

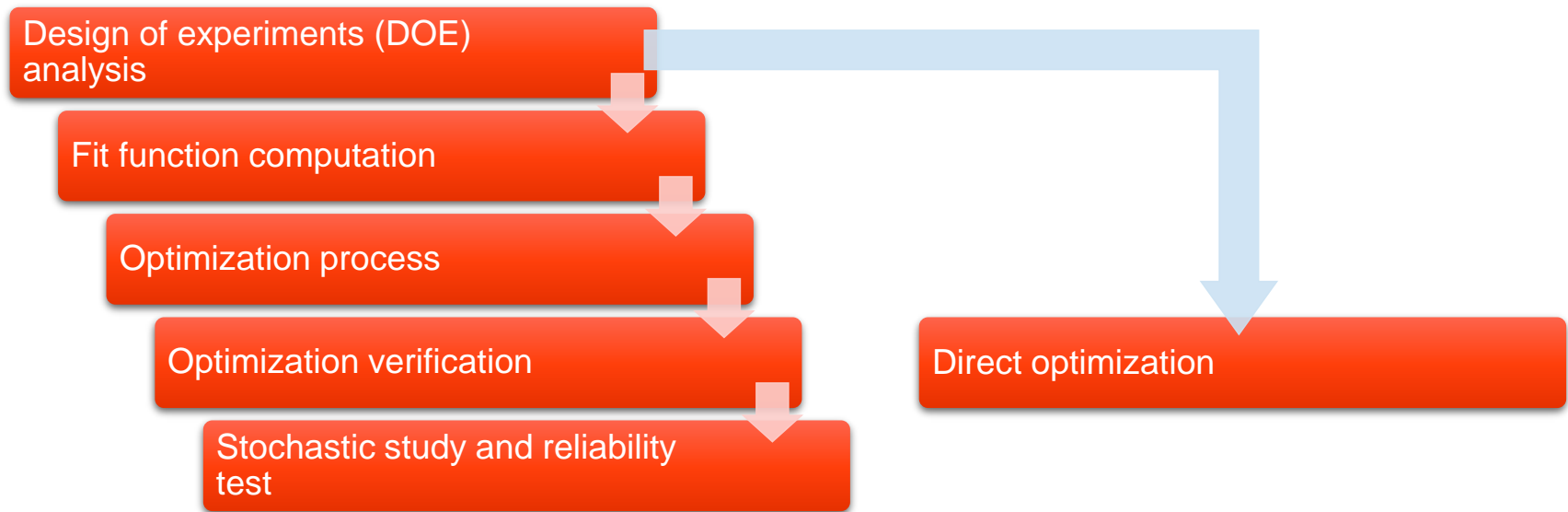
HYPERSTUDY: MULTIDISCIPLINARY DESIGN OPTIMIZATION PROCESS

ALTAIR MULTIDISCIPLINARY DESIGN OPTIMIZATION PLATFORM
FOR ELECTRIC MOTORS

November 2021, Altair Flux / FluxMotor Valorization and Support Team

OUTLINE

- Two optimization workflow are available in HyperStudy
 - Optimization based on fit functions
 - Direct optimization method



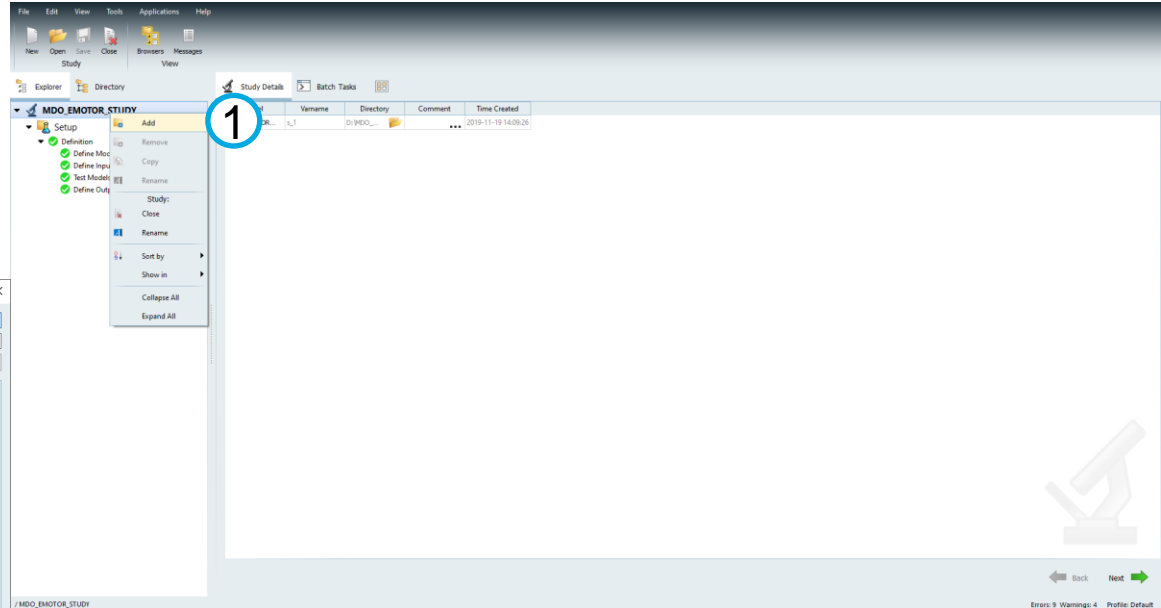
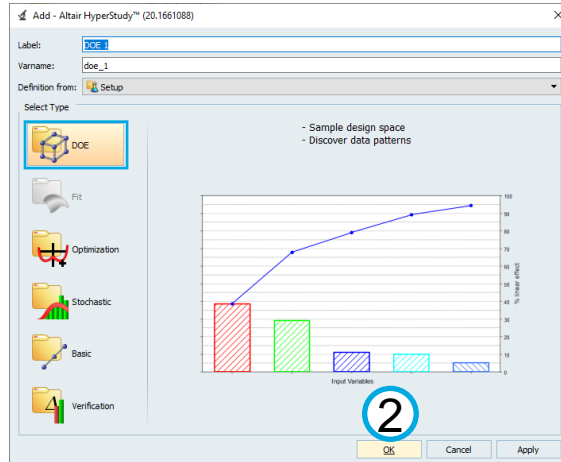
OPTIMIZATION BASED ON FIT FUNCTIONS

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis initialization
- Add a new DOE analysis

Step	Action
1	Right click on the project "MDO_MOTOR_STUDY", click on [Add]
2	Select the type as "DOE", click on [OK]



DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis initialization
- Verify model definitions

Step	Action
1	Click on [DOE 1] – [Definition] – [Test Models]
2	Click on [Run Definition] to verify the models before the DOE analysis

Model Resources									
	Active	Label	Varname	Type	Resource	Solver Input File	Solver Execution Script	Solver Input Arguments	Comment
1	<input checked="" type="checkbox"/>	OptiStruct	m_1	Parameterized File	D:\...\1_OptiStruc...	morphed.fem	OptiStruct	\${file} -optskip -nt 4	...
2	<input checked="" type="checkbox"/>	tostep	m_2	Operator		hst_input.hstp	HM Batch	-tcl_step.tcl	...
3	<input checked="" type="checkbox"/>	runFMFXFM	m_3	Operator		hst_input.hstp	Script_16		...
4	<input checked="" type="checkbox"/>	FluxMotor	m_4	FluxMotor	D:\...\Connecto...	hst_input.hstp	FluxMotor		...
5	<input checked="" type="checkbox"/>	Flux base	m_5	Flux	D:\...\5_Base_Po...	hst_input.hstp	Flux	-batch	...
6	<input checked="" type="checkbox"/>	Flux specific p...	m_6	Flux	D:\...\6_BasePo...	hst_input.hstp	Flux	-batch	...
7	<input checked="" type="checkbox"/>	Flux thermal	m_7	Flux	D:\...\7_Thermal...	hst_input.hstp	Flux	-batch	...

Test Models									
Model Data									
Show in Study Directory Show in Explorer									
	Active	Label	Test				Type	Resource	Sequence
1	<input checked="" type="checkbox"/>	OptiStruct	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Parameterized File	D:\...\1_OptiStruc...	1
2	<input checked="" type="checkbox"/>	tostep	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Operator		2
3	<input checked="" type="checkbox"/>	runFMFXFM	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Operator		3
4	<input checked="" type="checkbox"/>	FluxMotor	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	FluxMotor	D:\...\Connecto...	4
5	<input checked="" type="checkbox"/>	Flux base	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	D:\...\5_Base_Po...	5
6	<input checked="" type="checkbox"/>	Flux specific p...	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	D:\...\6_BasePo...	6
7	<input checked="" type="checkbox"/>	Flux thermal	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	D:\...\7_Thermal...	7

Stop

Run Definition

Back

Next

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis initialization
- Verify output responses

Step	Action
1	Click on [DOE 1] – [Definition] – [Define Output Responses]
2	Verify all the output values

DOE 1

- Definition
 - Define Models
 - Define Input Variables
 - Test Models
 - Define Output Responses

