Using Impact Testing for Production Quality Control

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Stiffness of Mechanical Structures

- *Modal frequency* is the *most sensitive parameter* to stiffness changes in a mechanical structure
- If *stiffness increases* anywhere on a structure, *some modal frequencies* will also *increase*
- If *stiffness decreases* anywhere on a structure, *some modal frequencies* will also *decrease*
- *Modal frequency* is the *easiest parameter to estimate* from experimental data

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Three-Step Process for Pass-Fail Testing

1. *Impact the test article* and calculate *one or more FRFs* from the force & response sensors
2. *Curve fit* the FRFs to estimate the modal frequency of several modes, and *store* the *modal frequencies* as *components of a "shape"*
3. *Numerically compare* the *current "shape"* with one or more *archived shapes*

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Sensitivity of Modal Frequency to Stiffness Changes

- **How much each modal frequency changes with a stiffness change depends on,**
  1. **Its *mode shape***
  2. ***Where* the structure is *impacted***
  3. ***Where* the structural *response is measured***
- ***Lower frequency* modes have *"global"* mode shapes, and are *less sensitive* to stiffness changes**
- ***Higher frequency* modes may have *"local"* mode shapes, and are *more sensitive* to stiffness changes**

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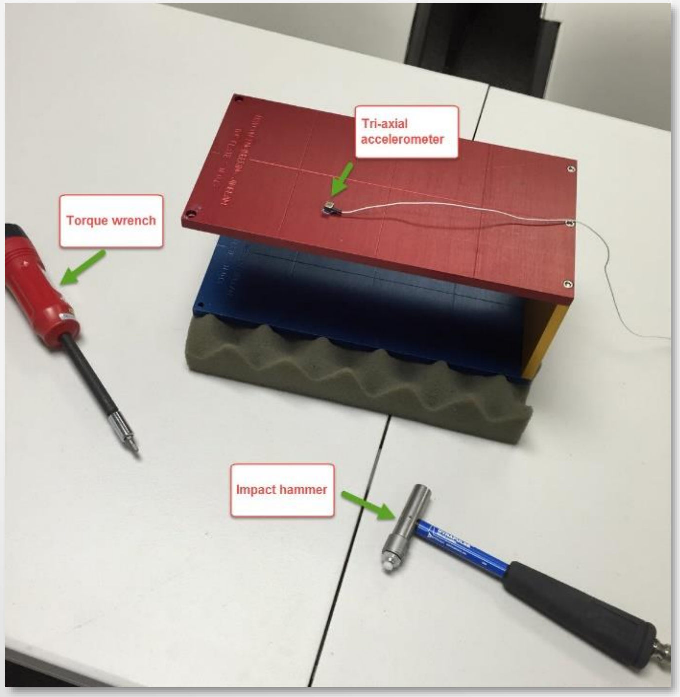
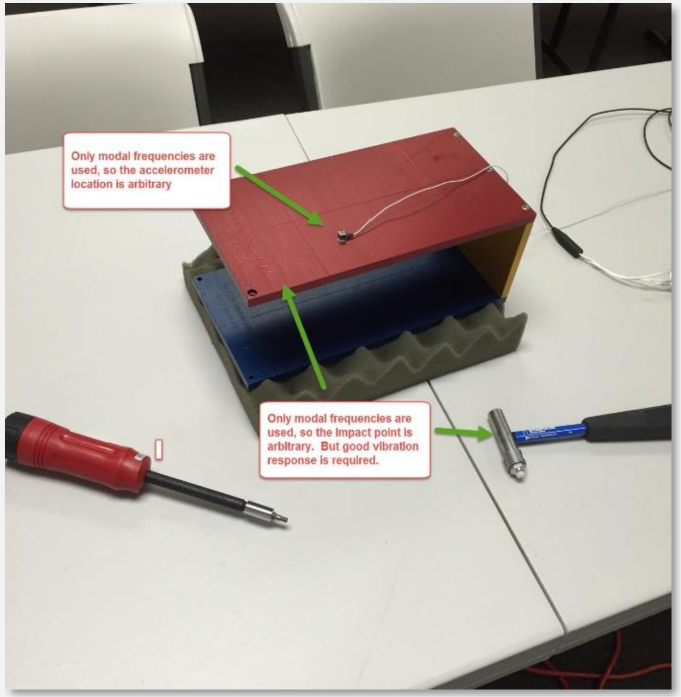
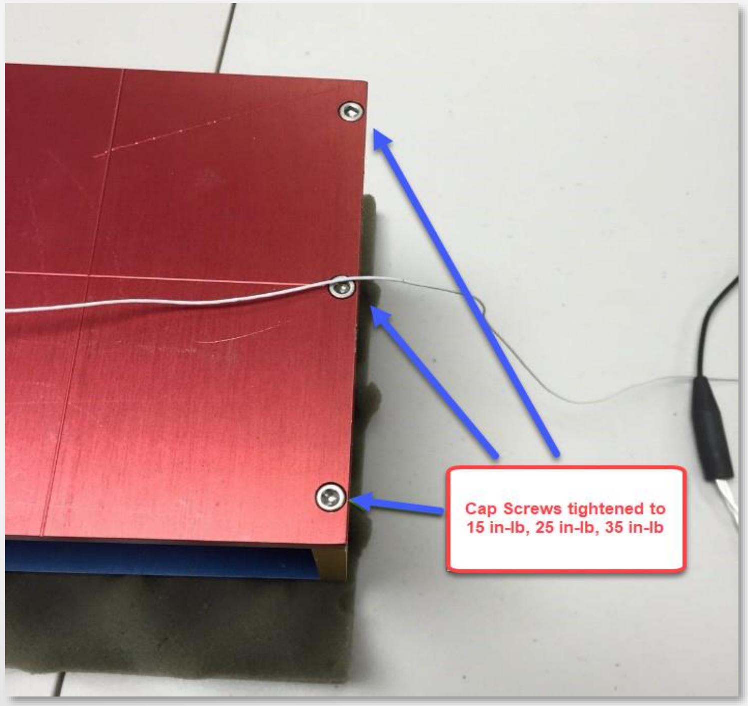
Jim Beam Test Article

