MEscope Application Note 29

Updating an FEA Model of an Aluminum Plate

The steps in this Application Note can be carried out using any MEscope package that includes the **VES-4600 Advanced Modal Analysis** and **VES-8000 Finite element Analysis** options. Without these options, you can still carry out the steps in this App Note using the **AppNote29** project file. These steps might also require ***a more recent release date*** of MEscope.

APP NOTE 29 PROJECT FILE

- To retrieve the Project file for this App Note, **click here** to download **AppNote29.zip**

This Project contains ***numbered Hotkeys & Scripts*** of commands for carrying out the steps of this App Note.

- ***Hold down*** **the Ctrl key** and ***click on a*** **Hotkey** to open its Script window

STRUCTURAL DYNAMICS MODIFICATION (SDM

SDM has become a practical tool for improving the engineering designs of mechanical systems. It provides a very quick and inexpensive approach for investigating the effects of design modifications to a structure, thus eliminating the need for costly prototype fabrication and testing.

MODAL MODEL

SDM is unique in that it works directly with a modal model of the structure, either an **Experimental Modal Analysis (EMA)** modal model, a **Finite Element Analysis (FEA)** modal model, or a **hybrid** modal model consisting of both **EMA** & **FEA** mode shapes. **EMA** mode shapes are extracted from experimental data on a real-world test article. **FEA** mode shapes are extracted from a finite element computer model.

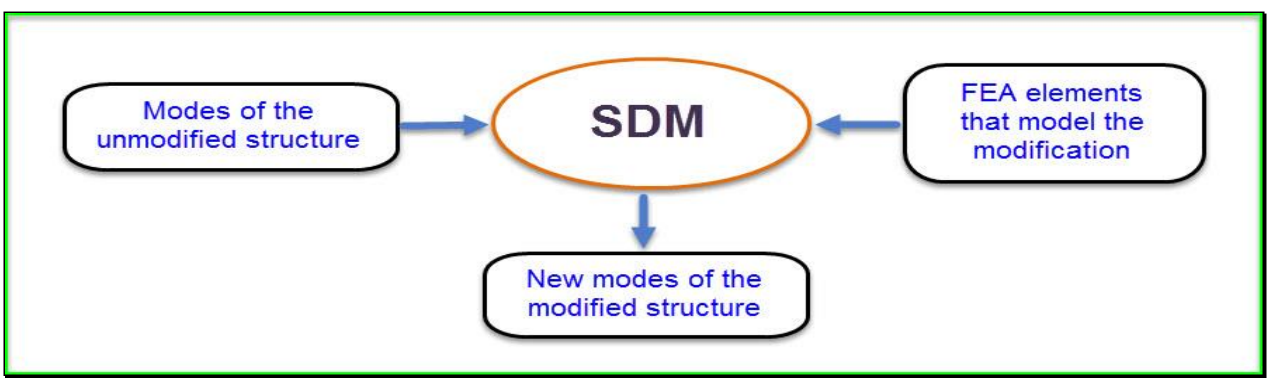
A **modal model** is a set of ***properly scaled*** mode shapes. **SDM** assumes that the mode shapes are scaled to **Unit Modal Masses**, called **UMM** mode shapes. A modal model ***preserves the mass & elastic properties*** of a structure, and it ***fully represents its dynamic properties***.

DESIGN MODIFICATIONS

Once the dynamic properties of an unmodified structure are defined in the form of its modal model, **SDM** can be used to predict the dynamic effects of certain kinds of mechanical design modifications to the structure. These modifications can be as simple as point mass, linear spring, or linear damper ***additions to*** or ***removals from*** the structure, or more complex modifications that are modeled using **FEA** elements such as **RODS, BEAMS, PLATES** (membranes) and **SOLID ELEMENTS**.

SDM solves an eigenvalue problem in modal space and is computationally more efficient and therefore faster than **FEA** which obtains mode shapes by solving an eigenvalue problem in physical space.

Another advantage is that **SDM** only requires the mode shape components of the unmodified structure ***for the DOFs (points & directions) where the modification elements are attached*** to the structure.



SDM *Diagram*

SDM is depicted in the diagram above.

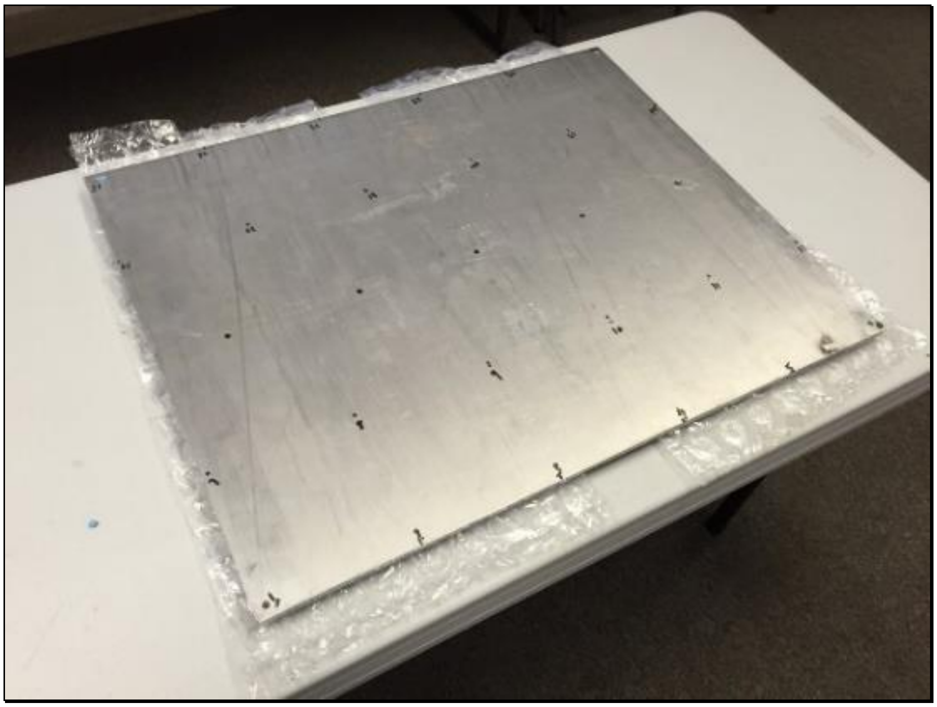
FEA MODEL UPDATING

Because of its computational speed, **SDM** can be used to quickly evaluate ***thousands of potential modifications*** to the physical properties of an **FEA** model. Although the **FEA** mode shapes of a structure may correlate well with its **EMA** mode shapes of a structure, the frequencies of the **FEA** mode shapes may differ significantly for the frequencies of the **EMA** resonances. Since modal frequencies are ***very sensitive*** to the physical properties of a structure, the difference between **FEA** & **EMA** modal frequencies can result from inaccurate physical properties in the **FEA** model.

