Argonne NATIONAL LABORATORY

Introductory Course: Using LS-OPT® on the TRACC Cluster

1.6a - Design Optimization; Simple Problem

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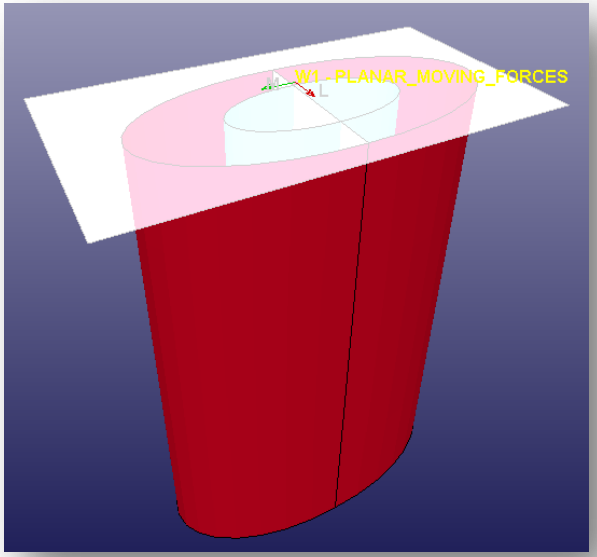
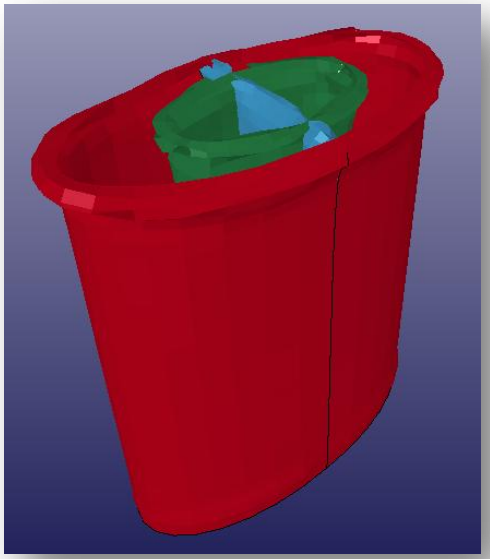
Problem Description

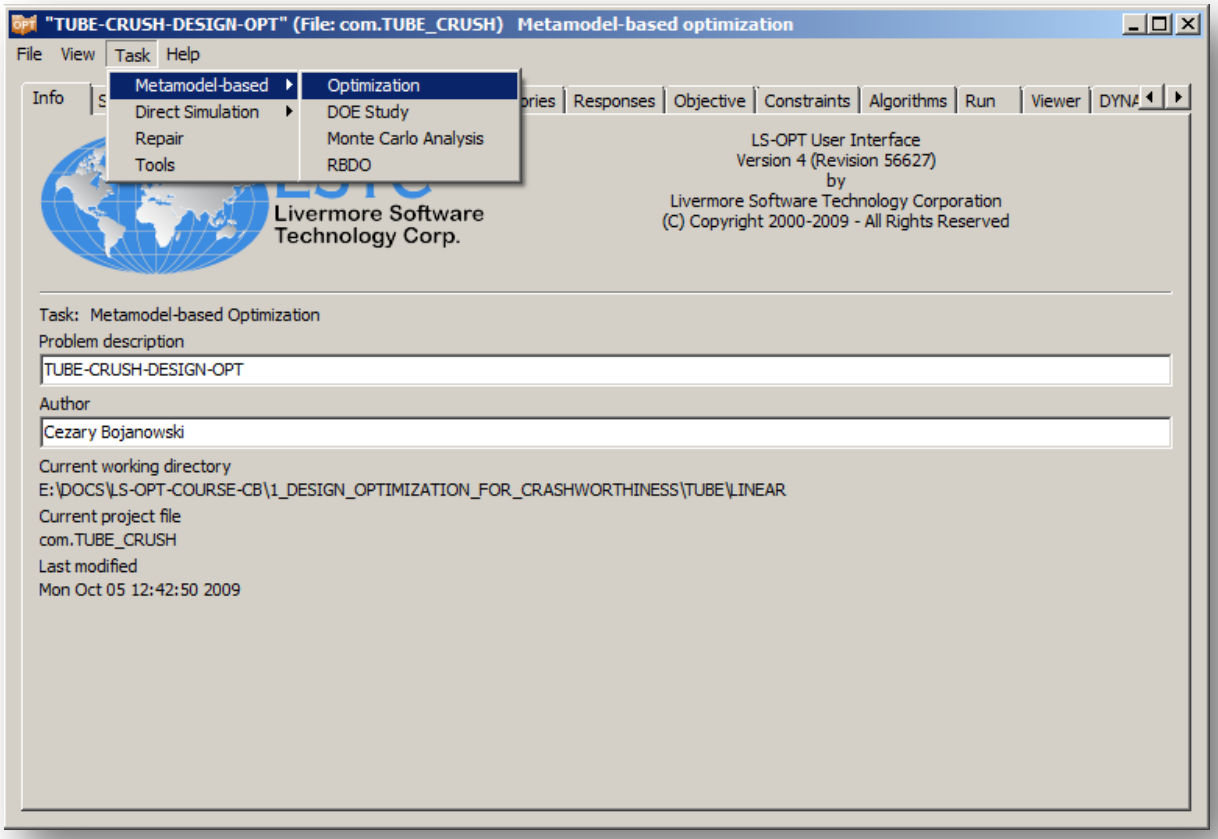
- Steel tubes crushed with falling rigid wall
- Objective: Minimize mass of the structure
- Constraints: maximum crush
- Three design variables:
  - thickness of inner tube – `t1`
  - thickness of inner plate – `t2`
  - thickness of outer tube – `t3`





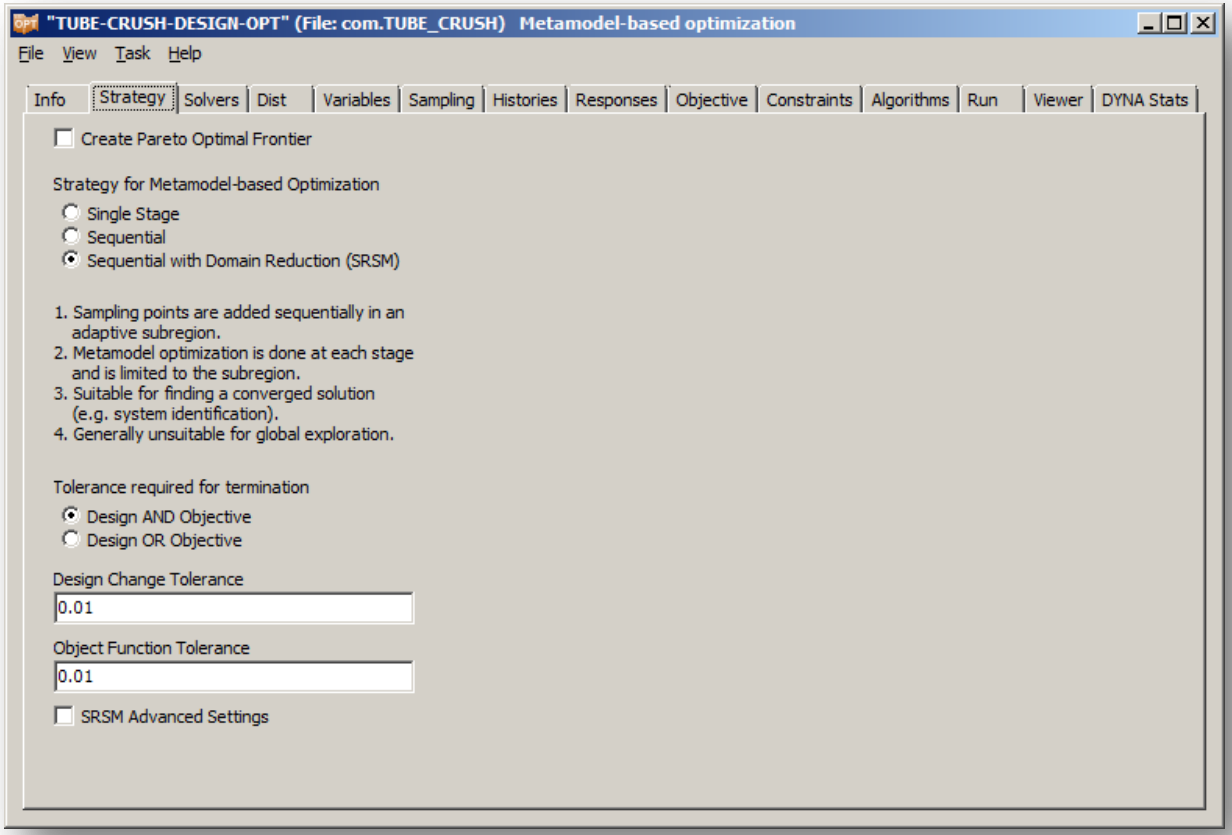
Task Selection

- Go to Task Tab and
- Select Metamodel – based Optimization



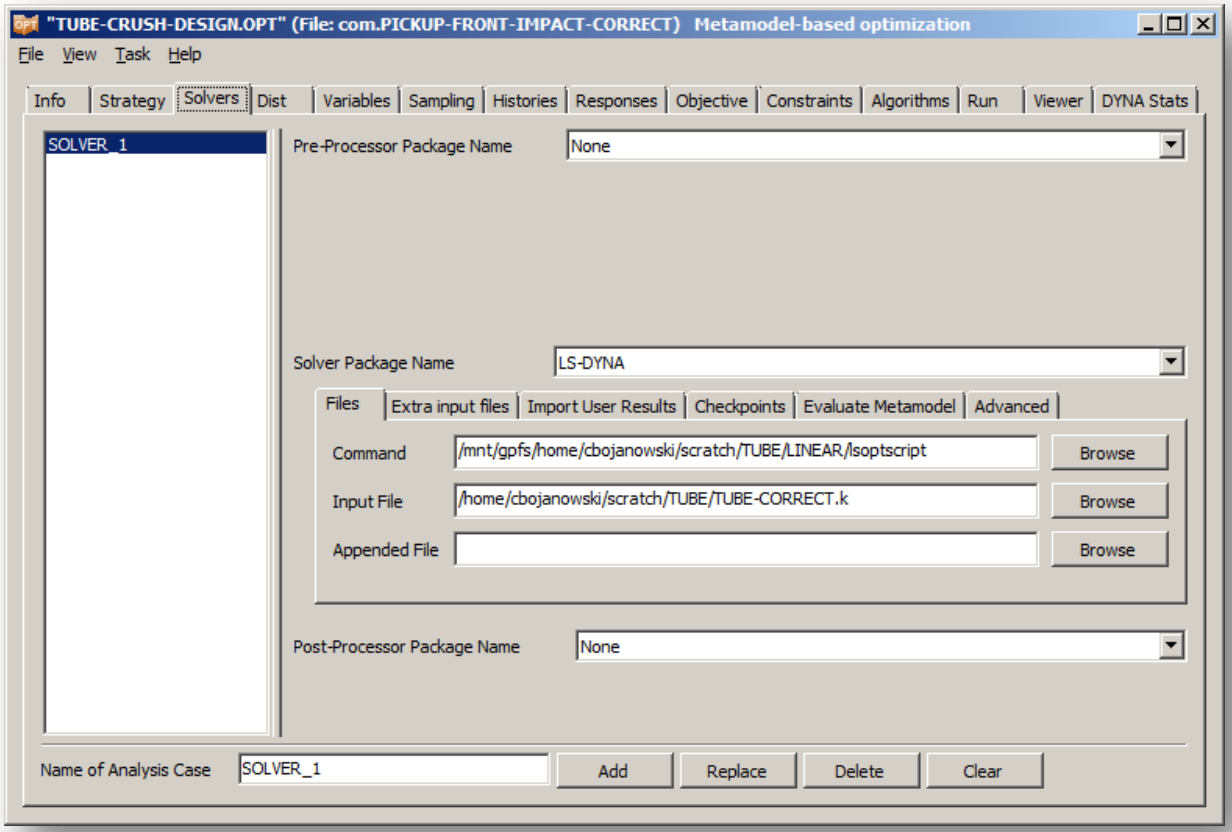
Linear Response Surface – First Iteration

- Go to the Strategy panel
- Choose Sequential with Domain Reduction (SRSM)
- Leave the defaults for the convergence tolerance



