

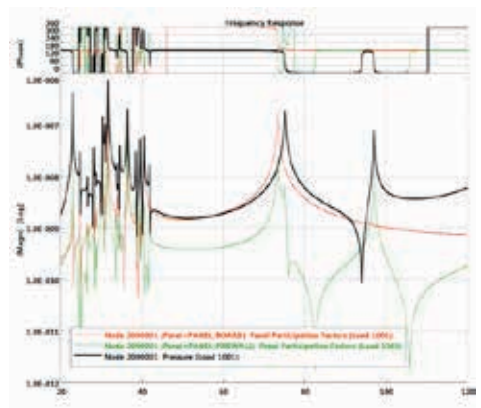
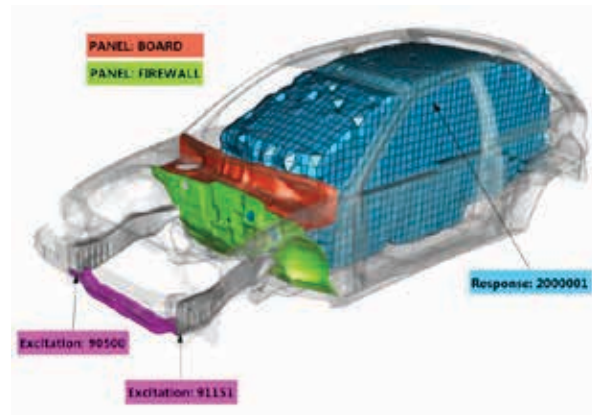
# Vibroacoustic Coupling: a new approach

Kostas Skolarikis  
BETA CAE Systems International AG

# Vibroacoustic Coupling, Background



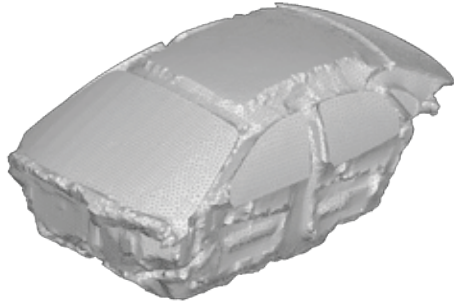
+



# Vibroacoustic Coupling, Background



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$$\mathbf{M}_s \ddot{\mathbf{d}} + \mathbf{K}_s \mathbf{d} = \mathbf{f}_s + \mathbf{A} \mathbf{p}$$

$$\begin{bmatrix} \mathbf{M}_s & 0 \\ \rho c^2 \mathbf{A}^T & \mathbf{M}_f \end{bmatrix} \begin{bmatrix} \ddot{\mathbf{d}} \\ \ddot{\mathbf{p}} \end{bmatrix} + \begin{bmatrix} \mathbf{K}_s & -\mathbf{A} \\ 0 & \mathbf{K}_f \end{bmatrix} \begin{bmatrix} \mathbf{d} \\ \mathbf{p} \end{bmatrix} = \begin{bmatrix} \mathbf{f}_s \\ 0 \end{bmatrix}$$

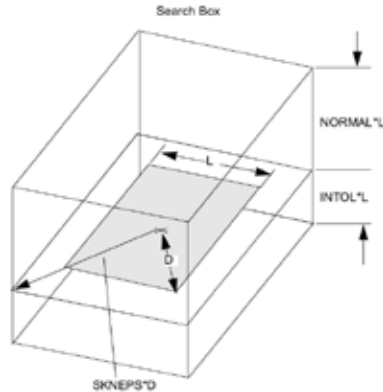
$$\mathbf{M}_f \ddot{\mathbf{p}} + \mathbf{K}_f \mathbf{p} = -\rho c^2 \mathbf{A}^T \ddot{\mathbf{d}}$$

