VIBRATION RESEARCH

VIBRATION TESTING
SINE VS RANDOM

THE INNOVATOR IN
SOUND & VIBRATION TECHNOLOGY

CORE VALUES

COLLABORATION

CAPABLE & COMPETENT

ACCOUNTABLE & RESPONSIBLE

STRONG & DRIVEN WORK ETHIC

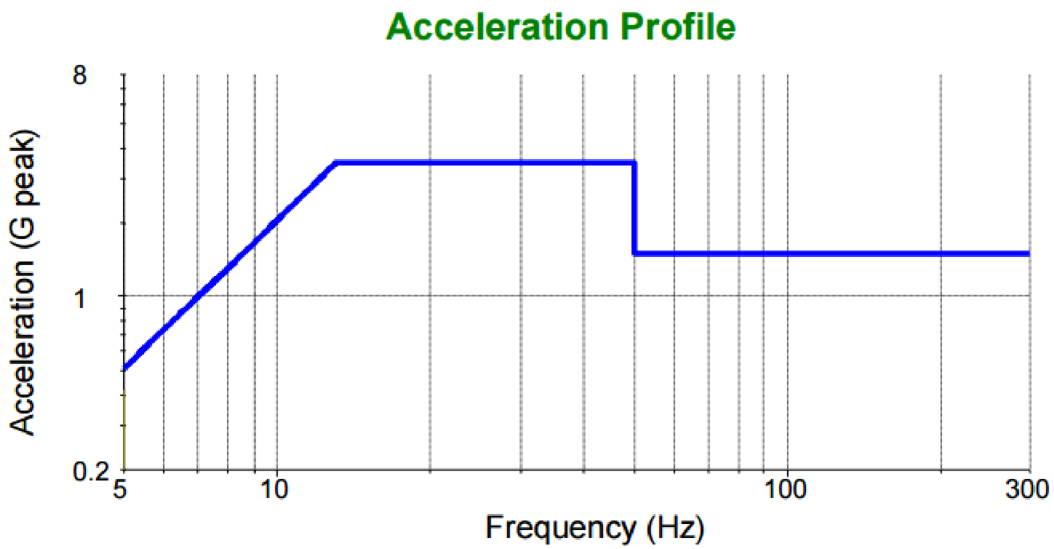
DO THE RIGHT THING

INNOVATION

WHICH TEST SHOULD I RUN?

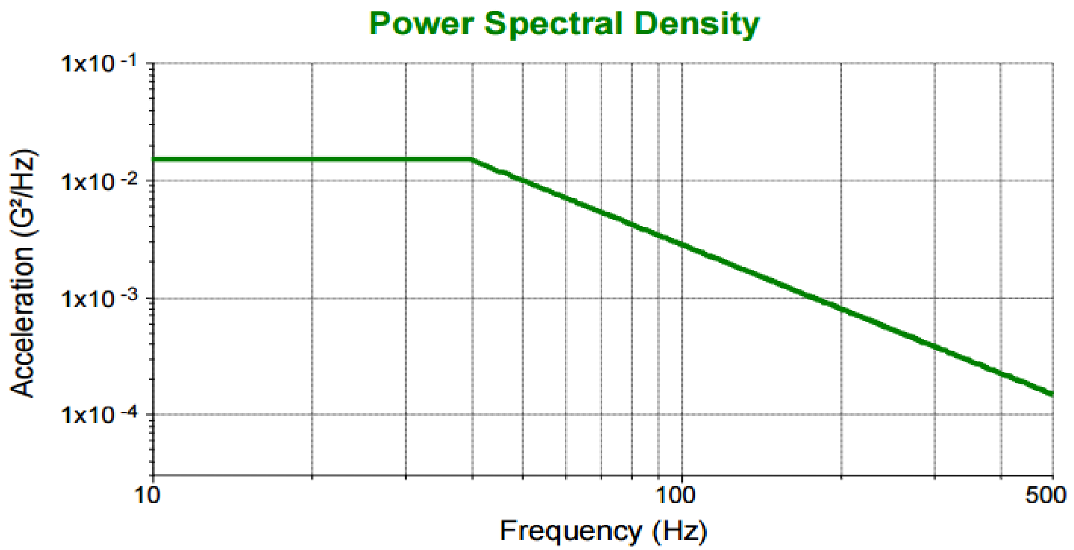
SINE TEST

- 3.5 G from 5Hz to 50Hz
- 1.5 G from 50Hz to 300 Hz
- Limit to 0.4in double amplitude
- Test all axes to same level