1

Define Output Responses									
Data Sources Objectives/Constraints - Goals Gradients									
Add Output Response Remove Output Response File Assistant Evaluate from Fit Model									
	Active	Label	Varname	Expression	Value	Goals	Evaluate From	Output Type	
37	<input checked="" type="checkbox"/>	T_COIL	r_37	ds_37[0]	161.54155		f0 Expression	Real	
38	<input checked="" type="checkbox"/>	T_MAG_1A	r_38	ds_38[0]	46.332990		f0 Expression	Real	
39	<input checked="" type="checkbox"/>	T_MAG_1A_SYM	r_39	ds_39[0]	46.331942		f0 Expression	Real	
40	<input checked="" type="checkbox"/>	T_MAG_1B	r_40	ds_40[0]	44.383888		f0 Expression	Real	
41	<input checked="" type="checkbox"/>	T_MAG_1B_SYM	r_41	ds_41[0]	44.388309		f0 Expression	Real	
42	<input checked="" type="checkbox"/>	T_MAG_1B_SYM_1	r_42	ds_42[0]	44.388309		f0 Expression	Real	
43	<input checked="" type="checkbox"/>	T_MAG_1C	r_43	ds_43[0]	45.516570		f0 Expression	Real	
44	<input checked="" type="checkbox"/>	T_MAG_1C_SYM	r_44	ds_44[0]	45.524590		f0 Expression	Real	
45	<input checked="" type="checkbox"/>	T_MAG_2A	r_45	ds_45[0]	45.897433		f0 Expression	Real	
46	<input checked="" type="checkbox"/>	T_MAG_2A_SYM	r_46	ds_46[0]	45.916338		f0 Expression	Real	
47	<input checked="" type="checkbox"/>	T_MAG_2B	r_47	ds_47[0]	45.065854		f0 Expression	Real	
48	<input checked="" type="checkbox"/>	T_MAG_2B_SYM	r_48	ds_48[0]	45.073259		f0 Expression	Real	
49	<input checked="" type="checkbox"/>	T_MAG_2C	r_49	ds_49[0]	46.001984		f0 Expression	Real	
50	<input checked="" type="checkbox"/>	T_MAG_2C_SYM	r_50	ds_50[0]	45.982872		f0 Expression	Real	
51	<input checked="" type="checkbox"/>	T_ROTOR_YOKE	r_51	ds_51[0]	45.706645		f0 Expression	Real	
52	<input checked="" type="checkbox"/>	T_STATOR_YOKE	r_52	ds_52[0]	90.183028		f0 Expression	Real	
53	<input checked="" type="checkbox"/>	Max_Stress	r_53	max(ds_53)	170.67368		f0 Expression	Real	
54	<input checked="" type="checkbox"/>	max_temperature_magnet	r_54	max(r_38,...)	46.332990		f0 Expression	Real	

2

- DOE analysis evaluation
 - Specify the DOE analysis

Attention:
Please define a number of run greater than or equal to this recommended value.

	Mode	Label	Varname	Details
1	<input checked="" type="radio"/>	Modified Extensible Lattice Sequence	Meis	
2	<input type="radio"/>	D-Optimal	DOpt	
3	<input type="radio"/>	Fractional Factorial	FracFact	
4	<input type="radio"/>	Full Factorial	FullFact	
5	<input type="radio"/>	Plackett Burman	PlackettBurman	
6	<input type="radio"/>	Taguchi	Taguchi	
7	<input type="radio"/>	Central Composite	Ccd	
8	<input type="radio"/>	Box Behnken	Box	Exceeds maximum of (7) variables
9	<input type="radio"/>	Latin HyperCube	LatinHyperCube	
10	<input type="radio"/>	Hammersley	Hammersley	
11	<input type="radio"/>	User Defined	User	
12	<input type="radio"/>	Run Matrix	RunMatrix	
13	<input type="radio"/>	None	None	

[Show less ...](#)

Specifications

Number of Runs: 100
Sequence Offset: 1
Use Fractional Matrix

Levels

Apply Back Next

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis evaluation
- Evaluate DOE tasks

Step	Action
1	Click on [DOE 1] – [Evaluate]
2	Click on [Multi-Execution] to increase the number of parallel computation
3	Click on [Evaluate Tasks]

Note:

The project is solved in a computation server.
RAM of the server is **192 Gb**.

With the following information:

Number of Runs: **400**

Number of multi-execution: **10**

Computation time is **21 hours**

The screenshot displays the Altair HyperMesh software interface during a DOE analysis evaluation. The interface is divided into several panels:

- Left Panel (Tree View):** Shows the project hierarchy. Under 'DOE 1', the 'Evaluate' task is highlighted with a blue circle and the number 1.
- Center Panel (Evaluation Tasks Table):** A table with columns 'Active', 'Write', 'Execute', and 'Extract'. It lists tasks 1 through 29. Task 1, 'Create Design', is checked in the 'Active' column.
- Right Panel (Task List):** A table with columns 'Active' and 'Task'. It lists tasks 1 through 6: 'Create Design', 'Write Input Files', 'Execute Analysis', 'Extract Output Responses', 'Purge', and 'Create Reports'. Task 1 is checked in the 'Active' column.
- Bottom Panel (Run Tasks):** A panel with a 'Run Tasks' button and a 'Evaluate Tasks' button. The 'Evaluate Tasks' button is highlighted with a blue circle and the number 3.
- Top Panel (Multi-Execution):** A panel with a 'Multi-Execution - 10' dropdown menu. A blue circle with the number 2 points to this dropdown.

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- Evaluate tasks in DOE analysis

The screenshot shows the Altair HyperMesh software interface for DOE analysis. The 'Evaluation Tasks' tab is active, displaying a table of tasks and their status. The 'Evaluate' task is highlighted in the left sidebar. The bottom status bar shows '1% (Remaining ~ 35:24:12)' and 'Errors: 0 Warnings: 24'.

Active	Write	Execute	Extract	Comment
1	Success	Success	Success	
2	Success	Success	Success	
3	Success	Success	Success	
4	Success	Success	Success	
5	Success	Started		
6	Success	Started		
7	Success	Started		
8	Success	Started		
9				
10				
11				
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19				
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21				
22				
23				
24				
25				
26				
27				
28				
29				

Task Details Table:

Active	Task	Batch
1	Create Design	
2	Write Input Files	
3	Execute Analysis	
4	Extract Output Responses	
5	Purge	
6	Create Reports	

Run Tasks

Stop Evaluate Tasks Back Next

1% (Remaining ~ 35:24:12) Errors: 0 Warnings: 24 Profile: Default

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis evaluation
- View DOE analysis results

Click on [Evaluation Data] to see all the evaluated combinations of input values and the results

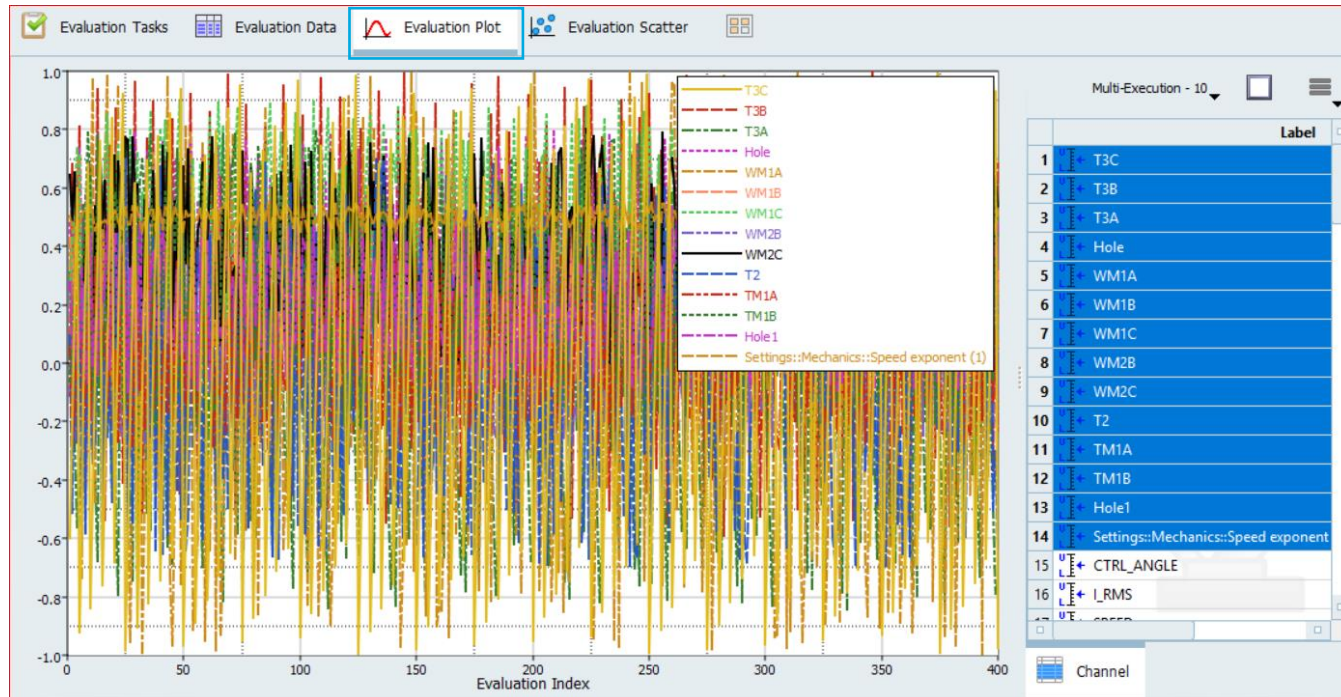
	Masses...r (kg)	Masses...s (kg)	lase s... (rpm)	lase s...er (W)	lase s...cy (%)	ORQU...SPEE	T_COIL	Post Process	Comment
1	4.7734552	1.4003700	7252.6156	129064.60	94.500221	27.106209	159.09214	<input checked="" type="checkbox"/>	
2	4.6800649	1.4351349	7232.1008	134372.67	94.680517	37.622321	156.84660	<input checked="" type="checkbox"/>	
3	4.7539699	1.3707686	7202.3129	126543.91	94.414781	25.677909	161.88661	<input checked="" type="checkbox"/>	
4	4.8138793	1.3486256	7128.0910	132530.62	94.665994	34.302503	153.72592	<input checked="" type="checkbox"/>	
5	4.7685334	1.2463635	7055.2962	119874.73	94.149002	25.189149	167.01016	<input checked="" type="checkbox"/>	
6	4.6752892	1.2781808	7081.2442	125803.80	94.379874	39.039294	162.12196	<input checked="" type="checkbox"/>	
7	4.6718367	1.2921405	7174.7762	124692.00	94.344319	27.338696	167.06339	<input checked="" type="checkbox"/>	
8	4.7494655	1.3738462	7170.9833	134693.99	94.724099	40.911462	153.58130	<input checked="" type="checkbox"/>	
9	4.8069119	1.2125358	7052.1742	122003.90	94.241268	23.089476	163.35878	<input checked="" type="checkbox"/>	
10	4.7503111	1.3209739	7145.6881	128065.03	94.497427	32.348243	160.84719	<input checked="" type="checkbox"/>	
11	4.8521846	1.5124010	7241.8264	135712.52	94.723712	33.718580	152.57964	<input checked="" type="checkbox"/>	
12	4.6919799	1.3025690	7086.3486	127055.01	94.419889	32.783858	159.77524	<input checked="" type="checkbox"/>	
13	4.7651461	1.2535964	7079.8540	124179.13	94.314412	27.577615	162.80135	<input checked="" type="checkbox"/>	
14	4.7732883	1.2944921	7120.5381	121755.31	94.209360	17.335376	163.99141	<input checked="" type="checkbox"/>	
15	4.7294801	1.4086514	7194.1866	133506.68	94.680095	42.070650	155.33613	<input checked="" type="checkbox"/>	
16	4.7498339	1.3081858	7143.5260	124822.71	94.356238	29.092020	163.00739	<input checked="" type="checkbox"/>	
17	4.7818854	1.3974352	7185.2349	131856.32	94.624831	33.225372	158.56132	<input checked="" type="checkbox"/>	
18	4.6961070	1.2857358	7121.8489	126398.65	94.392414	29.772937	162.48831	<input checked="" type="checkbox"/>	

DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis evaluation

- View DOE analysis results

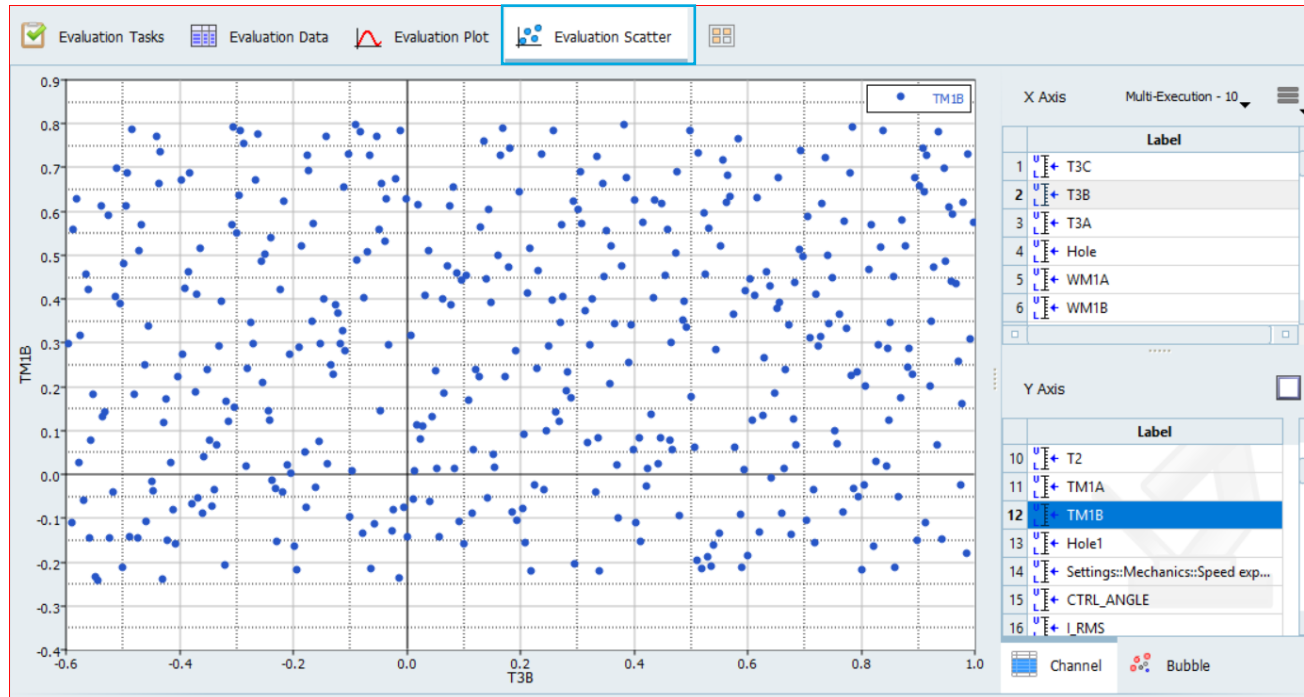
Click on [Evaluation Plot] to plot the curves of parameters during the evaluation task



DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis evaluation
- View DOE analysis results

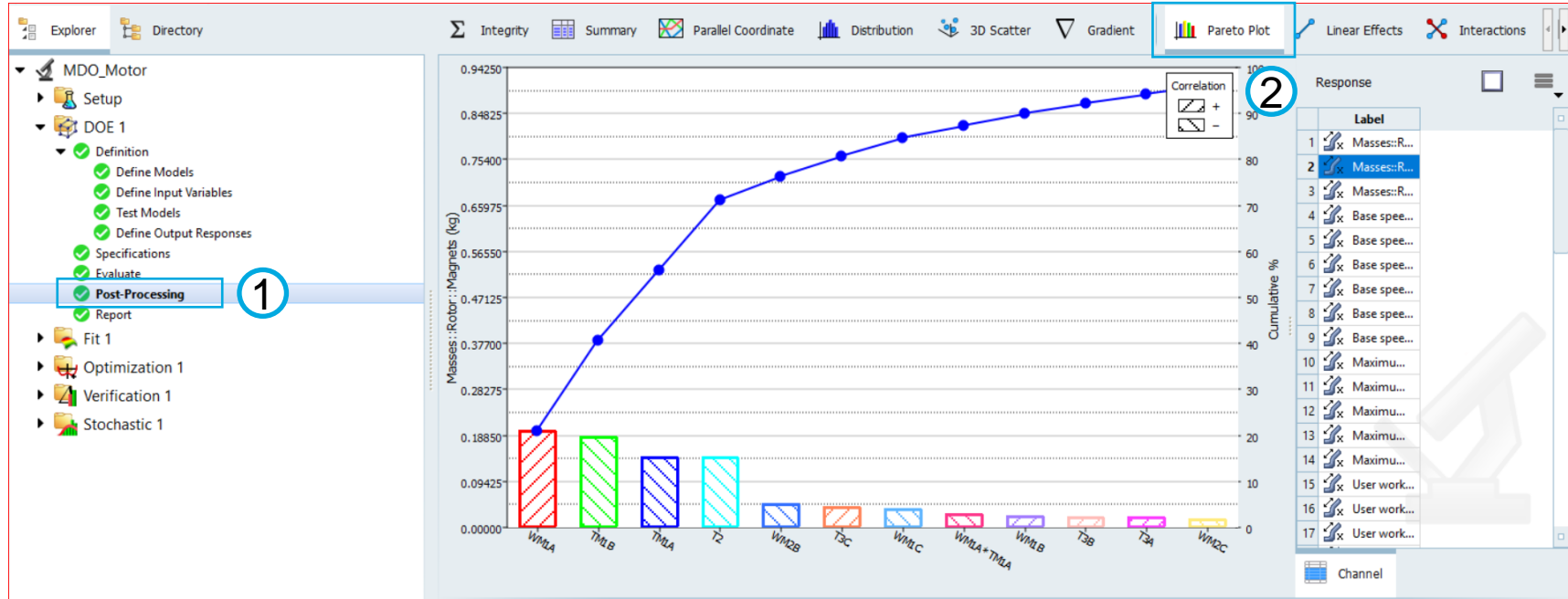
Click on [Evaluation Scatter] to plot the related curve between two evaluated parameters



DESIGN OF EXPERIMENTS (DOE) ANALYSIS

- DOE analysis post-processing

Step	Action
1	Click on [Post-Processing] in the [DOE 1] model
2	Use the HyperStudy function to analyze the DOE results

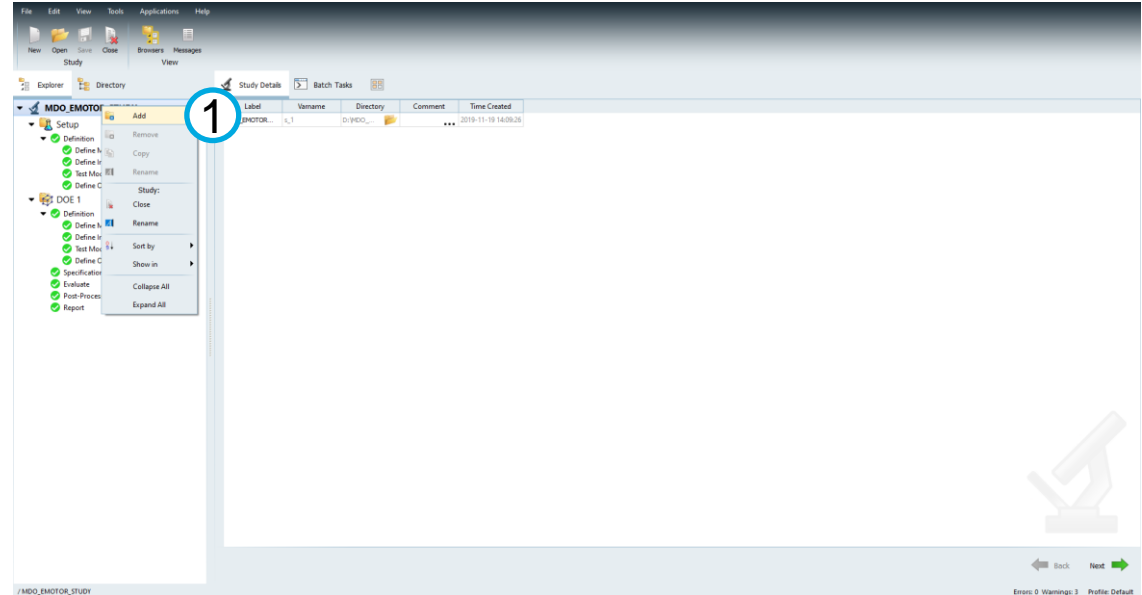
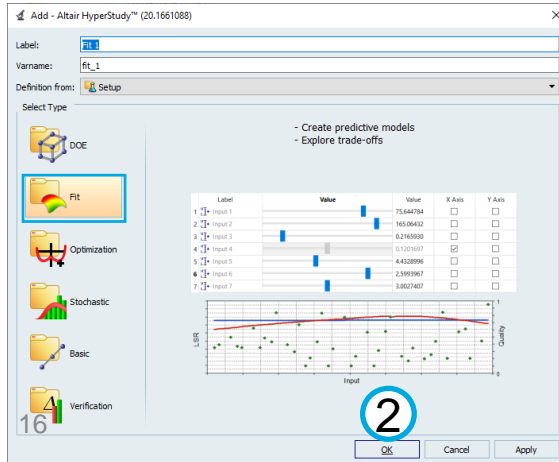


