Acoustics Simulation of RJ-45 Connector Assembly

Satish Kumar M, Application Engineer II
Sunil Acharya, Principal Application Engineer

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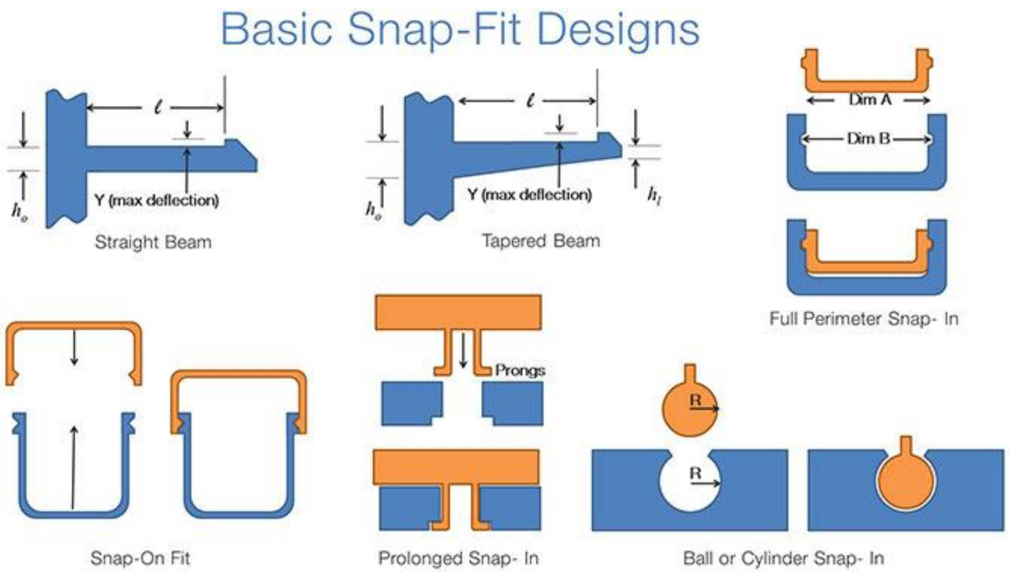
Overview

- **Background**
- **Approach taken**
- **Lessons Learned and Summary**
- **Open Discussion**

Background

- Snap-fit assembly is a common feature in manufacturing of various industrial thermoplastic products.

- Connector industry applications
  - Mechanical assembly
  - Maintaining electrical contact



Fiber Optics Connectors*

PCB Connectors*

Power Connectors*

*https://www.te.com/usa-en/products/connectors.html

Motivation:

- Snap Fit Design Challenges
  - Dynamic assembly/contact/robustness
  - New designs , Smaller Size, Complex Shapes
  - New materials (Polymeric)

- Traditional design typically focusses on Reaction Force Calculation
  - Accounts for Haptic Feedback during Assembly

- Lack of design approaches for “acoustic feedback”
  - Important during assembly without clear “line of sight” (eg: automotive connectors)
  - Acoustics is closely related to “Perception of Quality” (eg: keyboard clicks, watch mechanism)

Need Explicit Solver with Multiphysics Capabilities

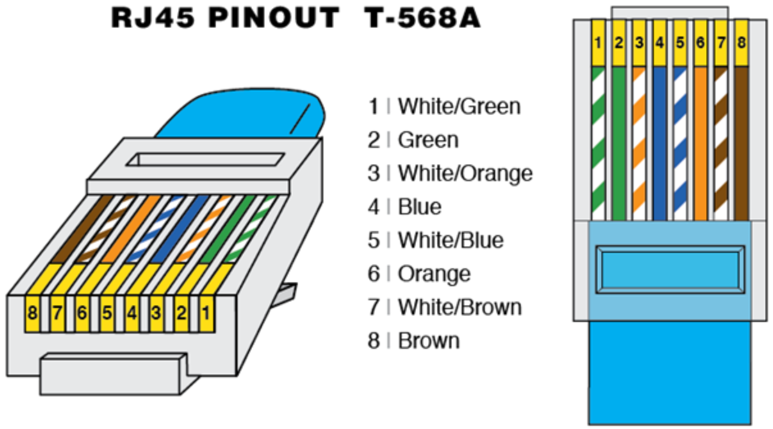
RJ45 Connectors

- RJ45 stands for 'Registered Jack 45'.
- RJ45 connectors are primarily used for plugging an internet-enabled device directly into hardware such as a modem, router, or server.
- Types of RJ45 Connector
  - *Male Connector*
  - *Female Connector*
- RJ45 Pin Assignment

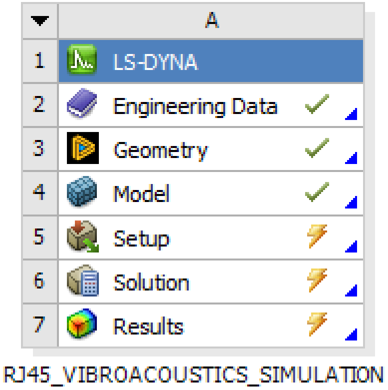
RJ45 plug connections are based on 8P8C cabling.

