



Altair

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**HyperWorks**

## HS-1035: Optimization Study Using an Excel Spreadsheet

In this tutorial, you will learn how to:

- Couple HyperStudy with a spreadsheet.
- Identify input variables and output responses.
- Set up an Optimization study.
- Analyze Optimization results.

Problem formulation:

- Find the cross-sectional dimension's width and height in mm.
- Minimize the beam volume such that the tip deflection  $< 0.53$  mm.


The Excel spreadsheet used in this tutorial can be found in `<hst.zip>/HS-1035/`. Copy the file from this directory to your working directory.

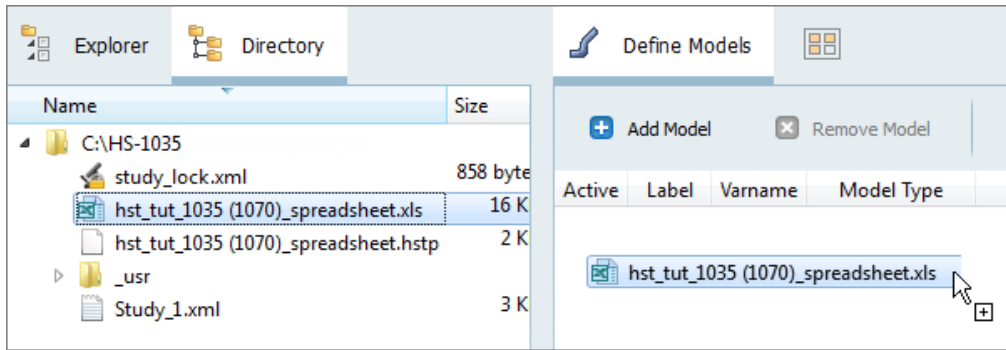
### Step 1: Review the Excel Spreadsheet

1. In Excel, open the `hst_tut_1035(1070)_spreadsheet.xls` file.
2. Review the information, and locate the columns that contain the input variables and output responses.

**Note:** When you create an Excel spreadsheet model, it is important that the spreadsheet is formatted correctly. A variable's value and label can be formatted in two consecutive rows or two consecutive columns. Variable labels should only contain English characters, or a combination of English characters and numbers. If a label is not created for a variable, HyperStudy will assign one by default.

### Step 2: Perform the Study Setup

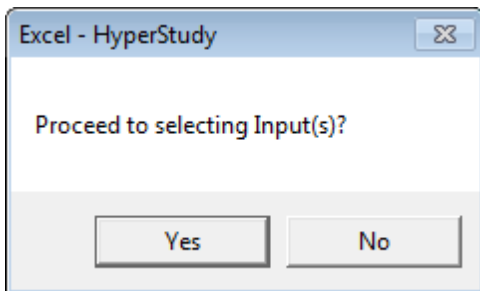
1. Start HyperStudy.
2. To start a new study, click **File** > **New** from the menu bar, or click  on the toolbar.
3. In the **HyperStudy – Add** dialog, enter a study name, select a location for the study, and click **OK**.
4. Go to the **Define Models** step.
5. Add a Spreadsheet model by dragging-and-dropping the `hst_tut_1035(1070)_spreadsheet.xls` file from the **Directory** into the work area.



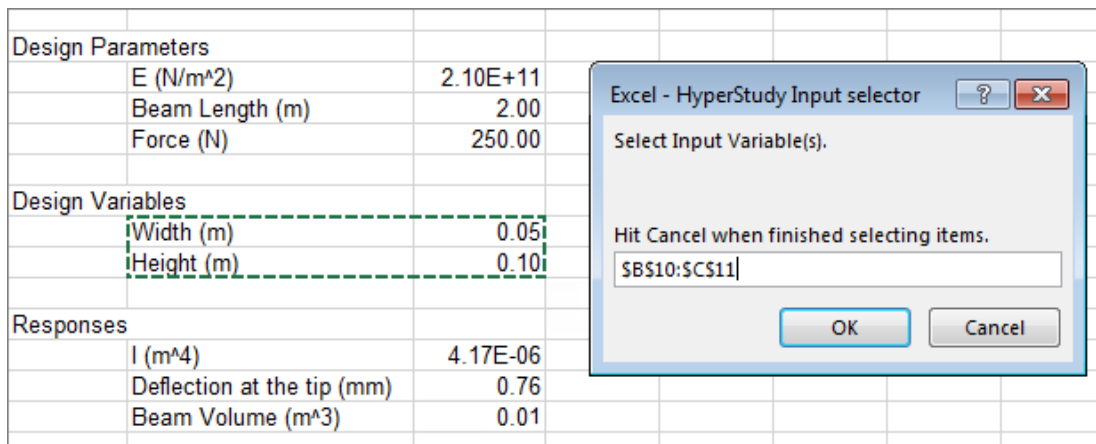
The **Resource**, **Solver input file**, and **Solver input arguments** fields become populated. The **Solver input file** field displays `hst_input.hstp`, this is the name of the solver input file HyperStudy writes during an evaluation.

