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HyperWorks

# Altair HyperStudy 2019 Tutorials

## HS-4230: Optimization Study with Discrete Variables

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# HS-4230: Optimization Study with Discrete Variables

In this tutorial you will learn how to use discrete variables. The sample base input template `plate.tpl` can be found in `<hst.zip>/HS-4230/`and copied to your working directory.

The objective of this tutorial is to maximize the minimum frequency of the first five modes of a plate. The input variables are the thickness of each of the three components, defined in the input deck via the PSHELL card. The thickness should be between 0.05 and 0.15; the initial thickness within the files is 0.1. The optimization type is size. Furthermore, optimum design should have input variables from a discrete set of 0.05, 0.08, 0.11, and 0.14 for all three thicknesses. By default, HyperStudy will add the values from the lower and upper bounds to this set. Hence the resulting set is 0.05, 0.08, 0.11, 0.14, and 0.15. Delete any of these values if needed.

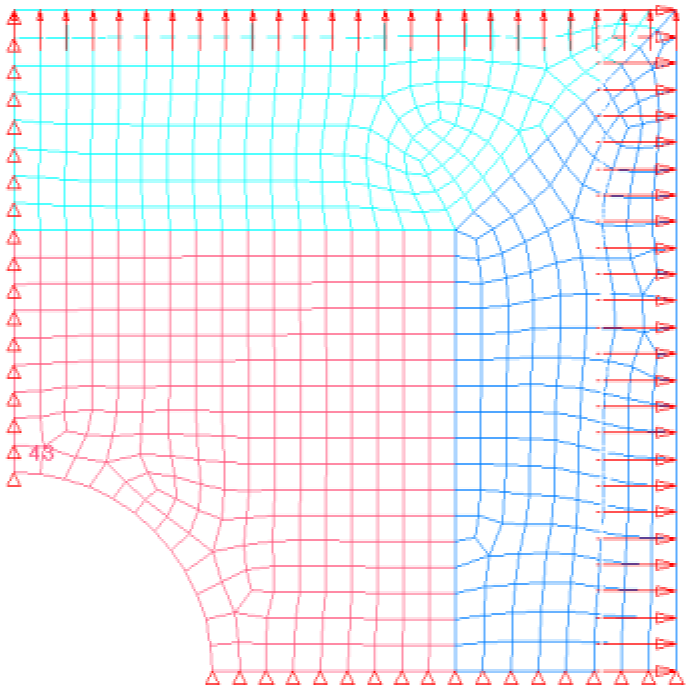
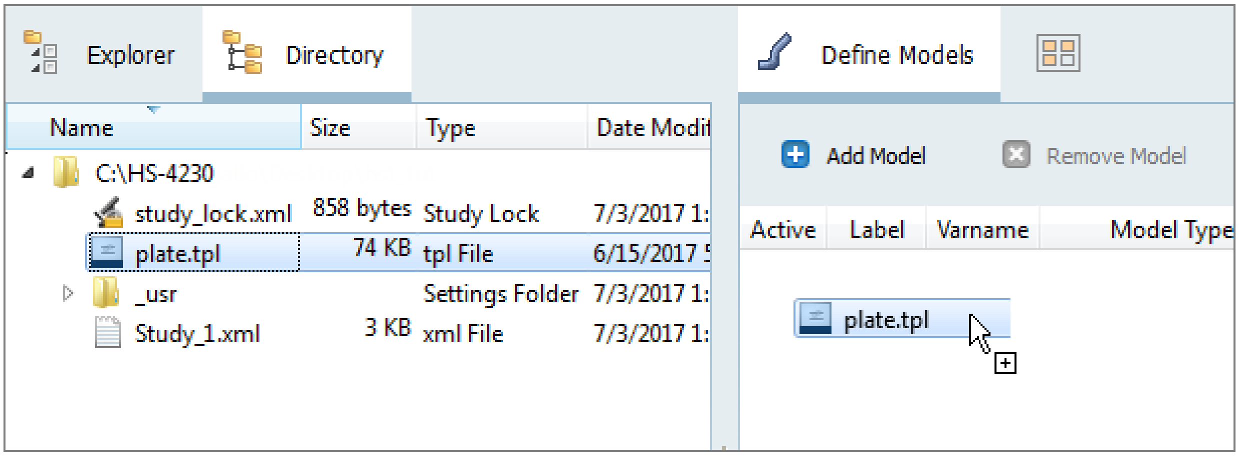


