Autodesk Nastran for Inventor: Unlocking Dynamics

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About the speaker

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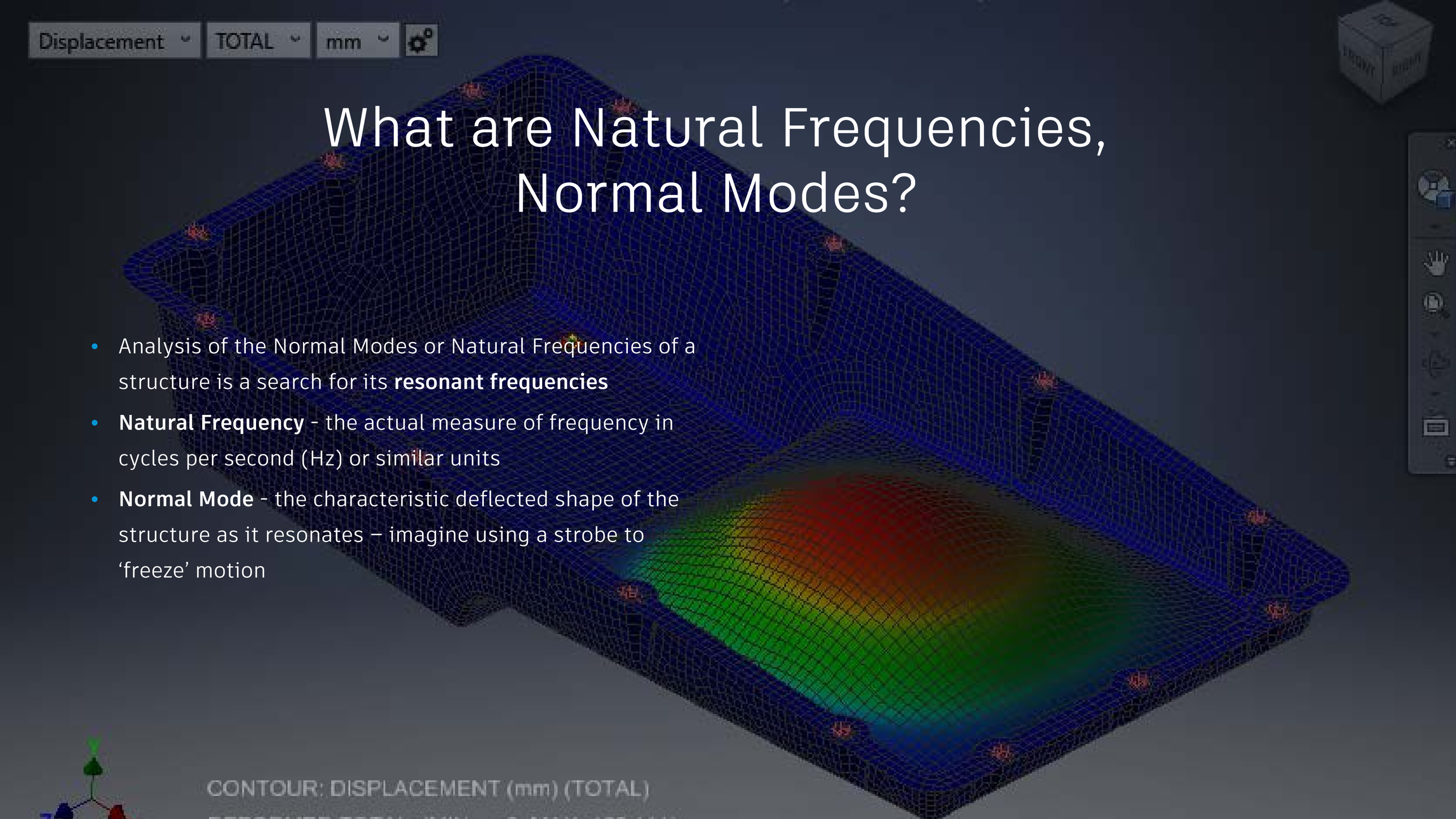
Normal Modes Analysis

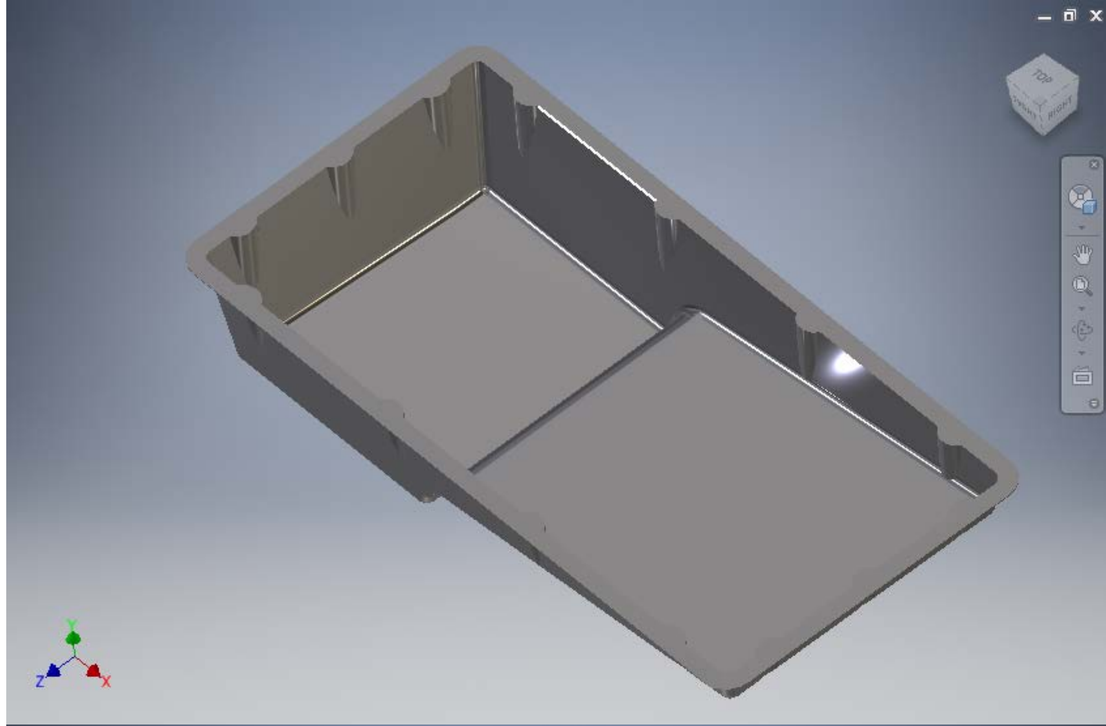


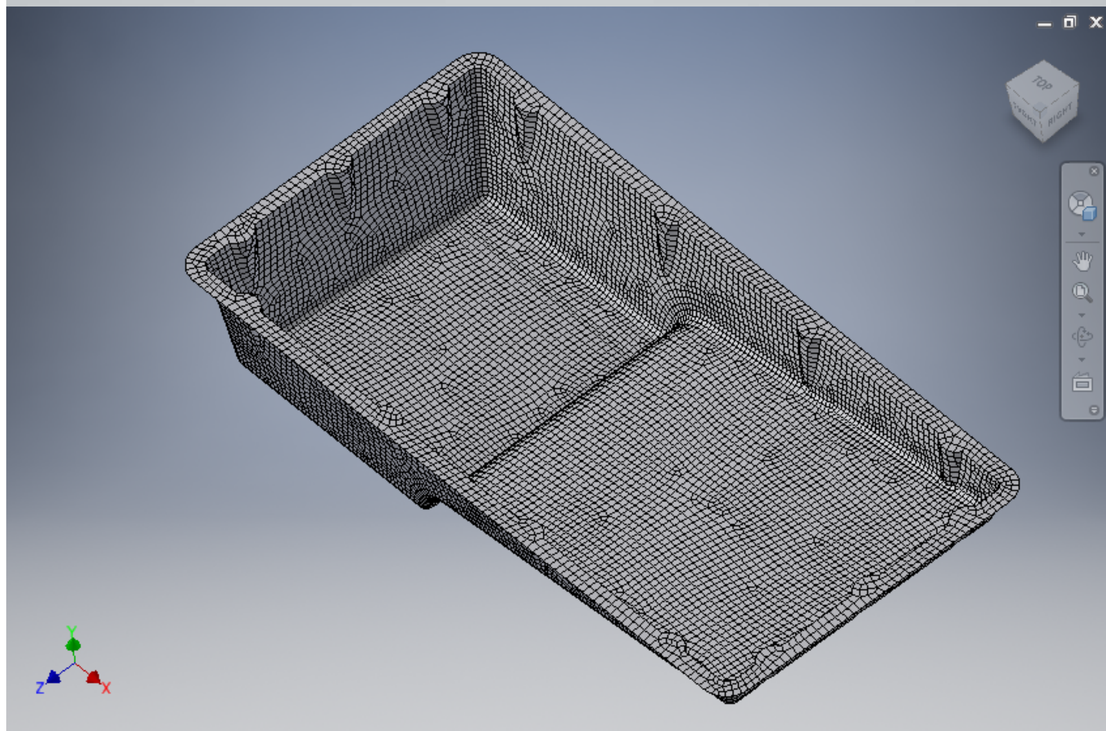
What are Natural Frequencies, Normal Modes?

- Analysis of the Normal Modes or Natural Frequencies of a structure is a search for its **resonant frequencies**
- **Natural Frequency** - the actual measure of frequency in cycles per second (Hz) or similar units
- **Normal Mode** - the characteristic deflected shape of the structure as it resonates – imagine using a strobe to ‘freeze’ motion

How many frequencies in a structure?

- There are infinite resonant frequencies in a real structure
- An FEA model simplifies to the number of Degrees of Freedom (63498)
- We are usually only interested in first subset (we will use 1 – 20)
- Energy required to get a significant response increases as frequency increases





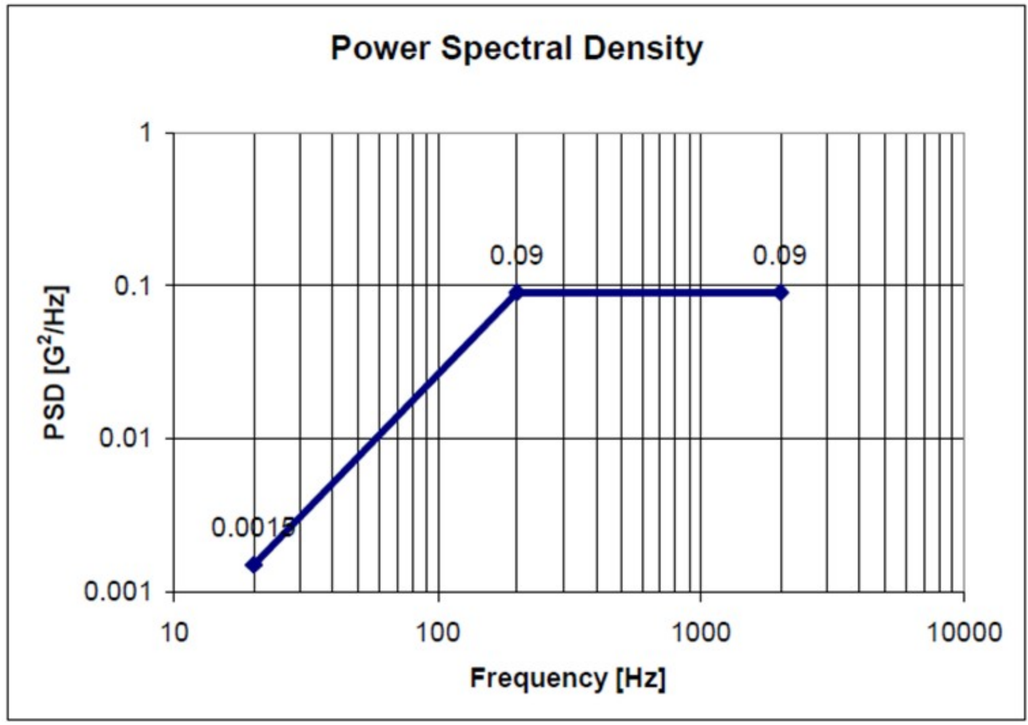
What modes are important?

