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**HyperWorks**

## HS-5000: Stochastic Method Comparison and Reliability-Based Design Optimization of the Arm Model

Continuing from tutorial HS-4000: Optimization Method Comparison: Arm Model Shape Optimization, you will perform Stochastic studies and a Reliability-Based Design Optimization (RBDO) using the same fitting function. You will run a Stochastic study around the nominal point.

Before running this tutorial, complete tutorial Tutorial HS-4000: Optimization Method Comparison: Arm Model Shape Optimization. You can also import the archive file `HS-4000.hstx`, available in `<hst.zip>/HS-5000/`.

In the Stochastic study, you will be using a Hammersley distribution successively with 100, 300, and 1000 runs in order to compare the convergence of statistical results. You defined all six input variables as random variables following a normal distribution.

### Step 1: Run a Stochastic Study

In this step, you will check the robustness of the optimal solution found with GRSM.

1. In the **Explorer**, right-click and select **Add** from the context menu.
2. In the **Add - HyperStudy** dialog, select **Stochastic** and click **OK**.
3. Go to the **Select Input Variables** step.
4. In the **Active** column, clear the **radius\_1**, **radius\_2** and **radius\_3** check boxes.

	Active	Label	Varname	Low
1	<input checked="" type="checkbox"/>	length_1	m_1_length_1	-0.500
2	<input checked="" type="checkbox"/>	length_2	m_1_length_2	0.000
3	<input checked="" type="checkbox"/>	length_3	m_1_length_3	-1.000
4	<input checked="" type="checkbox"/>	length_4	m_1_length_4	-1.000
5	<input checked="" type="checkbox"/>	length_5	m_1_length_5	-1.000
6	<input type="checkbox"/>	radius_1	m_1_radius_1	-2.000
7	<input type="checkbox"/>	radius_2	m_1_radius_2	-0.500
8	<input type="checkbox"/>	radius_3	m_1_radius_3	-0.500
9	<input checked="" type="checkbox"/>	height	m_1_height	-1.000

5. In the **Nominal** column, copy the parameter values at the optimal design.

For Stochastic studies, you must provide data about the standard variation  $\sigma$  (or variance  $\sigma^2$ ) of parameters in order to take into account uncertainties. By default,  $\sigma^2$  is computed in HyperStudy using the range rule  $\sigma^2 = ((\text{Upper Bound} - \text{Lower Bound})/4)^2$  which is a function of the input variable's bounds. If you do not have reliable data about the standard deviation, the default  $\sigma^2$  can be modified by changing the upper and lower bounds of the parameters.

- a. Go to the GRSM, 6 IV, Exact Solver Optimization, **Evaluate** step, **Iteration History** tab, and copy the length\_1, length\_2, length\_3, length\_4, and length\_5 parameter values.

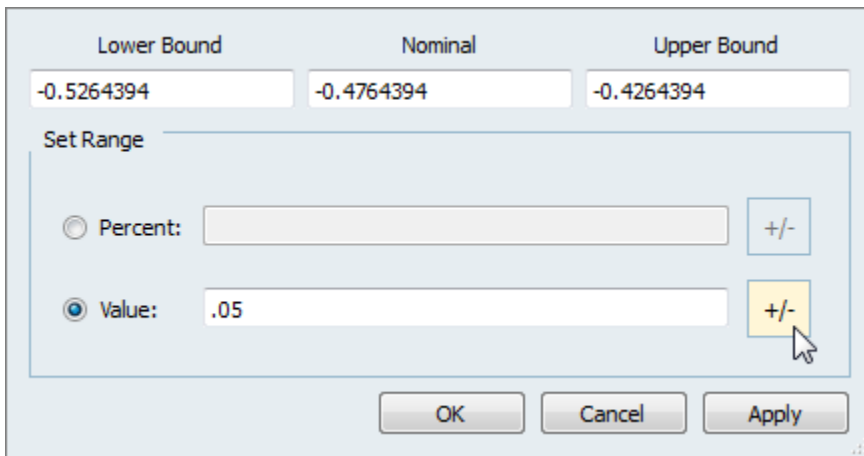
	length_1	length_2	length_3	length_4	length_5	h
1	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.00000
2	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.00000
3	-0.4992779	0.0016672	-0.9912966	0.0498490	0.7815539	0.99908
4	-0.4291008	5.86e-04	-0.9886176	0.2059647	0.4663968	0.99951
5	-0.2325116	1.34e-04	-0.9993315	0.3377470	0.2309717	0.99995
6	-0.2325116	1.34e-04	-0.9993315	0.3377470	0.2309717	0.99995
7	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
8	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
9	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
10	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
11	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
12	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
13	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
14	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000
15	-0.4764394	0.0000000	-1.0000000	0.4958683	0.0347269	1.00000

- b. Go to the Stochastic study, **Select Input Variables** step, and select the **Nominal** fields for length\_1, length\_2, length\_3, length\_4, and length\_5. Right-click on the selected fields, and select **Paste transpose** from the context menu.