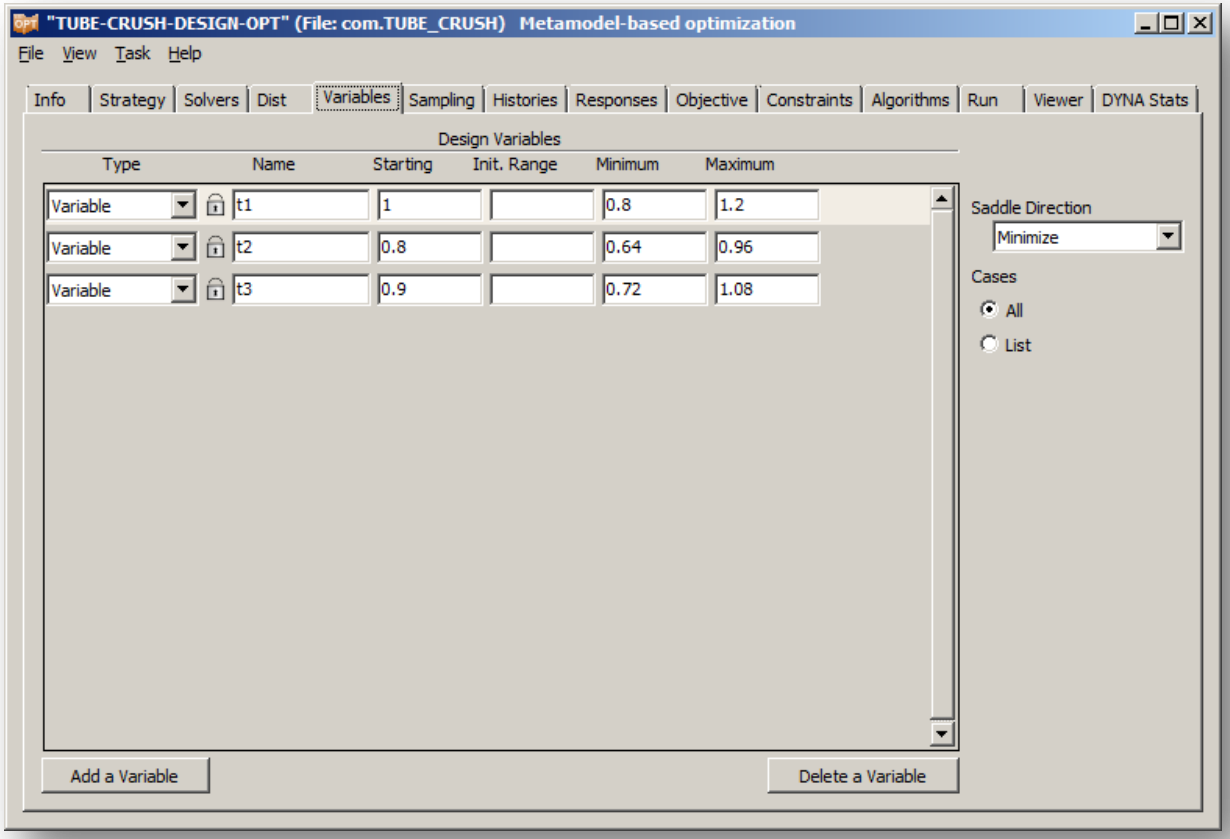
Solvers Panel

- In the Solvers panel browse to your LS-DYNA® executables (Windows) or to `lsoptscript` (Linux system at TRACC) at Command line
- For the input file find the `TUBE-CORRECT.k` file
- Type `SOLVER_1` in the Name of Analysis Case field and hit Add



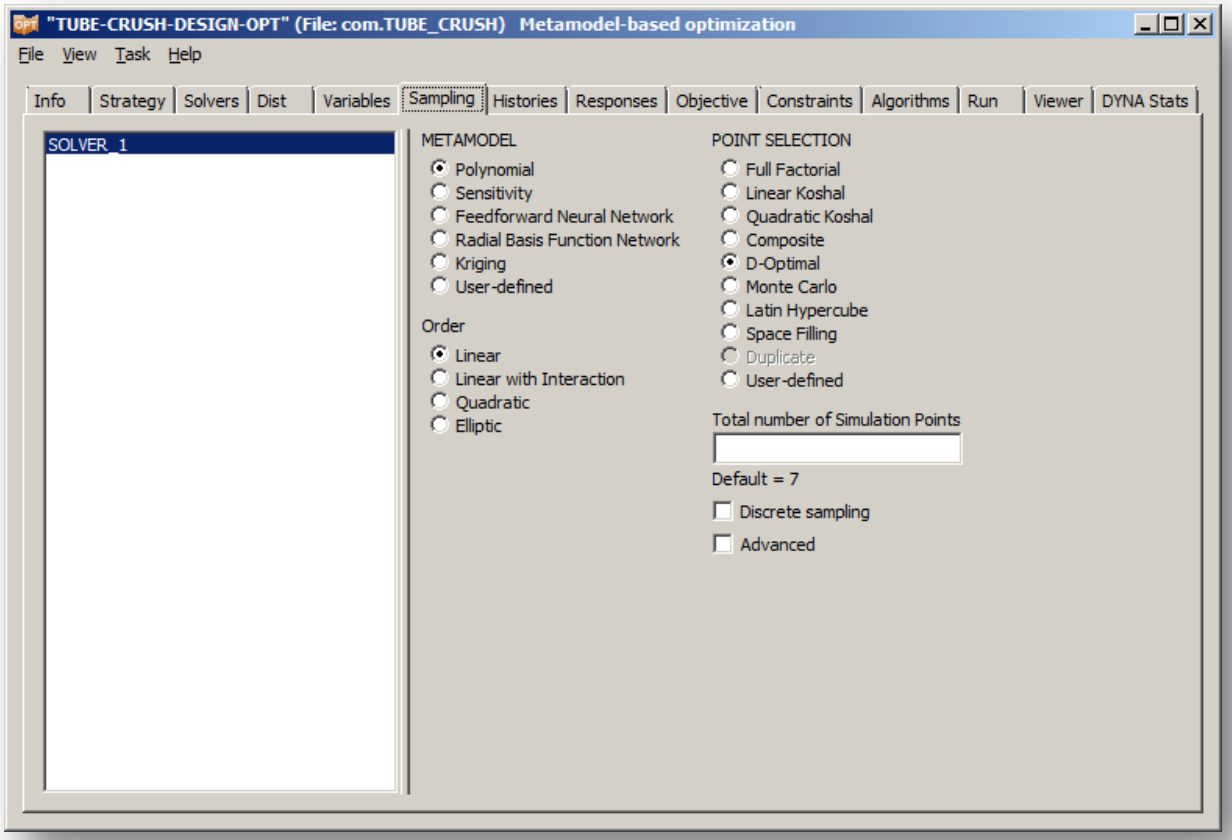
Variables Panel

- In the Variables panel Add three variables:
  - `t1` with starting value of `1` with lower bound `0.8` and upper bound `1.2`
  - `t2` with starting value of `0.8` with lower bound `0.64` and upper bound `0.96`
  - `t3` with starting value of `0.9` with lower bound `0.72` and upper bound `1.08`



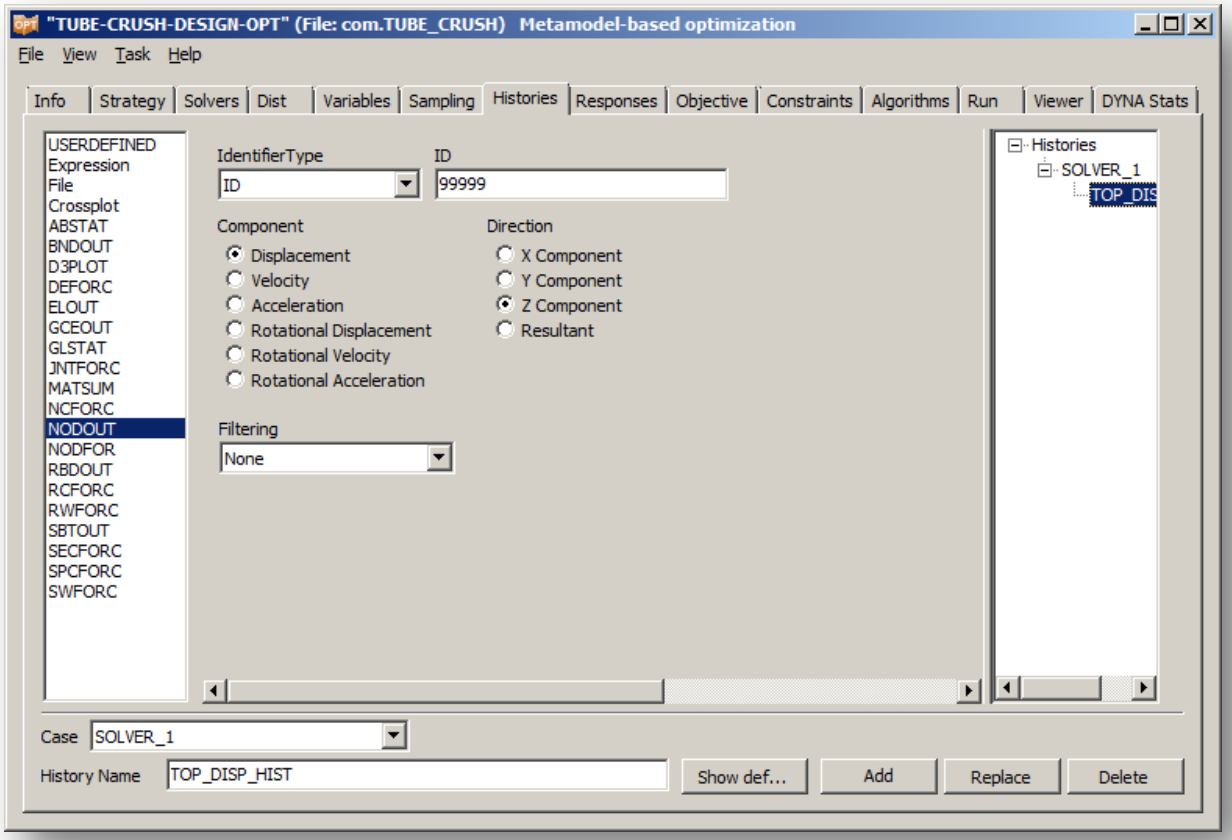
Sampling Panel

- In the Sampling panel select Polynomial Metamodel with Linear order
- For Point Selection choose D-Optimal criterion



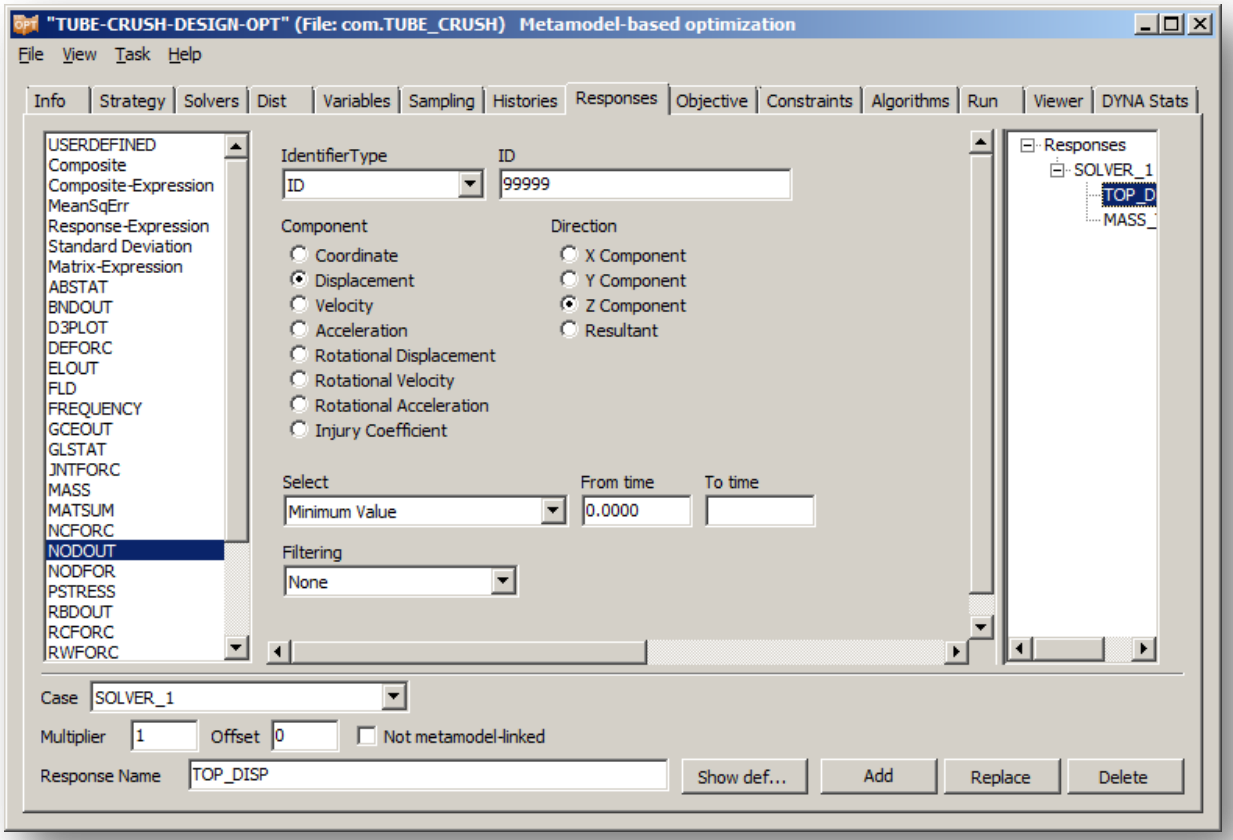
Histories Panel

- In the Histories panel from the right window select NODOUT file
- For ID identifier type 99999 – the node on rigid wall
- For the component choose Z Component of the displacement
- Give it a name TOP_DISP_HIST and confirm by Add button