# Vibroacoustic Coupling, Background

$$[A^T] = \int_S \{N_f\} [N_s] dS$$

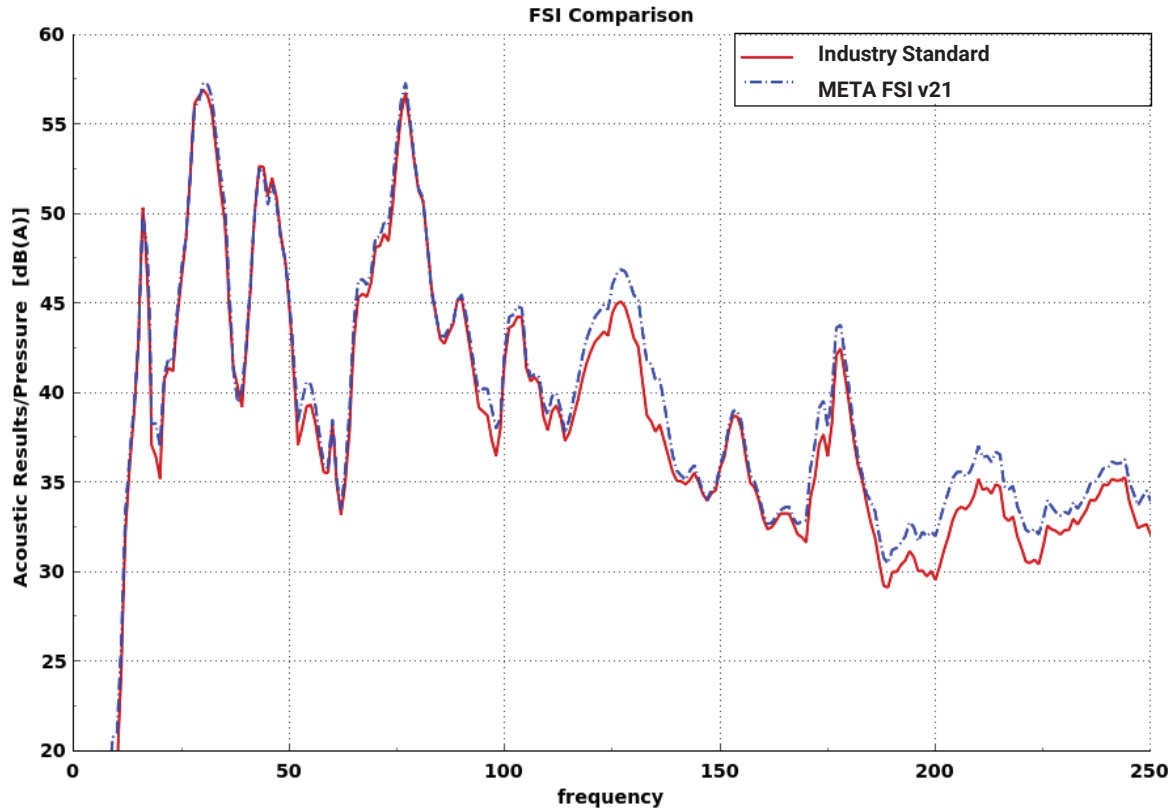
$N_f, N_s$  : shape functions

$S$  : coupling area

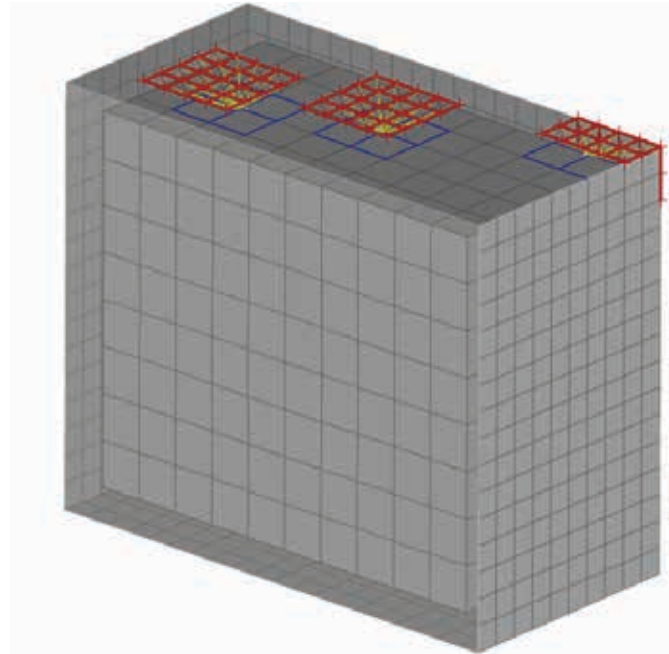
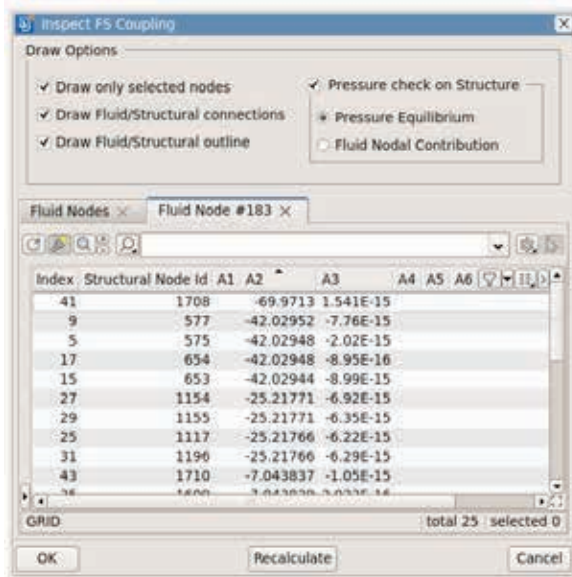


