Discussion on acoustic databases in LS-DYNA®

Zhe Cui, Yun Huang

Livermore Software Technology Corporation

Oct. 2017

Content

- Introduction
- Binary database for fringe plot
- ASCII database for XY plot
- Summary

Introduction

Since ls971 R6 version, a series of frequency domain features of acoustic simulation have been implemented to LS-DYNA. This paper gives a brief review of these databases.

Acoustic BEM (boundary element method) including the approximate methods: Rayleigh method, Kirchhoff method).
Keyword ***FREQUENCY_DOMAIN_ACOUSTIC_BEM**

Acoustic FEM (finite element method)
Keyword ***FREQUENCY_DOMAIN_ACOUSTIC_FEM**

Vibration solvers ERP (equivalent radiated power, based on Steady State Dynamics). Keyword ***FREQUENCY_DOMAIN_SSD_ERP**)

Fringe plot of binary databases:

- D3ACS
- D3ACP
- D3ACC
- D3ATV
- D3ERP
- D3EIGV_AC

XYplot of ASCII databases:

- Press_Pa and Press_dB,
- Press_Pa_real and Press_Pa_imag
- Press_Pa_t amd Press_dB_t
- Press_Power and Press_radef
- Press_dB(A), Press_dB(B), Press_dB(C) and Press_dB(D)
- Panel_contribution_NID

Fringe plot: D3ACS

The binary plot file D3ACS shows the solution of frequency domain FEM acoustic computation or collocation BEM acoustic computation.

Keywords

- ***FREQUENCY_DOMAIN_ACOUSTIC_FEM** or
- ***FREQUENCY_DOMAIN_ACOUSTIC_BEM**
- ***DATABASE_FREQUENCY_BINARY_D3ACS**

FEM acoustic: the acoustic pressure in the finite element acoustic volume including the surface.

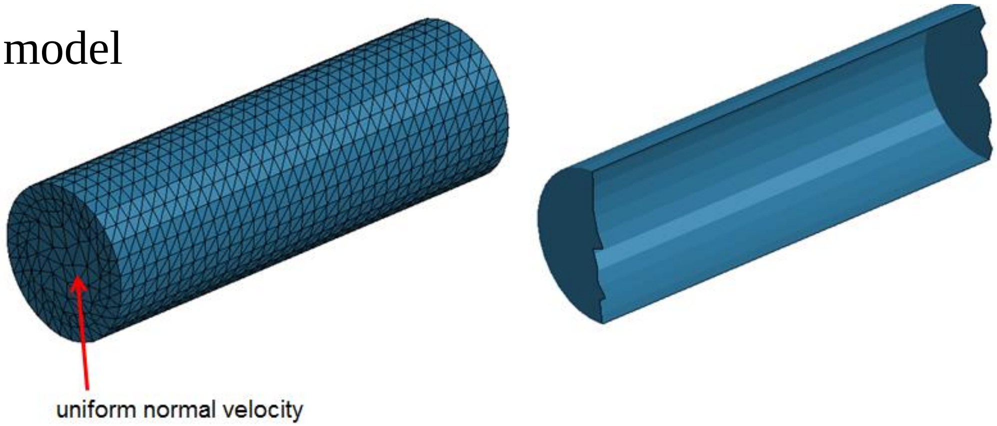
Collocation BEM acoustic: the acoustic pressure on the surface (boundary elements) of the acoustic volume.

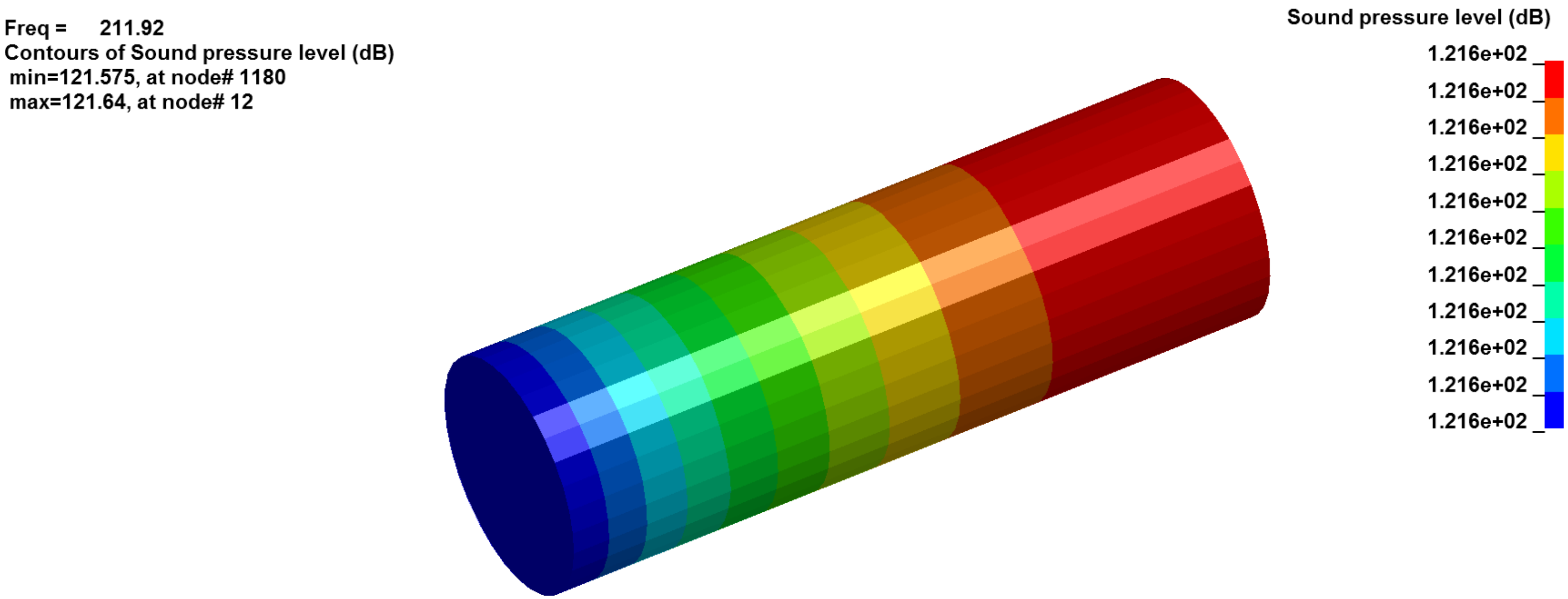
The results including:

