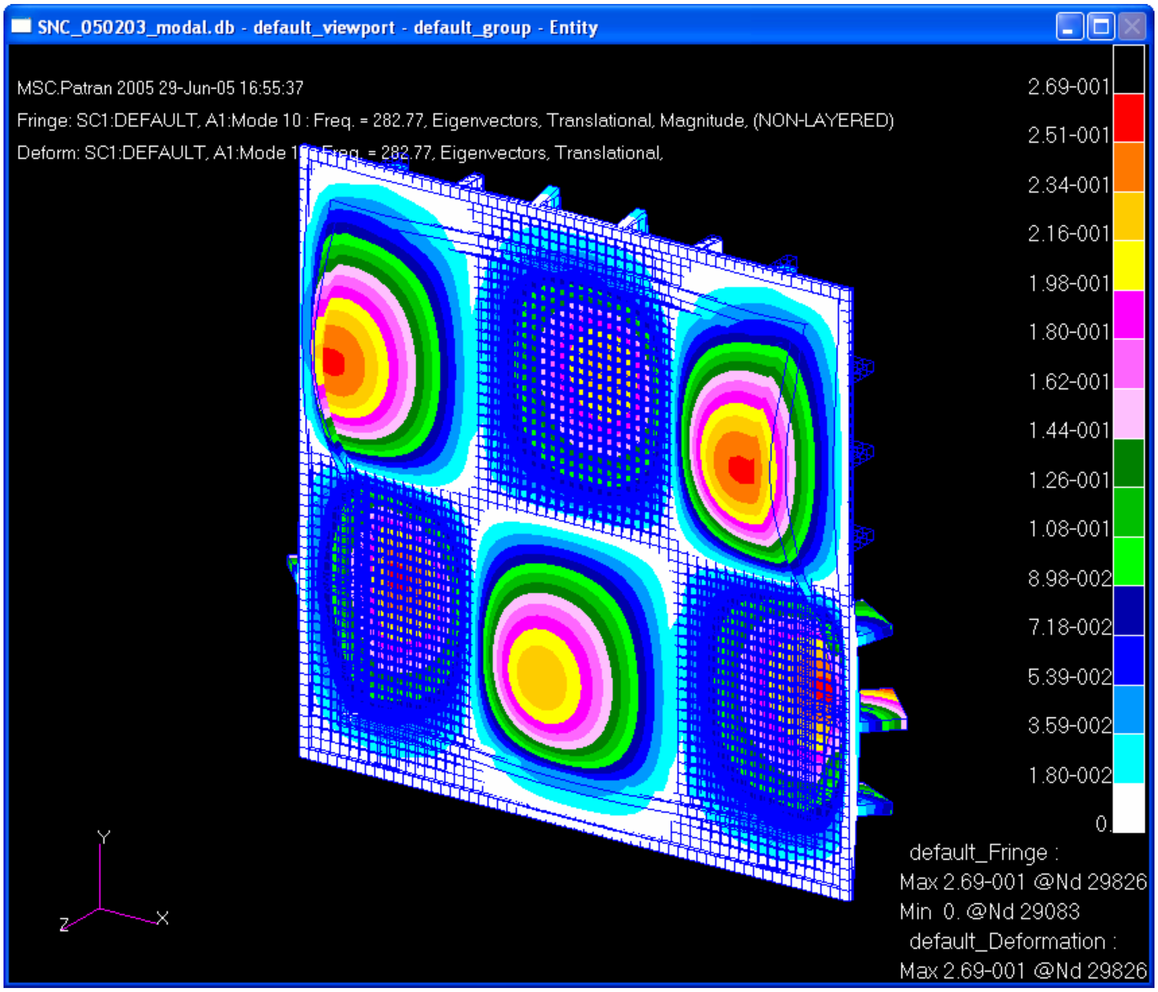

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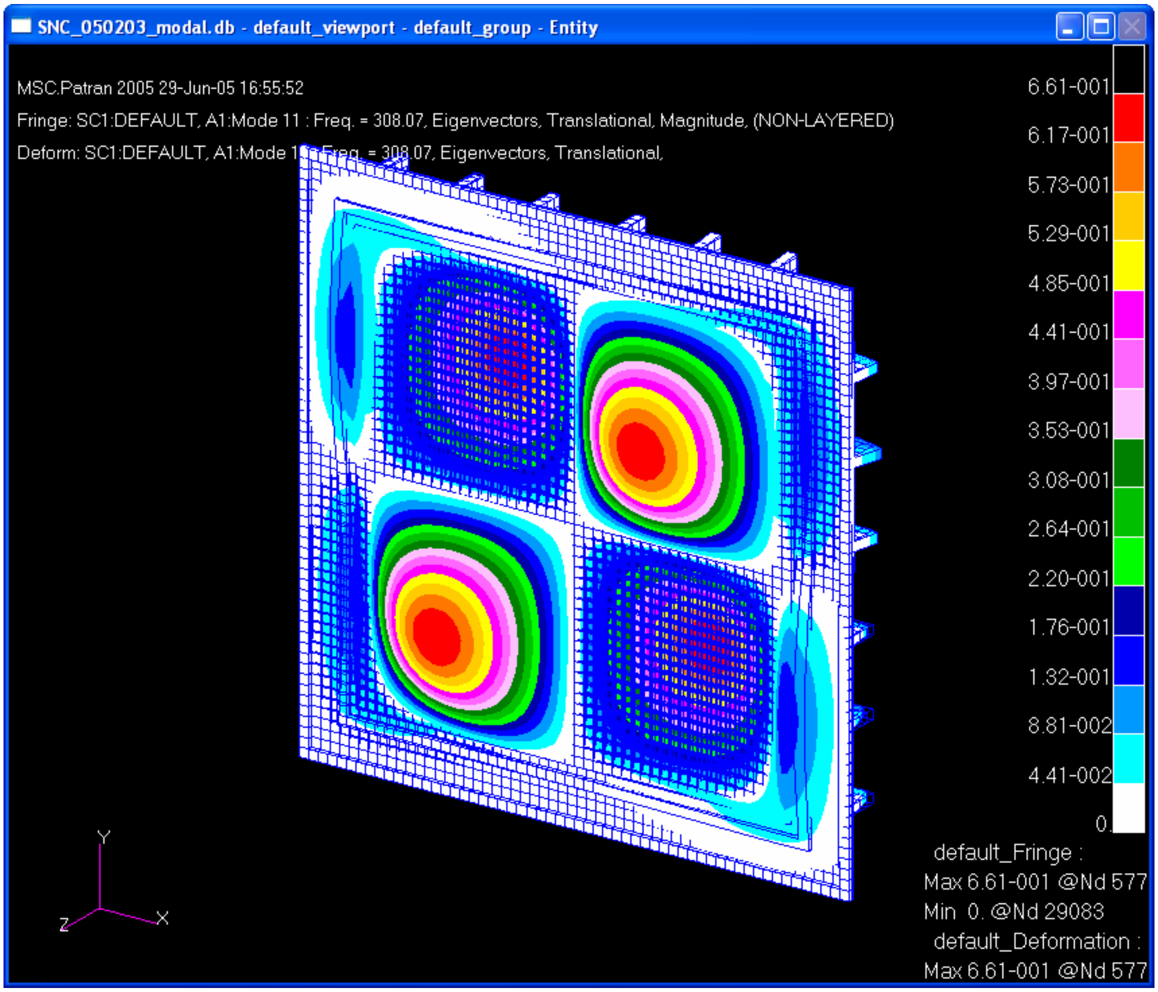

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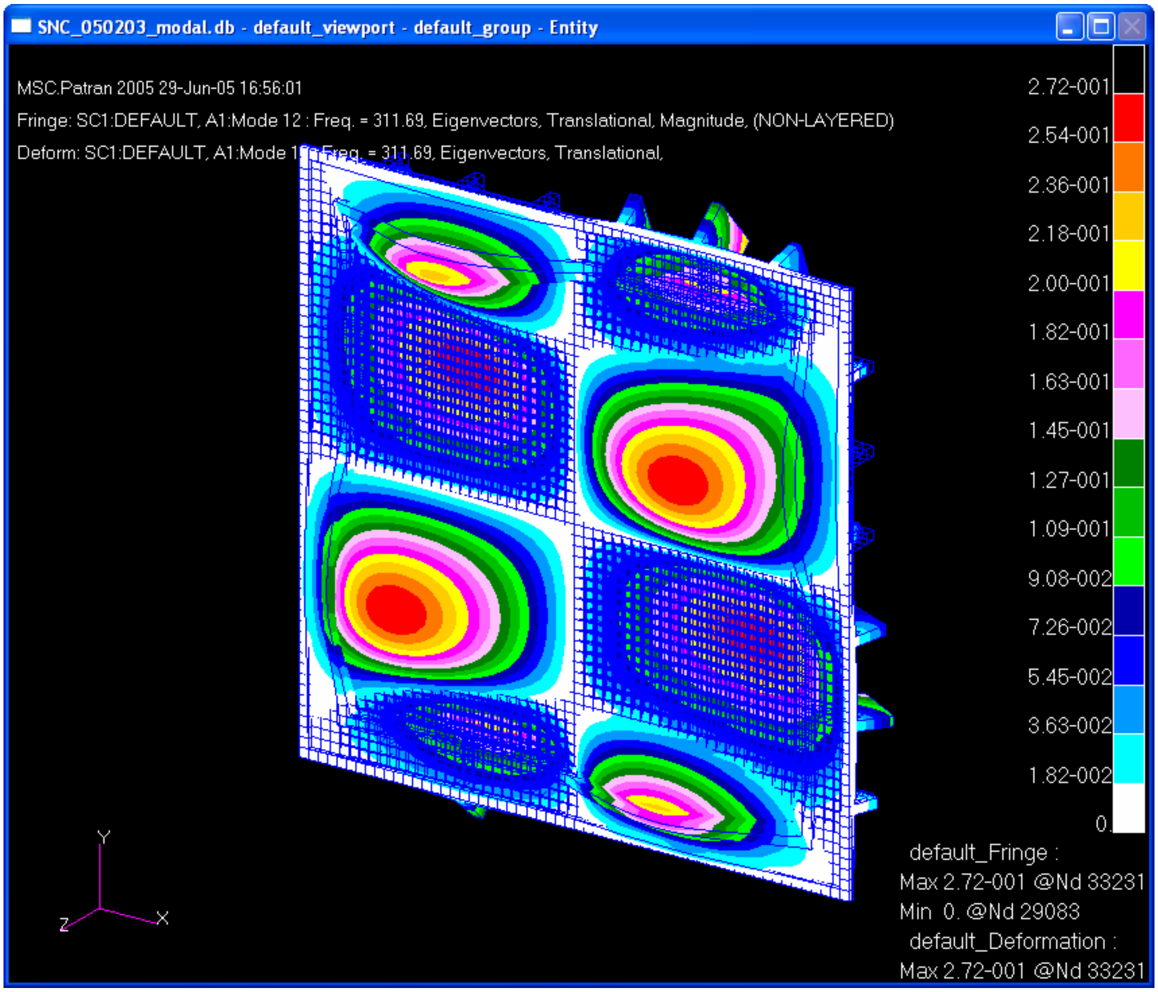

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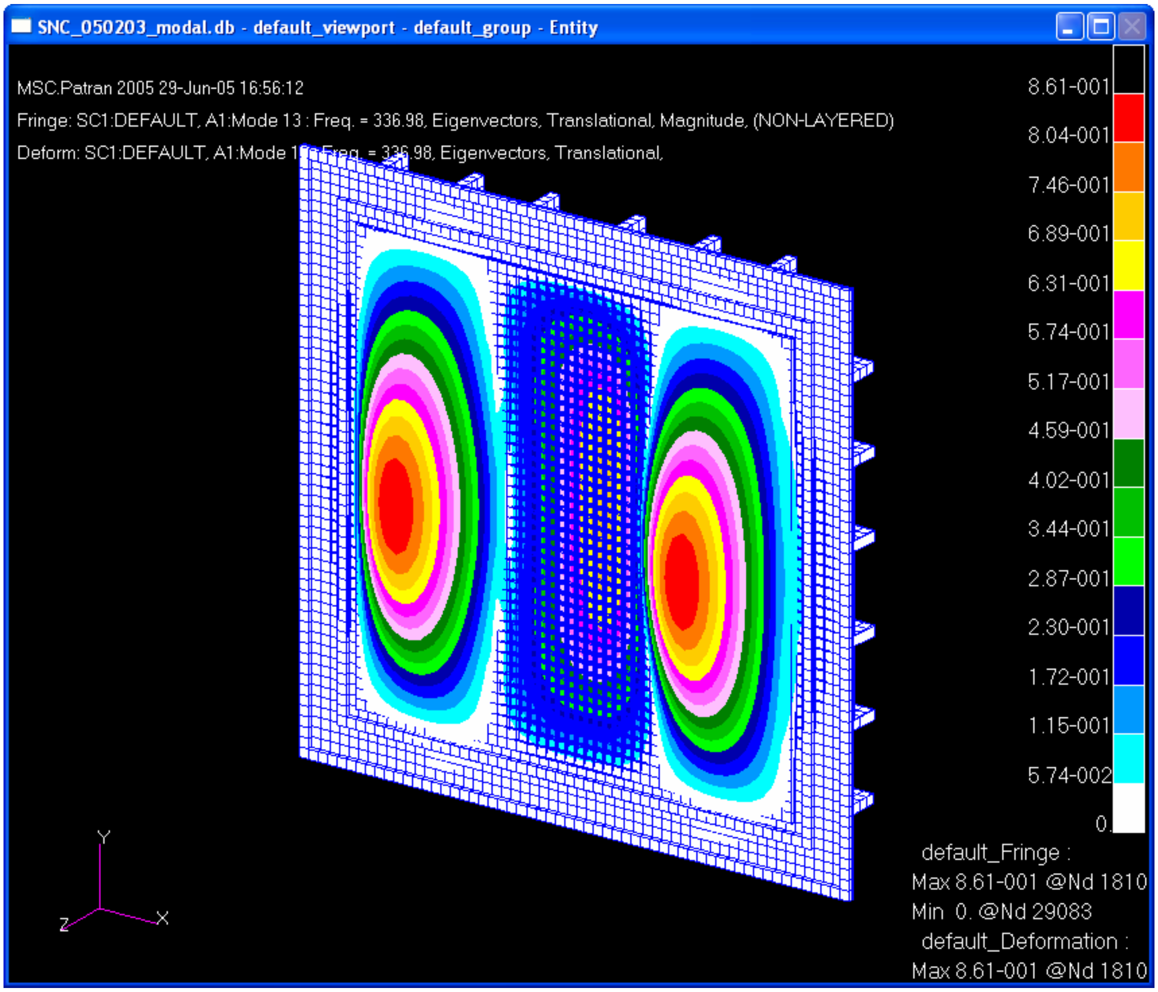