coupling area detection

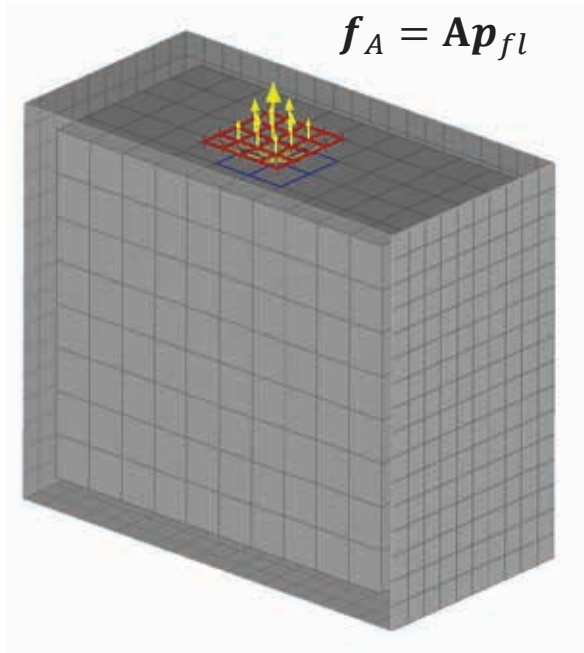
# Inspection and Validation



# Inspection and Validation, Preprocessing Tools

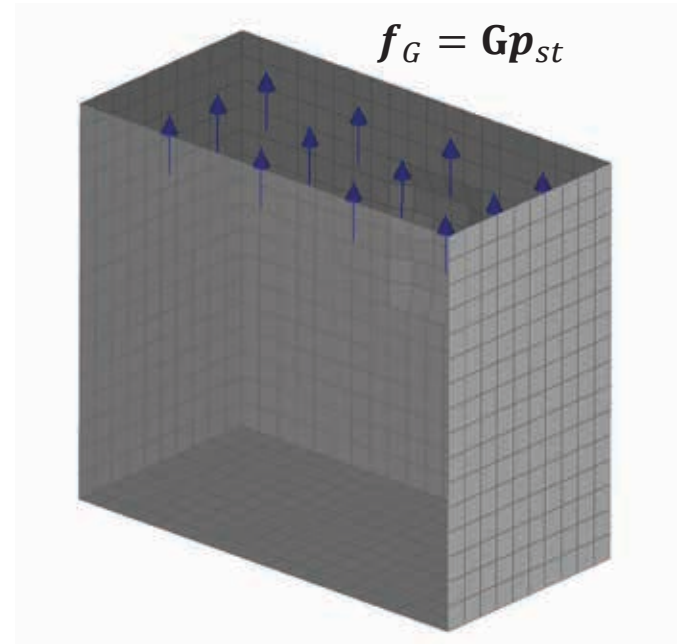


# Inspection and Validation, Point Equilibrium Test



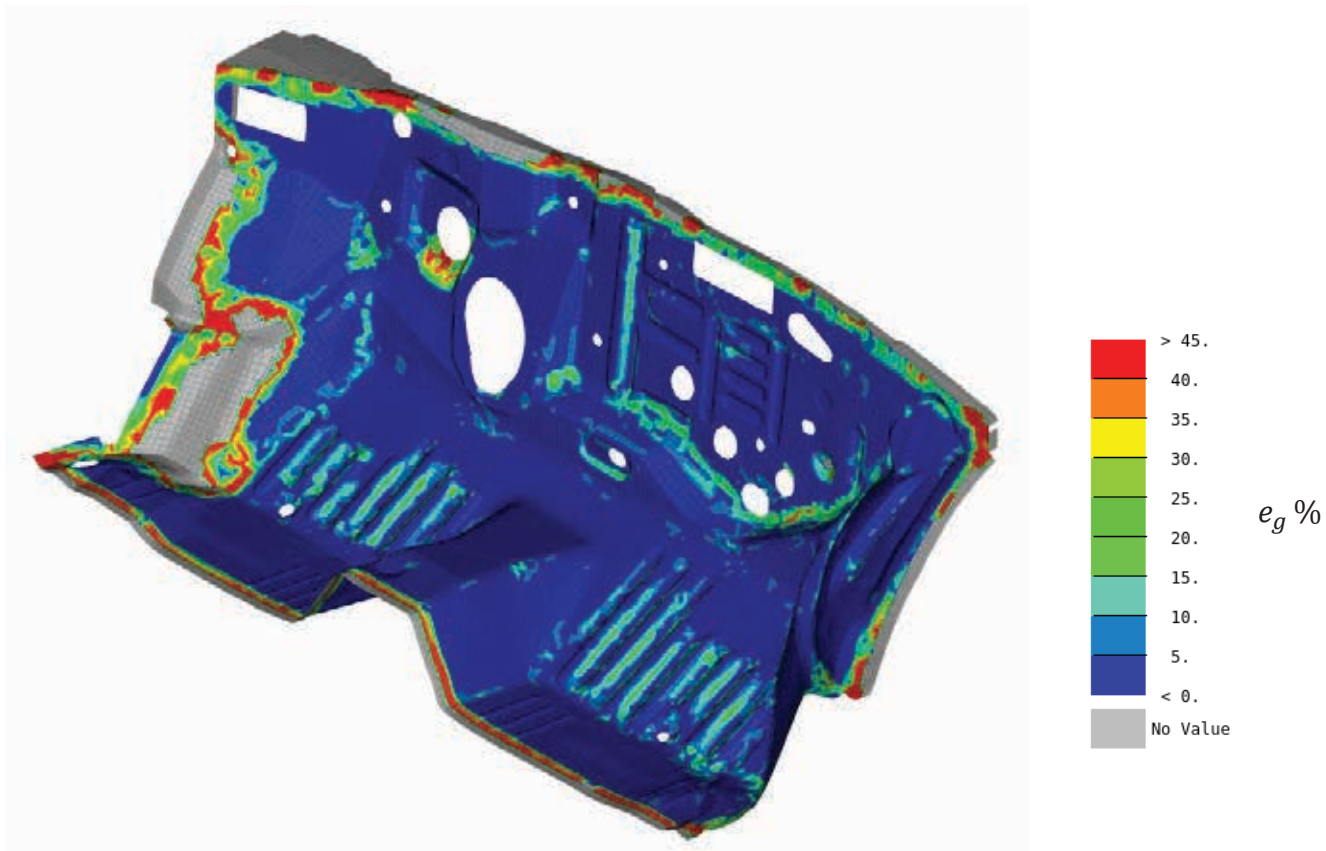
Point Equilibrium error measure

≡



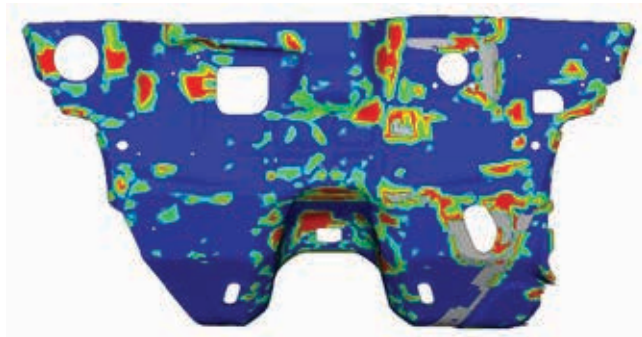
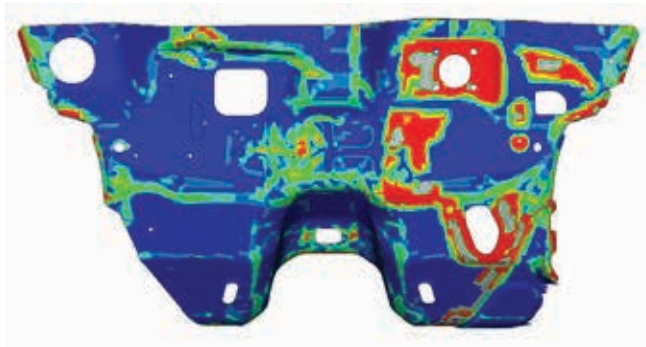
$$e_{g_i} = \frac{\|f_{A_i} - f_{G_i}\|}{\|f_{G_i}\|}$$

# Inspection and Validation, Point Equilibrium Test

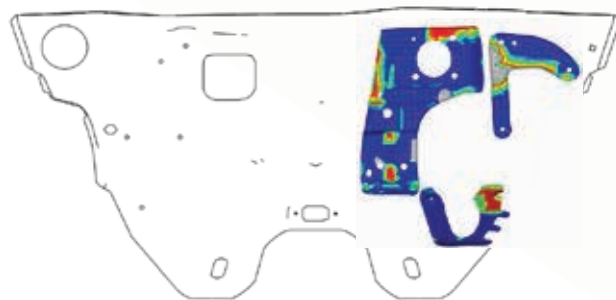
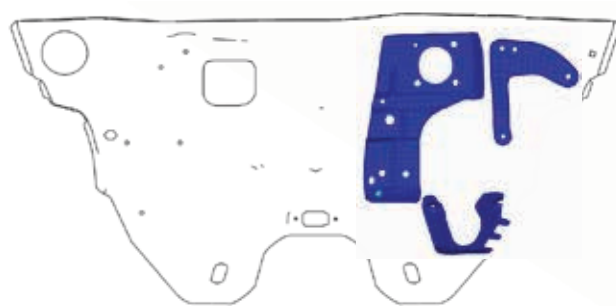