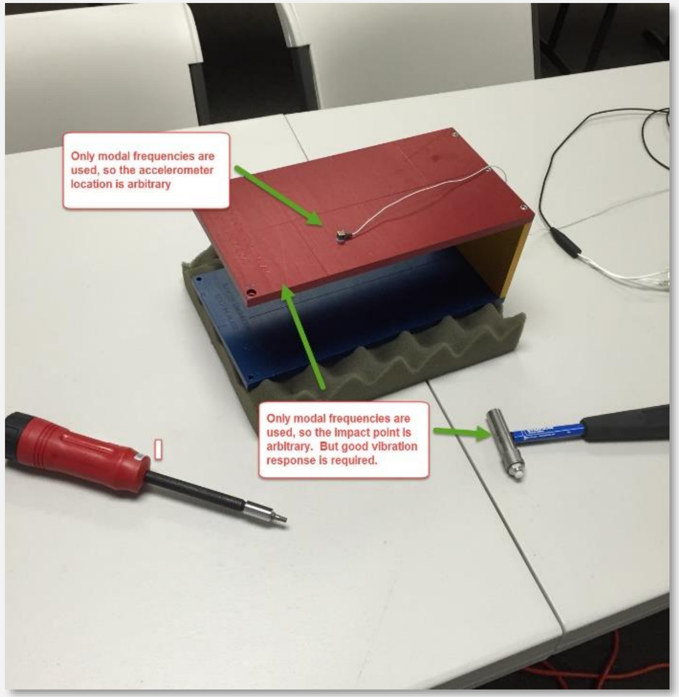




The Jim Beam was impacted on the top plate and its acceleration response was measured with a tri-axial accelerometer

Torque Applied to Three Cap Screws





Three different torque values were applied to each screw; 15 in-lbs, 25 in-lbs, 35 in-lbs

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27 Torque Cases

- Three different torques were applied to each screw; *15, 25, & 35 in-lbs*
- Three different torques applied to each screw gave a total of *27 different torque cases*
- For *each torque case*, the structure was impacted and *three FRFs were calculated* between the impact force & the responses of the tri-axial accelerometer
- A *total of 81 FRFs* were calculated from the impact & response data for the *27 different torque cases*
- Three FRFs were curve fit and *six modal frequencies* were *archived as "shapes"* in a database for *each torque case*

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Pass-Fail Test

1. *Impact the top plate* and *acquire* the *force* & *three responses* of the tri-axial accelerometer
2. Calculate *three FRFs* between the force & response signals
3. *Curve fit* the FRFs for the modal frequencies of *six modes*
4. Use FaCTs to compare the *current modal frequencies* with *archived frequencies,* including those of a *properly assembled structure*
5. If FaCTs is *less than 0.90*, the structure *fails* the assembly test
6. If the structure *fails* the test, *FaCTs identifies the 10 best cap screw torques* required to pass the test

