Altair

HyperWorks

Altair MotionView 2019 Tutorials

MV-3000: DOE using MotionView - HyperStudy

altairhyperworks.com

MV-3000: DOE using MotionView - HyperStudy

In this tutorial, you will:

- Use Hyperstudy to set-up a DOE study of a MotionView model
- Perform DOE study in the MotionView – HyperStudy environment
- Create approximation (using the DOE results) which can be subsequently used to perform optimization of the MotionView model

Theory

HyperStudy allows you to perform Design of Experiments (DOE), optimization, and stochastic studies in a CAE environment. The objective of a DOE, or Design of Experiments, study is to understand how changes to the parameters (design variables) of a model influence its performance (response).

After a DOE study is complete, ***approximation*** can be created from the results of the DOE study. The ***approximation*** is in the form of a polynomial equation of an output as a function of all input variables. This is called as the ***regression equation***.

The ***regression equation*** can then be used to perform ***Optimization***.

Note The goal of DOE is to develop an understanding of the behavior of the system, not to find an optimal, single solution.

HyperStudy can be used to study different aspects of a design under various conditions, including non-linear behavior.

HyperStudy also does the following:

- Provides a variety of DOE study types, including user-defined
- Facilitates multi-disciplinary DOE, optimization, and stochastic studies
- Provides a variety of sampling techniques and distributions for stochastic studies
- Parameterizes any solver input model via a user-friendly interface
- Uses an extensive expression builder to perform mathematical operations
- Uses a robust optimization engine
- Includes built-in support for post-processing study results
- Includes multiple results formats such as MVW, TXT for study results

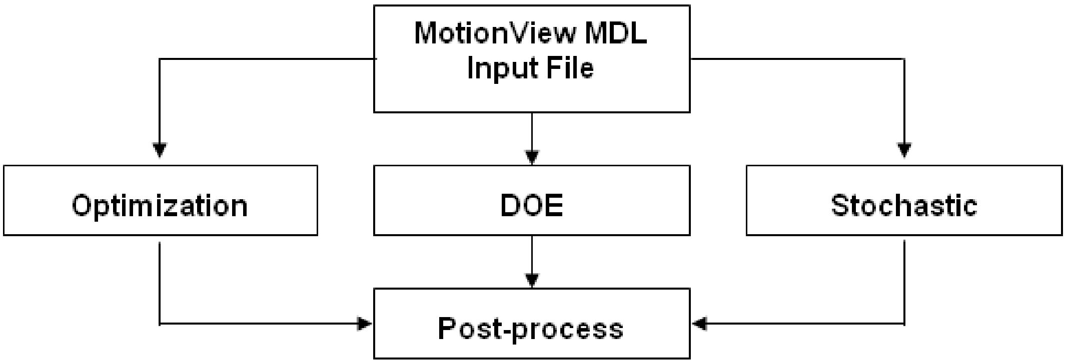
Tools

In MotionView, HyperStudy can be accessed from

- The Main-Menu under 'Applications ->HyperStudy'

You can then select MDL property data as design variables in a DOE or an optimization exercise. Solver scripts registered in the MotionView *Preferences file* are available through the HyperStudy interface to conduct sequential solver runs for DOE or optimization.

For any study, the HyperStudy process is shown below:

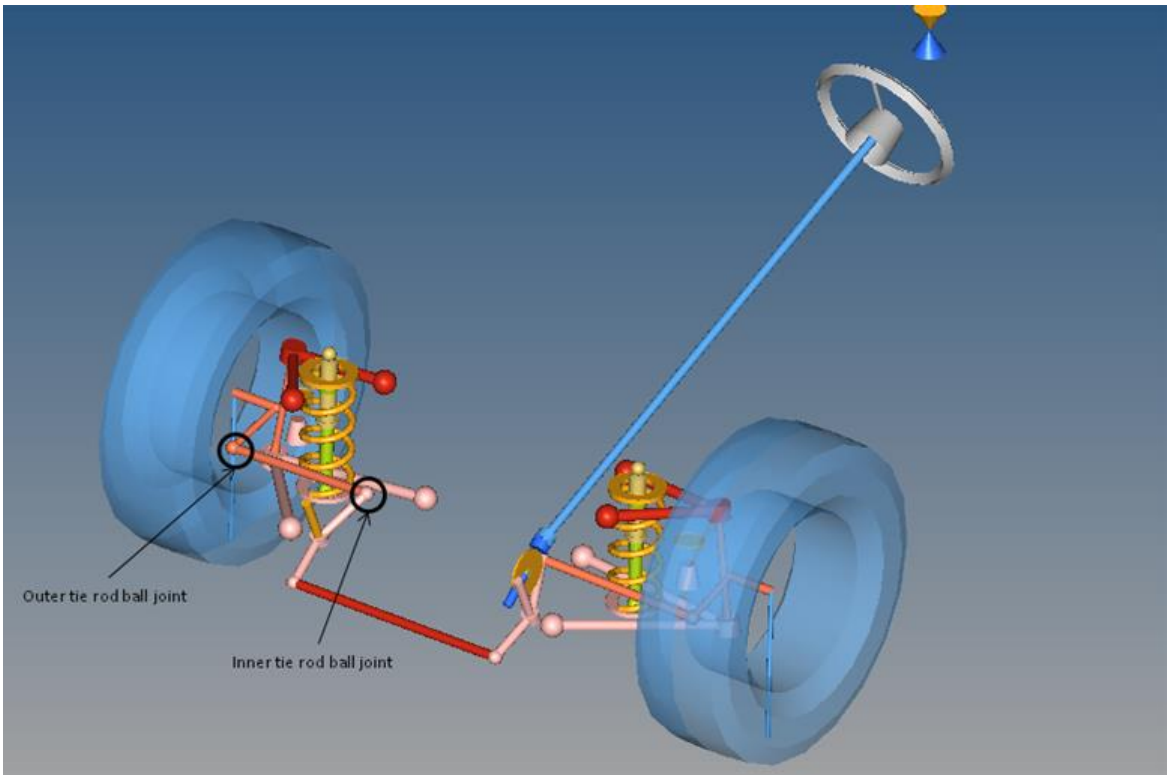


The HyperStudy process

MotionView MDL files can be directly loaded into HyperStudy. Any solver input file, such as MotionSolve, ADAMS, or Abaqus, can be parameterized and the template file submitted as input for HyperStudy. The parameterized file identifies the design variables to be changed during DOE, optimization, or stochastic studies. The solver runs are carried out accordingly and the results are then post-processed within HyperStudy.

Copy the files `hs.mdl` and `target_toe.csv`, located in the `mbd_modeling\doe` folder, to your `<working directory>`.

In the following steps, you will create a study to carry out subsequent DOE study on a front SLA suspension model.



While performing a Static Ride Analysis, you will determine the effects of varying the coordinate positions of the origin points of the inner and outer tie-rod joints on the toe-curve.

Step 1: Study Set-up.

1. Start a new MotionView session.

2. Click the ***Open Model*** icon, , on the **Model-Main** toolbar.

   Or

   From the menu bar, select ***File > Open > Model***.

3. Select the file model `hs.mdl`, located in your `<working directory>`, and click ***Open***.

4. Review the model and the toe-curve output request under **Static Ride Analysis**.

5. From the **Applications** menu, select ***HyperStudy***.

   HyperStudy is launched. The message "*Establishing connection between MotionView and Hyperstudy*" is displayed.

6. Start new study using one of the following ways:

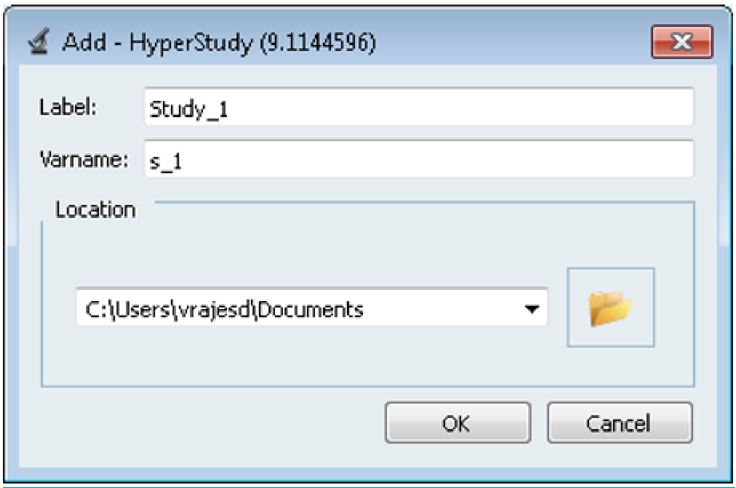
   – From the Welcome page, click on the ***New Study*** icon, .

   Or

   – From the toolbar, click the ***New Study*** icon, .

   Or

   – From main menu, select ***File > New***. The **HyperStudy - Add Study** dialog is displayed.



   Accept the default label and variable names.

   Under **Location**, click the file browser and select `<working directory>\`.

   – Click ***OK***.

7. Model definition.

   – From the study **Setup** tree, select ***Define models***.