In this example, two physical properties of the aluminum plate shown in the figure below will be updated to make its **FEA** mode shape frequencies ***more closely match*** its **EMA** mode shape frequencies. The two properties are the thickness and density of the aluminum material of the plate.

SDM will be used in **FEA Model Updating** to calculate the influence of ***100's of different plate thickness & material density values*** of the **FEA** model of the plate structure so that its modal frequencies are ***more closely matched*** with its **EMA** modal frequencies.

The dimensions of the plate are 20 inches (508 mm) by 25 inches (635 mm) by 3/8 inches (9.525 mm) thick.



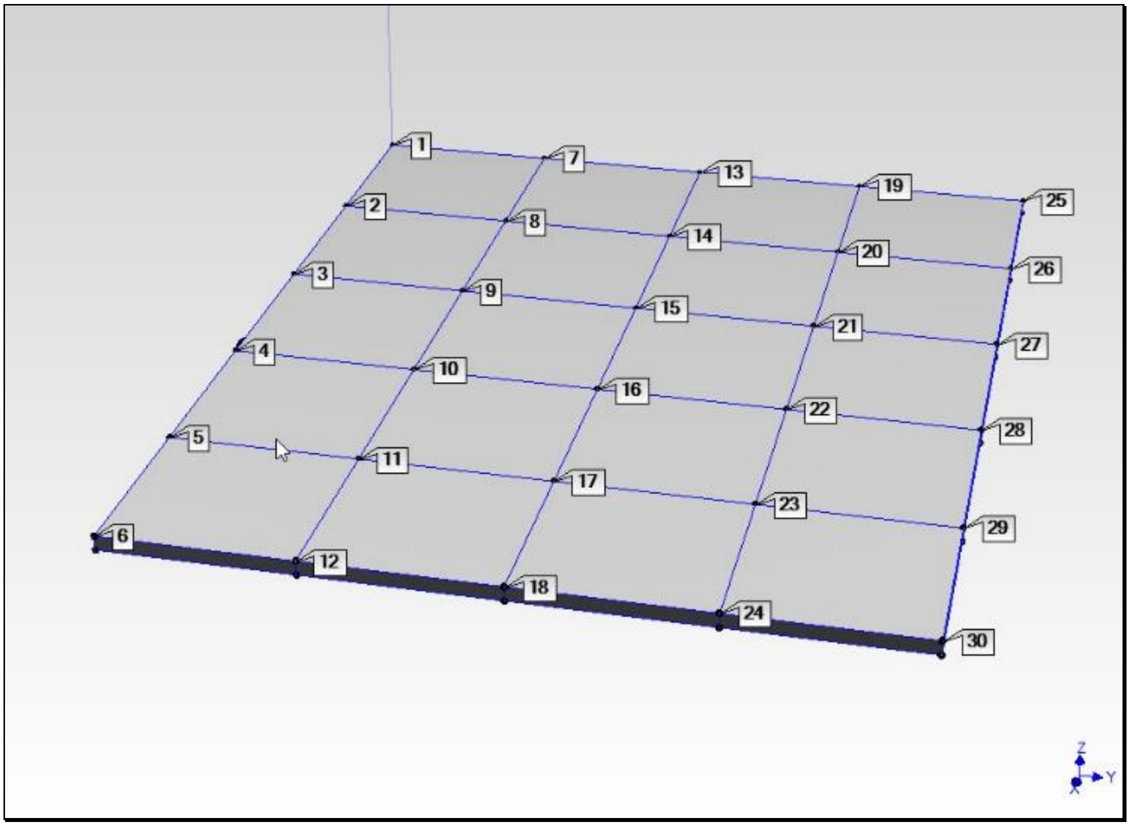
Aluminum Plate Test Article

ROVING IMPACT MODAL TEST

A roving impact modal test was conducted on the aluminum plate. The plate was tested while resting on bubble pack, which approximates free-free boundary conditions. The plate was impacted with an instrumented hammer at each point in a rectangular grid of 30 points which are numbered as shown below. A fixed reference accelerometer was attached near Point 5.

Thirty **FRFs** were calculated from the acquired impact time waveforms. The plate was impacted in the Z-direction, normal to its surface. Therefore, only Z-direction motion at each of the 30 points is defined by the **EMA** mode shapes that are extracted from the **FRFs** by curve fitting them.

The reference accelerometer can have been attached ***anywhere on the surface***. The location of the reference accelerometer ***will not influence the mode shapes*** extracted from the **FRF** measurements. The mode shapes ***only depend on each* DOF *where the plate was impacted*** with the hammer.

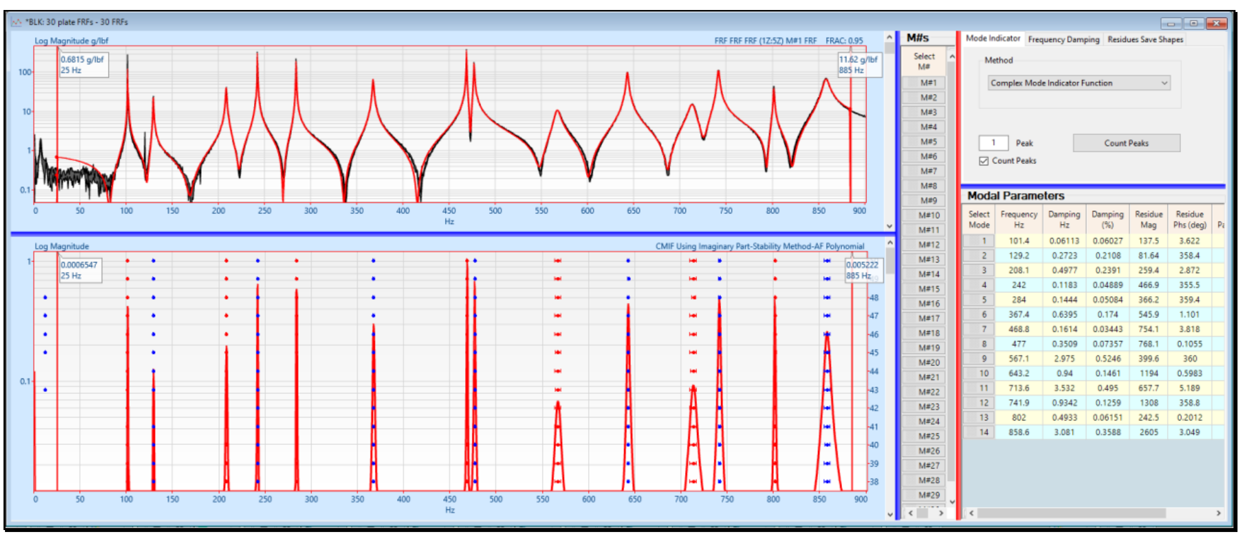


Impact Test Points for Roving Impact Modal Test.