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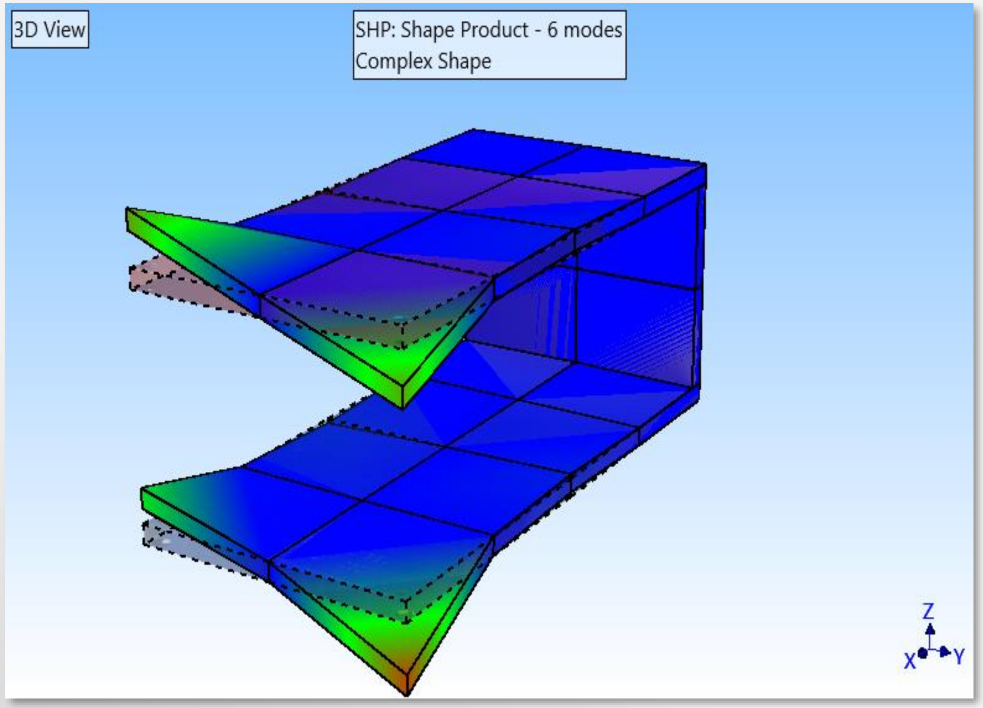
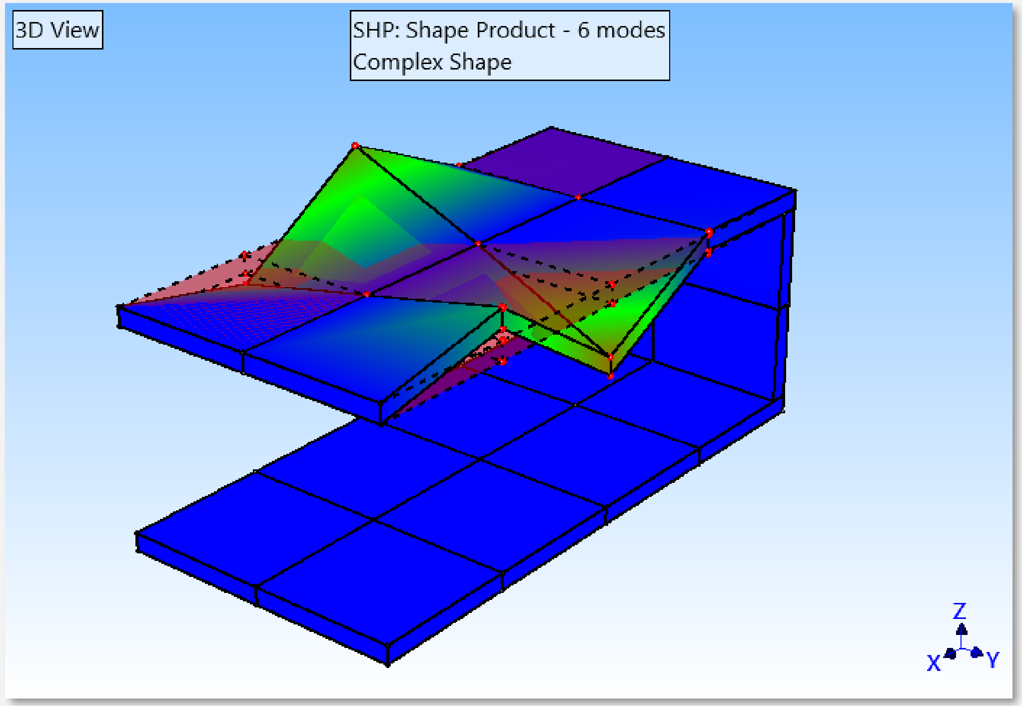
Best Locations for Impact & Response Measurement

Multiplying the mode shapes together gives the *most active points* for impacting and measuring response