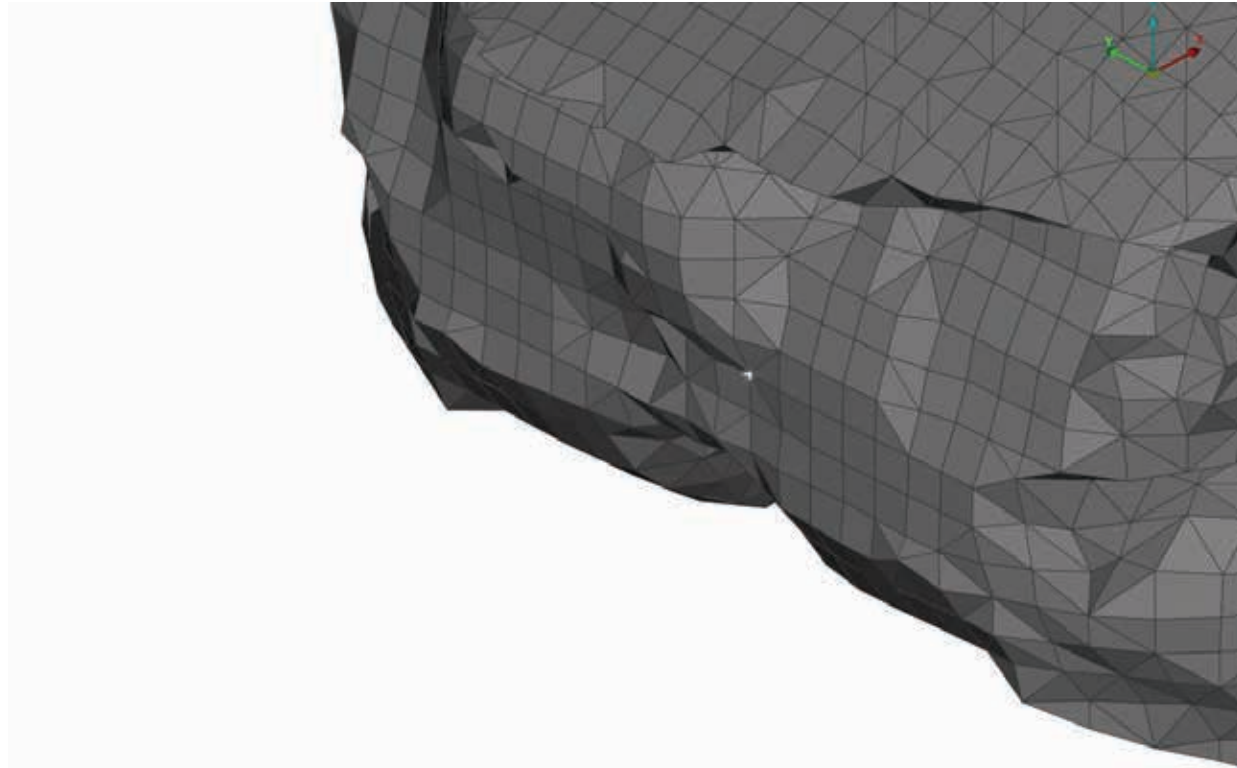
# Inspection and Validation, Point Equilibrium Test



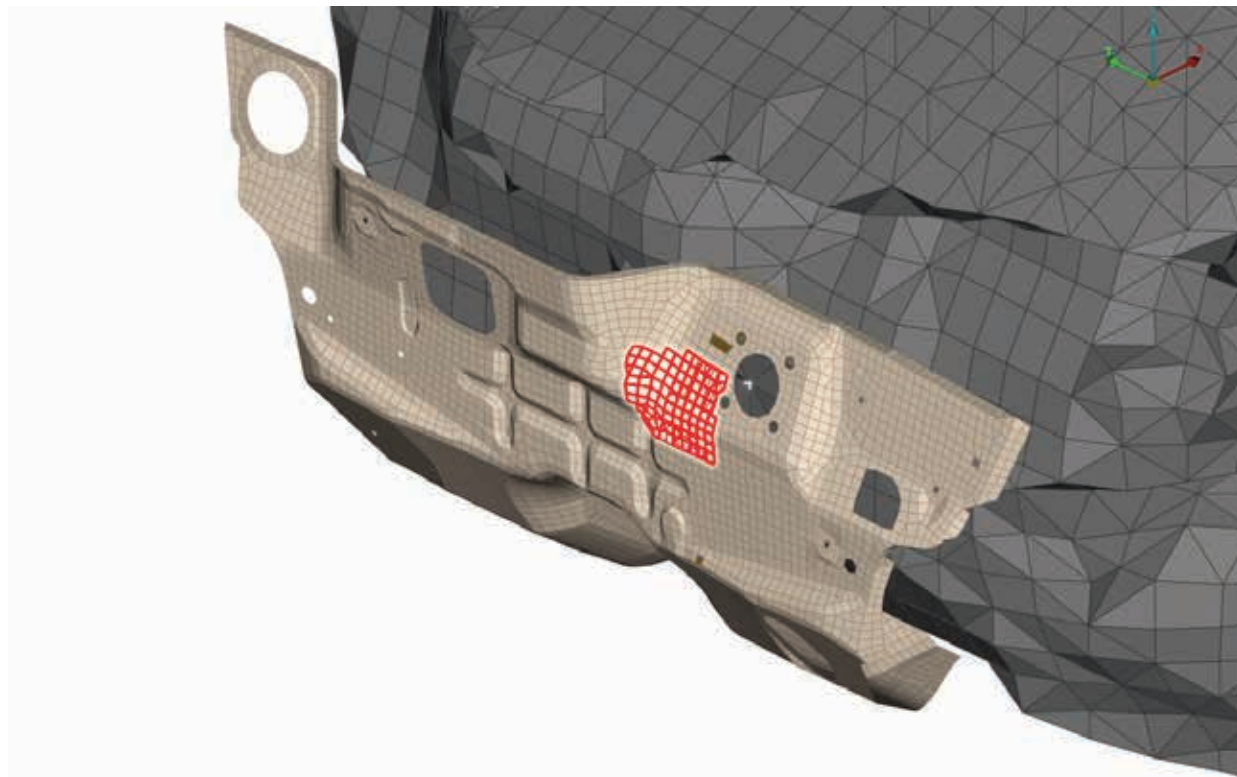
# Inspection and Validation, Point Equilibrium Test