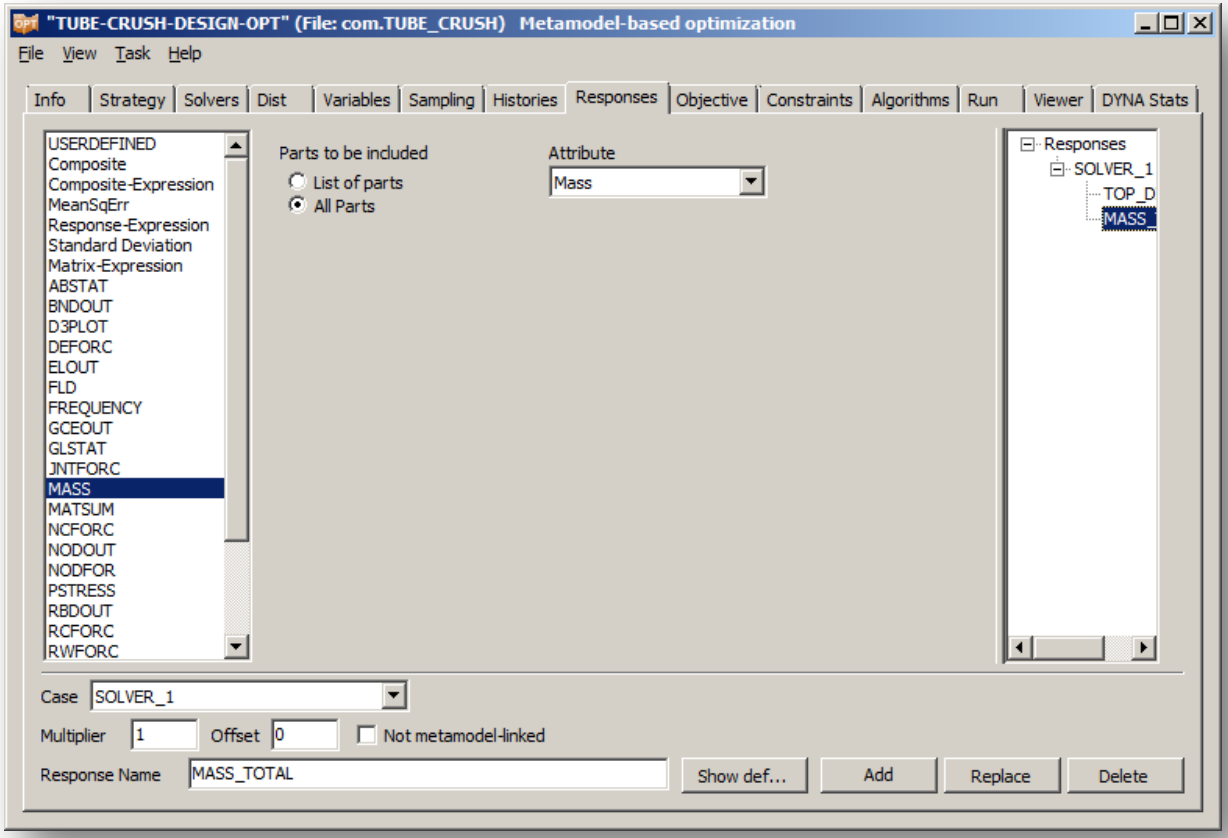
Responses Panel

- In the Responses panel also choose NODOUT from the left window
- For Z Displacement Component choose Identifier Type ID and type 99999 in ID window
- Select minimum value
- In Response Name type TOP_DISP and hit Add
- Note the difference response and history



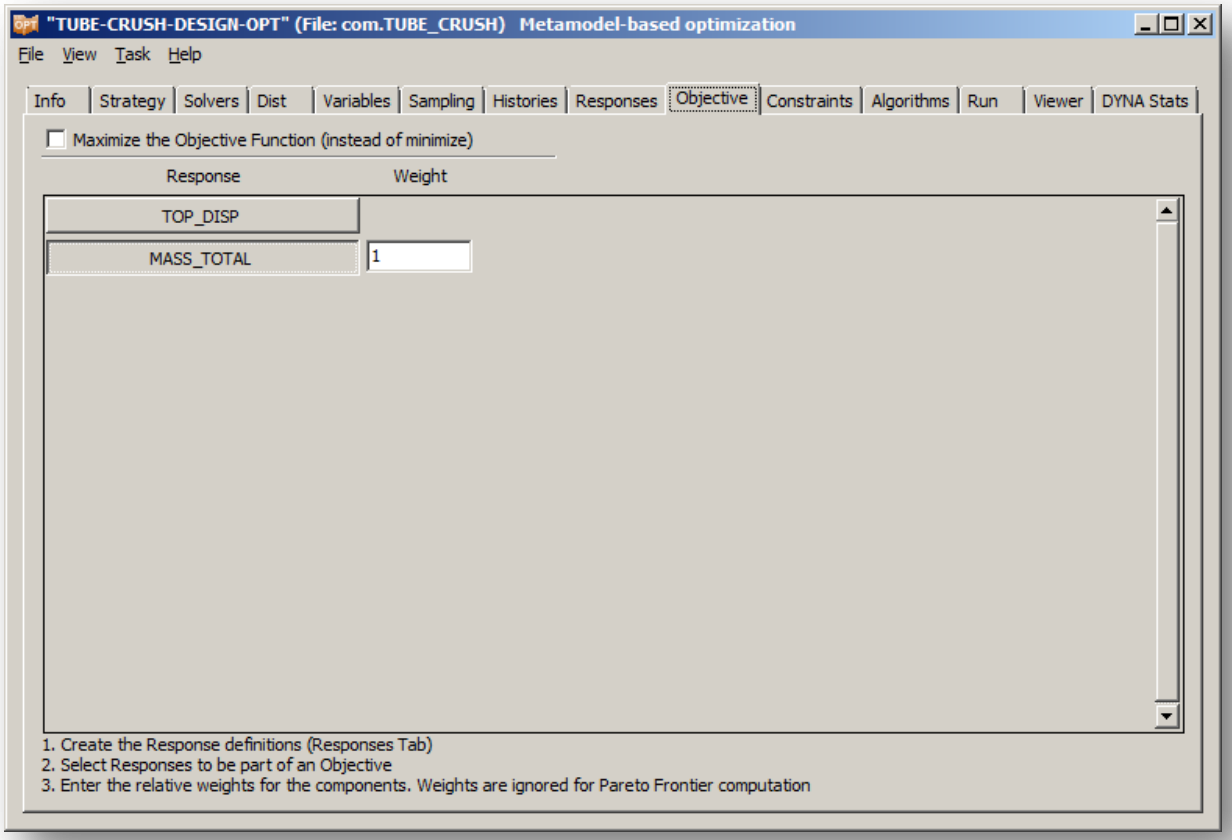
Responses Panel

- From responses window select MASS
- Select All Parts to be included and leave the Attribute Mass
- For Response Name enter MASS_TOTAL
- Hit Add to create the response