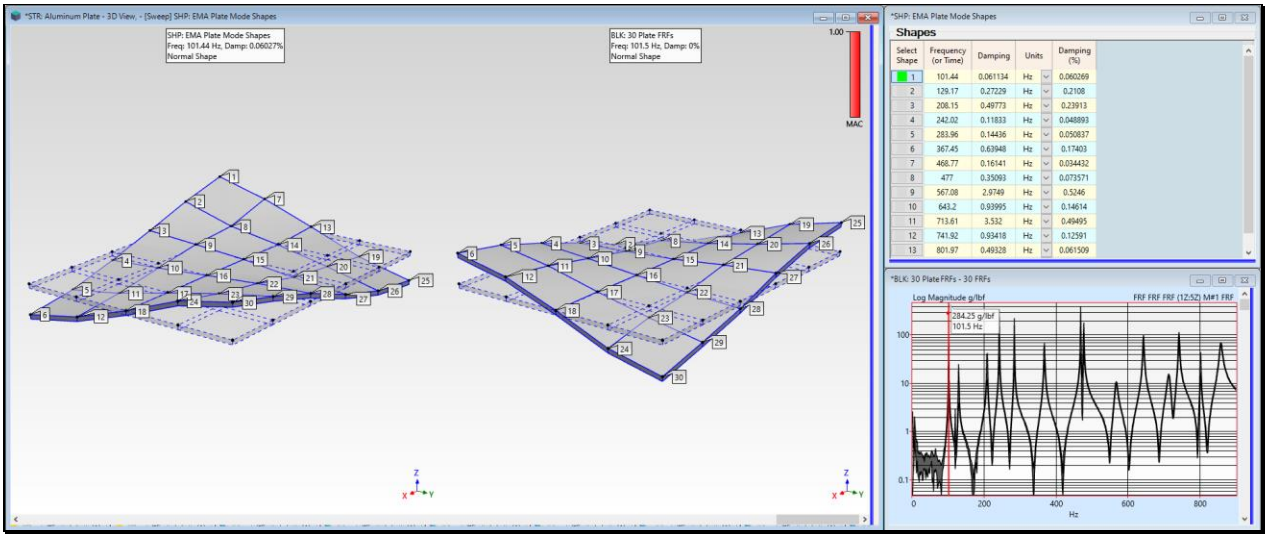
STEP 1 - CURVE FITTING THE FRFs

- ***Press* Hotkey 1 EMA Plate Mode Shapes**

When **Hotkey 1** is ***pressed***, **EMA** mode shapes for 14 modes are extracted from the **FRFs**. Each mode shape has **30 M#s,** (with **DOFs 1Z through 30Z**). A curve fit on one of the **FRFs** is shown below.



Curve Fit of an Experimental FRF.



*Animation of an **EMA** Mode Shape Side-by-Side with the Closest Matching ODS.*

If you ***press*** **Yes** in the dialog that opens, sweep animation will begin through the **EMA** mode shapes in **SHP: EMA Mode Shapes.** Each mode shape is displayed side-by-side with the ***closest matching*** **ODS** at the **Line** cursor position in **BLK: 30 Plate FRFs**

- ***Press*** a **Select Shape** button in **SHP: EMA Mode Shapes** to display that mode shape and its ***closest matching*** **ODS**

The ***closest matching*** **ODS** has the **Maximum MAC** value with the currently selected **EMA** mode shape.

Notice that all the shape pairs have **MAC ➔ 1.0**, indicating that each ***closest matching*** **ODS** is ***co-linear*** with each selected **EMA** mode shape.

STEP 2 - FEA MODE SHAPES OF THE PLATE

An **FEA** model was constructed using ***80 FEA plate (membrane) elements***. It is saved in the **STR: FEA Plate Model** file. The following properties of the aluminum material were selected from the **FEA Materials** dialog box, and the plate thickness was nominally chosen as **0.375 in. (9.525 mm)**

Young's modulus of elasticity: 1E+07 lbf/in^2 (6.895E+04 N/mm^2)

Density: 0.101 lbm/in^3 (2.796E-06 kg/mm^3)

Poisson's Ratio: 0.33

Plate thickness: 0.375 in (9.525 mm)

To display the aluminum material properties,

- Open the **FEA | FEA Materials** dialog box.

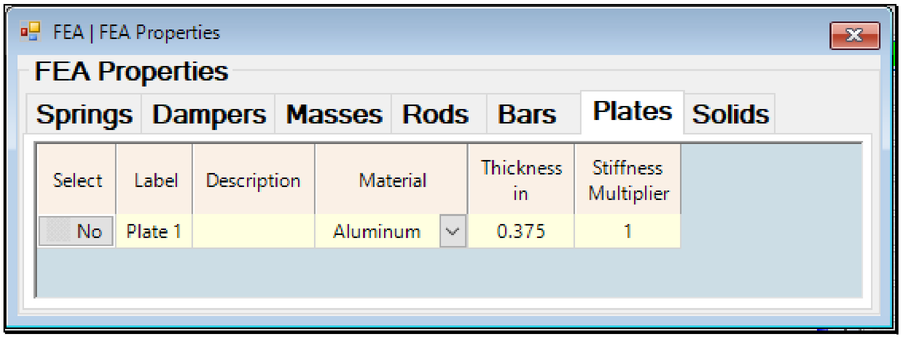
FEA | FEA Materials

FEA Materials

Select	Label	Description	Elasticity lbf/in^2	Poisson's Ratio	Density lbm/in^3
No	Carbon Steel		3E+07	0.3	0.283
No	Stainless Steel		2.8E+07	0.3	0.289
No	Gray Cast Iron		1.4E+07	0.26	0.264
No	Ductile Cast Iron		2.45E+07	0.3	0.256
No	Aluminum		1E+07	0.33	0.101
No	Copper		1.67E+07	0.33	0.321
No	Concrete		3.7E+06	0.2	0.087