- Real part of the pressure
- Imaginary part of the pressure
- Acoustic intensity
- The magnitude of the pressure
- Sound pressure level (dB)
- Real part of normal velocity on the surface nodes
- Imaginary part of normal velocity on the surface nodes

Fringe plot: D3ACS

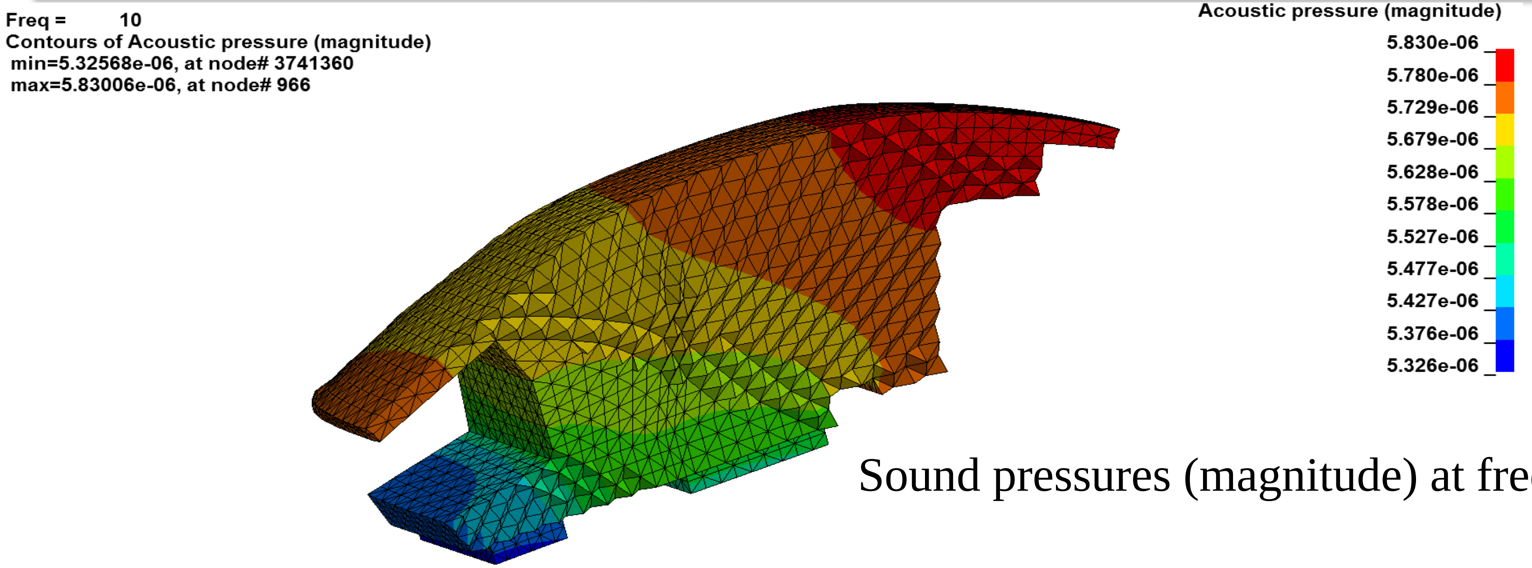
A cylinder BEM model



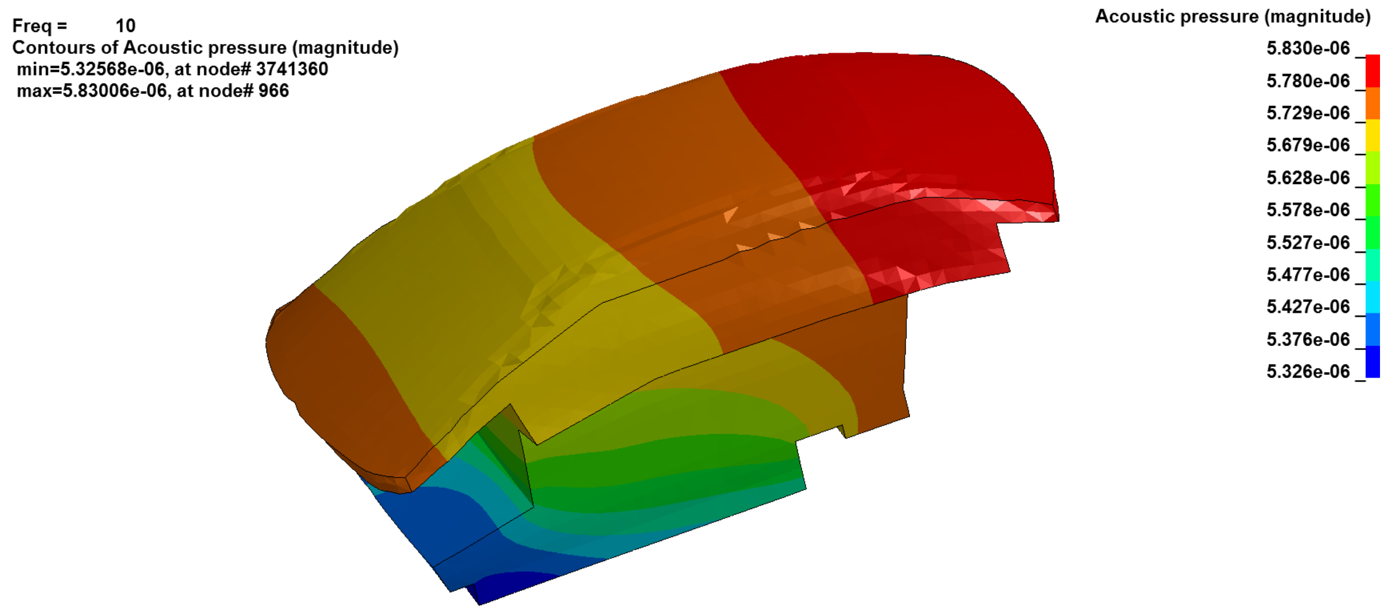


Sound pressure Level (dB) at frequency 211.92 Hz

Fringe plot: D3ACS



Sound pressures (magnitude) at frequency 10 Hz



Fringe plot: D3ACP

The binary plot file D3ACP shows the fringe plot of acoustic pressure at field points in BEM acoustic analysis.