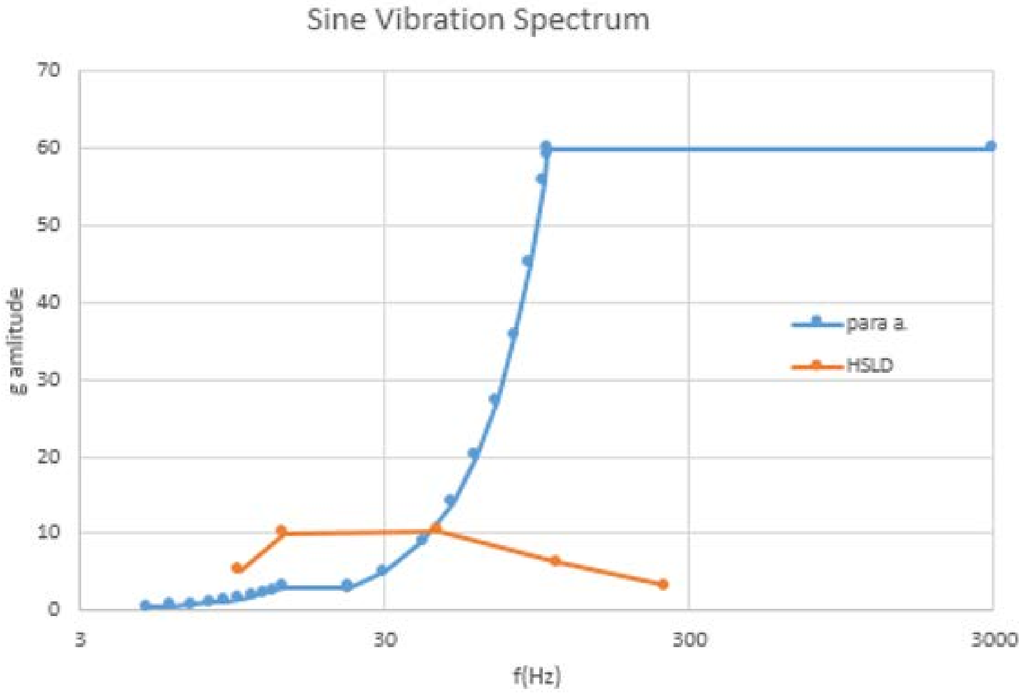
- Bridge – say .5 Hz to 5 Hz important. Above 20 Hz effectively ignores excitation

- Crankshaft in a F1 racing car - say 60,000 RPM – means 1000 Hz is critical

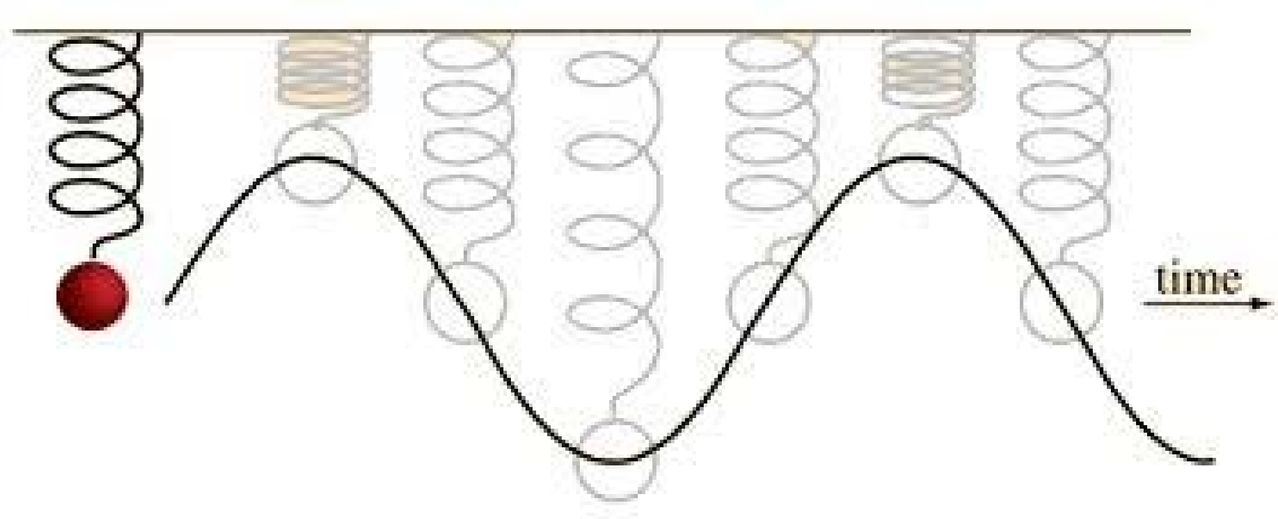
What modes are important?

- Important question ;
- what is the range of input or driving frequencies?
- That will dictate which modes are critical
- From specification or known environment
- Use safety factor of 1.5 to 2 if no specification

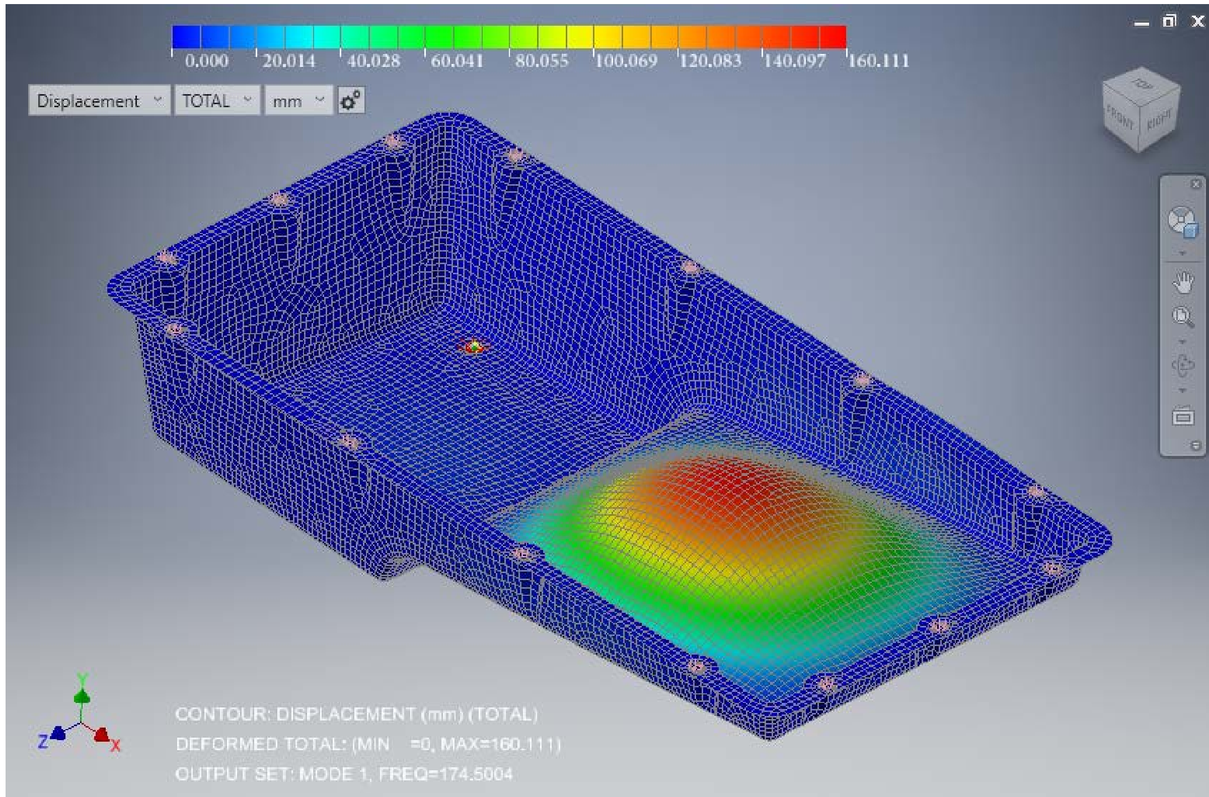




How do we do it?