To display the **FEA** plate thickness,

- Open the **FEA | FEA Properties** dialog and ***click*** on the **Plates** tab

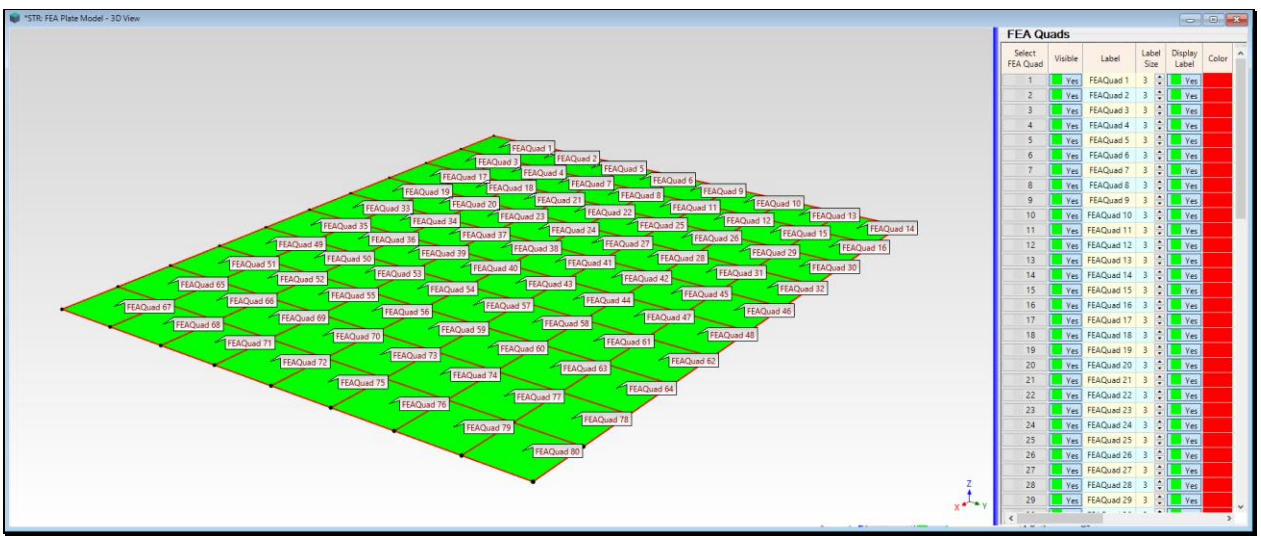


FEA PLATE ELEMENTS

The **FEA** model shown below has 99 points (or nodes) AND 80 **FEA** Quad Plate elements. The eigen-solution of **FEA** mode shapes will include ***6 rigid body mode shapes*** along with ***flexible body mode shapes***. Each **FEA** mode shape will have ***593 DOFs*** (three translational & 3 rotational **DOFS** at each point).

The points (nodes) of the **FEA** model that ***coincide*** with the **EMA** test points have been given the ***same point numbers*** as the test points. This is required to calculate Modal Assurance Criterion (**MAC**) values using common **DOFs** between pairs of the **FEA** & **EMA** mode shapes.

The **FEA** mode shapes are **UMM mode shapes**, which is required by **SDM** for **FEA Model Updating.**



***FEA** Model with 80 **FEA** Quad Plate Elements*

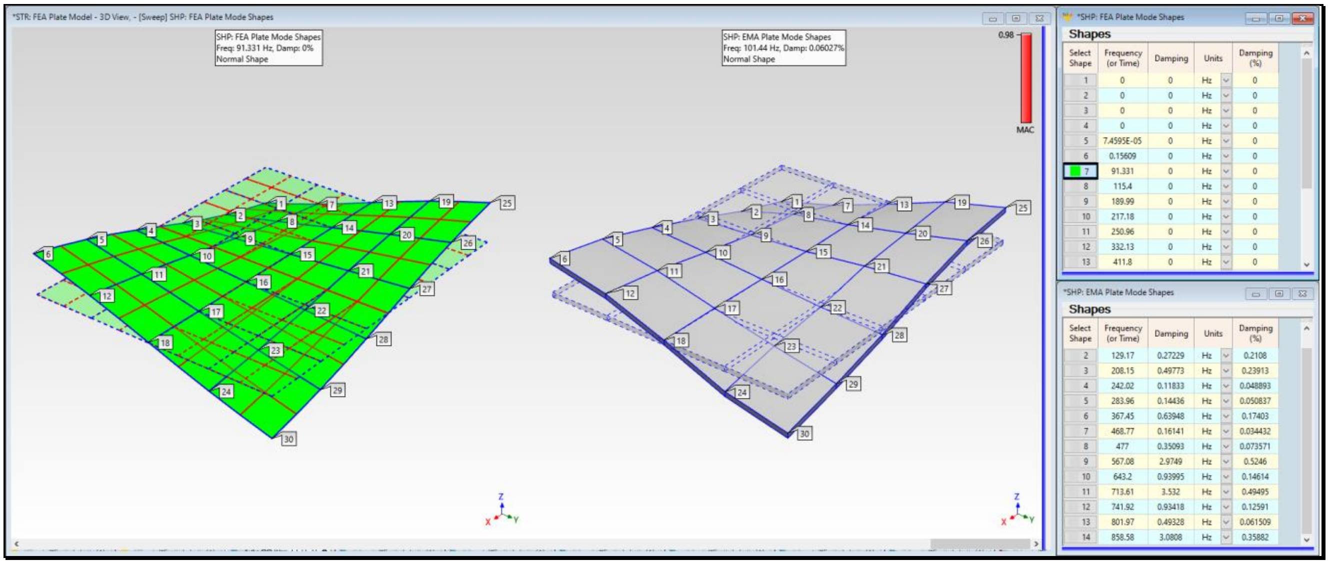
- ***Press*** **Hotkey 2 FEA Plate Mode Shapes**

When **Hotkey 2** is ***pressed***, the **FEA** model of the plate is solved for its mode shapes, the **FEA** mode shapes are stored into **SHP: FEA Mode Shapes**, and a **sweep animation** of the **FEA** mode shapes is begun. Each **FEA** mode shape is displayed side-by-side with its ***closest matching*** **EMA** mode shape.

The ***closest matching*** **EMA** mode shape has the **Maximum MAC** value with each **FEA** mode shape.

All the mode shape pairs have **MAC** ***close to*** **1.0**. this indicates that each **FEA** mode shape is like its ***closest matching*** **EMA** mode shape with **Maximum MAC**.

- ***Press*** a **Select Shape** button in **SHP: FEA Mode Shapes** to display that mode shape and its ***closest matching*** **EMA** mode shape



*Animation of an **FEA** Mode Shape Side-by-Side with Closest Matching **EMA** Mode Shape.*

MODE SHAPE COMPARISON (MAC)

The **Modal Assurance Criterion** (**MAC**) value between each **EMA** mode shape and its ***closest matching flexible body*** **FEA** mode shape is also displayed in the upper right corner of the side-by-side display of the mode shapes. The matching pairs of **FEA** & **EMA** mode shapes are listed in the table below.