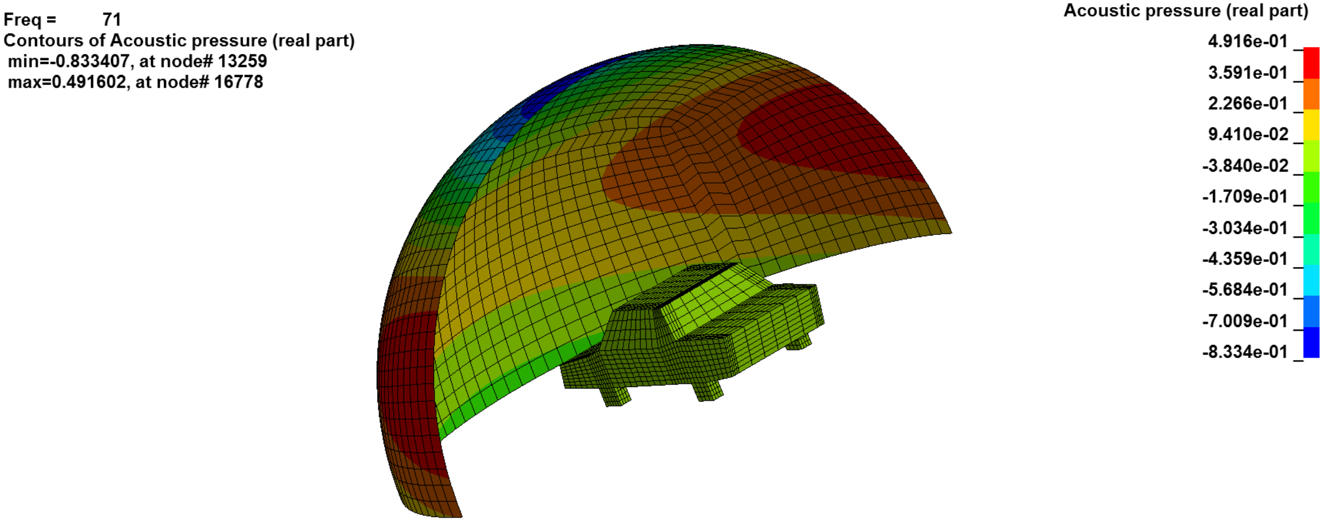
The keyword
- ***FREQUENCY_DOMAIN_ACOUSTIC_BEM**
- ***FREQUENCY_DOMAIN_ACOUSTIC_FRINGE_PLOT**

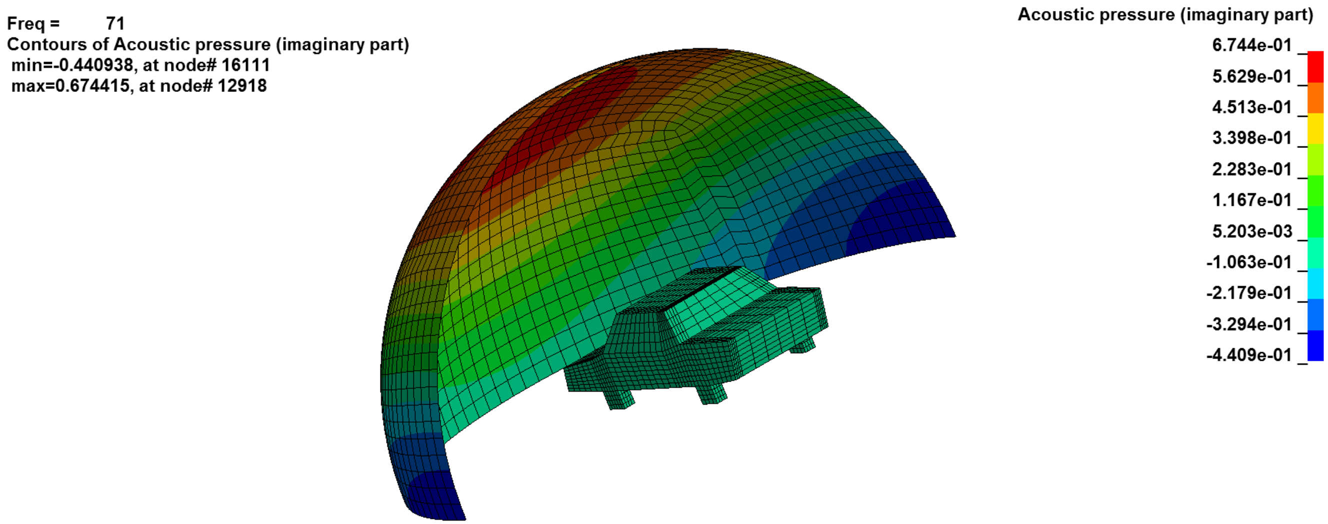
The results including:

- Real part of the pressure
- Imaginary part of the pressure
- Acoustic intensity
- Sound pressure level (dB)

Fringe plot: D3ACP

Real and imaginary parts of sound pressures at frequency 71 Hz





Fringe plot: D3ACC

The binary plot file D3ACC saves element acoustic pressure contribution and contribution percentage on selected field points from BEM acoustic analysis.

