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

1.6b - Design Optimization; Frontal Impact

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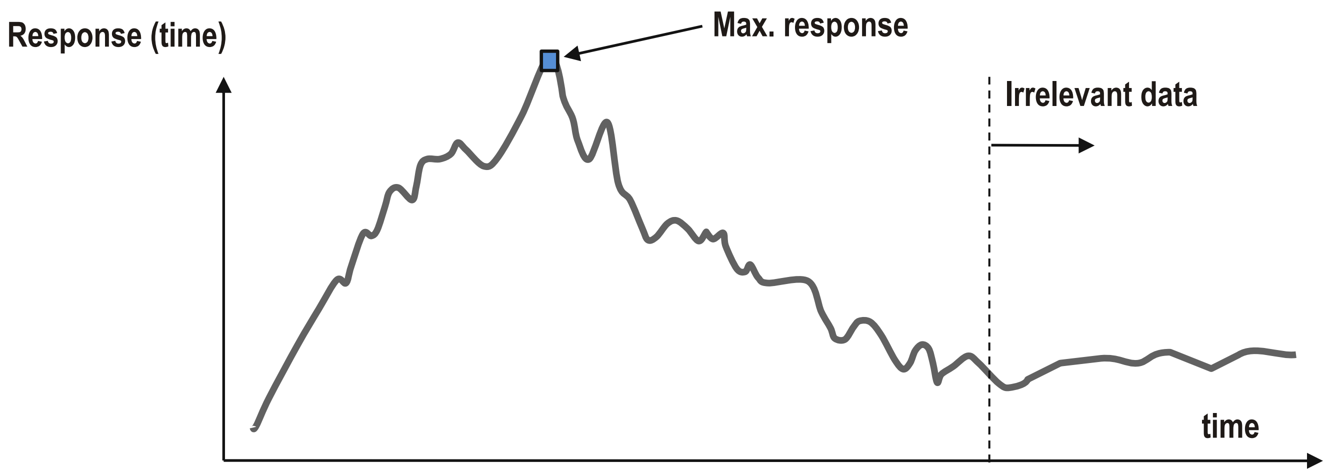
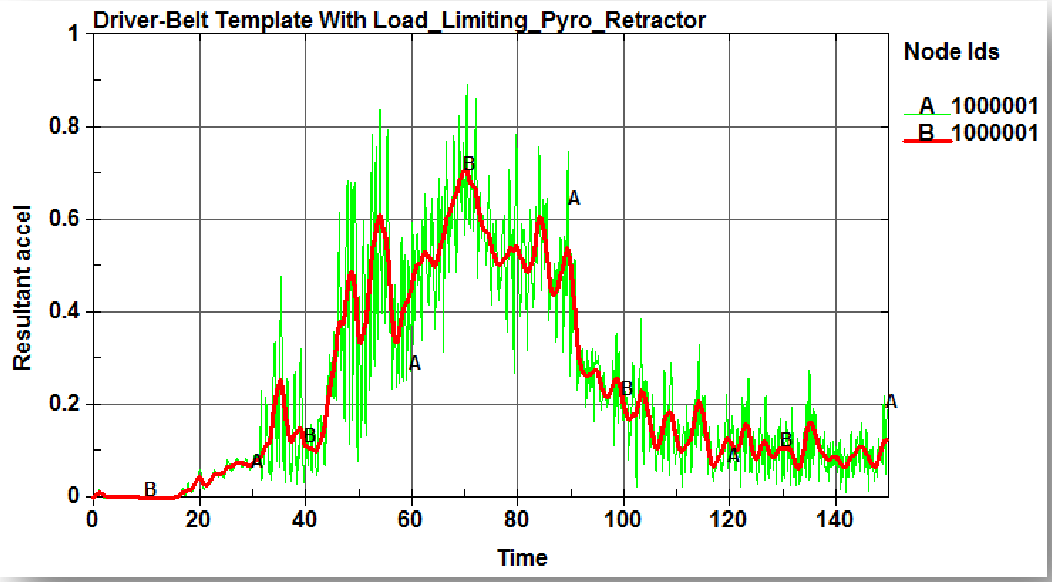
Design Optimization Process - Model Preparation

- Request only necessary output from LS-DYNA to prevent from storage space depletion – use "`clean`" script properly: `rm -rf d3plot* elout nodout rcforc`
- Run one simulation and check if the termination time can be decreased.