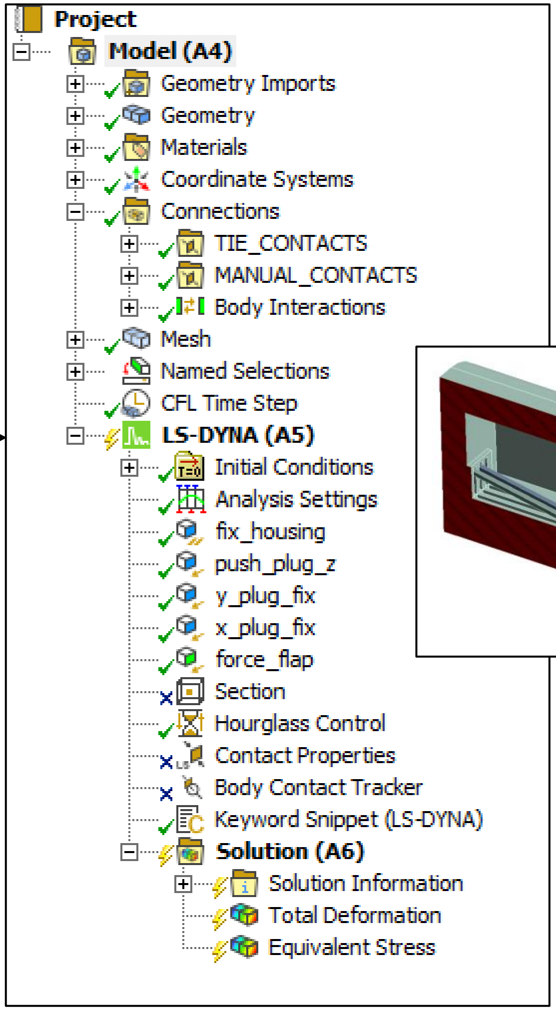
Male Connector

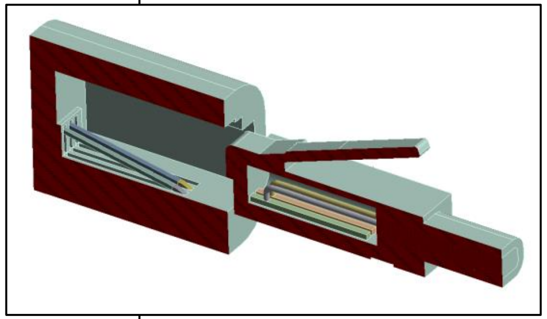
Female Connector



Approach taken – Workflow Setup





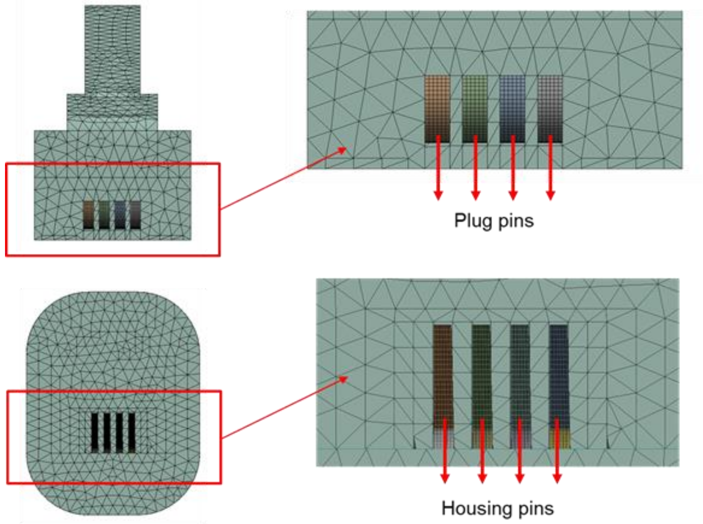


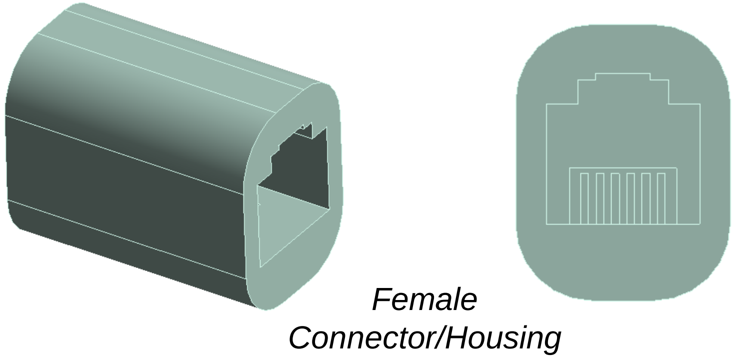
export .k file

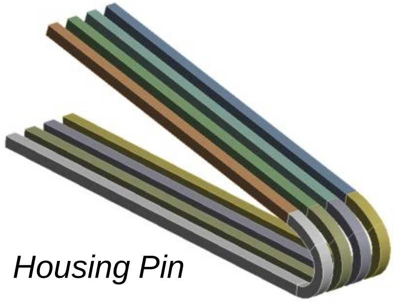
LS-RUN & LS Pre-Post

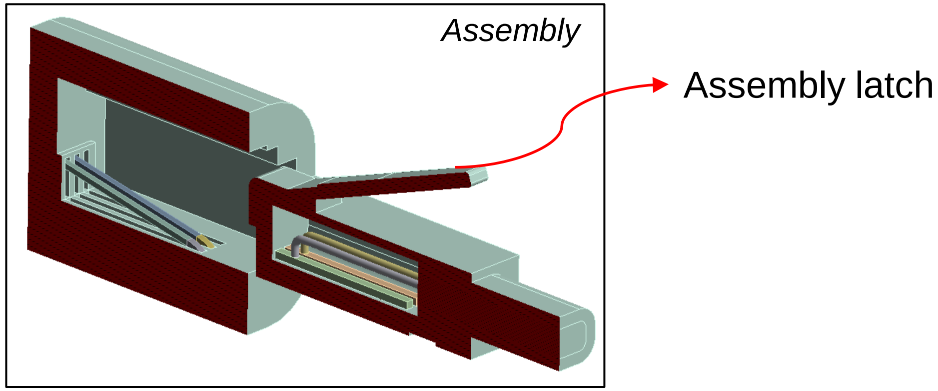
RJ45 Connector Geometry

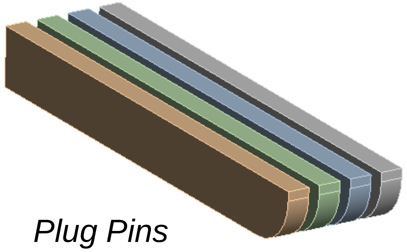
- Solid geometries.
- SpaceClaim was used to prepare the model for FEA.
- The most important parts are,
  - Female Connector/Housing
  - Male Connector/Plug
  - Housing Pins
  - Plug Pins