The keyword

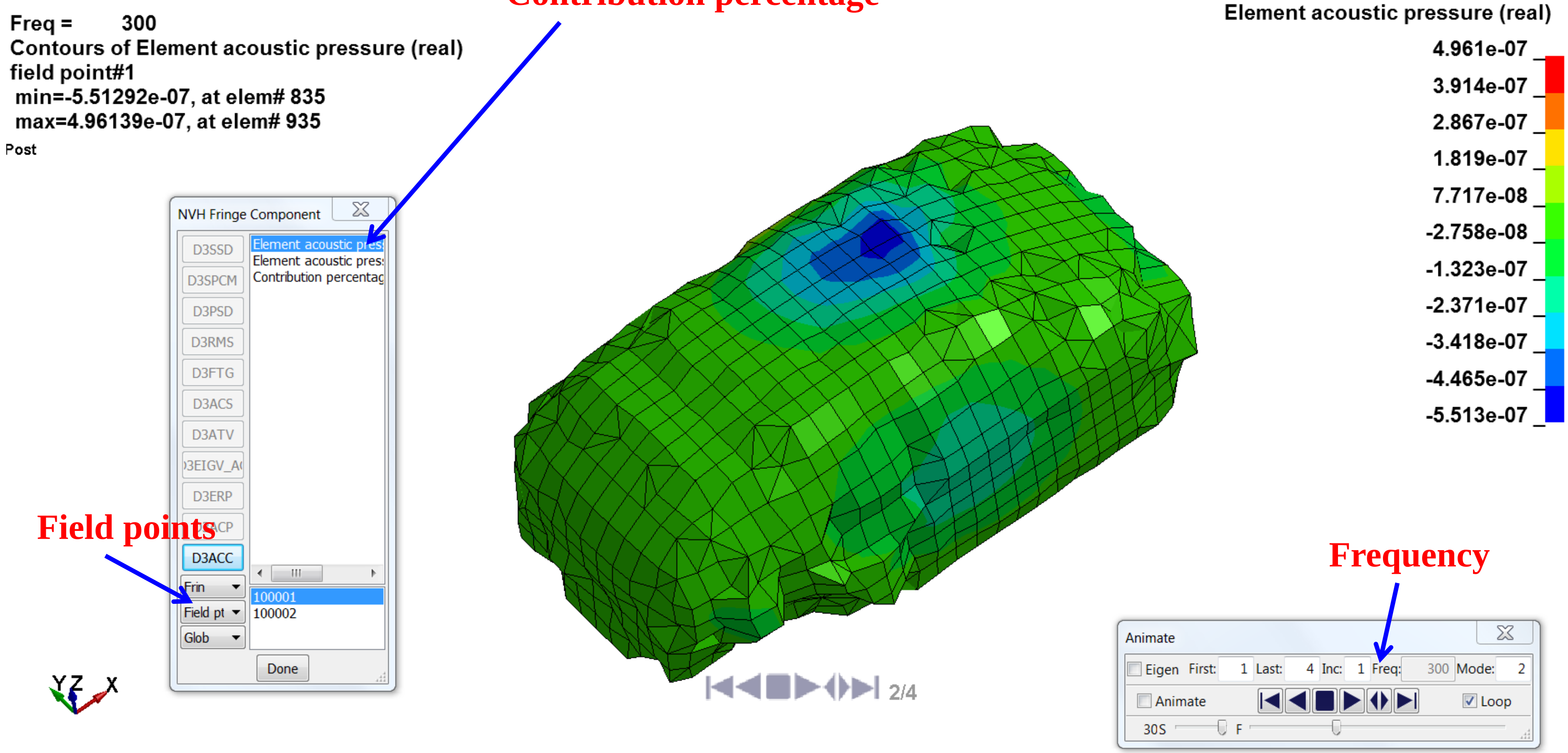
- ***FREQUENCY_DOMAIN_ACOUSTIC_BEM**
- ***FREQUENCY_DOMAIN_BINARY_D3ACC**

The results including:

- Real part of the pressure
- Imaginary part of the pressure
- Acoustic pressure contribution

Fringe plot: D3ACC

Element acoustic pressure (real)
Element acoustic pressure (imag)
Contribution percentage



Field points

Frequency

Fringe plot: D3ATV

The binary plot file D3ATV saves acoustic transfer vector results from BEM acoustic analysis.

The keyword
- ***FREQUENCY_DOMAIN_ACOUSTIC_BEM _ATV**
- ***DATABASE_FREQUENCY_BINARY_D3ATV**

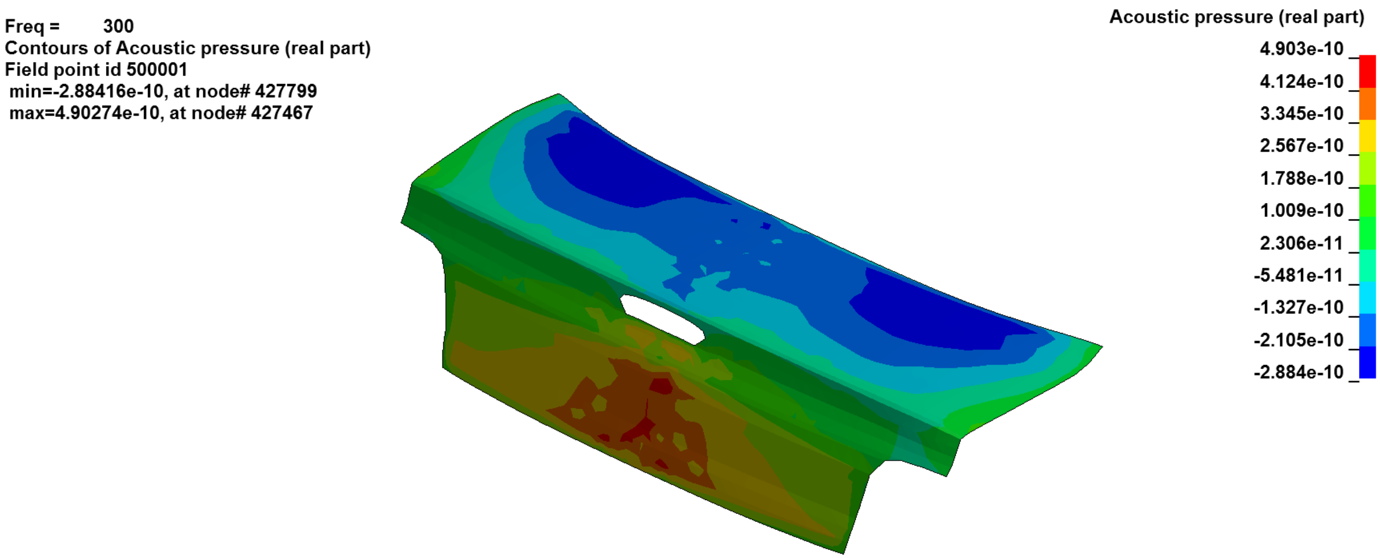
- ATV provides the acoustic pressure at field points due to unit normal velocity at each of the nodes (or elements) composing the acoustic domain surface.
- ATV is dependent on structure model, properties of acoustic fluid as well as location of field points.
- ATV is very efficient and provides huge saving in CPU times if multiple loading cases have to be considered.