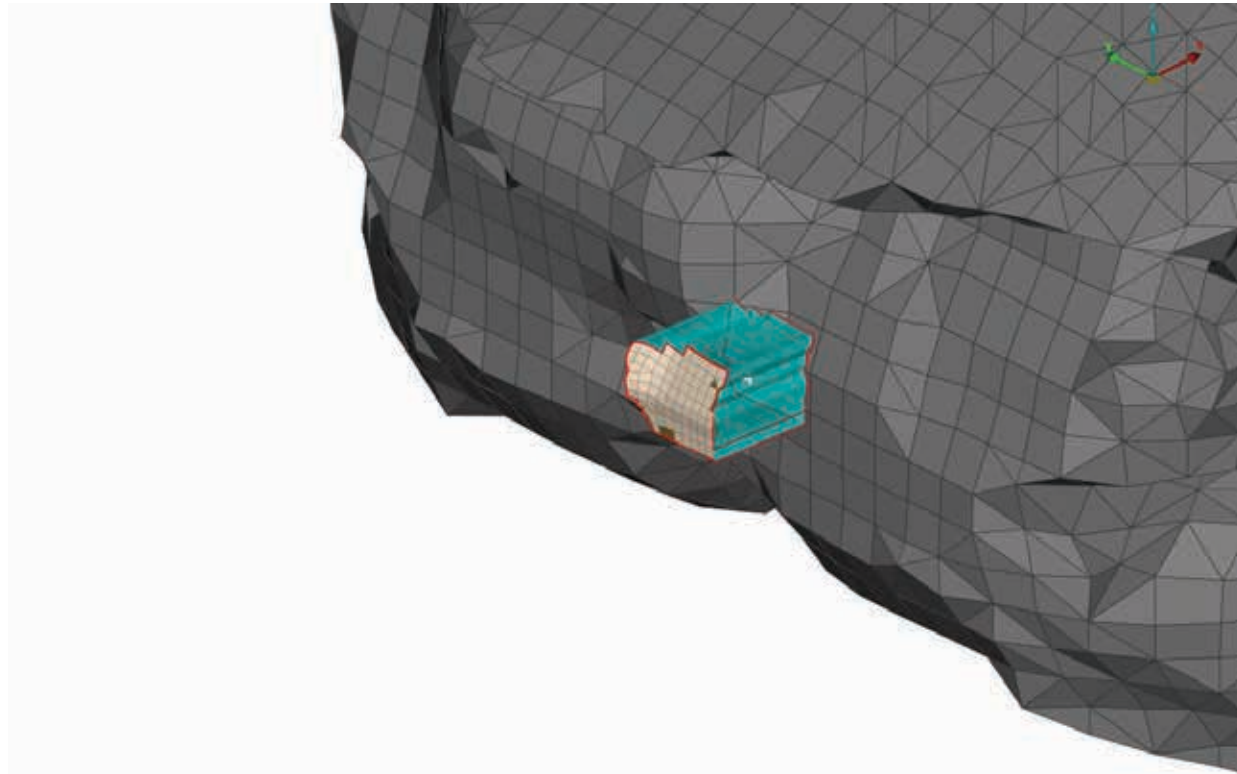
# Inspection and Validation, Patch Equilibrium Test



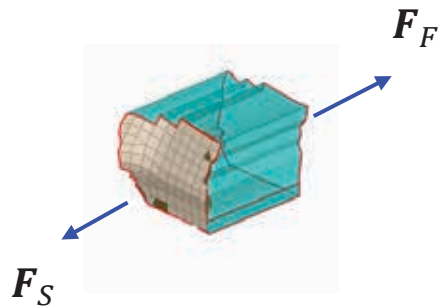
# Inspection and Validation, Patch Equilibrium Test



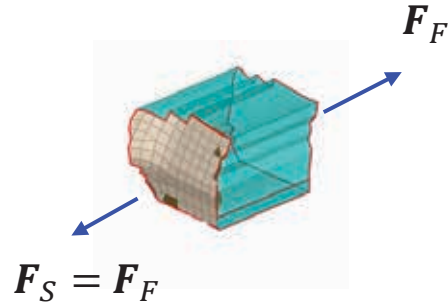
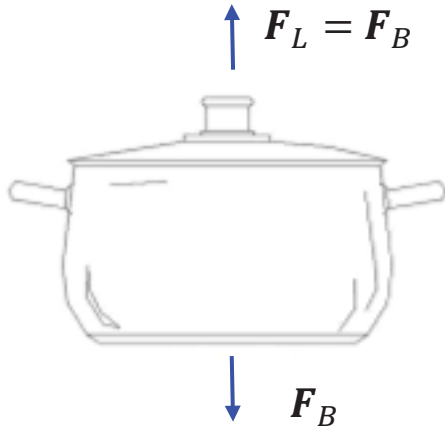
# Inspection and Validation, Patch Equilibrium Test



# Inspection and Validation, Patch Equilibrium Test



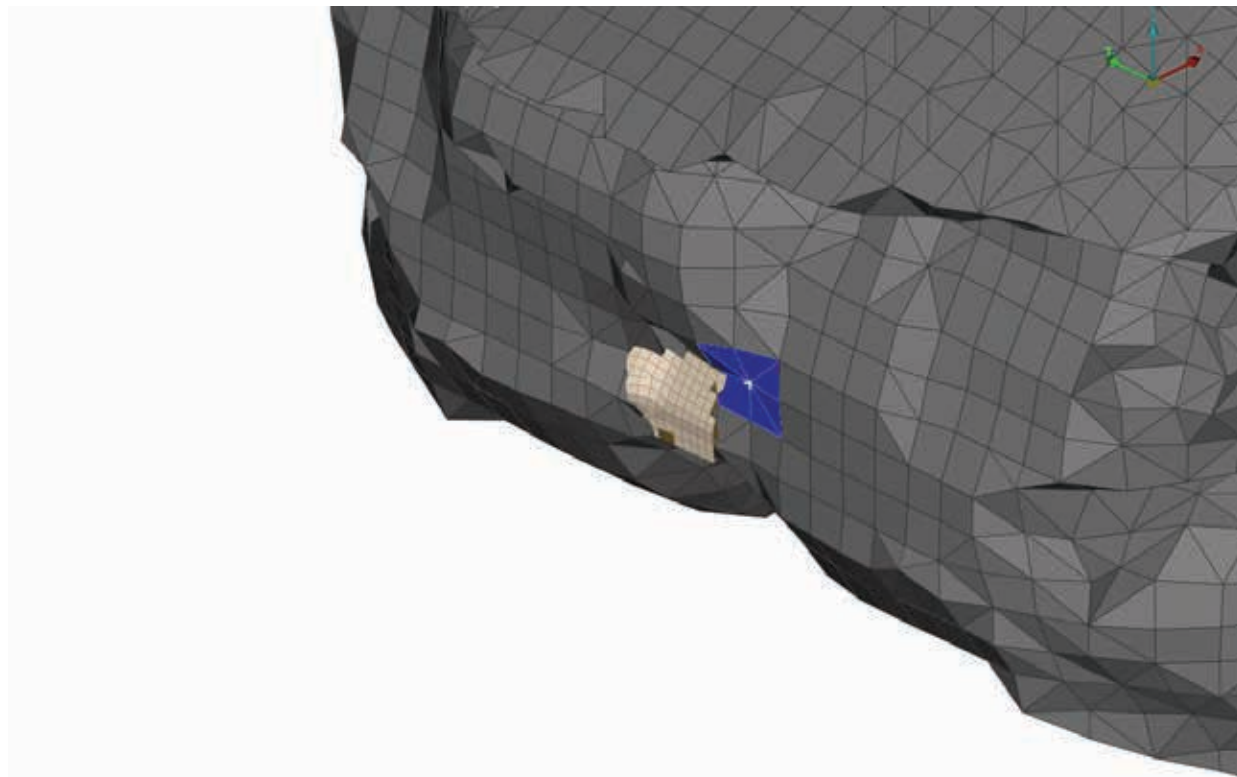
# Inspection and Validation, Patch Equilibrium Test