	Active	Label	Varname	Lower Bound	Nominal	Upper Bound	Comment
1	<input checked="" type="checkbox"/>	length_1	m_1_length_1	-0.5000000	-0.4764394	0.0000000	
2	<input checked="" type="checkbox"/>	length_2	m_1_length_2	0.0000000	0.0000000	0.0000000	
3	<input checked="" type="checkbox"/>	length_3	m_1_length_3	-1.0000000	-1.0000000	0.0000000	
4	<input checked="" type="checkbox"/>	length_4	m_1_length_4	-1.0000000	0.4958683	0.0000000	
5	<input checked="" type="checkbox"/>	length_5	m_1_length_5	-1.0000000	0.0347269	0.0000000	
6	<input type="checkbox"/>	radius_1	m_1_radius_1	-2.0000000	0.0000000	0.0000000	
7	<input type="checkbox"/>	radius_2	m_1_radius_2	-0.5000000	0.0000000	0.0000000	
8	<input type="checkbox"/>	radius_3	m_1_radius_3	-0.5000000	0.0000000	0.0000000	
9	<input checked="" type="checkbox"/>	height	m_1_height	-1.0000000	0.0000000	0.0000000	

- c. For **height**, change the **Nominal** value to 1.0.
6. Change the lower and upper bounds for every active input variable to match the dimensions' tolerances. For this tutorial, assume that the tolerances are within 0.05 mm.

- a. For all active input variables, click **\*\*\*** in the **Nominal** field.
- b. In the pop-up window, **Value** field, enter 0.05 and click **+/-**.



- c. Click **OK** to accept the changes and close the pop-up window.

The Lower and Upper bounds for all active input variables should replicate the image below.

	Active	Label	Varname	Lower Bound	Nominal	Upper Bound	Comment
1	<input checked="" type="checkbox"/>	length_1	m_1_length_1	-0.5264394 ...	-0.4764394 ...	-0.4264394 ...	...
2	<input checked="" type="checkbox"/>	length_2	m_1_length_2	-0.0500000 ...	0.0000000 ...	0.0500000 ...	...
3	<input checked="" type="checkbox"/>	length_3	m_1_length_3	-1.0500000 ...	-1.0000000 ...	-0.9500000 ...	...
4	<input checked="" type="checkbox"/>	length_4	m_1_length_4	0.4458683 ...	0.4958683 ...	0.5458683 ...	...
5	<input checked="" type="checkbox"/>	length_5	m_1_length_5	-0.0152731 ...	0.0347269 ...	0.0847269 ...	...
6	<input type="checkbox"/>	radius_1	m_1_radius_1	-2.0000000 ...	0.0000000 ...	2.0000000 ...	...
7	<input type="checkbox"/>	radius_2	m_1_radius_2	-0.5000000 ...	0.0000000 ...	1.0000000 ...	...
8	<input type="checkbox"/>	radius_3	m_1_radius_3	-0.5000000 ...	0.0000000 ...	1.0000000 ...	...
9	<input checked="" type="checkbox"/>	height	m_1_height	0.9500000 ...	1.0000000 ...	1.0500000 ...	...

- 7. Click the **Distributions** tab, and verify that **Distribution** is set to **Normal Variance** for all active input variables.

Look at the columns A and B. Column A displays the nominal parameter values, and column B displays the variance  $\sigma^2$  which is computed using the standard deviation  $\sigma$  of a parameter around its mean.

Variance is computed as follows:  $\sigma^2 = ((\text{Upper Bound} - \text{Lower Bound})/4)^2$ . For instance, the variance for the input variable length\_1 is  $\sigma^2 = ((-0.45 + 0.55)/4)^2 = 6.25e-4$ .