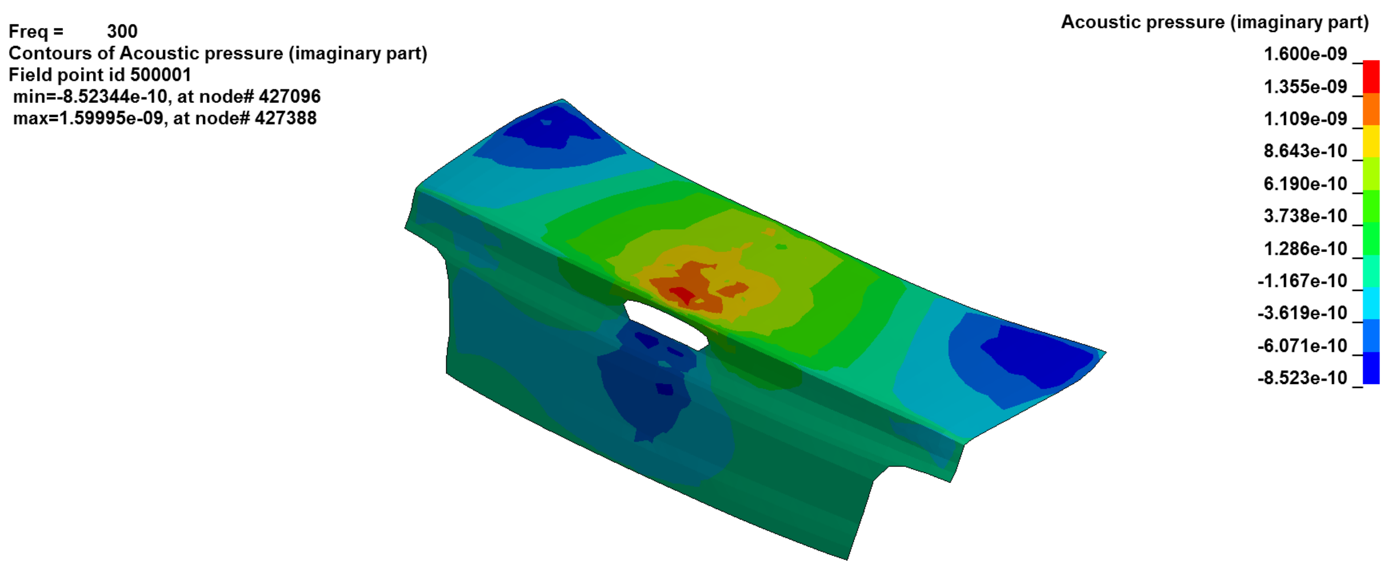
The results including:

- Real part of the pressure
- Imaginary part of the pressure
- Sound pressure level (dB)

Fringe plot: D3ATV

Real and imaginary part of pressures ATV at point 500001





Fringe plot: D3ERP

The binary plot file D3ERP saves ERP (equivalent radiated power) results from SSD (ERP option) analysis.

The keyword

- *** FREQUENCY_DOMAIN_SSD_ERP**

The ERP calculation is based on plane wave assumption for the radiated acoustic waves. First we calculate the ERP density, which is defined as