Patch Equilibrium error measure

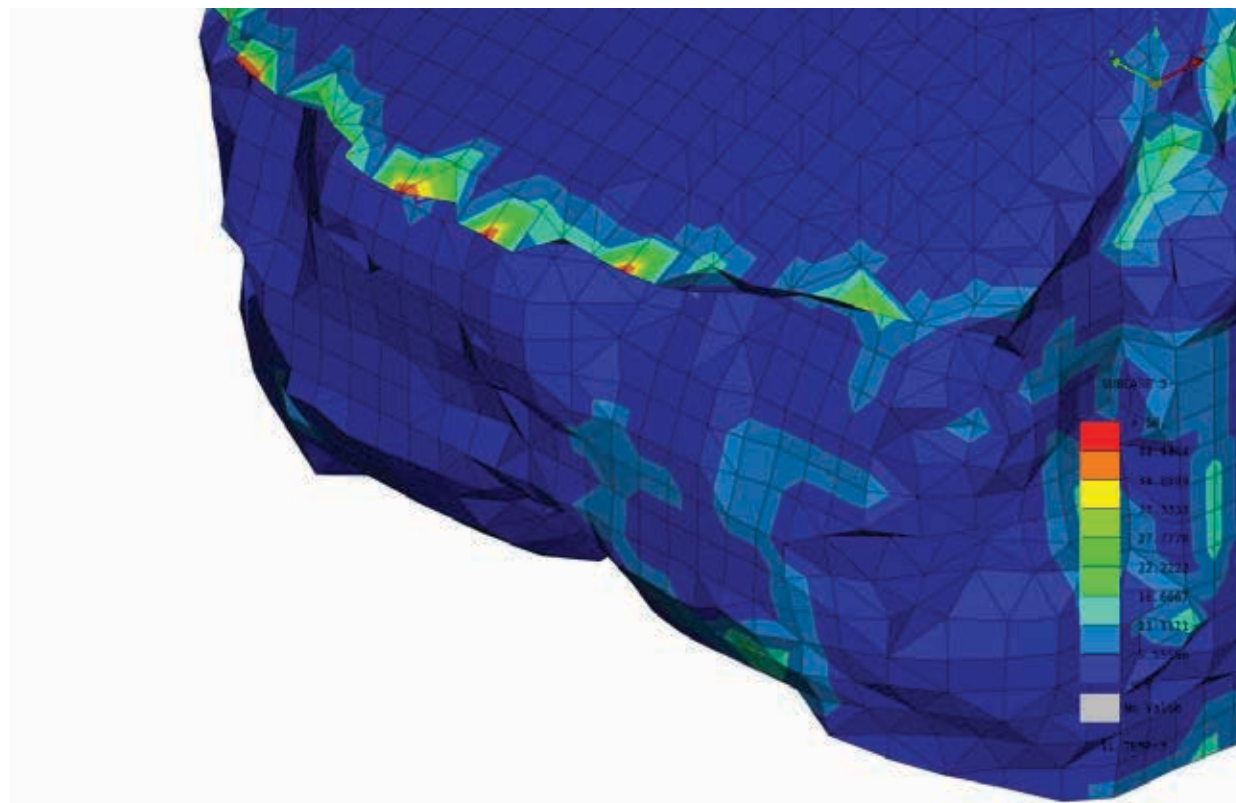
$$e_p = \frac{|F_S - F_F|}{F_F}$$

# Inspection and Validation, Patch Equilibrium Test



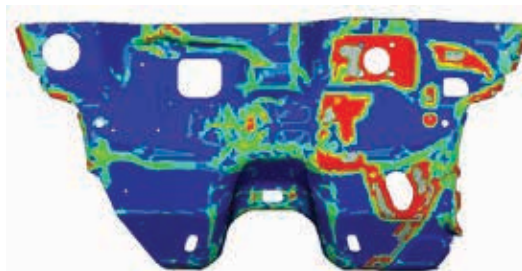


# Inspection and Validation, Patch Equilibrium Test

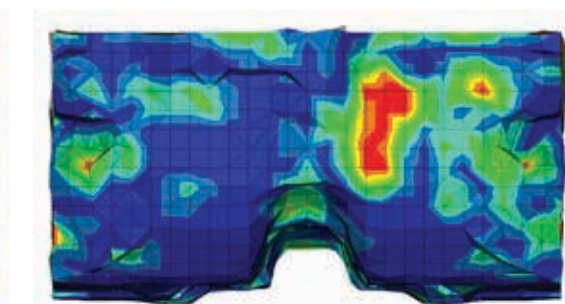
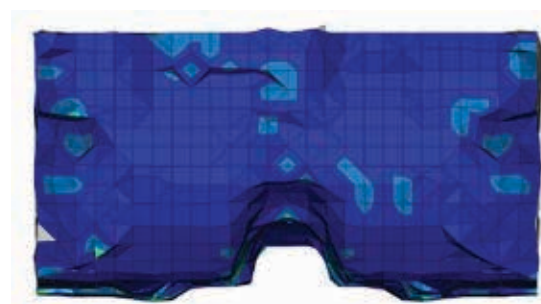
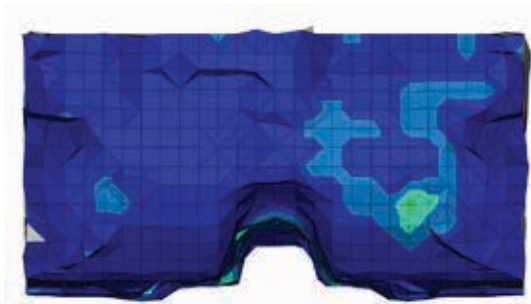