Best Locations on Top & Bottom Plates



Best Mid-Plate Locations

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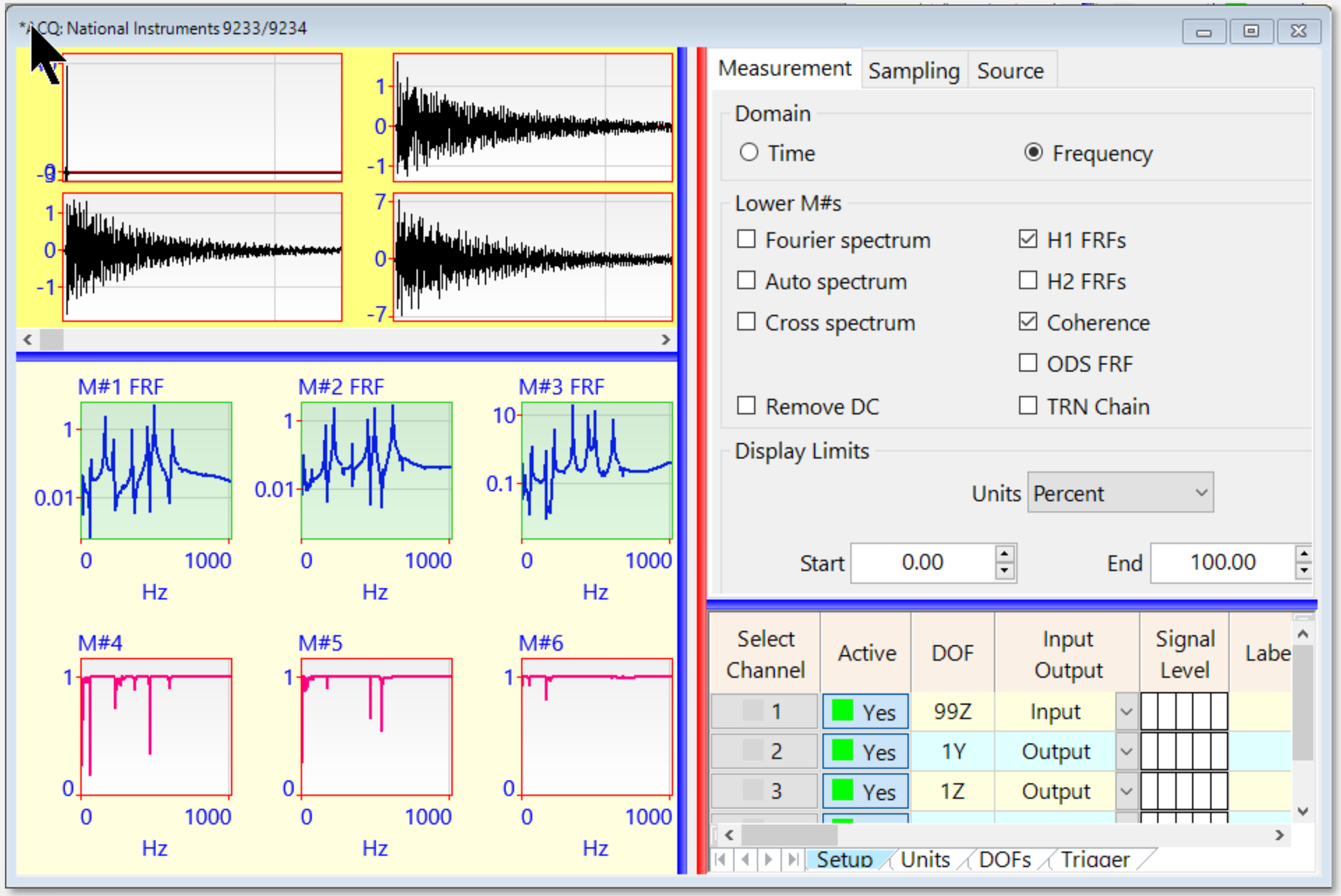
Acquisition, FRF & Coherence Calculation