Figure 1: Double Symmetric Plate Model

## Step 1: Perform the Study Setup

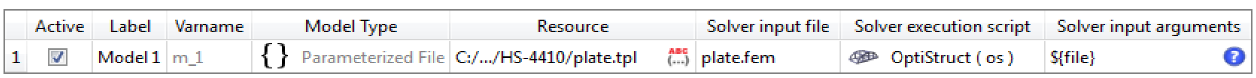
1. Start HyperStudy.
2. To start a new study, click ***File*** > ***New*** from the menu bar, or click on the toolbar.
3. In the **HyperStudy – Add** dialog, enter a study name, select a location for the study, and click ***OK***.
4. Go to the **Define models** step.
5. Add a Parameterized File model.

a. From the **Directory**, drag-and-drop the `plate.tpl` file into the work area.

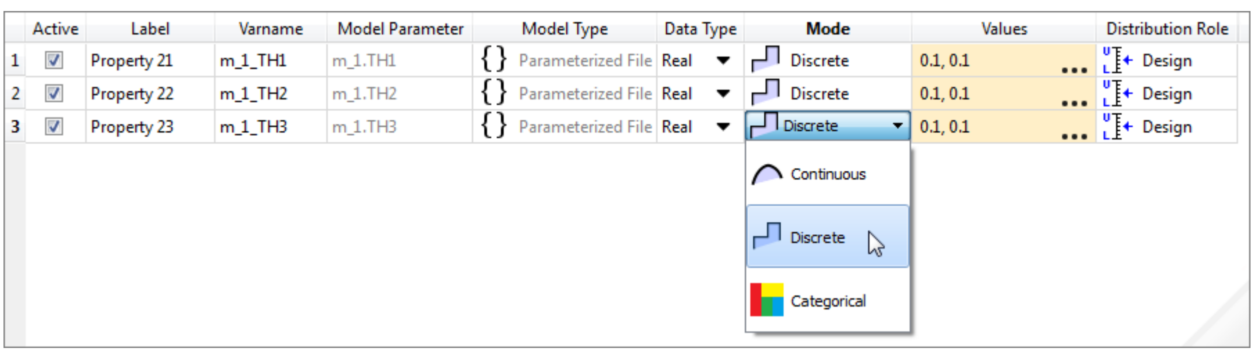



b. In the **Solver input file** column, enter `plate.fem`. This is the name of the solver input file HyperStudy writes during any evaluation.