   – Click Add Model to open the **Add Model** dialog.

   – Under **Type**, select ***MotionView*** to add a MotionView model to the study.

   – Accept the default variable name.

   – Click ***OK***.

   – The following table with model data is created.

	Active	Label	Varname	Model Type	Resource	Solver input file	Solver execution script	Solver...uments	Comment
1	☑	Model 1	m_1	Motion...	C:/Working_directory/MV-3000/hs.mdl	m_1.xml	MotionSolve (ms)	${file}	...

8. Model data.

   Please note that following details are automatically filled when you define the model (previous step).

   - Under **Active**, check the box to activate or deactivate the model from study.
   - The label of model entered in previous step.
   - The variable name of model entered in the previous step.
   - The model type selected in previous step.
   - Point to the source file (here model file is sourced from MotionView through the MotionView – HyperStudy interfacing).

   Enter a name for the solver input file with the proper extension (for Motionsolve ->`.xml`) and select the solver execution script ***MotionSolve - standalone (ms)***.

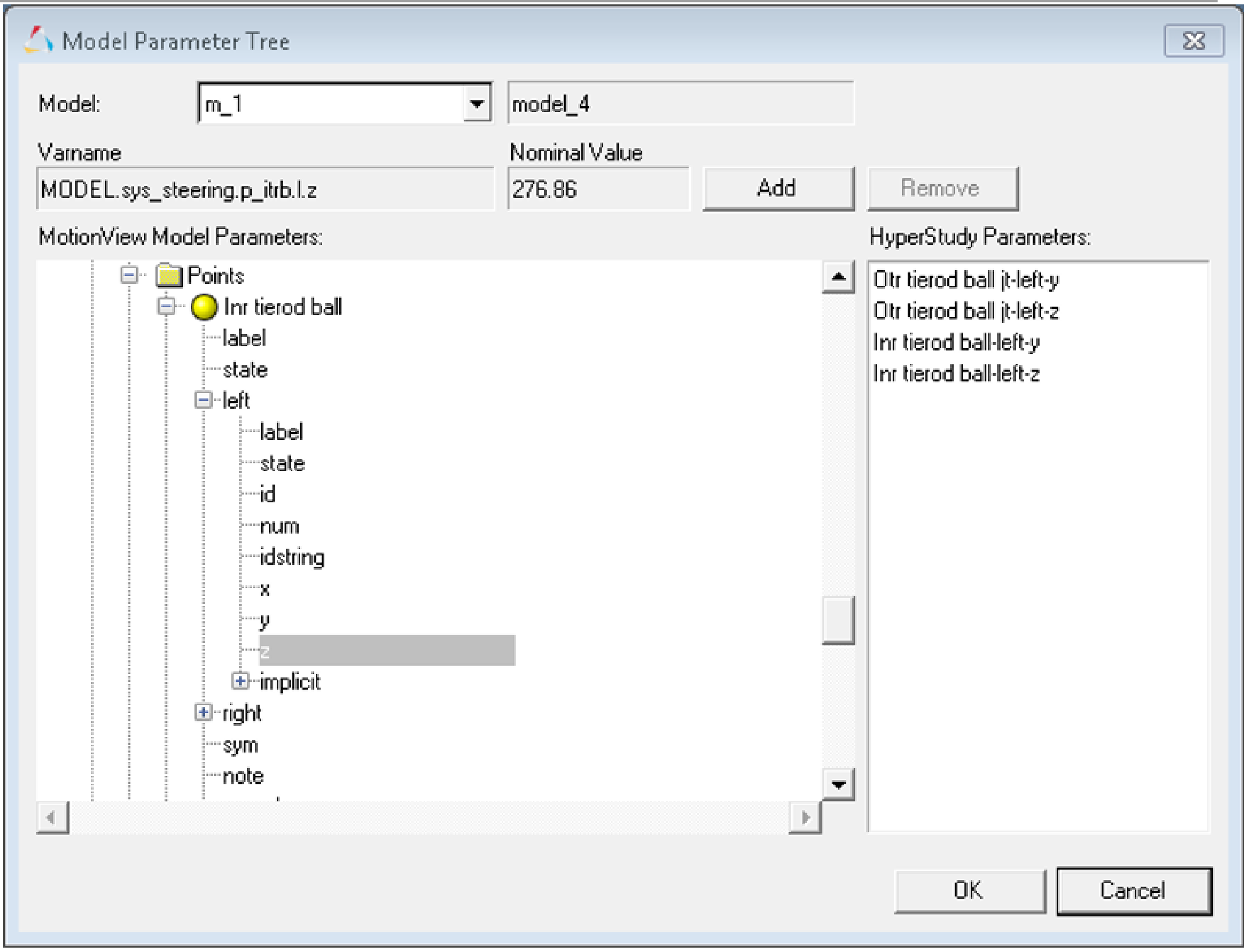
9. Create design variables.

   – Click ***Import Variables*** to specify the design variables for the study.

   – The **Model Browser** window opens in MotionView, allowing you to select the variables interactively.

   – Select the following from the Browser using the **Model Parameter Tree** dialog:

System	Point	Coordinate	Function
Front SLA susp.	Otr tie-rod ball-jt -left	Y	Double-click or Click ***Add***
Front SLA susp.	Otr tie-rod ball-jt –left	Z	Double-click or Click ***Add***
Parallel Steering	Inr tie-rod ball - left	Y	Double-click or Click ***Add***
Parallel Steering	Inr tie-rod ball - left	Z	Double-click or Click ***Add***



Model Parameter Tree dialog

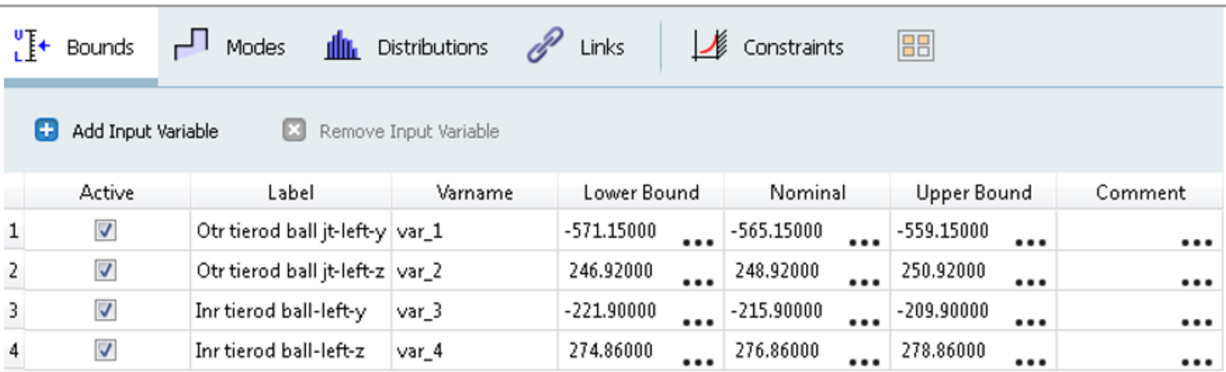
– Click ***Done***.

– Click ***Next*** to go to **Define Design Variables**.

10. Define design variables.

– From the **Define design variables** tab, edit the upper and lower bounds of the design variables according to the following table.