FIT FUNCTION COMPUTATION

FIT FUNCTION COMPUTATION

- Initialization for fit function computation
- Add a new fit function analysis

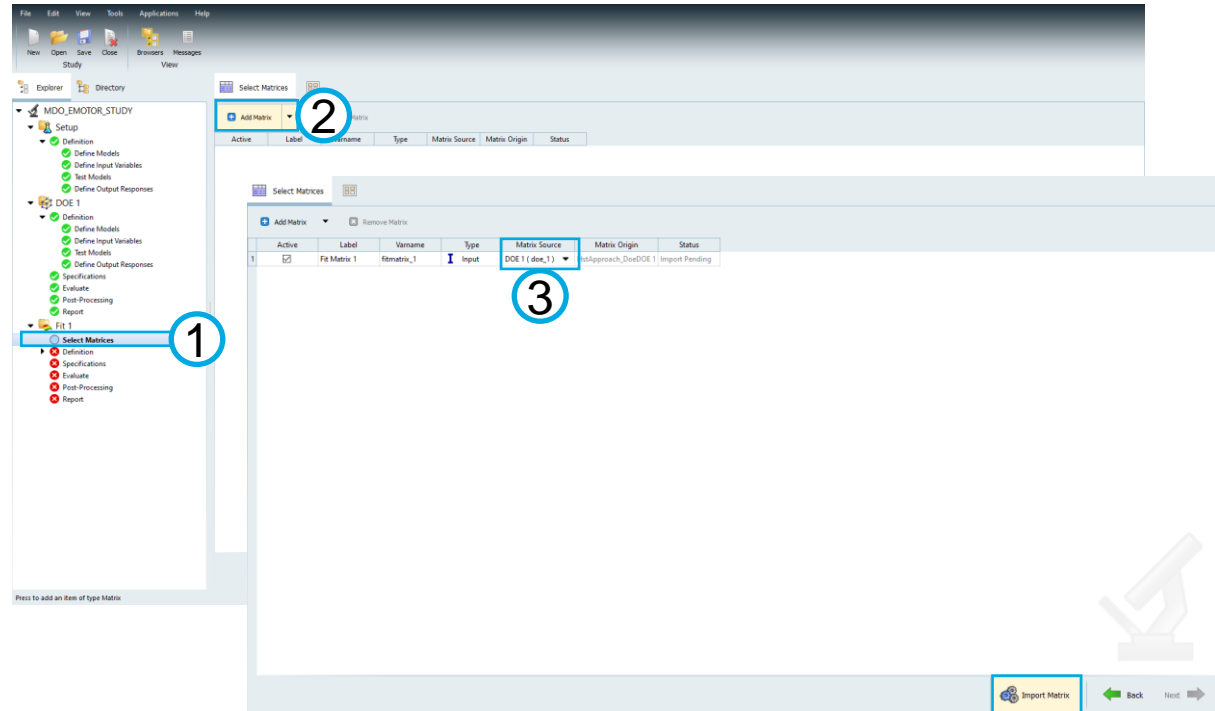
Step	Action
1	Right click on the project "MDO_MOTOR_STUDY", click on [Add]
2	Select the type as "Fit", click on [OK]



FIT FUNCTION COMPUTATION

- Initialization for fit function computation
 - Define input matrix

Step	Action
1	Click on [Fit 1] – [Select Matrices]
2	Click on [Add Matrix]
3	Select “DOE 1” as the Matrix Source
4	Click on [Import Matrix]



FIT FUNCTION COMPUTATION

- Initialization for fit function computation
 - Verify model definitions

Step	Action
1	Click on [Fit 1] – [Definition] – [Test Models]
2	Click on [Run Definition] to verify the models before computing fit functions

Define Models

1

Add Model Remove Model Model Resources

Active	Label	Varname	Type	Resource	Solver Input File	Solver Execution Script	Solver Input Arguments	Comment
1	OptiStruct	m_1	Parameterized File	E:\...\1_OptiStruct\ref_model.tpl	morphed.fem	OptiStruct	\$(file) -optskip -nt 4	...
2	tostep	m_2	Operator		hst_input.hst	HM Batch	-tcl to_step.tcl	...
3	runFMFXFM	m_3	Operator		hst_input.hst	Script_16		...
4	FluxMotor	m_4	FluxMotor	E:\...\Connector_FM_Hst\Connector_F...	hst_input.hst	FluxMotor		...
5	Flux base	m_5	Flux	E:\...\5_Base_Point\BasePoint_HSTDY.F2...	hst_input.hst	Flux	-batch	...
6	Flux specific point	m_6	Flux	E:\...\6_BasePointHalfTorque\BasePoint...	hst_input.hst	Flux	-batch	...
7	Flux thermal	m_7	Flux	E:\...\7_Thermal\Thermal_HSTDY.F2HST	hst_input.hst	Flux	-batch	...

Test Models Model Data

Show in Study Directory Show in Explorer

Active	Label	Test	Type	Resource	Sequence
1	OptiStruct	Write Execute Extract	Parameterized File	ref_model.tpl	1
2	tostep	Write Execute Extract	Operator		2
3	runFMFXFM	Write Execute Extract	Operator		3
4	FluxMotor	Write Execute Extract	FluxMotor	E:\...\Connector_FM_Hst\Connector_FM_Hst.fm2hst	4
5	Flux base	Write Execute Extract	Flux	E:\...\5_Base_Point\BasePoint_HSTDY.F2HST	5
6	Flux specific p...	Write Execute Extract	Flux	E:\...\6_BasePointHalfTorque\BasePointHalfTorque_HS...	6
7	Flux thermal	Write Execute Extract	Flux	E:\...\7_Thermal\Thermal_HSTDY.F2HST	7

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Stop Run Definition Back Next

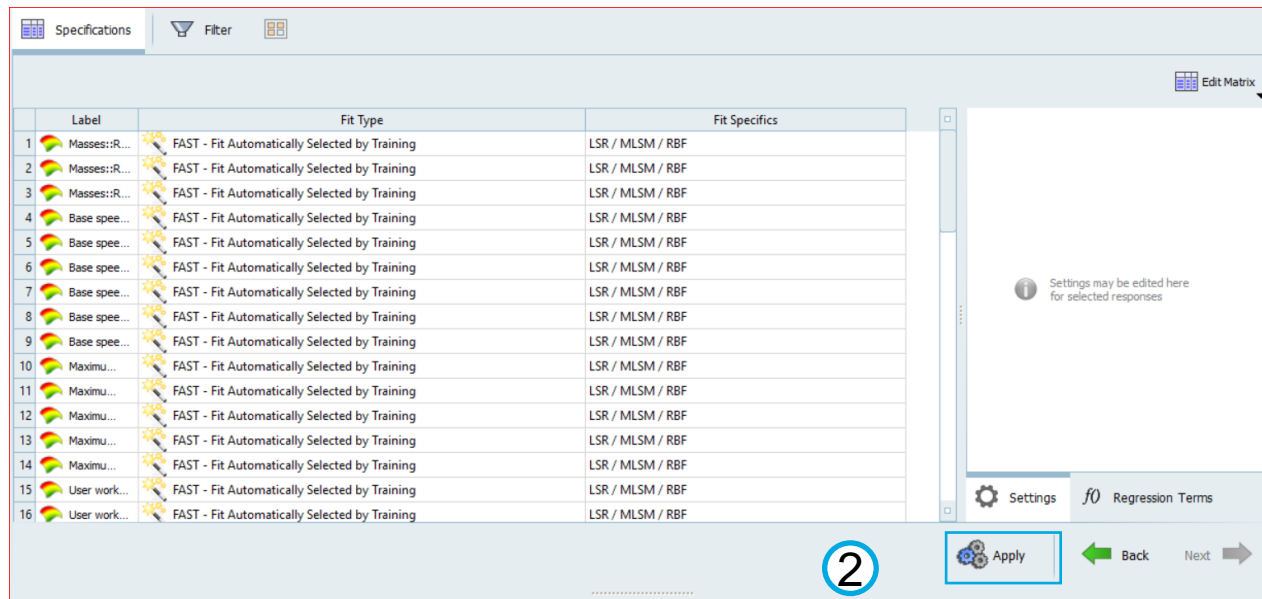
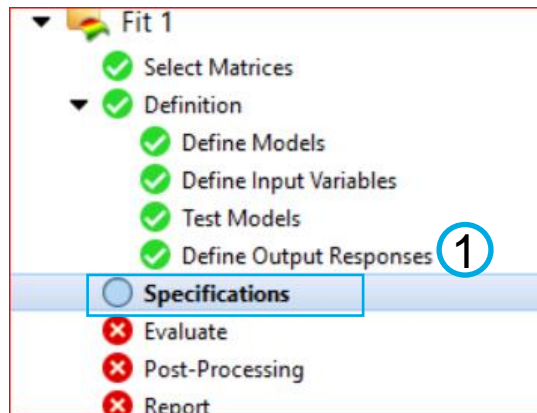
Run Definition

2 Back Next

FIT FUNCTION COMPUTATION

- Initialization for fit function computation
 - Define fit function setting

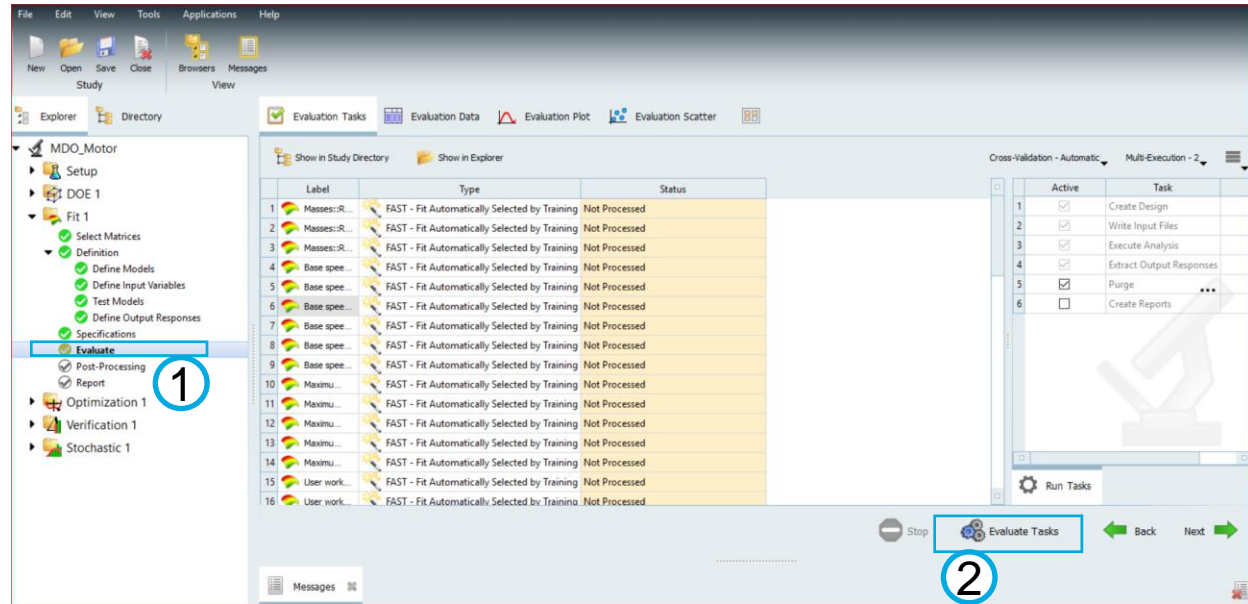
Step	Action
1	Click on [Fit 1] - [Specifications]
2	Click on [Apply] to confirm the fit function setting