	Active	Label	Varname	Distribution	Role	Distribution	A	
1	<input checked="" type="checkbox"/>	length_1	m_1_length_1		Random Parameter	Normal Variance ▲	-0.4764394 ...	6.25e-
2	<input checked="" type="checkbox"/>	length_2	m_1_length_2		Random Parameter	Normal Variance ▲	0.0000000 ...	6.25e-
3	<input checked="" type="checkbox"/>	length_3	m_1_length_3		Random Parameter	Normal Variance ▲	-1.0000000 ...	6.25e-
4	<input checked="" type="checkbox"/>	length_4	m_1_length_4		Random Parameter	Normal Variance ▲	0.4958683 ...	6.25e-
5	<input checked="" type="checkbox"/>	length_5	m_1_length_5		Random Parameter	Normal Variance ▲	0.0347269 ...	6.25e-
6	<input type="checkbox"/>	radius_1	m_1_radius_1		Random Parameter	Normal Variance ▲	0.0000000 ...	1.0000
7	<input type="checkbox"/>	radius_2	m_1_radius_2		Random Parameter	Normal Variance ▲	0.0000000 ...	0.1400
8	<input type="checkbox"/>	radius_3	m_1_radius_3		Random Parameter	Normal Variance ▲	0.0000000 ...	0.1400
9	<input checked="" type="checkbox"/>	height	m_1_height		Random Parameter	Normal Variance ▲	1.0000000 ...	6.25e-

8. Go to the **Select Output Responses** step.
9. Define Max\_Disp, Volume and Max\_Stress by selecting the options indicated in the image below from the **Evaluate From** column.

Even though Max\_stress was not used in the Optimization, you will use it in the Stochastic study to check the reliability.

	Active	Label	Varname	Expression	Evaluate From	Comment
1	<input checked="" type="checkbox"/>	Max_Disp	m_1_r_1	max(m_1_ds_1)	Fit, RBF ( fit_4 )	Data Source 1 ...
2	<input checked="" type="checkbox"/>	Max_Stress	m_1_r_2	max(m_1_ds_2)	Fit, RBF ( fit_4 )	Data Source 2 ...
3	<input checked="" type="checkbox"/>	Volume	m_1_r_3	m_1_ds_3[0]	Fit, RBF ( fit_4 )	Data Source 3 ...

10. Go to the **Specifications** step.
11. In the work area, set the **Mode** to **Hammersley**.  
Hammersley sampling belongs to the category of quasi-Monte Carlo methods. This method uses a quasi-random number generator, based on the Hammersley points, to uniformly sample a unit hypercube.
12. Click **Apply**.
13. Go to the **Evaluate** step.
14. Click **Evaluate Tasks** to execute all the runs and extract the results.
15. To study the method convergence:
  - a. Go back to the **Specifications** step and change the **Number of runs** to 300 and then 1000 in the **Settings** tab.
  - b. Go to the **Evaluate** step, and click **Evaluate Tasks**.
16. Go to the **Post-Processing** step.

## Step 2: Post Processing the Results of the Stochastic Study

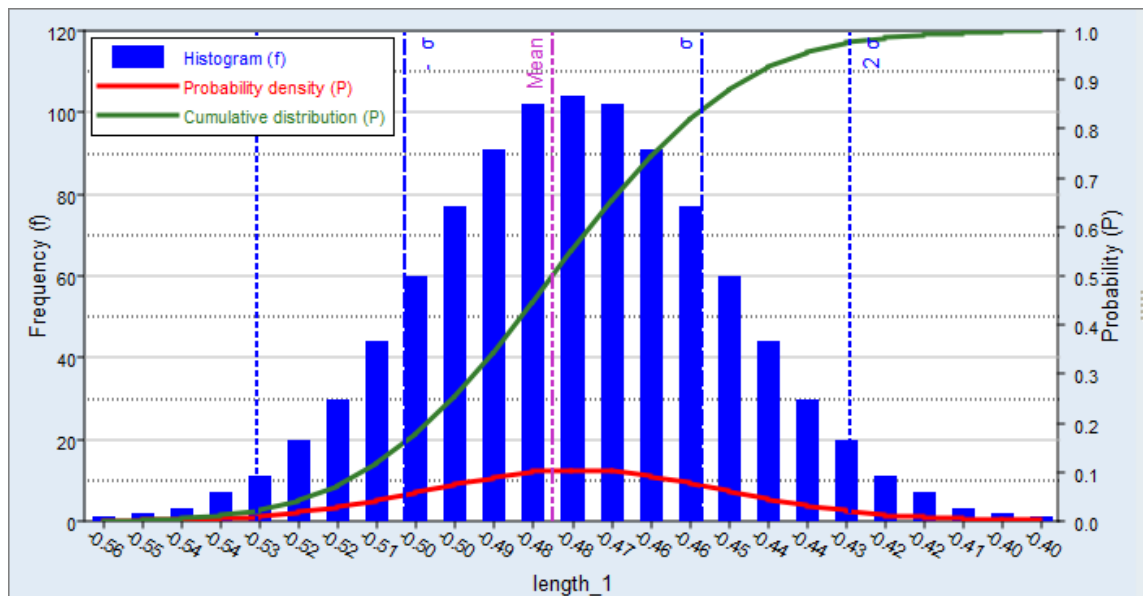
1. Click the **Integrity** tab to review the statistics of the input variables and the output responses around the nominal design.