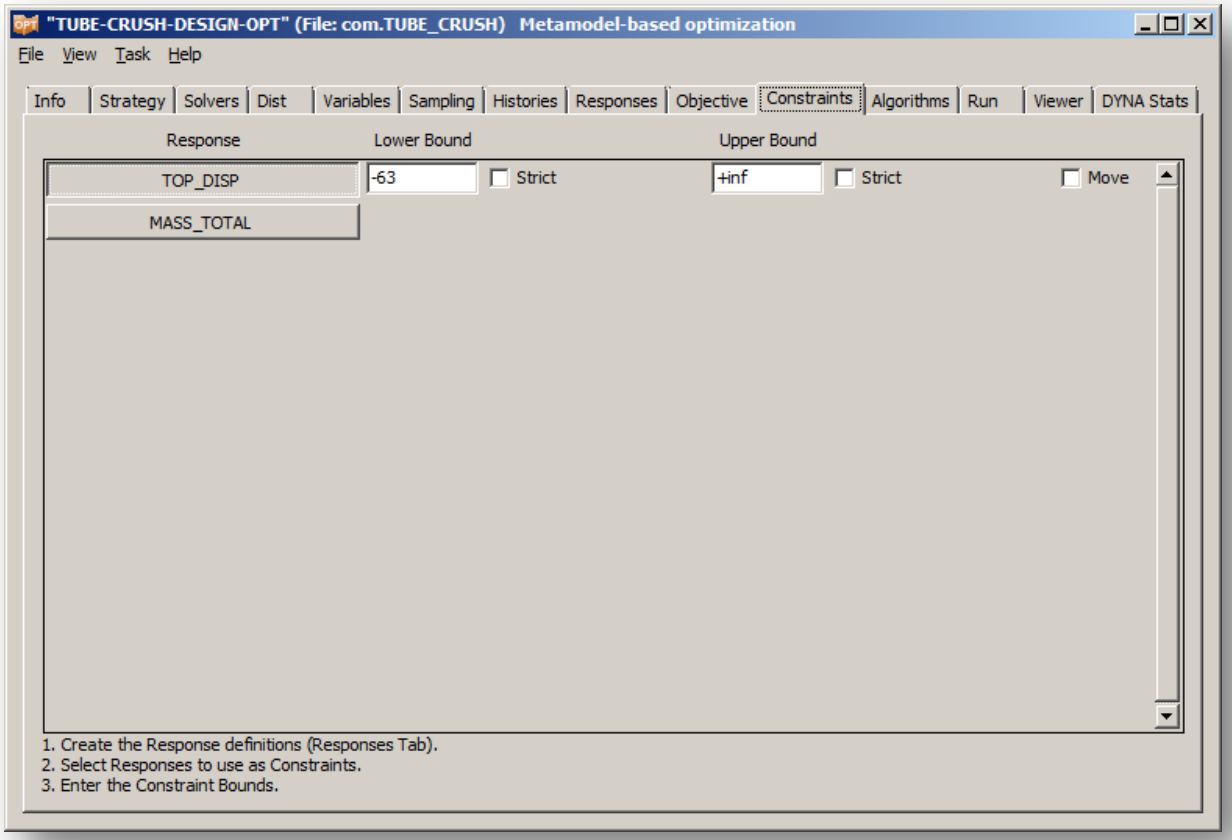
Objectives Panel

- In Objectives panel select MASS_TOTAL with default weight 1.0



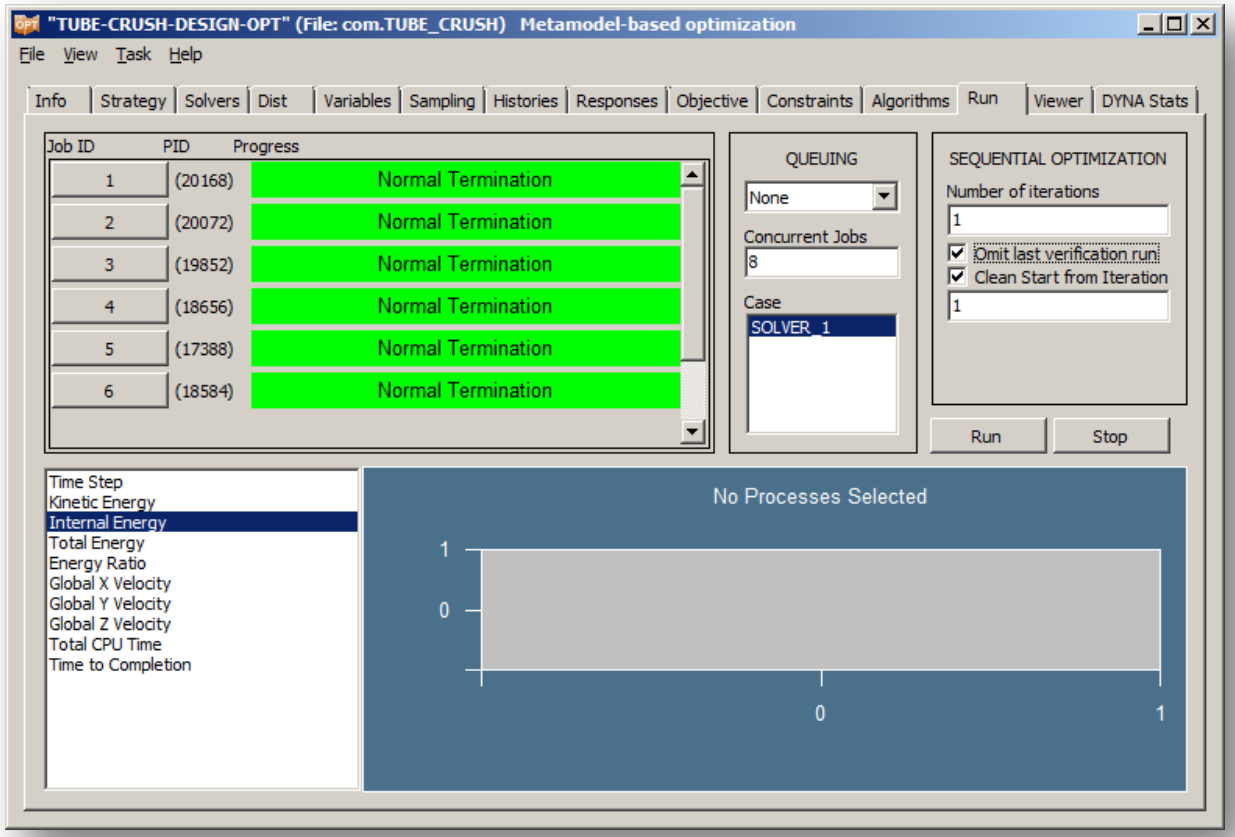
Constraints Panel

- From Responses select `TOP_DISP`
- For lower bound type `-63` and leave the Upper bound default (`+inf`)



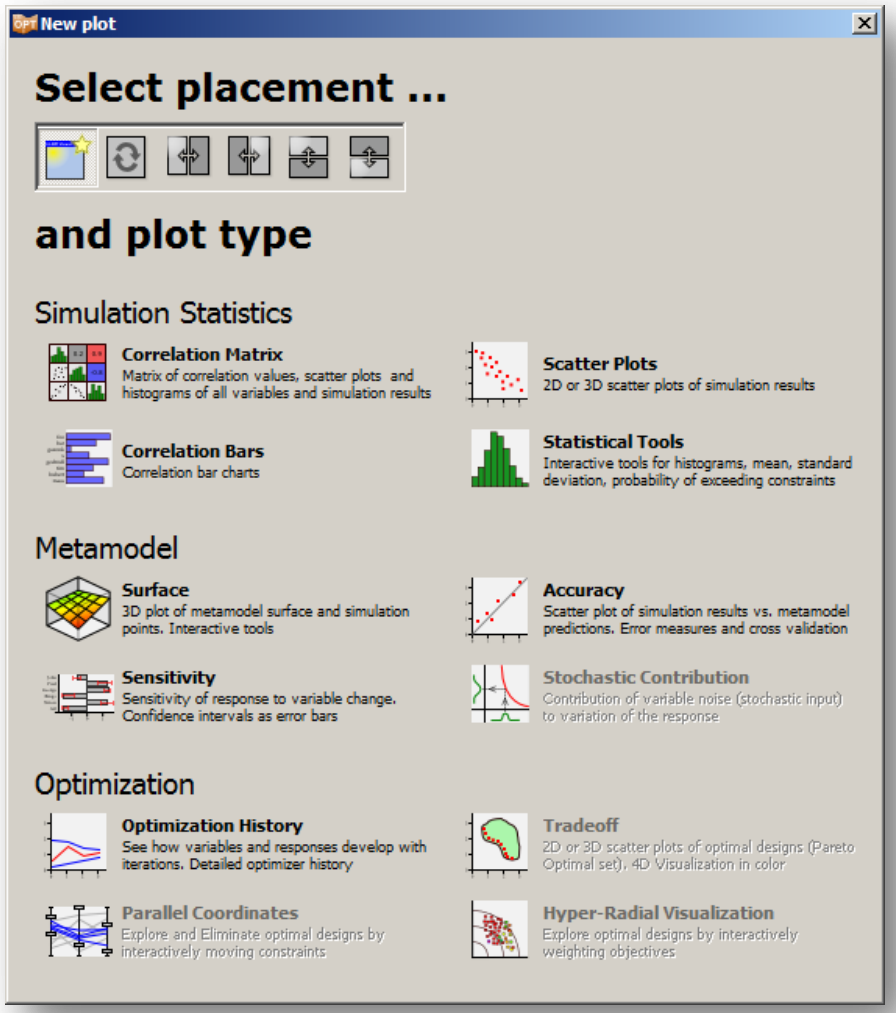
Run Panel

- Select PBS for QUEUING software (TRACC cluster users)
- For Concurrent Jobs enter 8
- For Number of Iteration enter 1 and
- Check Omit last verification run and Clean Start from iteration 1
- Hit Run to start simulations



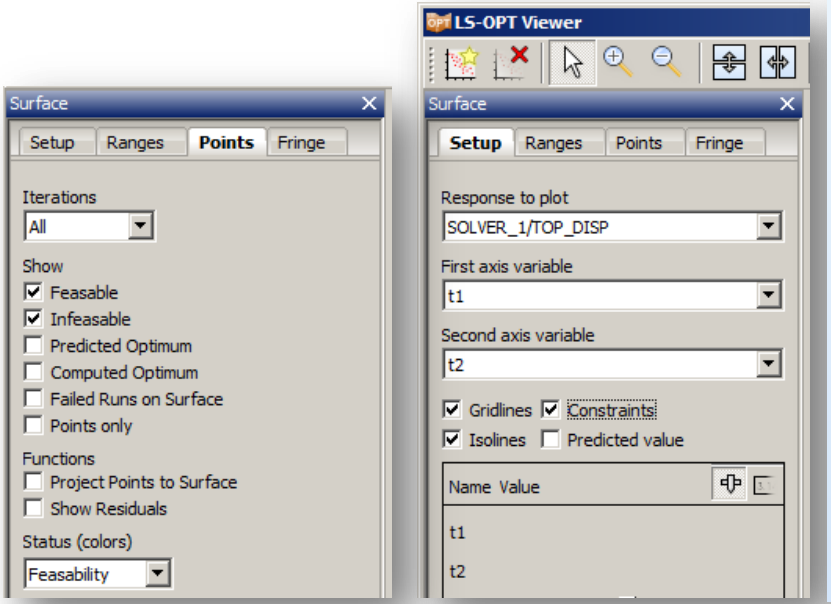
Viewer

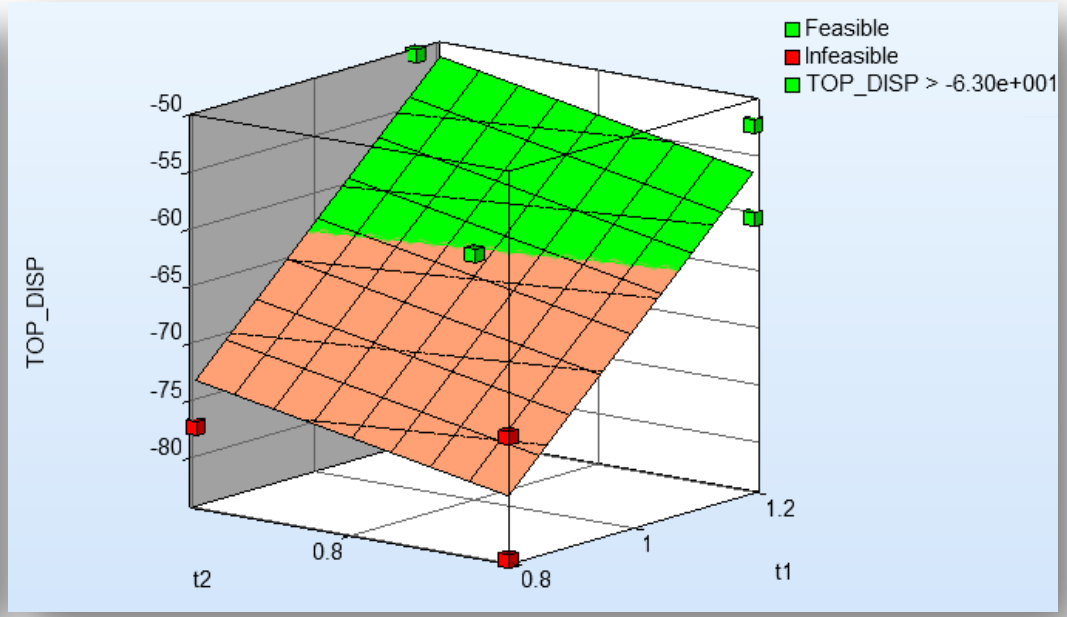
- Go to Viewer panel and the viewer options should pop up automatically
- From Metamodel menu select Surface
- New window should appear



Linear Response Surface

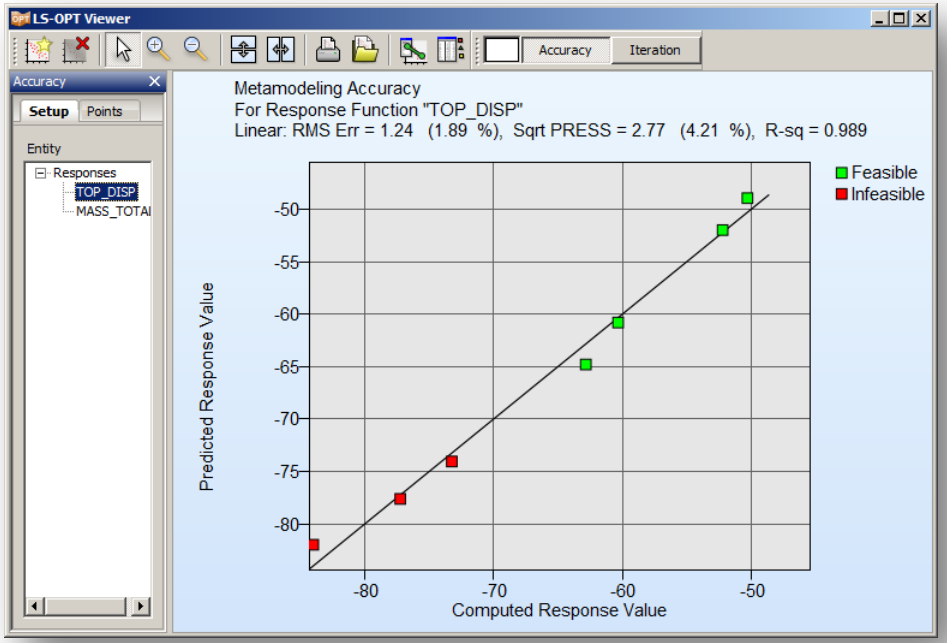
- From the Points Menu select All Iterations
- Check Feasible and Infeasible, For Status select Feasibility
- In Setup menu Select `TOP_DISP` as a Response to plot
- First axis select `t1` and the second `t2`
- Check Constraints and Isolines