RANDOM TEST

- 0.015 G^2/Hz from 10 Hz to 40 Hz
- 0.015 G^2/Hz at 40Hz to 0.00015 G^2/Hz at 500Hz
- Test all axes to same level



COMPARING ACCELERATION

- Sine vibration is measured in Gpk
- Random vibration is measured in GRMS
- For random Gaussian vibration
  - Gpk ≈ 4 x GRMS
  - Gpk for the Random test is approximately 4.3Gpk

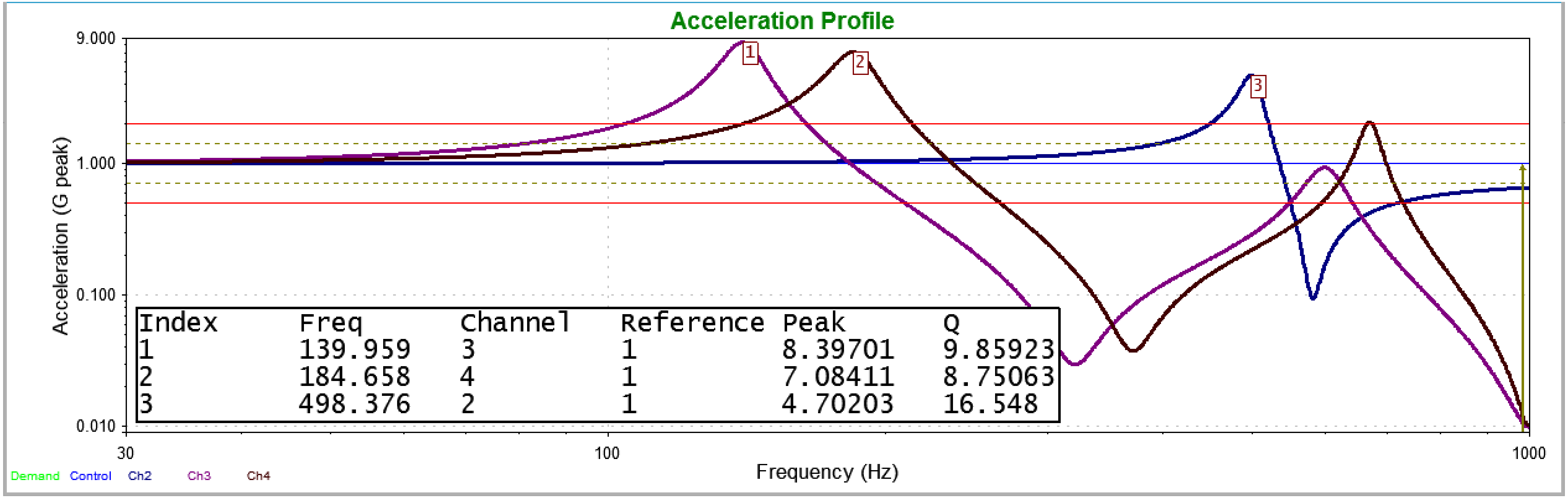
Does this make the Random test more damaging?

ASSUMPTIONS

- Failures due to vibration are caused at the peak G level seen by the product
- Most products have resonances at one or more frequencies
- At resonance, the vibration levels applied to the product are amplified by the Q factor of the resonance

ACCELERATION AT RESONANCES

For Sine: $A_{product,sine} = Q \times A_{control,sine}$



FOR RANDOM

- Not all vibration is amplified by a resonance at any given point in time
- IF Q > 5 the resonance acts as a band-pass filter with amplification = to Q and BW = Δf
  - $Q = f_n / \Delta f$
  - f_n = resonant frequency
  - Δf = ½ power bandwidth of resonance
- For a given RMS level, the PSD level is inversely proportional to the full BW of the random spectrum. A more concentrated random vibration will have a higher PSD Value
  - $PSD_{Control} = A_{control,rms}^2 / \Delta f$ *
  - Δf = full BW of random PSD