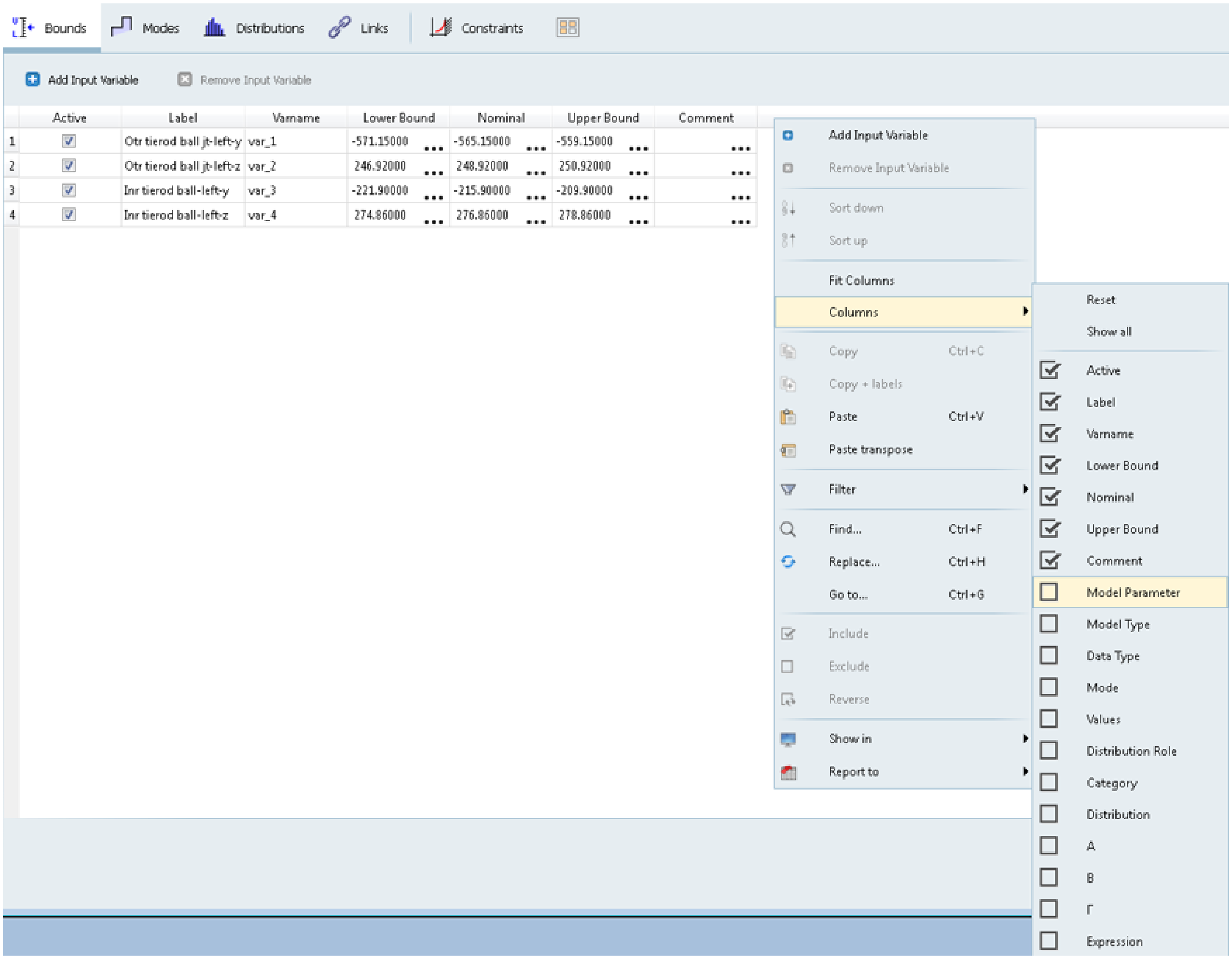
Point	Coordinate	Lower	Upper
Outer tie-rod ball-jt -left	Y	-571.15	-559.15
Outer tie-rod ball-jt - left	Z	246.92	250.92
Inner tie-rod ball - left	Y	-221.9	-209.9
Inner tie-rod ball - left	Z	274.86	278.86



– This step also includes definition of other properties to the design variables. The options **Details** and **Distributions** specify variations of design variables in the range specified. The option **Link Variables** is used to link different design variables through a mathematical expression.

– Click on each tab to observe these options.

– Right click on the column header row to view more options that you may want to add.



- Click ***Next*** to go to **Specifications**.

11. Specifications.

    This section allows you to specify the initial run for DOE.

    – Select the ***Nominal Run*** radio button for this study and click the ***Apply*** button.

    – Click ***Next*** to go to **Evaluate**.

12. Evaluate.

    – Click ***Evaluate Tasks*** to perform the nominal run.

    – Make sure that all settings for the run (**Write**, **Execute** and **Extract**) are activated.

    MotionSolve runs in the background and the analysis is carried out for the base configuration. Please note the messages in status bar of the HyperStudy interface and the MotionView interface. If message log is not visible, click the ***Messages*** button, 

, or go to ***View > Messages*** to display the log.

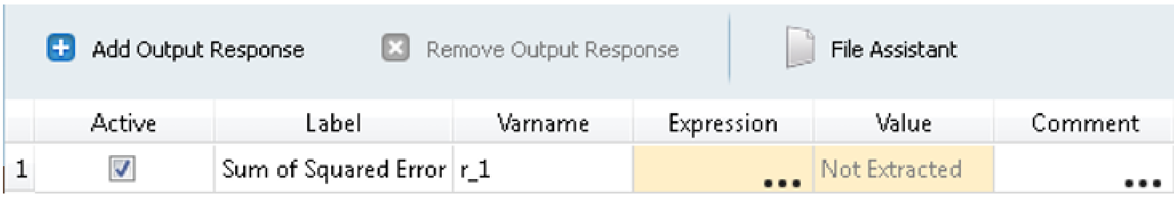
    – Once the nominal run is complete, click ***Next*** to go to **Define responses**.

13. Define Response.

    – Click ***Add Response*** to add a new response.

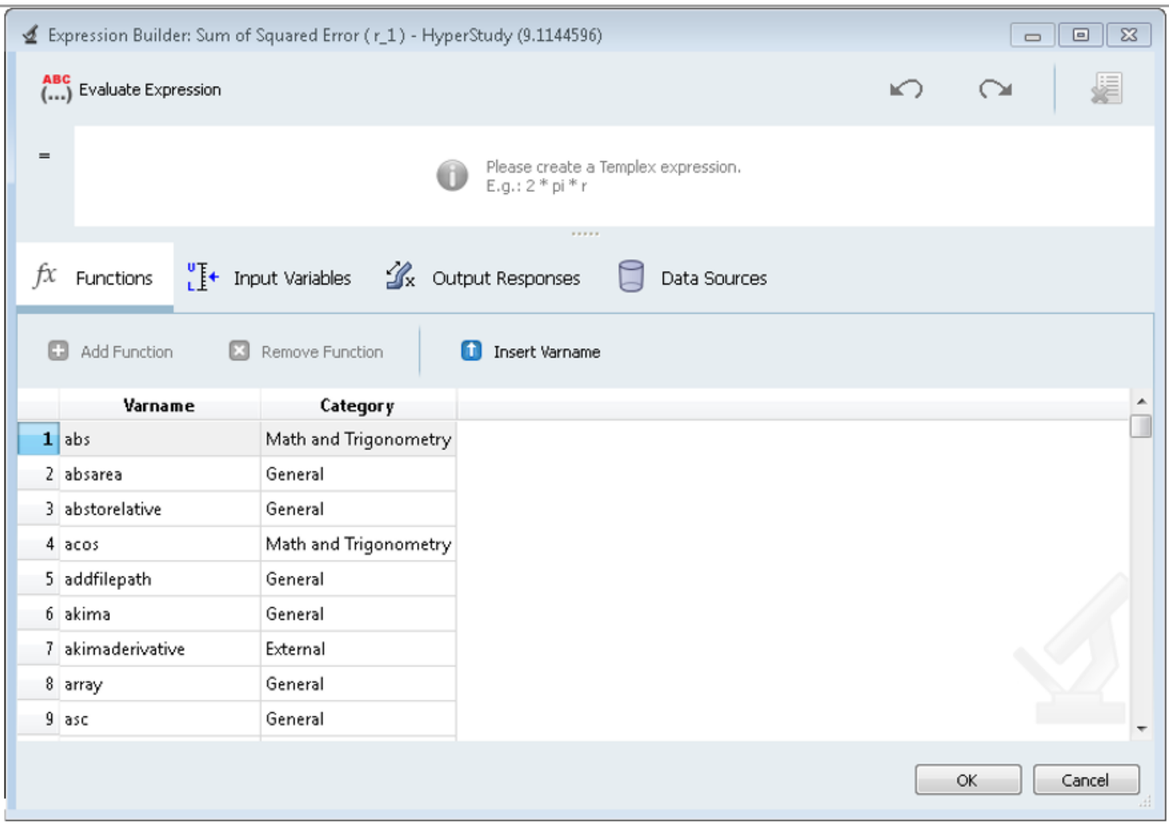
    – Label the response `Sum of Squared Error`.

    – Accept the variable name and click ***OK***.



Response table data

    – Click the ellipses, **...**, in the **Expression** cell of **Response** table to launch the **Expression Builder**.



Expression builder

Note: You can move the cursor over the function to display the function help.

For this exercise, the response function requires two Data Sources:

– The elements of **Data Source 1** contain actual data points of the toe curve from the solver run for the nominal configuration.

– The elements of **Data Source 2** contain data points from the target curve.

– Click the ***Data Sources*** tab to source the data from the files.

Data Source 1:

– Click Add Data Source to add a new data source using the solver output file.

Response data table

– Click the ellipses, **...**, in the **File** cell of Data Source table data to launch the **Data Source Builder: Data Source 1 (ds_1)** dialog box.