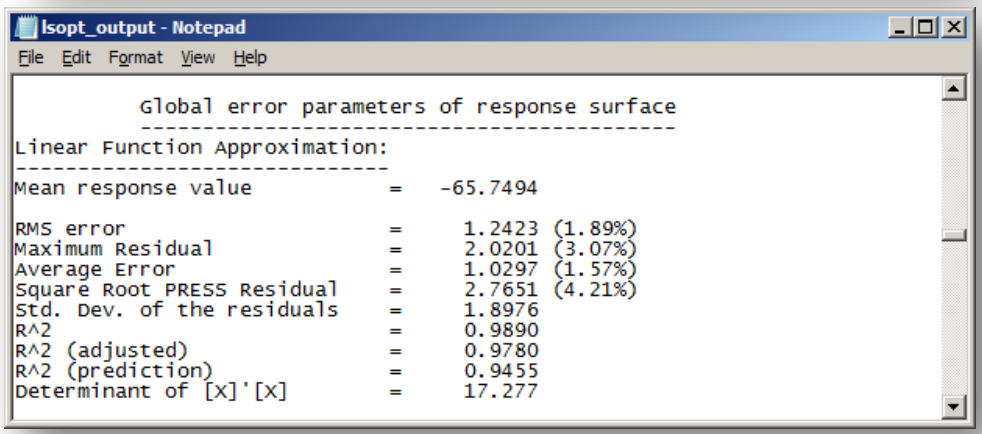




Accuracy

- In the Viewer tab press Restart viewer
- Select Accuracy in the Metamodel menu
- Select `TOP_DISP` from Responses to see the metamodeling errors
- Locate the same data in `lsopt_output` data file

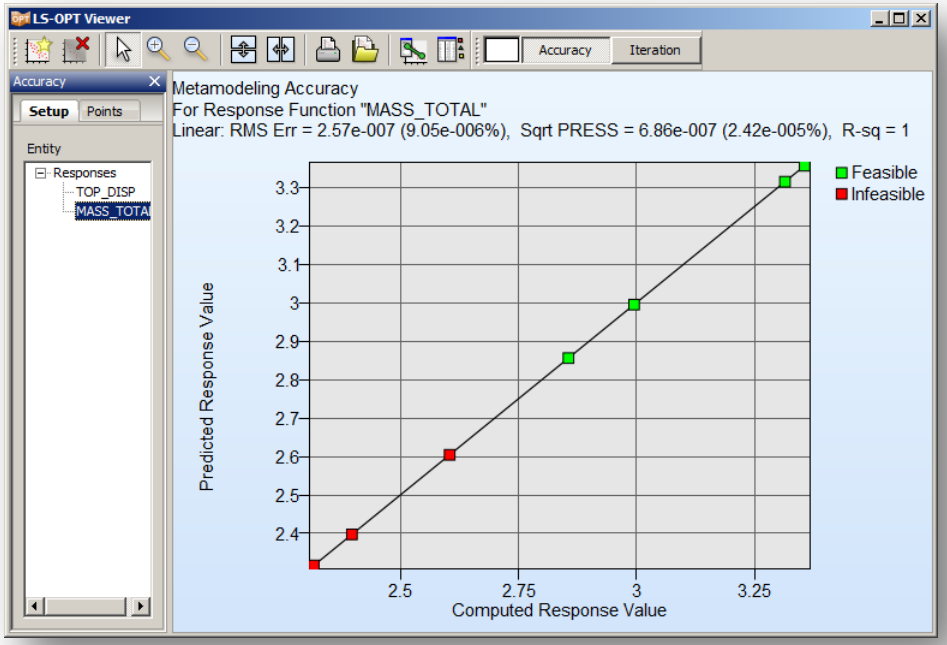


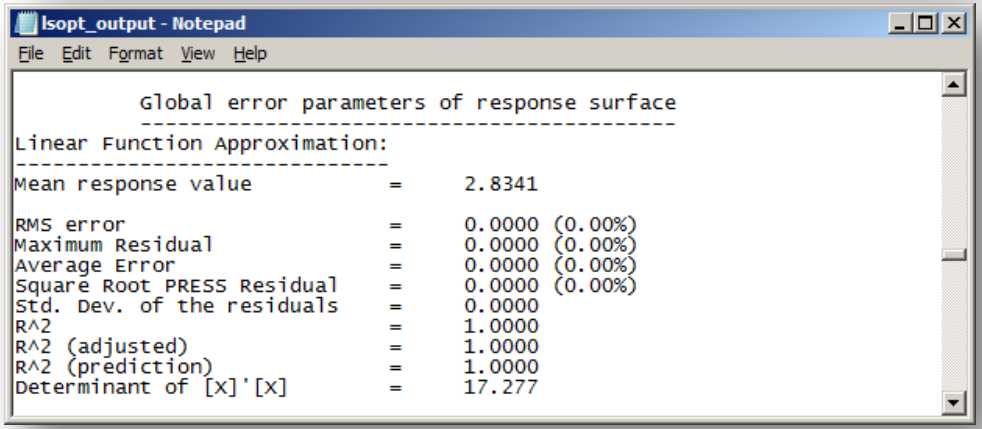


Accuracy

- Select MASS_TOTAL from Responses to see the metamodeling errors for the mass

- Verify the perfect fit in the lsopt_output file





Sensitivities

- Go back to the Viewer tab and restart the viewer
- Select Sensitivity in the Metamodel menu
- See the importance of variables for the response
- Locate the same data in the `lsopt_output` file

lsopt_output - Notepad

File Edit Format View Help

Individual regression coefficients: confidence intervals

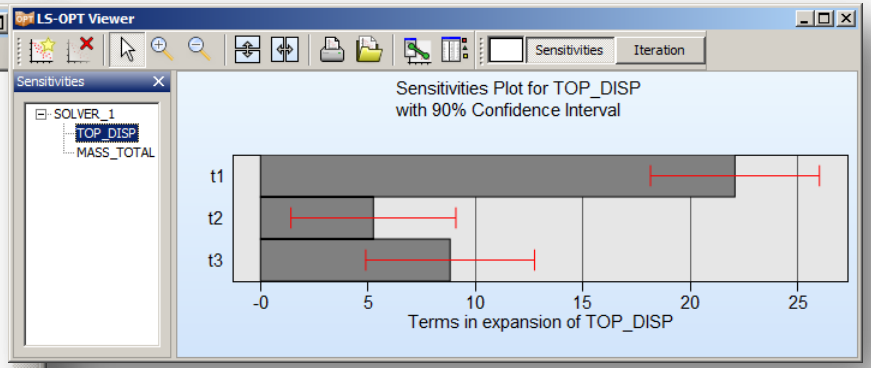
Coeff.	Coeff. Value	Confidence Int.(90%) Lower	Confidence Int.(90%) Upper	Confidence Int.(95%) Lower	Confidence Int.(95%) Upper	% Confidence not zero
t1	22.07	18.14	26	16.75	27.38	100
t2	5.248	1.411	9.086	0.05851	10.44	95
t3	8.819	4.893	12.74	3.51	14.13	99

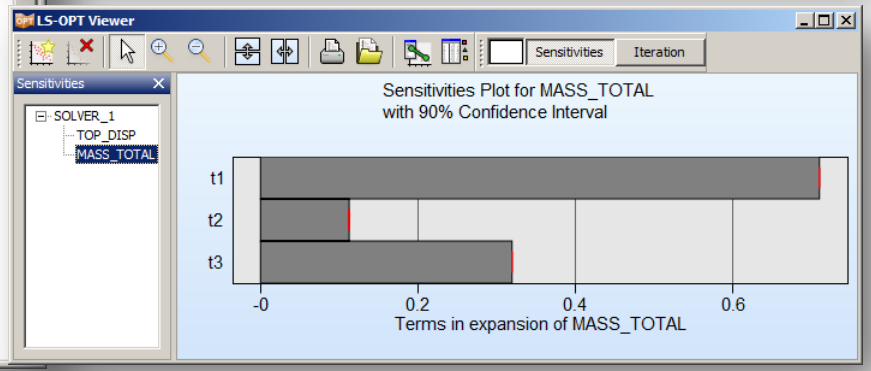
Ranking of terms based on bound of confidence interval

Coeff.	Absolute Value (90%)	10-Scale
t1	18.14	10.0
t3	4.893	2.7
t2	1.411	0.8

Confidence intervals on mean value at center of region of interest

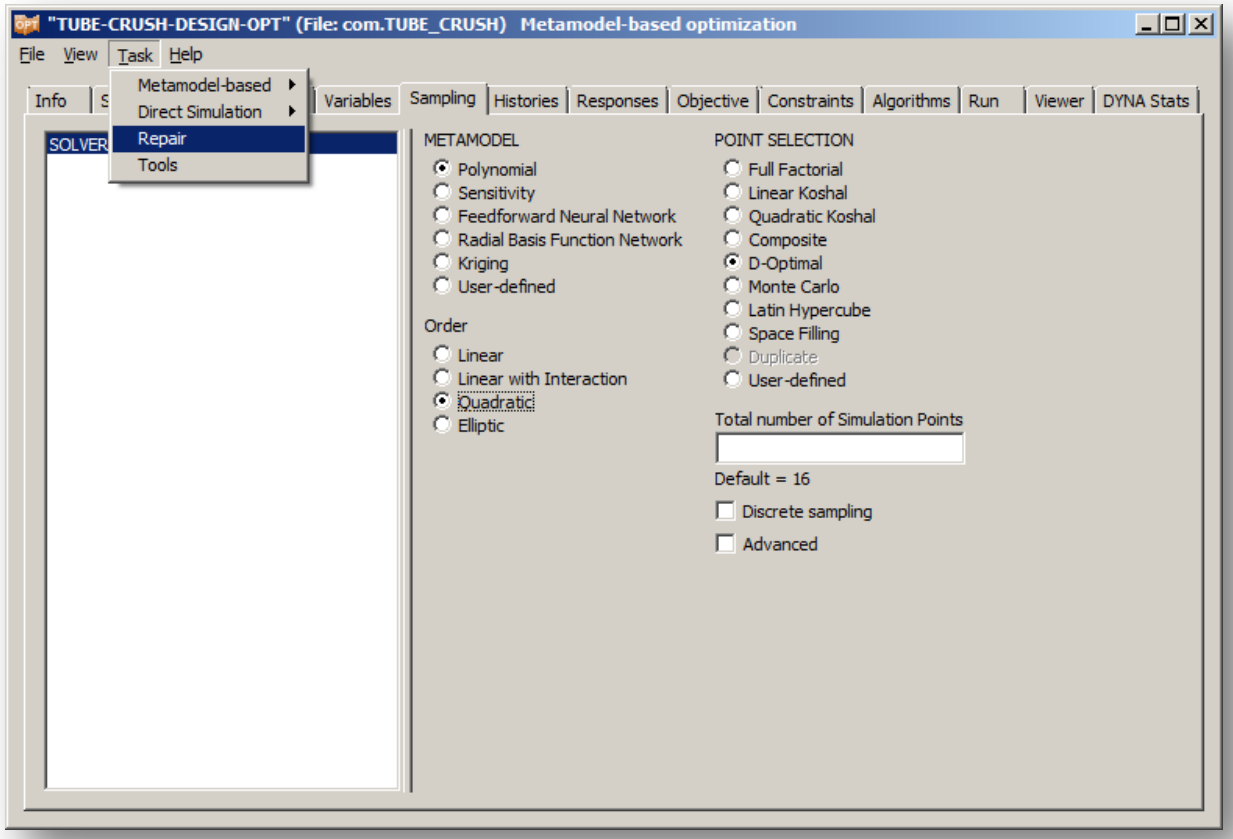
Coeff.	Coeff. Value	Confidence Int.(90%) Lower	Confidence Int.(90%) Upper	Confidence Int.(95%) Lower	Confidence Int.(95%) Upper
Mean	-64.81	-66.59	-63.03	-67.21	-62.41





Repair Tool - Quadratic Response Surface

- Select Repair from the Task menu
- Go to Sampling panel to change the Order of polynomial to Quadratic
- We will build Quadratic response surface without loosing already obtained data. Points can be augmented to existing vector.

