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Altair HyperStudy 2019 Tutorials

HS-2215: Extensible DOE Study of a Space Frame Structure
with Input Variable Constraints

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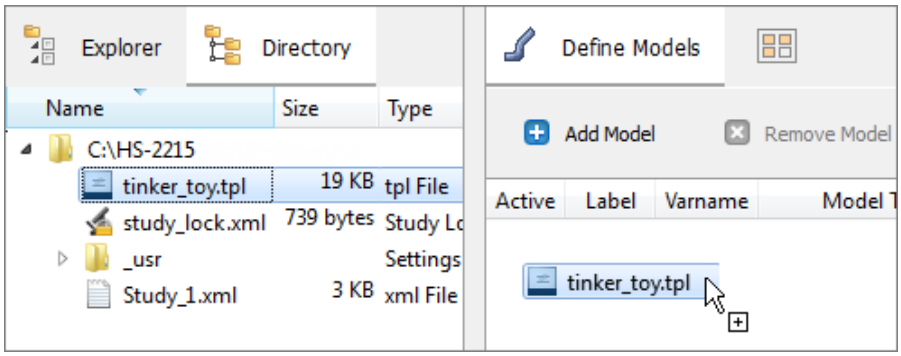
HS-2215: Extensible DOE Study of a Space Frame Structure with Input Variable Constraints

In this tutorial you will use a DOE to investigate the effects of the cross sectional dimensions and joint stiffness of a truss structure's volume and natural frequencies. The tubular truss dimensions must be constrained, such that the inner radius is always less than the outer radius. You will also use the extensible feature of the Modified Extensible Lattice Sequence in a progressive set of steps to add additional runs to a DOE.

The files used in this tutorial can be found in `<hst.zip>/HS-2215/`. Copy the files from this directory to your working directory.

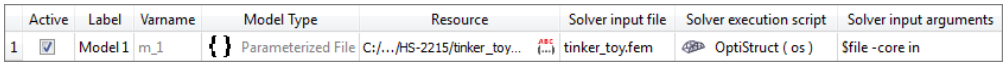
Step 1: Perform the Study Setup

1. Start HyperStudy.
2. To start a new study, click ***File*** > ***New*** from the menu bar, or click on the toolbar.
3. In the **HyperStudy – Add** dialog, enter a study name, select a location for the study, and click ***OK***.
4. Go to the **Define Models** step.
5. Add a Parameterized File model.
   a. From the **Directory**, drag-and-drop the `tinker_toy.tpl` file into the work area.



   b. In the **Solver input file** column, enter `tinker_toy.fem`. This is the name of the solver input file HyperStudy writes during any evaluation.
   c. In the **Solver execution script** column, select ***OptiStruct (os)***.
   d. In the **Solver input arguments** column, after ${file}, enter `-core in`.

      This option forces OptiStruct to run with maximum memory, which will make the analysis run more quickly. The small size of the finite element model makes this possible in this example.



6. Click ***Import Variables***. Three input variables are imported from the `tinker_toy.tpl` resource file.

7. Go to the **Define Input Variables** step.
8. Review the input variable's lower and upper bound ranges.
9. Click the ***Constraints*** tab.
10. Add an input variable constraint.
    a. Click ***Add Constraint***.
    b. In the **Add - HyperStudy** dialog, add one constraint.
    c. Define the constraint.

    Note: Use the Expression Builder to select input variables to append to the Left Expression and Right Expression fields.

    - For **Left Expression**, enter `m_1_outer_diam`.
    - Set **Comparison** to **>=**.
    - For **Right Expression**, enter `m_1_inner_diam`.

	Active	Label	Varname	Left Expression	Comparison	Right Expression	Comment
1	☑	Con 1	con_1	m_1_outer_diam ...	>=	m_1_inner_diam ...	...