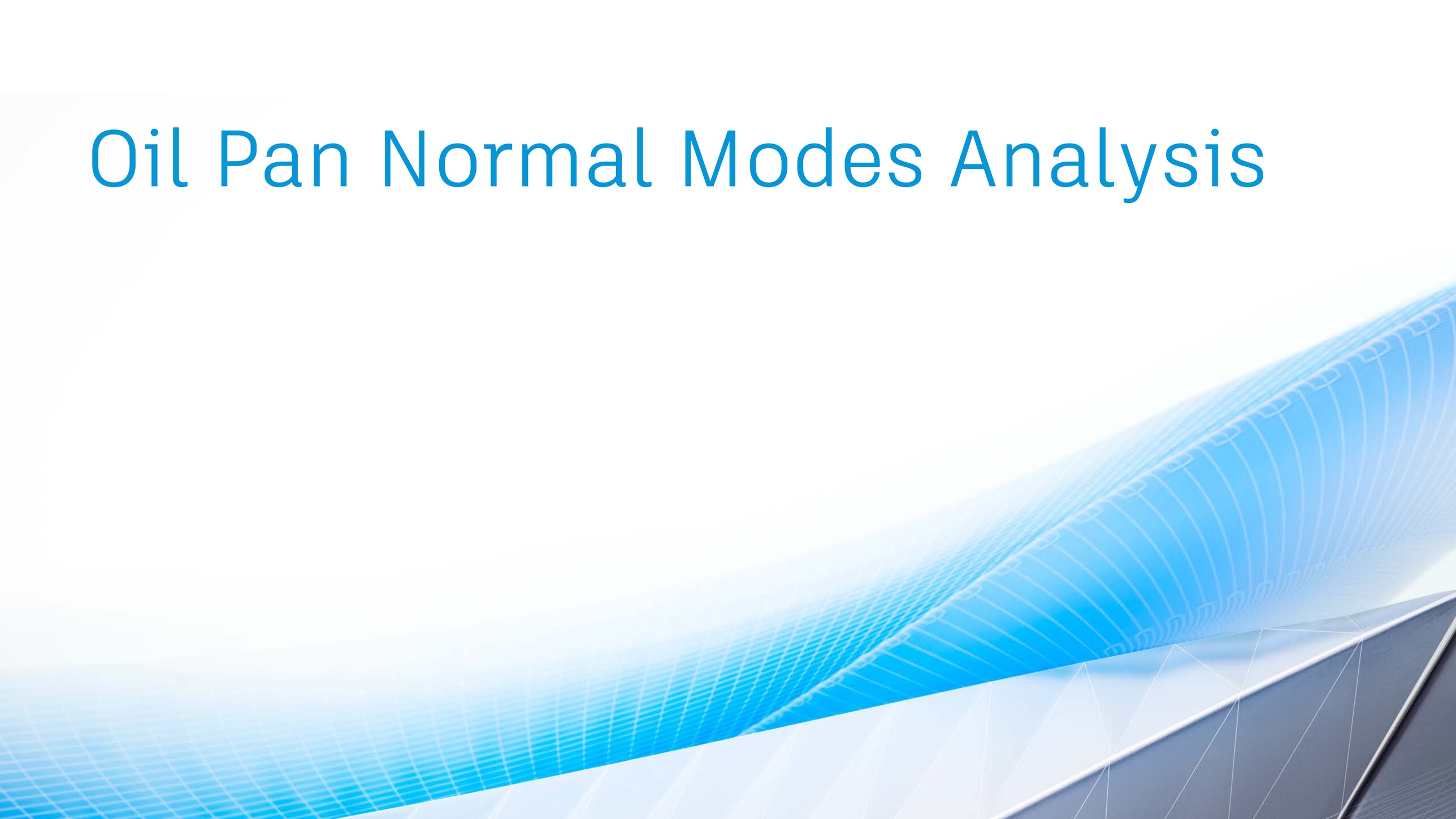
- In the theoretical approach we look for all the frequencies of a system that show a **perfect balance** between:
  - the internal stored energy
  - kinetic energy due to motion
- In the theoretical solution we don't need an external excitation!
- Normal Modes solution gives **shapes** not actual displacements



Don’t miss out the Modal Survey!

- Normal modes are the essential building block in Dynamics
- Preparation for response analyses
- Essential to understand the physics of these
  - Transient
  - Frequency Response
  - Random
  - Etc …

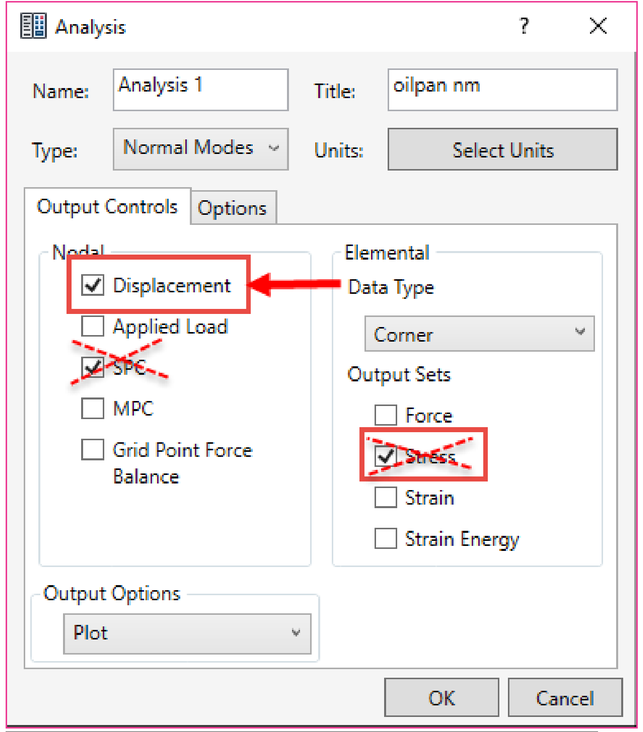
Oil Pan Normal Modes Analysis

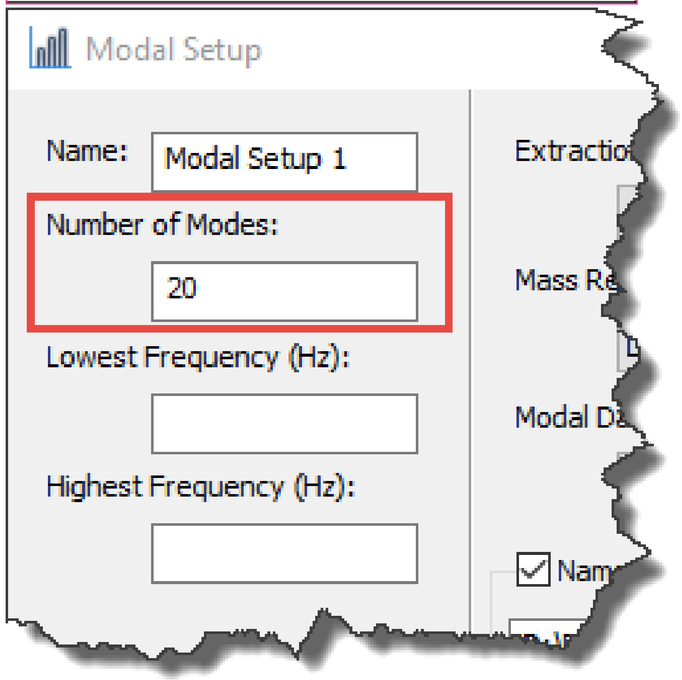


Hints and Tips

- Disable Stress and reaction force output – it is meaningless for Normal Modes analysis

- Control the number of modes you want (remember the modal survey)

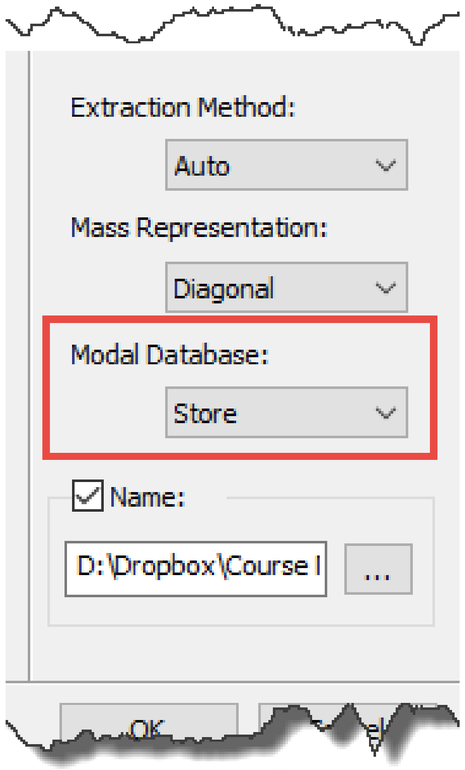


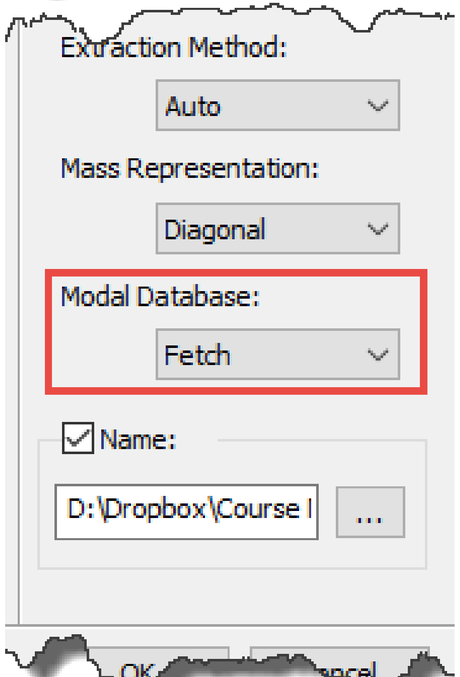


Hints and Tips

- **Store** the Modal Database – saves the eigen vectors

- You can then **fetch** the eigen vectors for a use in a Modal Response Analysis