The following ***rules of thumb*** are used with **MAC**,

MAC values ➔ ***between* 0 & 1**

MAC = 1.0 ➔ two shapes ***are co-linear (lie on the same straight line)***

MAC >= 0.9 ➔ two shapes ***are similar***

MAC < 0.9 ➔ two shapes ***are linearly independent (do not lie on the same straight line)***

The ***worst-case pair*** of closely matching mode shapes has a ***MAC*** ➔ **0.98**. These high **MAC** values indicate a ***very good correlation*** between the **EMA** & **FEA** mode shapes using their ***matching shape components (*DOFs 1Z through 30Z*)***.

MODAL FREQUENCY COMPARISON

The modal frequencies of the matching pairs of **FEA** & **EMA** mode shapes are listed in the table below.

Even though the **FEA** and **EMA** mode shapes are closely matched, each **EMA** modal frequency ***is higher than*** the frequency of its matching **FEA** mode.

These differences indicate that the stiffness of the real-world aluminum plate ***is greater than*** the stiffness of the **FEA** model. These frequency differences could be reduced by,

- ***Increasing the modulus of elasticity*** or ***reducing the density*** of the aluminum property of the **FEA** plates
- ***Increasing the thickness*** of the **FEA** plates

EMA Shape Number	EMA Frequency (Hz)	EMA Damping (Hz)	FEA Shape Number	FEA Frequency (Hz)	MAC
1	101.4	0.061	7	91.33	0.98
2	129.2	0.272	8	115.4	0.99
3	208.2	0.497	9	190.0	0.99
4	242.0	0.118	10	217.2	0.99
5	284.0	0.144	11	251.0	0.99
6	367.5	0.639	12	332.1	0.98
7	468.8	0.161	13	411.8	0.98
8	477.0	0.351	14	424.1	0.98
9	567.1	2.975	15	495.4	0.99
10	643.2	0.940	16	563.2	0.99
11	713.6	3.532	17	625.6	0.98
12	741.9	0.934	18	653.2	0.98
13	802.0	0.493	19	688.4	0.98
14	858.6	3.081	20	756.2	0.98

EMA** Versus **FEA** Modal Frequencies & Mode Shape **MAC

DIFFERENCE BETWEEN MODAL SENSITIVITY & FEA MODEL UPDATING

In MEscope, **SDM** is used to provide solutions for both **Modal Sensitivity Analysis** and **FEA Model Updating**. But **SDM** is used differently by these two commands.

FEA Model Updating requires the ***element properties of the unmodified*** **FEA model**. **Modal Sensitivity Analysis** does not require the ***element properties of the unmodified*** **FEA model**.

MODAL SENSITIVITY ANALYIS

To perform **Modal Sensitivity Analysis**, only a **modal model** of the ***unmodified*** **structure** and the **FEA *modification elements are required***. The mass, stiffness and damping properties of the modification elements are converted into mass, stiffness, & damping modification matrices, which are then transformed into modal coordinates using the mode shapes of the ***unmodified*** structure.

The modification matrices in modal coordinates are then added to the modal matrices of the ***unmodified*** structure, and those equations are solved for the new modes of the ***modified*** structure.

FEA MODEL UPDATING

To update the properties of an **FEA** model, **SDM** is used in a different way. First, the mass & stiffness properties of the ***unmodified*** **FEA** model ***are subtracted from*** the mass & stiffness properties of the ***modified*** **FEA** model. Then those differences are added to the modal matrices of the ***unmodified*** model.

STEP 3 - FEA MODEL UPDATING

The physical properties used for the plate elements of the **FEA** model were,

Young's modulus of elasticity: 1E+07 lbf/in^2 (6.895E+04 N/mm^2)

Density: 0.101 lbm/in^3 (2.796E-06 kg/mm^3)

Poisson's Ratio: 0.33

Plate thickness: 0.375 in (9.525 mm)

The Plate is made from **6061-T651** aluminum. The correct density for that type of aluminum is **0.0975 lbm/in^3 (2.966E-6 kg/mm^3**. This is less than the density used in the **FEA** model. The Plate elements were assigned a ***nominal thickness of* 0.375 in (9.525 mm)**. Errors in either of these parameters could cause the **FEA** modal frequencies to be less than their corresponding **EMA** frequencies.

- ***Press* Hotkey 3 FEA Model Updating**

When **Hotkey 3** is ***pressed***, the **FEA Model Updating** window will open, as shown below.

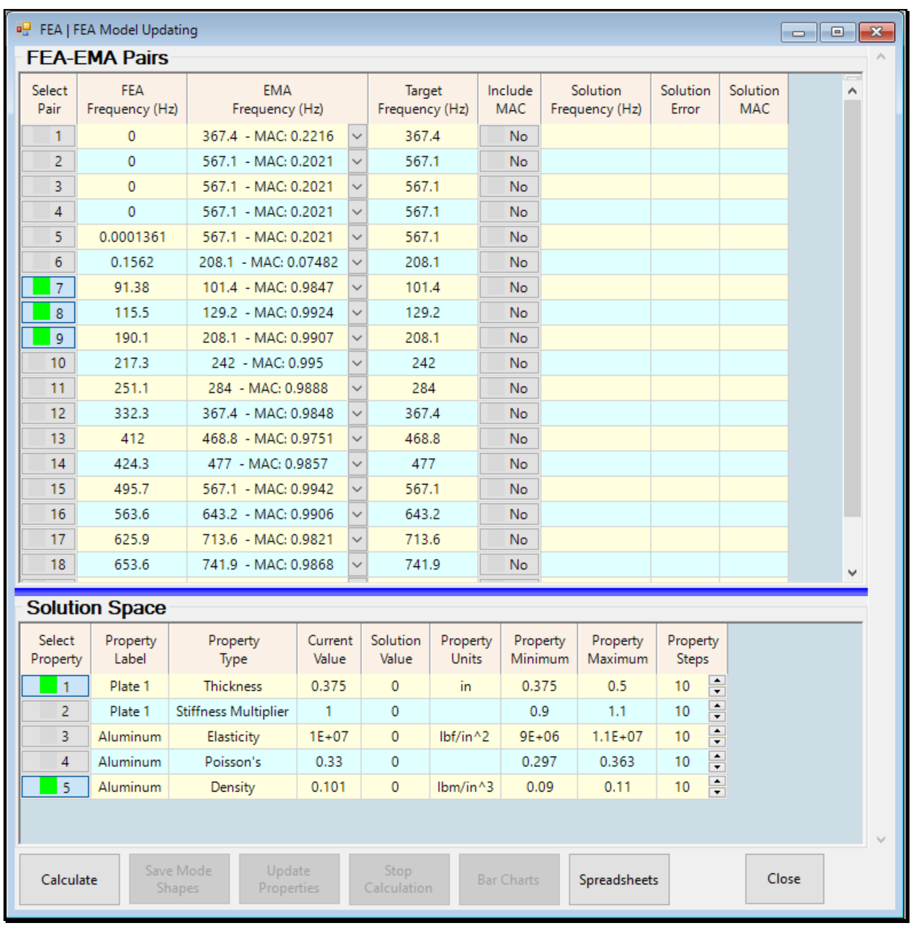
UPPER SPREADSHEET

The frequencies of the **FEA** mode shapes are listed in the first column of the ***upper spreadsheet***. The modal frequency of each closely matched **EMA** mode shape (with the highest **MAC** value) is listed in the next column.