11. Go to the **Specifications** step.

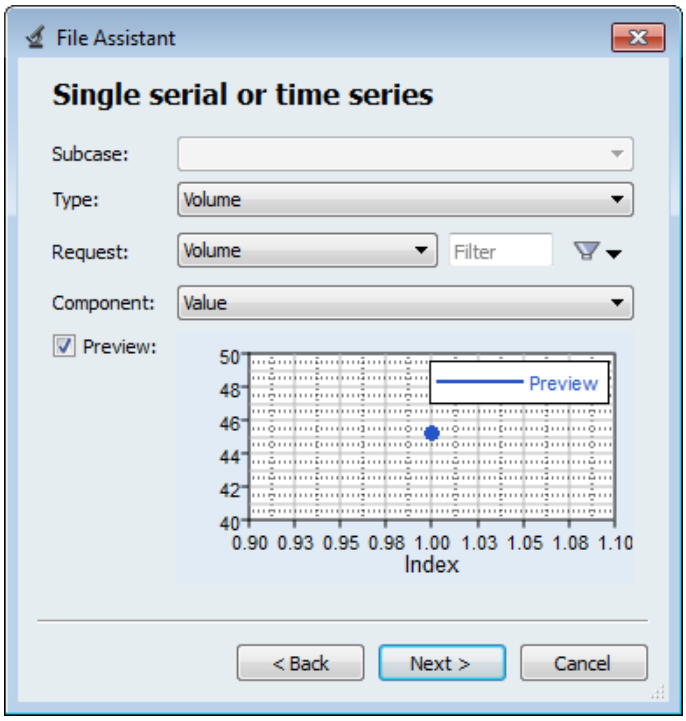
Step 2: Perform the Nominal Run

1. In the work area, set the **Mode** to ***Nominal Run***.
2. Click ***Apply***.
3. Go to the **Evaluate** step.
4. Click ***Evaluate Tasks***. An `approaches/nom_1/` directory is created inside the study directory.
5. Go to the **Define Output Responses** step.

Step 3: Create and Define Output Responses

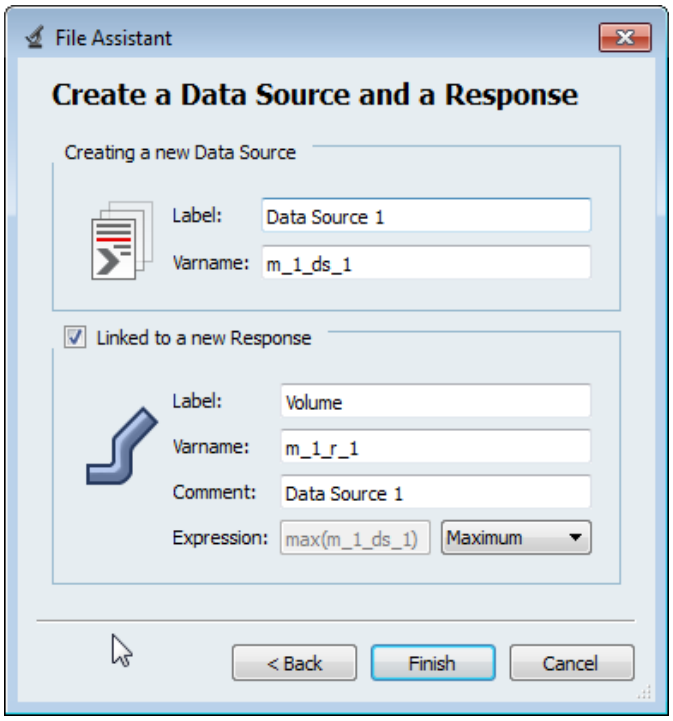
1. Create the Volume output response.
    a. From the **Directory**, drag-and-drop the `tinker_toy.out` file, located in `approaches/nom_1/run_00001/m_1`, into the work area.
    b. In the **File Assistant** dialog, set the **Reading technology** to ***Altair® HyperWorks® (HstReaderPdd)*** and click ***Next***.
    c. Select **Single item in a time series**, then click ***Next***.
    d. Define the following options, and then click ***Next***.

- Set **Type** to ***Volume***.
- Set **Request** to ***Volume***.
- Set **Component** to ***Value***.



e. Label the output response `Volume`.

f. Set **Expression** to ***Maximum***.



g. Click ***Finish***. The Volume output response is added to the work area.