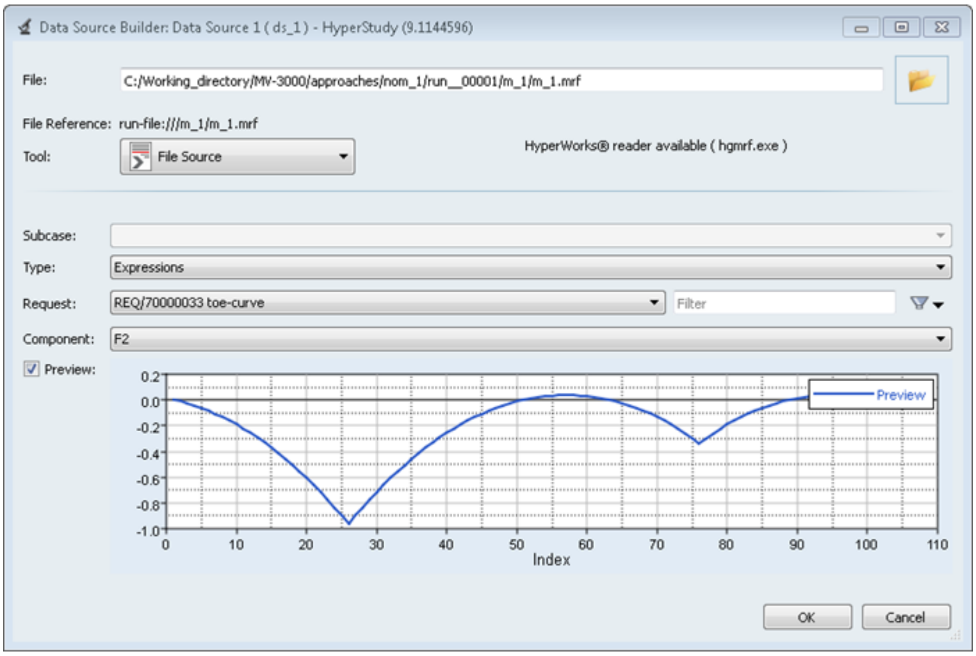
– Click the file browser button, , and select the file `m_1.mrf` from `<working directory>\approaches\nom_1\run__00001\m_1\`.

– This enables the **Type, Request** and **Component** fields.

– From the **Type** drop-down menu, select ***Expressions***.

– From the **Request** drop-down menu, select ***REQ/70000033 toe-curve***.

– From the **Component** drop-down menu, select ***F2***.



Data Source 1 dialog box

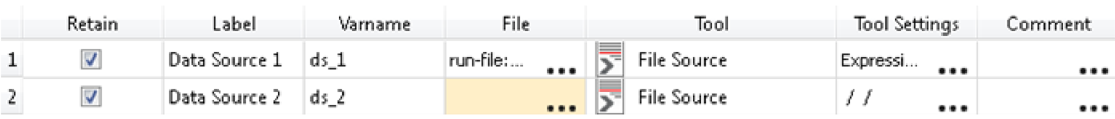
You have now selected the toe curve data from the solver run as the data elements for Data Source 1.

– Click ***OK***.

Data Source 2:

Create a Data Source to hold the data elements from the target toe curve.

– Click ***Add Data Source*** to add a new data source using a reference file.



	Retain	Label	Varname	File	Tool	Tool Settings	Comment
1	☑	Data Source 1	ds_1	run-file:... •••	File Source	Expressi... •••	•••
2	☑	Data Source 2	ds_2	•••	File Source	/ / •••	•••

Response data table

– Click the **...** in the **File** cell of the Data Source 2 table data to launch the **Data Source Builder: Data Source 2 (ds_2)** dialog box.

– Click the file browser button, , and select the file `target_toe.csv`, located in your `<working directory>\`.

– Set Type to ***Unknown*** and Request to ***Block 1***.

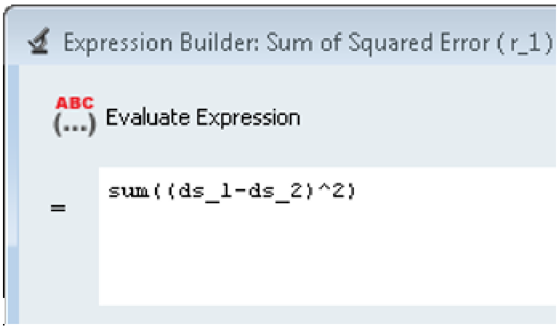
– From the **Component** drop-down menu, select ***Column 1***.

– Click ***OK***.

14. In the **Expression** field, create the following expression:

    `sum((ds_1-ds_2))^2)`

    This expression evaluates the sum of the square of the difference between the "actual toe change" values (from solver run) and the "targeted toe curve" (from imported file). In the next tutorial, MV-3010, we will use HyperStudy to minimize the value of this expression to get the required suspension configuration.



15. Click ***Evaluate expression*** to verify that the expression is evaluated correctly. You should get a value of 16.289.

16. Click ***OK*** to close the Expression builder and hit **Evaluate** button, 

.

    – If you do not encounter any error messages and were able to successfully extract the response for the nominal run, click ***Next*** to go to **Post Processing**.

    – Observe the table with the design variable values used for the nominal run and other tabs with the post-processing options.

    – Click ***Next*** to go to **Report**.

    – Observe various reporting formats available. The images and data captured during the post-processing can be exported in any of the formats provided on **Report** page.

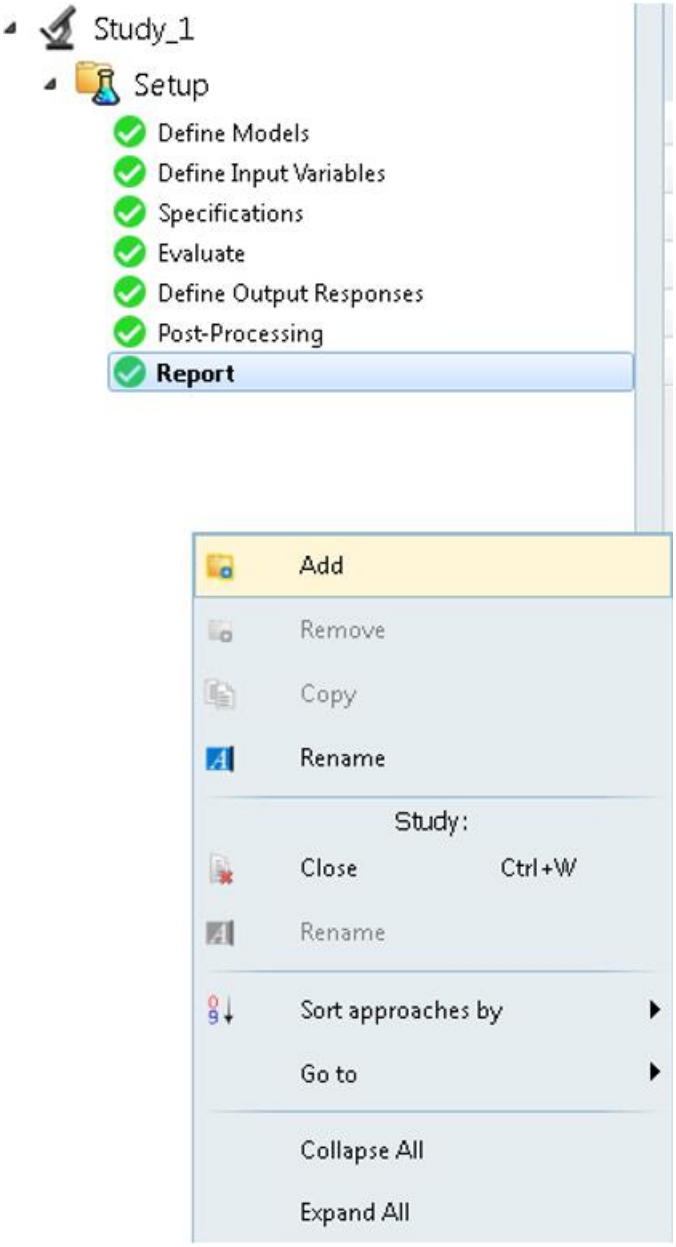
16. From the **File** menu, select ***Save As…***.

17. Save this study set-up as `Setup.xml` to your `<working directory>\`.

Step 2: DOE Study.

1. Adding new DOE study.

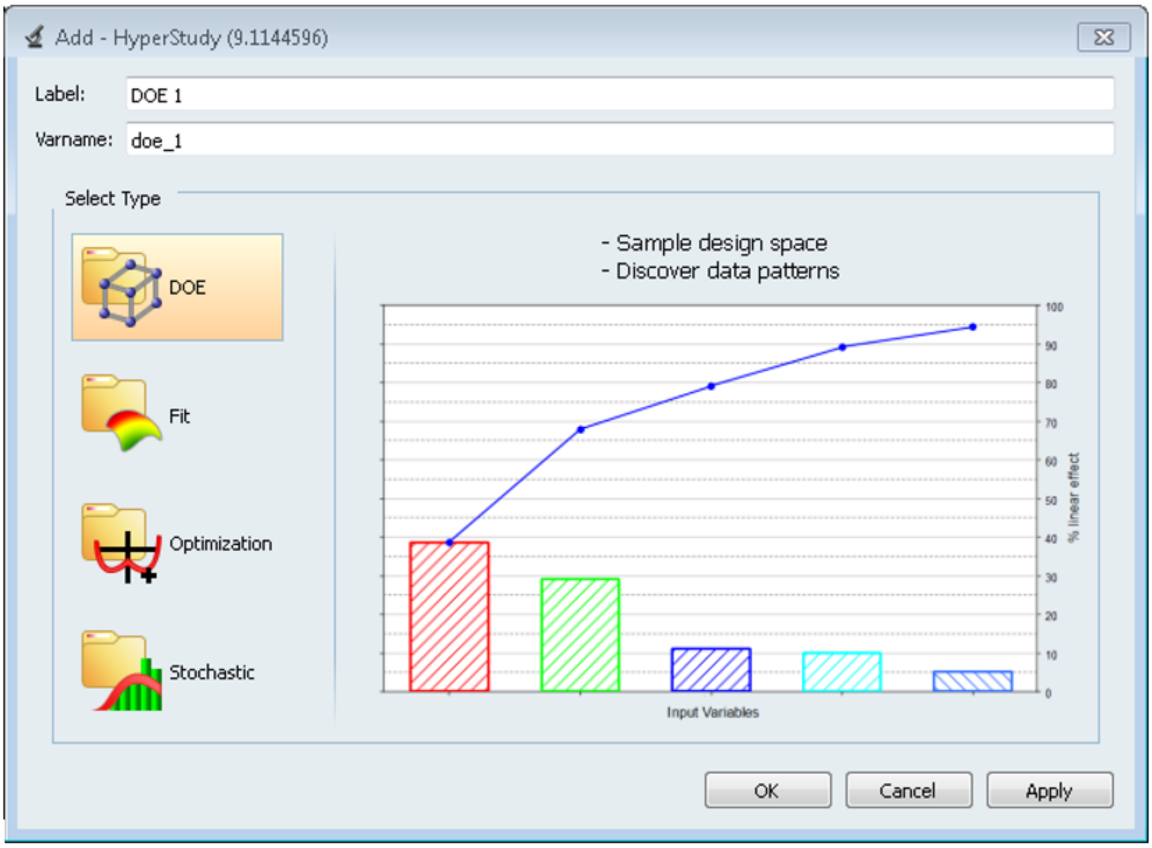
   – Right-click in the Explorer browser area and from the context menu, click ***Add*** to display the **Add Approach** dialog.