- ***Select* mode pairs 7, 8, & 9** in the ***upper spreadsheet***

LOWER SPREADSHEET

The solution spaces for the **FEA** properties are listed in the ***lower spreadsheet***. The solution space for each property is defined by three parameters, (**minimum**, **maximum** & **steps**).



FEA | FEA Model Updating

FEA-EMA Pairs

Select Pair	FEA Frequency (Hz)	EMA Frequency (Hz)	Target Frequency (Hz)	Include MAC	Solution Frequency (Hz)	Solution Error	Solution MAC
1	0	367.4 - MAC: 0.2216	367.4	No			
2	0	567.1 - MAC: 0.2021	567.1	No			
3	0	567.1 - MAC: 0.2021	567.1	No			
4	0	567.1 - MAC: 0.2021	567.1	No			
5	0.0001361	567.1 - MAC: 0.2021	567.1	No			
6	0.1562	208.1 - MAC: 0.07482	208.1	No			
7	91.38	101.4 - MAC: 0.9847	101.4	No			
8	115.5	129.2 - MAC: 0.9924	129.2	No			
9	190.1	208.1 - MAC: 0.9907	208.1	No			
10	217.3	242 - MAC: 0.995	242	No			
11	251.1	284 - MAC: 0.9888	284	No			
12	332.3	367.4 - MAC: 0.9848	367.4	No			
13	412	468.8 - MAC: 0.9751	468.8	No			
14	424.3	477 - MAC: 0.9857	477	No			
15	495.7	567.1 - MAC: 0.9942	567.1	No			
16	563.6	643.2 - MAC: 0.9906	643.2	No			
17	625.9	713.6 - MAC: 0.9821	713.6	No			
18	653.6	741.9 - MAC: 0.9868	741.9	No			

Solution Space

Select Property	Property Label	Property Type	Current Value	Solution Value	Property Units	Property Minimum	Property Maximum	Property Steps
1	Plate 1	Thickness	0.375	0	in	0.375	0.5	10
2	Plate 1	Stiffness Multiplier	1	0		0.9	1.1	10
3	Aluminum	Elasticity	1E+07	0	lbf/in^2	9E+06	1.1E+07	10
4	Aluminum	Poisson's	0.33	0		0.297	0.363	10
5	Aluminum	Density	0.101	0	lbm/in^3	0.09	0.11	10

***FEA Model Updating** Before Calculating 100 Solutions*

The solution space for the plate thickness is defined with 10 evenly spaced **Property Steps** between a **Property Minimum = 0.375** and a **Property Maximum = 0.50**. The solution space for the density is **defined with 10 evenly Property Steps between a Property Minimum = 0.90 and a Property Maximum = 0.11. 100** solutions will be calculated with **SDM** using all combinations of values in the solution space of the **Thickness & Density** properties.

- ***Press*** the **Select Property** buttons for the **Thickness** and **Density** properties in the ***lower spreadsheet***
- ***Press*** the **Calculate** button on the bottom of the **FEA Model Updating** window

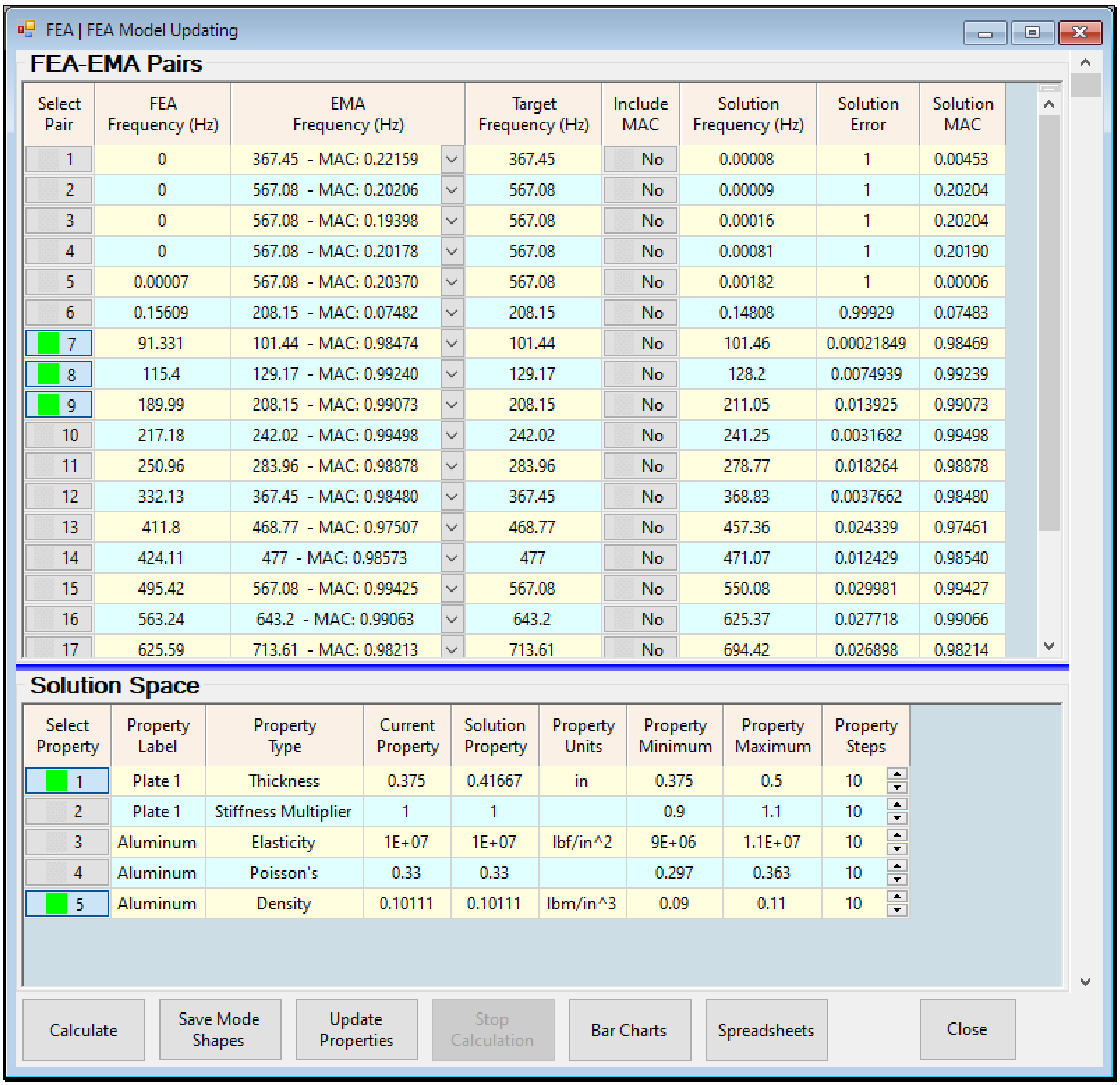
After 100 solutions have been calculated, they will be ordered from best to worst, and the best solution will be displayed in the **FEA Model Updating** window, as shown below.