Impact & response after an acquisition

Log Mag of FRFs

Coherences after Two Acquisitions



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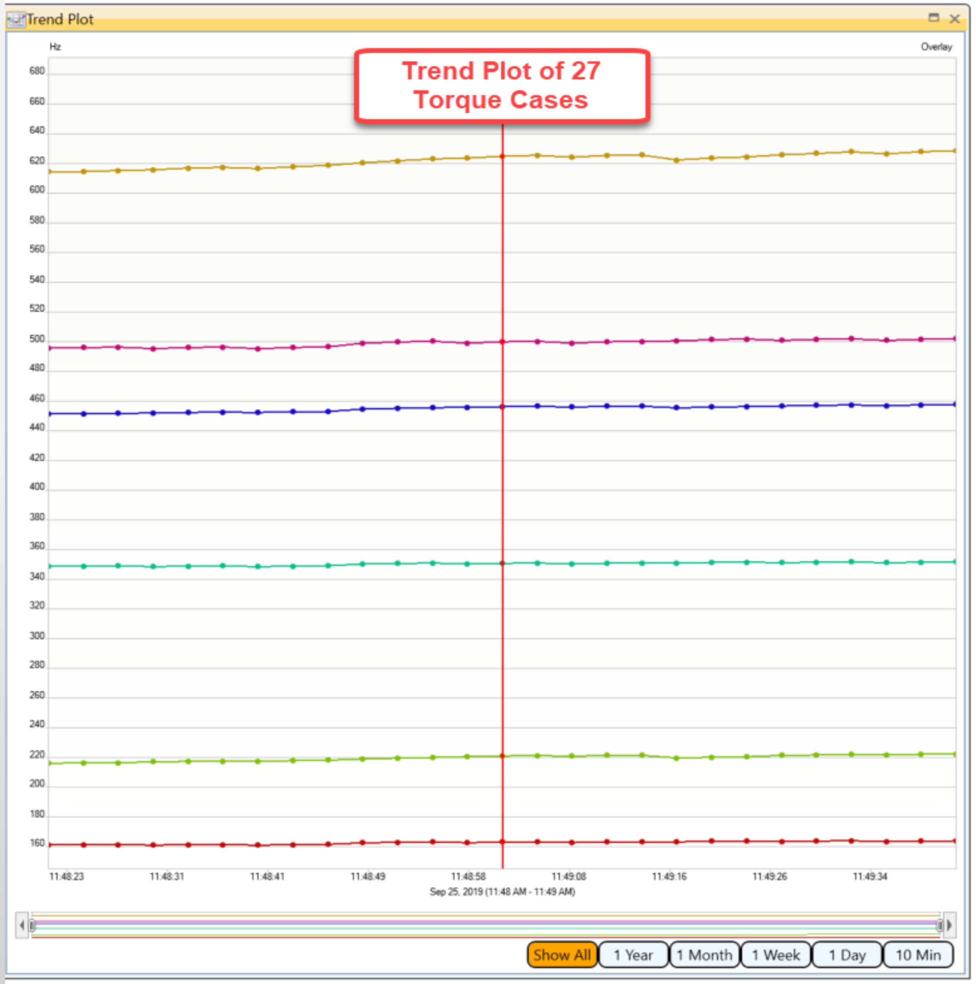
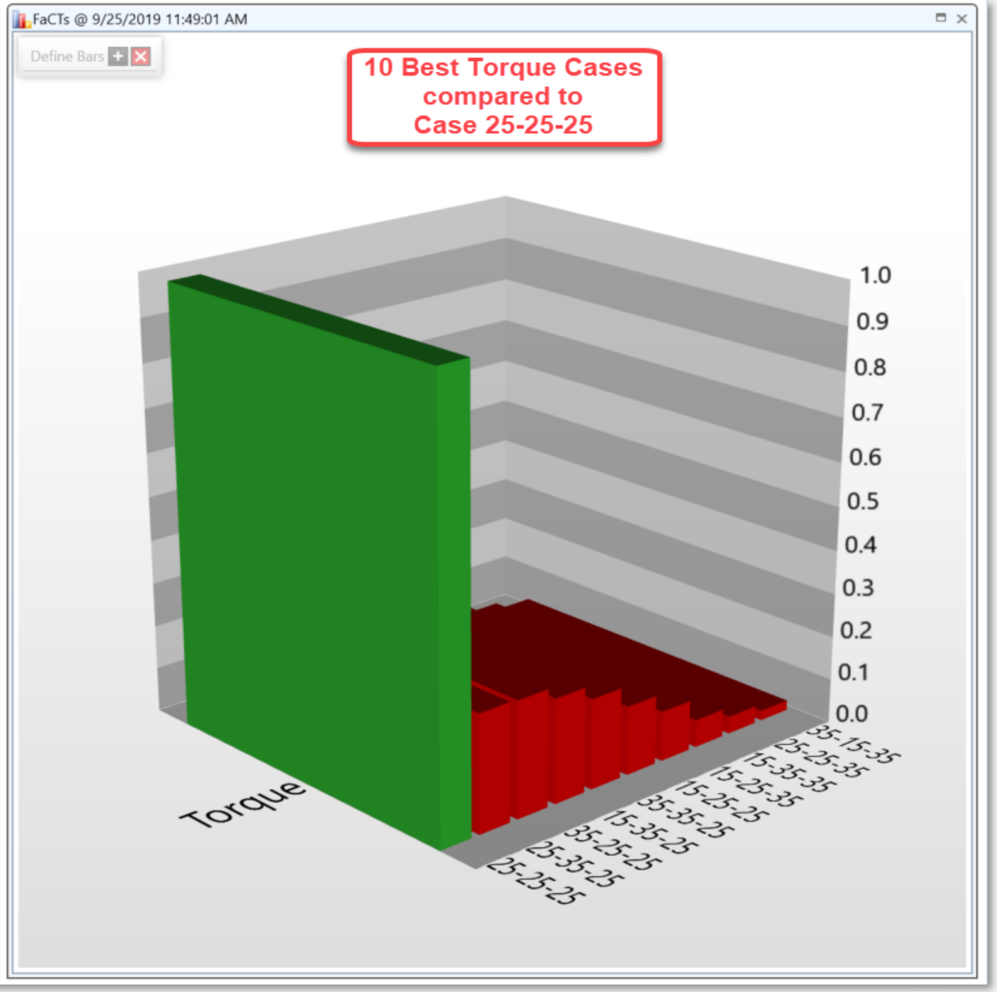
Trend Plot & FaCTs™ Bars

FaCTs bars of 10 closest matches to the 25-25-25 in-lbs case





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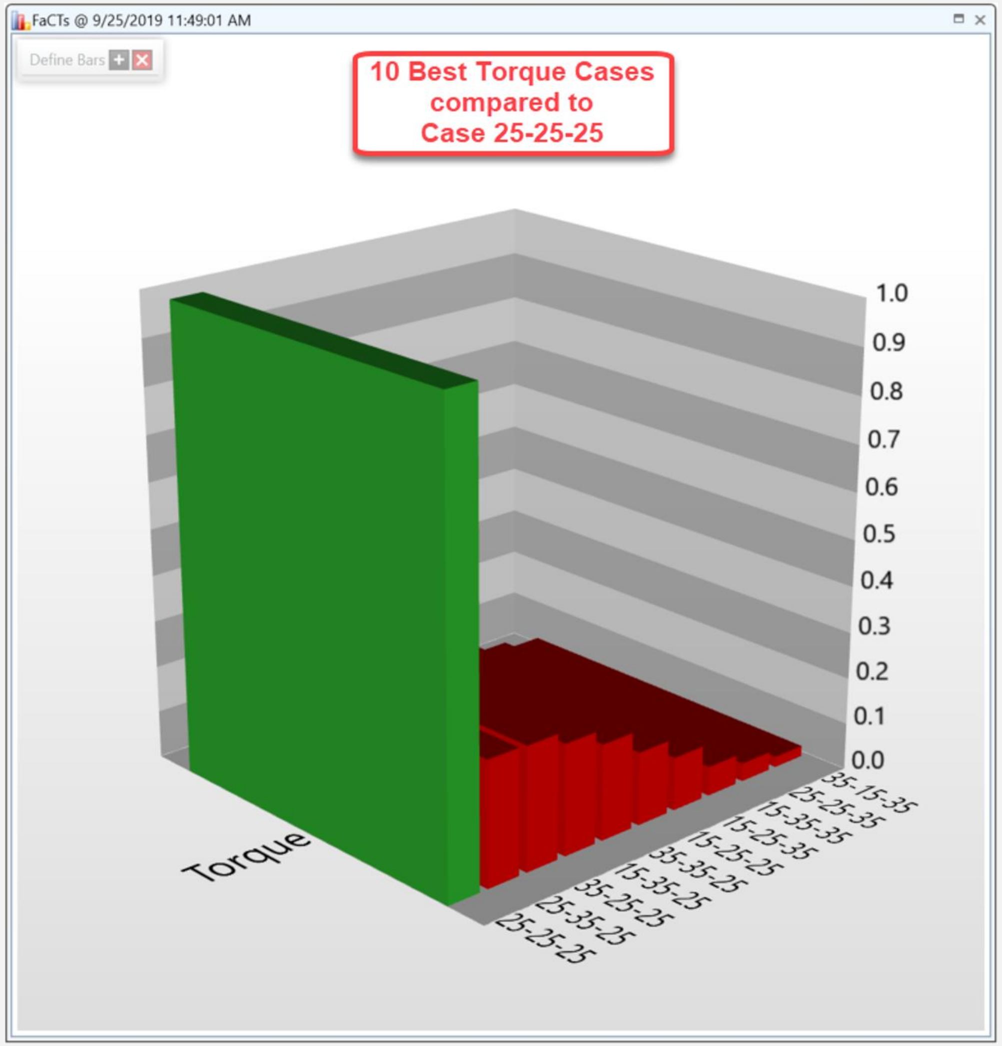
FaCTs Uses SDI to Search the Database