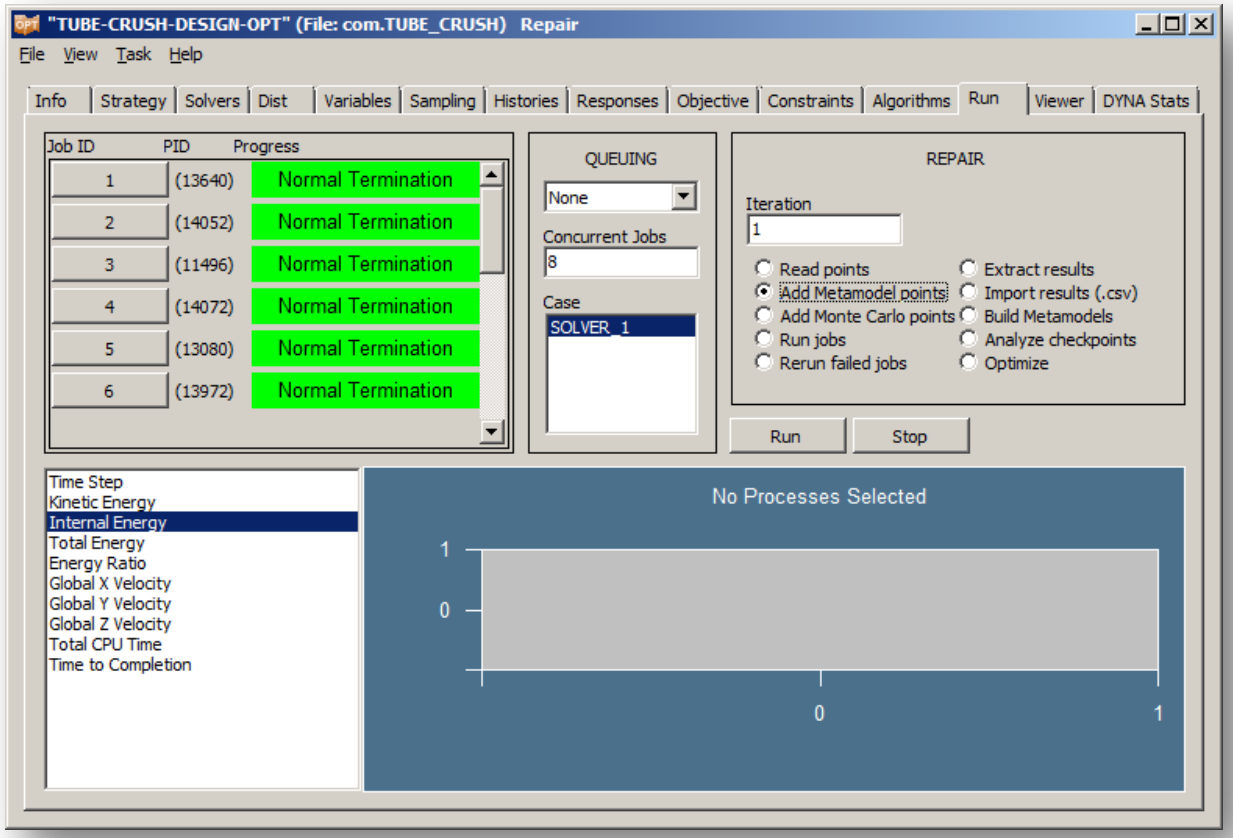


$$X_a(x_p) = \begin{bmatrix} X \\ A(x_p) \end{bmatrix}$$

$$\max\left|X_a^T X_a\right| = \max\left|X^T X + A^T A\right|$$

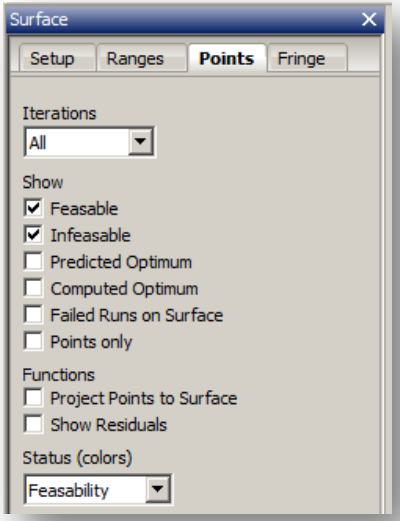
Run Panel

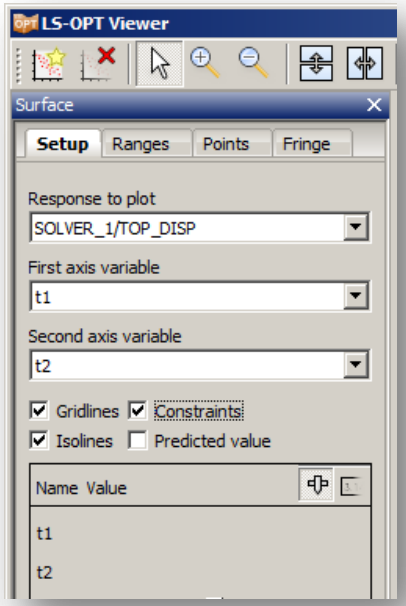
- Go to Run Panel
- From Repair menu select Add Metamodel points, press Run
- Select Run jobs, press Run
- Select Extract results, press Run
- Select Build Metamodels and press Run
- Select Optimize and press ...??? **RUN**

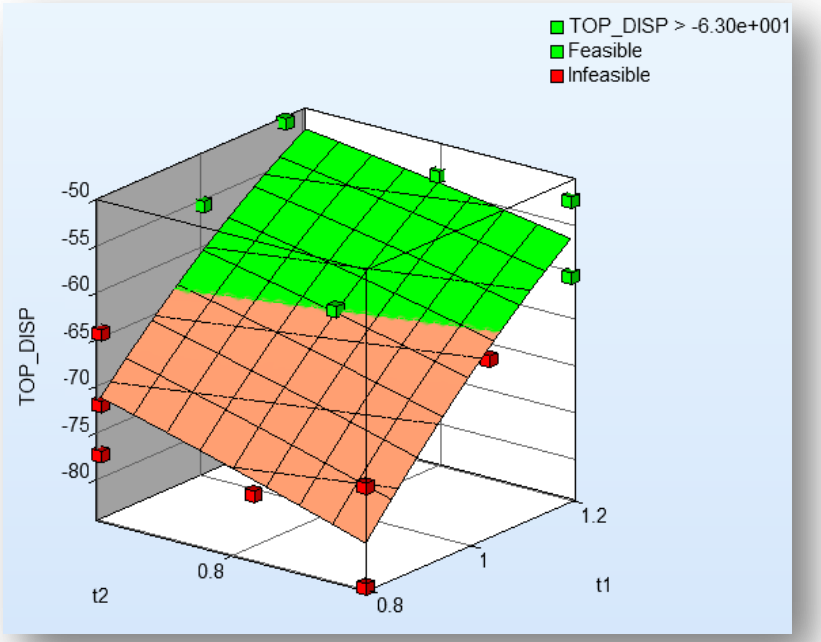


Viewer

- Go to Viewer panel and Restart Viewer
- Select Surface from Metamodel menu
- Show all points in the plot selecting this option in Points tab
- Show constraints on the surface checking this option in the Setup tab
- Clicking on a point we are obtaining numerical values in Point Selection window

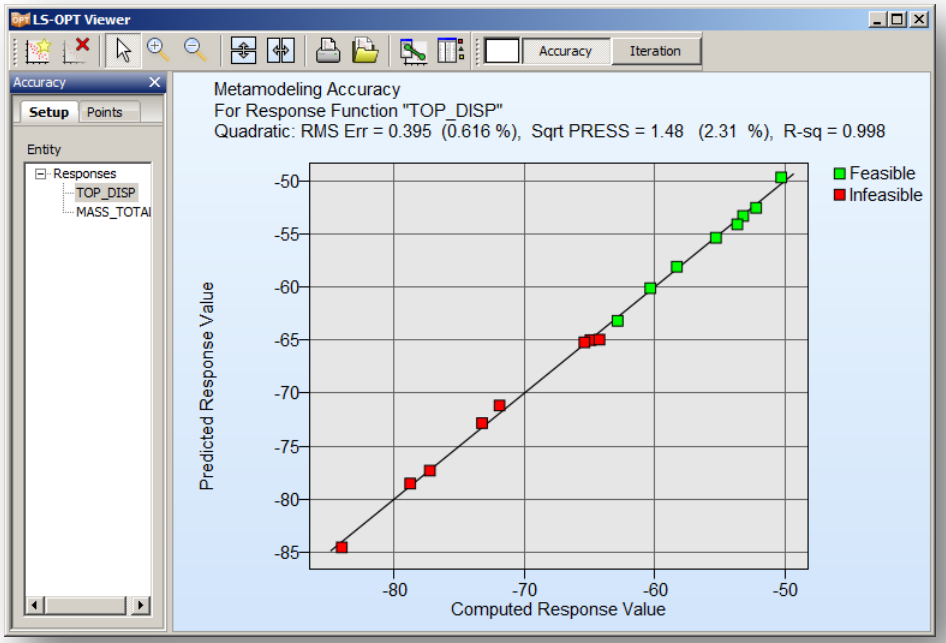






Accuracy

- Go to Viewer panel and Restart Viewer
- From Metamodel menu select Accuracy
- Display accuracy of the metamodeling of `TOP_DISP` response
- Locate the error parameters in the `lsopt_output.5` file
- Compare them with results from linear metamodel



lsopt_output - Notepad

File Edit Format View Help

```
        Global error parameters of response surface
        -------------------------------------------
Linear Function Approximation:
-------------------------------
Mean response value          =   -65.7494

RMS error                    =     1.2423 (1.89%)
Maximum Residual             =     2.0201 (3.07%)
Average Error                =     1.0297 (1.57%)
Square Root PRESS Residual   =     2.7651 (4.21%)
Std. Dev. of the residuals   =     1.8976
R^2                          =     0.9890
R^2 (adjusted)               =     0.9780
R^2 (prediction)             =     0.9455
Determinant of [X]'[X]       =     17.277
```

lsopt_output.5 - Notepad

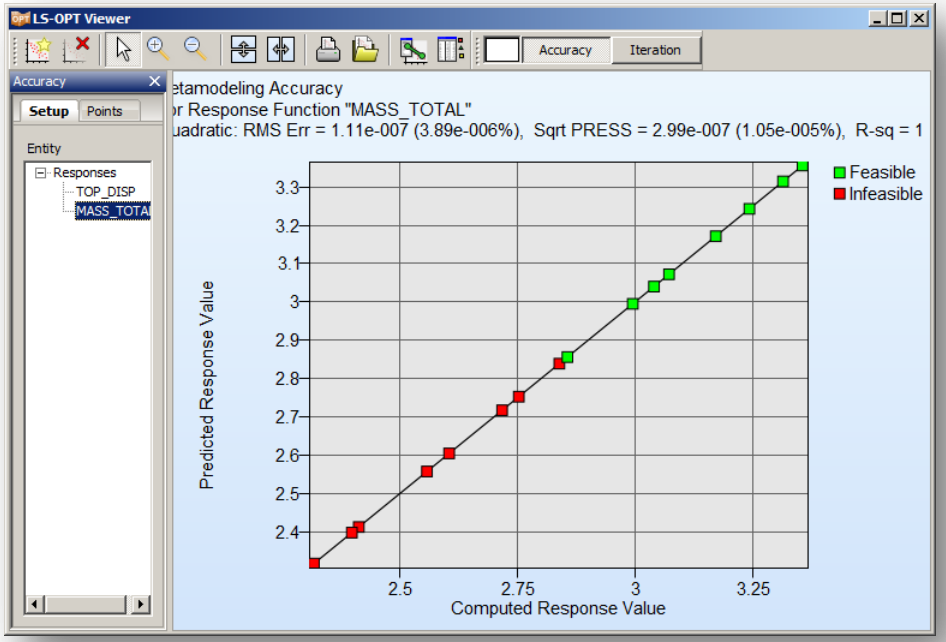
File Edit Format View Help

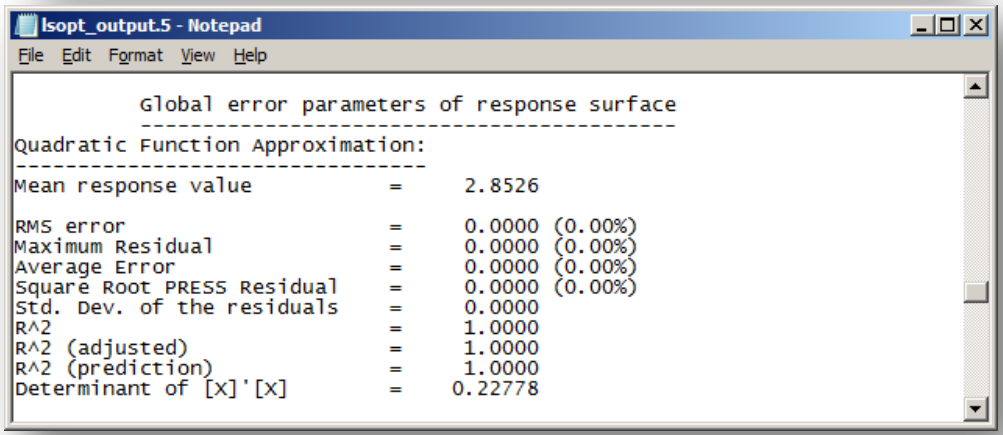
```
        Global error parameters of response surface
        -------------------------------------------
Quadratic Function Approximation:
---------------------------------
Mean response value          =   -64.1259

RMS error                    =     0.3948 (0.62%)
Maximum Residual             =     0.7381 (1.15%)
Average Error                =     0.3276 (0.51%)
Square Root PRESS Residual   =     1.4804 (2.31%)
Std. Dev. of the residuals   =     0.6447
R^2                          =     0.9985
R^2 (adjusted)               =     0.9969
R^2 (prediction)             =     0.9783
Determinant of [X]'[X]       =    0.22778
```