2. Create the Frequency_Vector data source, which will be used in the frequency output responses.

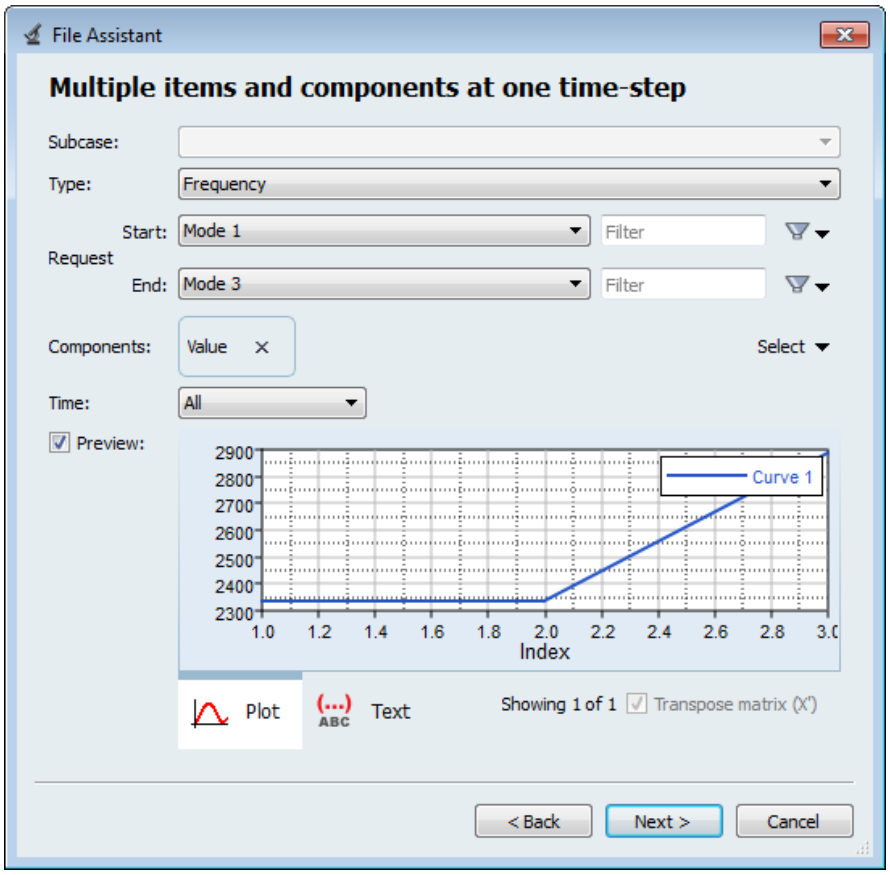
   a. From the **Directory**, drag-and-drop the `tinker_toy.out` file, located in `approaches/nom_1/run_00001/m_1`, into the work area.

   b. In the **File Assistant** dialog, set the **Reading technology** to ***Altair® HyperWorks® (HstReaderPdd)*** and click ***Next***.

   c. Select **Multiple items at multiple time steps (readsim)**, then click ***Next***.

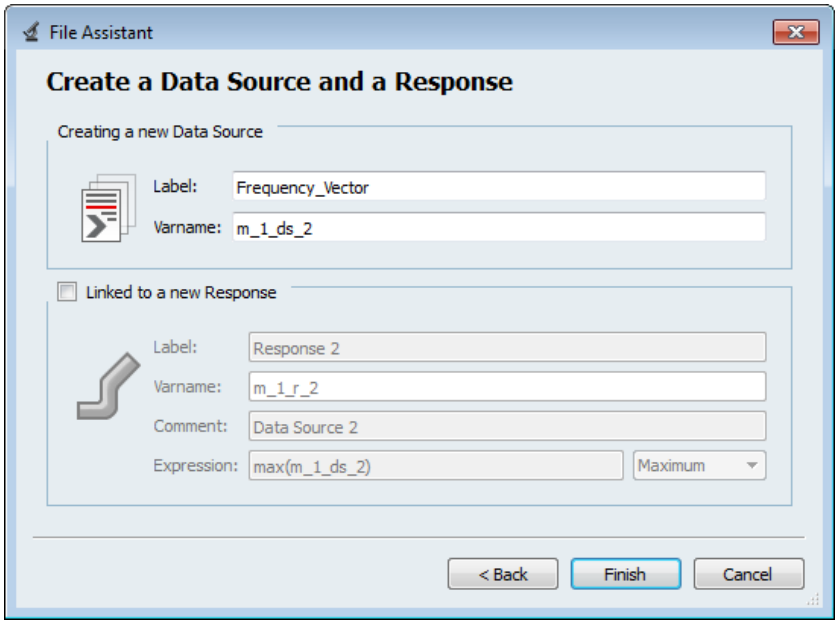
   d. Define the following options, and then click ***Next***.