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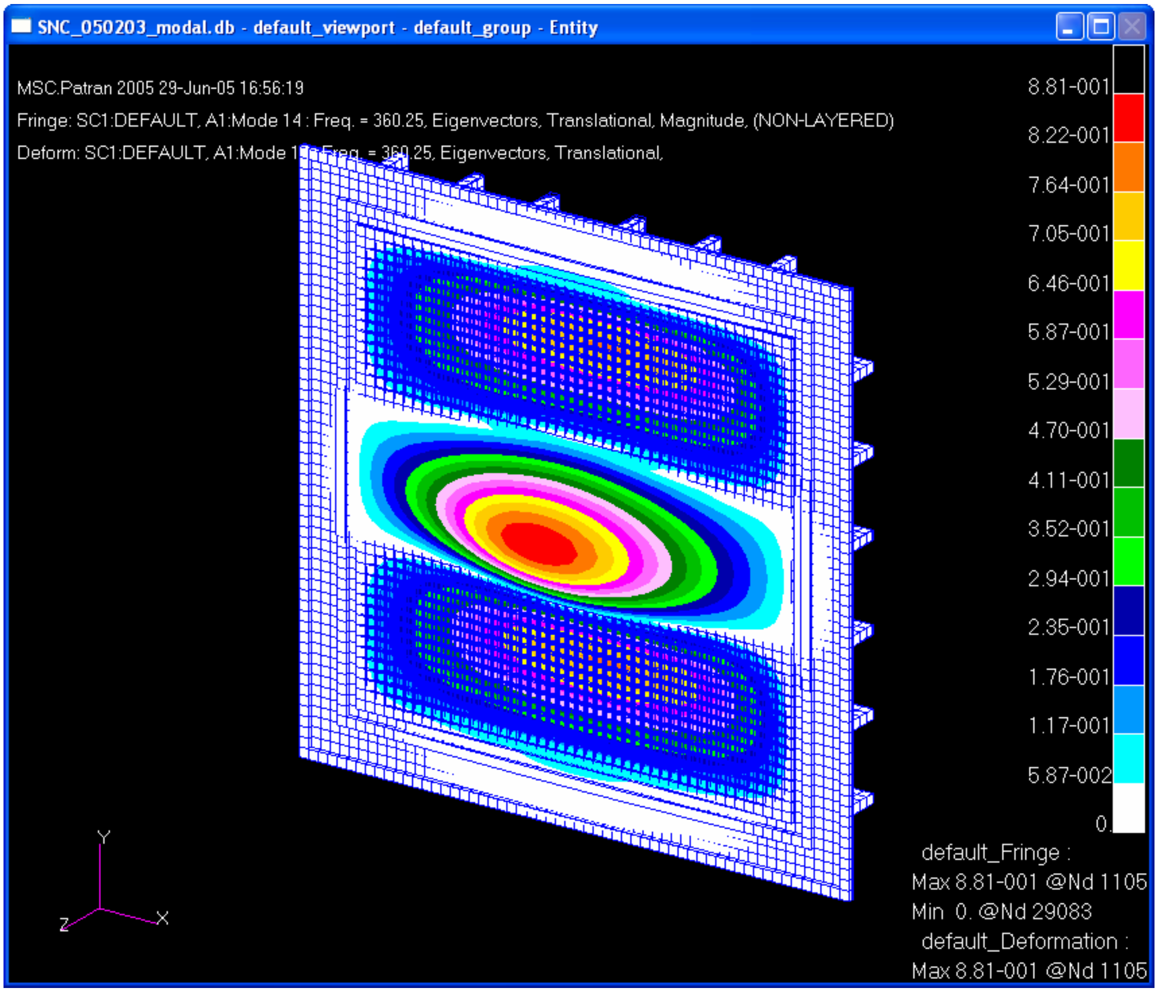

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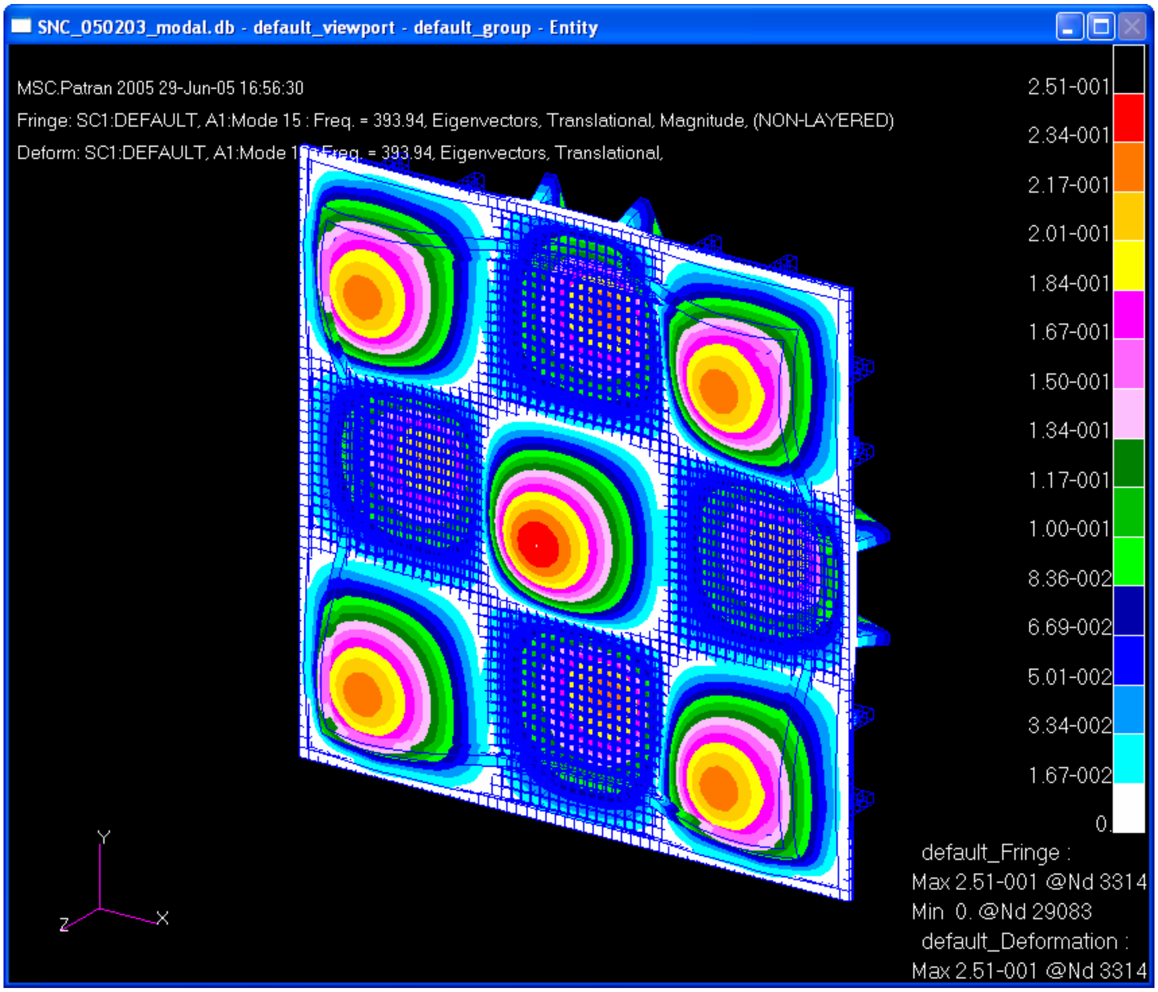

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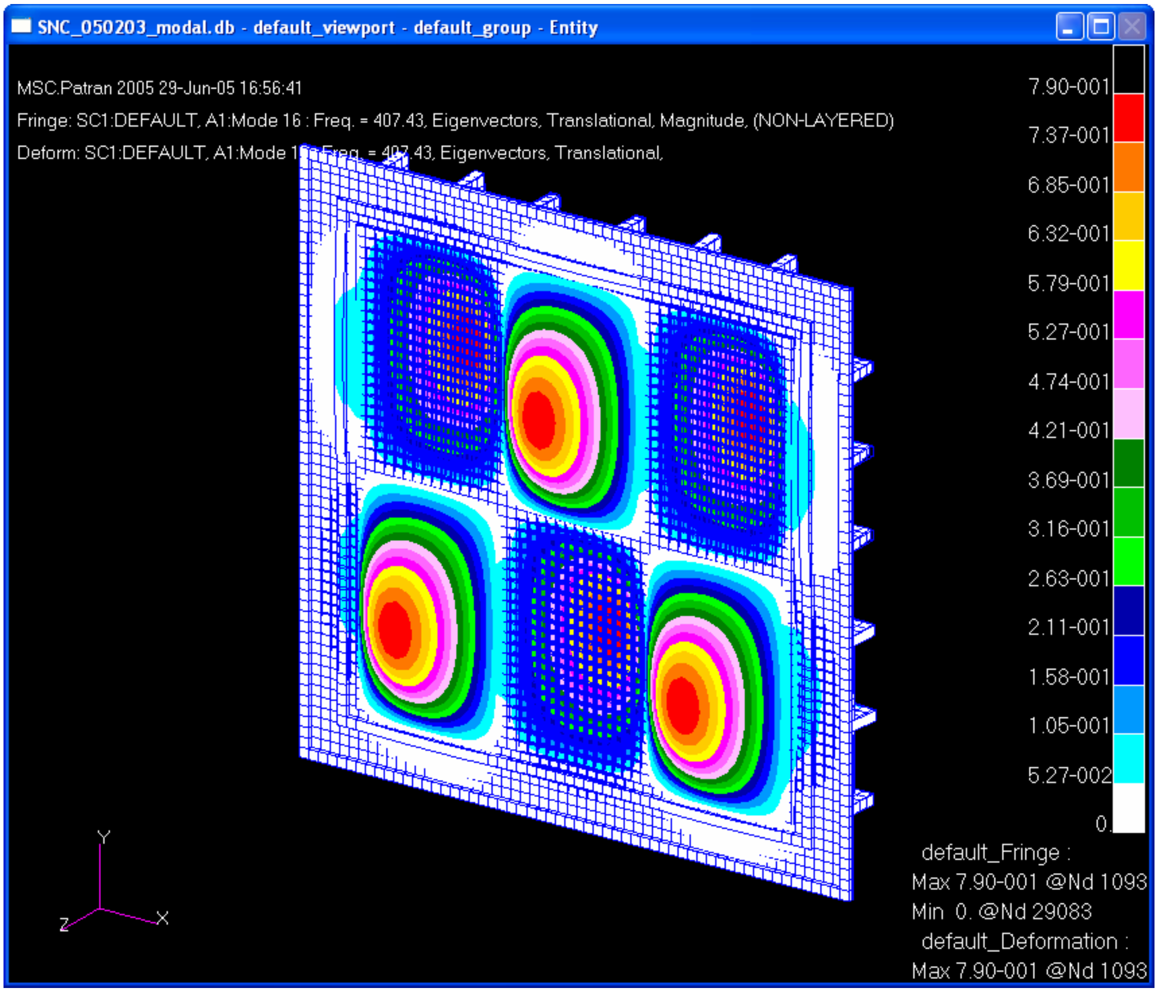

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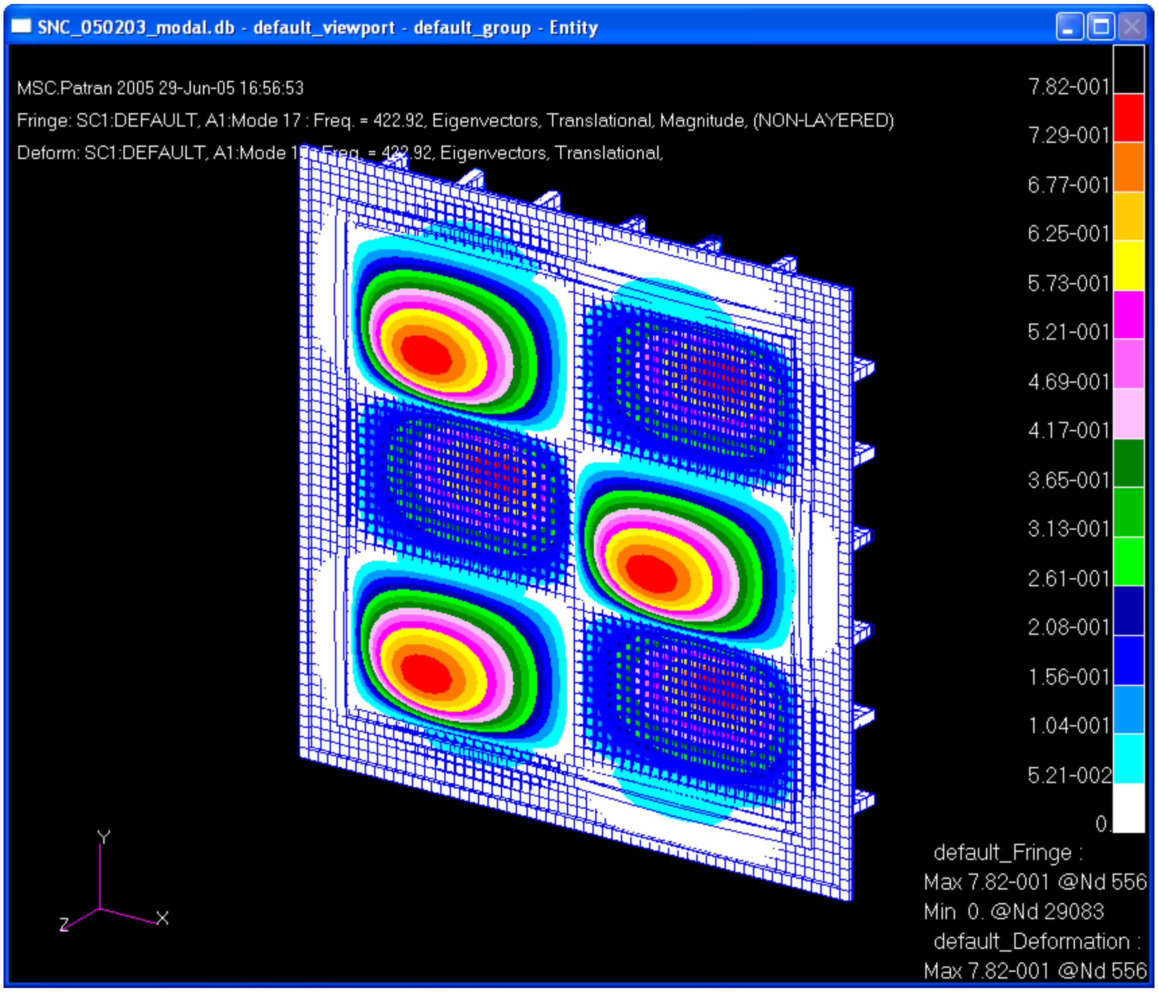