- The FaCTs bar for the ***25-25-25 case*** has a ***value of "1"***
- The remaining FaCTs bars are ordered from ***highest to lowest*** according to their SDI values
- Each FaCTs bar is ***labeled*** with its ***three torque values***



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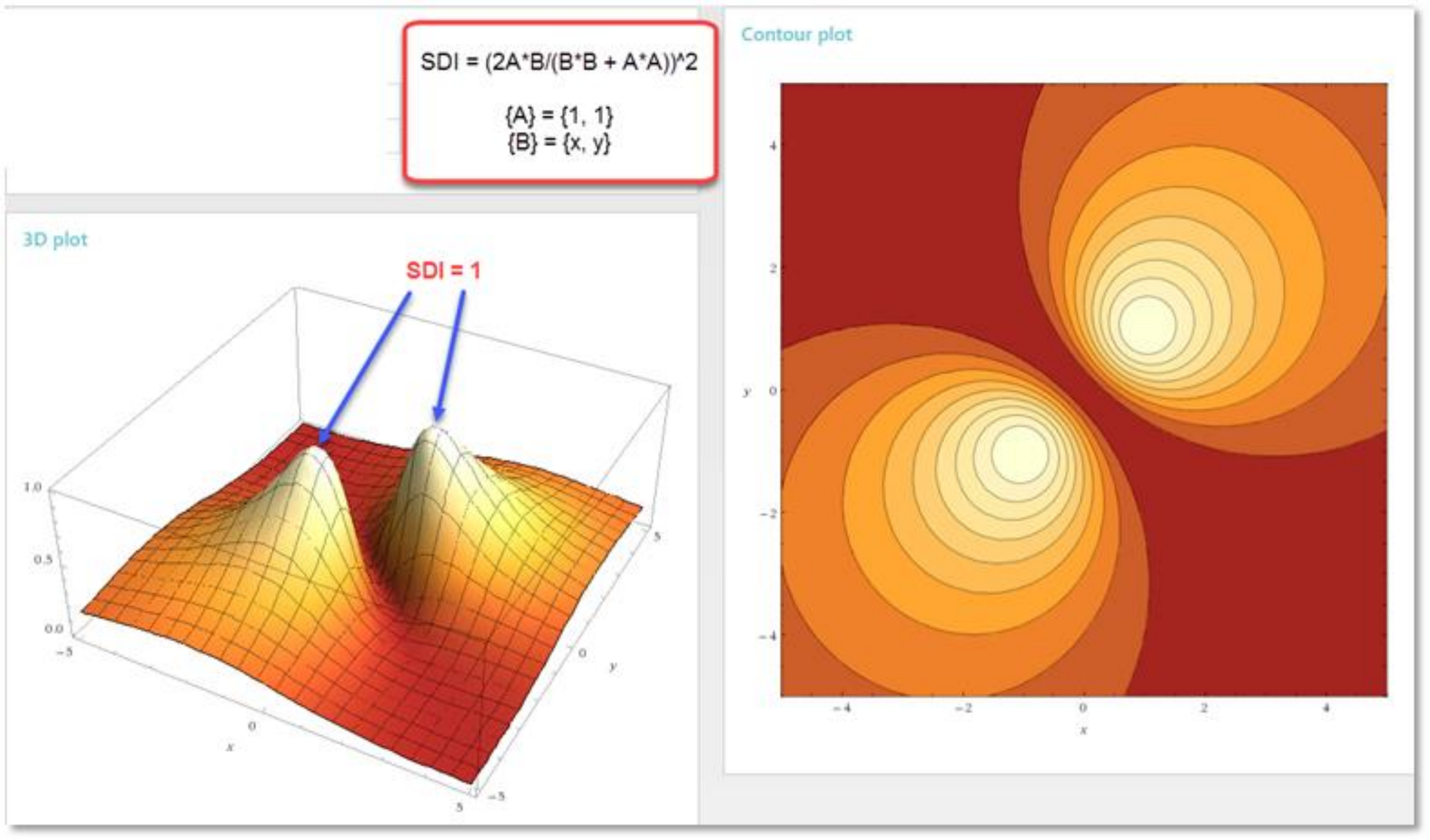
What is SDI (Shape Difference Indicator)?