| Active | Label                               | Varname    | Model Type  | Resource                                       | Solver input file | Solver execution script       | Solver input arguments |
|--------|-------------------------------------|------------|-------------|--|-------------------|-------------------------------|------------------------|
| 1      | <input checked="" type="checkbox"/> | Model1_m_1 | Spreadsheet | C:/HS-1035/hst_tut_1035 (1070)_spreadsheet.xls | hst_input.hstp    | Spreadsheet (SpreadSheet_HST) |                        |

6. Click **Import Variables**. The `hst_tut_1035 (1070)_spreadsheet.xls` spreadsheet opens.
7. Add input variables.
  - a. In the **Excel - HyperStudy** dialog, click **Yes** to begin selecting input variables.

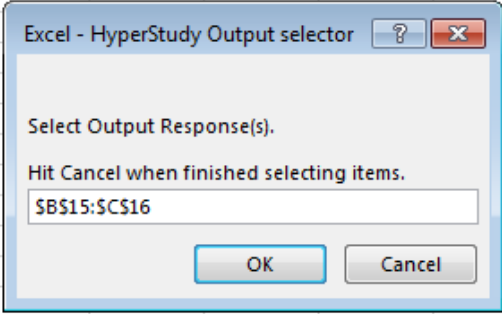


- b. In the spreadsheet, select the cells that contain the input variable's labels and values.



- c. In the **Excel - HyperStudy Input selector** dialog, click **OK**.
  - d. Click **Cancel** to stop selecting input variables.
8. Add output responses.
- a. In the **Excel - HyperStudy** dialog, click **Yes** to begin selecting output responses.
  - b. In the spreadsheet, select the cells that contain the output response's labels and values.

| Design Parameters             |          |
|-------------------------------|----------|
| E (N/m <sup>2</sup> )         | 2.10E+11 |
| Beam Length (m)               | 2.00     |
| Force (N)                     | 250.00   |
| Design Variables              |          |
| Width (m)                     | 0.05     |
| Height (m)                    | 0.10     |
| Responses                     |          |
| I (m <sup>4</sup> )           | 4.17E-06 |
| Deflection at the tip (mm)    | 0.76     |
| Beam Volume (m <sup>3</sup> ) | 0.01     |



- c. In the **Excel - HyperStudy Output selector** dialog, click **OK**.
  - d. Click **Cancel** to stop selecting output responses. Two input variables and two output responses are imported from the `hst_tut_1070_spreadsheet.xls` spreadsheet.
9. Go to the **Define Input Variables** step.
  10. Review the input variable's lower and upper bound ranges.
  11. Go to the **Specifications** step.

### Step 3: 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 `approach/nom_1/` directory is created inside the study directory. The `approaches/nom_1/run__00001/m_1` directory contains the `sse_output.csv` file, which is the result of the nominal run.
5. Go to the **Define Output Responses** step.

## Step 4: Create and Define Output Responses

Review the output responses imported into the study. The output responses were extracted from the `hst_output.hstp` file, which HyperStudy created for each run.

|   | Active                              | Label                      | Varname | Expression  | Value     |
|---|-------------------------------------|----------------------------|---------|-------------|-----------|
| 1 | <input checked="" type="checkbox"/> | Deflection at the tip (mm) | r_1     | ds_1[0] ... | 0.7619048 |
| 2 | <input checked="" type="checkbox"/> | Beam Volume (m^3)          | r_2     | ds_2[0] ... | 0.0100000 |