      - Set **Type** to ***Frequency***.
      - Set **Request** (Start - End) to ***Mode 1 - Mode 3***.
      - For **Components**, select ***Value***.



e. Clear the ***Linked to a new Response*** checkbox.

f. Label the data source `Frequency_Vector`.



g. Click ***Finish***.

3. Add three output responses.
   a. Click ***Add Output Response*** three times.
   b. In the work area, label the output responses `Frequency_1`, `Frequency_2`, and `Frequency_3`.
4. Define the Frequency_1 output responses.
   a. In the **Expression** column of the output response **Frequency_1**, click **...**.
   b. In the **Expression Builder**, click the ***Data Sources*** tab.
   c. In the work area, select ***Frequency_Vector***.
   d. From the **Insert Varname** drop-down menu, click ***First Element***.
   e. Click ***Insert Varname***. The expression `m_1_ds_2[0]` appears in the Evaluate Expression field.

   f. Click ***OK***.
5. Repeat step 4 to define Frequency_2 and Frequency_3, except change the value after `m_1_ds_2`.
   a. For **Frequency_2**, change `[0]` to `[1]`.
   b. For **Frequency_3**, change `[0]` to `[2]`.
6. Click ***Evaluate*** to extract the output response values.

	Active	Label	Varname	Expression	Value	Comment
1	☑	Volume	m_1_r_1	max(m_1_ds_1) ...	45.257800	Data Source 1 ...
2	☑	Frequency_1	r_2	m_1_ds_2[0] ...	2335.9880	...
3	☑	Frequency_2	r_3	m_1_ds_2[1] ...	2335.9880	...
4	☑	Frequency_3	r_4	m_1_ds_2[2] ...	2889.5160	...

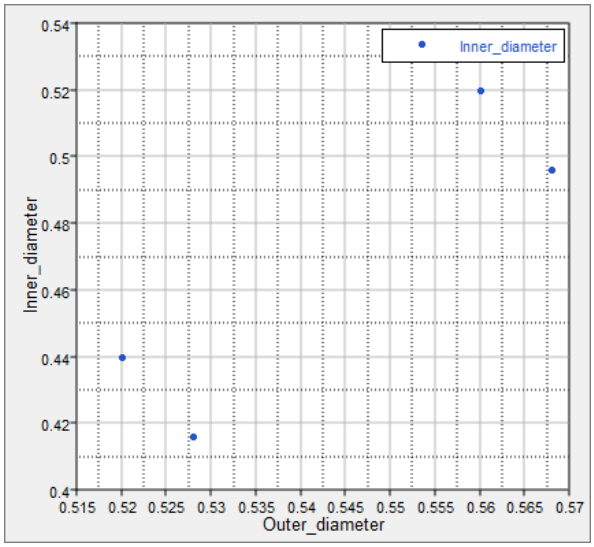
7. Click ***OK***. This complete the study setup.

Step 4: Run a Modified Extensible Lattice Sequence DOE Study, with 4 Runs

1. In the **Explorer**, right-click and select ***Add*** from the context menu.
2. In the **Add - HyperStudy** dialog, select ***Doe*** and click ***OK***.
3. Go to the **Specifications** step.