Or

– From the ***Toolbar***, click the ***Add Approach*** button, 

, to display the **HyperStudy - Add** dialog.



– Under **Select Type**, select ***Doe***.

– Accept the default label and variable name and click ***OK***.

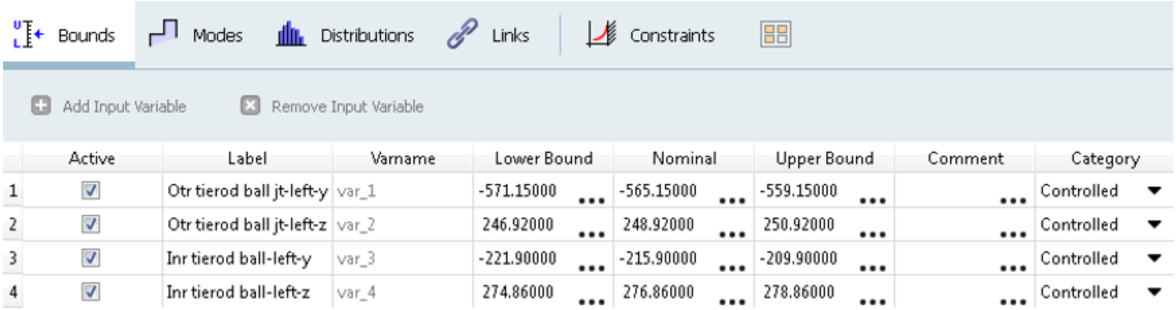
The DOE study tree is displayed in the Browser with name `Doe 1`.

– Click ***Next*** to go to **Select design variables**.

2. Select design variables for the DOE study.

   – All variables are used in the present DOE study, so make sure that all design variables are active.

   – All the design variables in this study are controlled. Therefore, for **Category**, leave all variables set to ***Controlled***.



	Active	Label	Varname	Lower Bound	Nominal	Upper Bound	Comment	Category
1	☑	Otr tierod ball jt-left-y	var_1	-571.15000	-565.15000	-559.15000		Controlled
2	☑	Otr tierod ball jt-left-z	var_2	246.92000	248.92000	250.92000		Controlled
3	☑	Inr tierod ball-left-y	var_3	-221.90000	-215.90000	-209.90000		Controlled
4	☑	Inr tierod ball-left-z	var_4	274.86000	276.86000	278.86000		Controlled

   – Click ***Next*** to go to **Select Output responses**.

3. Select responses for the DOE study:

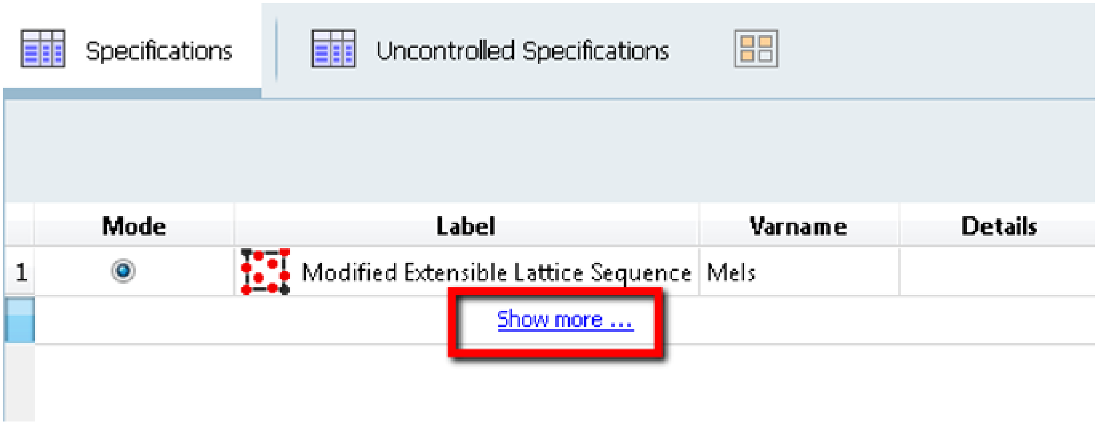
   – There is only one response in the present study - make sure to select the response.

   – Click ***Next*** to go to **Specifications**.

4. Specifications for the DOE study:

   The design space for the DOE study is created in this step. The present study has four design variables with two levels each. A full factorial will give $2^4 = 16$ experiments, as the number of experiments are less. We will do a full factorial run.

   – Click on **Show more…** button and select **Full Factorial** mode, Full Factorial .

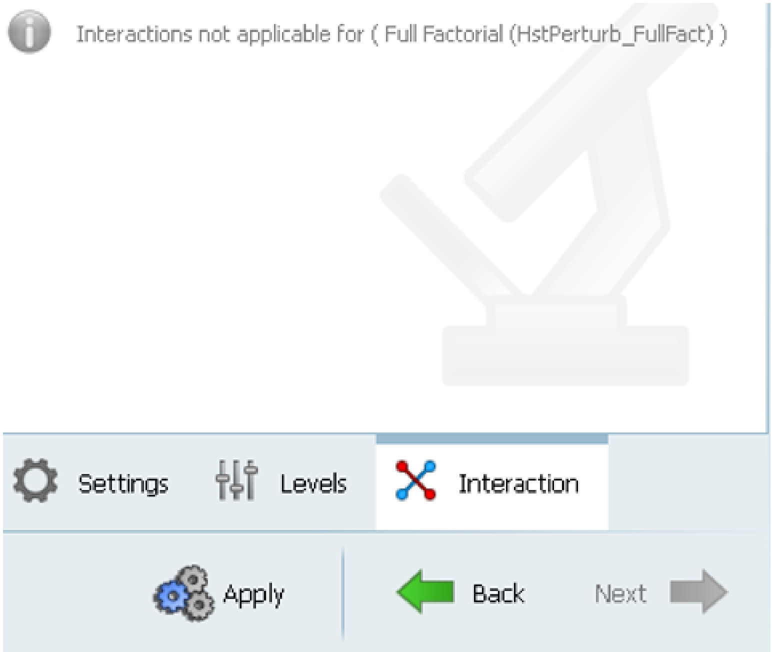


Note: Selecting any mode from the list shows all possible options in the **Parameters** panel area on the left side of GUI.

– Click the ***Levels*** tab to see the design variables and number of levels.

	Label	Levels
1	Otr tierod ball jt-left-y	2
2	Otr tierod ball jt-left-z	2
3	Inr tierod ball-left-y	2
4	Inr tierod ball-left-z	2

– Click the ***Interaction*** tab to observe that it is not applicable since all interactions are selected by default for a full factorial run.



Note: Options which are not applicable will be grayed out or a message will be shown.