Accuracy

- Display accuracy of the metamodeling of `MASS_TOTAL` response

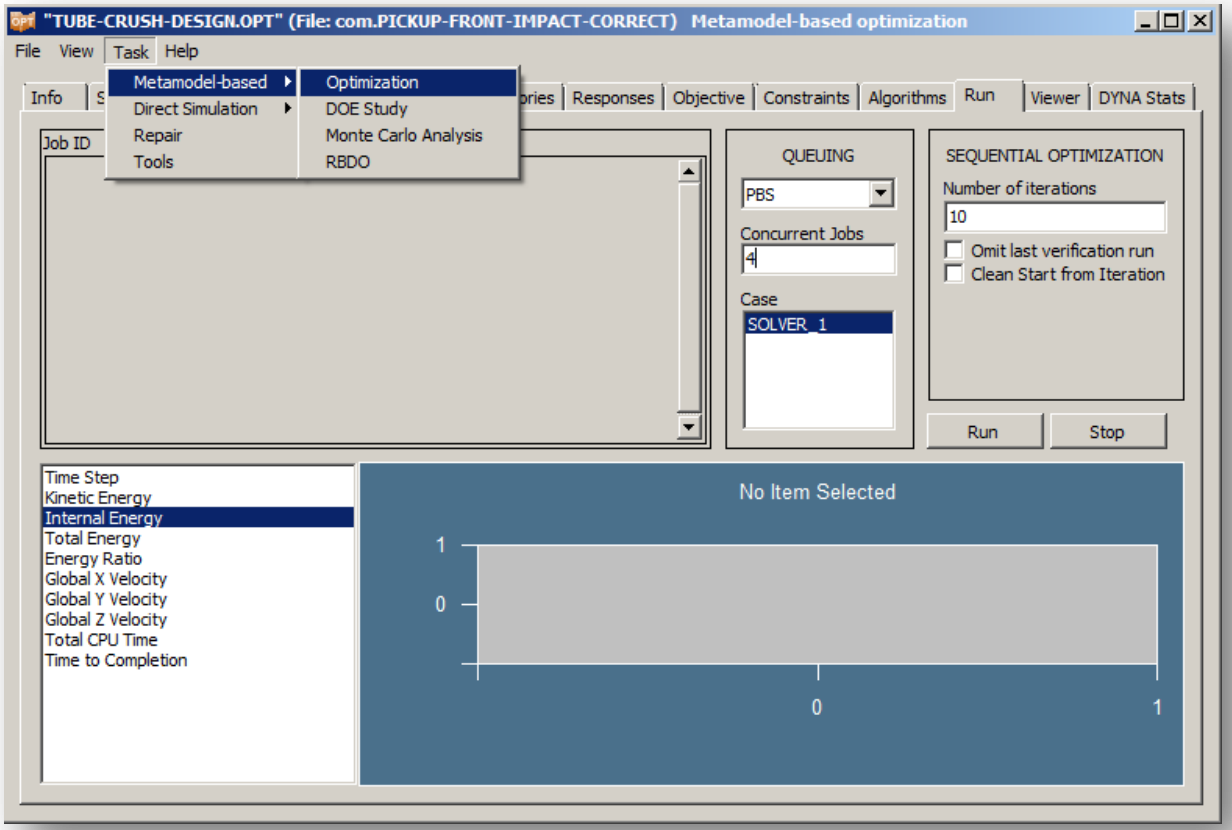
- Locate the same error parameters in the `lsopt_output` file





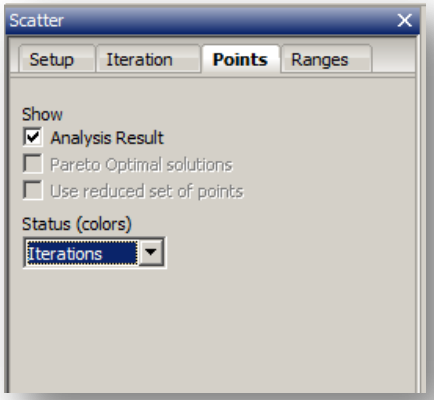
Linear Response Surface - Iterations

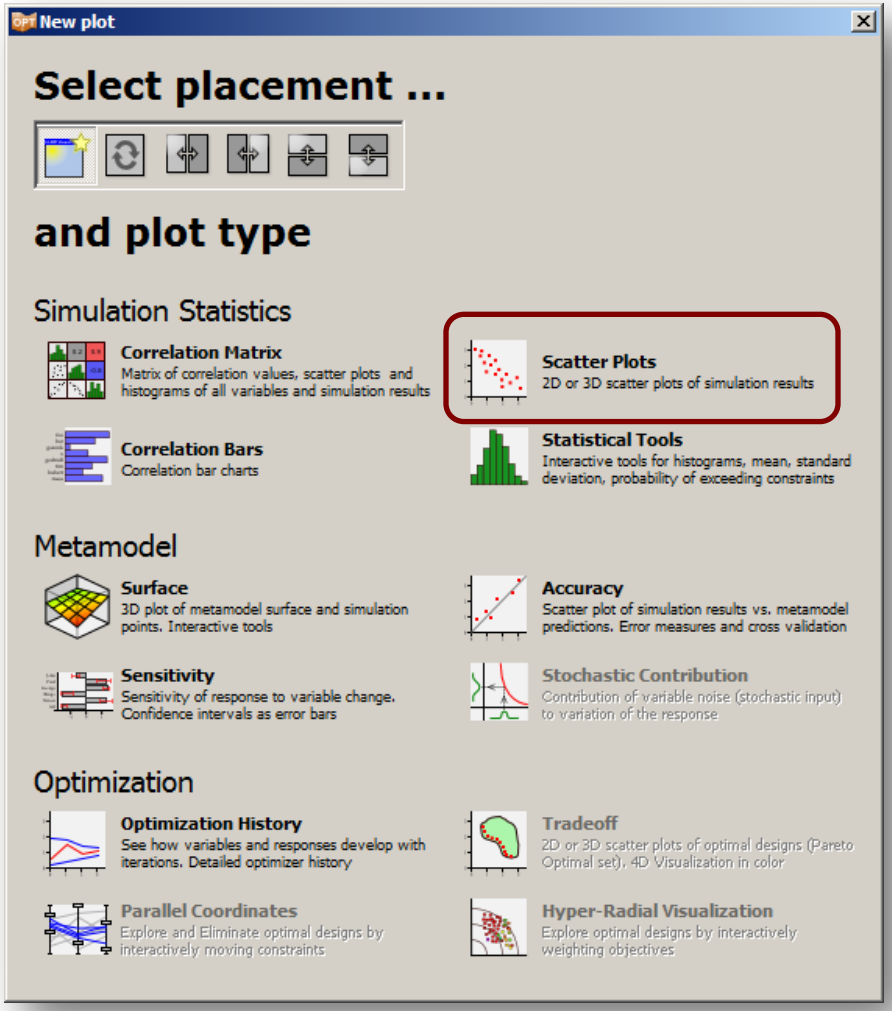
- Go to back to the command file created for linear metamodel
- Make sure that the Task is Metamodel-based Optimization
- Then go to Run panel
- Select PBS as QUEUING software and request `10` iterations, press Run



Viewer

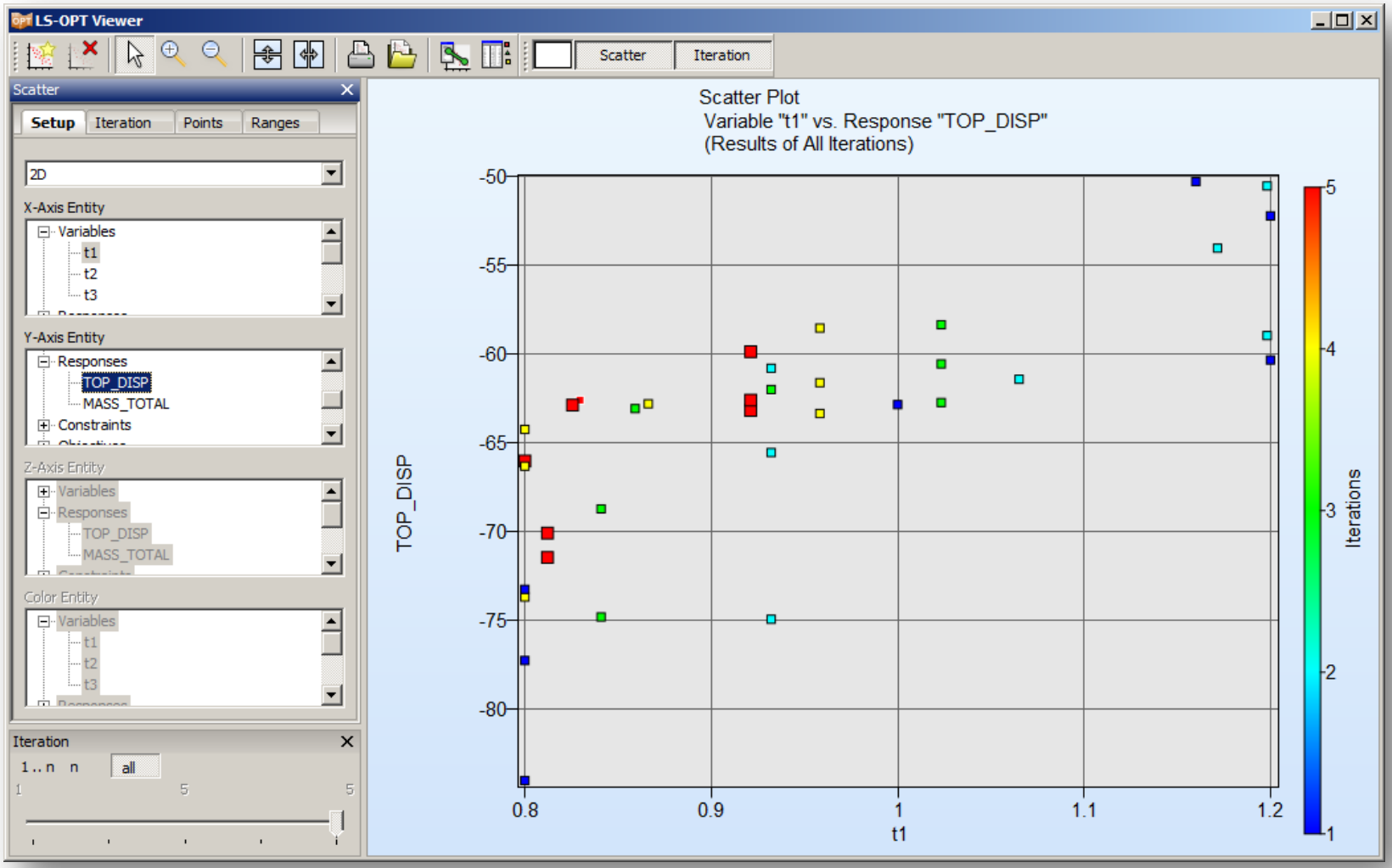
- Go to Viewer panel and Restart Viewer
- Select Scatter Plots from the Simulations Statistics menu
- In the new window go Points and change Status (colors) to iterations





Scatter Plot

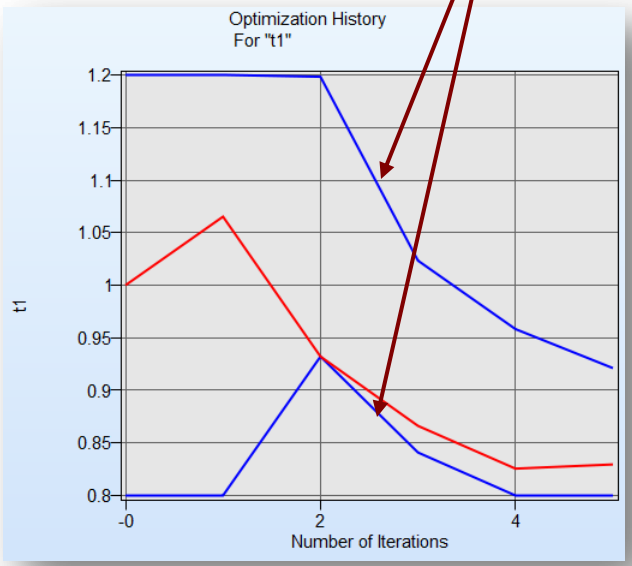
- In the Setup tab select for X-axis variable `t1` and `TOP_DISP` for y-axis