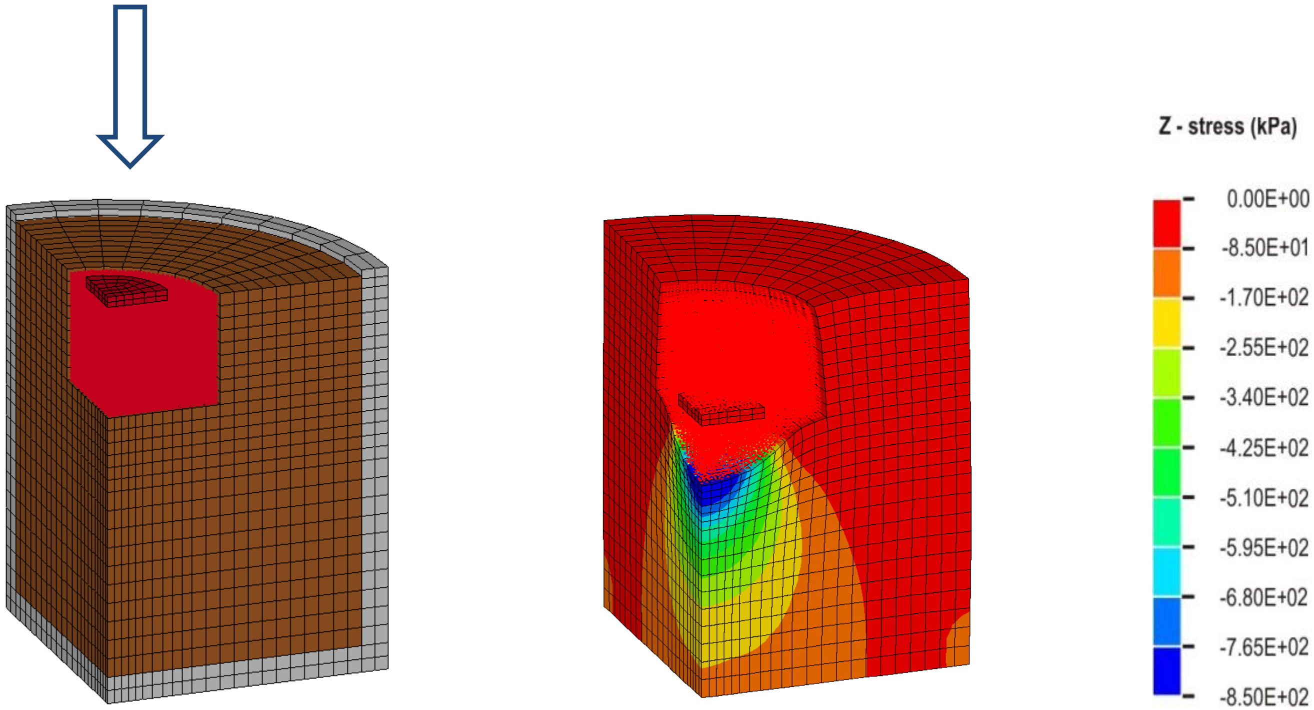
Model Preparation – Data Filtering and Resolution

- The model used for design should be stable and user should have confidence in its accuracy.
- If you are comparing maximal values of responses, make sure that you filter them to have reasonable values



Model Preparation – Number of Cores

- Problem description:
  - A rigid pad is pressed down into the soil with the rate of 1 in/sec
  - Model is built of 20,256 solid elements + 104,512 SPH particles
  - Simulation lasts 20 sec what corresponds to 20 in of penetration