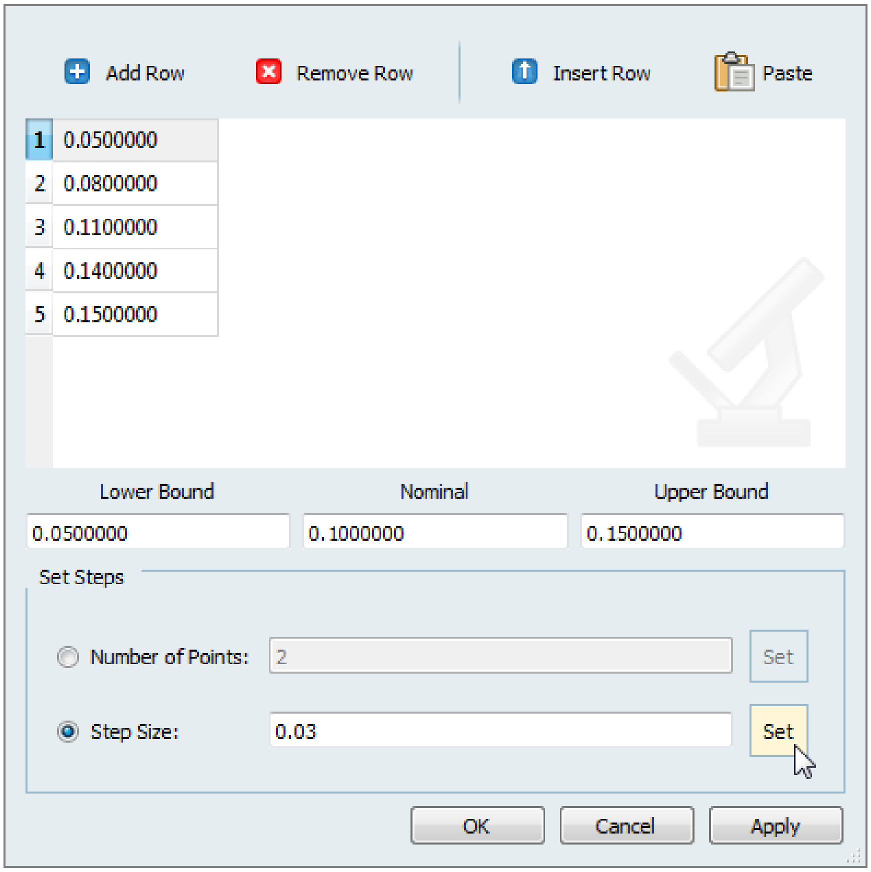
c. In the **Solver execution script** column, select ***OptiStruct (os)***.




6. Click ***Import Variables***. Three input variables are imported from the `plate.tpl` file.
7. Go to the **Define Input Variables** step.
8. Click the ***Modes*** tab.
9. In the **Mode** column of all three input variables, select ***Discrete***.




10. In the **Values** column of **Property 21**, click **...**.
11. Click ***Step Size***, enter `0.03`, and click ***Set***.




12. Click ***Apply***.
13. Click ***OK***.
14. Repeat steps 10 through 13 for **Property 22** and **Property 23**.
15. 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. The `approaches/nom_1/run__00001/m_1` sub-directory contains the `plate.out` file, which is the result of the nominal run, and will be used in the Optimization.
5. Go to the **Define Output Responses** step.