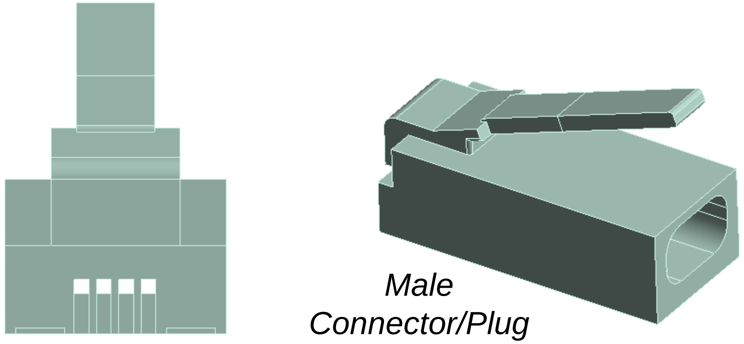








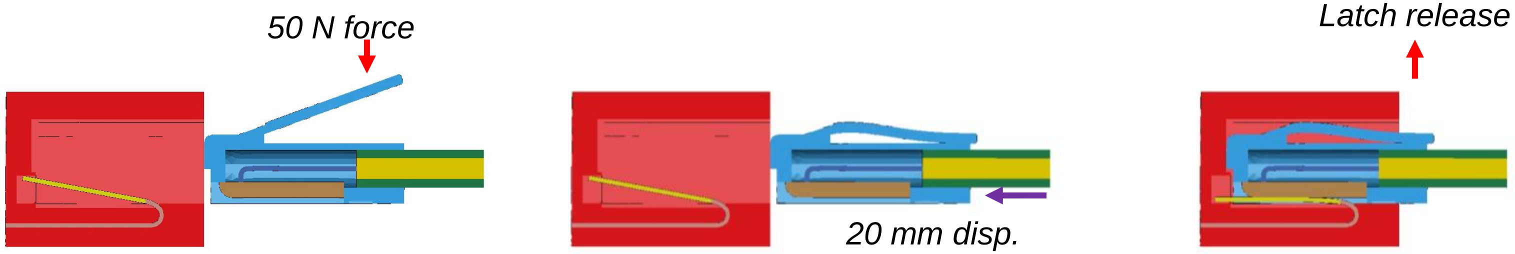




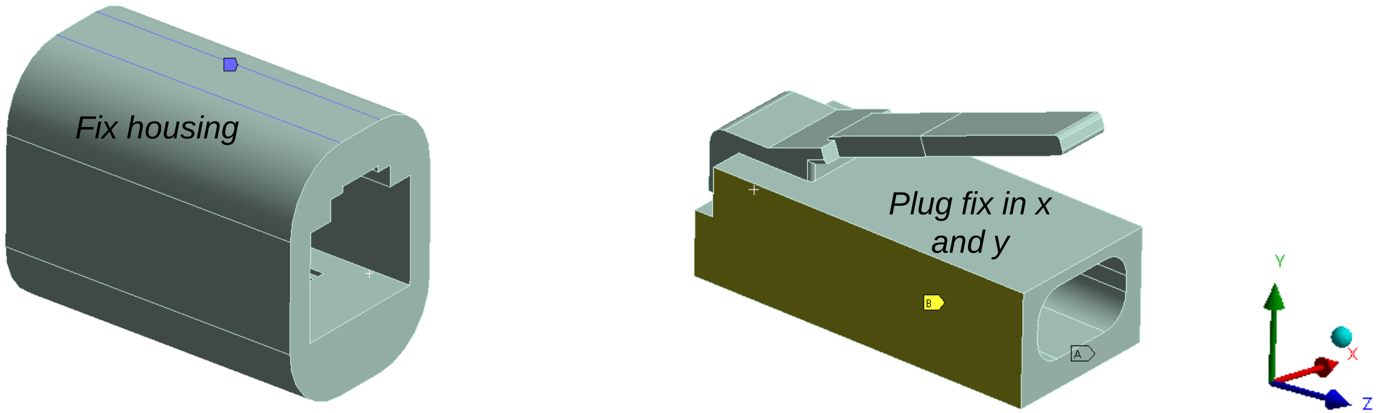
FE model setup in LS-DYNA for structural analysis

- Pins meshed with Hex elements.
- General contact ($\mu = 0.1$)
- Loading conditions are,
  - Assembly latch pushed in negative y-direction with 50 N.
  - Plug pushed in negative z-direction 20 mm.
  - Assembly latch load released to capture snap fit.
  - Assembled idle position.
- Boundary conditions are,
  - Housing fixed in all DOFs.
  - Plug fixed in x and y directions.

Loading conditions



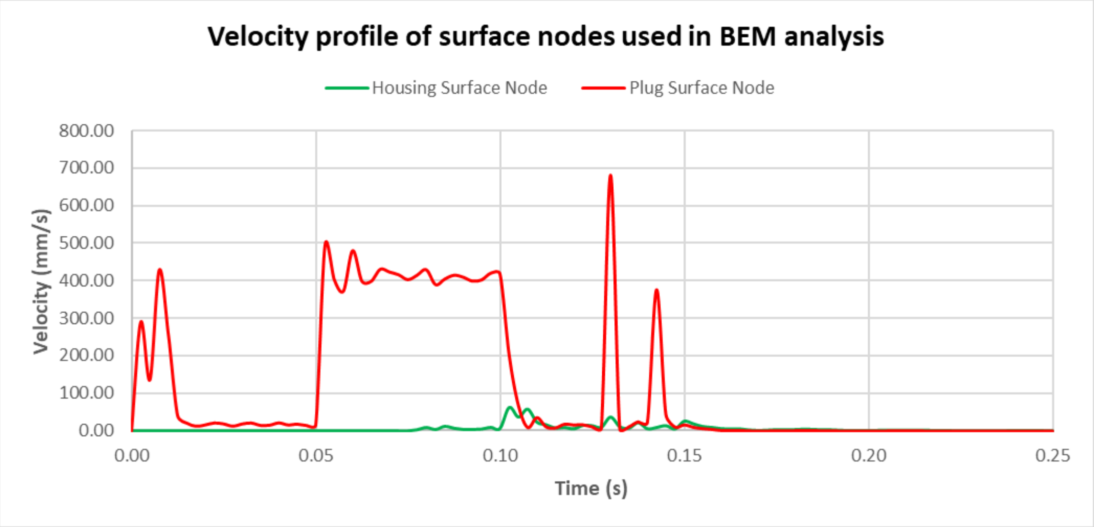
Boundary conditions



FE model setup in LS-DYNA for acoustic analysis

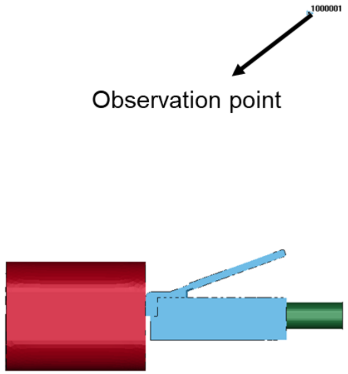
- Boundary element method
  - **Velocities from temporal analysis** are recorded in time domain.
  - Converted to frequency domain.
  - Helmholtz equation is solved,

$$\Delta p + k^2 p = 0$$

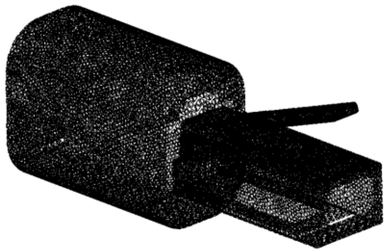


- *FREQUENCY_DOMAIN_ACOUSTIC_BEM is used to activate acoustics analysis
- Inputs to be prescribed are,