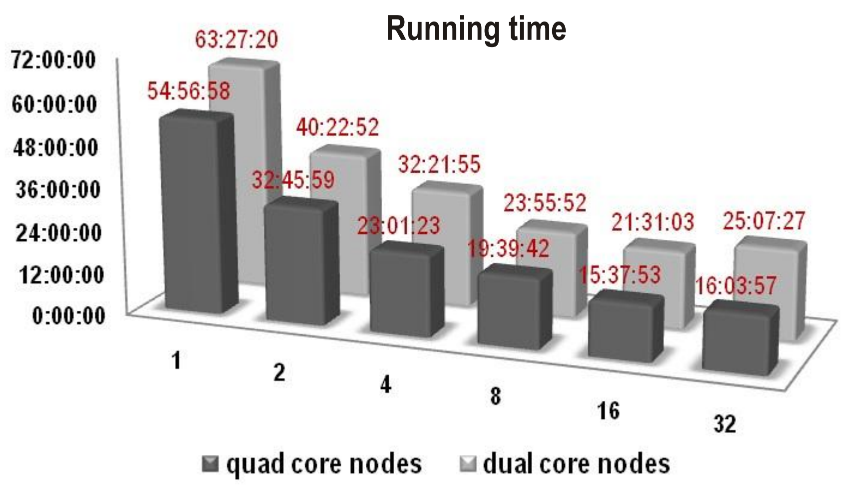


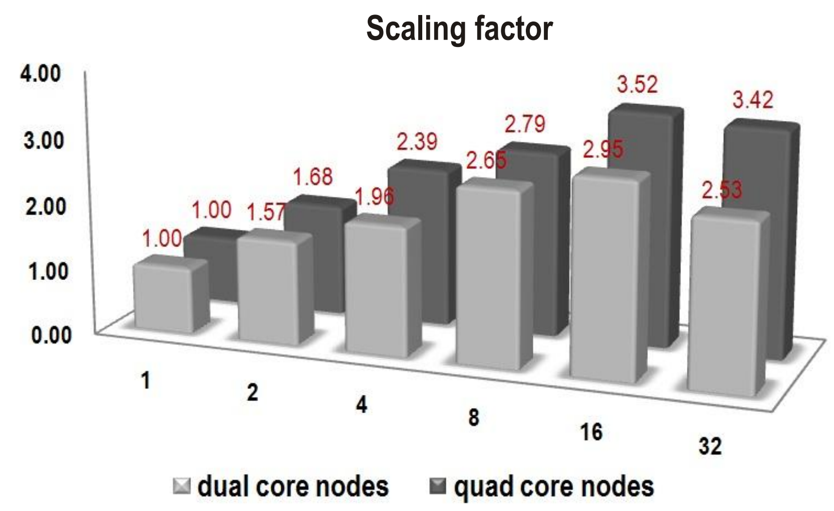
Model Preparation – Number of Cores

- Requesting more nodes for your job doesn't always mean that you will get your results faster

- Your job is scalable only up to some point that depends on the number of elements in your model and type of analysis you perform.

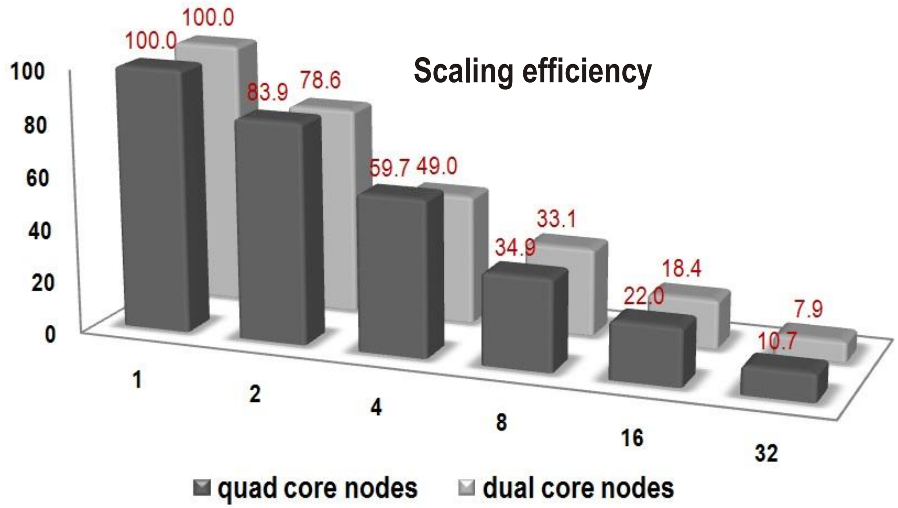
- As number of cores increases your waiting time in the queue grows accordingly.





Model Preparation – Number of Cores

- Scaling efficiency = Actual scaling factor / Ideal scaling factor * 100%
- In ideal case, linear scaling is expected and 100% of efficiency
- When requesting 8 cores, the run time dropped for this particular job to 36% of the time requested for 1 core.
- However, the efficiency of scaling was only 34.9%.
- If you are planning to submit multiple jobs, always request low number of cores.