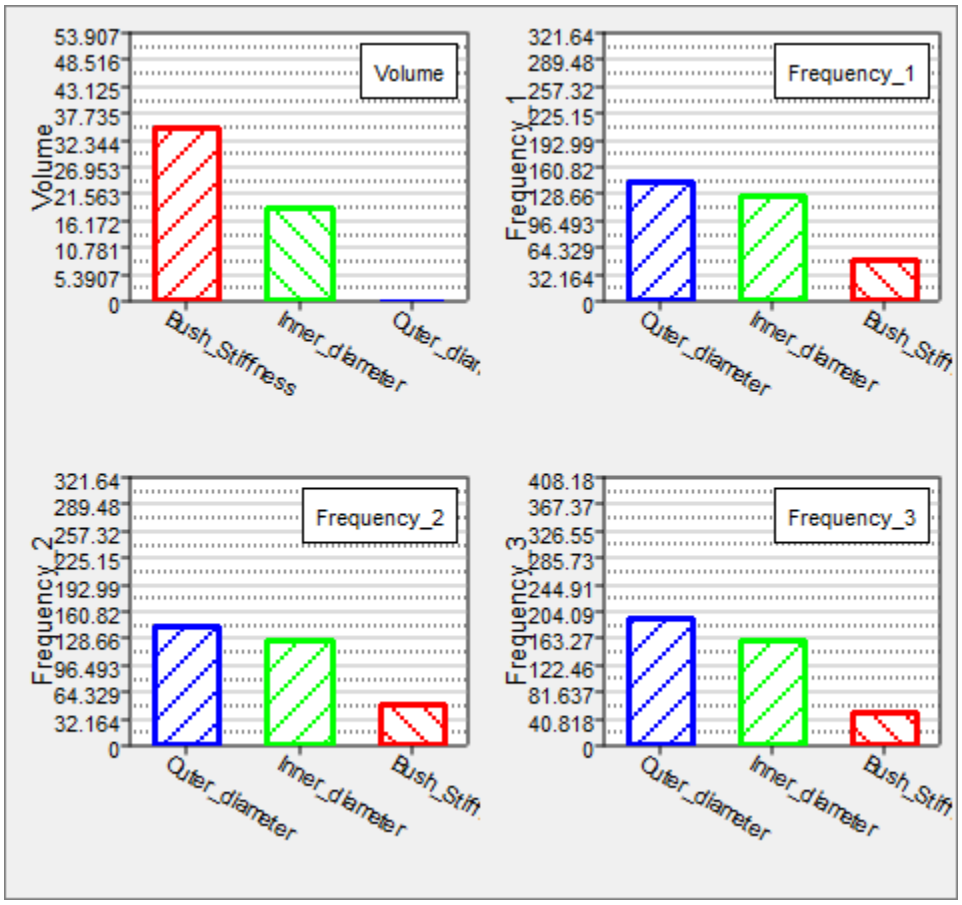
4. In the work area, set the **Mode** to ***Modified Extensible Lattice Sequence***.
5. In the **Settings** tab, change the **Number of runs** to 4, which is the minimum number of runs for a multivariate effects calculation.
6. Click ***Apply***.
7. Go to the **Evaluate** step.
8. Click ***Evaluate Tasks***.
9. Go to the **Post-Processing** step, and click the ***Scatter*** tab. Using the **Channel** selector, set the **X Axis** to ***Outer_diameter*** and the **Y Axis** to ***Inner_diameter***.

   All four runs satisfy the constraint, which is inner_radius < outer_radius.



10. Click the ***Pareto Plot*** tab, and note which input variables contribute to which output responses.

    Above the **Channel** selector, click and verify **Multivariate effects** is selected.

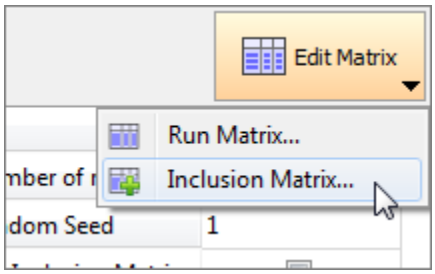


Step 5: Extend DOE with 7 Additional Runs

In this step you will run a second Modified Extensible Lattice Sequence DOE study with 7 new runs, and include the 4 runs from DOE1. This DOE will have a total of 11 runs, which is the default suggested number of runs for a MELS DOE with three input variables.

which is the minimum suggested number of runs for three input variables.

1. In the **Explorer**, right-click and select ***Add*** from the context menu.
2. In the **Add - HyperStudy** dialog, select ***Doe*** and click ***OK***.
3. Go to the **Specifications** step.
4. In the work area, set the **Mode** to ***Modified Extensible Lattice Sequence***.
5. In the **Settings** tab:
   a. Change the **Number of runs** to 7.
   b. Select the ***Use Inclusion Matrix*** checkbox.
6. Import run data from the DOE 1 using an Inclusion Matrix.
   a. Click ***Edit Matrix*** > ***Inclusion Matrix*** from the top, right corner of the work area.



b. In the **Edit Inclusion Matrix** dialog, click ***Import Values***.

c. In the **Import Values** dialog, select ***Approach Evaluation Data*** and click ***Next***.

d. Set approach to ***DOE 1***.