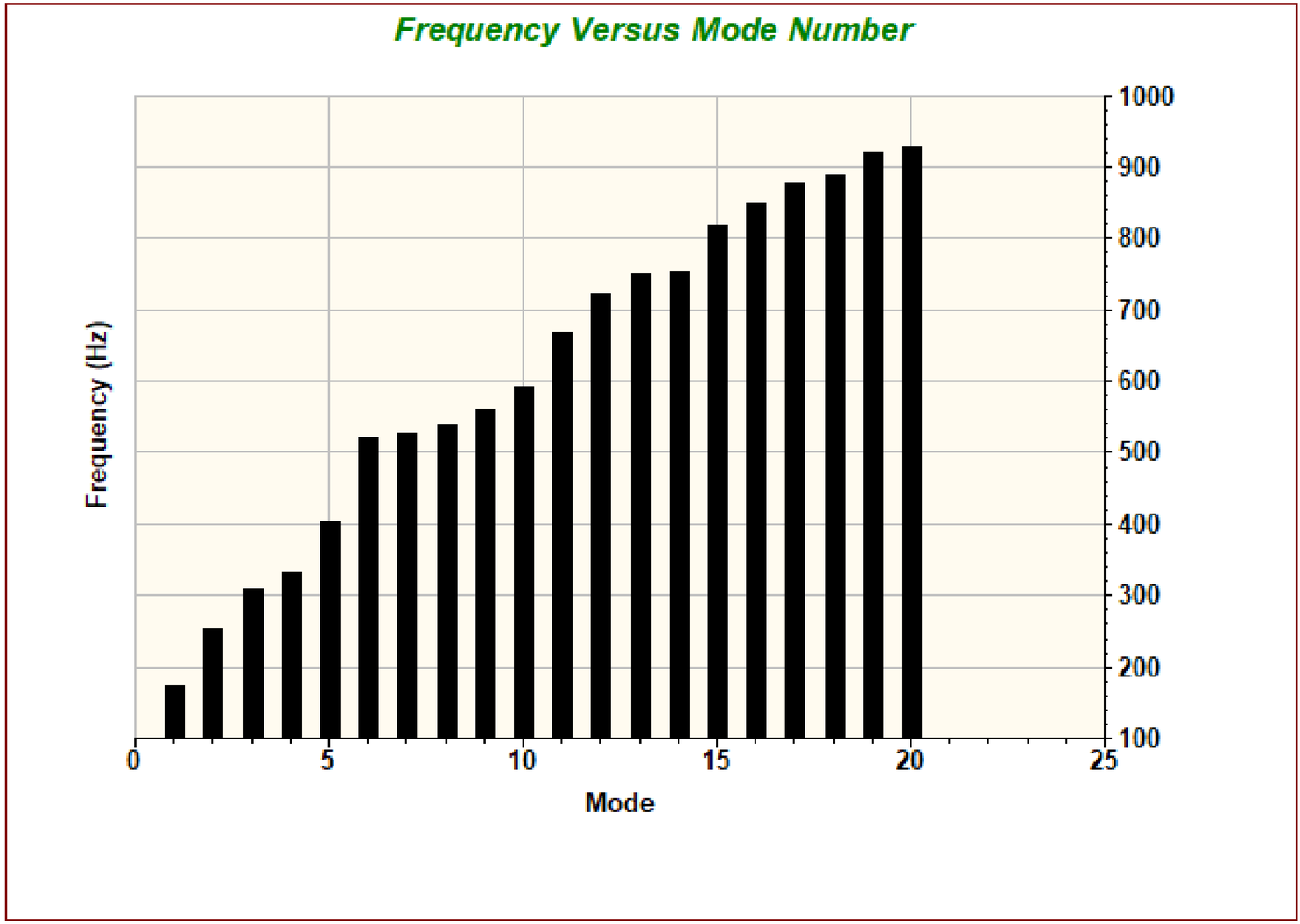




Oil Pan Normal Modes Analysis

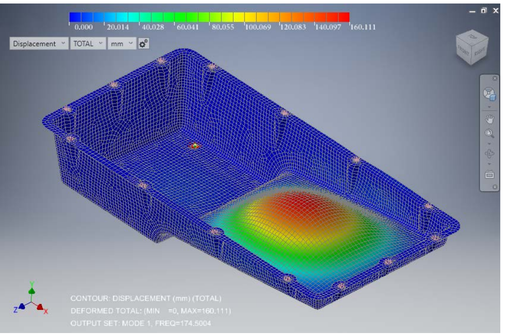
- Tabular Summary

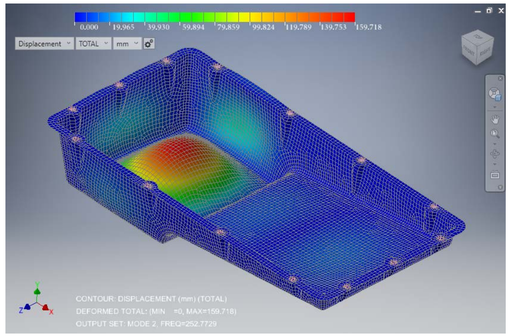
Mode	Frequency (Hz)
1	175
2	253
3	310
4	332
5	403
6	522
7	528
8	537
9	561
10	591
11	668
12	723
13	750
14	754
15	819
16	849
17	877
18	890
19	919
20	928

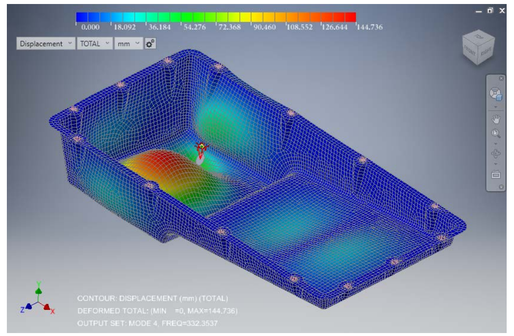


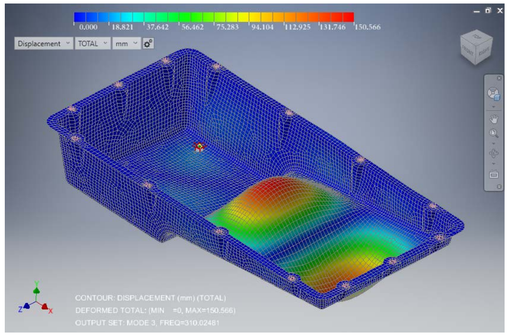
Oil Pan Normal Modes Analysis

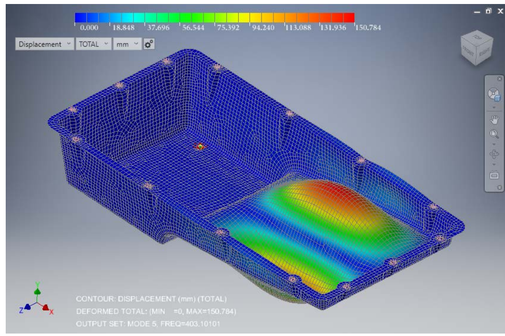
- Modes 1 to 5: 175 Hz to 403 Hz



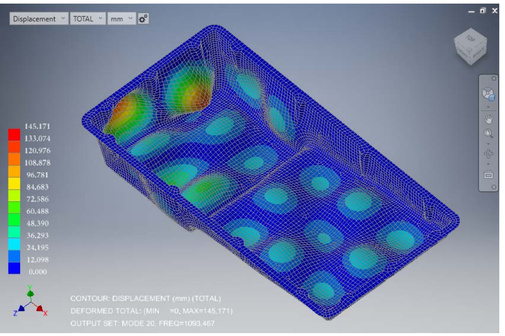








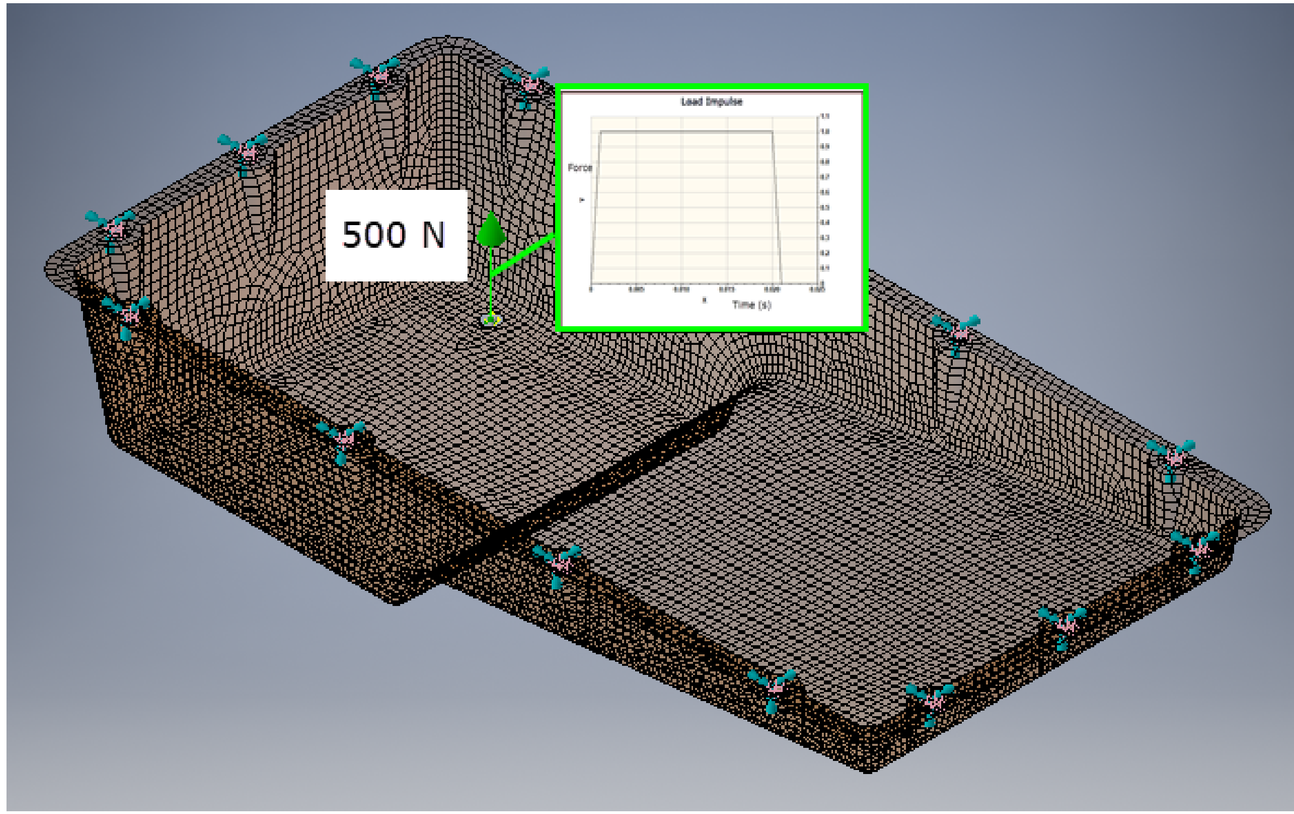
- Mode 20: 928 Hz



Transient Response Analysis

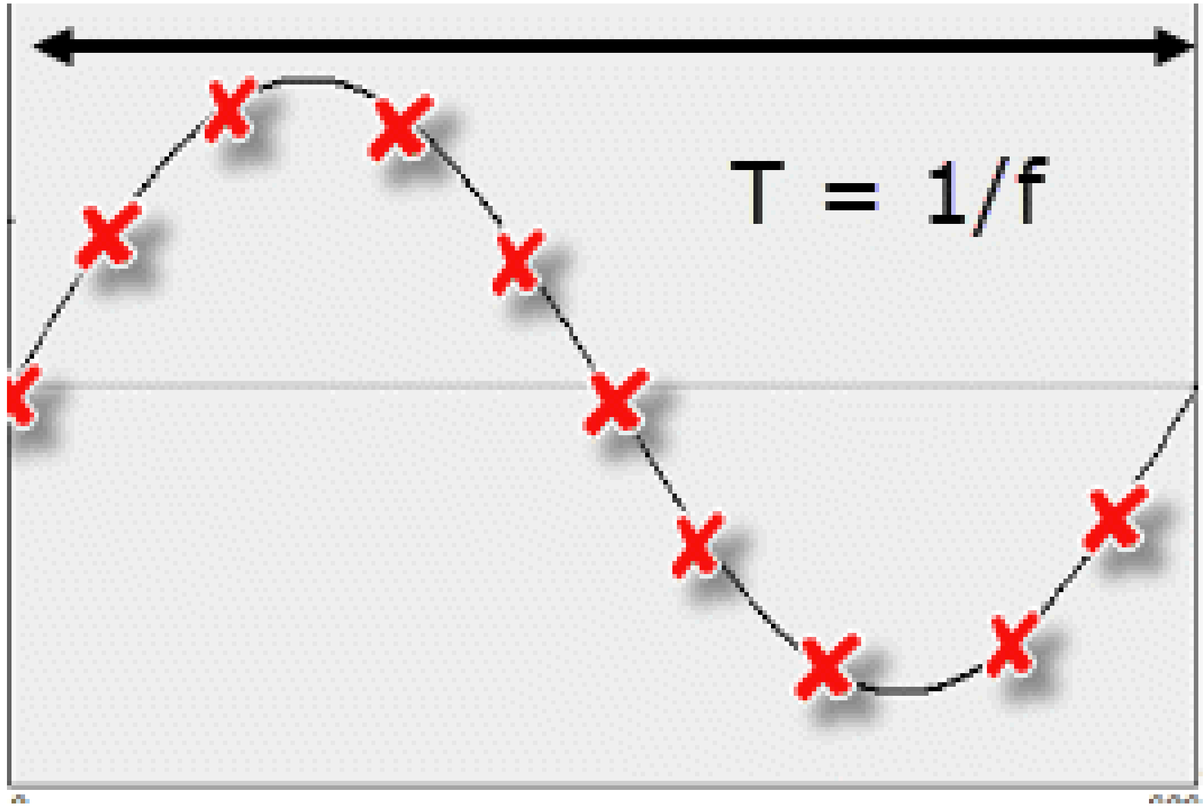
Transient Response

- Response through time
- Single event simulation
- Base driven:
  - impulsive loadings on a satellite during launch
  - earthquake response in a building
- External:
  - Impacts, strikes