Using the **Channel** selector, select the **Health** category to get a summarized view of statistics and spot eventual, missing, or bad values. The Range column can be useful to understand the spread of values in the data from the minimum to the maximum.

2. Click the **Distribution** tab to review a histogram of the Stochastic results.

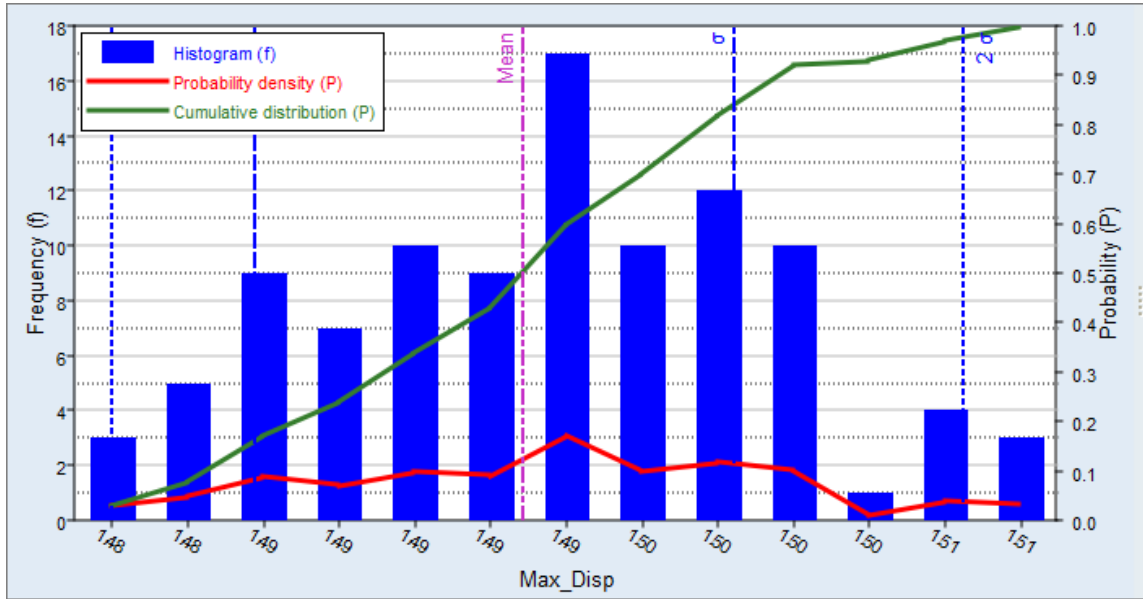
Using the **Channel** selector, select **Length\_1**.

The chart shows three pieces of information about the distribution of values for the selected input variable. The **Histogram** uses the left axis, and represents the frequency of runs yielding a sub-range of response values. The **Probability density** uses the right axis, and indicates the relative likelihood of the input variable to take a particular value. A higher value indicates that the values are more probable to occur. The **Cumulative distribution** is another curve that uses the right axis. It is equal to the integral of the Probability density. The value of the Cumulative distribution indicates what percentage of the data falls below the value's threshold. Note that the initial value of the Cumulative distribution will always equal 0, and the final value of the CDF will always be 1.0. This is because all of the data will reside between the upper and lower bounds.