## Step 3: Create and Define Output Responses

1. Create the Freq1 output response.

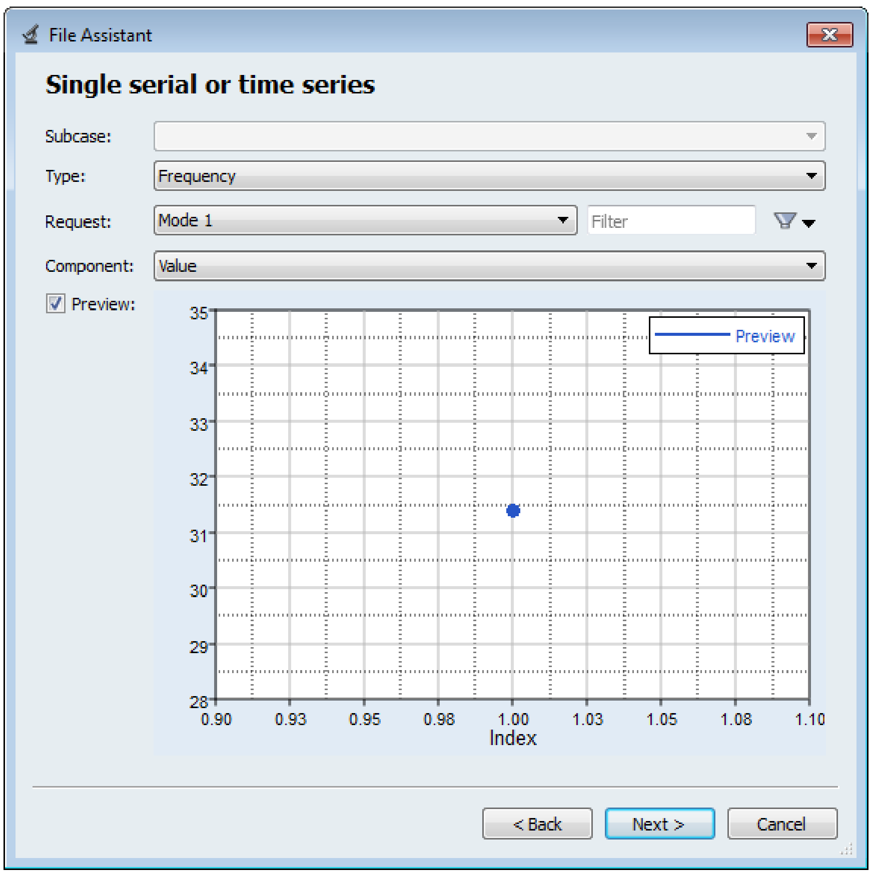
   a. From the **Directory**, drag-and-drop the `plate.out` file, located in `approaches/nom_1/run_00001/m_1`, into the work area.

   b. In the **File Assistant** dialog, set the **Reading technology** to ***Altair® HyperWorks®*** 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 ***Frequency***.
   - Set **Request** to ***Mode 1***.
   - Set **Component** to ***Value***.




   e. Label the output response `Freq1`.

   f. Set **Expression** to ***First Element***.

   g. Click ***Finish***. The Freq1 output response is added to the work area.

2. Create the Volume output response.
   a. From the **Directory**, drag-and-drop the `plate.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®*** 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 ***First Element***.
   g. Click ***Finish***. The Volume output response is added to the work area.
3. Click ***Evaluate*** to extract the output response values.

| | Active | Label | Varname | Expression | Value | Comment |
|---|---|---|---|---|---|---|
| 1 | ☑ | Freq1 | m_1_r_1 | m_1_ds_1[0] ... | Not Extracted | Data Source 1 ... |
| 2 | ☑ | Volume | m_1_r_2 | m_1_ds_2[0] ... | Not Extracted | Data Source 2 ... |

## Step 4: Run an Optimization Study

1. In the **Explorer**, right-click and select ***Add*** from the context menu.
2. In the **Add - HyperStudy** dialog, select ***Optimization*** and click ***OK***.
3. Go to the **Select Input Variables** step.
4. Review the input variable's lower and upper bound ranges.
5. Go to the **Select Output Responses** step.
6. Click ***Add Objective***.
7. In the **Add - HyperStudy** dialog, add one objective.
8. Define the objective.
   a. Set **Type** to ***Minimize***.
   b. Set **Apply On** to ***Volume (r_2)***.

| | Active | Label | Varname | Type | Apply On | Evaluate From |
|---|---|---|---|---|---|---|
| 1 | ☑ | Objective 1 | obj_1 | Minimize | Volume ( r_2 ) | SOLVER |

9. Click the ***Constraint*** tab.
10. Click ***Add Constraint***.
11. In the **Add - HyperStudy** dialog, add one constraint.
12. Define the constraint.
    a. Set **Apply On** to ***Freq1 (r_1)***.
    b. Set **Bound Type** to **>=** (greater than or equal to).
    c. For **Bound Value**, enter `32`.

| | Active | Label | Varname | Type | Apply On | Bound Type | Bound Value |
|---|---|---|---|---|---|---|---|
| 1 | ☑ | Constraint 1 | c_1 | Deterministic | Freq1 ( r_1 ) | >= | 32.000000 |

13. Click ***Apply***.
14. Go to the **Specifications** step.
15. In the work area, set the **Mode** to ***Adaptive Response Surface Method (ARSM)***.