# Inspection and Validation, Patch Equilibrium Test

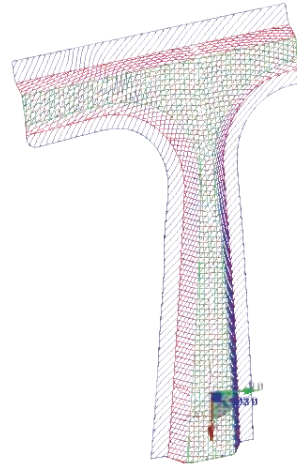
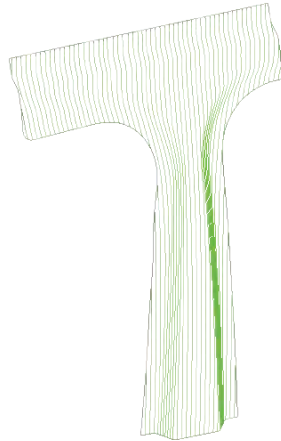
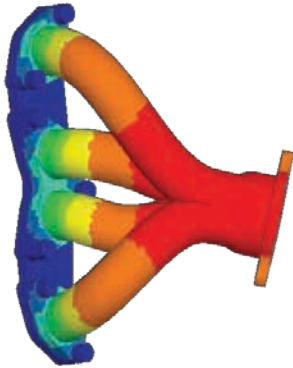
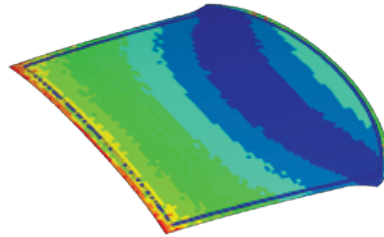
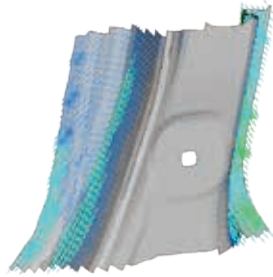
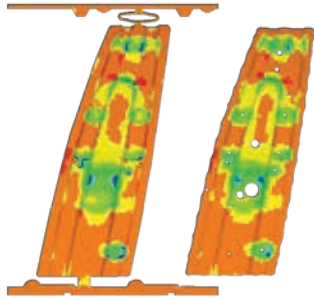
Point test



Patch test



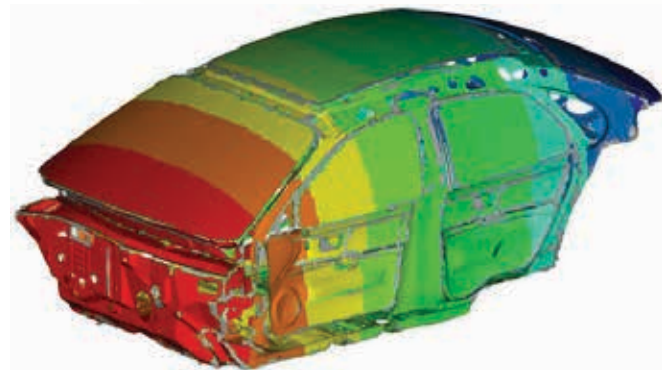
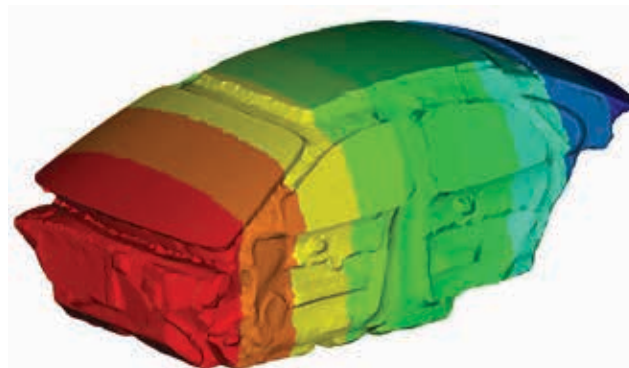
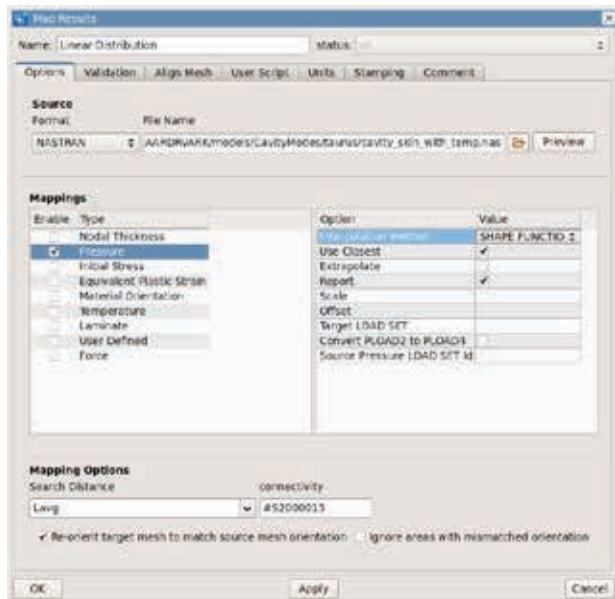
# Results Mapper



Transfer data related to

- Thinning
- Stresses and Plastic Strains
- Pressure Distributions
- Nodal Temperatures
- Material Orientations
- Laminates