## Step 5: Run an Optimization Study

- In the **Explorer**, right-click and select **Add** from the context menu.
- In the **Add - HyperStudy** dialog, select **Optimization** and click **OK**.
- Go to the **Select Input Variables** step.
- Apply a set range of +17% to both input variable's lower and upper bounds.
  - In the **Lower Bound** column of both input variables, click **...**.
  - Under **Set Range**, in the **Percent** field, enter +17.
  - Click the **+/-** button.
  - Click **Apply**.

|   | Active                              | Label      | Varname | Lower Bound   | Nominal       | Upper Bound   |
|---|-------------------------------------|------------|---------|---------------|---------------|---------------|
| 1 | <input checked="" type="checkbox"/> | Width (m)  | var_1   | 0.0415000 ... | 0.0500000 ... | 0.0585000 ... |
| 2 | <input checked="" type="checkbox"/> | Height (m) | var_2   | 0.0830000 ... | 0.1000000 ... | 0.1170000 ... |

- Go to the **Select Output Responses** step.
- Add an objective to the Beam Volume (m^3) output response.
  - In the **Objectives** column of Beam Volume (m^3), click **+**.
  - In the pop-up window, set **Type** to **Minimize** and click **OK**.

|   | Active                              | Label                      | Varname | Objectives   | Constraints                         | Evaluate From | Expression |
|---|-------------------------------------|----------------------------|---------|--------------|-------------------------------------|---------------|------------|
| 1 | <input checked="" type="checkbox"/> | Deflection at the tip (mm) | r_1     |              | <input checked="" type="checkbox"/> | Solver        | ds_1[0]    |
| 2 | <input checked="" type="checkbox"/> | Beam Volume (m^3)          | r_2     | Minimize ... | <input checked="" type="checkbox"/> | Solver        | ds_2[0]    |

- Add a constraint on the Deflection at the tip (mm) output response.
  - In the **Constraints** column of Deflection at the tip (mm), click **+**.
  - In the pop-up window, define the following and click **OK**.
    - Set **Bound Type** to **<=** (less than or equal to).
    - For **Bound Value**, enter 0.53.

| Active                              | Label                         | Varname | Objectives                          | Constraints                         | Evaluate From | Expression |
|-------------------------------------|-------------------------------|---------|-------------------------------------|-------------------------------------|---------------|------------|
| <input checked="" type="checkbox"/> | Deflection at the tip (mm)    | r_1     | <input checked="" type="checkbox"/> | $\leq 0.5300000$ ...                | Solver        | ds_1[0]    |
| <input checked="" type="checkbox"/> | Beam Volume (m <sup>3</sup> ) | r_2     | Minimize ...                        | <input checked="" type="checkbox"/> | Solver        | ds_2[0]    |

8. Click **Apply**.
9. Go to the **Specifications** step.
10. In the work area, set the **Mode** to **Adaptive Response Surface Method (ARSM)**.

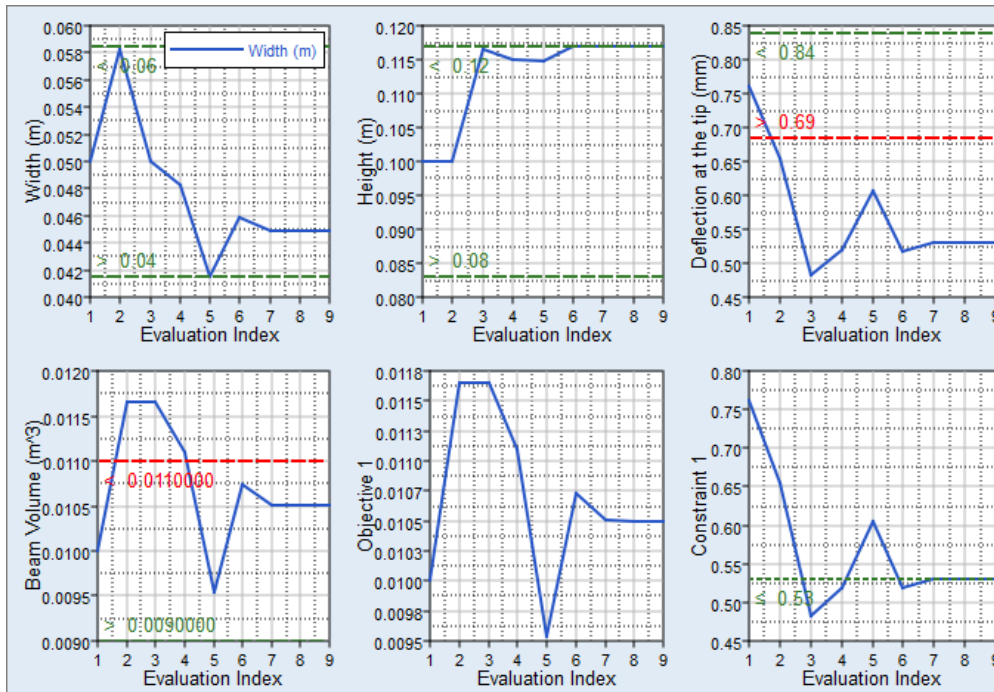
**Note:** Only the methods that are valid for the problem formulation are enabled.