OPTION	VALUE
Density of Fluid	1.21E-12 $\mathrm{ton/mm^3}$
Speed of Sound	3.4E+05 mm/s
Minimal frequency	0.0 Hz
Maximal frequency	20000.0 Hz
Reference pressure	2.0E-11 MPa



Field point away from the connector



Boundary Elements

Analyses Setup

Scenario No.	TOTAL TIME	ASSEMBLY TIME	FRICTION	MATERIAL MODEL
Scenario 1	0.25 s	0.15 s	0.1	PLASTIC
Scenario 2	0.35 s	0.25 s	0.1	PLASTIC
Scenario 3	0.35 s	0.25 s	0.1	ELASTIC
Scenario 4	1.0 s	0.25 s	0.1	PLASTIC

<table>
<tr><th>Part</th><th>LS-DYNA Equivalent material model</th><th>Material Properties</th></tr>
<tr><td>Plug pins/Housing pins</td><td>*MAT_ELASTIC</td><td>E=1.1E+05 MPa
μ = 0.34</td></tr>
<tr><td rowspan="2">All other parts</td><td rowspan="2">*MAT_ELASTIC/*MAT_PIECEWISE_LINEAR_PLASTICITY</td><td>E=2513 MPa, μ = 0.3975</td></tr>
<tr><td>E=2454.55 MPa, μ = 0.4, sigy=23.3902 MPa</td></tr>
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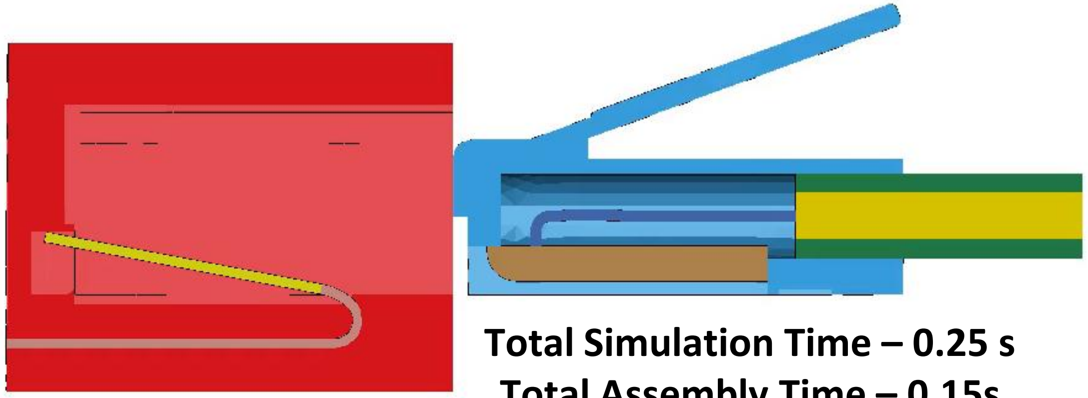
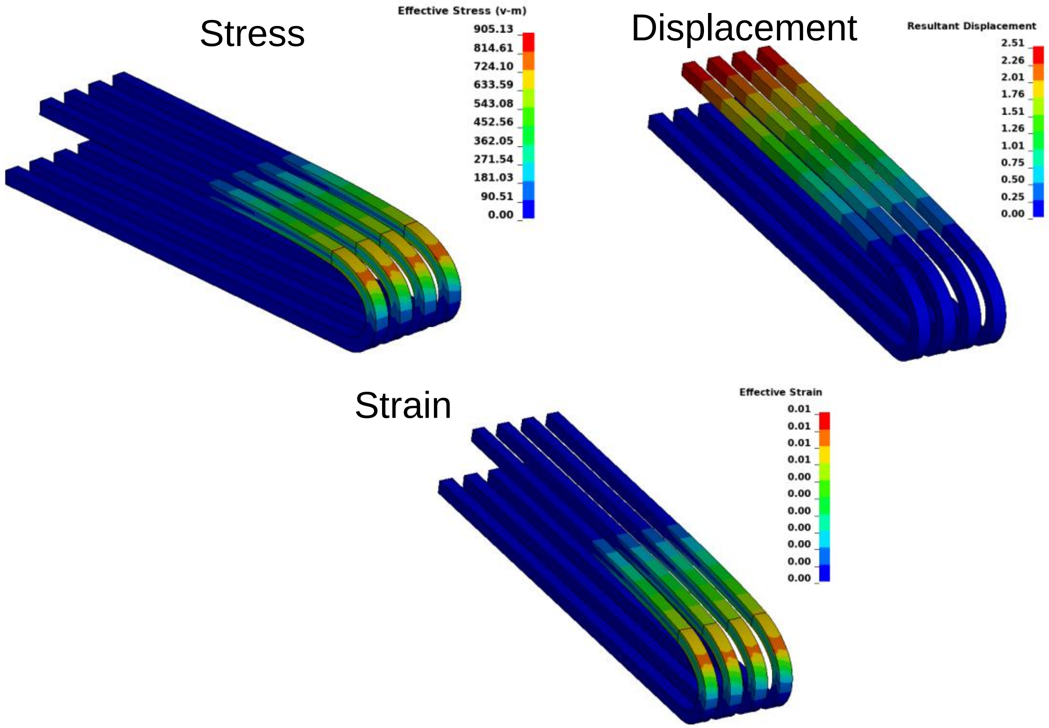
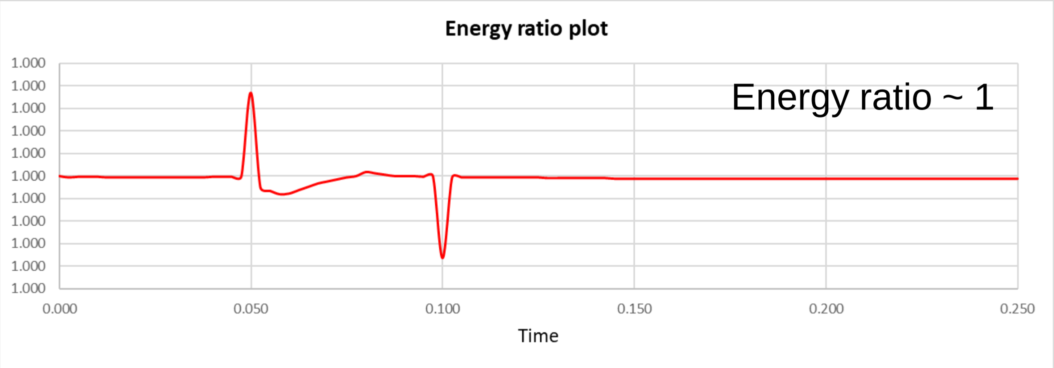
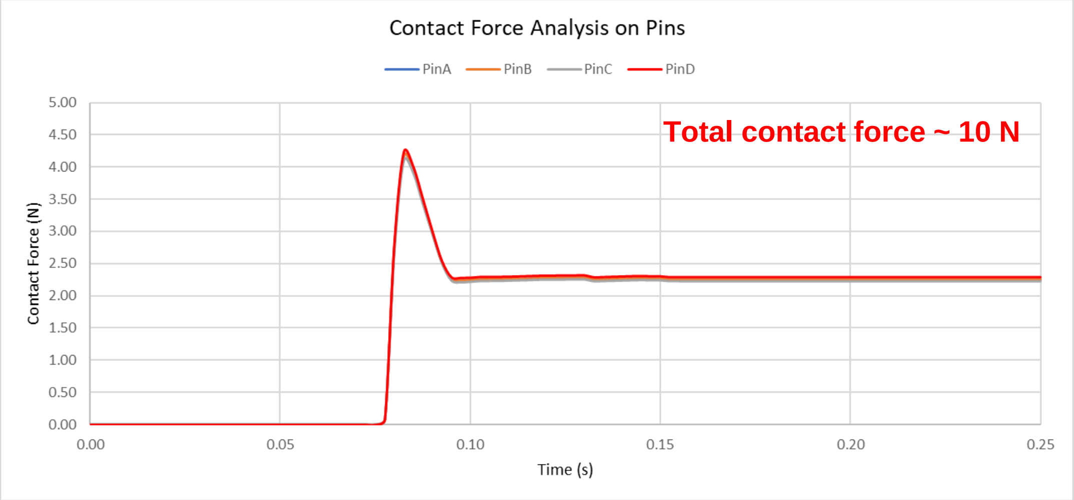
Structural Analysis - Results