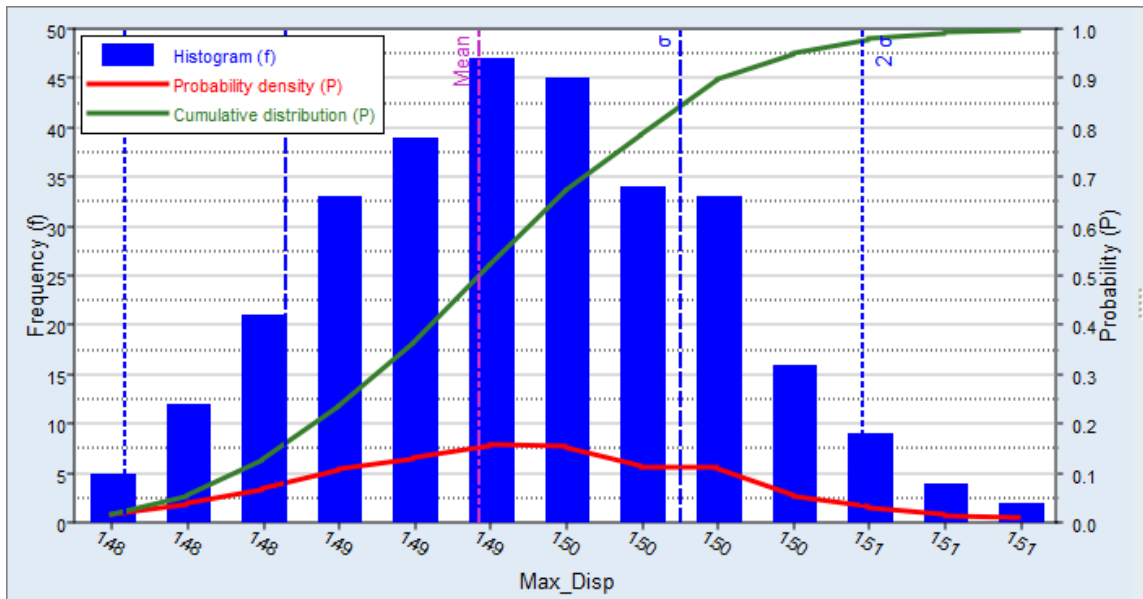


3. Review the Probability density and the Cumulative distribution of Max\_Displacement. Compare the distributions obtained with the different number of runs for Hammersley (100, 300, and 1000).

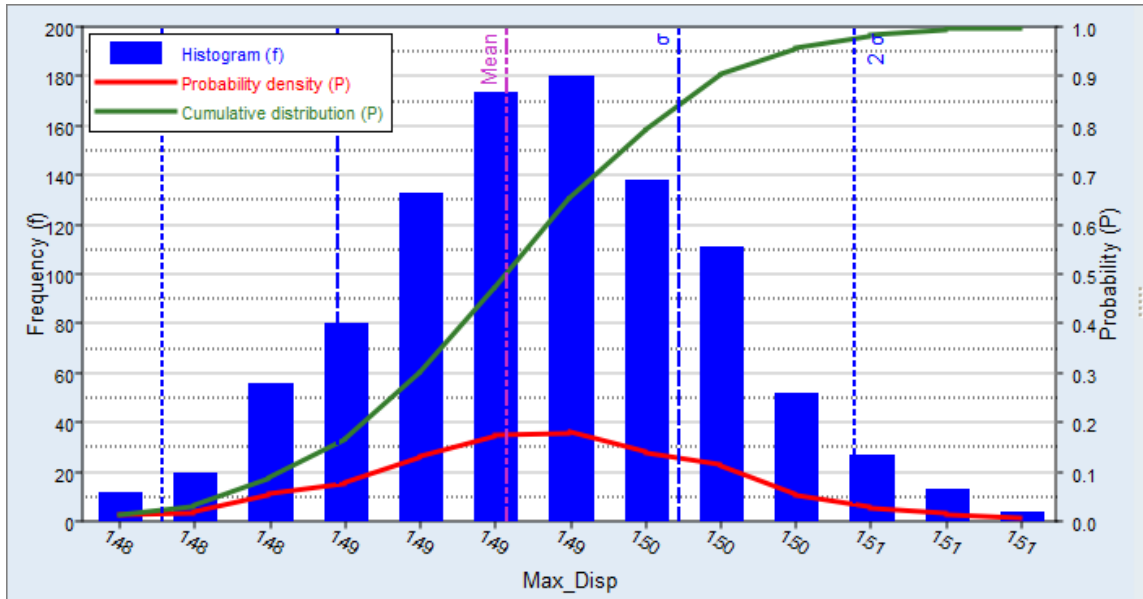
Note that the pattern of the distribution changes quite a bit from 100 to 300 runs, but very little from 300 to 1000 runs.



Hammersley, 100 runs



Hammersley, 300 runs



Hammersley, 1000 runs

4. Click the **Integrity** tab to review the statistics of the output responses around the nominal design.

The column range can be useful to understand the spread of values in the data from the minimum to the maximum.

	Label	Varname	Category	Points	Unique	No Values	Bad Values	Excluded	Range
1	length_1	m_1_length_1	Variable	1000	1000	0	0	0	0.1645263
2	length_2	m_1_length_2	Variable	1000	1000	0	0	0	0.1495726
3	length_3	m_1_length_3	Variable	1000	1000	0	0	0	0.1577675
4	length_4	m_1_length_4	Variable	1000	1000	0	0	0	0.1590478
5	length_5	m_1_length_5	Variable	1000	1000	0	0	0	0.1537191
6	height	m_1_height	Variable	1000	1000	0	0	0	0.1480346
7	Max_Dis	m_1_r_1	Response	1000	1000	0	0	0	0.0413813
8	Max_Stress	m_1_r_2	Response	1000	1000	0	0	0	13.517775
9	Volume	m_1_r_3	Response	1000	1000	0	0	0	17740.778

5. Add a reliability.
  - a. Click the **Reliability** tab to estimate the Probability of failure for the output responses (probability for an output response to violate a user selected bound).
  - b. Click **Add Reliability**.
  - c. Define the reliability. The Bound Values are those from the Optimization problem definition ( $Max\_Disp \leq 1.5$ ).
    - Set **Response** to **Max\_Dis(m\_1\_r\_1)**.
    - Set **Bound Type** to **<=**.
    - For **Bound Value**, enter 1.50.