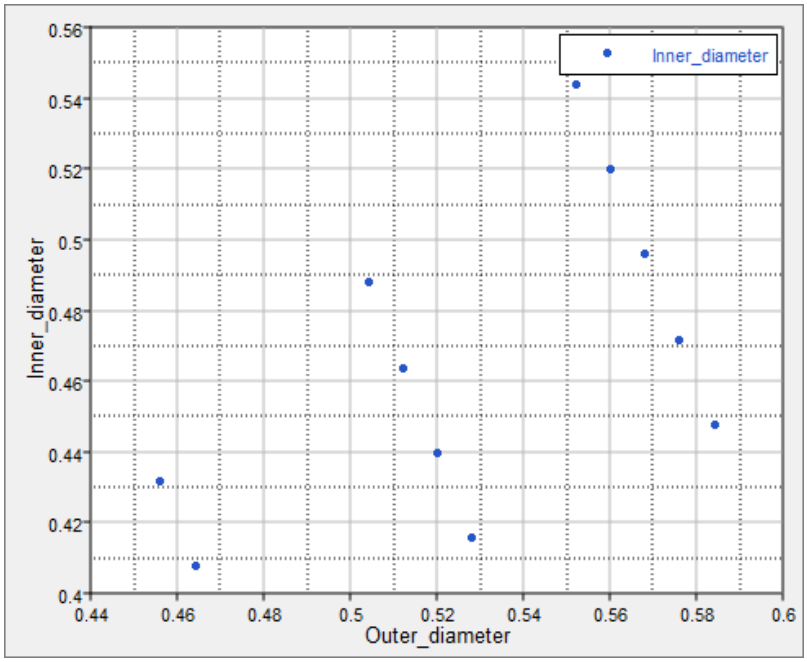
e. Click ***Next***.

f. Click ***Finish***.

g. Review the imported run data and click ***OK***.

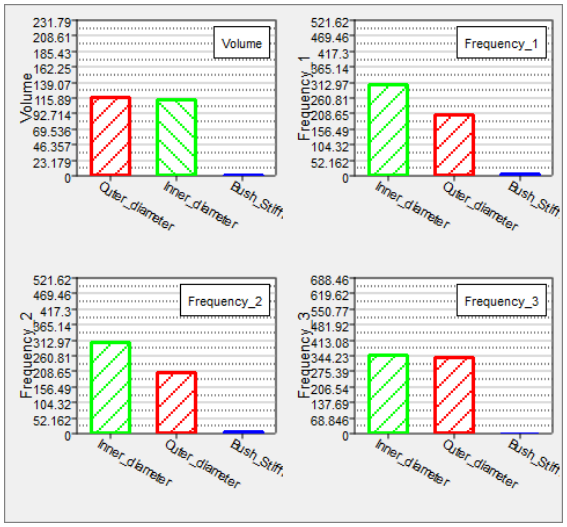
7. Click ***Apply***.
8. Go to the **Evaluate** step.
9. Click ***Evaluate Tasks***.
10. Go to the **Post-Processing** step, and click the ***Scatter*** tab. Using the **Channel** selector, set the **X Axis** to ***Outer_diameter*** and the **Y Axis** to ***Inner_diameter***.

    Note that all 11 runs still satisfy the constraint, which is inner_radius < outer_radius.

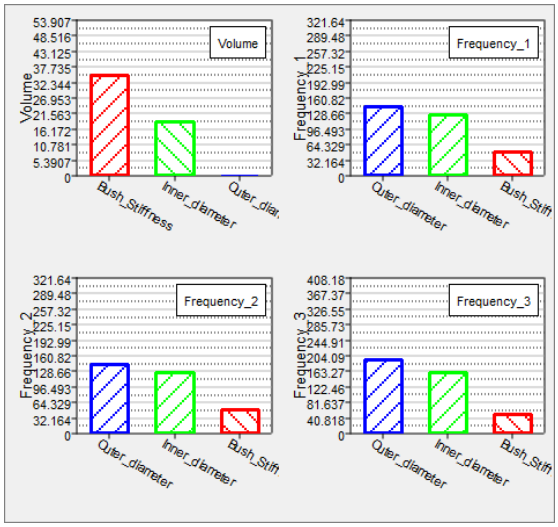


11. Click the ***Pareto Plot*** tab, and compare the results to the Pareto Plot from DOE 1.

    Note that the magnitude and order of importance has changed in some cases.