Total Simulation Time – 0.25 s
Total Assembly Time – 0.15s







Note: The above results are from one simulation out of the four different iteration that were run.

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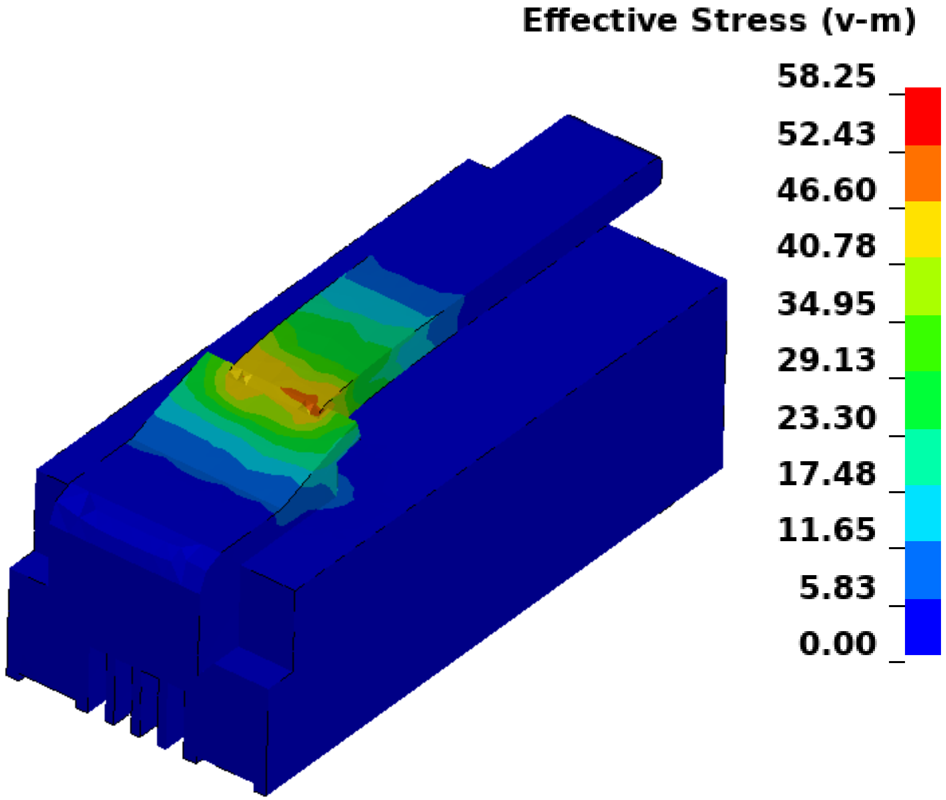
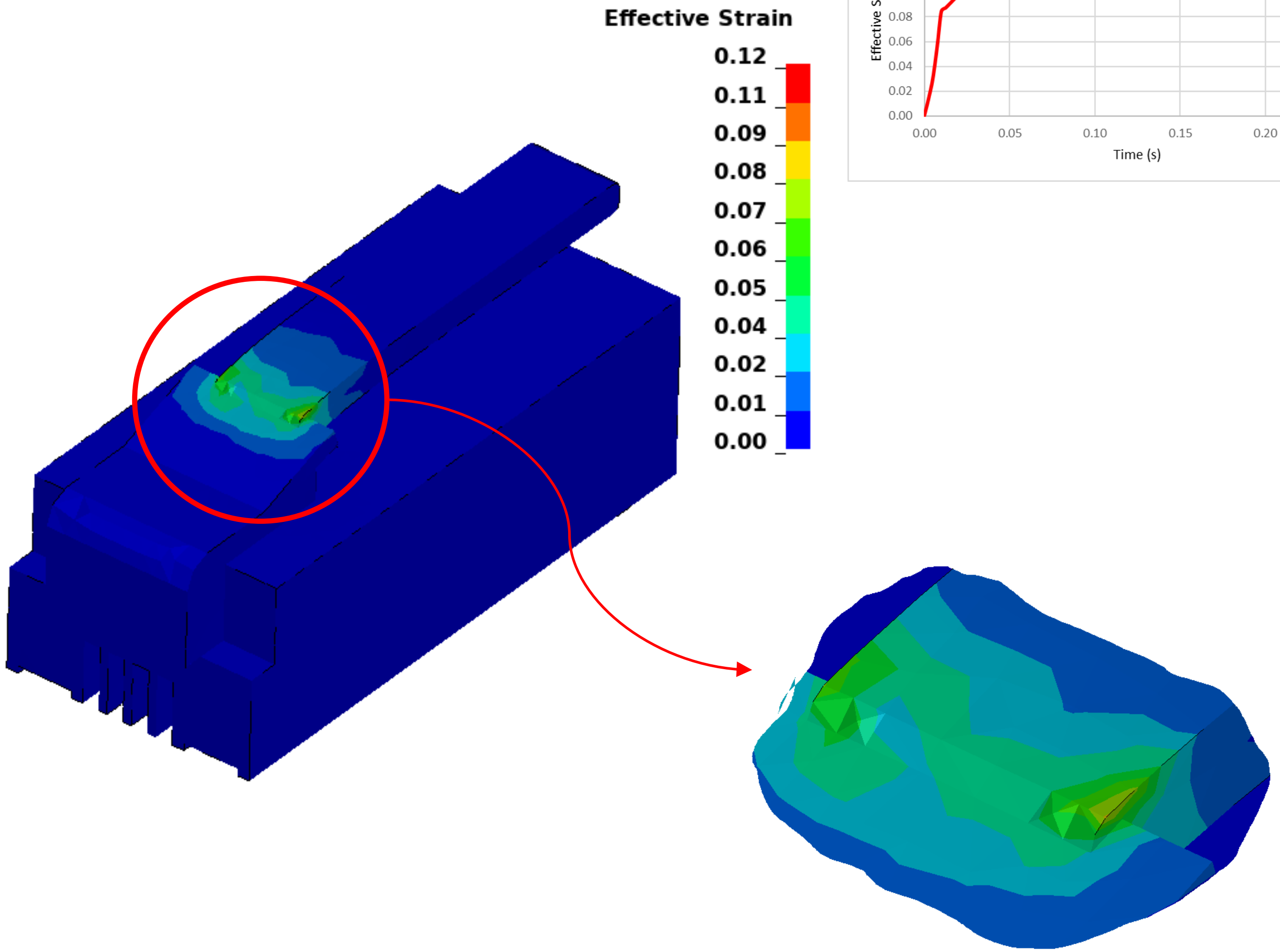
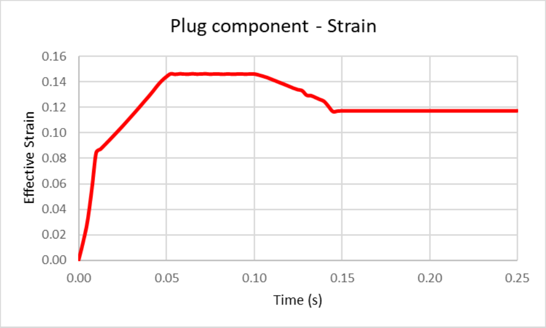
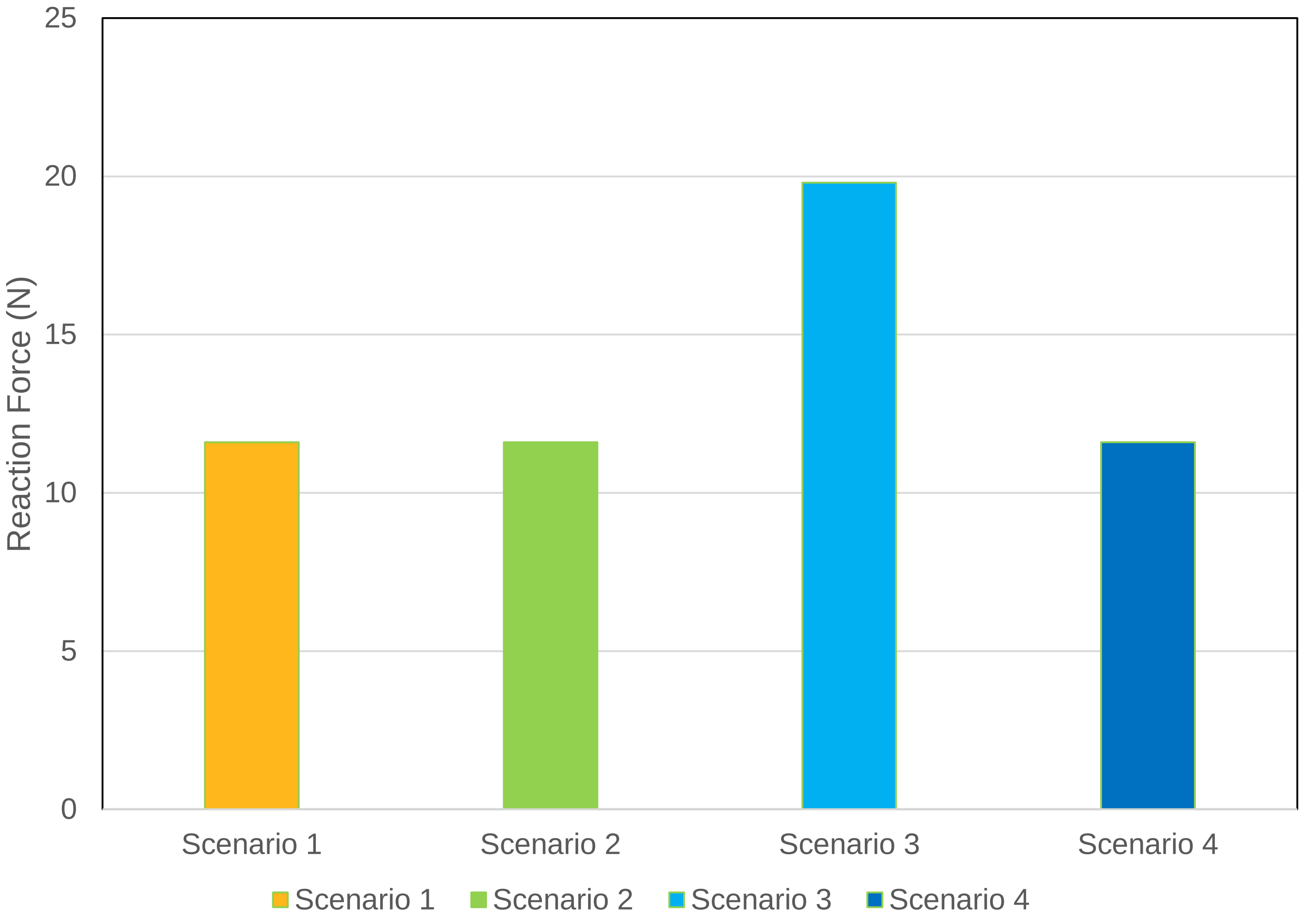
Structural Analysis - Results