- **SDI** values ➔ ***between 0.0 & 1.0***
- **SDI = 1.0** ➔ two shapes have ***equal components***
- **SDI > 0.9** ➔ two shapes are ***similar***
- **SDI < 0.9** ➔ two shapes are ***different (some components are not equal)***



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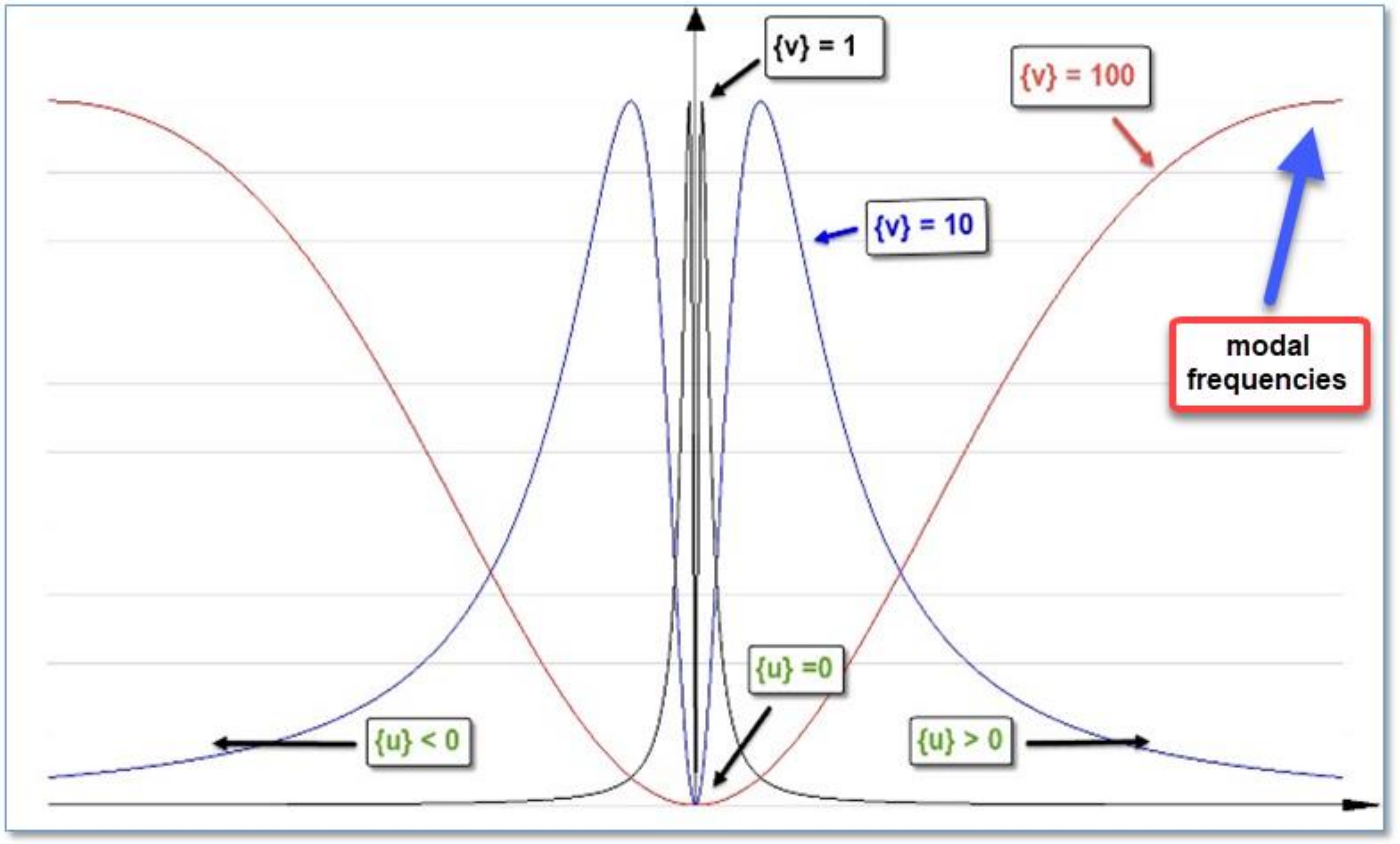
SDI Sensitivity