    **Note:** Only the methods that are valid for the problem formulation are enabled.

16. Click ***Apply***.
17. Go to the **Evaluate** step.
18. Click ***Evaluate Tasks***.

## Step 5: View the Iteration History of an Optimization Study

1. Click the ***Iteration History*** tab to monitor the progress of the Optimization iteration.

| | Property 21 | Property 22 | Property 23 | Freq1 | Volume | Objective 1 | Constraint 1 | Iteration | StepIndex | StepMa |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0500000 | 0.0500000 | 0.0500000 | 15.697810 | 116.19200 | 116.19200 | **15.697810** | 1 | 1 | 1 |
| 2 | 0.0800000 | 0.0500000 | 0.0500000 | 23.938540 | 144.24100 | 144.24100 | **23.938540** | 2 | 2 | 2 |
| 3 | 0.0500000 | 0.0800000 | 0.0500000 | 16.920270 | 137.02600 | 137.02600 | **16.920270** | 3 | 3 | 3 |
| 4 | 0.0500000 | 0.0500000 | 0.0800000 | 16.919700 | 137.02600 | 137.02600 | **16.919700** | 4 | 4 | 4 |
| 5 | 0.0800000 | 0.0800000 | 0.0800000 | 25.115920 | 185.90800 | 185.90800 | **25.115920** | 5 | 5 | 5 |
| 6 | 0.1100000 | 0.0500000 | 0.0800000 | 33.327920 | 193.12300 | 193.12300 | 33.327920 | 6 | 6 | 6 |
| 7 | 0.1100000 | 0.0500000 | 0.0500000 | 34.453890 | 172.29000 | 172.29000 | 34.453890 | 7 | 7 | 7 |

## Step 6: Setup a DOE to Find the True Best Design

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 ***Full Factorial***.
5. Click ***Apply***.
6. Go to the **Evaluate** step.
7. Click ***Evaluate Tasks***.
8. Go to the **Post processing** step.
9. Click the ***Summary*** tab.
10. Sort run data based on the Volume (which was to be minimized) by right-clicking on the ***Volume*** column and selecting ***Sort down*** from the context menu. The lowest volume design which satisfies the constraint (frequency > 32) is the same as that found by the optimizer.

    **Note:** The DOE took 125 solver calls to exhaust all combinations, whereas the Optimization found it in 8 solver calls.

| | Property 21 | Property 22 | Property 23 | Freq1 | Volume |
|---|---|---|---|---|---|
| 1 | 0.0500000 | 0.0500000 | 0.0500000 | 15.697810 | 116.19200 |
| 2 | 0.0500000 | 0.0500000 | 0.0800000 | 16.919700 | 137.02600 |
| 6 | 0.0500000 | 0.0800000 | 0.0500000 | 16.920270 | 137.02600 |
| 26 | 0.0800000 | 0.0500000 | 0.0500000 | 23.938540 | 144.24100 |
| 3 | 0.0500000 | 0.0500000 | 0.1100000 | 17.302520 | 157.85900 |
| 7 | 0.0500000 | 0.0800000 | 0.0800000 | 19.933730 | 157.85900 |
| 11 | 0.0500000 | 0.1100000 | 0.0500000 | 17.302470 | 157.85900 |
| 27 | 0.0800000 | 0.0500000 | 0.0800000 | 24.038070 | 165.07400 |
| 31 | 0.0800000 | 0.0800000 | 0.0500000 | 24.039250 | 165.07400 |
| 51 | 0.1100000 | 0.0500000 | 0.0500000 | 34.453890 | 172.29000 |
| 4 | 0.0500000 | 0.0500000 | 0.1400000 | 17.073410 | 178.69200 |
| 8 | 0.0500000 | 0.0800000 | 0.1100000 | 21.839230 | 178.69200 |