The ***best solution*** is the one with mode pairs ***7, 8 & 9 closest in frequency to their target*** frequencies

The ***best solution*** is displayed when the scroll bar ***on the far right is at the top*** of its slider

The ***best updated thickness*= 0.4167 in.** which is greater than the nominal thickness (**0.375**) originally used

The ***best updated density* = 0.1011** which is the ***same as the density*** chosen for aluminum



Select Pair	FEA Frequency (Hz)	EMA Frequency (Hz)	Target Frequency (Hz)	Include MAC	Solution Frequency (Hz)	Solution Error	Solution MAC
1	0	367.45 - MAC: 0.22159	367.45	No	0.00008	1	0.00453
2	0	567.08 - MAC: 0.20206	567.08	No	0.00009	1	0.20204
3	0	567.08 - MAC: 0.19398	567.08	No	0.00016	1	0.20204
4	0	567.08 - MAC: 0.20178	567.08	No	0.00081	1	0.20190
5	0.00007	567.08 - MAC: 0.20370	567.08	No	0.00182	1	0.00006
6	0.15609	208.15 - MAC: 0.07482	208.15	No	0.14808	0.99929	0.07483
7	91.331	101.44 - MAC: 0.98474	101.44	No	101.46	0.00021849	0.98469
8	115.4	129.17 - MAC: 0.99240	129.17	No	128.2	0.0074939	0.99239
9	189.99	208.15 - MAC: 0.99073	208.15	No	211.05	0.013925	0.99073
10	217.18	242.02 - MAC: 0.99498	242.02	No	241.25	0.0031682	0.99498
11	250.96	283.96 - MAC: 0.98878	283.96	No	278.77	0.018264	0.98878
12	332.13	367.45 - MAC: 0.98480	367.45	No	368.83	0.0037662	0.98480
13	411.8	468.77 - MAC: 0.97507	468.77	No	457.36	0.024339	0.97461
14	424.11	477 - MAC: 0.98573	477	No	471.07	0.012429	0.98540
15	495.42	567.08 - MAC: 0.99425	567.08	No	550.08	0.029981	0.99427
16	563.24	643.2 - MAC: 0.99063	643.2	No	625.37	0.027718	0.99066
17	625.59	713.61 - MAC: 0.98213	713.61	No	694.42	0.026898	0.98214

Select Property	Property Label	Property Type	Current Property	Solution Property	Property Units	Property Minimum	Property Maximum	Property Steps
1	Plate 1	Thickness	0.375	0.41667	in	0.375	0.5	10
2	Plate 1	Stiffness Multiplier	1	1		0.9	1.1	10
3	Aluminum	Elasticity	1E+07	1E+07	lbf/in^2	9E+06	1.1E+07	10
4	Aluminum	Poisson's	0.33	0.33		0.297	0.363	10
5	Aluminum	Density	0.10111	0.10111	lbm/in^3	0.09	0.11	10

FEA Model Updating *After Calculating 100 Solutions*

- Scroll through the ***first several solutions***

The first several solutions yield similar updated frequencies. ***Any one of those solutions*** could be used for updating the **FEA** model.

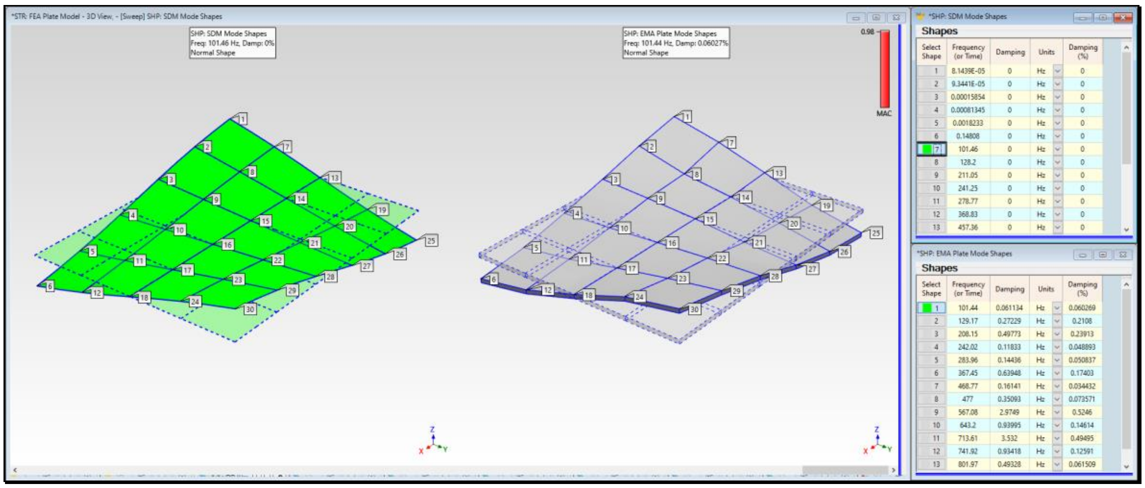
- ***Press*** the **Save Mode Shapes** button in the **FEA Model Updating** window

When the **Save Mode Shapes** button is ***pressed***, **SDM** is used to calculate mode shapes using the currently displayed **Solution Properties** in the **FEA Model Updating** window.

STEP 4 - SDM MODE SHAPES VERSUS EMA MODE SHAPES

- ***Press*** **Hotkey 4 SDM vs. EMA Mode Shapes**

When **Hotkey 4 is *pressed***, sweep animation through the mode shapes in **SHP: SDM Mode Shapes** will begin, and each **SDM** mode shape is displayed side-by-side with its ***closest matching*** **EMA** mode shape. The **MAC** value of each pair of mode shapes is also displayed in the ***upper right corner*** of the mode shapes display, and in the table below.