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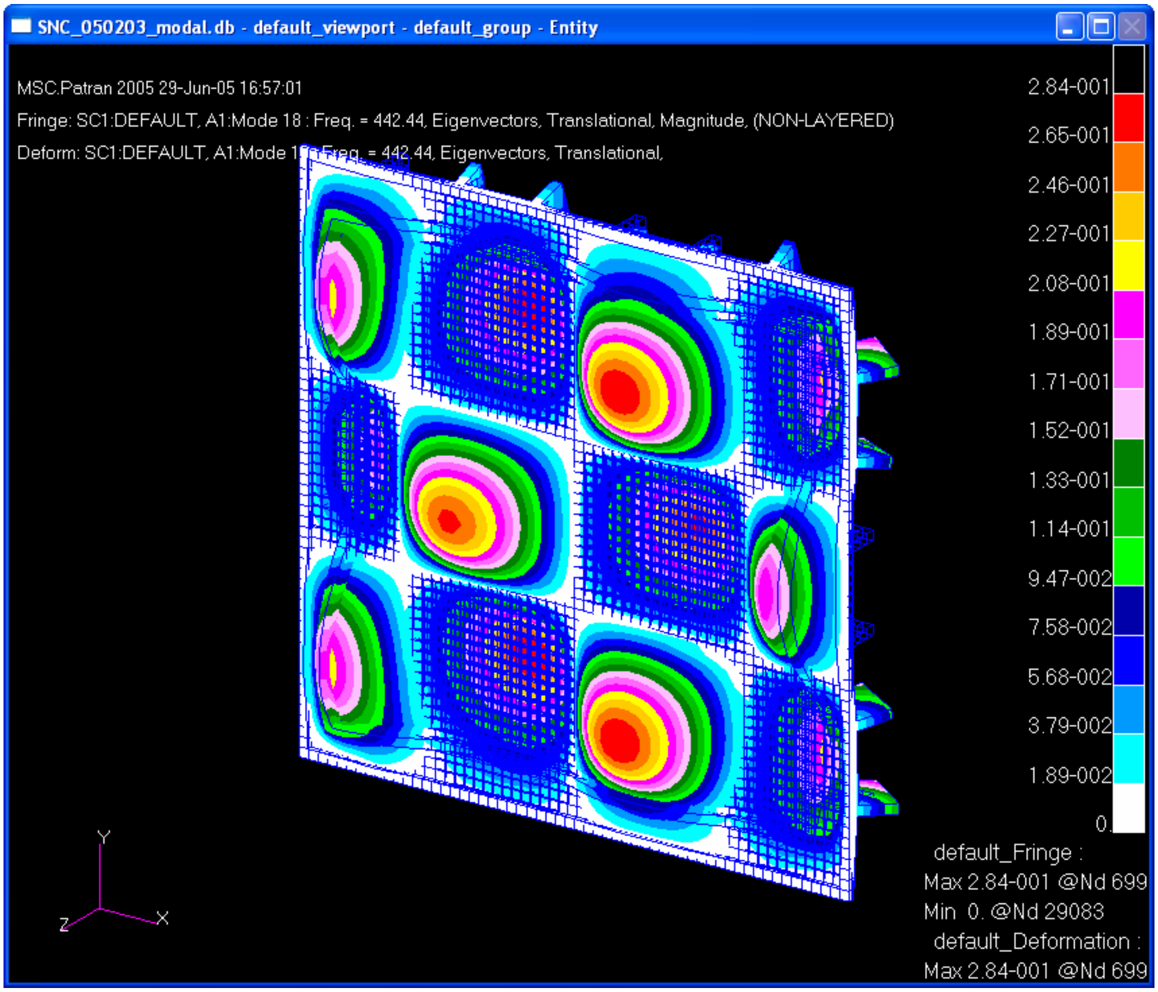

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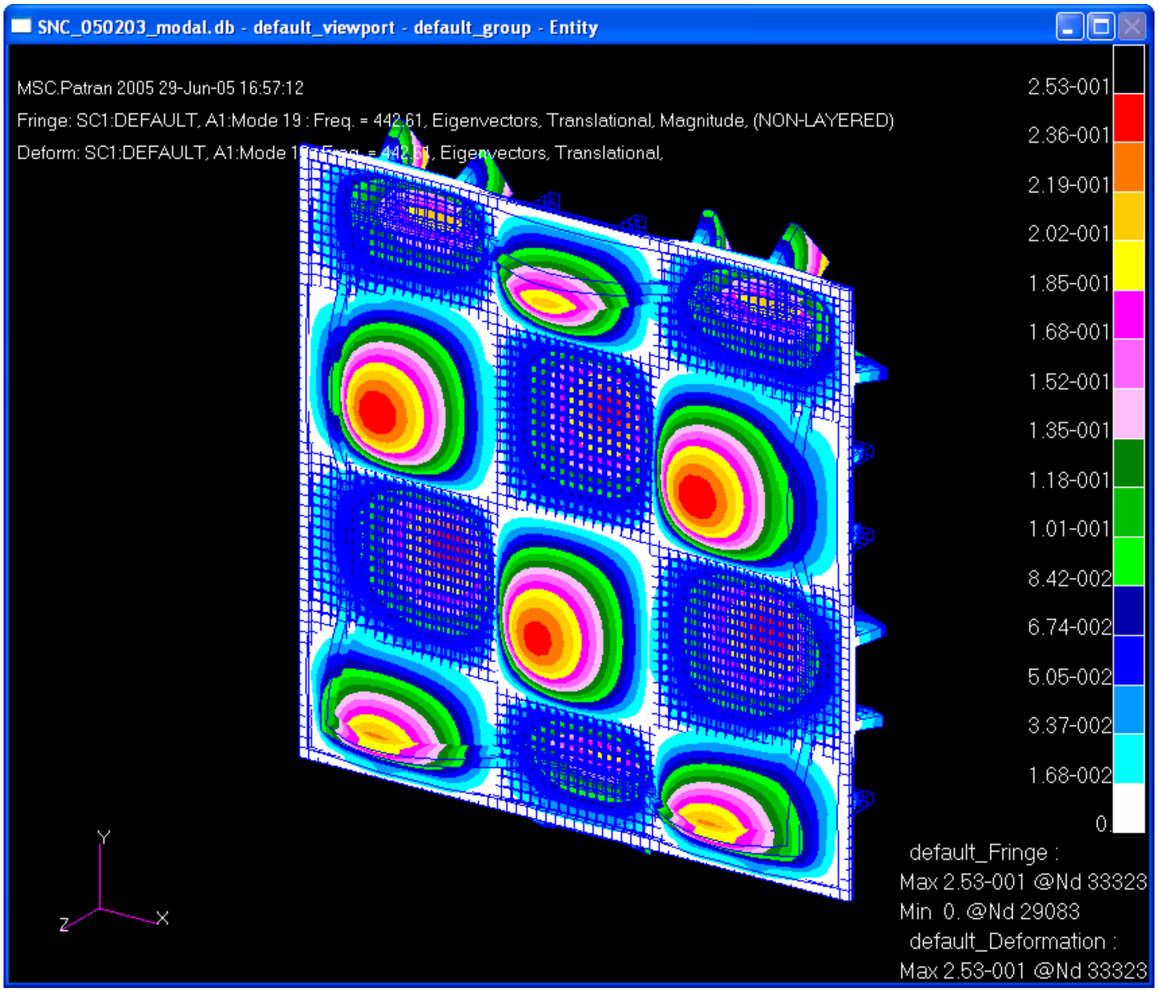

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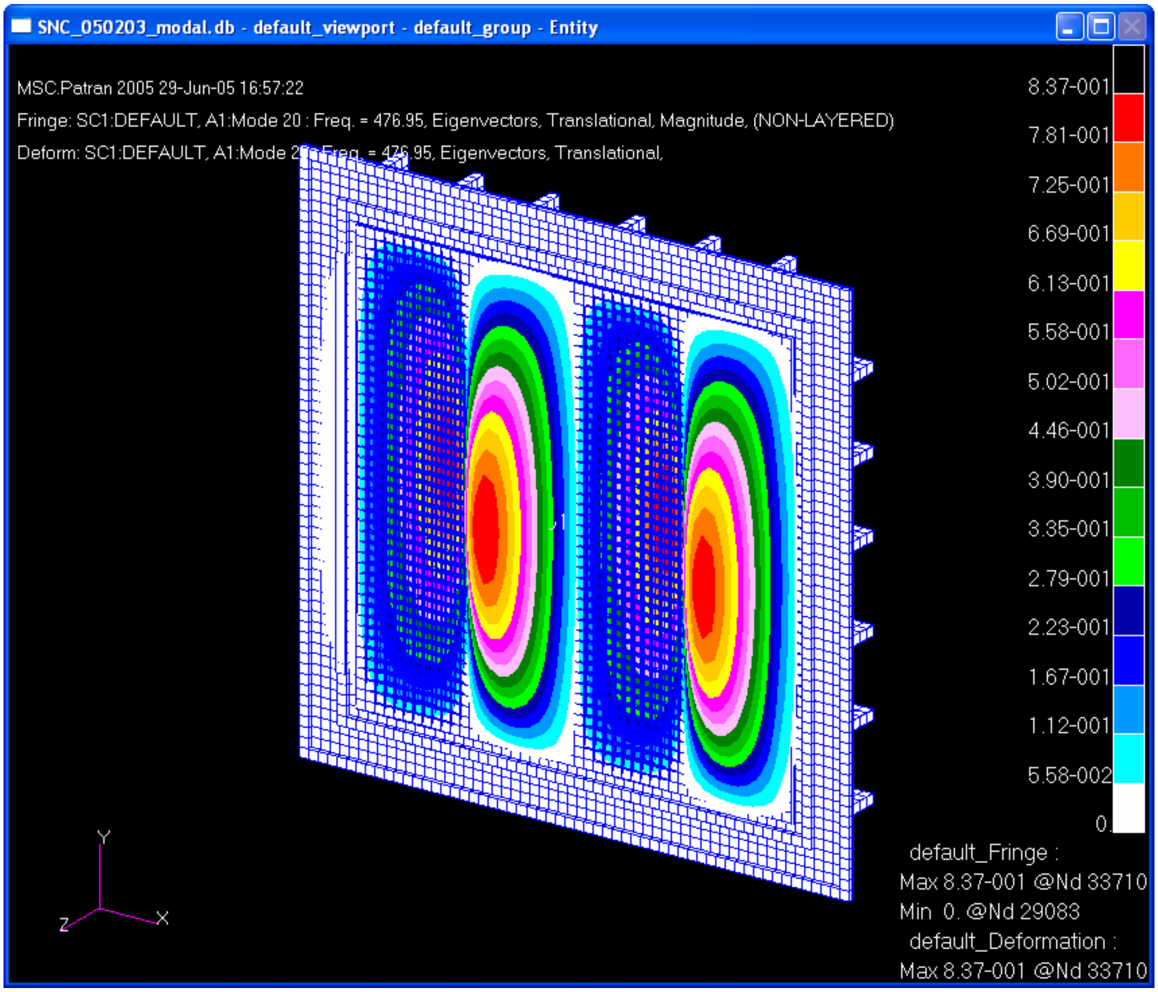

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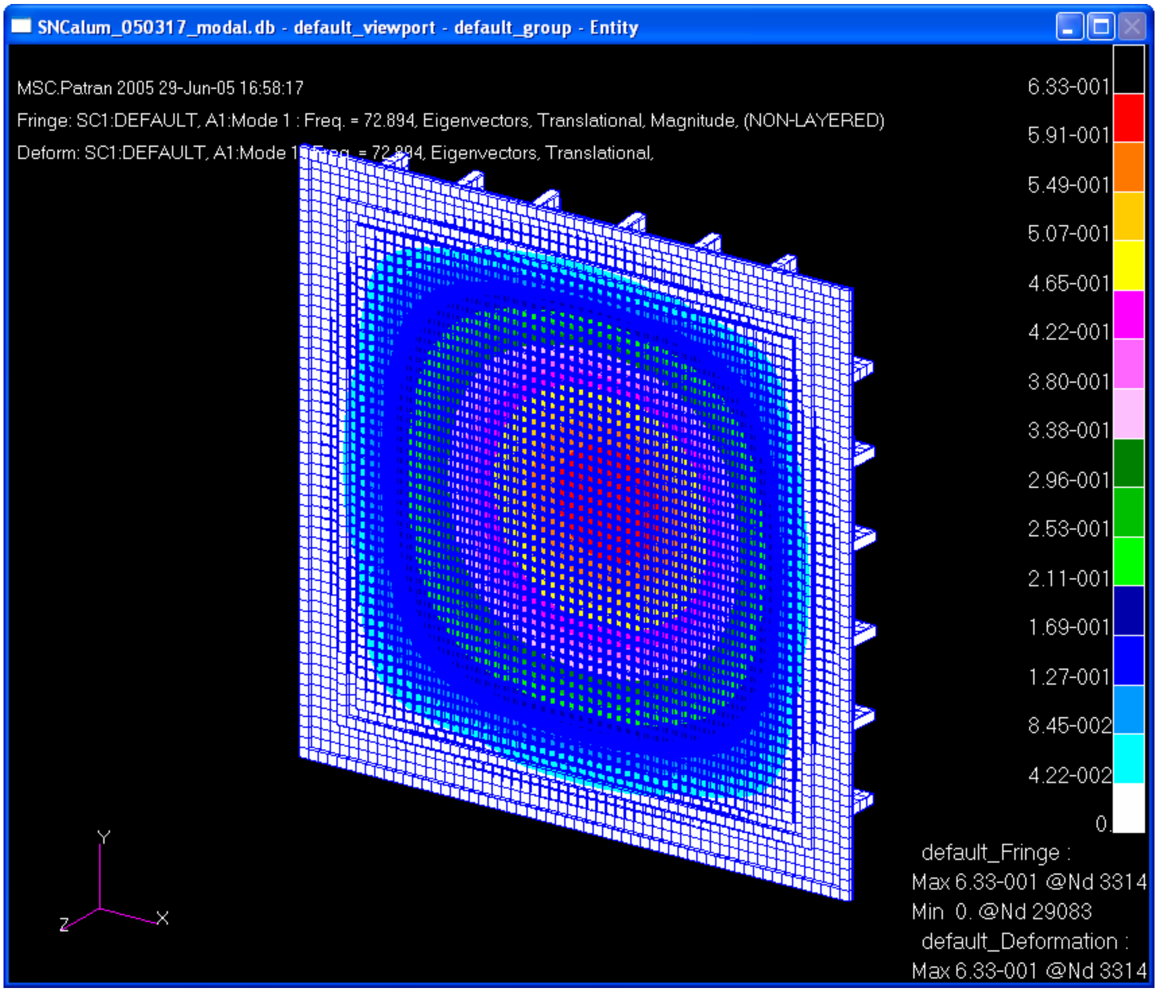