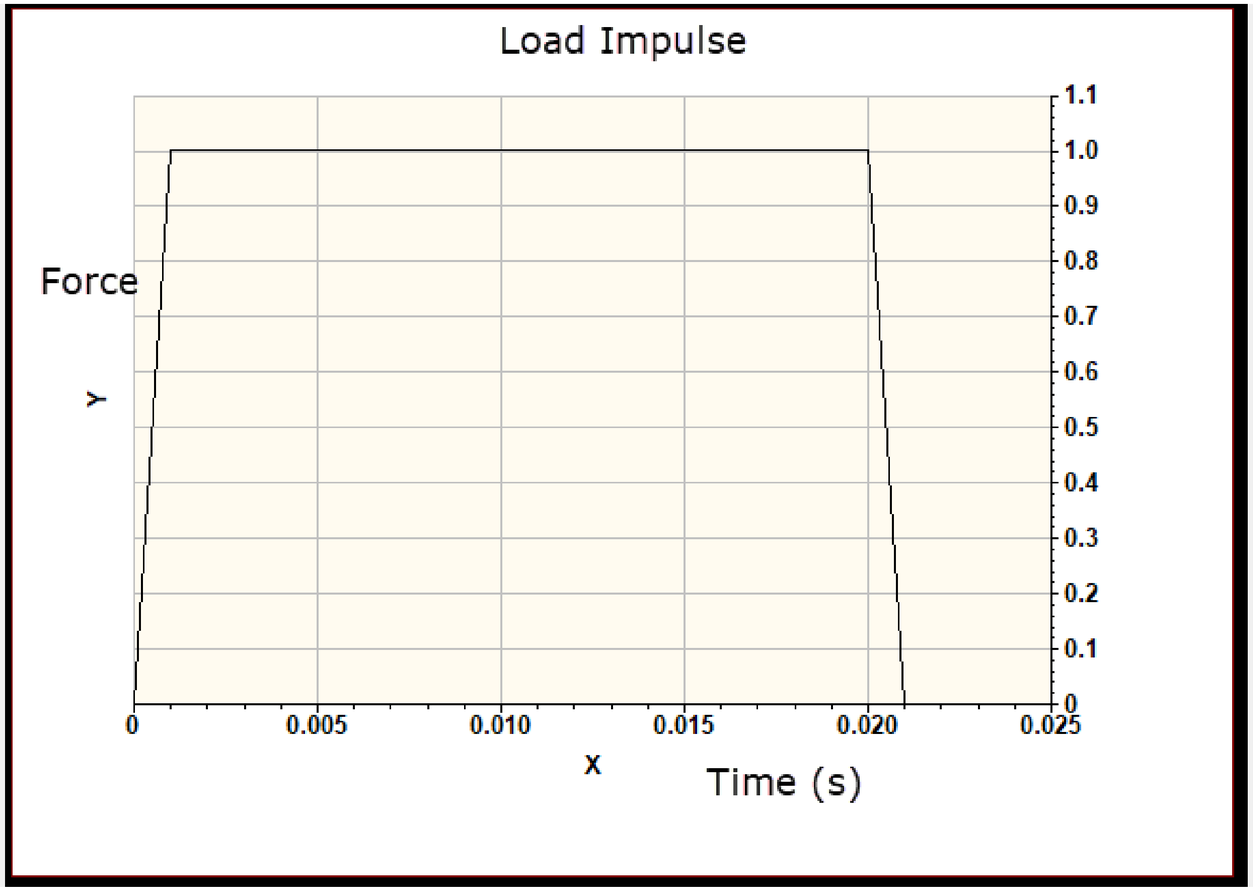
Transient Response – Time step estimation

- The time step should be small enough to capture the **highest frequency of interest** in the response.
- For example, if this is mode 10: 591 Hz, each time period is 0.00169s (1.69ms)
- Need at least 10 steps to capture the response, i.e. time step =0.000169 (0.169ms)



Transient Response – Time step estimation

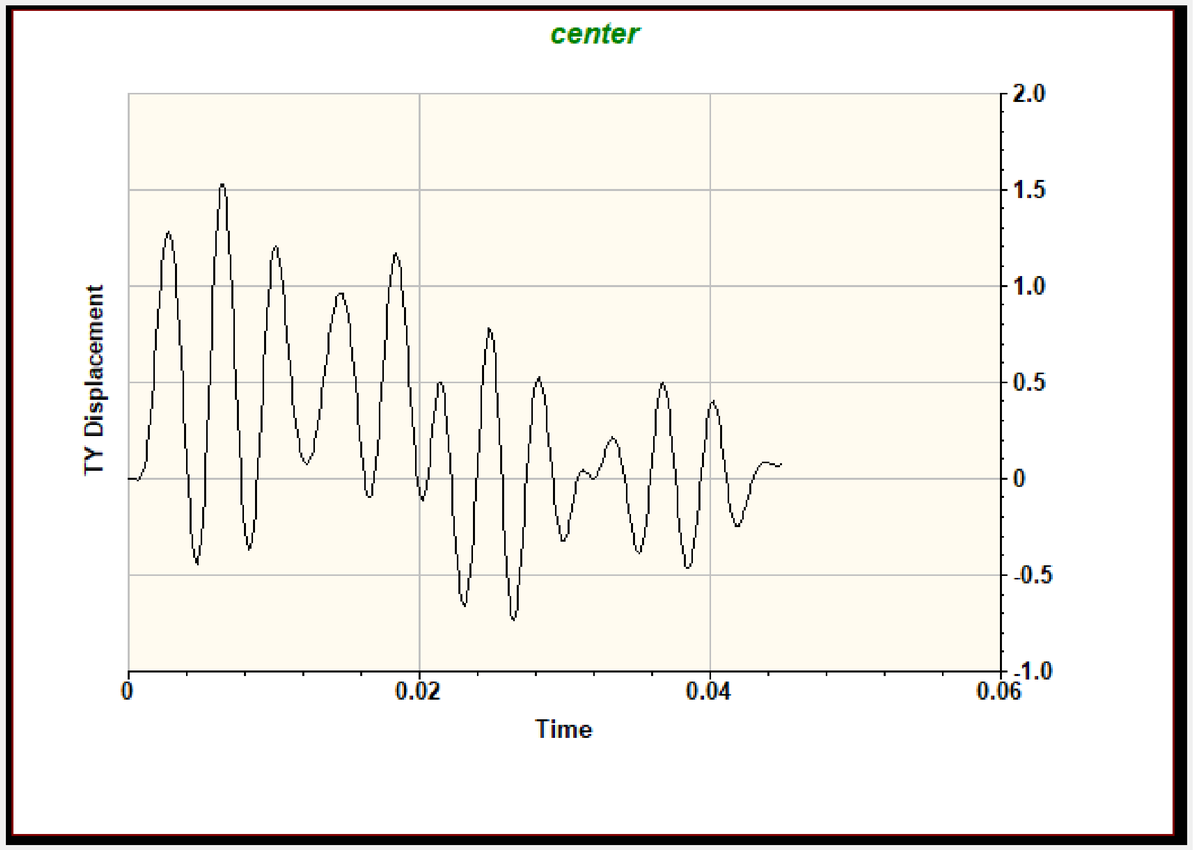
- **Load input** accuracy is also dependent on the time step chosen
- Loading is 0.021s (21ms)duration
- Need at a time step of at least 0.0021s (2.1ms)
- Ok – covered by highest frequency
- Loading **or** highest frequency of interest can dictate time step



Transient Response – Duration estimation

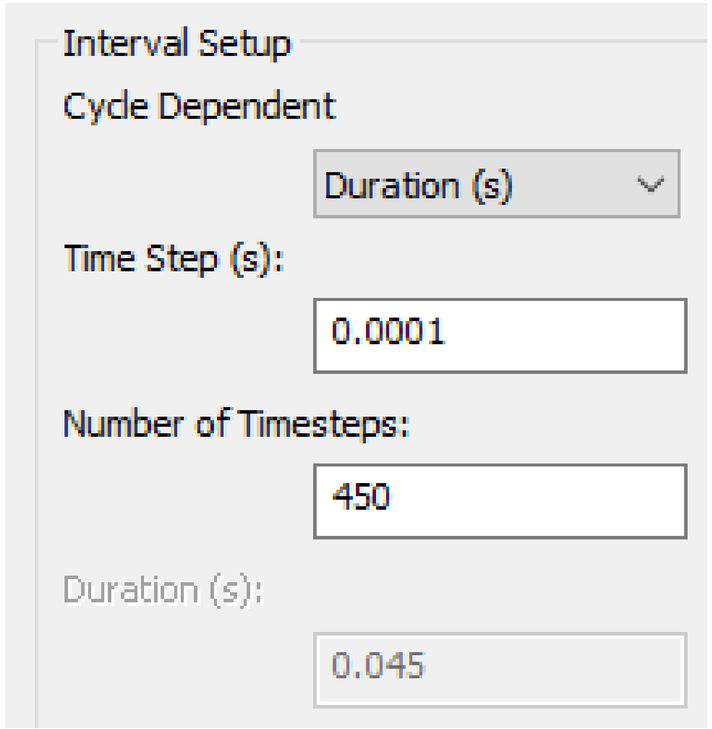
- Modes will combine creating peaks
- The number of time steps:
  - Enough to ensure all peak responses are captured
  - Response should be clearly decaying at the analysis cutoff point
  - No surprises at a later time!