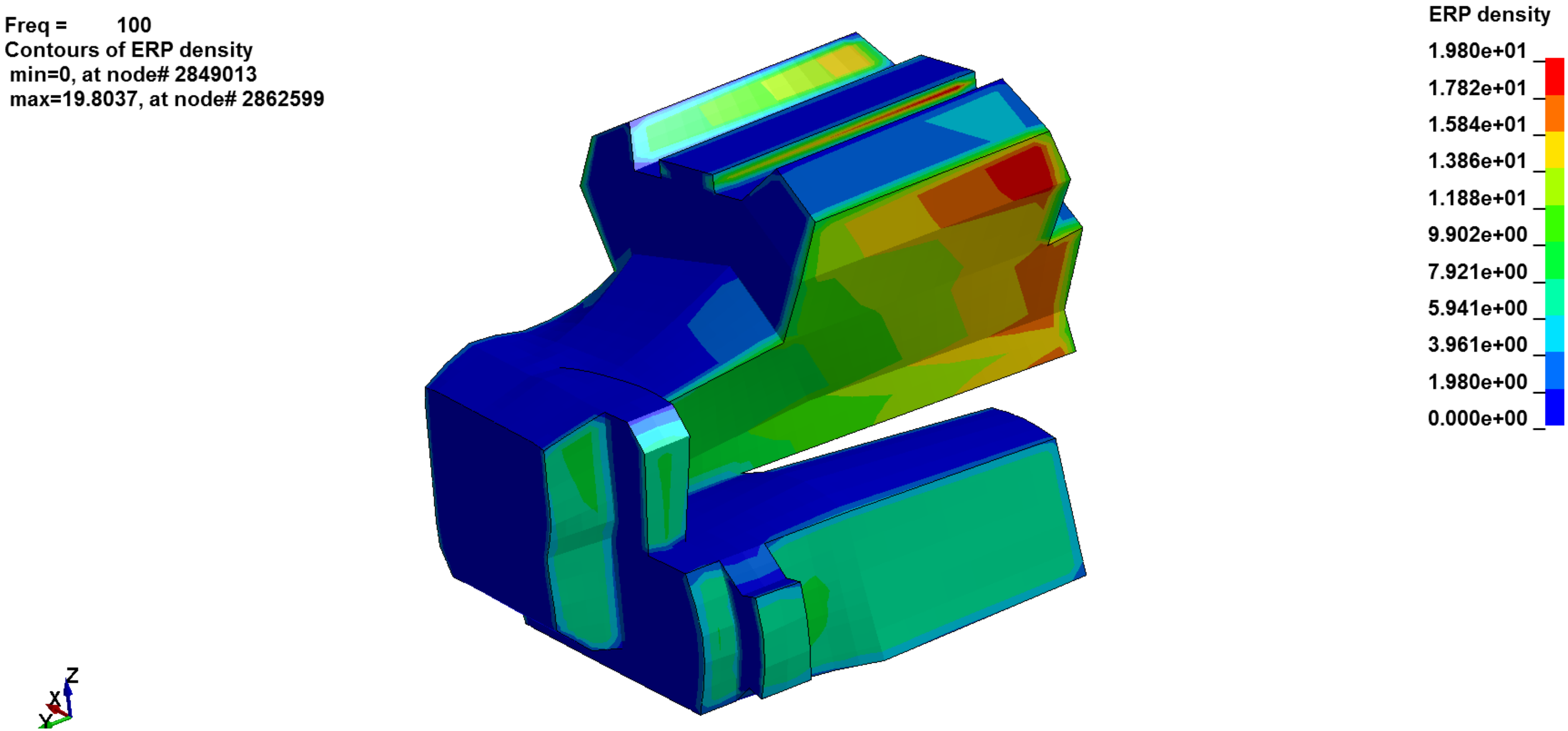
$$ERP_\rho = \frac{1}{2}\rho c \,\mathrm{Re}\left[v_n \cdot \bar{v}_n\right]$$

The results including:

- Real part of the normal velocity
- Imaginary part of the normal velocity
- Absolute value of normal velocity
- Acoustic density
- ERP density

Fringe plot: D3ERP

ERP density plot at frequency 100 Hz



Fringe plot: D3EIGV_AC

The binary plot file D3EIGV_AC saves acoustic eigen frequencies and eigen vectors.

The keyword
•* **FREQUENCY_DOMAIN_ACOUSTIC_FEM_EIGENVALUE**

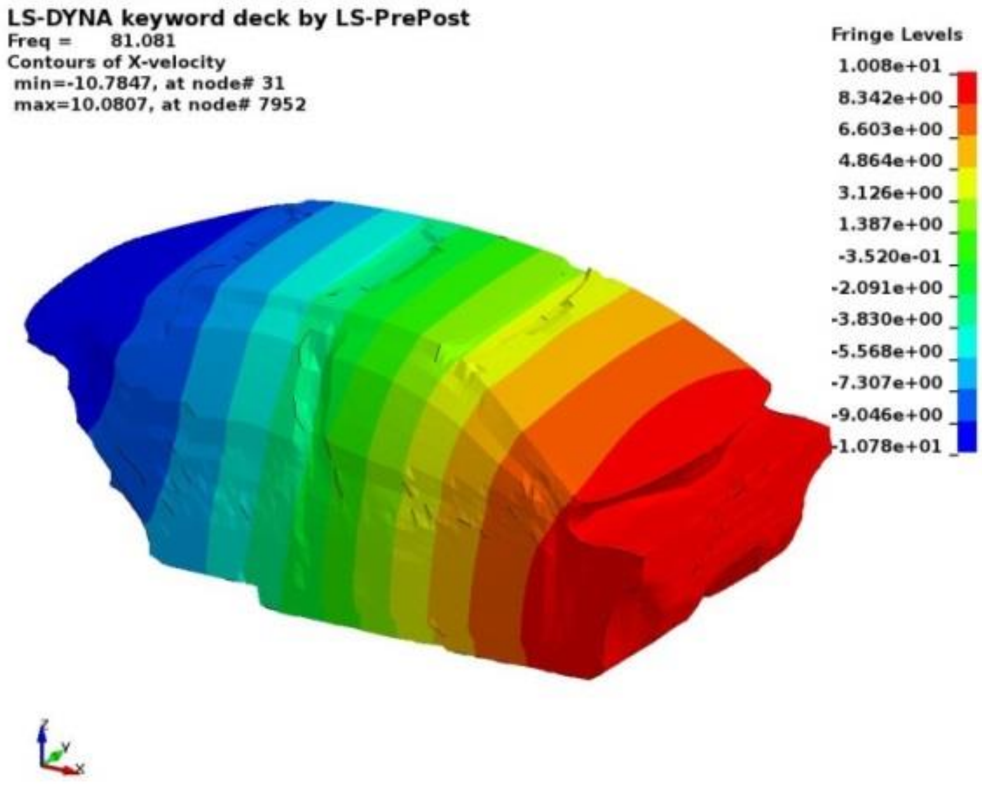
- The acoustic eigen vector is an array of acoustic pressure given at the nodes in the acoustic volume. Each node has one scalar acoustic pressure.
- The acoustic eigenvalue analysis not only provides valuable characteristic information on the acoustic system itself, but also provides basis for modal solution method.

The results including:

- Acoustic pressure (real number)

Fringe plot: D3EIGV_AC

Acoustic eigenvector for the 2nd mode



Binary databases summary

LS-DYNA

File name	Purpose	Activated by
D3ACS	Acoustic pressure on surface by BEM, in volume including surface by FEM	***DATABASE_FREQUENCY_BINARY_D3ACS** by BEM or FEM
D3ACP	Acoustic pressure plot	***FREQUENCY_DOMAIN_ACOUSTIC_FRINGE_PLOT** by BEM
D3ACC	Acoustic element contribution plot	***DATABASE_FREQUENCY_BINARY_D3ACC** by BEM
D3ATV	Acoustic transfer vector	***FREQUENCY_DOMAIN_ACOUSTIC_BEM_ATV** ***DATABASE_FREQUENCY_BINARY_D3ATV**
D3ERP	Equivalent radiated power plot	***FREQUENCY_DOMAIN_SSD_ERP**
D3EIGV_AC	Acoustic eigen vector	***FREQUENCY_DOMAIN_ACOUSTIC_FEM_EIGENVALUE**

XY-Plot ASCII databases

- The default acoustic ASCII databases are Press_Pa and Press_dB for both BEM and FEM acoustic solvers.