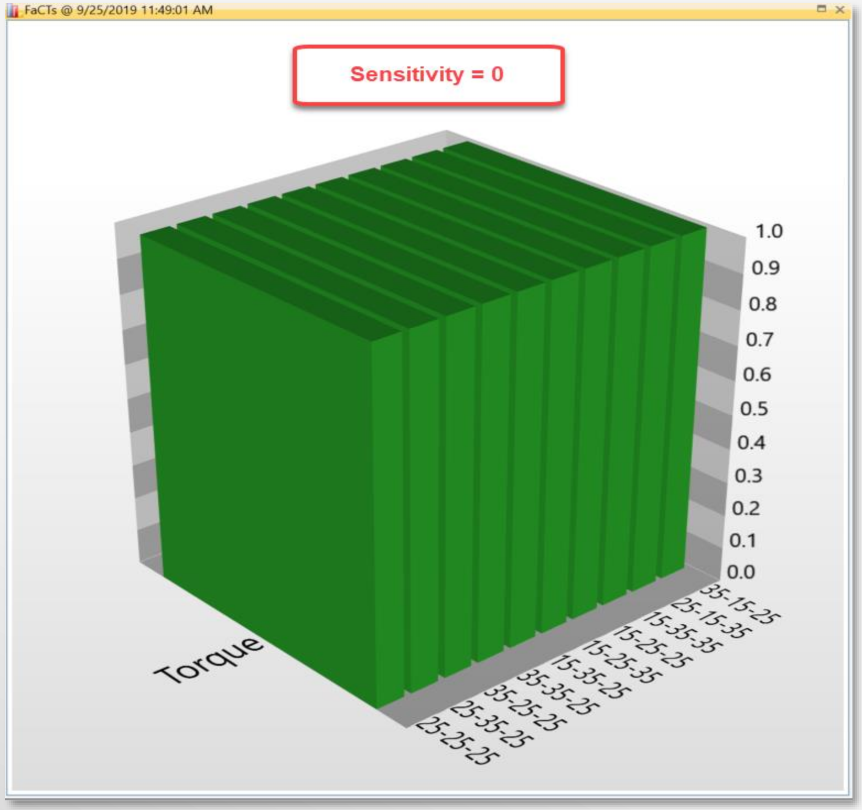
- Small numbers → *very sensitive*
- Large numbers → *not sensitive*

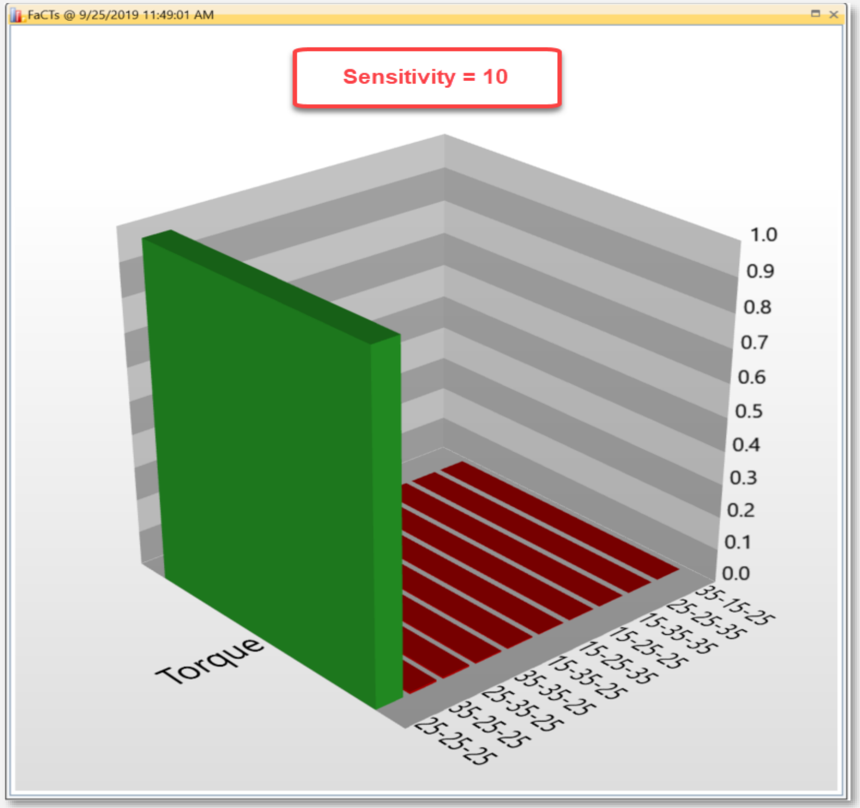
- *Modal frequency "shapes"* have large components
- *More SDI sensitivity* is needed to numerically compare two *modal frequency "shapes"*



← *more sensitive* *less sensitive* →

FaCTs™ (Sensitivity = 0) & (Sensitivity = 10)





Sensitivity = 0 ➔ all FaCTs bars *close to "1"*

Sensitivity = 10 ➔ Case *25-25-25* FaCTs bar is *"1"*

All others are *close to "0"*

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Conclusions

- Each screw of the top plate of the Jim Beam was tightened using *three different torques 15, 25, & 35 in-lbs*
- *27 torque cases* were created for all torque combinations (3 torques x 3 screws)
- For each torque case, the Jim Beam *was impacted*, *three FRFs* were calculated, the FRFs were *curve fit*, and the frequencies of *six modes* were stored as a *"shape"* in an archival database
- FaCTs™ displays the SDI bars of the *10 closest matches* of the *current shape* to the *archived shapes*
- Using this *three-step testing process*, *modal frequencies* can be used in *production* or *qualification* testing to identify *very small stiffness changes* in assembled structures
- When *applying torques* to assemble parts, FaCTs™ will also *provide the torques* necessary to pass a structure that *initially fails* a test

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