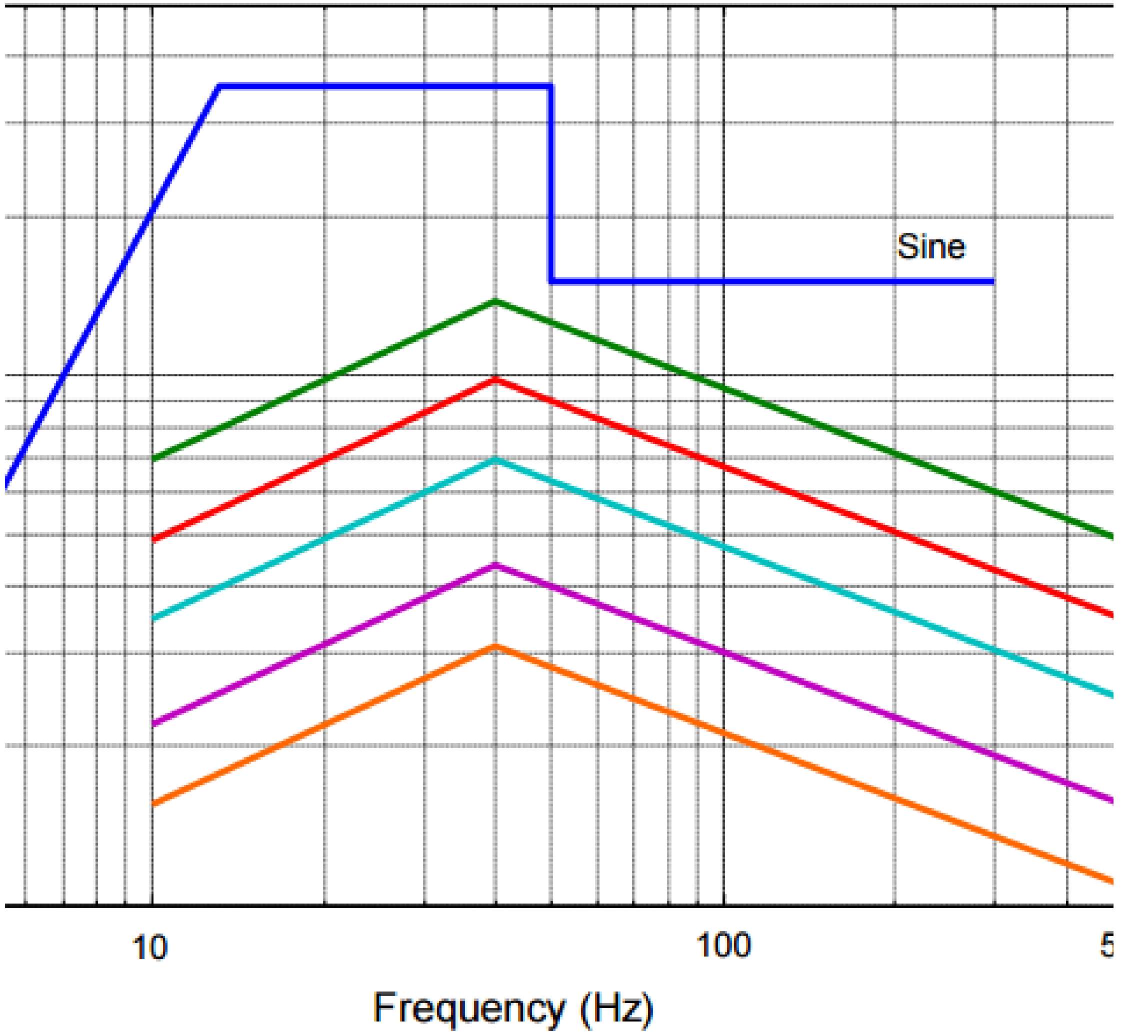
    *Applies to flat random spectrum only

FOR RANDOM (CONTINUED)