- If the IPFILE is equal to 1 in BEM or FEM keywords, the real and imagniary parts of the sound pressure are output to ASCII files Press_Pa_real and Press_Pa_imag as the sound pressure is a complex variable.

- If the TRSLT is great than zero in BEM, the time domain data of sound pressue and sound pressure level are calculated using inverse FFT and output to ASCII files Press_Pa_t and Press_dB_t.

XY-Plot ASCII databases

- Sound power or acoustic power is the rate at which sound energy is emitted, reflected, transmitted or received, per unit time. The sound power of a source is the total power emitted by that source in all directions. It is calculated by collocation BEM (methods 3 and 4) and output to Press_Power.

- The radiation efficiency indicates how much sound power *W* a given structure radiates compared with the vibrating infinite flat surface for the same area. In general, the radiation efficiency is low meaning that structural vibrations have difficulty to produce noise. It is calculated by collocation BEM (methods 3 and 4) and output to Press_radef.

$$\sigma = \frac{W}{\frac{1}{2}\rho c S \left\langle |v|^2 \right\rangle}$$

XY-Plot ASCII databases

- A-weighting: the A-weighting filter covers the full audio range - 20 Hz to 20 kHz and the shape is similar to the response of the human ear at the lower levels. A-weighted noise measurements are widely used for general purpose noise measurement.

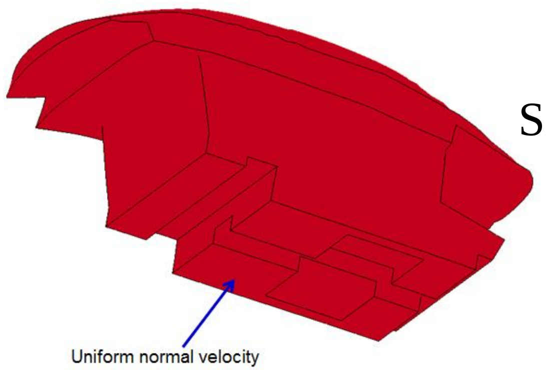
- B-weighting: no longer in common use, was initially developed to cover the mid-range between the A and C-weighting networks.

- C-weighting: a standard frequency weighting for sound level meters, commonly used for higher level measurements. C-weighting correlates better with the human response to high noise levels.

- D-weighting: sound level meter frequency weighting developed for measuring aircraft noise especially non-bypass military engines. It is not in common use since IEC 61672 2003. More recent ISO standards recommend A-weighting for commercial aircraft noise.

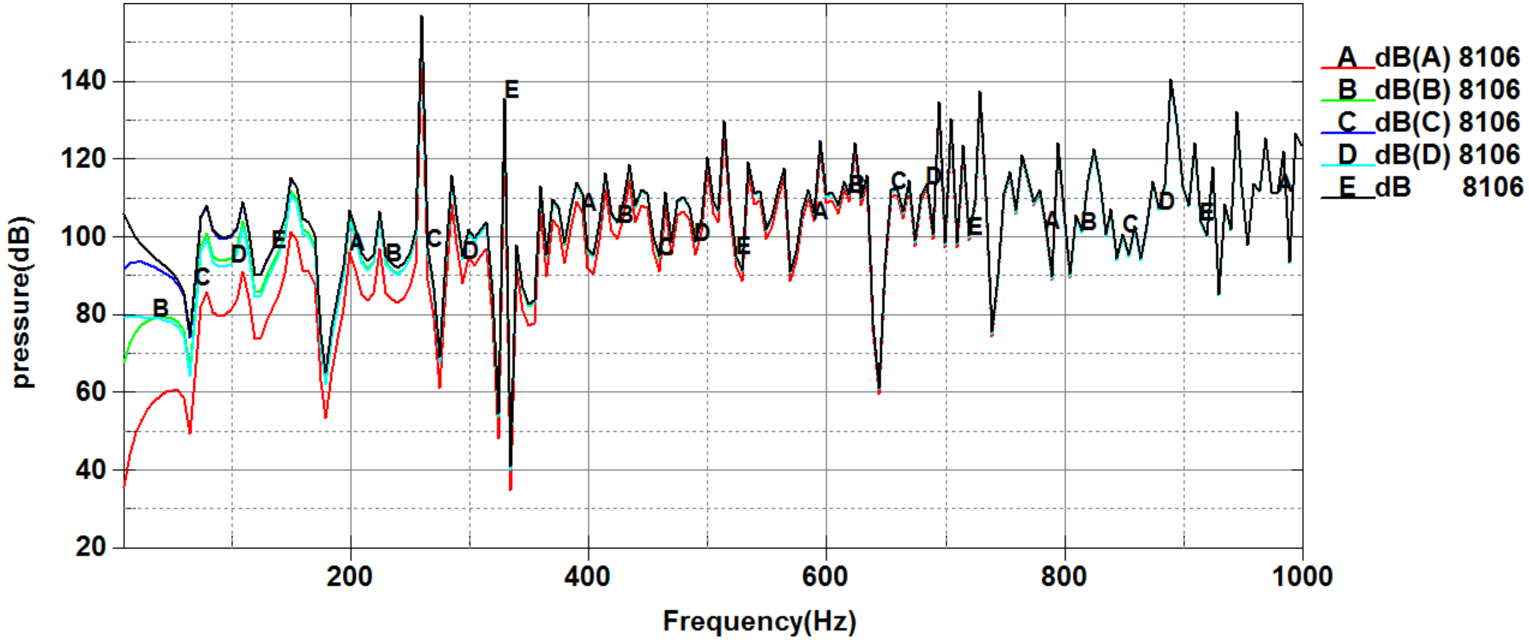
Source of information: http://www.acoustic-glossary.co.uk/frequency-weighting.htm