The results show the convergence of the Hammersley method in function of the number of runs. The convergence is enhanced by increasing the number of runs. As



the results obtained with 300 or 1000 runs are quite similar, you can assume that in this case 300 runs are enough to get accurate results.

	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure
1	<input checked="" type="checkbox"/>	Max_Displ (m_1_r_1)	<=	1.5000000	0.8100000	0.1900000

Hammersley, 100 runs

	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure
1	<input checked="" type="checkbox"/>	Max_Displ (m_1_r_1)	<=	1.5000000	0.7966667	0.2033333

Hammersley, 300 runs

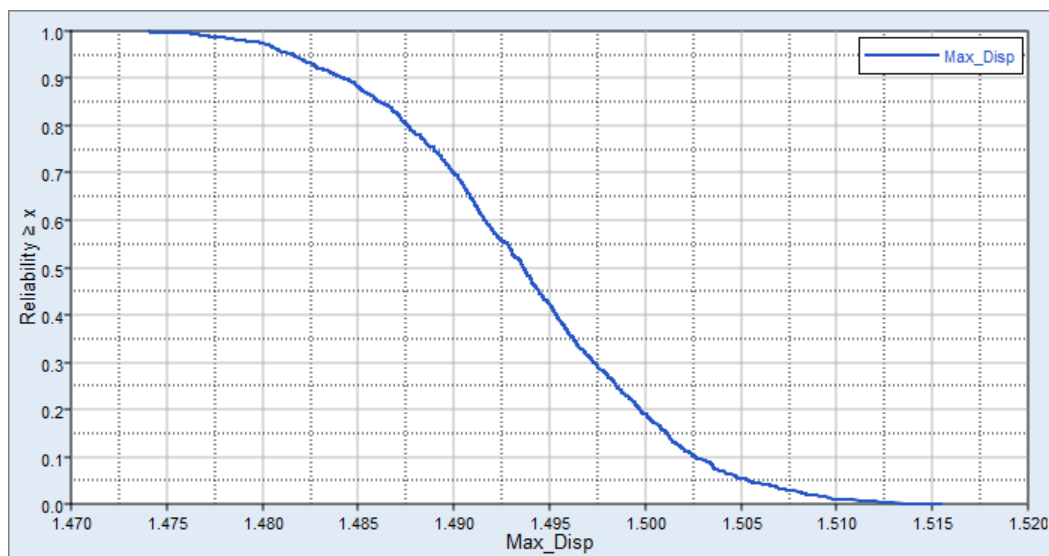
	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure
1	<input checked="" type="checkbox"/>	Max_Displ (m_1_r_1)	<=	1.5000000	0.8090000	0.1910000

Hammersley, 1000 runs

- d. Study the effects of bounds on the reliability by entering different values in the **Bound Value** columns.
- e. **Optional:** Check the reliability on Max\_Stress.

	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure
1	<input checked="" type="checkbox"/>	Max_Displ (m_1_r_1)	<=	1.5000000	0.8090000	0.1910000
2	<input checked="" type="checkbox"/>	Max_Stress (m_1_r_2)	<=	300.00000	1.0000000	0.0000000

- 6. Click the **Reliability Plot** tab to see the relationship between the desired threshold and the reliability of the system. The values reported in the **Reliability** column of the **Reliability** tab can be observed on these reliability curves. On the Max\_Displ reliability curve, only 11.4% of the designs have a value above 1.5, which means 88.6% are below 1.5. A reliability of 95% can be reached by changing the threshold for Max\_Displ to 1.5034.



	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure	Comment
1	<input checked="" type="checkbox"/>	Max_Displ (m_1_r_1)	<=	1.5035000	0.9500000	0.0500000	...

### Step 3: Reliability-Based Design Optimization Study (RBDO)

In this step, you will be searching for 95% reliability on the Optimization constraint ( $\text{max\_disp} < 1.5 \text{ mm}$ ). You will use fitting functions as opposed to the exact solver to evaluate the output responses. Among the approximations, you will use the RBF that is created with MELS DOE. As a result, you will use the SORA method. You will continue using the six important input variables that all follow a normal distribution. You will start the Optimization from the previously obtained optimum solution with GRSM.