FIT FUNCTION COMPUTATION

- Fit function computation process
- Evaluate tasks

Step	Action
1	Click on [Evaluate]
2	Click on [Evaluate Tasks] to compute fit functions



FIT FUNCTION COMPUTATION

- Fit function computation process
- Post-processing

Step	Action
1	Click on [Fit 1] – [Post-Processing]
2	Use the HyperStudy function to analyze the fit function computation results

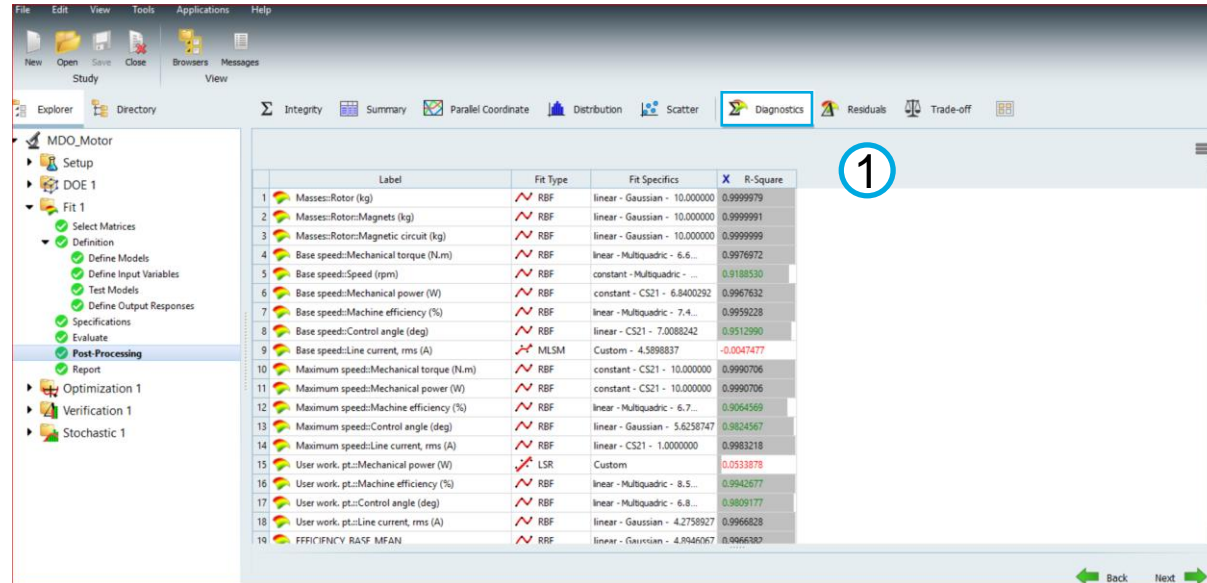
The screenshot shows the Altair HyperStudy software interface. On the left sidebar, the 'Post-Processing' option is highlighted under the 'Fit 1' folder, with a red circle and the number '1' next to it. The main window displays a data table with the following columns: Label, Varname, Category, Points, Unique, No Values, Bad Values, Excluded, and Range. The table contains 18 rows of data. A red circle with the number '2' is placed over the 'Summary' tab in the top navigation bar.

Label	Varname	Category	Points	Unique	No Values	Bad Values	Excluded	Range
1	T3C var_1	Variable	279	279	0	0	0	1.9808000
2	T3B var_2	Variable	279	279	0	0	0	1.5923200
3	T3A var_3	Variable	279	279	0	0	0	1.4407200
4	Hole var_4	Variable	279	279	0	0	0	0.7908756
5	WM1A var_5	Variable	279	279	0	0	0	1.9881535
6	WM1B var_6	Variable	279	279	0	0	0	0.5985010
7	WM1C var_7	Variable	279	279	0	0	0	0.8957133
8	WM2B var_8	Variable	279	279	0	0	0	0.7979540
9	WM2C var_9	Variable	279	279	0	0	0	0.7991417
10	T2 var_10	Variable	279	279	0	0	0	1.3933453
11	TM1A var_11	Variable	279	279	0	0	0	0.6732687
12	TM1B var_12	Variable	279	279	0	0	0	1.0398859
13	Hole1 var_13	Variable	279	279	0	0	0	0.5982534
14	Settings... var_14	Variable	279	279	0	0	0	0.0997303
15	Masses... r_1	Response	279	279	0	0	0	0.2799070
16	Masses... r_2	Response	279	279	0	0	0	0.5884803
17	Masses... r_3	Response	279	279	0	0	0	0.5185557
18	Base sp... r_4	Response	279	279	0	0	0	40.474993

FIT FUNCTION COMPUTATION

- Fit function computation process
- Post-processing

Step	Action
1	Use the [Diagnostic] function to analyze the fit function computation quality



	Label	Fit Type	Fit Specifics	R-Square
1	Masses:Rotor (kg)	RBF	linear - Gaussian - 10.000000	0.9999979
2	Masses:Rotor:Magnets (kg)	RBF	linear - Gaussian - 10.000000	0.9999991
3	Masses:Rotor:Magnetic circuit (kg)	RBF	linear - Gaussian - 10.000000	0.9999999
4	Base speed:Mechanical torque (N.m)	RBF	linear - Multiquadric - 6.6...	0.9976972
5	Base speed:Speed (rpm)	RBF	constant - Multiquadric - ...	0.9108530
6	Base speed:Mechanical power (W)	RBF	constant - CS21 - 6.8400292	0.9967632
7	Base speed:Machine efficiency (%)	RBF	linear - Multiquadric - 7.4...	0.9959228
8	Base speed:Control angle (deg)	RBF	linear - CS21 - 7.0088242	0.9512990
9	Base speed:Line current, rms (A)	MLSM	Custom - 4.5898837	-0.0047477
10	Maximum speed:Mechanical torque (N.m)	RBF	constant - CS21 - 10.000000	0.9990706
11	Maximum speed:Mechanical power (W)	RBF	constant - CS21 - 10.000000	0.9990706
12	Maximum speed:Machine efficiency (%)	RBF	linear - Multiquadric - 6.7...	0.9064569
13	Maximum speed:Control angle (deg)	RBF	linear - Gaussian - 5.6258747	0.9824567
14	Maximum speed:Line current, rms (A)	RBF	linear - CS21 - 1.0000000	0.9983218
15	User work_pt.:Mechanical power (W)	LSR	Custom	0.0533878
16	User work_pt.:Machine efficiency (%)	RBF	linear - Multiquadric - 8.5...	0.9942677
17	User work_pt.:Control angle (deg)	RBF	linear - Multiquadric - 6.8...	0.9809177
18	User work_pt.:Line current, rms (A)	RBF	linear - Gaussian - 4.2758927	0.9966828
19	FFF(CFMCV) R&Q MFAN	RBF	linear - Gaussian - 4.9046067	0.9066380

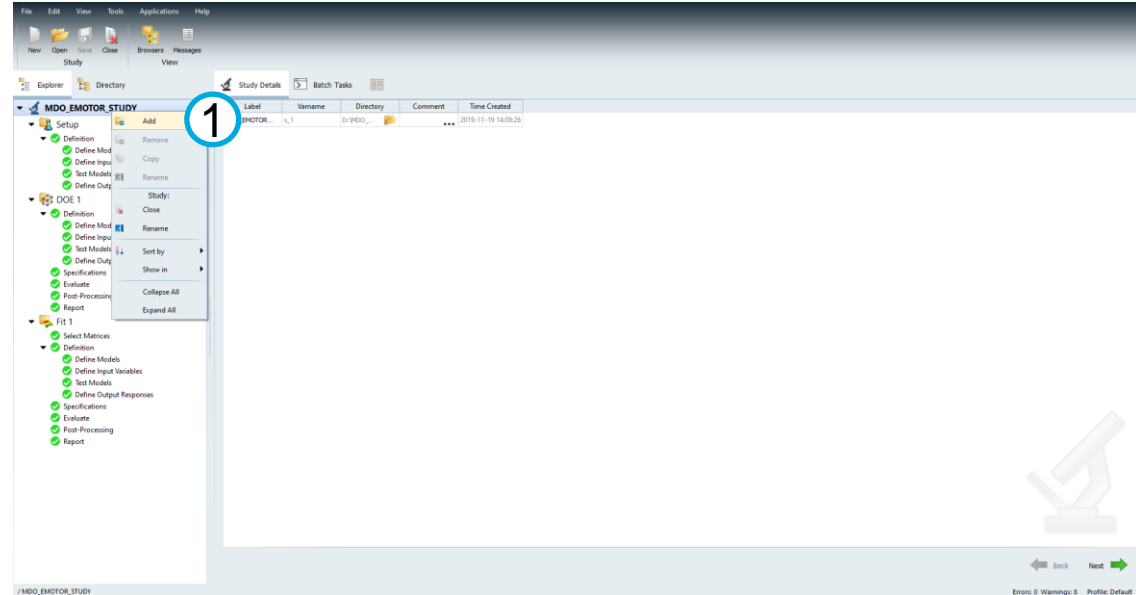
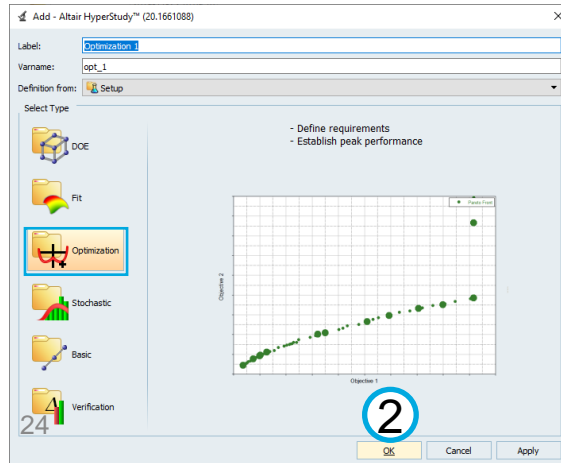
Note: if the value is closer to 1, the more accurate is the Fit function obtained.