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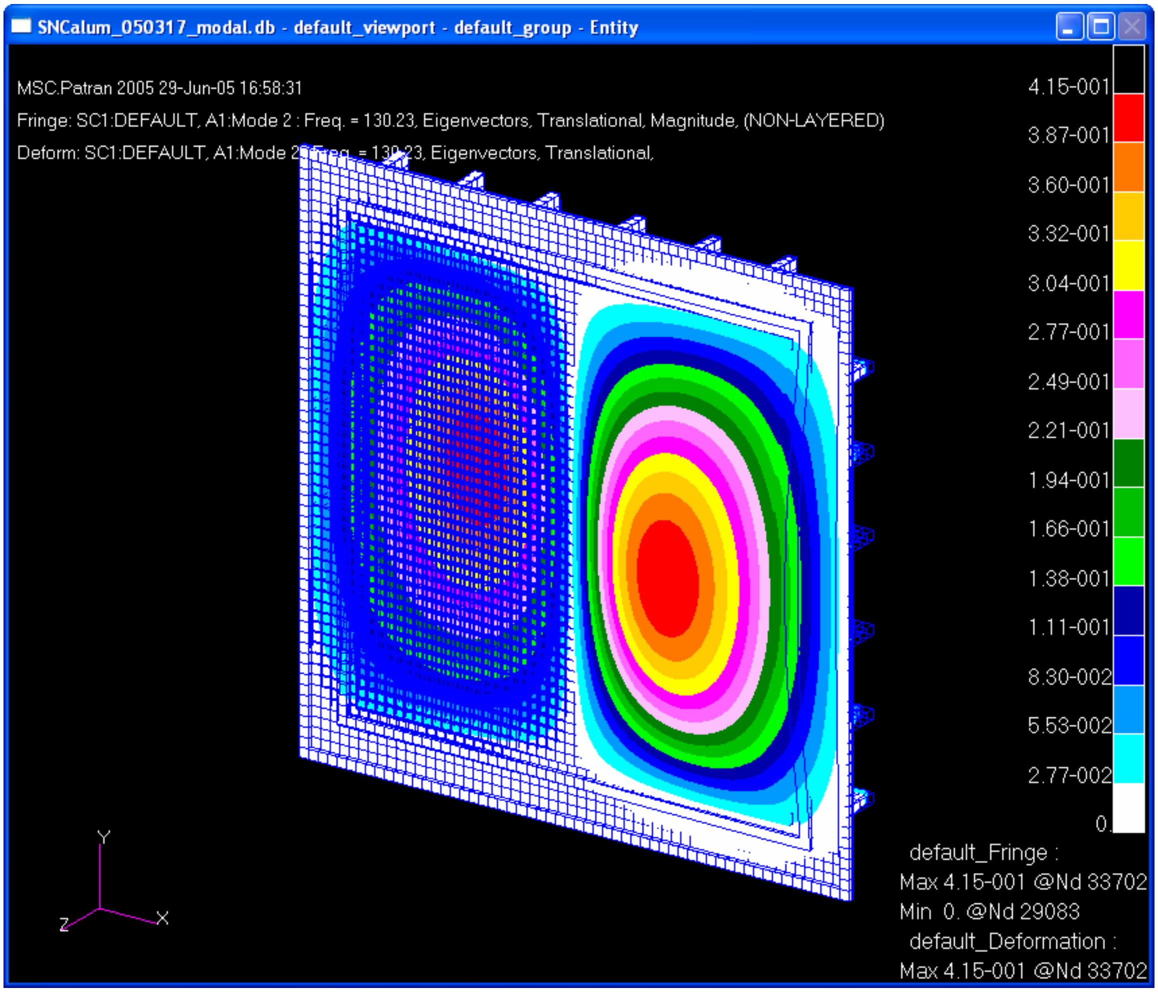

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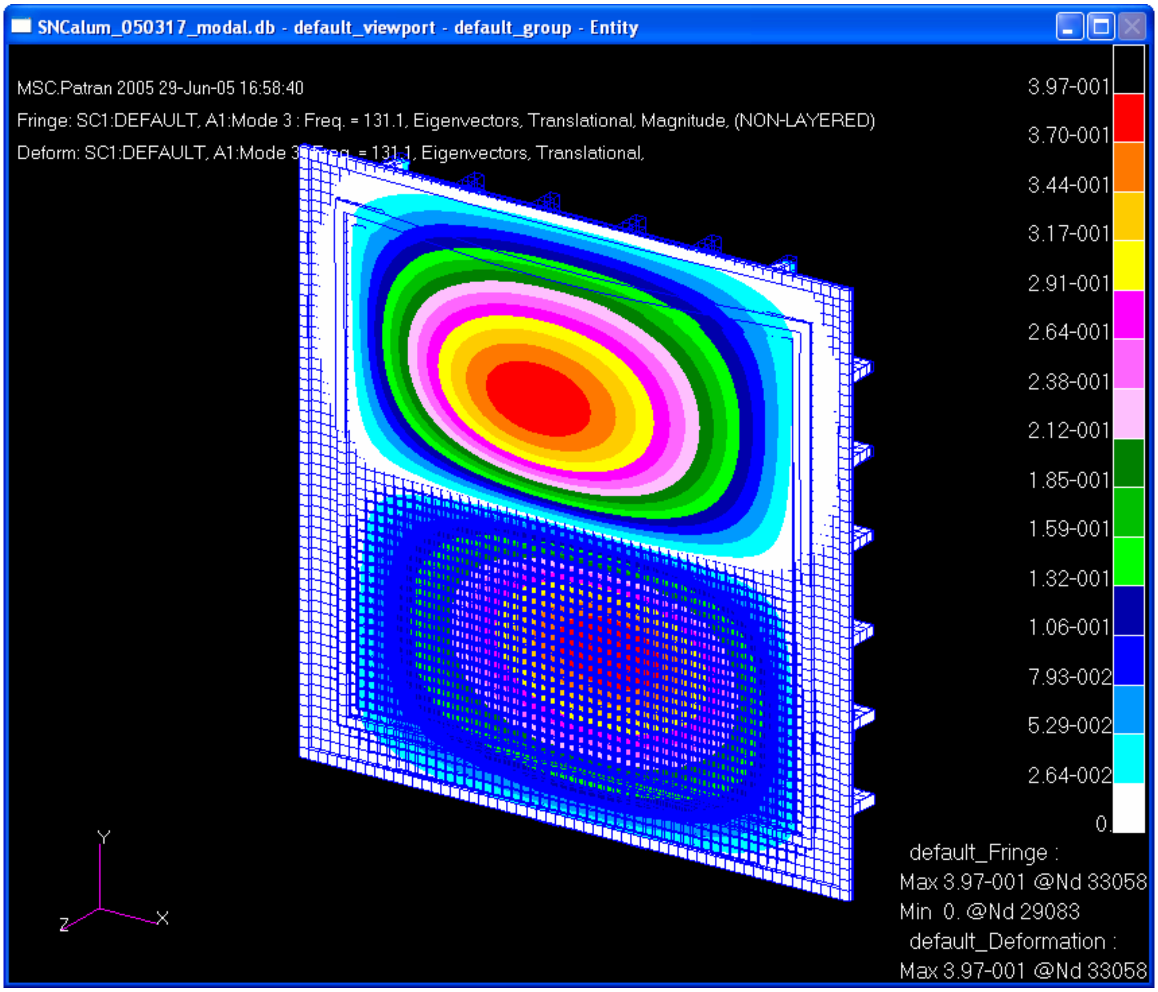

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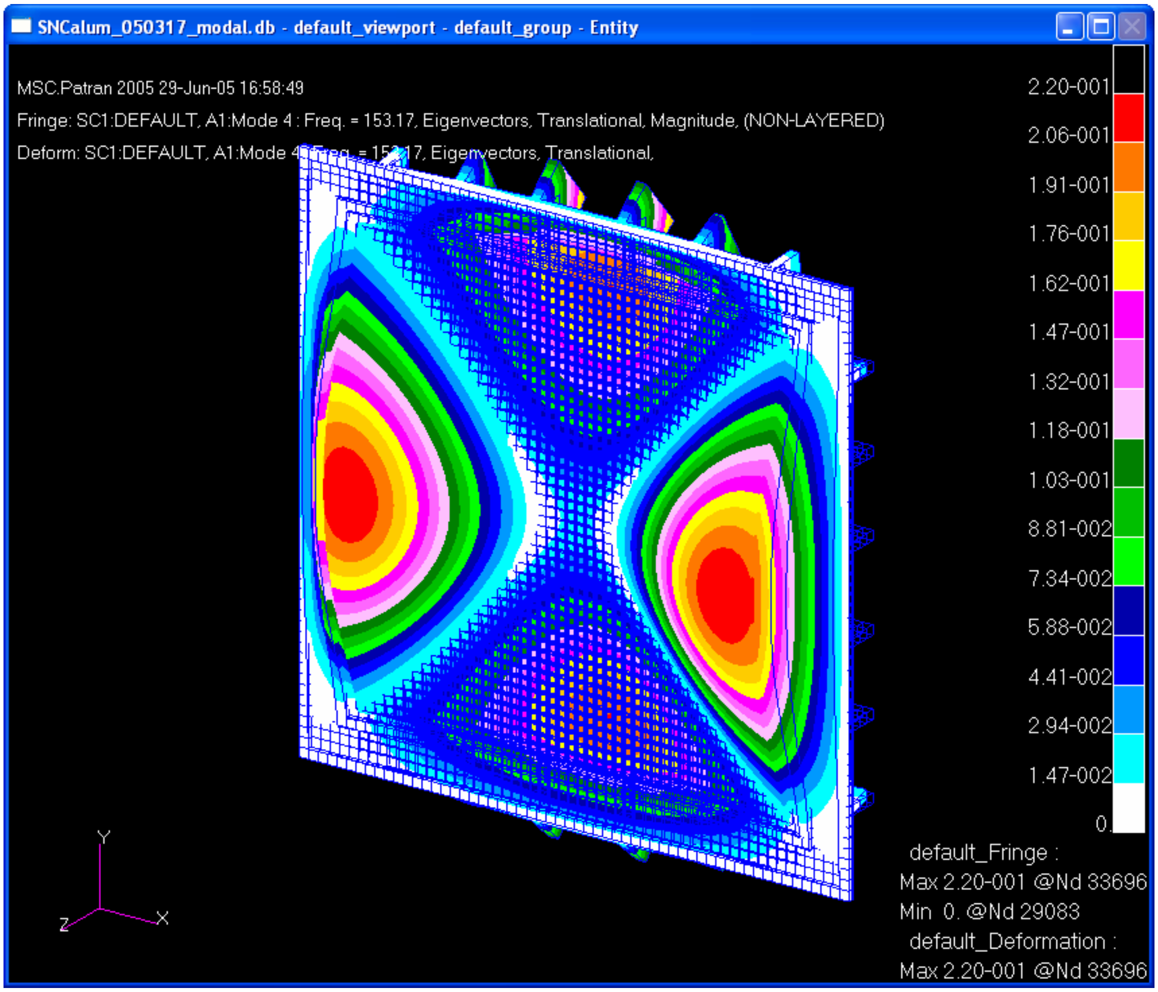

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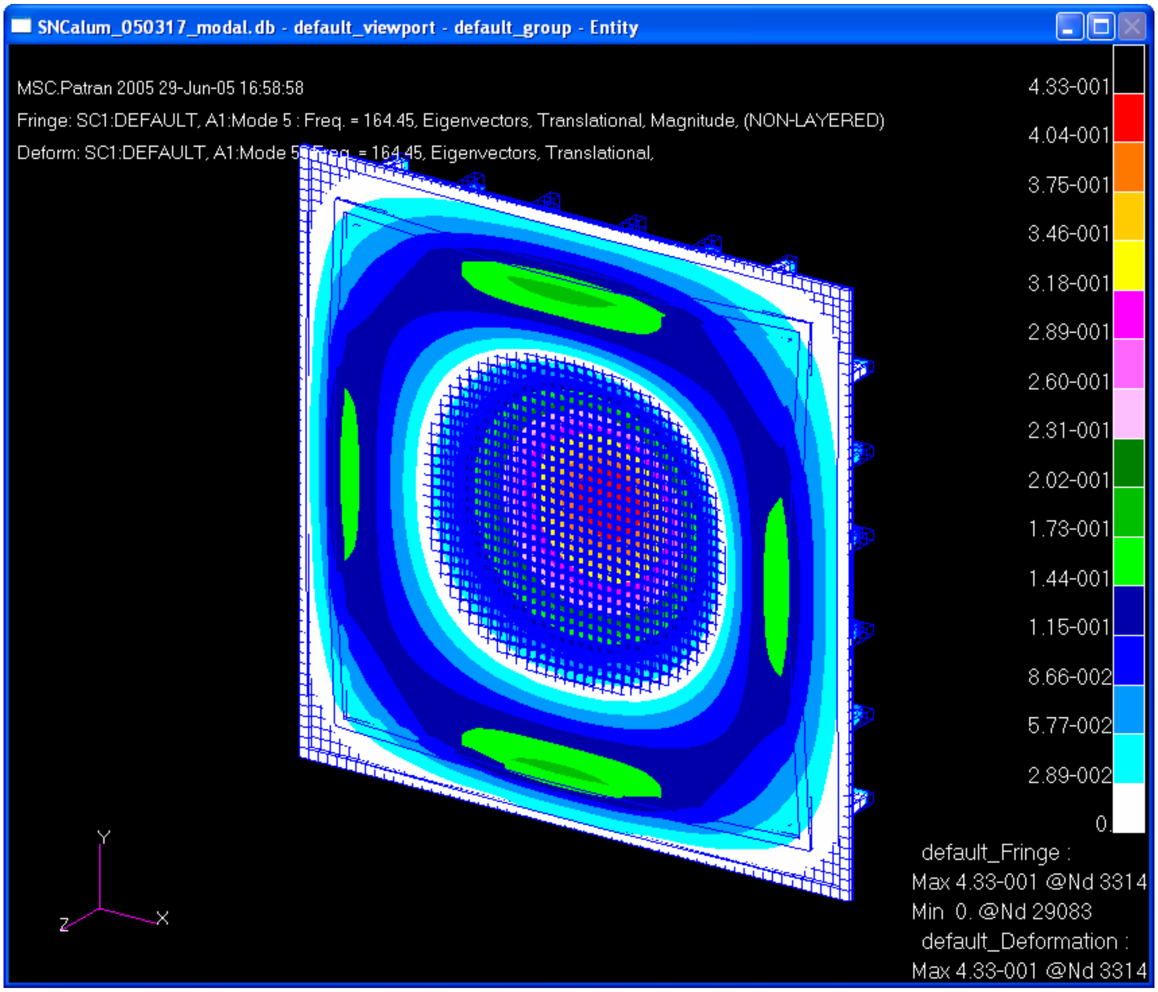