Model Preparation - Decomposition

- Check how your model is decomposed. To do it use pfile:

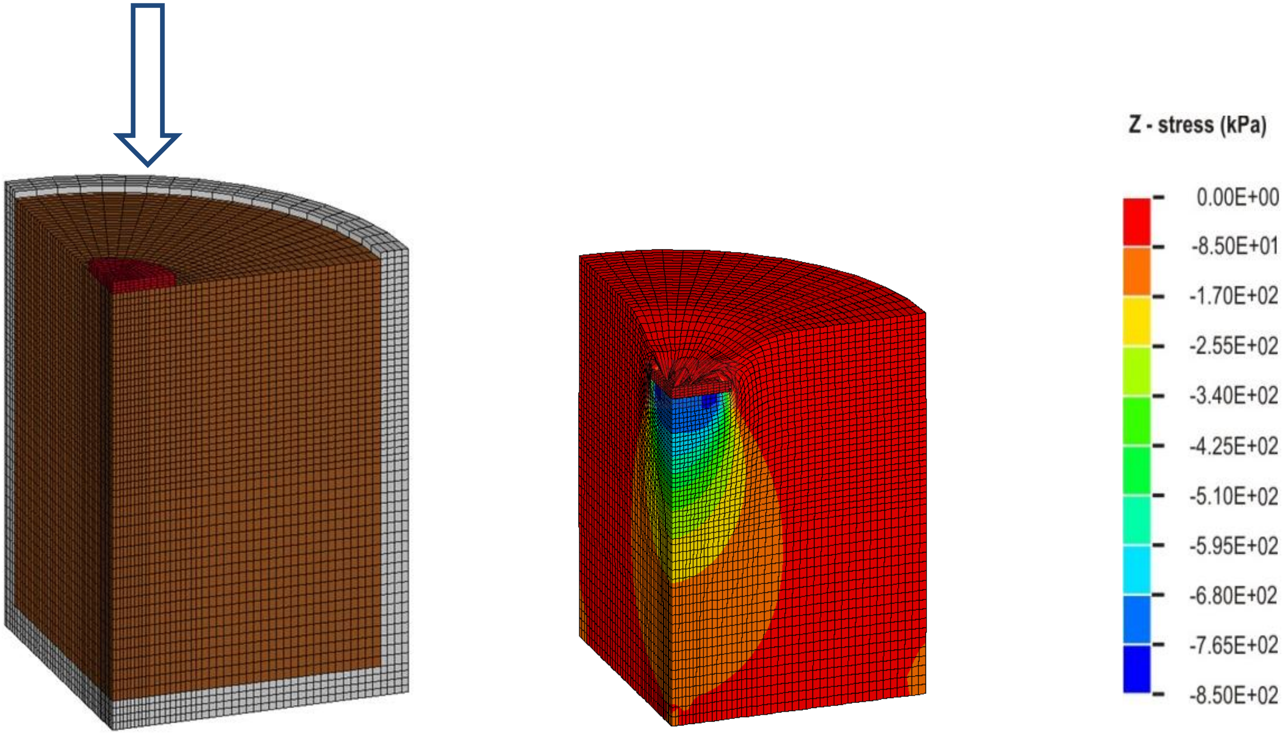
```
decomposition {  numproc 8
                 show }
```

- The default decomposition method in LS-DYNA (Recursive Coordinate Bisection - RCB) works by recursively dividing the model in half, each time slicing the current piece of the model perpendicularly to one of the three coordinate axes.

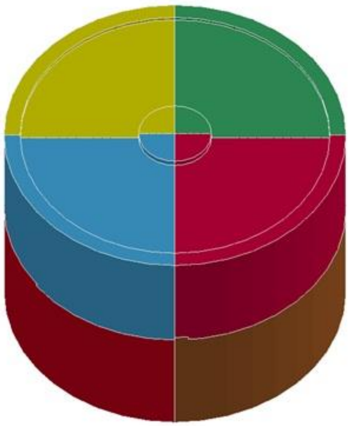
- The result is that it tends to generate cube shaped domains aligned along the coordinate axes. This is often not the behavior desired.

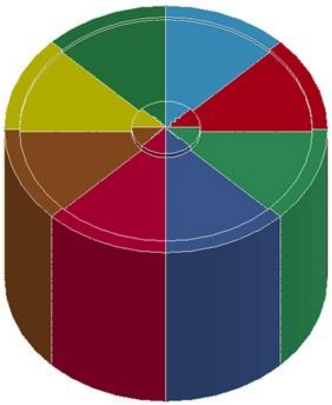
Model Preparation - Decomposition

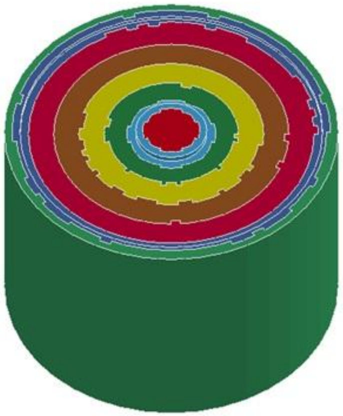
- How to decompose the model? Two things are important:
  - Amount of messages passed between the nodes,
  - What is happening in the elements?