*Animation of an **SDM** Mode Shape Side-by-Side with the Closest Matching **EMA** Mode Shape.*

SDM Shape Number	SDM Frequency (Hz)	EMA Shape Number	EMA Frequency (Hz)	EMA Damping (Hz)	MAC
7	101.5	1	101.5	0.04487	0.98
8	128.2	2	129.1	0.264	0.99
9	211	3	208.1	0.4977	0.99
10	241.3	4	242.0	0.1089	0.99
11	278.8	5	284.0	0.1444	0.99
12	368.8	6	367.5	0.6455	0.98
13	457.4	7	468.7	0.1659	0.97
14	471.1	8	477.0	0.3509	0.99
15	550.1	9	567.1	2.979	0.99
16	625.4	10	643.2	0.9498	0.99
17	694.4	11	713.6	3.583	0.98
18	725.4	12	741.9	0.9449	0.99
19	764.3	13	802.0	0.4814	0.98
20	839.5	14	858.6	3.087	0.98

STEP 5 - UPDATED FEA MODE SHAPES VERSUS SDM MODE SHAPES

In this step, the **FEA Model Updating** process is repeated, but this time the properties of the **FEA** model itself are updated and **FEA** mode shapes are calculated from the updated **FEA** model. The **FEA** mode shapes are then compared in side-by-side animation with the **SDM** mode shapes that were calculated using the **updated FEA Properties** that were used by **SDM** in **Step 4**.

- ***Press* Hotkey 3 FEA Model Updating *again***
- ***Press*** the **Calculate** button on the bottom of the **FEA Model Updating** window

When the calculation of 100 solutions has completed.

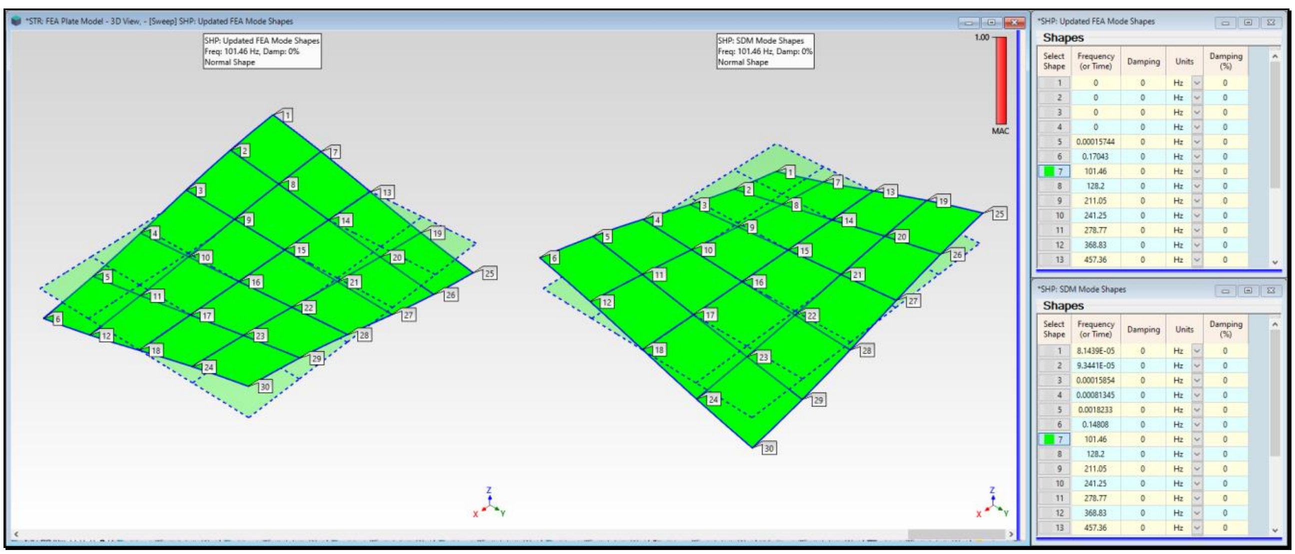
- ***Press*** the **Update Properties** button on the bottom of the **FEA Model Updating** window

The **Thickness** & **Density** properties are now updated in the **FEA Properties** & **FEA Materials** boxes.

- ***Press* Hotkey 5 Updated FEA vs. SDM Mode Shapes**

When **Hotkey 5 is *pressed***, **FEA** mode shapes are calculated from the FEA model with updated properties, and those mode shapes are compared in animation with the calculated with **SDM** and the plates with updated properties.

The comparison display will sweep through the mode shapes of the updated **FEA** model and display each mode shape side-by-side with the ***closest matching*** mode shape calculated by **SDM**. This side-by-side comparison is shown below.



*Mode Shape of the Updated **FEA** Model Animated Side-by-Side with the Closest Matching **SDM** Mode Shape.*

The table below lists the modal frequencies and **MAC** values between each mode shape of the updated FEA model and its ***closest matching*** **SDM** mode shape using the same updated plate **Thickness** and aluminum **Density** modifications.

Shape Number	Updated FEA Frequency (Hz)	SDM Frequency (Hz)	MAC
1	0	0.0001111	0.99
2	0	0.0001581	1.00
3	0	0.0001822	0.42
4	0	0.0008134	0.71
5	0	0.001824	0.90
6	0.1704	0.1481	1.00
7	101.5	101.5	1.00
8	128.2	128.2	1.00
9	211	211	1.00
10	241.3	241.3	1.00
11	278.8	278.8	1.00
12	368.8	368.8	1.00
13	457.4	457.4	1.00
14	471.1	471.1	1.00
15	550.1	550.1	1.00
16	625.4	625.4	1.00
17	694.4	694.4	1.00
18	725.4	725.4	1.00
19	764.3	764.3	1.00
20	839.5	839.5	1.00

*Updated **FEA** Model Versus **SDM** Modal Frequencies & Mode Shape **MAC**.*

CONCLUSION

The table above shows a ***perfect match*** of the frequencies & **MAC** values between the flexible body mode shapes of the **updated FEA** model and those of the **SDM** calculation.

In this case, the **SDM** eigen-solution in modal space ***perfectly matched*** the eigen-solution in physical space calculated from the **FEA** model.

The eigen-solution in physical space used by the **FEA** solver yielded mode shapes that included ***all the dynamic properties*** of the plate, yet the accuracy of **SDM** was not impacted by using a ***truncated modal model***,(only 20 of the modes of the plate).

Even though **SDM** started with a ***truncated modal model*** of the dynamics of the ***unmodified plate,*** the mode shapes calculated by **SDM** using the **modified plate properties** ***closely compared*** with the mode shapes of the **updated FEA** model.

STEP 6 - REVIEW STEPS

To review the steps of this App Note,

- ***Press*** **Hotkey 6 Review Steps**