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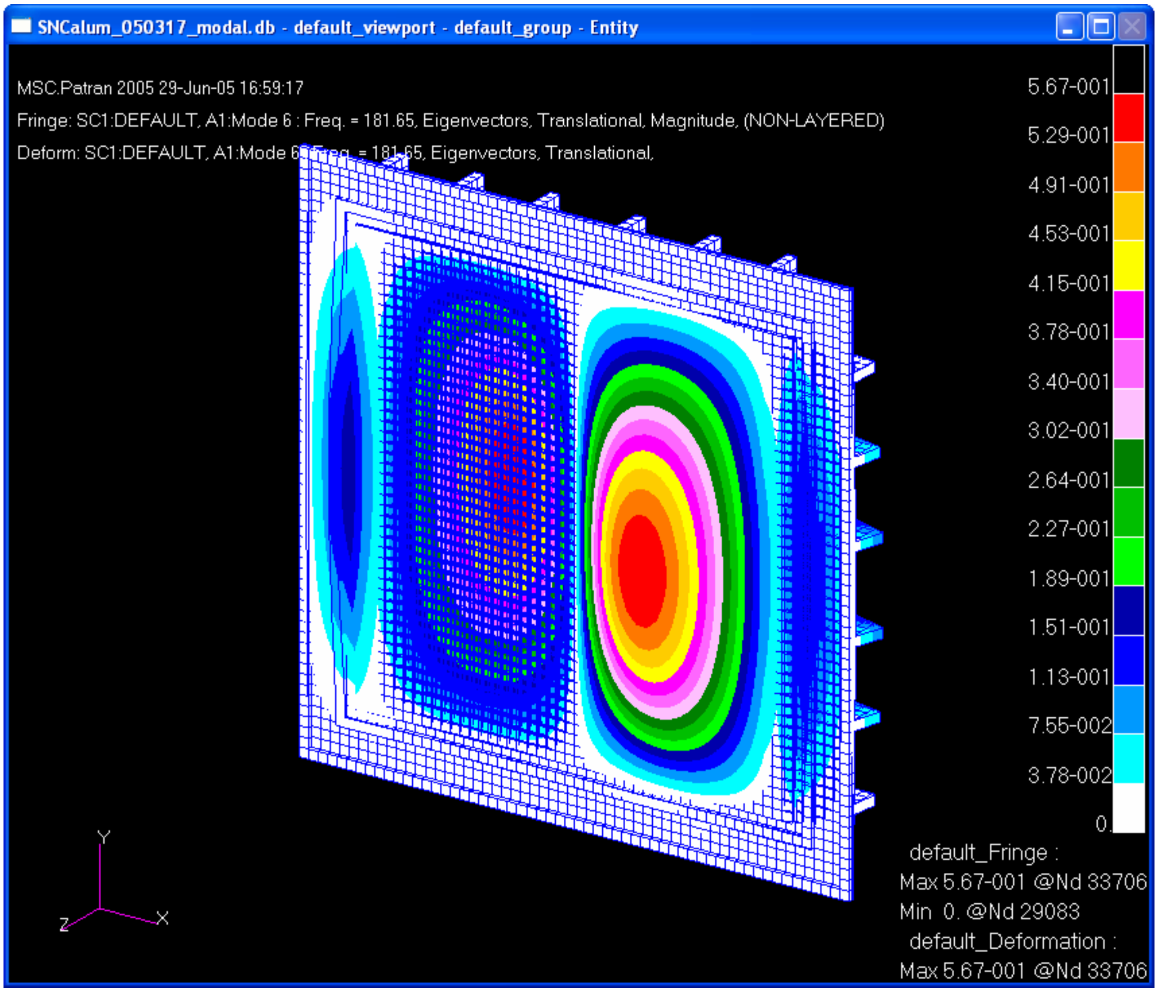

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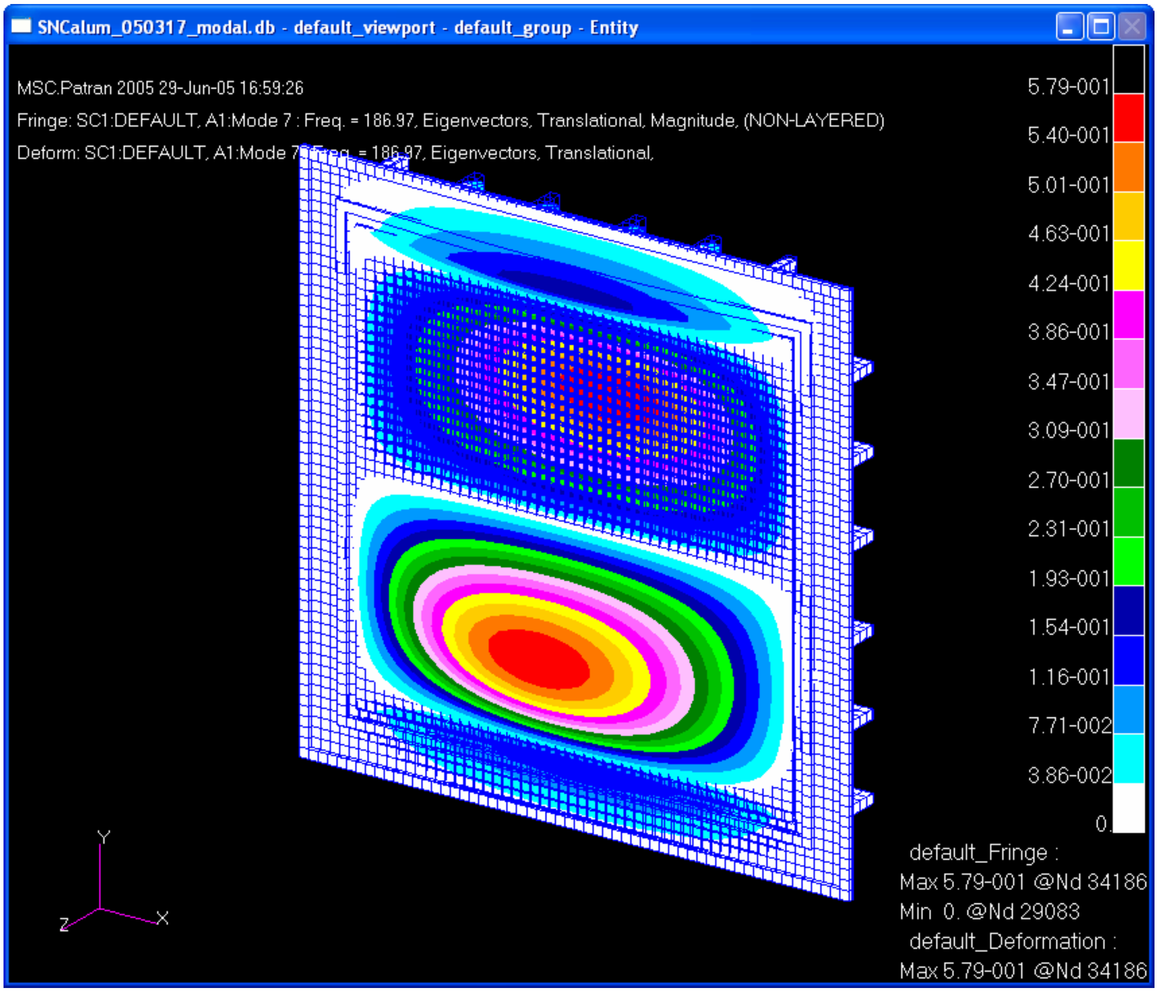

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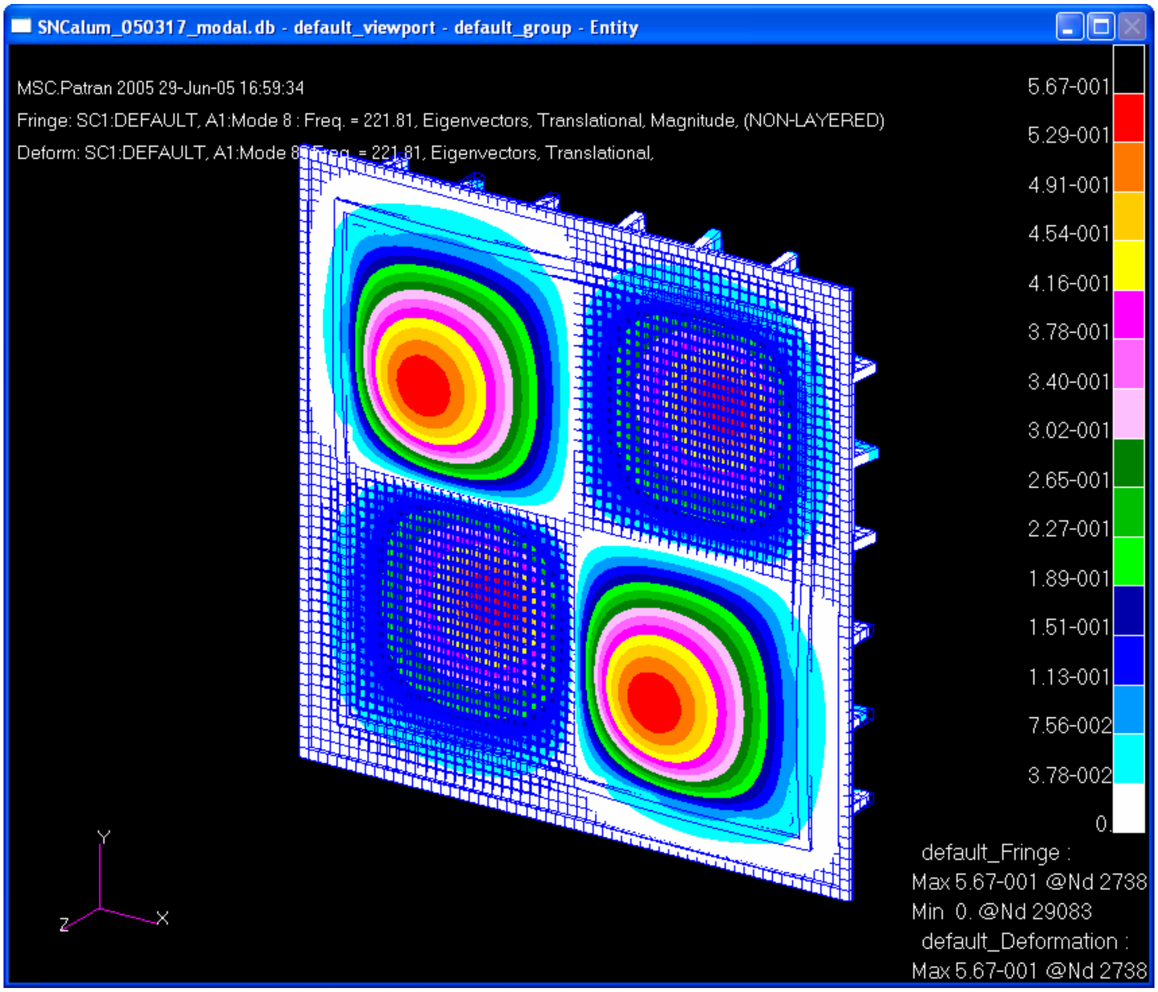

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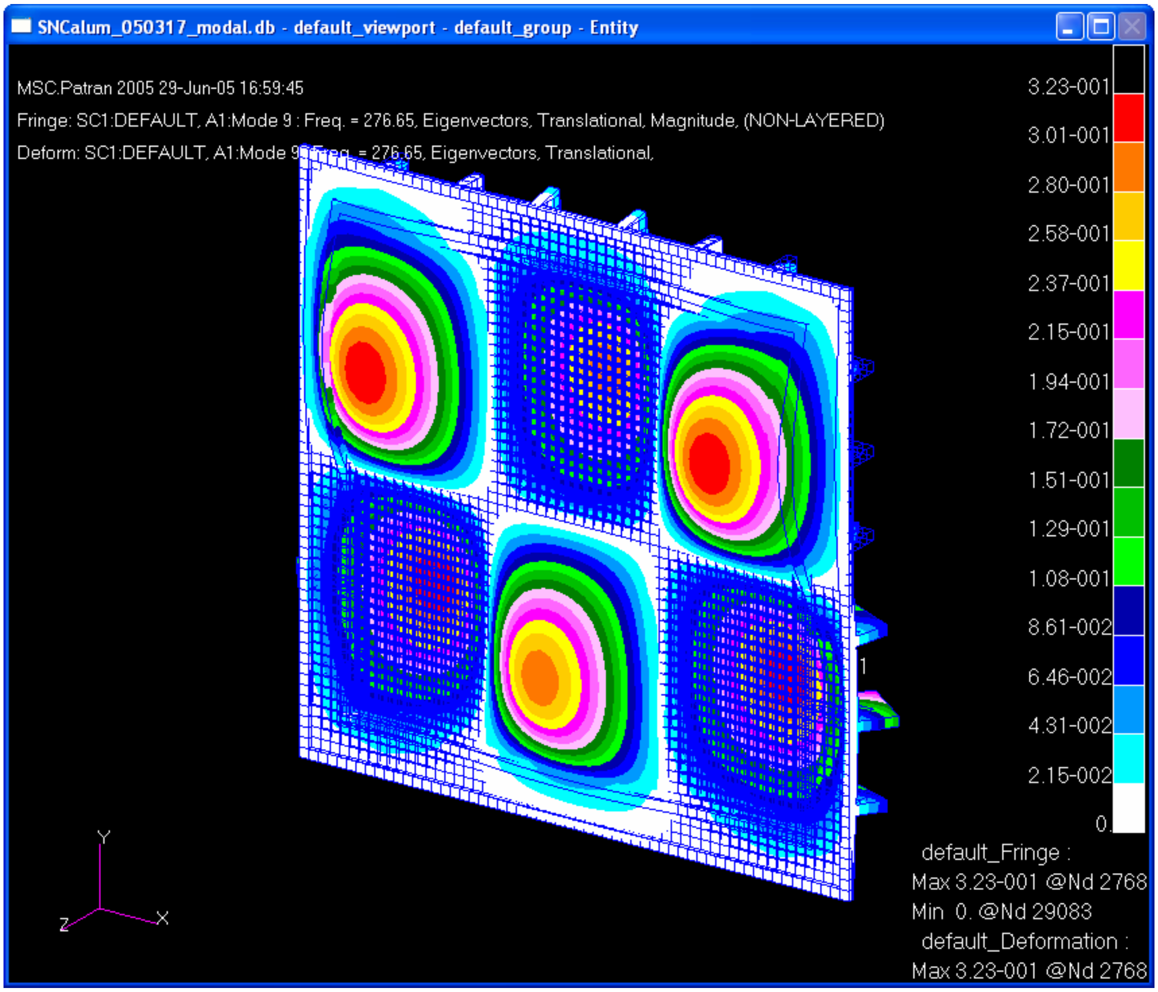