5. Click ***Apply*** to generate the design space.

6. Click ***Next*** to go to **Evaluate**.

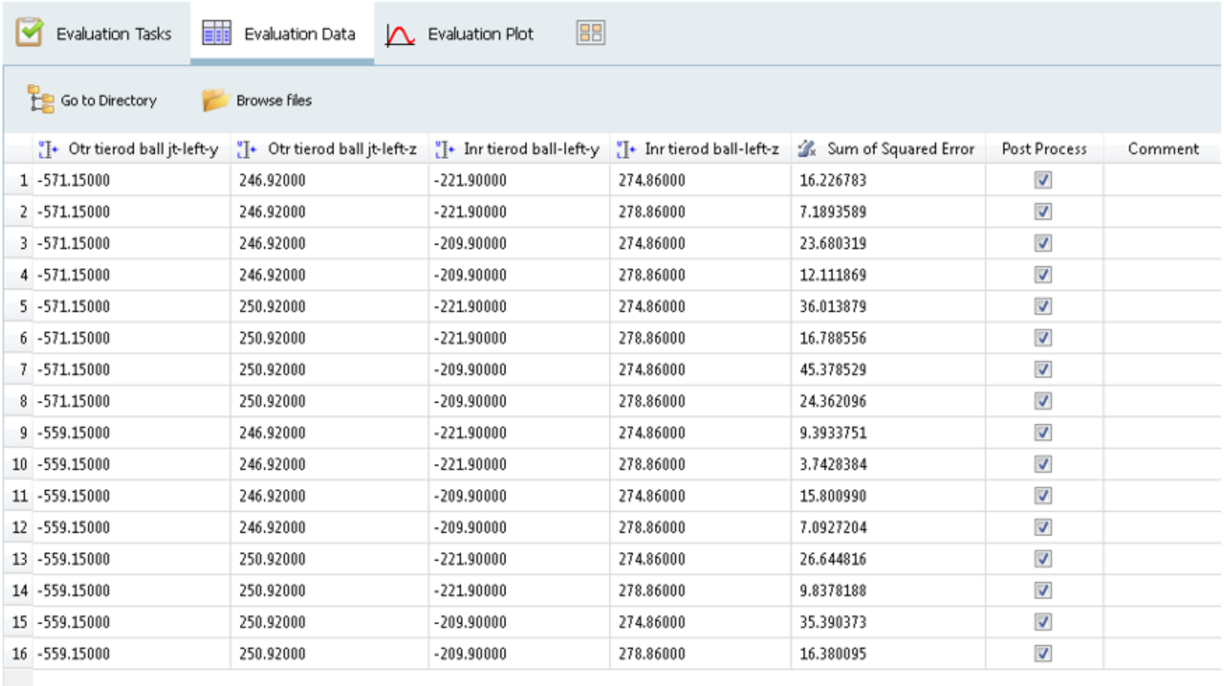
DOE run:

The **Tasks** tab of Evaluate shows a table of 16 rows and four columns. Column 1 shows the experiment number while other columns corresponding to each experiment get updated with the experiment status of failure or success in the three stages of model execution: **Write**, **Execute** and **Extract**.

Design variable values used under each experiment can be seen under the **Evaluation Data** tab.

The last column corresponds to the response value from each run. The values gets populated once the run is completed.

– Click ***Evaluate Tasks*** to start the DOE study.



	Otr tierod ball jt-left-y	Otr tierod ball jt-left-z	Inr tierod ball-left-y	Inr tierod ball-left-z	Sum of Squared Error	Post Process	Comment
1	-571.15000	246.92000	-221.90000	274.86000	16.226783	☑	
2	-571.15000	246.92000	-221.90000	278.86000	7.1893589	☑	
3	-571.15000	246.92000	-209.90000	274.86000	23.680319	☑	
4	-571.15000	246.92000	-209.90000	278.86000	12.111869	☑	
5	-571.15000	250.92000	-221.90000	274.86000	36.013879	☑	
6	-571.15000	250.92000	-221.90000	278.86000	16.788556	☑	
7	-571.15000	250.92000	-209.90000	274.86000	45.378529	☑	
8	-571.15000	250.92000	-209.90000	278.86000	24.362096	☑	
9	-559.15000	246.92000	-221.90000	274.86000	9.3933751	☑	
10	-559.15000	246.92000	-221.90000	278.86000	3.7428384	☑	
11	-559.15000	246.92000	-209.90000	274.86000	15.800990	☑	
12	-559.15000	246.92000	-209.90000	278.86000	7.0927204	☑	
13	-559.15000	250.92000	-221.90000	274.86000	26.644816	☑	
14	-559.15000	250.92000	-221.90000	278.86000	9.8378188	☑	
15	-559.15000	250.92000	-209.90000	274.86000	35.390373	☑	
16	-559.15000	250.92000	-209.90000	278.86000	16.380095	☑	

Once all the runs are finished, the tasks table gets filled up with the status for each run (Success/Fail).

– In the present DOE study, all runs are successfully completed. Click ***Next*** to go to **Post Processing**.

7. Viewing Main Effect and Interaction plots:

The post-processing section has variety of utilities to helps user to effectively post process results. ***Summary*** tab of Post processing page will provide a summary of design along with responses.

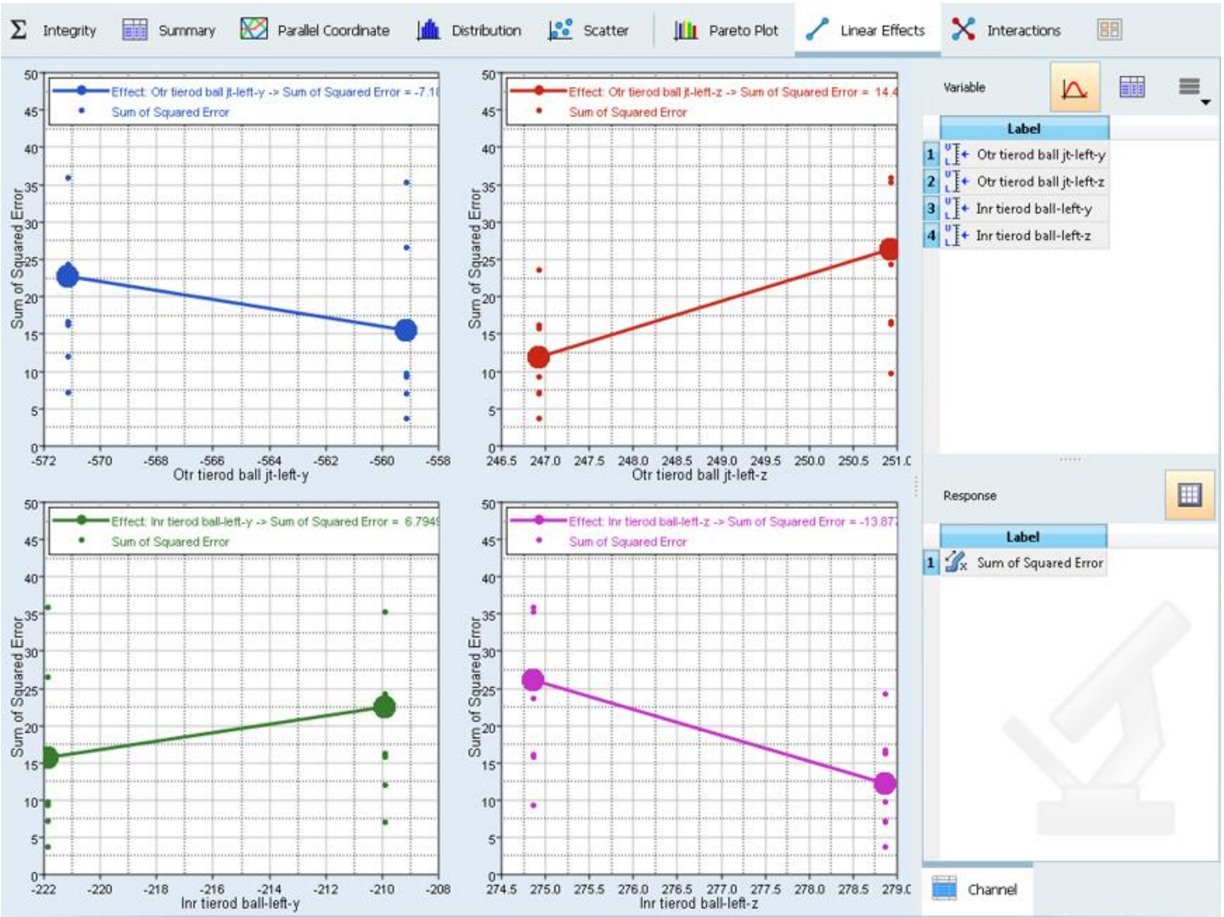
The New Generation HyperStudy allows you to sort data by right-clicking on the column heading and selecting the options from context menu.

The options to post-process are available in other tabs. The main effects can be plotted by selecting the ***Linear Effects*** tab.

Main Effects:

– Click the **Linear Effects** tab to open the main effects plot window. From the **Channel** page, select ***Variables*** and ***Responses*** for which main effects need to be plotted. Press the left mouse button and move over the variable or responses list for multiple selection.

– Select all controlled variables and responses to plot the main effect plot. This plot shows the effect of each parameter on the response.



DOE – Main effects plot

Note: Click on window icon, , (highlighted above) to toggle it to multiple windows, . Each curve is displayed in a different plot window.