11. Click **Apply**.
12. Go to the **Evaluate** step.
13. Click **Evaluate Tasks**.
14. Optional.

- To stop the optimization, click .
- To monitor the progress of the Optimization, click the **Task** tab.

**Step 6: View the Evaluation Data and Plot of an Optimization Approach**

Use the **Evaluation Data** and **Evaluation Plot** tabs to review the values of input variables, output responses, objective functions, and constraints for all runs evaluated during the optimization.



### Step 7: View the Iteration History and Plot of an Optimization Approach

Use the **Iteration History** and **Iteration Plot** tabs to review the values of input variables, output responses, objective function, and constraints for each iteration during the optimization.

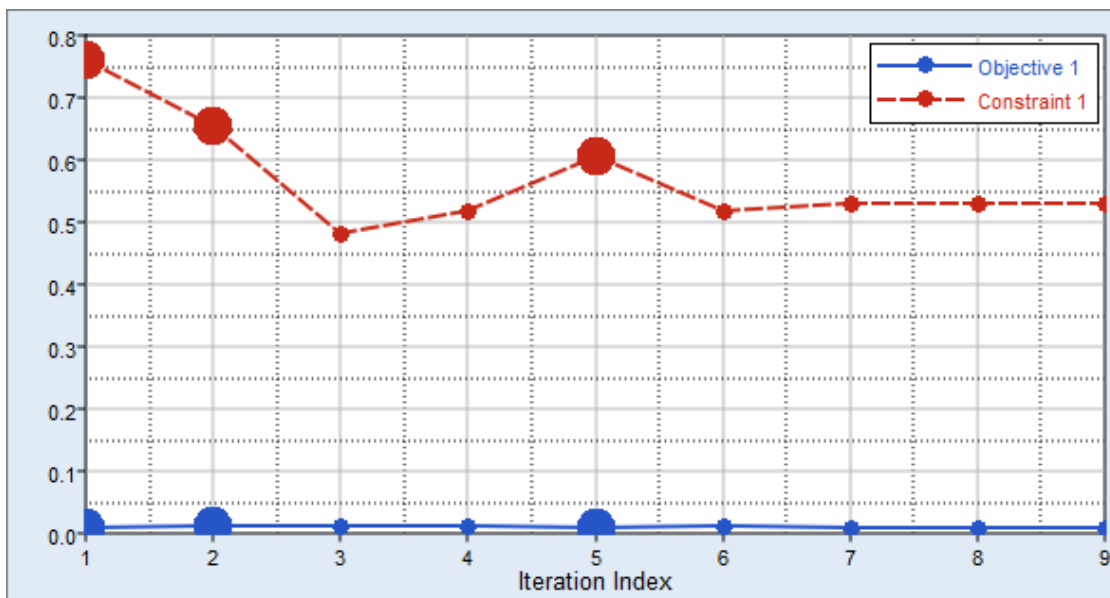
1. Click the **Iteration History** tab to view the iteration history results in a table.


As this study was run with ARSM, you will see the same designs in both the Evaluation Data and Iteration History. From the iteration table, you can see that iterations 1, 2, and 5 are displayed in a red font, which indicates that these iterations have a constraint violation. The constraint that is violated, Constraint 1, is displayed in a red, bold font. Iterations 3, 4, and 6-8 are feasible, but not optimal designs. The ninth iteration, highlighted in green, indicates that this design is the optimal design.