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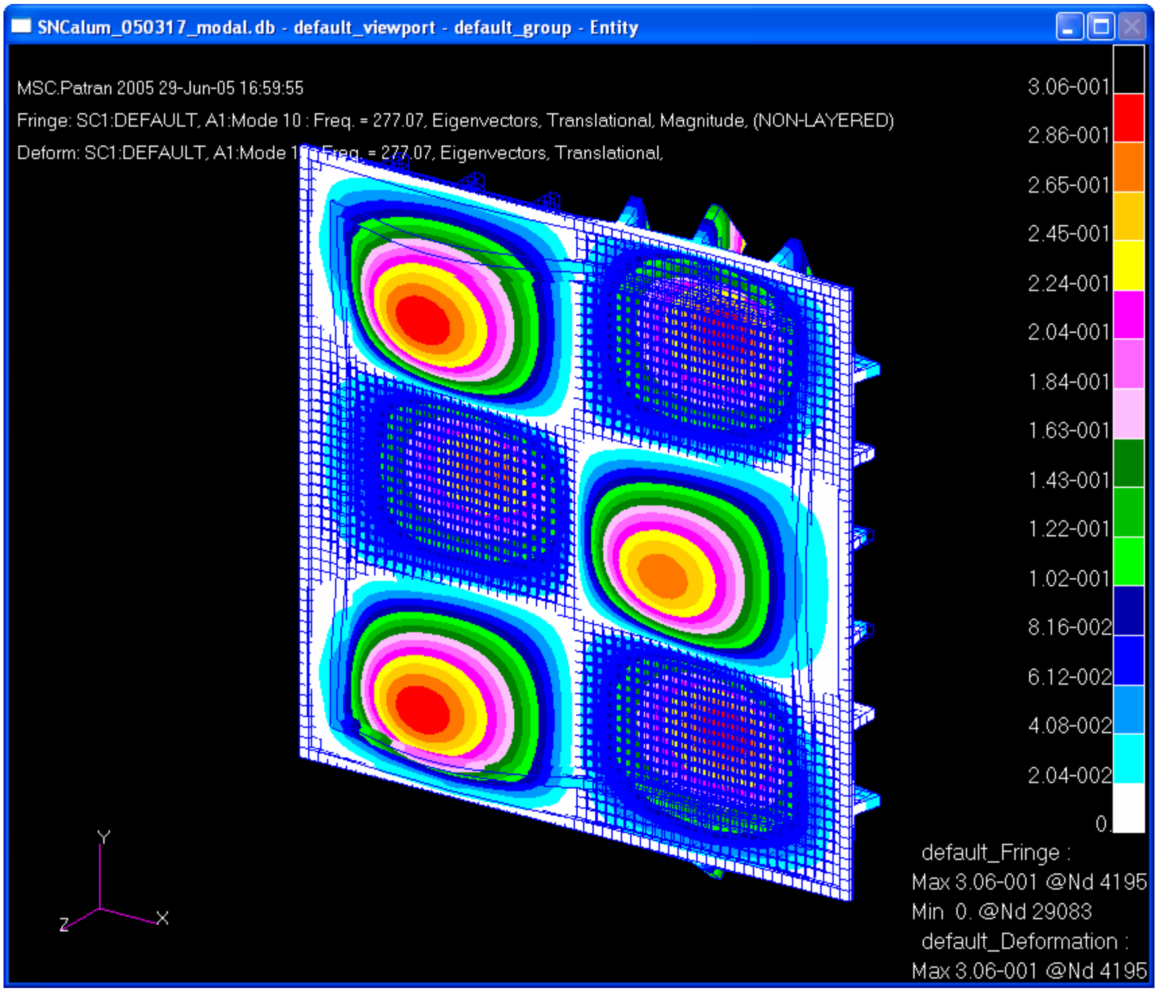

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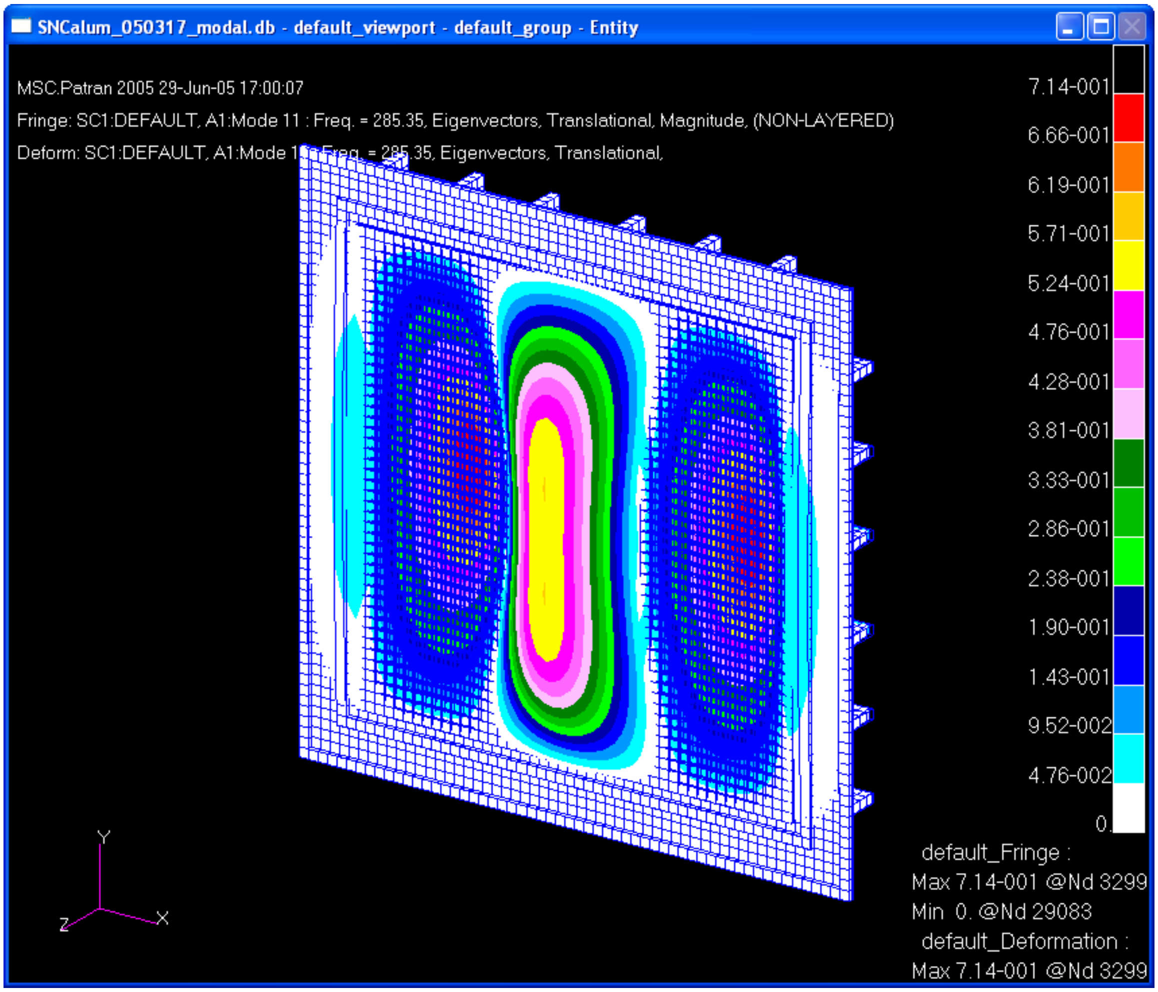

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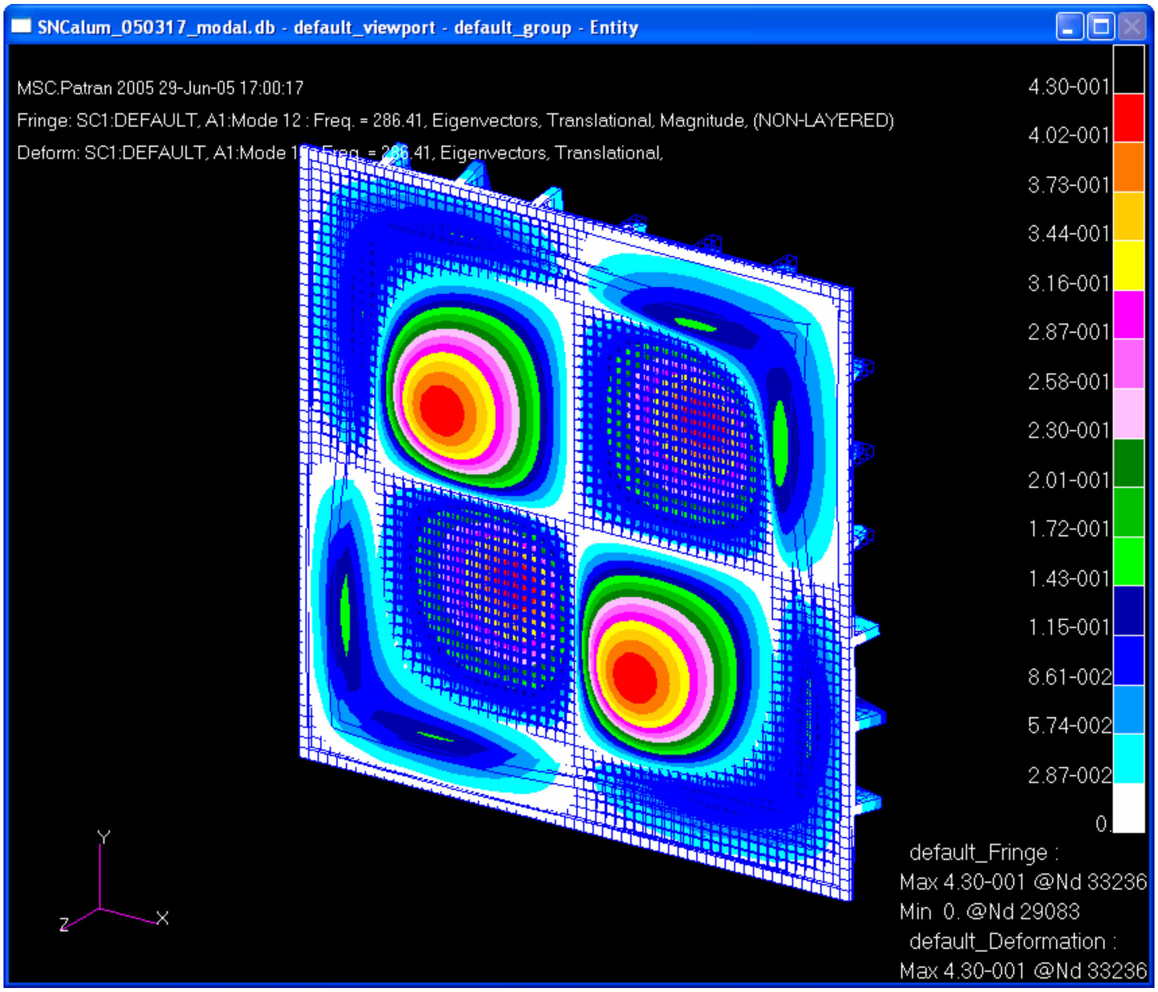

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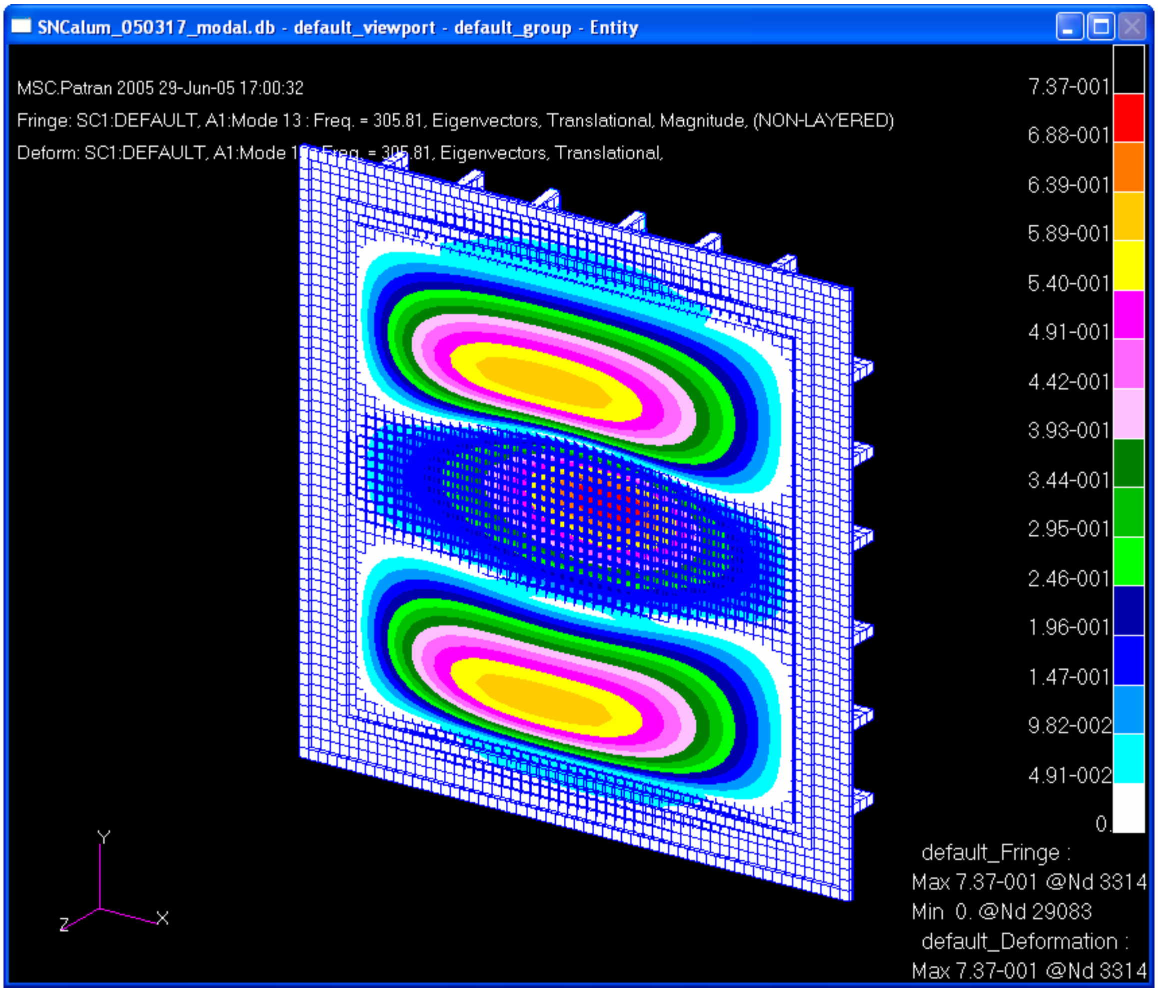