- Random tests are defined in terms of a PSD, an amplitude-squared measure, so at the resonant frequency the PSD will be amplified by Q^2
- Since the resonance acts as a band-pass filter we can approximate vibration levels by calculating just the energy at the resonant frequency that passes through and is amplified by the resonance (assuming 4 sigma peaks)
  - $A_{product,peak} = 4 \times A_{product,rms}$
    $= 4 \times [PSD_{product} \times \Delta f]^{1/2}$
    $= 4 \times [Q^2 \times PSD_{control} \times \Delta f]^{1/2}$
    $= 4 \times [PSD_{control} \times Q \times \Delta f]$
- Note 2 Key features of the peak amplitude for a random test:
  - A_{pk} is proportional to only the square root of Q. A high-Q resonance will result in a more severe test in Sine than it will in random, if all other parameters are equal
  - A_{pk} is proportional to the square root of the resonant frequency, fn, so the higher the resonant frequency, the higher the peak values in the output

COMPARISON

- It is possible to compare the peak vibration levels on the product for both sine and random by comparing the equations
  - $A_{product,sine} = A_{product,peak,random}$
  - Depending on Q Value the resultant will vary, but in this case the sine test is more severe than the random.



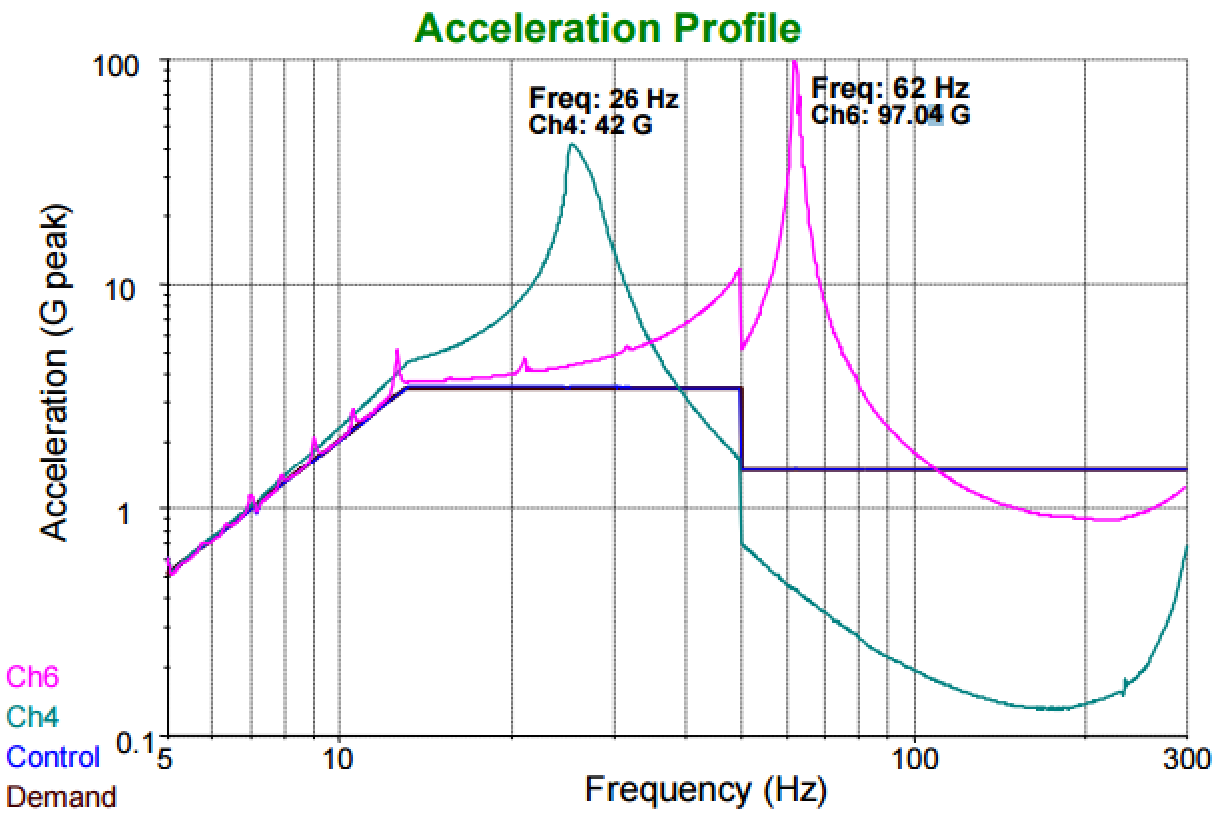
REAL WORLD PROOF

Test Setup

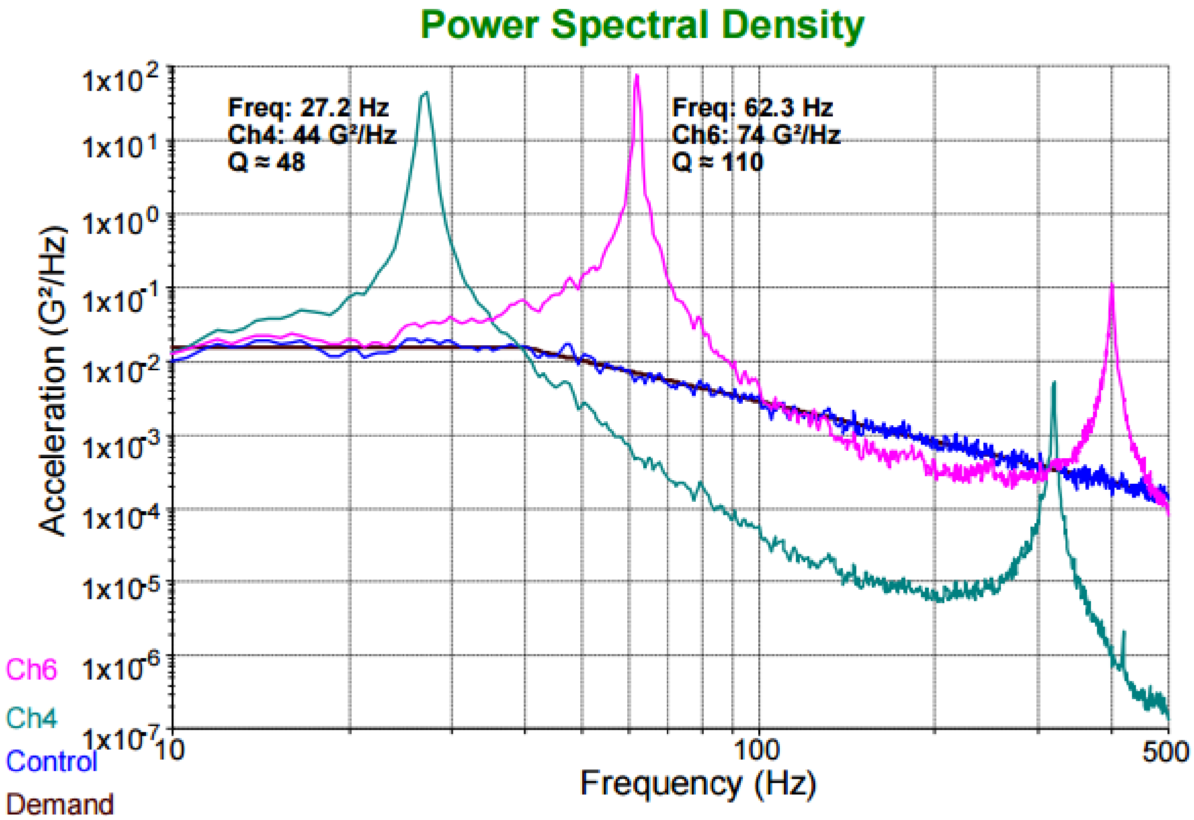
- Mounted 2 elements with different resonant frequencies on a slip plate
- Configured a random test and a sine test based on specifications
- Elements were aluminum masses attached by threaded rods of different length and thickness
- Accelerometers mounted on each mass at the top of the rod.
- Observe G Levels at the control point
    - Expected Levels:
        - Sine: $3.5G_{pk}$
        - Random: $4.2\ G_{pk}$