OPTIMIZATION PROCESS

OPTIMIZATION PROCESS

- Optimization initialization
 - Add a new optimization application

Step	Action
1	Right click on the project "MDO_MOTOR_STUDY", click on [Add]
2	Select the type as "Optimization", click on [OK]



OPTIMIZATION PROCESS

- Optimization initialization
- Link to fit function results


Step	Action
1	Click on [Optimization 1] – [Definition] – [Define output Responses]
2	Click on [Evaluate From] to select all the output responses
3	Click on [Evaluate from Fit Model] – [Fit 1] to link the optimization with the fit functions

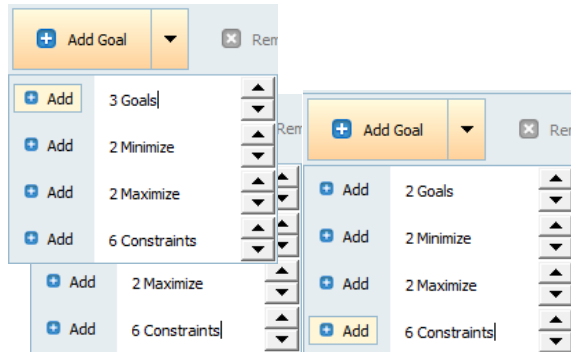
The screenshot displays the Altair MDO_EMTOR_STUDY software interface. The left sidebar shows a tree view of the study structure, with 'Optimization 1' selected. The central table lists various output responses, including masses, base speed, and maximum speed. The right sidebar shows the 'Evaluate From' column, which is used to link the optimization with the fit functions. A large blue arrow points from the 'Evaluate From' column in the table to the 'Evaluate from Fit Model' button in the right sidebar. Three numbered callouts (1, 2, 3) highlight specific actions: 1 points to the 'Define Output Responses' button in the left sidebar; 2 points to the 'Evaluate From' column header in the table; 3 points to the 'Evaluate from Fit Model' button in the right sidebar.

Active	Label	Vname	Expression	Value	Goals	Evaluate From	Output Type	Unit
1	Masses:Rotor (kg)	r_1	ds-140	N/A	Minimize	Fit 1 (fit_1)	Real	...
2	Masses:Rotor:Magnets (kg)	r_2	ds-240	N/A	Minimize	Fit 1 (fit_1)	Real	...
3	Masses:Rotor:Magnetic circuit (kg)	r_3	ds-240	N/A	...	Fit 1 (fit_1)	Real	...
4	Base speed:Mechanical torque (N.m)	r_4	ds-440	N/A	>= 180.00000	Fit 1 (fit_1)	Real	...
5	Base speed:Speed (rpm)	r_5	ds-540	N/A	...	Fit 1 (fit_1)	Real	...
6	Base speed:Mechanical power (W)	r_6	ds-640	N/A	Multiple	Fit 1 (fit_1)	Real	...
7	Base speed:Machine efficiency (%)	r_7	ds-740	N/A	...	Fit 1 (fit_1)	Real	...
8	Base speed:Control angle (deg)	r_8	ds-840	N/A	...	Fit 1 (fit_1)	Real	...
9	Base speed:Line current, rms (A)	r_9	ds-940	N/A	...	Fit 1 (fit_1)	Real	...
10	Maximum speed:Mechanical torque (N.m)	r_10	ds-1040	N/A	...	Fit 1 (fit_1)	Real	...
11	Maximum speed:Mechanical power (W)	r_11	ds-1140	N/A	...	Fit 1 (fit_1)	Real	...
12	Maximum speed:Machine efficiency (%)	r_12	ds-1240	N/A	...	Fit 1 (fit_1)	Real	...
13	Maximum speed:Control angle (deg)	r_13	ds-1340	N/A	...	Fit 1 (fit_1)	Real	...
14	Maximum speed:Line current, rms (A)	r_14	ds-1440	N/A	...	Fit 1 (fit_1)	Real	...
15	User work_pt.:Mechanical power (W)	r_15	ds-1540	N/A	...	Fit 1 (fit_1)	Real	...
16	User work_pt.:Machine efficiency (%)	r_16	ds-1640	N/A	...	Fit 1 (fit_1)	Real	...
17	User work_pt.:Control angle (deg)	r_17	ds-1740	N/A	...	Fit 1 (fit_1)	Real	...
18	User work_pt.:Line current, rms (A)	r_18	ds-1840	N/A	...	Fit 1 (fit_1)	Real	...
19	EFFICIENCY_BASE_MEAN	r_19	ds-1940	N/A	...	Fit 1 (fit_1)	Real	PHYS

OPTIMIZATION PROCESS

- Optimization initialization
 - Define optimization goals and constraints

Step	Action
1	Click on [Objectives/Constraints - goals]
2	Click on the icon  to add <ul style="list-style-type: none"> 3 Goals 6 constraints



Define Output Responses									
Data Sources									
Objectives/Constraints - Goals									
Gradients									
Standard Constraint Enforcement									
Active	Label	Varname	Apply On	Type	... 1 2 ...	Comment		
1	MaxPowerBaseSpeed	goal_1	Base speed::Mechanical power (W) (r_6)	Maximize	N/A	N/A			
2	MinRotorMass	goal_2	Masses::Rotor (kg) (r_1)	Minimize	N/A	N/A			
3	MinMagnetMass	goal_3	Masses::Rotor::Magnets (kg) (r_2)	Minimize	N/A	N/A			
4	TorqueBassSpeed	constraint_4	Base speed::Mechanical torque (N.m) (r_4)	Constraint	>=	180.00000			
5	PowerBassSpeed	constraint_5	Base speed::Mechanical power (W) (r_6)	Constraint	>=	140000.00			
6	TemperatureWinding	constraint_6	T_COIL (r_37)	Constraint	<=	180.00000			
7	TorqueBassSpeedRipple	constraint_7	TORQUE_RIPPLE_BASE_SPEED (r_21)	Constraint	<=	29.000000			
8	TempMagnetMax	constraint_8	max_temperature_magnet (r_54)	Constraint	<=	100.00000			
9	MechanicalStress	constraint_9	Max_Stress (r_53)	Constraint	<=	380.00000			

OPTIMIZATION PROCESS

- Optimization initialization
- Define optimization goals and constraints

Step	Action
1	Modify the goals and constraints as shown in the following table

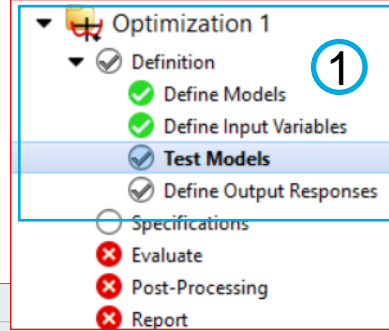
Label	Varname	Apply on	Type	1	2
MaxPowerBaseSpeed	goal_1	Base speed::Mechanical power (W) (r_6)	Maximize		
MinRotorMass	goal_2	Masses::Rotor (kg) (r_1)	Minimize		
MinMagnetMass	goal_3	Masses::Rotor::Magnets (kg) (r_2)	Minimize		
TorqueBassSpeed	constraint_3	Base speed::Mechanical torque (N.m) (r_4)	Constraint	>=	180
PowerBassSpeed	constraint_4	Base speed::Mechanical power (W) (r_6)	Constraint	>=	140000
TemperatureWinding	constraint_5	T_COIL (r_38)	Constraint	<=	180
TorqueBassSpeedRipple	constraint_6	TORQUE_BASE_SPEED_RIPPLE (r_53)	Constraint	<=	29
TempMagnetMax	constraint_7	MAX_MAGNET_TEMPERATURE (r_54)	Constraint	<=	100
MechanicalStress	constraint_8	MECHANICAL_STRESS_MAX (r_56)	Constraint	<=	380

Active	Label	Varname	Apply On	Type	1	2
1	<input checked="" type="checkbox"/> MaxPowerBaseSpeed	goal_1	Base speed::Mechanical power (W) (r_6)	Maximize	N/A	N/A
2	<input checked="" type="checkbox"/> MinRotorMass	goal_2	Masses::Rotor (kg) (r_1)	Minimize	N/A	N/A
3	<input checked="" type="checkbox"/> MinMagnetMass	goal_3	Masses::Rotor::Magnets (kg) (r_2)	Minimize	N/A	N/A
4	<input checked="" type="checkbox"/> TorqueBassSpeed	constraint_4	Base speed::Mechanical torque (N.m) (r_4)	Constraint	>=	180.00000
5	<input checked="" type="checkbox"/> PowerBassSpeed	constraint_5	Base speed::Mechanical power (W) (r_6)	Constraint	>=	140000.00
6	<input checked="" type="checkbox"/> TemperatureWinding	constraint_6	T_COIL (r_37)	Constraint	<=	180.00000
7	<input checked="" type="checkbox"/> TorqueBassSpeedRipple	constraint_7	TORQUE_RIPPLE_BASE_SPEED (r_21)	Constraint	<=	29.000000
8	<input checked="" type="checkbox"/> TempMagnetMax	constraint_8	max_temperature_magnet (r_54)	Constraint	<=	100.00000
9	<input checked="" type="checkbox"/> MechanicalStress	constraint_9	Max_Stress (r_53)	Constraint	<=	380.00000

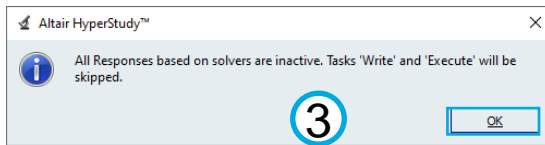
OPTIMIZATION PROCESS

- Optimization initialization
- Verify model definition

Step	Action
1	Click on [Optimization 1] – [Definition] – [Test Models]
2	Click on [Run Definition] to verify the models before running optimization process
3	Click on [OK]