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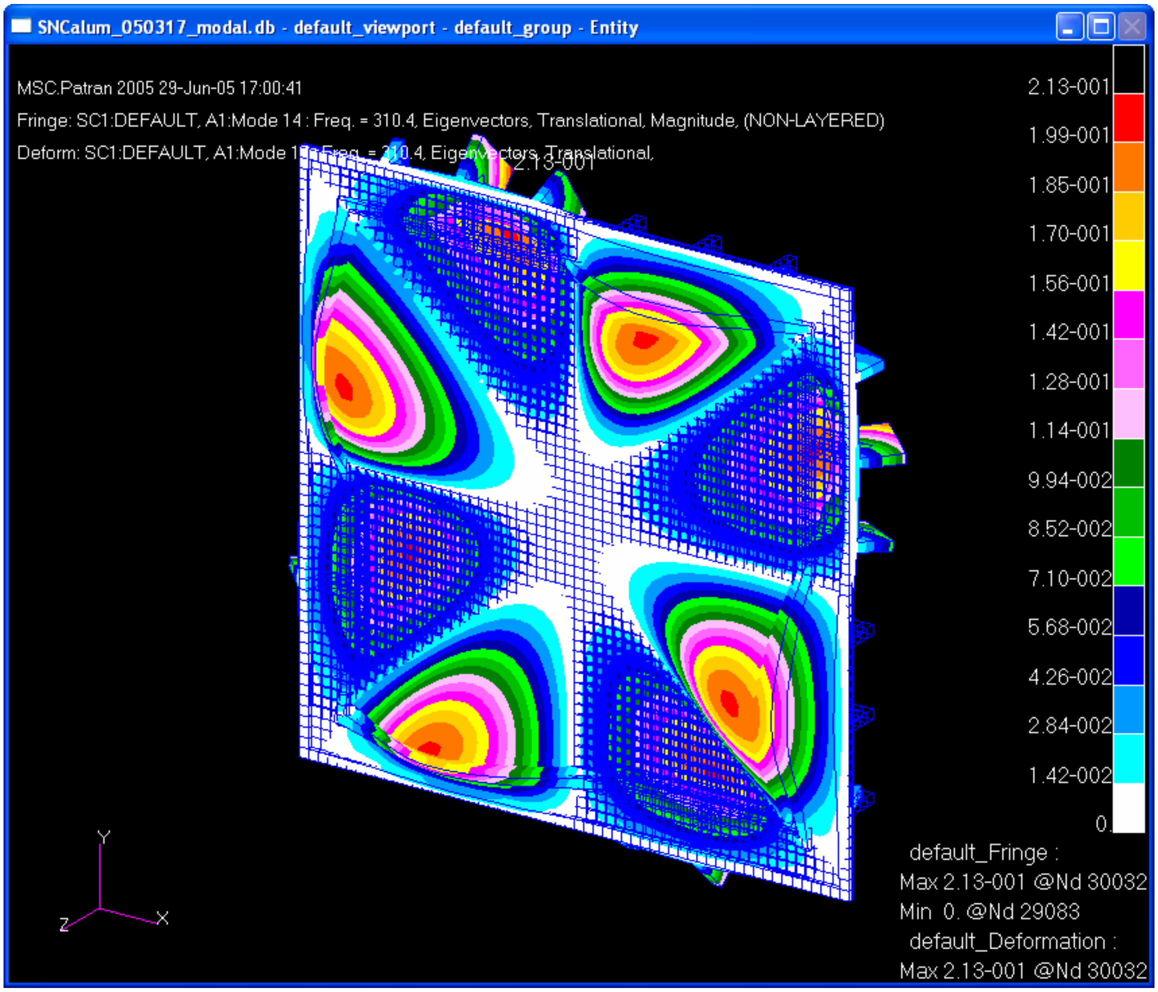

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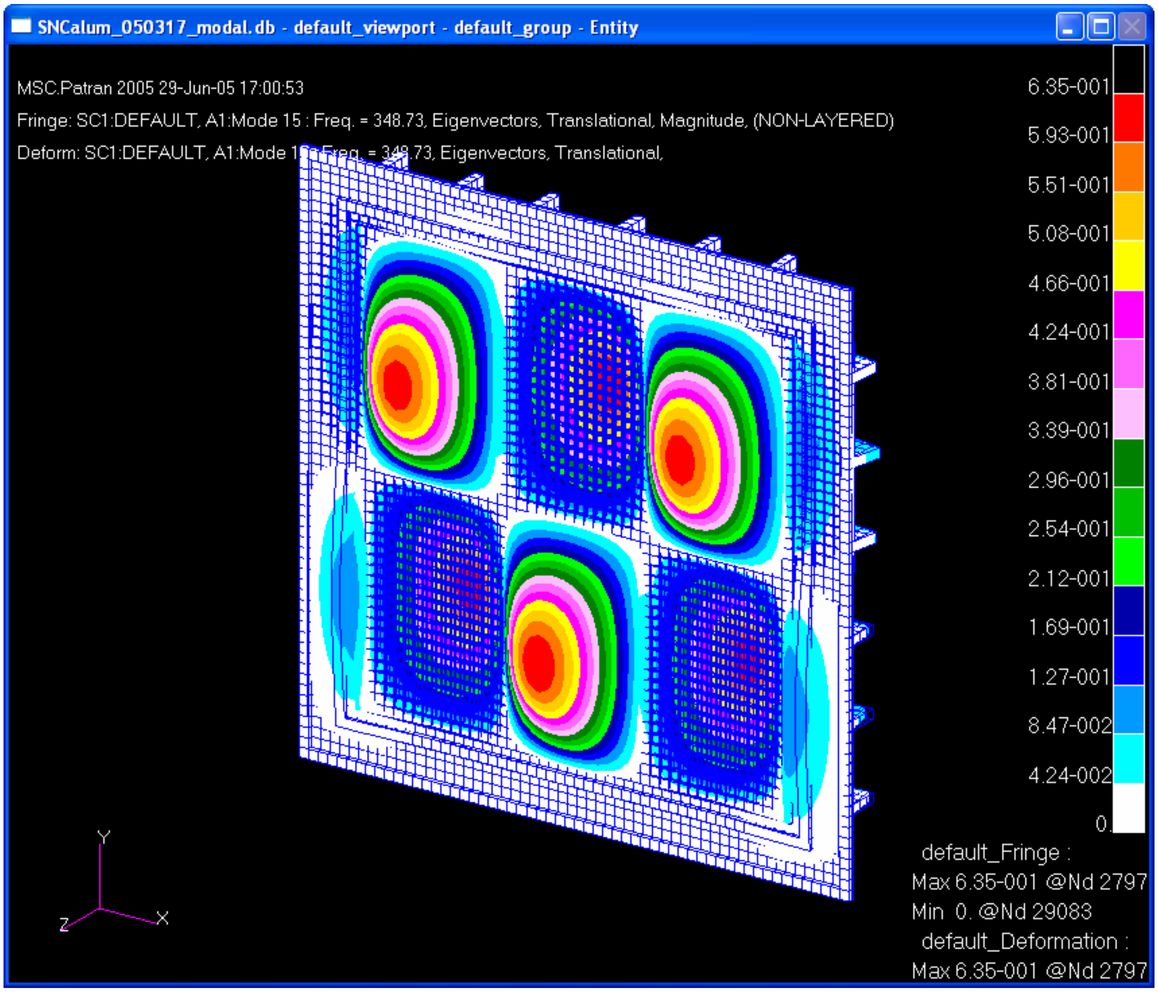

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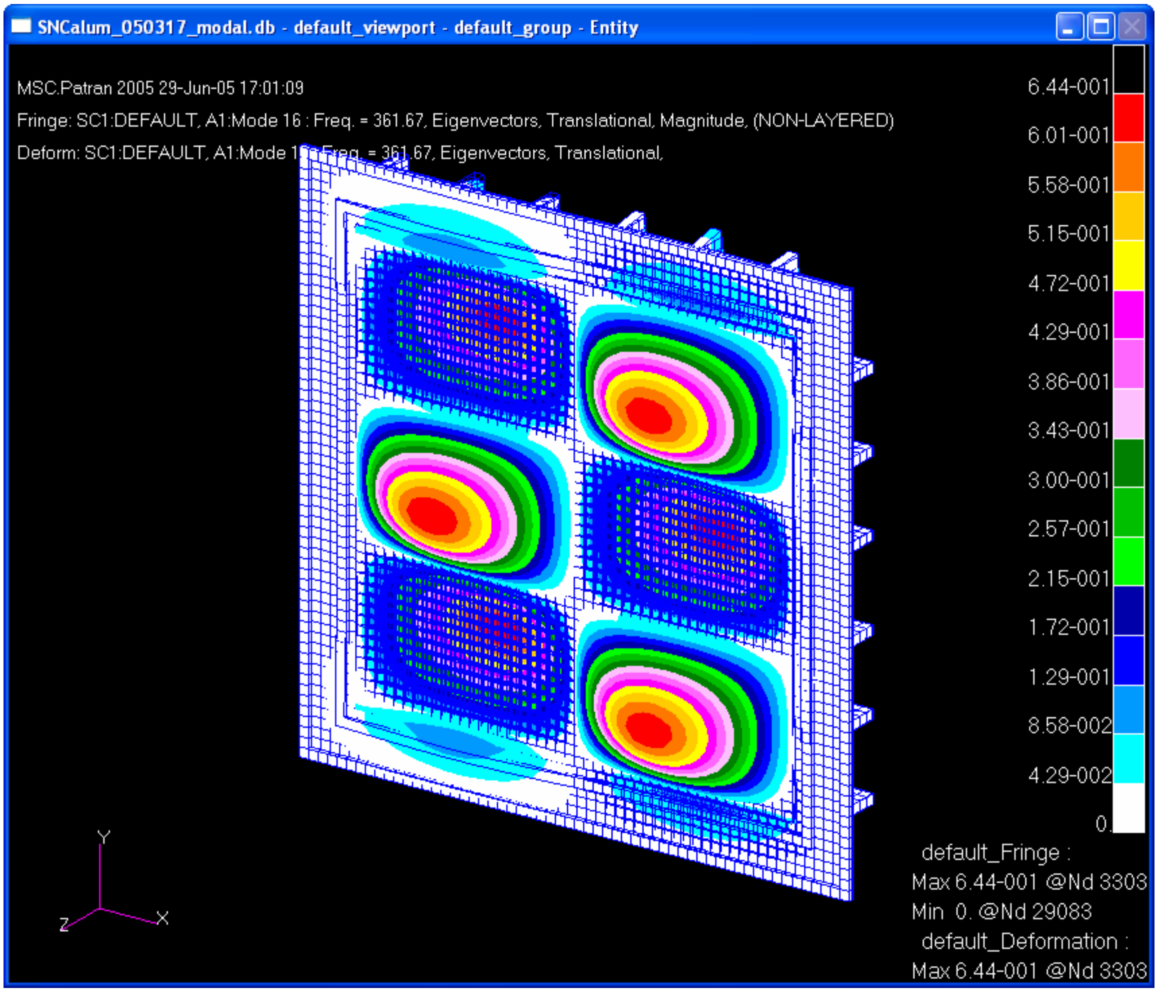

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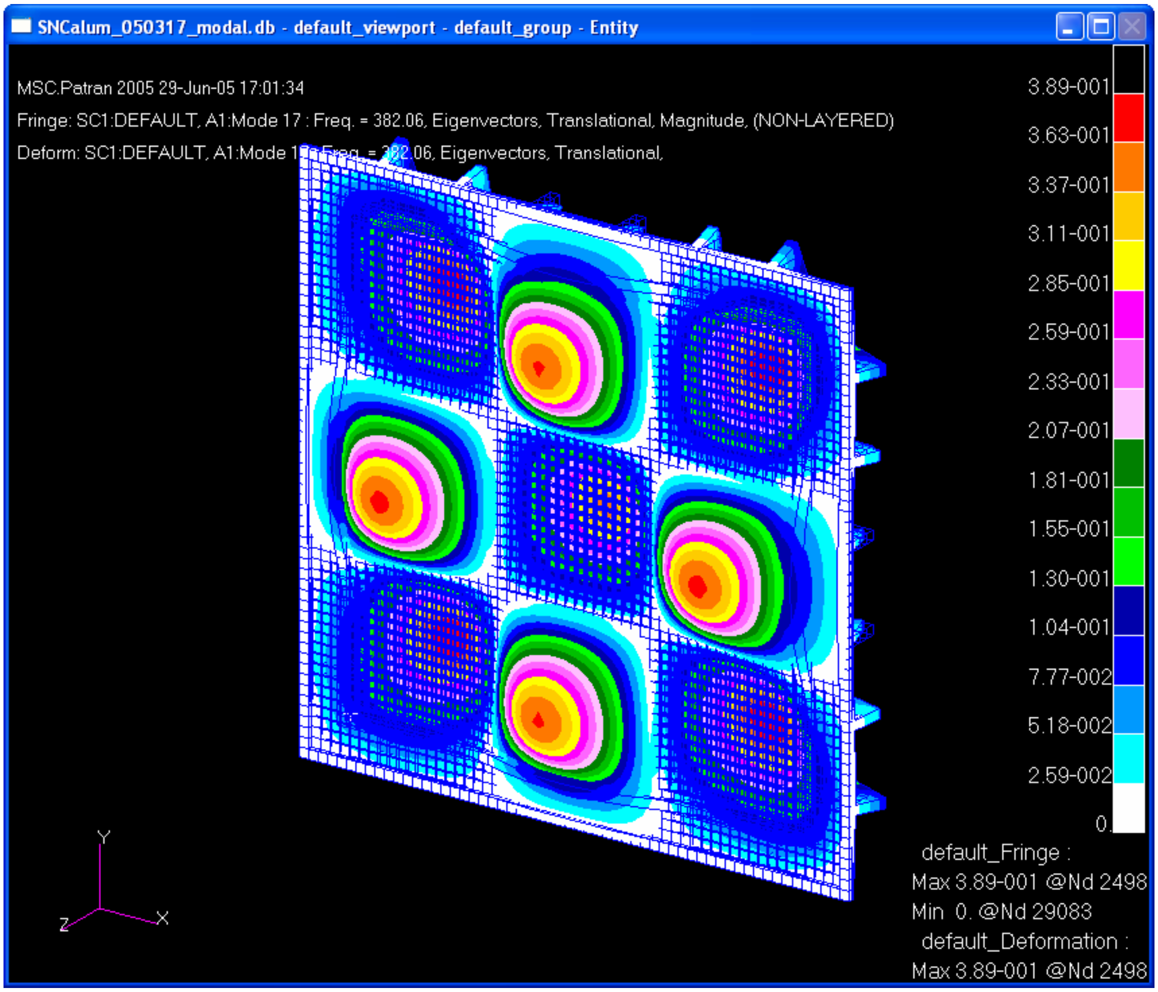