Pareto Plot from DOE2

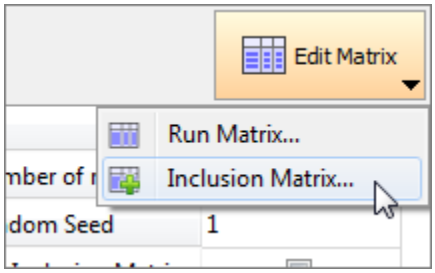


Pareto Plot from DOE1

Step 6: Extend DOE with 4 Additional Runs

In this step you will run a third Modified Extensible Lattice Sequence DOE study with 4 new runs, and include the 11 runs from DOE 2. This DOE will have a total of 15 runs, which exceeds the number of suggested runs.

1. In the **Explorer**, right-click and select ***Add*** from the context menu.
2. In the **Add - HyperStudy** dialog, select ***Doe*** and click ***OK***.
3. Go to the **Specifications** step.
4. In the work area, set the **Mode** to ***Modified Extensible Lattice Sequence***.
5. In the **Settings** tab:
   a. Change the **Number of runs** to 4.
   b. Select the ***Use Inclusion Matrix*** checkbox.
6. Import run data from the DOE 2 using an Inclusion Matrix.
   a. Click ***Edit Matrix*** > ***Inclusion Matrix*** from the top, right corner of the work area.



   b. In the **Edit Inclusion Matrix** dialog, click ***Import Values***.
   c. In the **Import Values** dialog, select ***Approach Evaluation Data*** and click ***Next***.

d. Set the approach to ***DOE 2***.

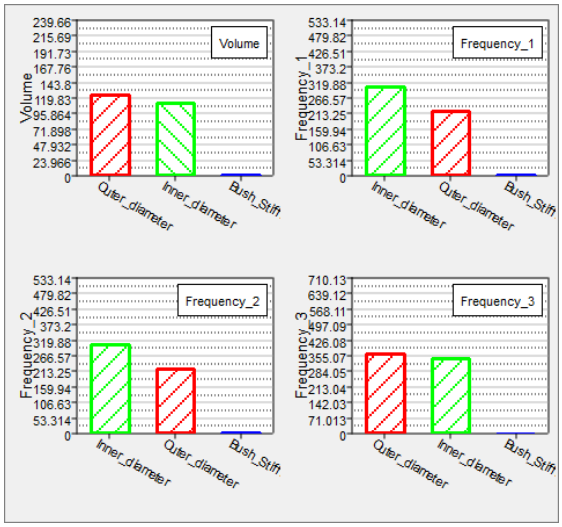
e. Click ***Next***.

f. Click ***Finish***.

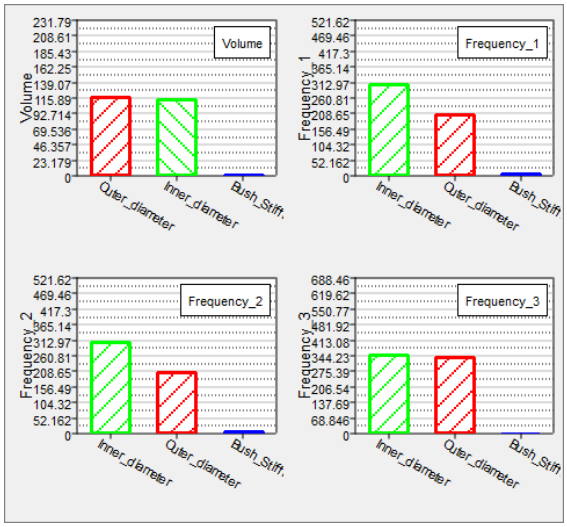
g. Review the imported run data and click ***OK***.

7. Click ***Apply***.
8. Go to the **Evaluate** step.
9. Click ***Evaluate Tasks***.
10. Go to the **Post-Processing** step, and click the ***Pareto Plot*** tab. Compare the results to the Pareto Plots from DOE 2.

    Note that the results are qualitatively the same, indicating that you will likely have enough runs to draw solid conclusions.



Pareto Plot from DOE3



Pareto Plot from DOE2