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. In the **Active** column, clear the **radius\_1**, **radius\_2** and **radius\_3** check boxes.
5. In the **Nominal** column, copy the parameter values at the optimal design.
  - a. Go to the GRSM, 6 IV, Exact Solver Optimization, **Evaluate** step, **Iteration History** tab, and copy the length\_1, length\_2, length\_3, length\_4, and length\_5 parameter values.
  - b. Go to the **Select Input Variables** step of the Optimization study you just created, and select the **Nominal** fields for length\_1, length\_2, length\_3, length\_4, and length\_5. Right-click on the selected fields, and select **Paste transpose** from the context menu.
  - c. For **height**, change the **Nominal** value to 1.0.
6. Click the **Distributions** tab, and set the **Distribution Role** to **Design with Random** for all active input variables.

	Active	Label	Varname		Distribution Role	Distribution	A	B	$\Gamma$
1	<input checked="" type="checkbox"/>	length_1	m_1_length_1		Design with Random	Normal Variance	-0.4764394 ...	0.3906250 ...	
2	<input checked="" type="checkbox"/>	length_2	m_1_length_2		Design with Random	Normal Variance	0.0000000 ...	0.2500000 ...	
3	<input checked="" type="checkbox"/>	length_3	m_1_length_3		Design with Random	Normal Variance	-1.0000000 ...	0.2500000 ...	
4	<input checked="" type="checkbox"/>	length_4	m_1_length_4		Design with Random	Normal Variance	0.4958683 ...	0.2500000 ...	
5	<input checked="" type="checkbox"/>	length_5	m_1_length_5		Design with Random	Normal Variance	0.0347269 ...	0.2500000 ...	
6	<input type="checkbox"/>	radius_1	m_1_radius_1		Design	Normal Variance	0.0000000 ...	1.0000000 ...	
7	<input type="checkbox"/>	radius_2	m_1_radius_2		Design	Normal Variance	0.0000000 ...	0.1406250 ...	
8	<input type="checkbox"/>	radius_3	m_1_radius_3		Design	Normal Variance	0.0000000 ...	0.1406250 ...	
9	<input checked="" type="checkbox"/>	height	m_1_height		Design with Random	Normal Variance	1.0000000 ...	0.2500000 ...	

7. In the **B** column, enter  $6.25 \times 10^{-4}$  for all active input variables.

Active	Label	Varname	Distribution Role	Distribution	A	B
<input checked="" type="checkbox"/>	length_1	m_1_length_1	Design with Random	Normal Variance	-0.4764394 ...	6.25e-04 ...
<input checked="" type="checkbox"/>	length_2	m_1_length_2	Design with Random	Normal Variance	0.0000000 ...	6.25e-04 ...
<input checked="" type="checkbox"/>	length_3	m_1_length_3	Design with Random	Normal Variance	-1.0000000 ...	6.25e-04 ...
<input checked="" type="checkbox"/>	length_4	m_1_length_4	Design with Random	Normal Variance	0.4958683 ...	6.25e-04 ...
<input checked="" type="checkbox"/>	length_5	m_1_length_5	Design with Random	Normal Variance	0.0347269 ...	6.25e-04 ...
<input type="checkbox"/>	radius_1	m_1_radius_1	Design	Normal Variance	0.0000000 ...	1.0000000 ...
<input type="checkbox"/>	radius_2	m_1_radius_2	Design	Normal Variance	0.0000000 ...	0.1406250 ...
<input type="checkbox"/>	radius_3	m_1_radius_3	Design	Normal Variance	0.0000000 ...	0.1406250 ...
<input checked="" type="checkbox"/>	height	m_1_height	Design with Random	Normal Variance	1.0000000 ...	6.25e-04 ...

8. Go to the **Select Output Responses** tab.
9. Apply an objective on the Volume output response.
  - a. In the **Objectives** column for Volume, click
  - b. In the pop-up window, set **Type** to **Minimize** and click **OK**.
  - c. In the **Evaluate From** column for Volume, select **Fit, RBF (fit\_4)**.

Active	Label	Varname	Objectives	Constraints	Evaluate From	Expression
<input checked="" type="checkbox"/>	Max_Displacement	m_1_r_1			Solver	max(m_1_ds_1)
<input checked="" type="checkbox"/>	Max_Stress	m_1_r_2			Solver	max(m_1_ds_2)
<input checked="" type="checkbox"/>	Volume	m_1_r_3	Minimize ...		Fit, RBF ( fit_4 )	m_1_ds_3[0]

10. Apply an objective on the Max\_Displacement output response.
  - a. In the **Constraints** column for Max\_Displacement, click
  - b. In the pop-up window, define the following and click **OK**.
    - Set **Type** to **Random**.
    - Set **Bound Type** to **<=**.
    - For **Bound Value**, enter 1.50.
    - For **CFD Limit**, enter 95.0.
  - c. In the **Evaluate From** column for Max\_Displacement, select **Fit, RBF (fit\_4)**.