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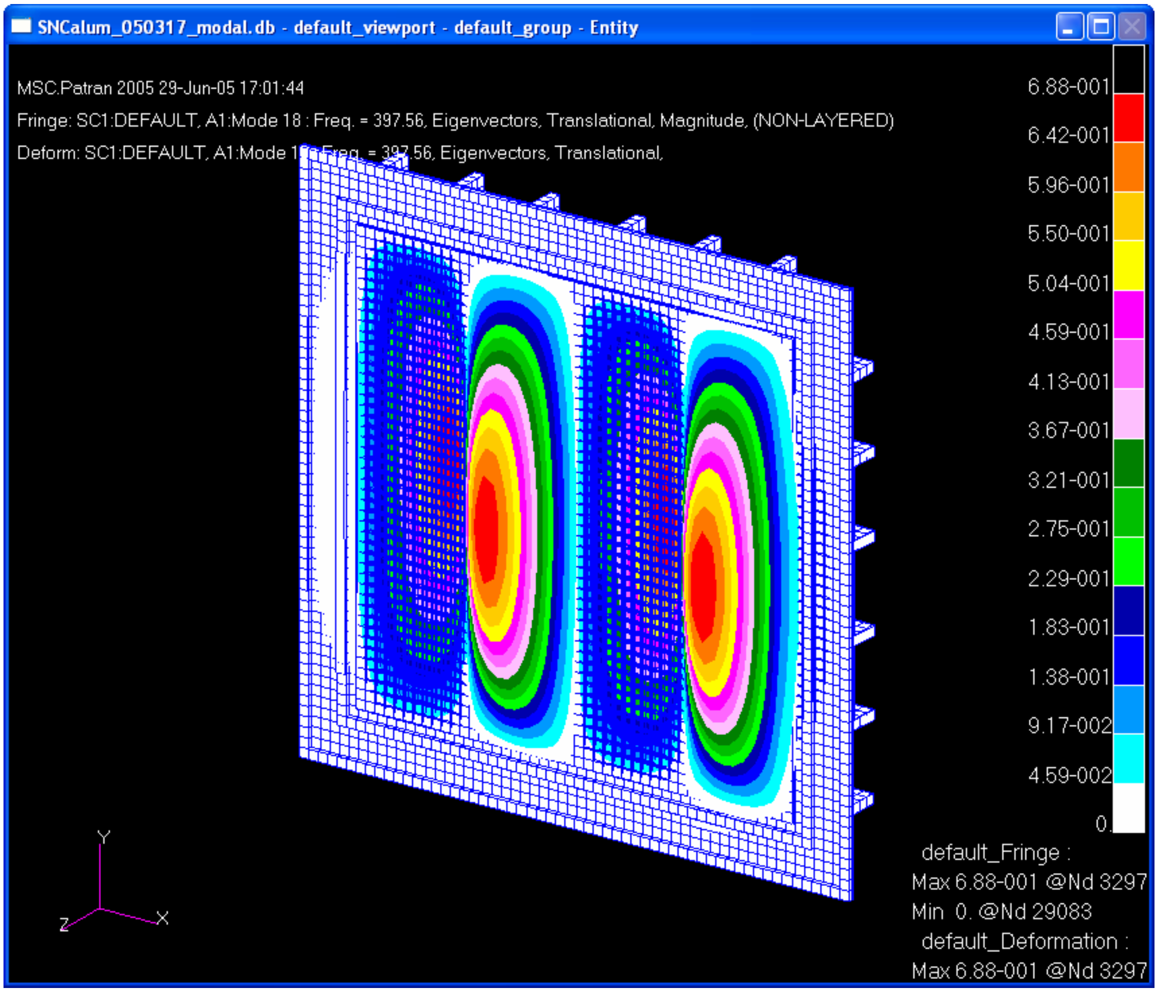

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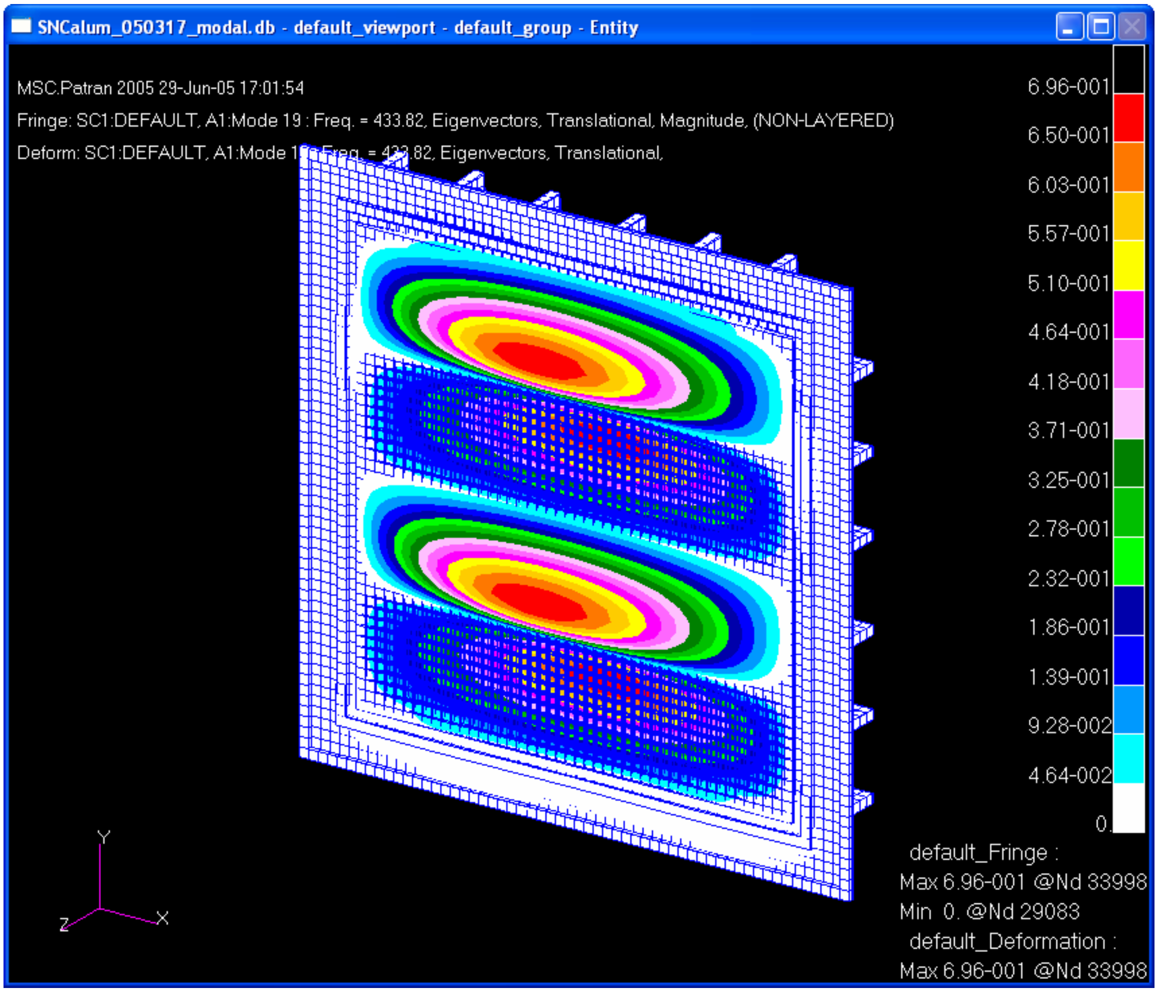

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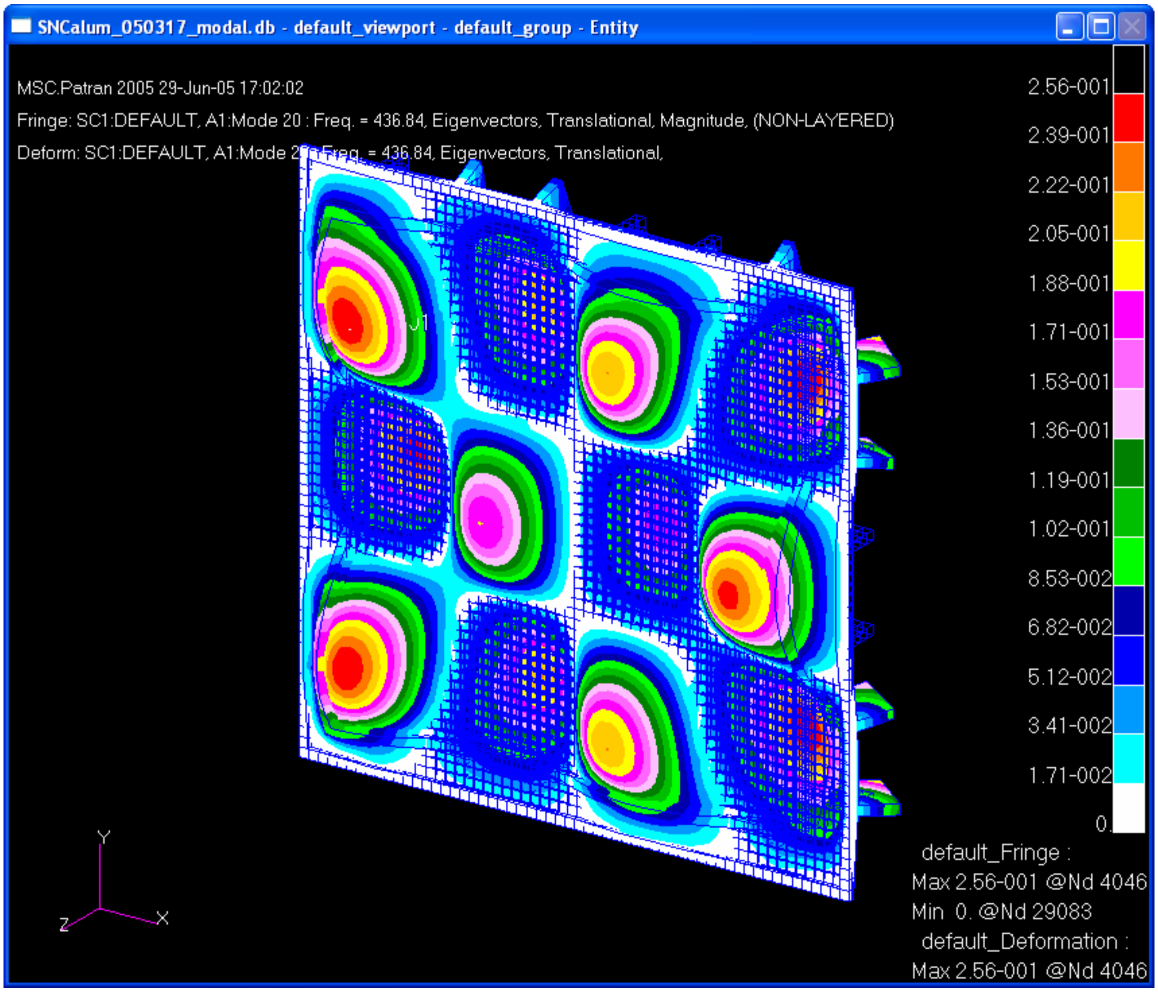

Figure A80. Modal analysis of an aluminum core honeycomb panel, Mode 20.

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
01- 09 - 2007	Contractor Report	

4. TITLE AND SUBTITLE
Finite Element Development and Specifications of a Patched, Recessed Nomex Core Honeycomb Panel for Increased Sound Transmission Loss

5a. CONTRACT NUMBER
NAS1-00135B

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Grosveld, Ferdinand W.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
561581.02.08.07.18.02

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)
NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
NASA/CR-2007-214898

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 71
Availability: NASA CASI (301) 621-0390

13. SUPPLEMENTARY NOTES
Daniel L. Palumbo
An electronic version can be found at http://ntrs.nasa.gov

14. ABSTRACT
This informal report summarizes the development and the design specifications of a recessed nomex core honeycomb panel in fulfillment of the deliverable in Task Order 13RBE, Revision 10, Subtask 17. The honeycomb panel, with 0.020-inch thick aluminum face sheets, has 0.016-inch thick aluminum patches applied to twenty-five, 6 by 6 inch, quarter inch thick recessed cores. A 10 dB higher transmission loss over the frequency range 250 – 1000 Hz was predicted by a MSC/NASTRAN finite element model when compared with the transmission loss of the base nomex core honeycomb panel. The static displacement, due to a unit force applied at either the core or recessed core area, was of the same order of magnitude as the static displacement of the base honeycomb panel when exposed to the same unit force. The mass of the new honeycomb design is 5.1% more than the base honeycomb panel. A physical model was constructed and is being tested.

15. SUBJECT TERMS
Recessed core; Structural acoustic optimization; Voided core

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** / **19b. TELEPHONE NUMBER** *(Include area code)*
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