Active	Label	Test			Type	Resource	Sequence
1	OptiStruct	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	{ Parameterized File	E:\...\1_OptiStruct\ref_model.tpl
2	tostep	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	Operator	
3	runFMFXFM	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	Operator	
4	FluxMotor	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	FluxMotor	E:\...\Connector_FM_Hst\Connector_FM_Hst.fm2hst
5	Flux base	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	Flux	E:\...\5_Base_Point\BasePoint_HSTDY.F2HST
6	Flux specific p...	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	Flux	E:\...\6_BasePointHalfTorque\BasePointHalfTorque_HS...
7	Flux thermal	<input type="radio"/> Write	<input type="radio"/> Execute	<input type="radio"/> Extract	All	Flux	E:\...\7_Thermal\Thermal_HSTDY.F2HST

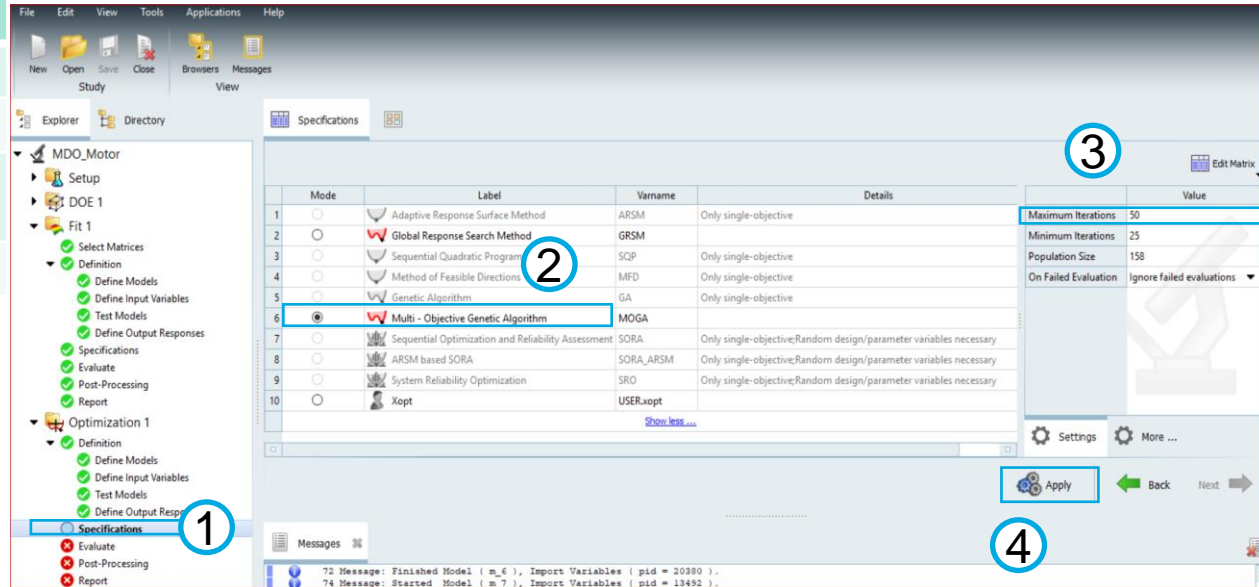


Active	Label	Test			Type	Resource	Sequence
1	OptiStruct	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	{ Parameterized File	E:\...\1_OptiStruct\ref_model.tpl
2	tostep	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Operator	
3	runFMFXFM	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Operator	
4	FluxMotor	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	FluxMotor	E:\...\Connector_FM_Hst\Connector_FM_Hst.fm2hst
5	Flux base	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	E:\...\5_Base_Point\BasePoint_HSTDY.F2HST
6	Flux specific p...	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	E:\...\6_BasePointHalfTorque\BasePointHalfTorque_HS...
7	Flux thermal	<input checked="" type="checkbox"/> Write	<input checked="" type="checkbox"/> Execute	<input checked="" type="checkbox"/> Extract	All	Flux	E:\...\7_Thermal\Thermal_HSTDY.F2HST

OPTIMIZATION PROCESS

- Optimization initialization
- Define optimization setting

Step	Action
1	Click on [Specifications]
2	Select “MOGA” algorithm
3	Define the “Maximum Iteration” number 100
4	Click on [Apply]

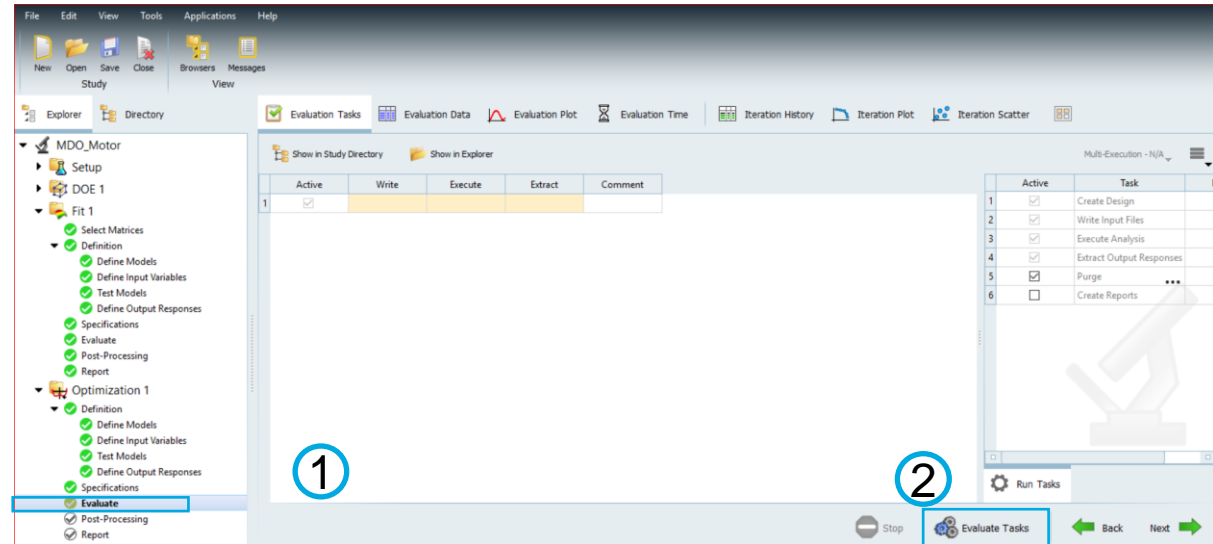


Note: The Multi Objective Generic Algorithm is a suitable method for the optimization problem based on fit functions.

OPTIMIZATION PROCESS

- Optimization evaluation
 - Evaluate tasks for the optimization problem

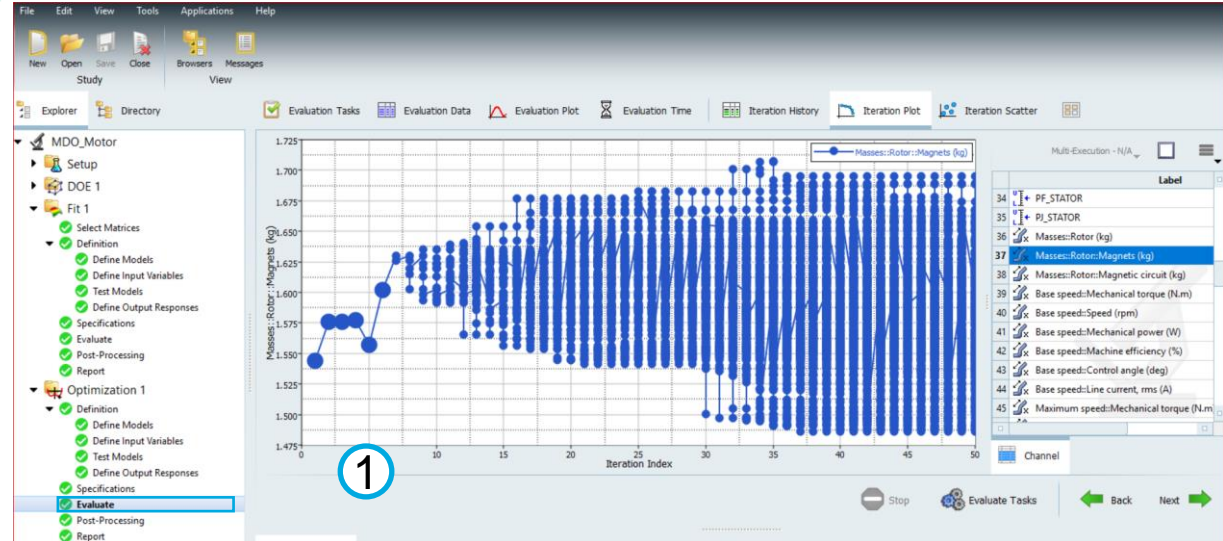
Step	Action
1	Click on [Evaluate]
2	Click on [Evaluate Tasks]



OPTIMIZATION PROCESS

- Optimization evaluation
 - Verify iteration convergence during the optimization process

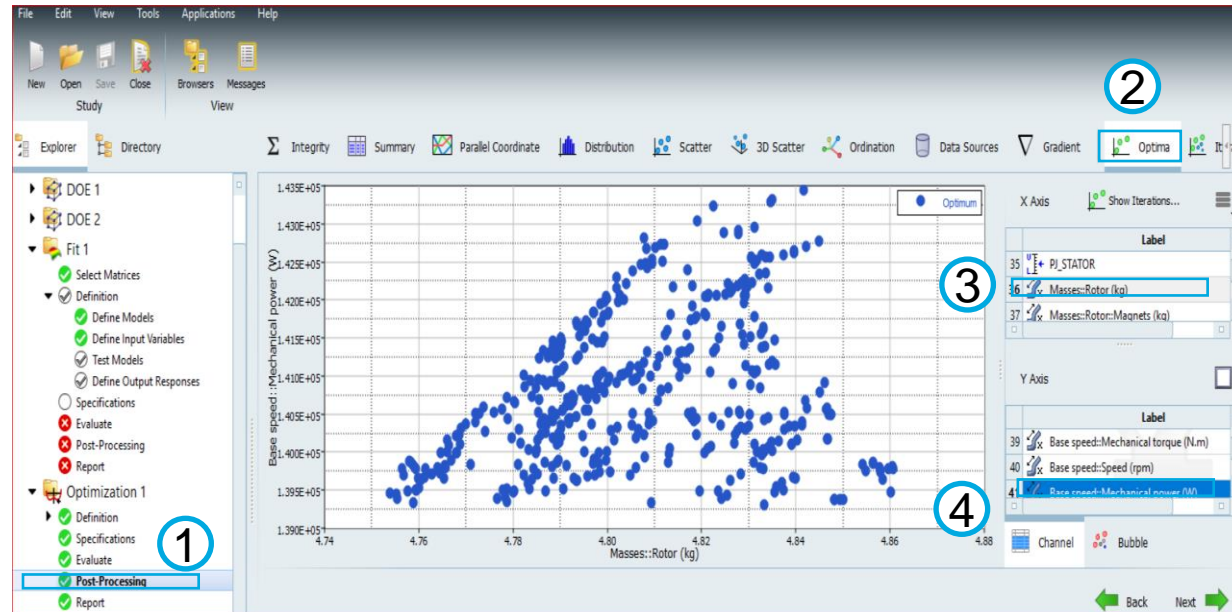
Step	Action
1	Click on [Iteration Plot]