Interactions:

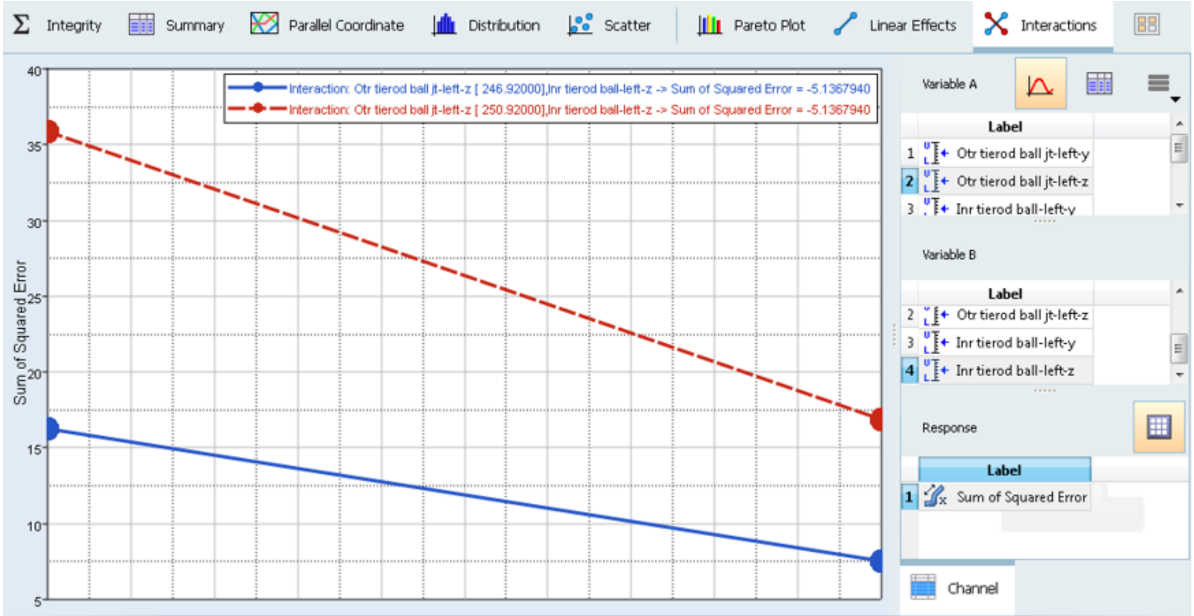
An interaction is the failure of one variable to produce the same effect on the output response at different levels of another input variable. In other words, the strength or the sign (direction) of an effect is different depending on the value (level) of some other variable(s). An interaction can be either positive or negative.

Interactions can be plotted from the **Interactions** tab following the above procedure.

– Select the design variables `Otr_tierod_ball_jt-left-z` and `Inr_tierod_ball_jt-left-z` and response `Sum of Squared Error`.

– Click the ***Interaction*** tab to observe that it is not applicable since all interactions are selected by default for a full factorial run.

This displays the interaction plot for these two variables only.



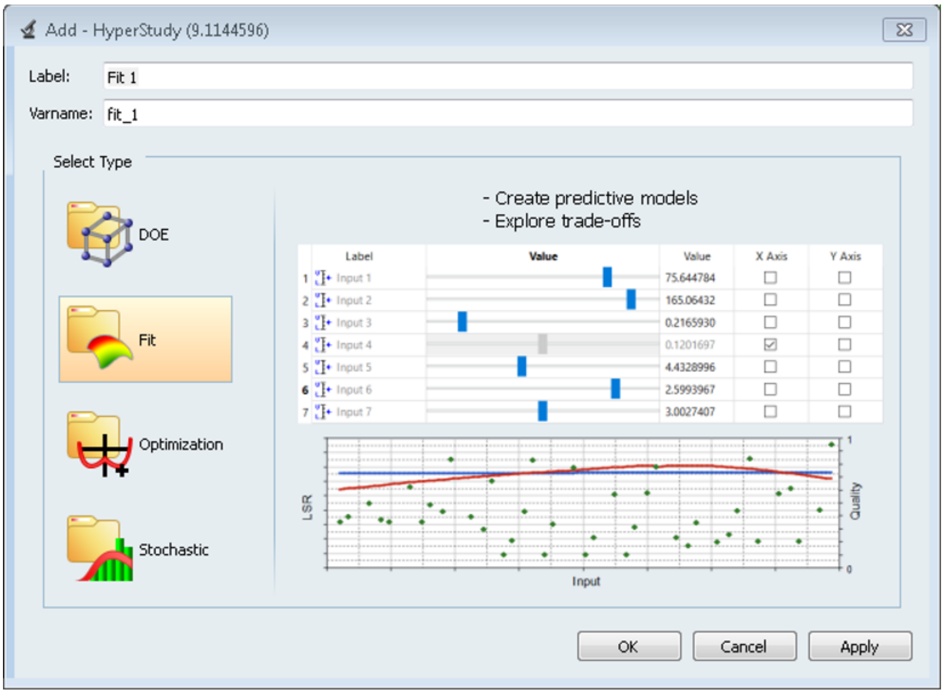
Controlled design variable plot for "Otr_tierod_ball_jt-left-z" & "Inr_tierod_ball_jt-left-z" interaction

Step 3: Approximation.

System response is approximated by using various curve fitting methods. An approximation for the response with the design variables variation is calculated using the data from above DOE study. The accuracy of the approximation can be checked and improved.

1. Adding an approximation.

– Right-click in the Explorer browser area and from the context menu, click ***Add*** to display the **Add Approach** dialog.



– Under **Select Type**, select ***Fit***.

– Accept the default label and variable names and click ***OK***.

– A new tree with the name `Fit 1` is created in the Browser.

– Click ***Next***.

2. Input matrix.

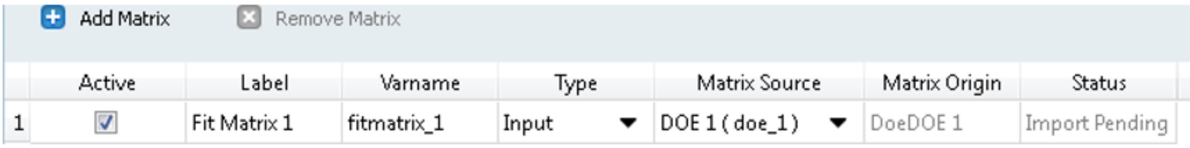
– Click Add Matrix.

A matrix table is created. Check if the following options to specify the DOE results as the input matrix have been selected by default.

– Under **Type**, use the drop-down menu to select ***Input***.

– For **Matrix Source**, select ***Doe 1*** from the drop-down menu.

In the present study, we are not using any validation matrix. So, no matrix will be added for validation matrix.



Observe that the status shows "Import pending".

– Click ***Import Matrix*** to import the DOE results for the input matrix.

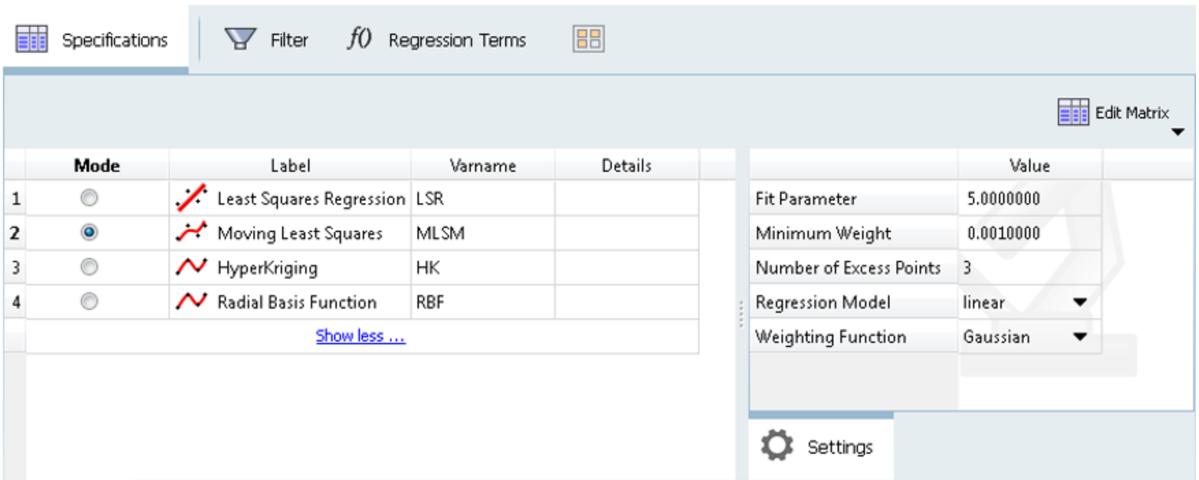
– Click ***Next*** to go to **Select Input Variables**.

– Select all design variables and click ***Next*** to go to **Select Output Responses**.

– Select the response and click ***Next*** to go to **Specifications**.

In this section, the approximation type and it's properties are defined.

– Click the **Show more…** button and Select the **Moving Least Squares (MLSM):**



– Click ***Apply*** to apply the approximation method.

– Click ***Next*** to go to **Evaluate**.

– Observe an empty **Tasks** table which corresponds to the DOE experiments.