# Results Mapper, weighting factors calculation



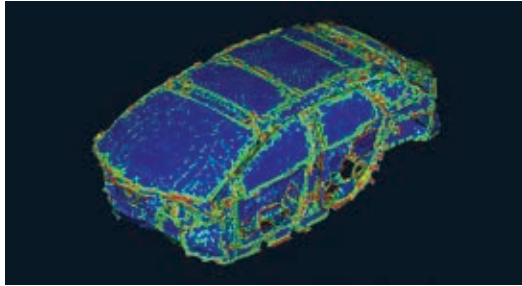
# Results

Algorithm A

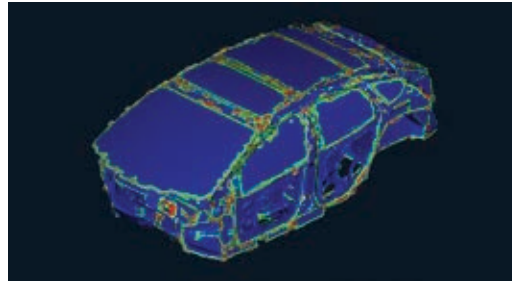
Algorithm B

Pressure Equilibrium

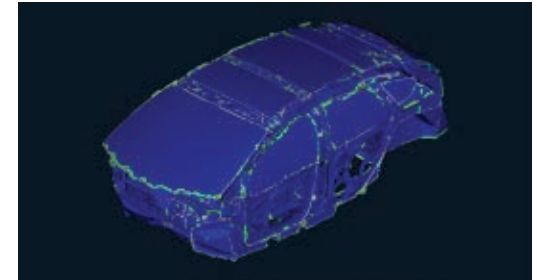
Point test



$\bar{e}_g$ : 34.1%

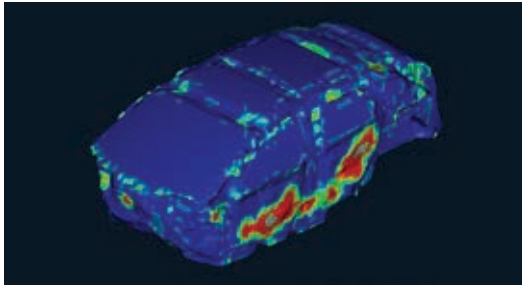


$\bar{e}_g$ : 21.0%

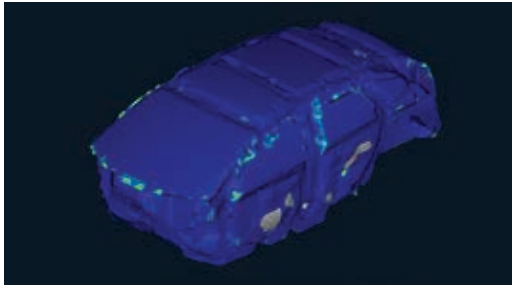


$\bar{e}_g$ : 4.0%

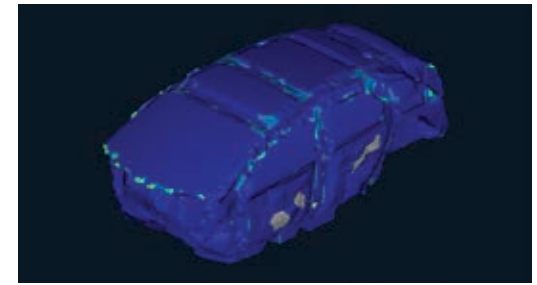
Patch test



$\bar{e}_p$ : 11.4%

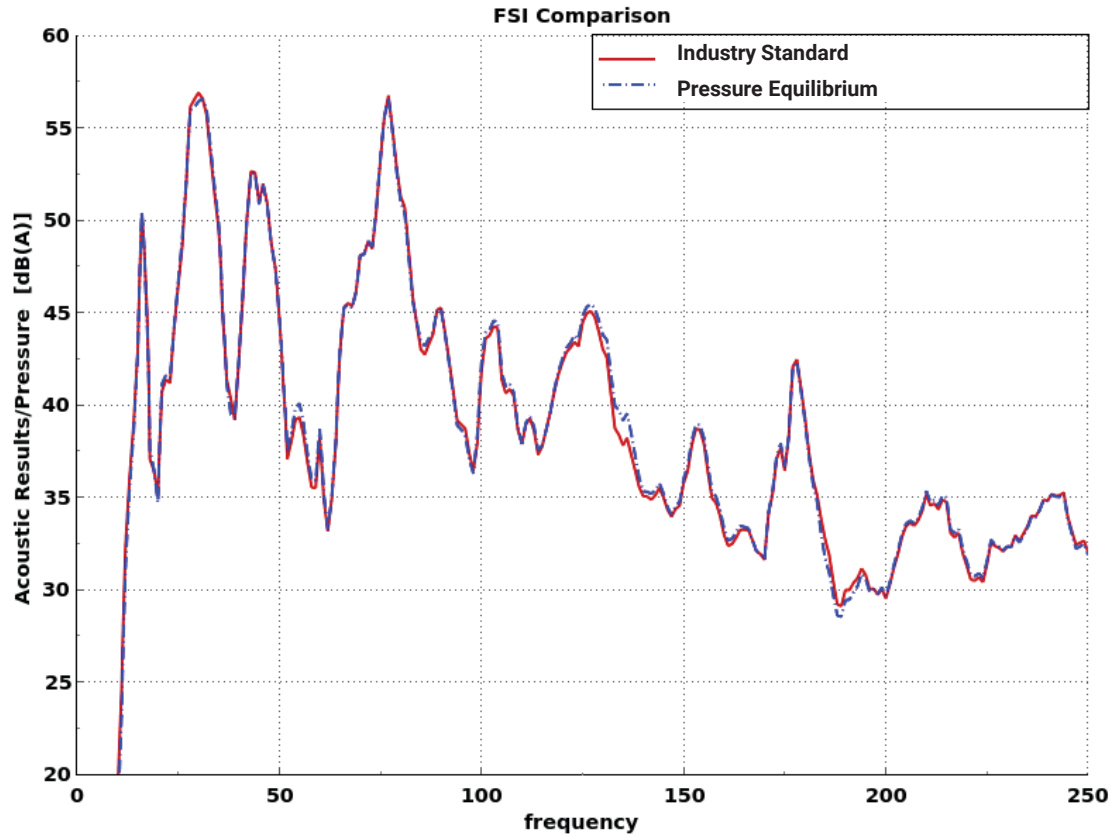


$\bar{e}_p$ : 4.2%



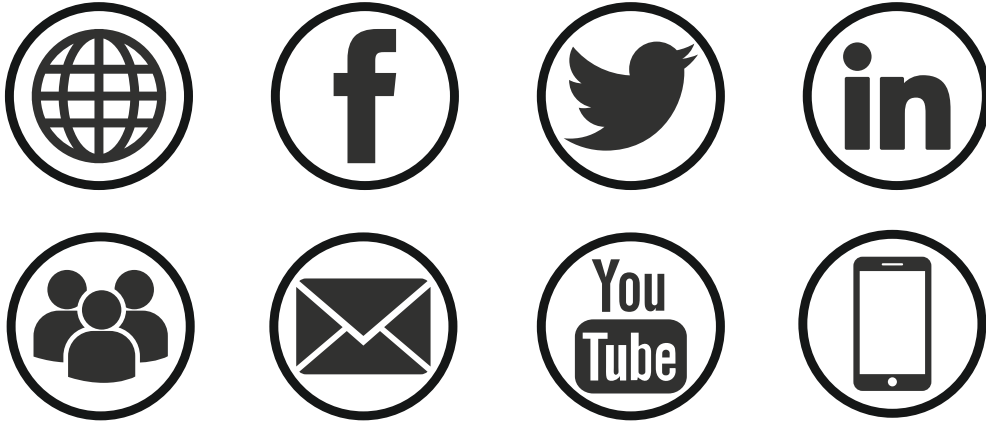
$\bar{e}_p$ : 3.7%

# Results



## Conclusions

- Two coupling validation tests
  - Point Equilibrium Test
  - Patch Equilibrium Test
- Improvements of the in-house coupling algorithm
  - Avoids the coupling of hidden or overlapping panels
  - Accounts for structural solids
  - Properly handles immersed structural panels
  - Evaluates NASTRAN coupling parameters consistently
  - Calculates accurate weighting factors
- Common coupling algorithm in ANSA/EPILYSIS/META



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