OPTIMIZATION PROCESS

- Optimization post-processing
- Plot optimal curve

Step	Action
1	Click on [Post-Processing]
2	Click on [Optimal] to see all the optimization results for the electric motor
3	Select the Goal "MinRotorMass"
4	Select the Goal "MaxPowerBaseSpeed"

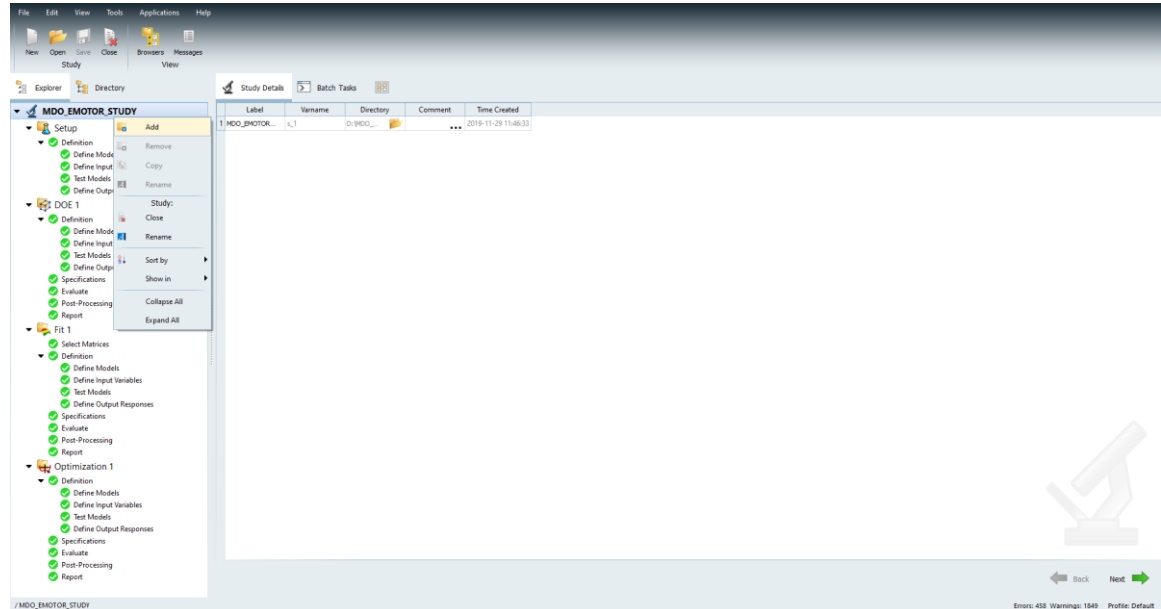
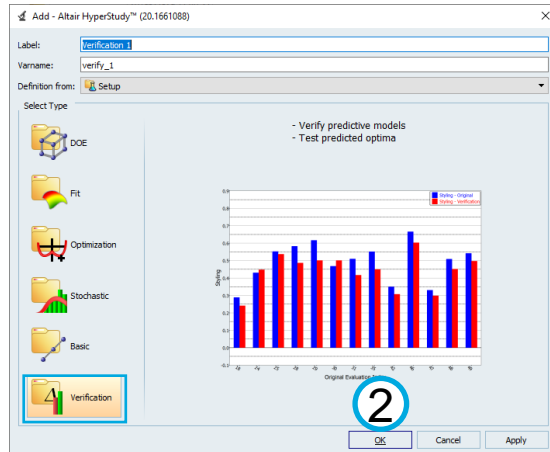


OPTIMIZATION VERIFICATION

OPTIMIZATION VERIFICATION

- Verification initialization
- Add a new verification

Step	Action
1	Right click on the project “MDO_MOTOR_STUDY”, click on [Add]
2	Select the type as “Verification”, click on [OK]

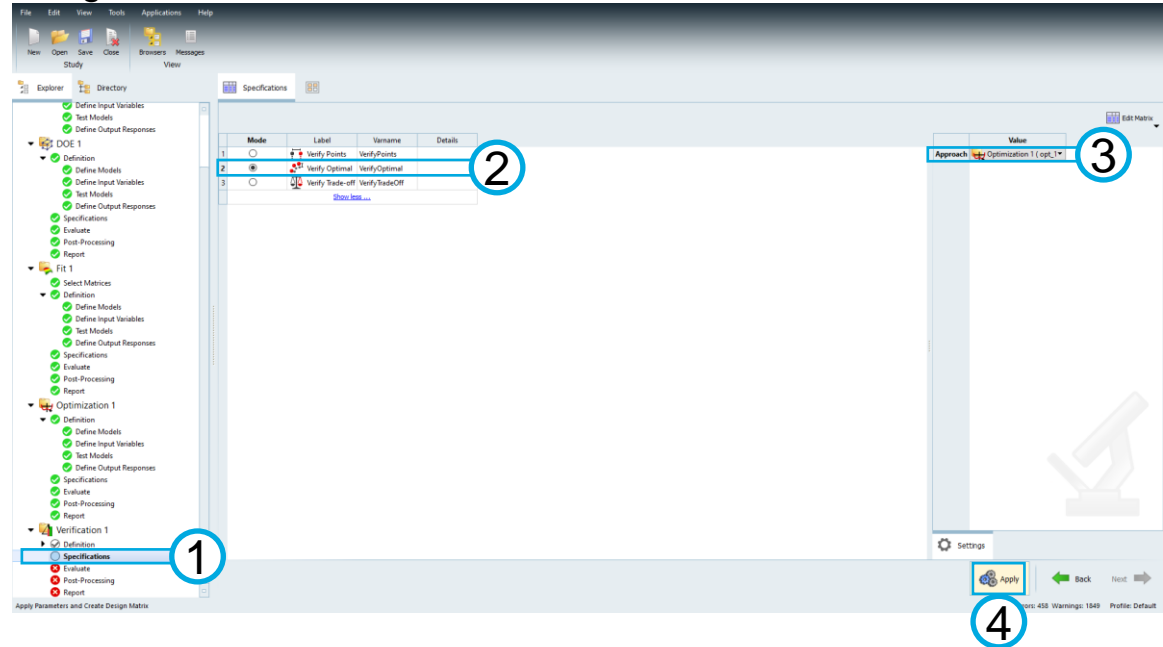


Note: The results of optimization problem based on fit functions will need to be check with real model.

OPTIMIZATION VERIFICATION

- Verification specification
 - Define verification mode and original value

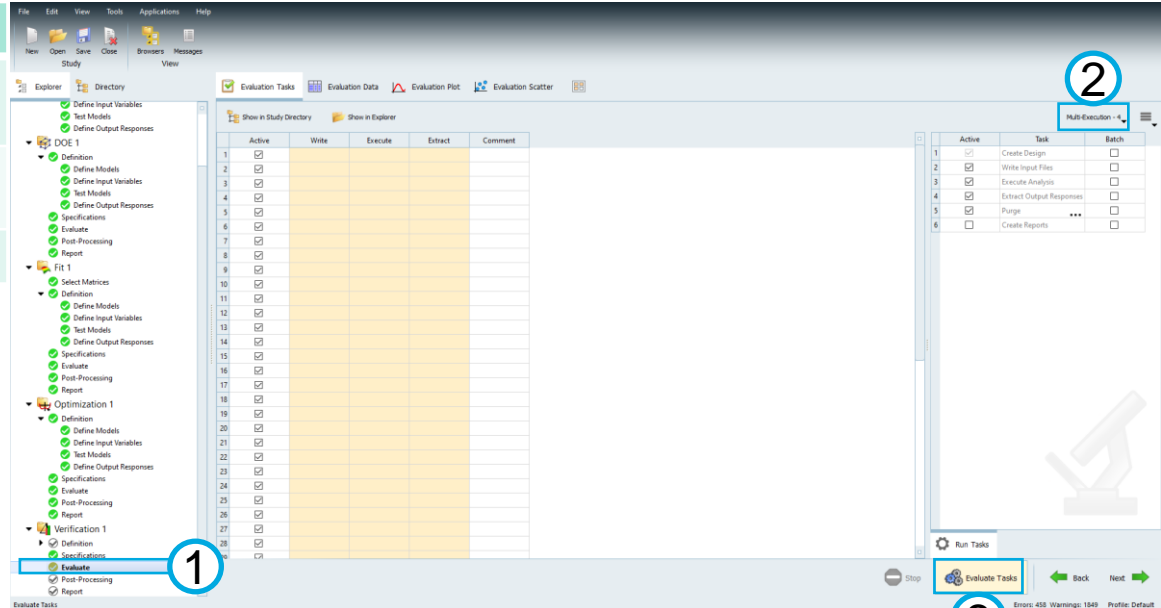
Step	Action
1	Click on [Verification 1] – [Specification]
2	Select the verification mode as “Verify Optimal”
3	Verify if the value is from the “Optimization 1”
4	Click on [Apply]



OPTIMIZATION VERIFICATION

- Verification evaluation
- Evaluate the verification tasks

Step	Action
1	Click on [Verification 1] – [Evaluate]
2	Click on [Multi-Execution] to define the multi-execution number
3	Click on [Evaluate Tasks]



CONCLUSION

CONCLUSION

Both direction optimization method and fit function based optimization have been used and tested in the MDO platform



Both the optimum found by the two method fulfilling all criteria



The fit function based optimization can save more time in the optimization part



THANK YOU

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