TEST RESULTS

SINE TEST



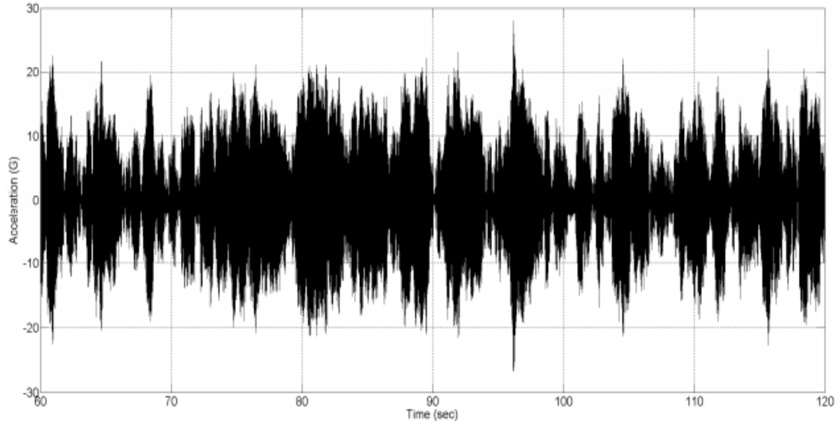
RANDOM TEST



EVALUATING THE RANDOM TIME HISTORY

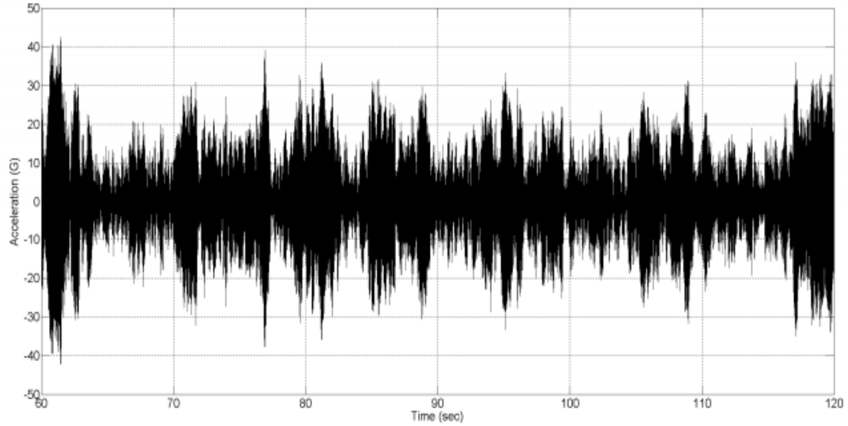
Element 1:

- Q ≈ 140; Resonant Frequency ≈ 27 Hz
- Calculated Peak Acceleration:
  - $A_{product,peak} = 4 \times [PSD_{control} \times Q \times f_n]^{1/2}$
  - $A_{product,peak} = 4 \times [0.015\ G^2/Hz \times 140 \times 27Hz]^{1/2} = \mathbf{30G_{pk}}$
- Actual Peak Acceleration: **$28G_{pk}$**



Element 2:

- Q ≈ 200; Resonant Frequency ≈ 62 Hz
- Calculated Peak Acceleration:
  - $A_{product,peak} = 4 \times [PSD_{control} \times Q \times f_n]^{1/2}$
  - $A_{product,peak} = 4 \times [0.00673\ G^2/Hz \times 200 \times 62Hz]^{1/2} = \mathbf{37G_{pk}}$
- Actual Peak Acceleration: **$40G_{pk}$**



RESULTS

	Q	Sine (G_{pk})	Random (G_{rms})	Random (G_{pk})	Predicted (G_{pk})
Control Point		3.5 G_{pk}	1.05 G_{rms}	4.8 G_{pk}	4.2 G_{pk}
27 Hz Resonance	140	42 G_{pk}	8.35 G_{rms}	28 G_{pk}	30 G_{pk}
62 Hz Resonance	200	97 G_{pk}	10.9 G_{rms}	42 G_{pk}	37 G_{pk}

Observations:

- At the **control** point, the **random test** has higher peak G levels than the sine test
- At the **resonant** points, the **sine test** has higher peak G levels than the random test.
- **From the products perspective the sine test is more severe!**

CONCLUSIONS

- The relative severity of a sine test and a random test will vary depending on the product’s resonant frequencies and Qs.
- In general, when sine and random tests have the same peak vibration levels at the control point, the product will see higher vibration levels with the sine test than with random due to the resonances of the product
- HOWEVER, you must also consider that a sine test only excites a single resonance at a time, so the sine test will not test the interaction between the two resonances in the product. Random excites the full frequency range and can be used to find problems resulting from the interaction between two resonances.

VIBRATION RESEARCH

ANY QUESTIONS?

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