Active	Label	Varname	Objectives	Constraints	Evaluate From
<input checked="" type="checkbox"/>	Max_Displacement	m_1_r_1		<= 1.5000000 ...	Fit, RBF ( fit_4 )
<input checked="" type="checkbox"/>	Max_Stress	m_1_r_2			Solver
<input checked="" type="checkbox"/>	Volume	m_1_r_3	Minimize ...		Fit, RBF ( fit_4 )

11. In the **Evaluate From** column for Max\_Stress, select **Fit, RBF (fit\_4)**.
12. Click **Apply**.
13. Go to the **Specifications** step.
14. In the work area, set the **Mode** to **Sequential Optimization and Reliability Assessment (SORA)**.

15. Click **Apply**.
16. Go to the **Evaluate** step.
17. Click **Evaluate Tasks**.
18. Click the **Iteration History** tab to review the results of the Optimization in a table.

A deterministic optimum is found first. As you can see in iteration 1, the displacement is at the constraint bound. This design is not 95% reliable as required in this probabilistic Optimization study. The SORA will work to make sure the constraint satisfies the probabilistic requirement. As seen in iteration 2, the design that meets 95% reliability is the one that has a max displacement shifted away from the bound of 1.5. Corresponding to this improvement, there is an increase in the objective value (volume).

	length_1	length_2	length_3	length_4	length_5	height	Max_Displacement	Max_Stress	Volume	Objective1	Constraint1	Constraint1 (V)
1	0.1121318	0.1909208	-0.9868386	-0.0116877	0.2926825	0.9999957	1.4999989	232.20310	1666996.4	1666996.4	1.4999989	1.5127075
2	0.0789470	0.2024848	-1.0000000	0.0039868	0.3331738	1.0000000	1.4873662	229.00344	1672361.7	1672361.7	1.4873662	1.5000004
3	0.0796390	0.2025820	-1.0000000	0.0040144	0.3333208	1.0000000	1.4873652	229.00563	1672361.9	1672361.9	1.4873652	1.4999999

19. As SORA uses the approximation method for the reliability calculation, it is recommended that you make a validation Stochastic study after the Optimization.
  - a. In the **Explorer**, right-click on the Hammersley Stochastic study and select **Copy Approach** from the context menu.
  - b. In the **Copy** dialog, **Label** field, enter Validation SORA and click **OK**.
20. Copy and paste the optimum solution from the SORA Optimization into the **Nominal** column of the input variables for the Validation SORA Stochastic study.
  - a. Go to the SORA Optimization, **Evaluate** step, **Iteration History** tab, and copy the length\_1, length\_2, length\_3, length\_4, and length\_5 parameter values.
  - b. Go to the **Select Input Variables** step of the Validation SORA Stochastic study you just created, and select the **Nominal** fields for length\_1, length\_2, length\_3, length\_4, and length\_5. Right-click on the selected fields, and select **Paste transpose** from the context menu.
21. Change the lower and upper bounds for every active input variable to match the dimensions' tolerances. For this tutorial, assume that the tolerances are within 0.05 mm.
  - a. For all active input variables, click in the **Nominal** field.
  - b. In the pop-up window, **Value** field, enter 0.05 and click **+/-**.
  - c. Click **OK** to accept the changes and close the pop-up window.
22. Go to the **Select Output Responses** step.
23. For Max\_Stress, verify that **Evaluate From** is set to **Fit, RBF (fit\_4)**.
24. Go to the **Specifications** step and verify that the **Mode** is set to **Hammersley** with 1000 runs.
25. Go to the **Evaluate** step, and click **Evaluate Tasks**.
26. Go to the **Post-Processing** step.
27. Add a reliability on Max\_Displacement.

- a. Click the **Reliability** tab.
- b. Click **Add Reliability**.
- c. Define the reliability.
  - Set **Response** to **Max\_Displ**.
  - Set **Bound Type** to **<=**.
  - For **Bound Value**, enter 1.50.

The result confirms that the optimum solution found with SORA is reliable at 95%.

	Active	Response	Bound Type	Bound Value	Reliability	Probability of Failure
1	<input checked="" type="checkbox"/>	Max_Displ ( m_1_r_1 ) ▼	<= ▼	1.500000	0.9490000	0.0510000

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