- Typically 3 or 4 free cycles of the **lowest frequency** content should be allowed to occur
- The duration required can be calculated
- Lowest frequency is 174.5 Hz.
- T = 1/f = 0.00573 (5.73ms)
- Time for 4 cycles is 0.0229s (22.9ms)

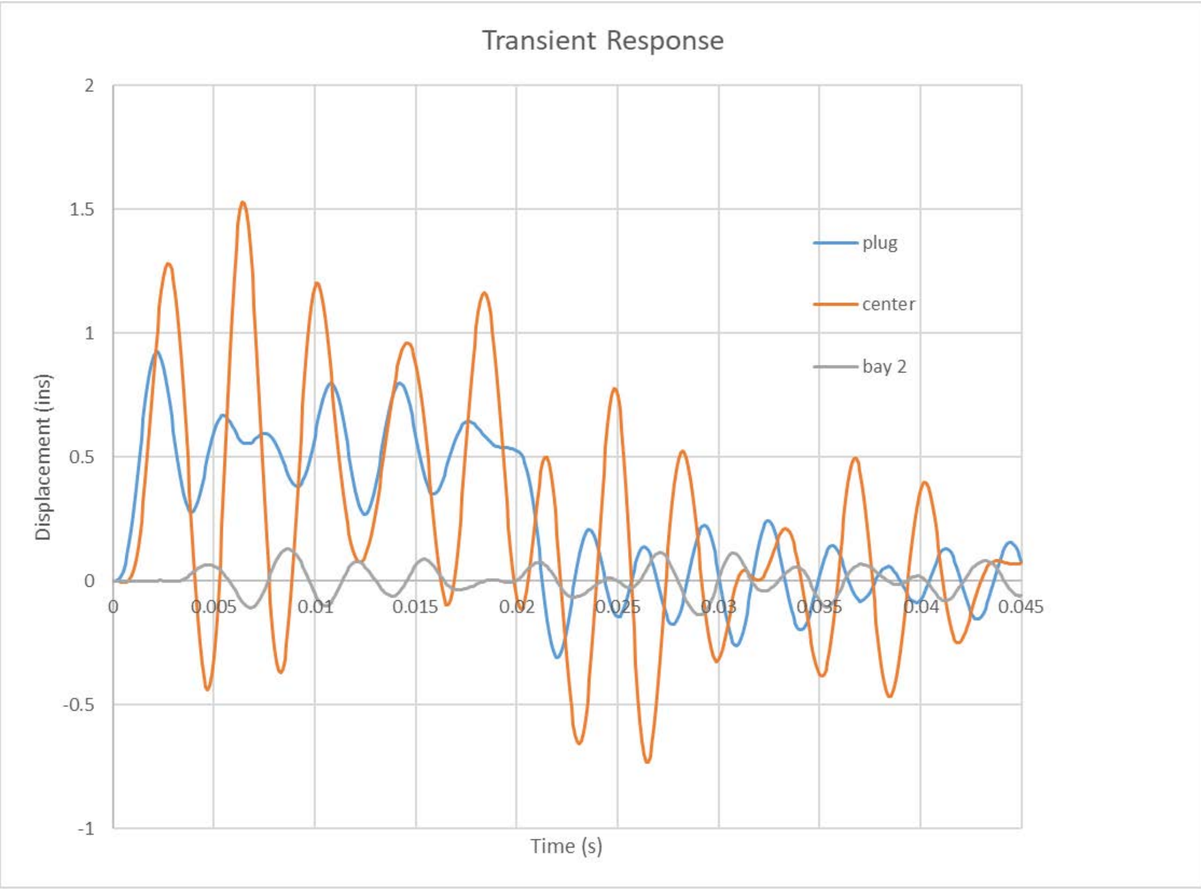


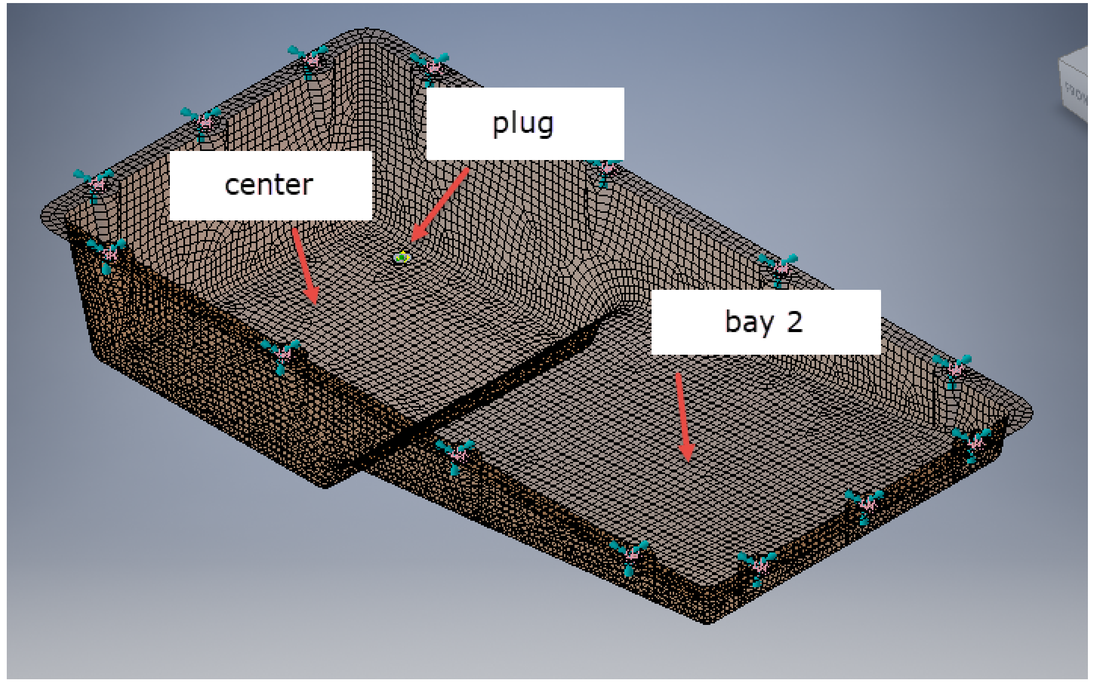
Transient Response – Duration estimation

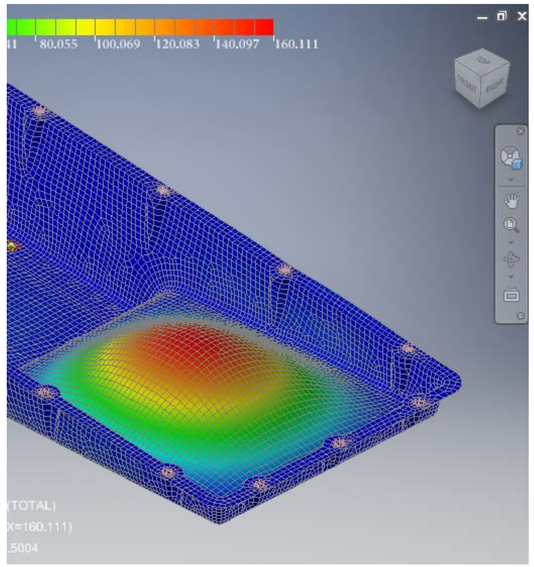
- Time step is 0.000169 (0.169ms)
- Time for 4 cycles at lowest frequency is 0.0229s (22.9ms)
- Add on load duration, 0.021s (21ms)
- Total duration = 0.0439s (43.9ms)
  - Rounding values:
  - Time Step .0001s (0.1ms)
  - Number = 450 (duration 0.0450s)

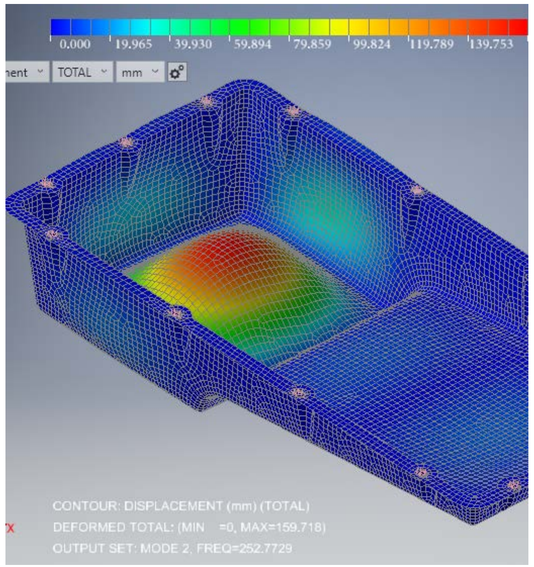


Oil Pan Demo


Transient Response
Displacement (ins)
Time (s)
plug
center
bay 2
2
1.5
1
0.5
0
-0.5
-1
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045


plug
center
bay 2


80.055
100.069
120.083
140.097
160.111


0.000
19.965
39.930
59.894
79.859
99.824
119.789
139.753
TOTAL
mm
CONTOUR: DISPLACEMENT (mm) (TOTAL)
DEFORMED TOTAL: (MIN =0, MAX=159.718)
OUTPUT SET: MODE 2, FREQ=252.7729

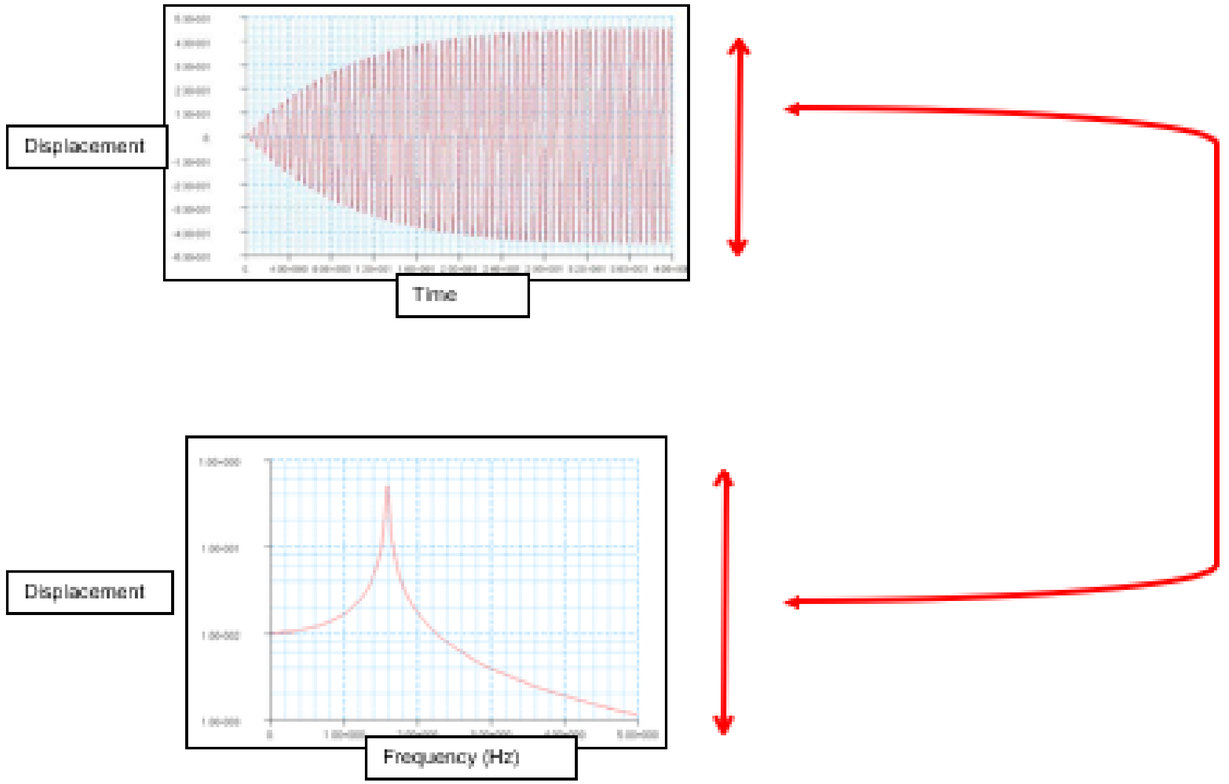
Frequency Response Analysis

Frequency Response

- An alternative is to vary the loading as a function of frequency
  - this can simulate a shaker table or exciter where we control the input frequency and investigate the response across a frequency range
  - Drive at many input frequencies
  - Measure response at each