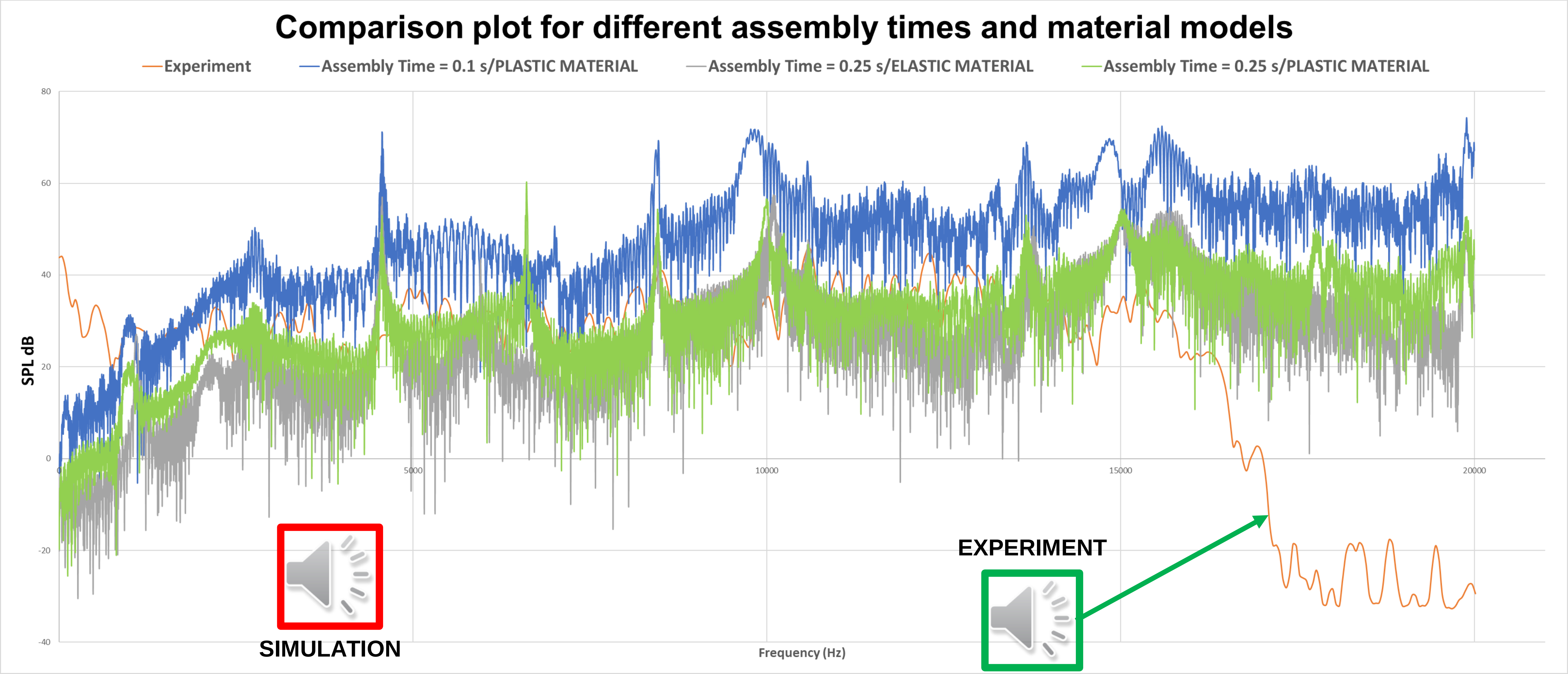


Haptic response

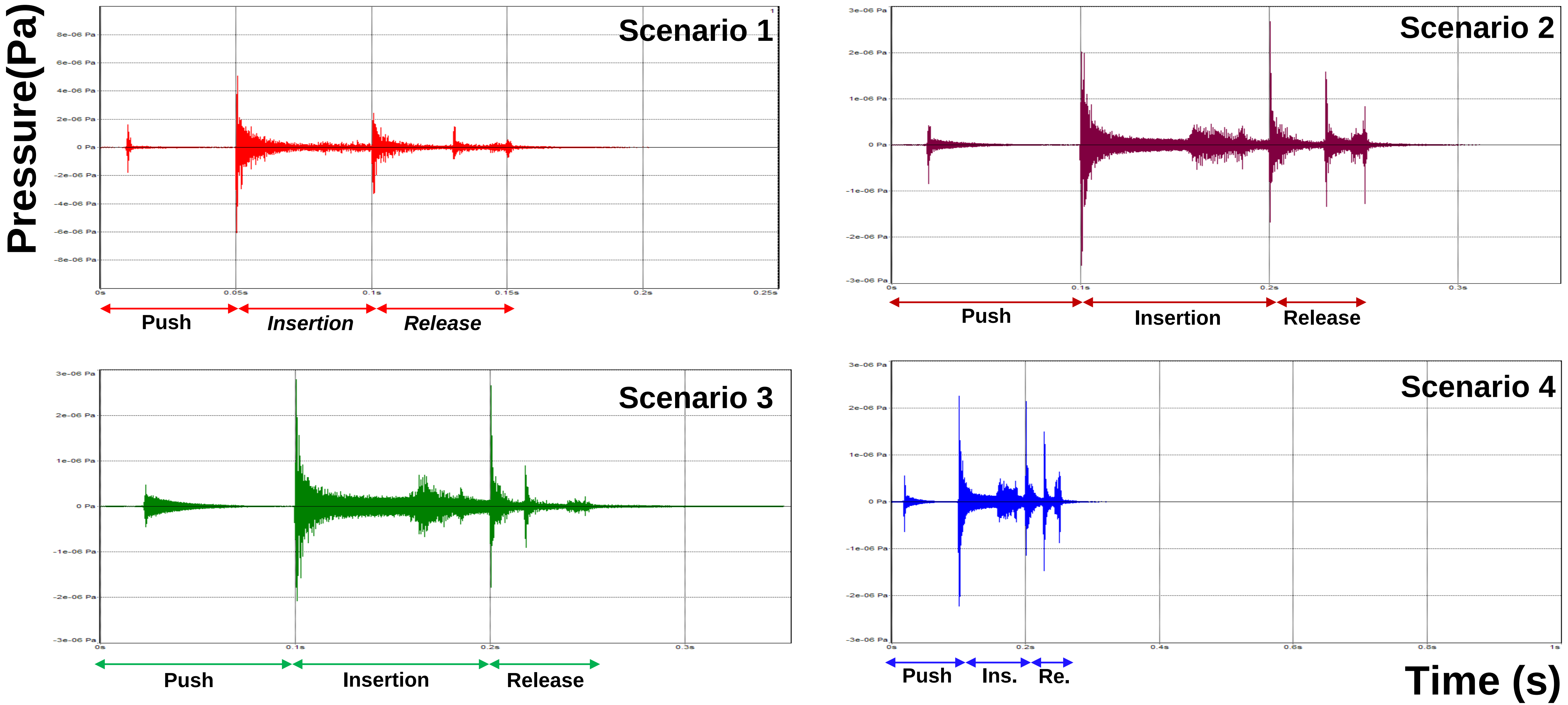


- No relevance to assembly time.
- Plasticity (isotropic hardening) reduces reaction force.

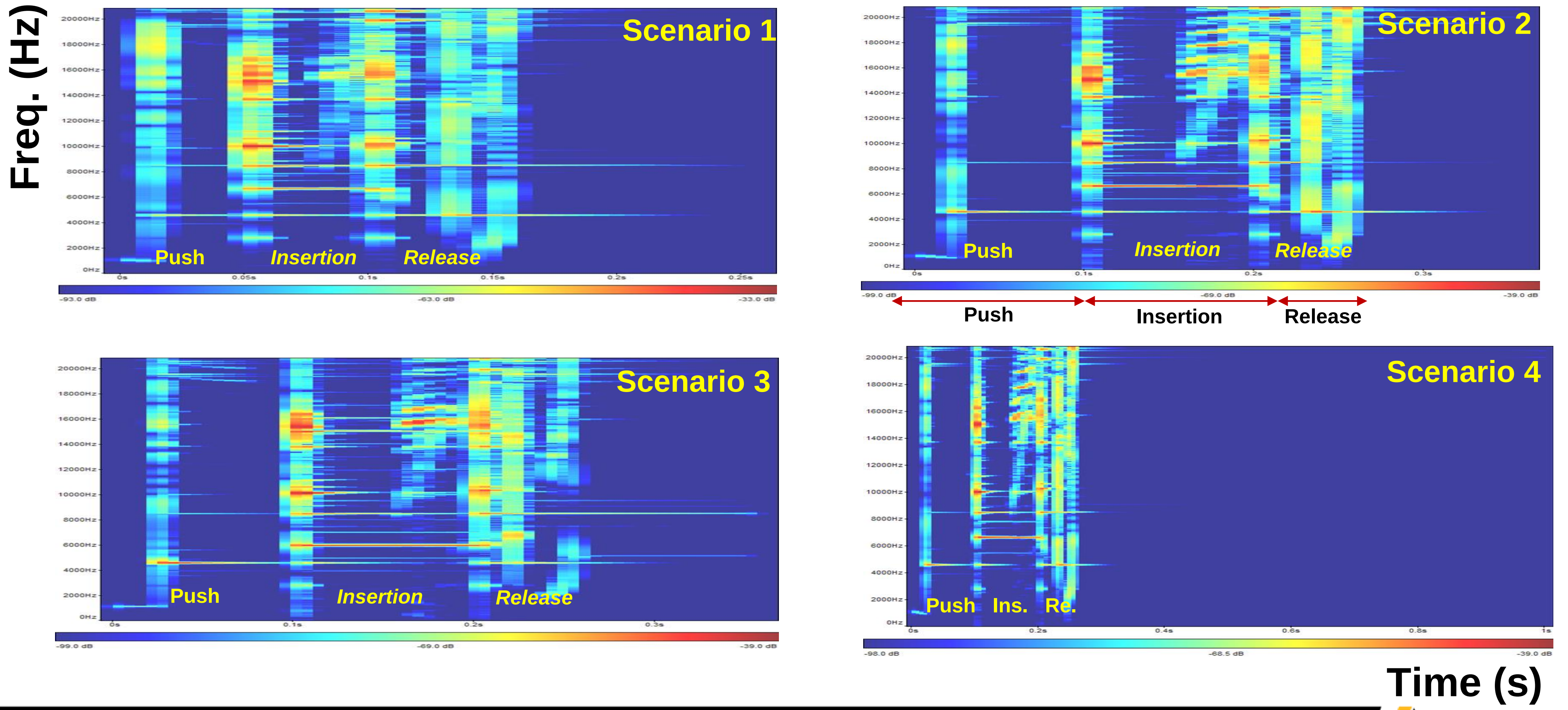
Acoustic Response



Acoustic Response



Acoustic Response



Summary

- Assembly time is inversely proportional to sound pressure level (SPL dB).
- Plasticity reduces the reaction force and has dampening effect on the acoustics response
- Challenges in postprocessing the vibro-acoustics with 2 deformable bodies in contact

$$SPL\ dB\ \alpha\ \frac{1}{assembly\ time}$$

- Future Work to include:
  - Studying Effect of materials on acoustics with advanced material models for thermoplastics
  - Experimental Validation
  - Custom workflows in ANSYS Sound for post-processing
  - Additional multi-physics relevant to connector industries (eg: electric, thermal)

LSDYNA offers single solver environment for structural dynamics and vibro-acoustics

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Thank You!

Many Thanks to..

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Zhe Cui, Senior R&D Engineer, ANSYS

Clement Dendieval, Sr Product Sales Manager, ANSYS

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