XY-Plot ASCII databases



Simple compartment FEM model

Normal SPL and weighted SPL at point 8106



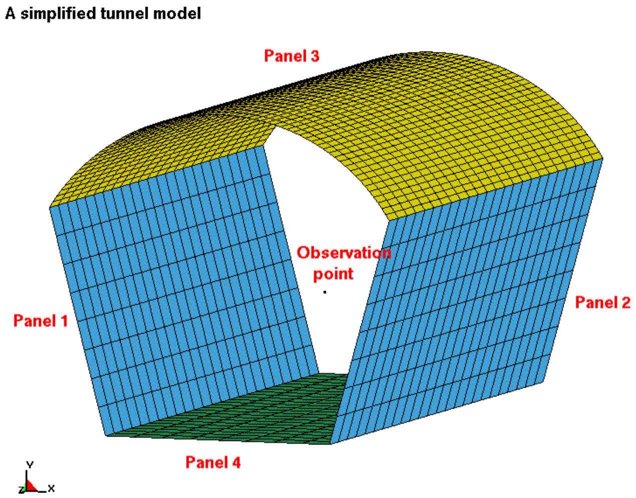
XY-Plot ASCII databases

Panel contribution analysis is conducted to identify the panels which have a high contribution on the acoustic response. It gives the contribution percentage of panels (given as part, set of parts or set of segments) on the acoustic results at observation points and output to ASCII file Panel_contribution_NID

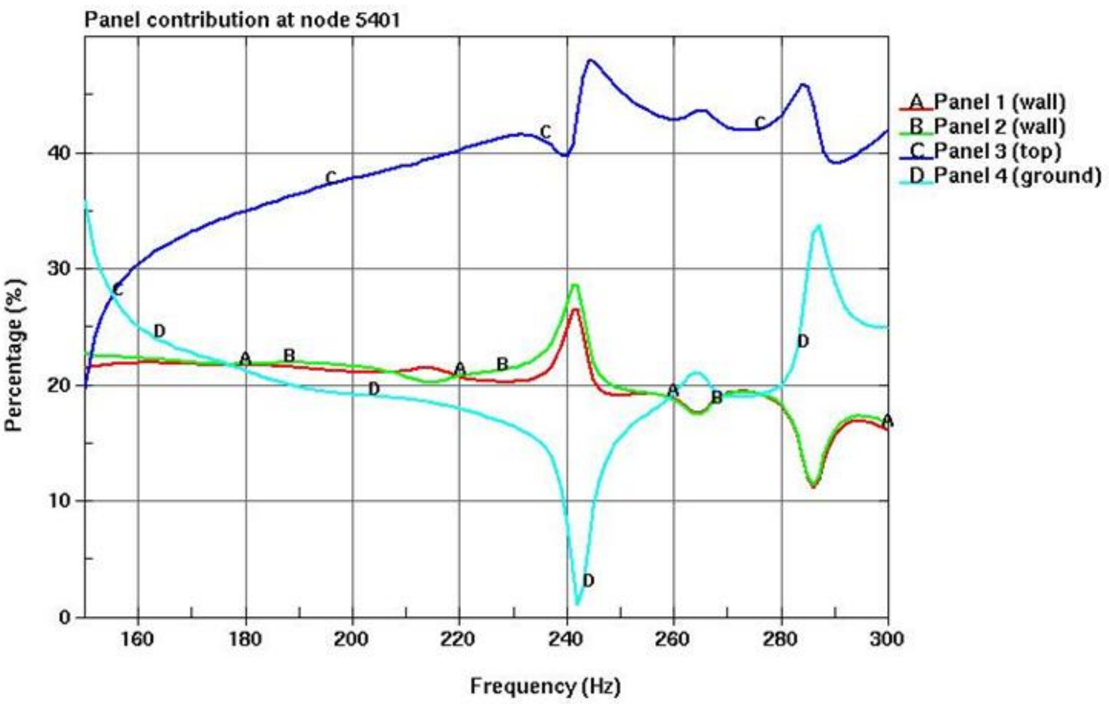
The keyword

- *** FREQUENCY_DOMAIN_ACOUSTIC_BEM_PANEL_CONTRIBUTION**

XY-Plot ASCII databases



Different panel contributions at point 5401



ASCII databases summary

File name	Purpose	Activated by
Press_Pa	Pressure (abs) vs. Freq	BEM or FEM
Press_dB	SPL (dB) vs. Freq	BEM or FEM
Press_Pa_real	Pressure (real) vs. Freq	IPFILE=1 by BEM or FEM
Press_Pa_imag	Pressure (imag) vs. Freq	IPFILE=1 by BEM or FEM
Press_Pa_t	Pressure (abs) vs. Time	TRSLT>0 by BEM
Press_dB_t	SPL (dB) vs. Time	TRSLT>0 by BEM
Press_Power	Sound Power vs. Freq	BEM Method = 3 or 4
Press_radef	Radiation efficiency vs. Freq	BEM Method = 3 or 4
Press_dB(A)	SPL (dB, A-weighting) vs. Freq	dBA=1 in BEM or FEM
Press_dB(B)	SPL (dB, B-weighting) vs. Freq	dBA=2 in BEM or FEM
Press_dB(C)	SPL (dB, C-weighting) vs. Freq	dBA=3 in BEM or FEM
Press_dB(D)	SPL (dB, D-weighting) vs. Freq	dBA=4 in BEM or FEM
Panel_contribution_NID	Panel contribution vs. Freq	Option: **PANEL_CONTRIBUTION** by BEM

Summary

- A series of ASCII & Binary databases have been implemented to do post-processing of the results in LS-DYNA.
- The paper gives detailed review of these acoustic databases, and explain the difference among them.
- Some examples are provided to demonstrate the application of these databases.
- Suggestions and feedback from users.

Thank you