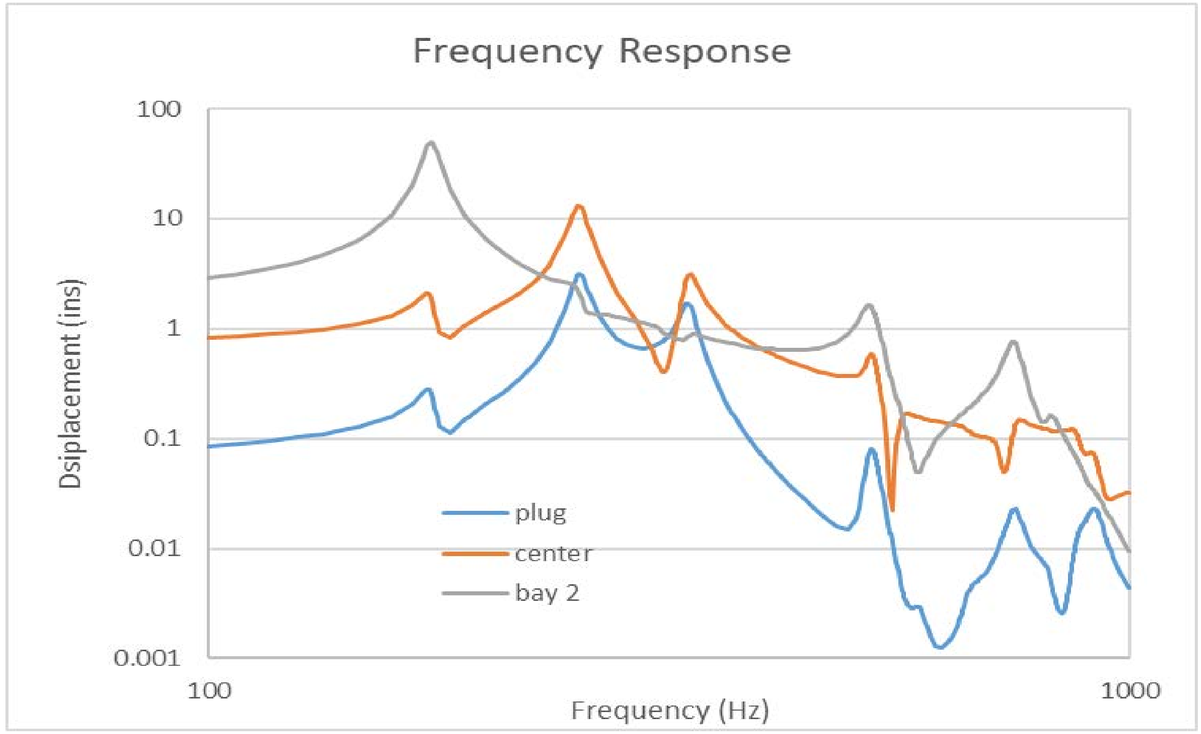
Frequency Response

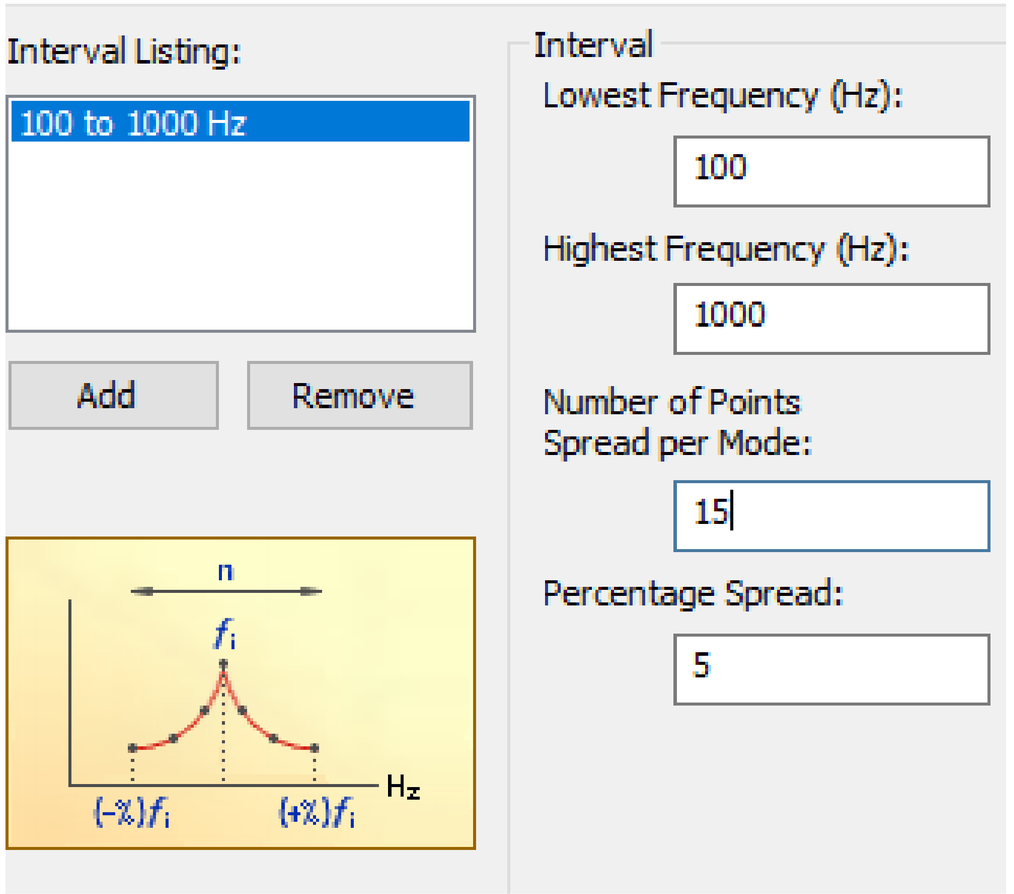
- We can do transient analyses at each frequency input….
- Or we can use a Frequency Response analysis
- The transitory response is ignored
- Focus on steady state peak responses



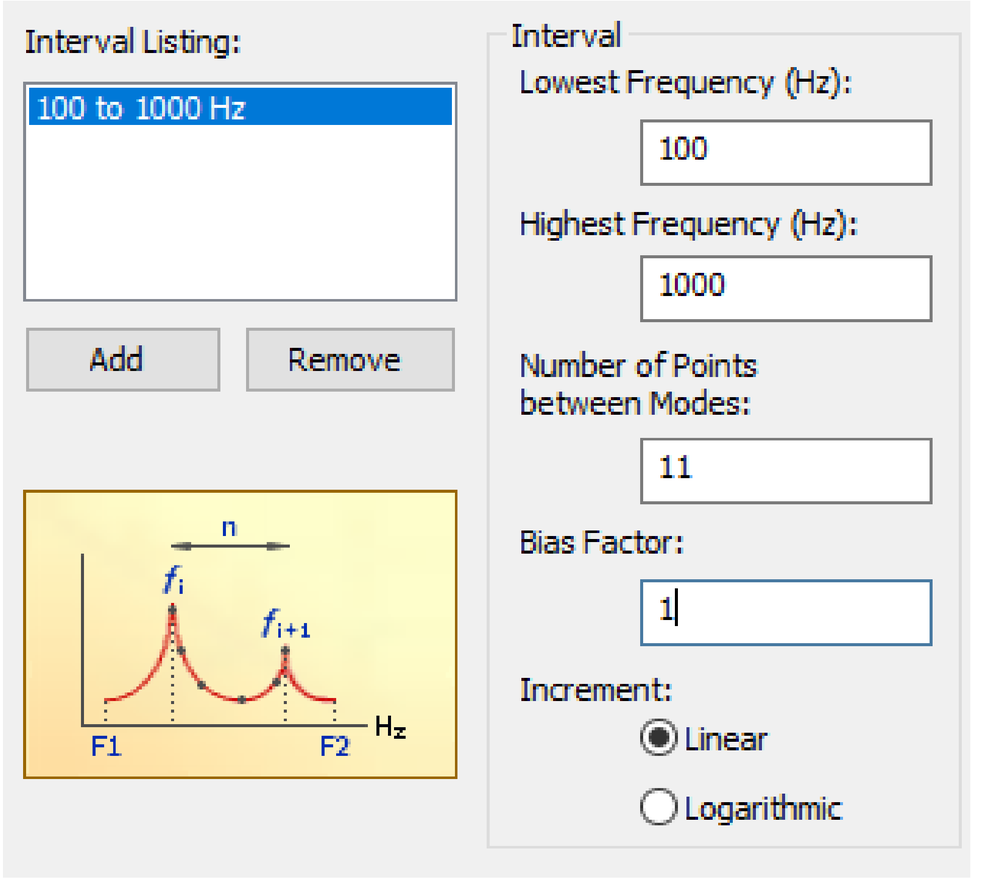
Frequency Response

- Frequency Response calculation points (sometimes called spectral lines):
- Must be at each natural frequency to ensure that the peak responses are captured
- Must be spread around each natural frequency to capture a good ‘shape’
- A general spread of points is required to capture the overall trend of the curve