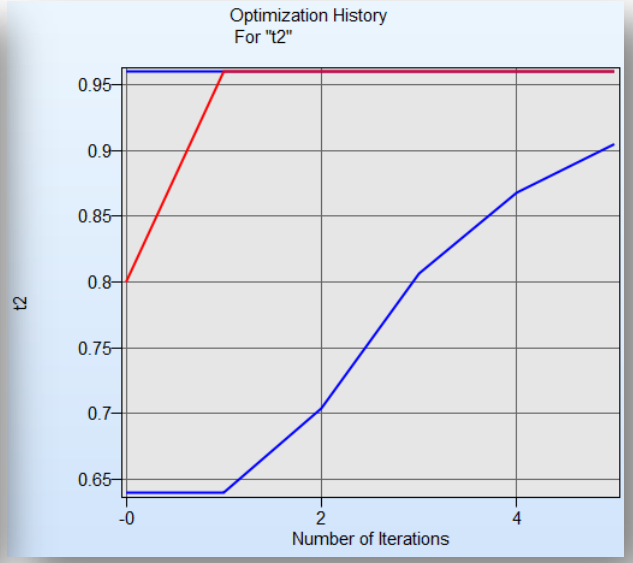


Optimization History

- Go to Viewer panel and Restart the Viewer
- Select Optimization History in the Optimization menu
- Follow the optimization process of various thicknesses `t1`, `t2`, `t3`

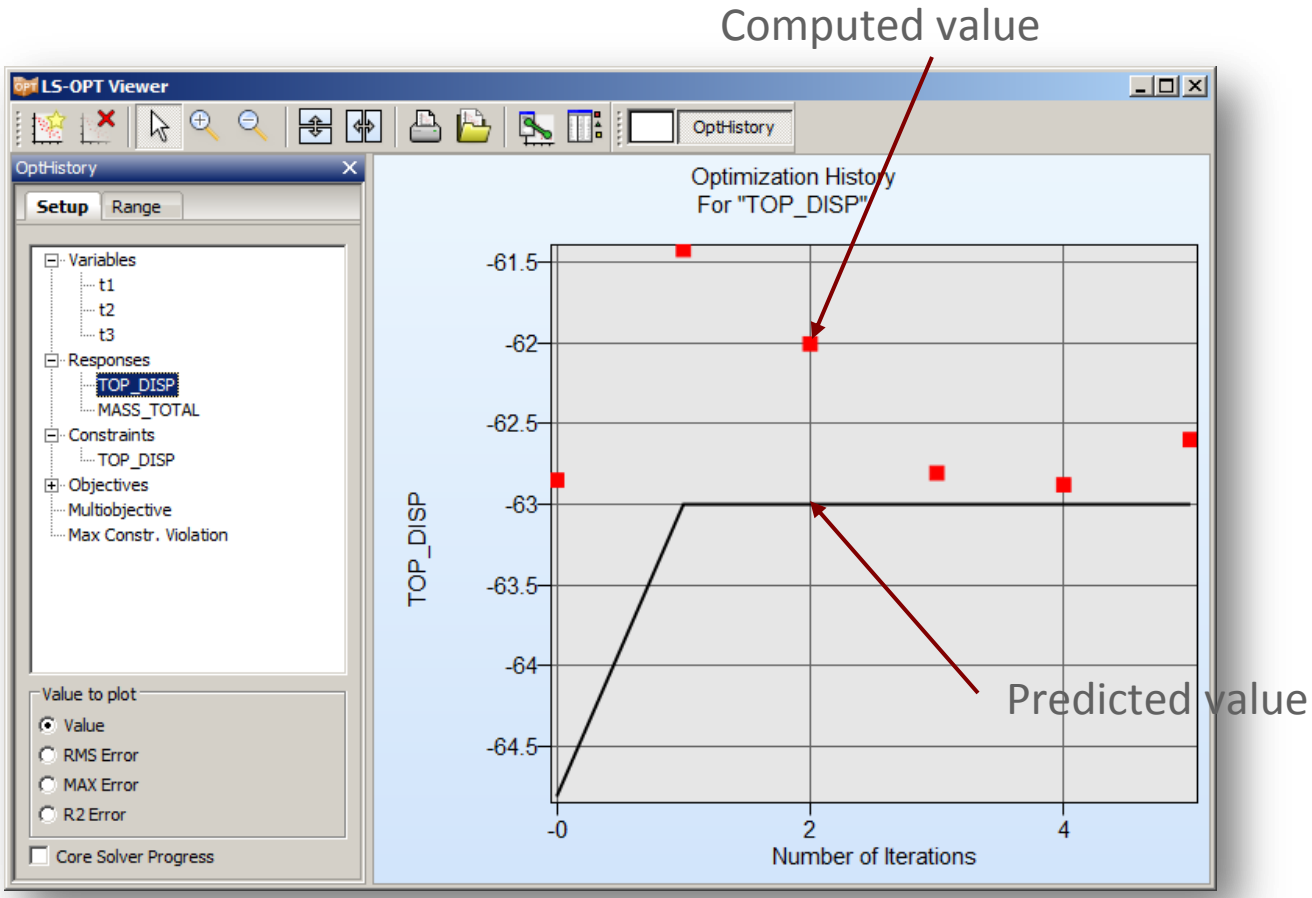
Shrinking bounds





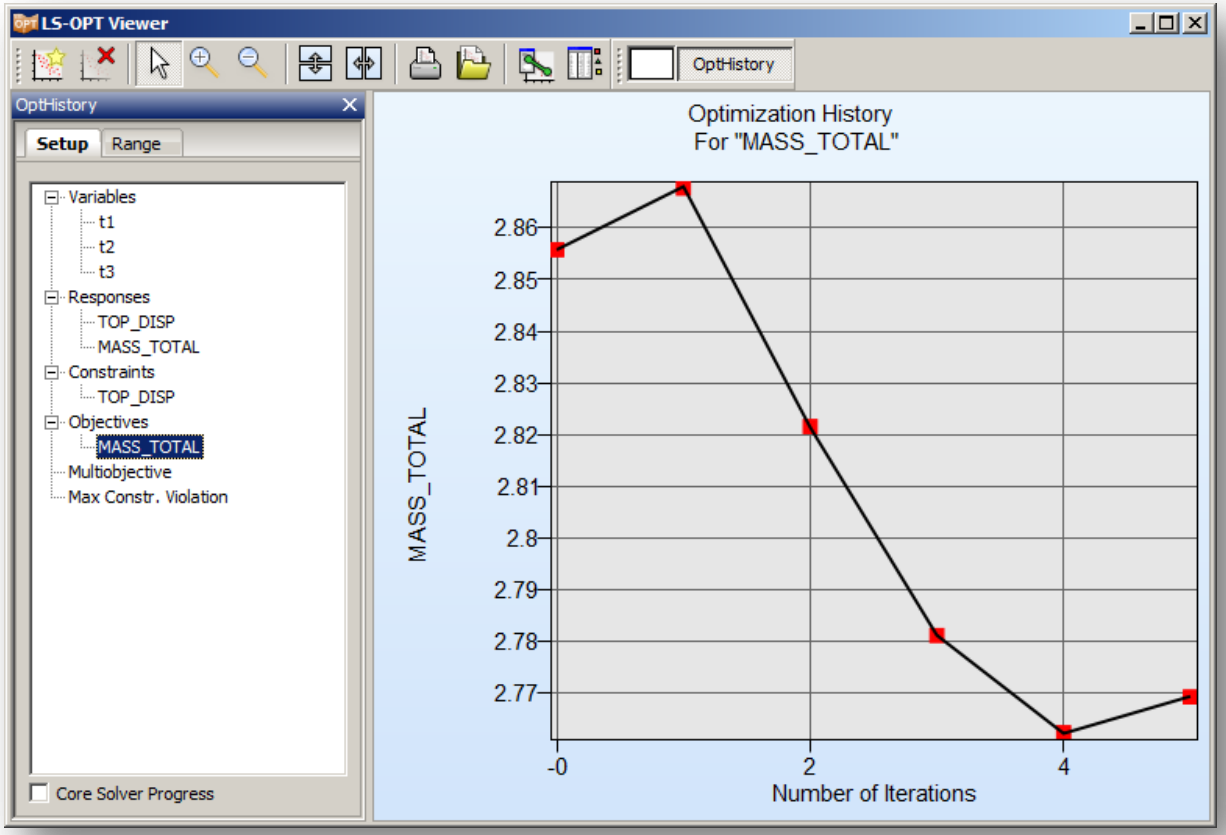
Optimization History

- Select from Responses TOP_DISP
- See the difference between computed (LS-DYNA®) value and the approximated one by Response Surface



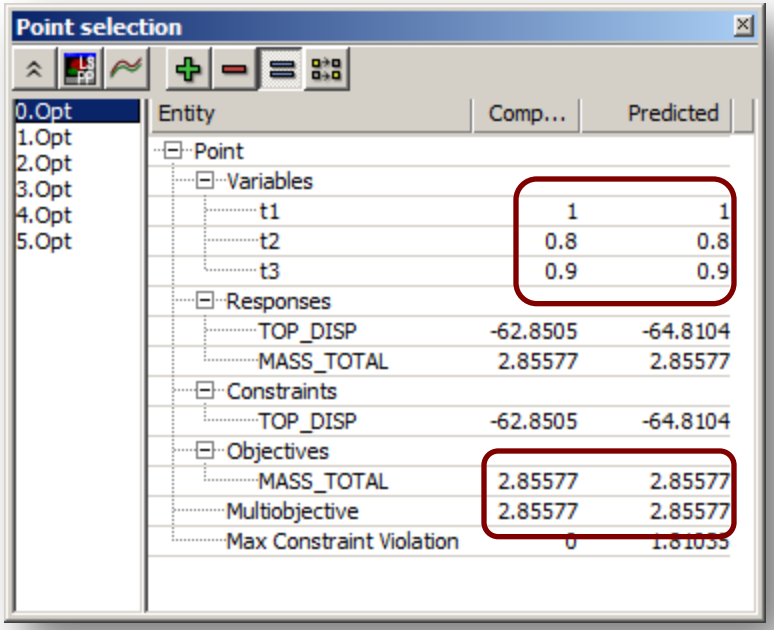
Optimization History

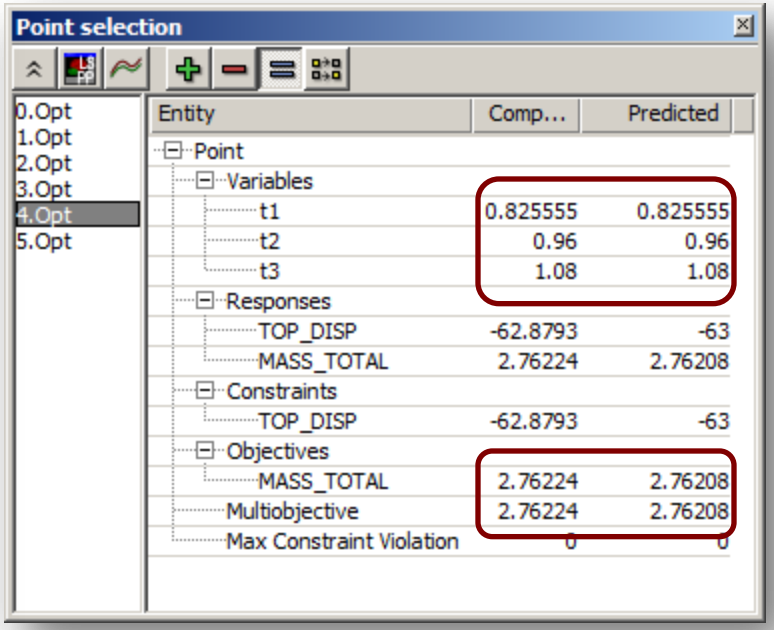
- Select from Objectives MASS_TOTAL
- There is on difference between calculated and approximated values – the metamodel was exact for the mass – it is linearly dependent on three design variables



Optimization History

- Click on one of the points in the graph to open Point Selection Window
- In Point Selection window Check the initial and optimal values of Variables
- The overall mass was reduced from 2.856 to 2.769





Constraint Violation

- Select Max Constr. Violation
- At the first iteration violation of constraints is dealt
- Then actual optimization progresses