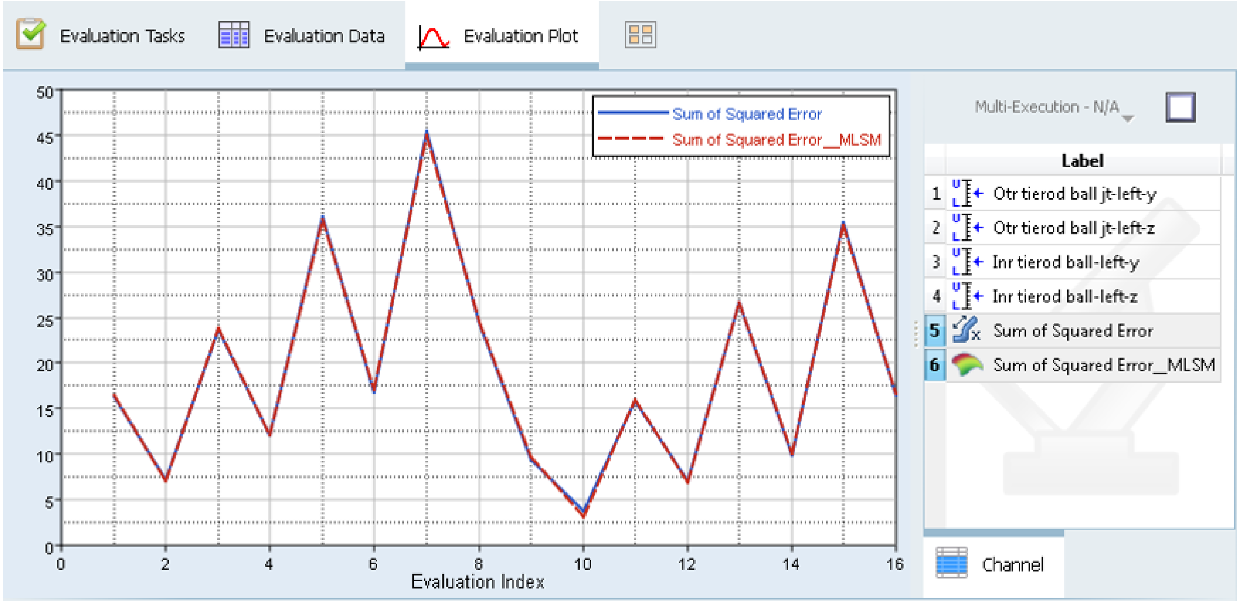
– Click ***Evaluate Tasks*** to evaluate the approximation for the DOE experiments.

Upon completion, the table is populated with the status value (Success or Fail).

– Click the other tabs available to observe the fit.

– Click the ***Evaluation Data*** tab to observe the experiment table with responses from the MotionSolve run and responses predicted using approximation. The same can be viewed in graph format by selecting the ***Evaluation plot*** tab.

– Select ***Sum of Squared of Squared Error*** and ***Squared of Squared Error_MLSM*** to plot against the experiment numbers.



This fit shows a good approximation to the response.

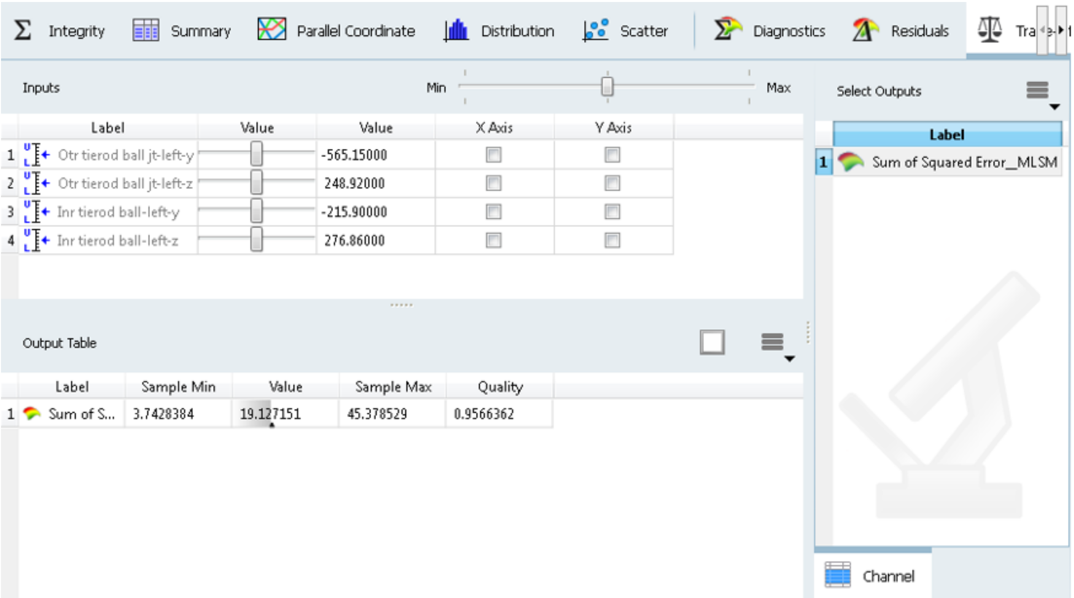
– Click **Next** to go to **Post Processing**.

– Post-processing provides you with statistical parameters and graphical tools useful in validating the correctness of approximation.

– The **Residuals** tab shows the difference between the response value from the solver and the response value from the regression equation.

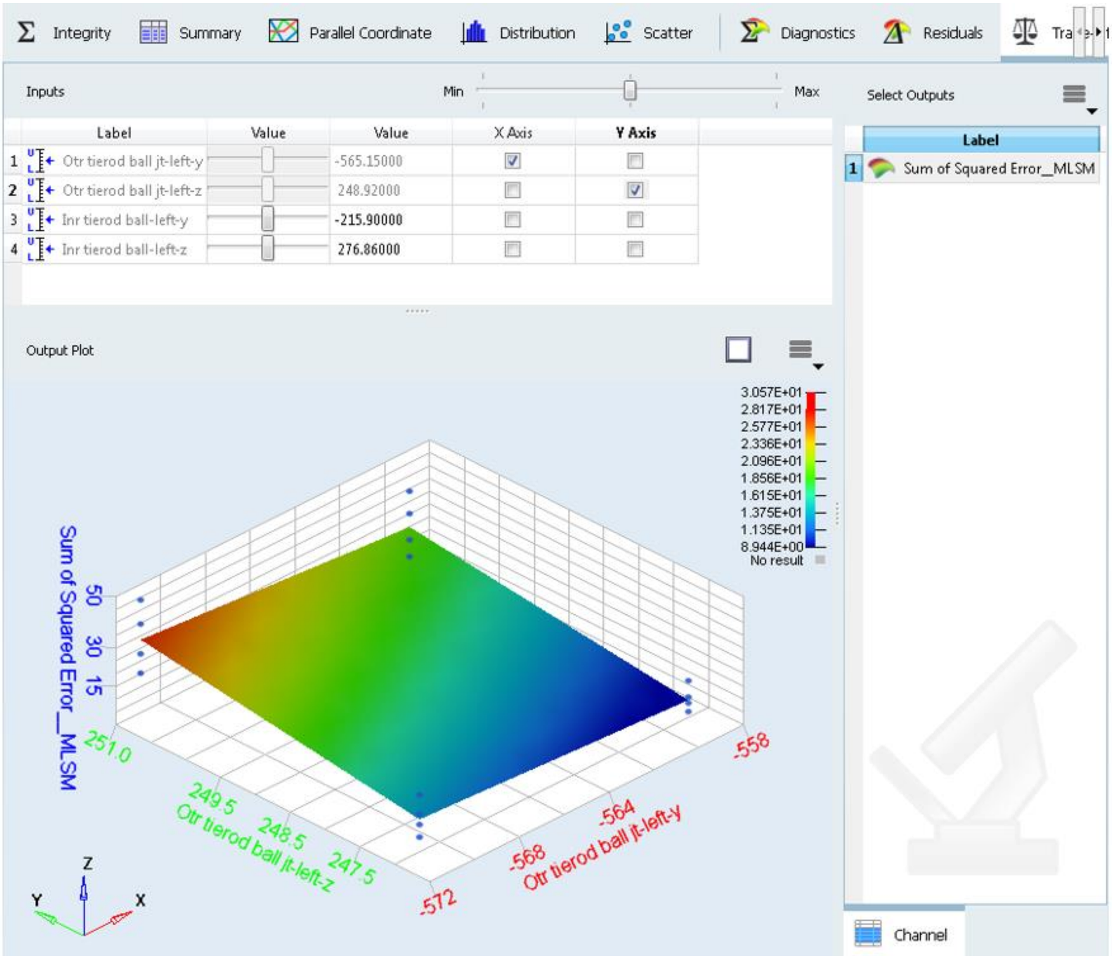
– The residual values can be used to determine which runs are generating more errors in the regression model.

– The **Trade-off** tab shows the plots of the main effects vs. response from the approximation.



Trade-off: 3-D plots

– Select `Otr_tierod_ball_jt-left-y` as X axis and `Otr_tierod_ball_jt-left-z` as Y axis to plot against response from the approximation.



– From the toolbar, click the Save icon, , to save the study.

Note All study files will be saved in the study directory with the folder names that are the same as the tree varnames. For example, **nom_1**,**doe_1** and **fit_1**.