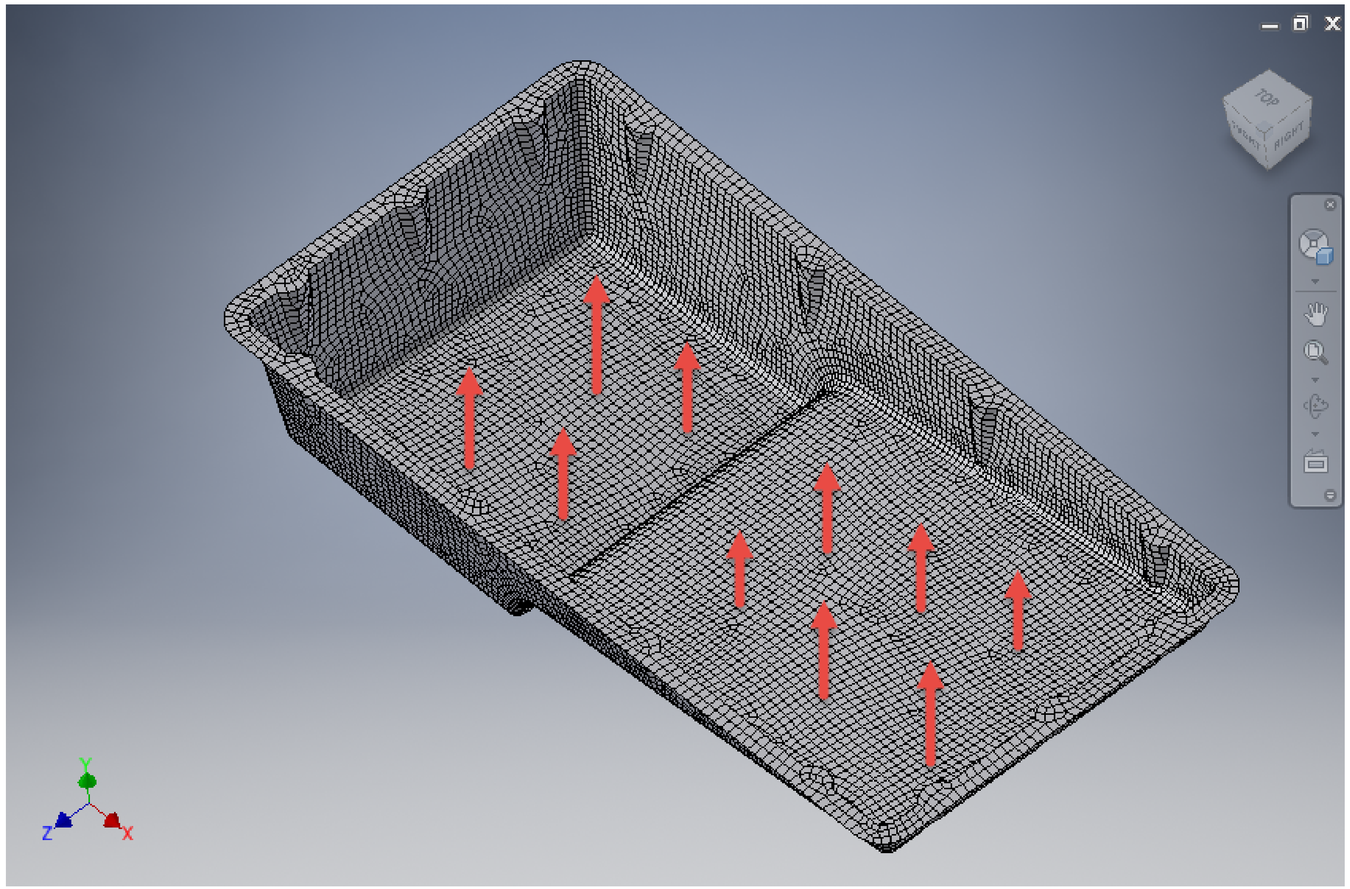
Capture the Peaks



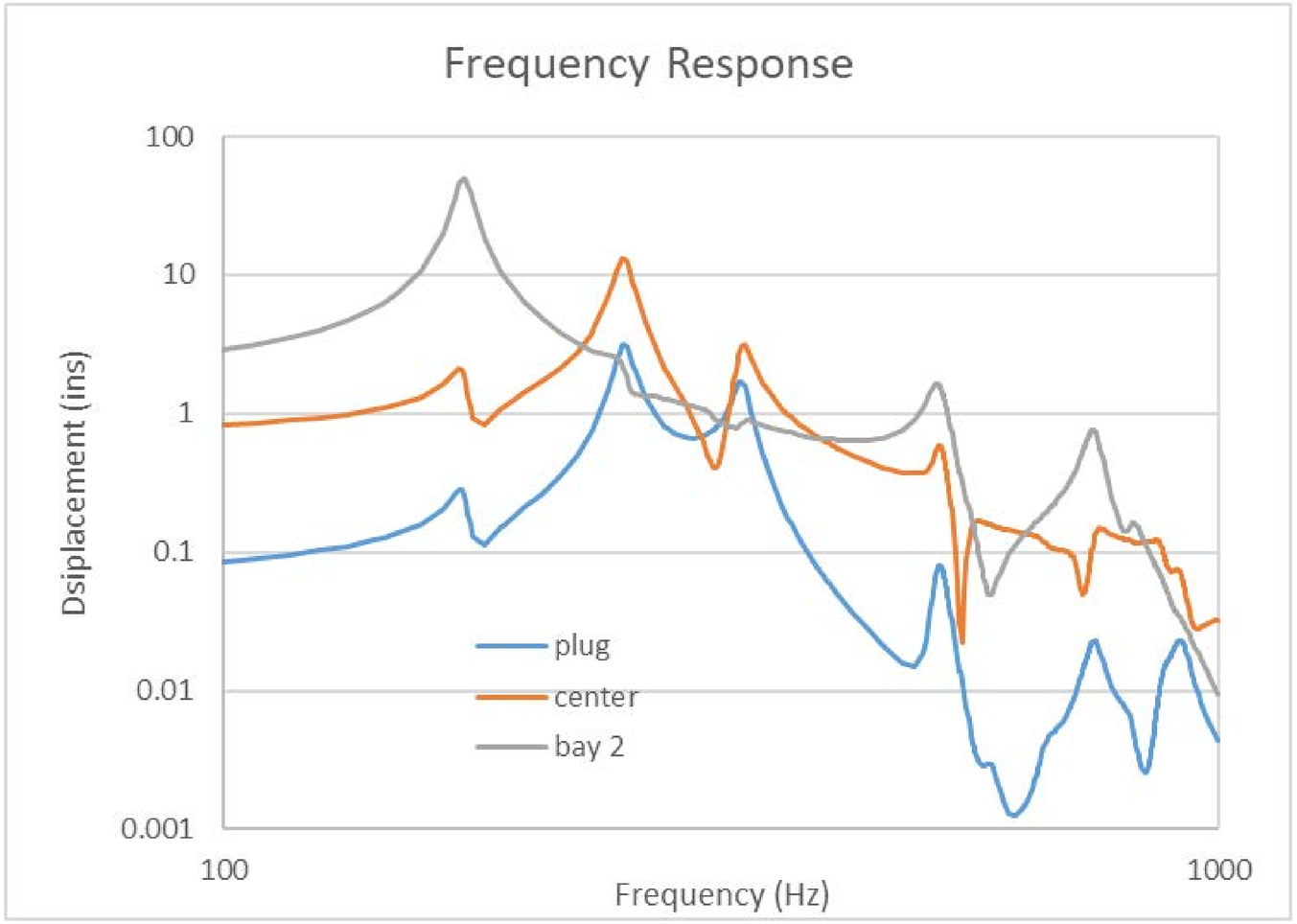
Fill in the Valleys

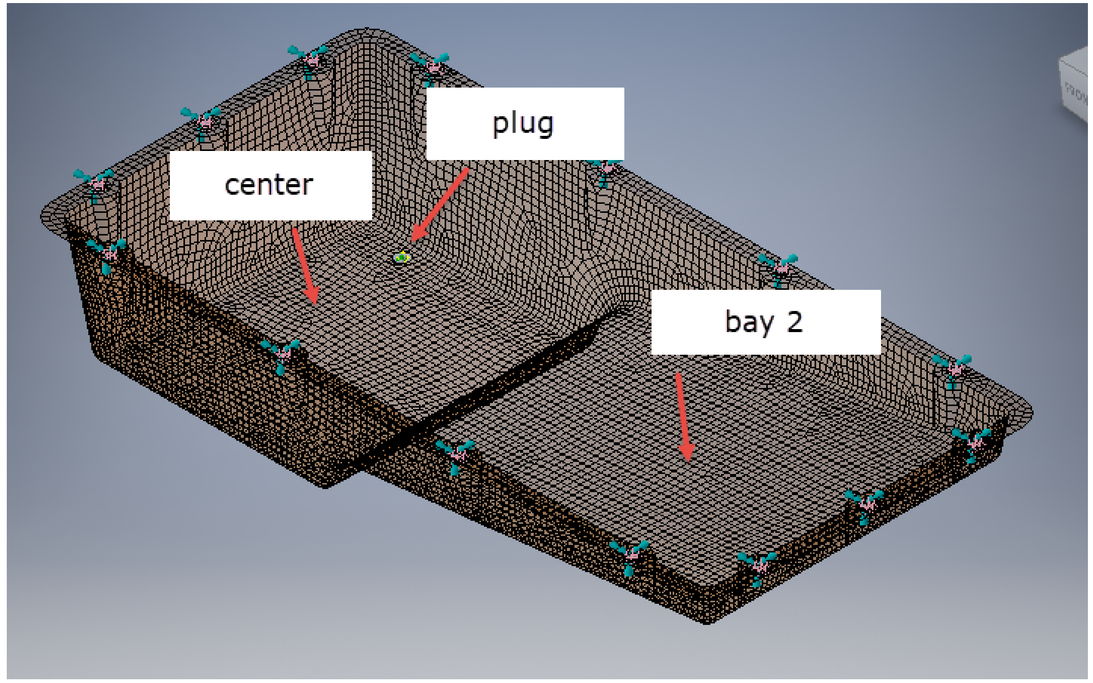
Frequency Response

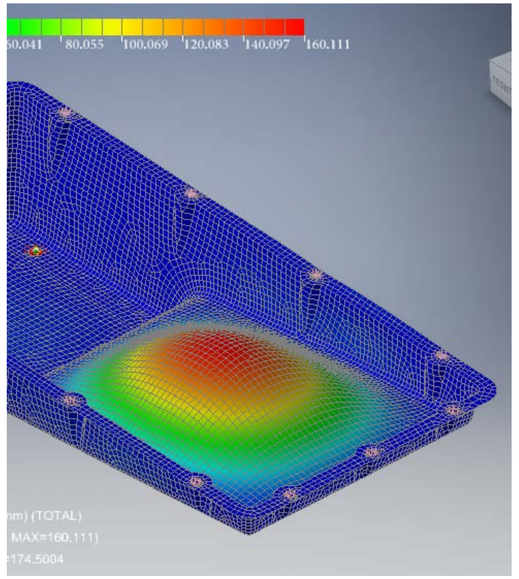
- Oil Pan Demo
- Constant Pressure Under Pan
- Varies Across Frequency Range

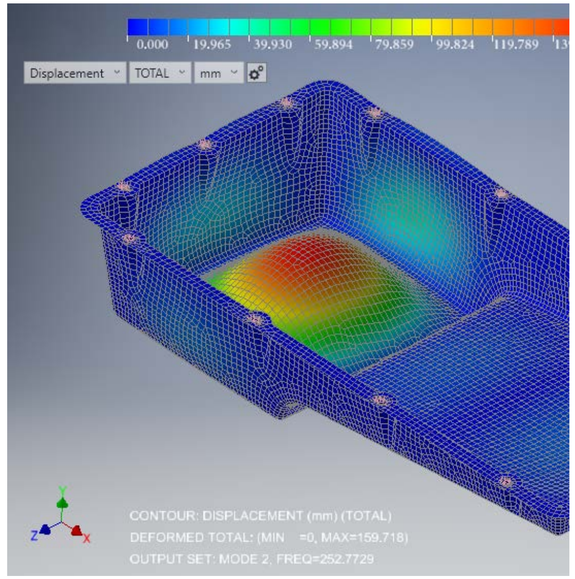


Oil Pan Demo


Frequency Response
100
10
1
0.1
0.01
0.001
Dsiplacement (ins)
plug
center
bay 2
100
1000
Frequency (Hz)


plug
center
bay 2


60.041
80.055
100.069
120.083
140.097
160.111


0.000
19.965
39.930
59.894
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99.824
119.789
Displacement
TOTAL
mm
CONTOUR: DISPLACEMENT (mm) (TOTAL)
DEFORMED TOTAL: (MIN =0, MAX=159.718)
OUTPUT SET: MODE 2, FREQ=252.7729

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