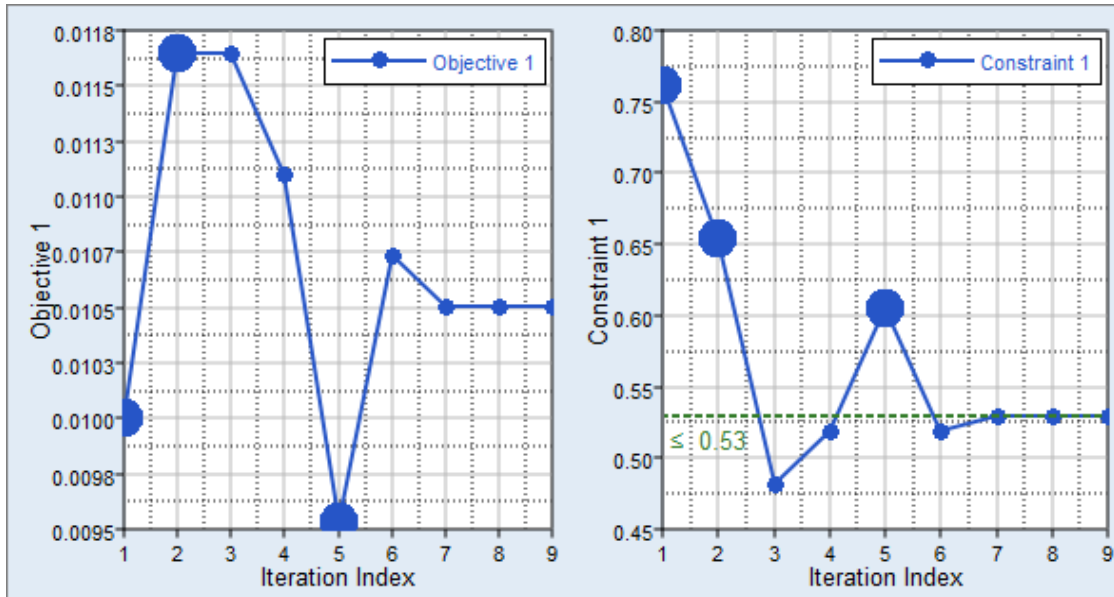
|   | Width (m) | Height (m) | Deflection at the tip (mm) | Beam Volume (m <sup>3</sup> ) | Objective 1 | Constraint 1     | Iteration |
|---|-----------|------------|----------------------------|-------------------------------|-------------|------------------|-----------|
| 1 | 0.0500000 | 0.1000000  | 0.7619048                  | 0.0100000                     | 0.0100000   | <b>0.7619048</b> | 1         |
| 2 | 0.0582500 | 0.1000000  | 0.6539955                  | 0.0116500                     | 0.0116500   | <b>0.6539955</b> | 2         |
| 3 | 0.0500000 | 0.1165000  | 0.4818623                  | 0.0116500                     | 0.0116500   | 0.4818623        | 3         |
| 4 | 0.0482661 | 0.1150000  | 0.5189614                  | 0.0111012                     | 0.0111012   | 0.5189614        | 4         |
| 5 | 0.0415000 | 0.1148652  | 0.6056987                  | 0.0095338                     | 0.0095338   | <b>0.6056987</b> | 5         |
| 6 | 0.0458771 | 0.1170000  | 0.5184621                  | 0.0107352                     | 0.0107352   | 0.5184621        | 6         |
| 7 | 0.0448812 | 0.1170000  | 0.5299670                  | 0.0105022                     | 0.0105022   | 0.5299670        | 7         |
| 8 | 0.0448795 | 0.1170000  | 0.5299870                  | 0.0105018                     | 0.0105018   | 0.5299870        | 8         |
| 9 | 0.0448790 | 0.1170000  | 0.5299922                  | 0.0105017                     | 0.0105017   | 0.5299922        | 9         |

2. Click the **Iteration Plot** tab to view the iteration history results in a plot.

Use the **Channel** selector to select **Objective 1** and **Constraint 1**.



- To view a single plot that contains the iteration history of **Objective 1** and **Constraint 1**, click . In the Objective plot, infeasible designs are identified with bigger markers. In the Constraint plot, you can see these designs have higher displacement value than the constraint bound of 0.53 and only the last three designs meet the constraint bound.



Last modified: v2017.2 (12.1156684)