Model Preparation - Decomposition







?

decomposition 1 - default

```
decomposition {
    numproc 8
    show }
```

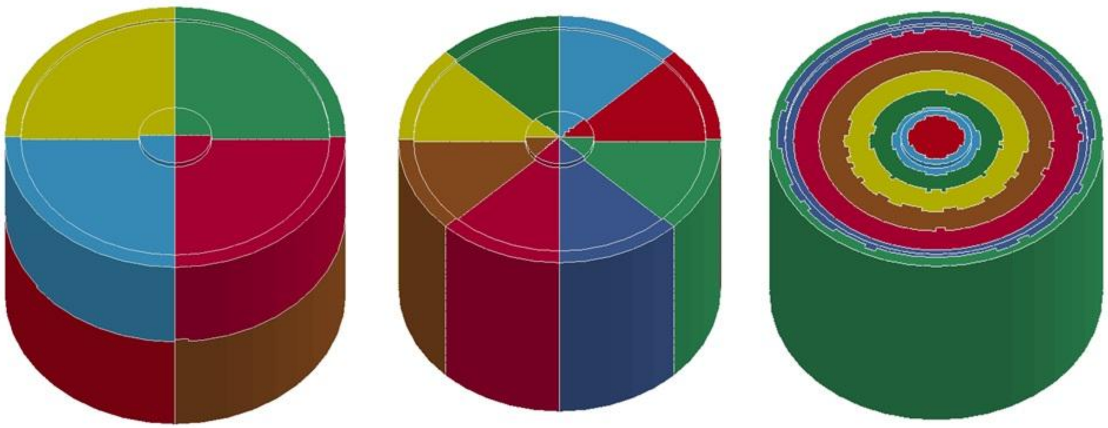
decomposition 2 - wedge type

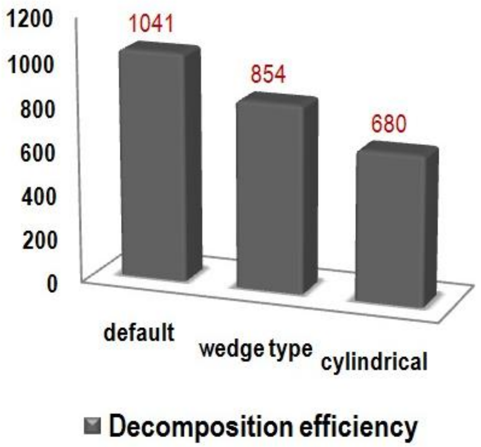
```
decomposition {
    numproc 8
    C2R 0 0 0 0 0 1 1 0 0
    SY 5000 }
```

decomposition 3 – cylindrical

```
decomposition {
    numproc 8
    C2R 0 0 0 0 0 1 1 0 0
    SX 100 }
```

Model Preparation - Decomposition





decomposition 1 - default

```
decomposition {
    numproc 8
    show }
```

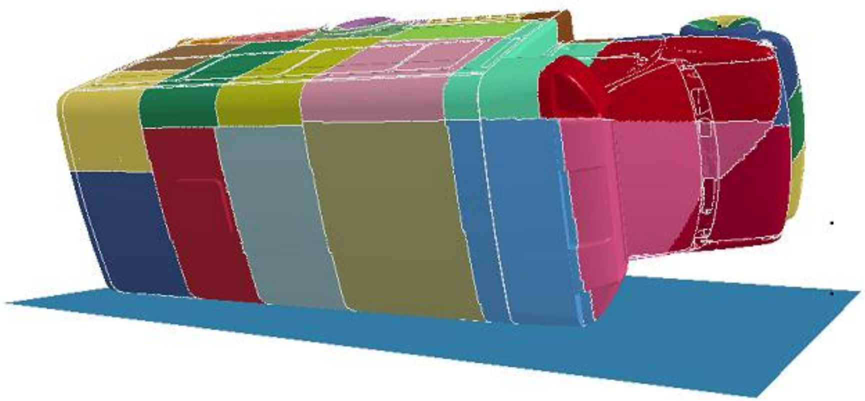
decomposition 2 - wedge type

```
decomposition {
    numproc 8
    C2R 0 0 0 0 0 1 1 0 0
    SY 5000 }
```

decomposition 3 – cylindrical

```
decomposition {
    numproc 8
    C2R 0 0 0 0 0 1 1 0 0
    SX 100 }
```

Model Preparation - Decomposition



decomposition 1 - default

```
decomposition {
    numproc 32
    show }
```

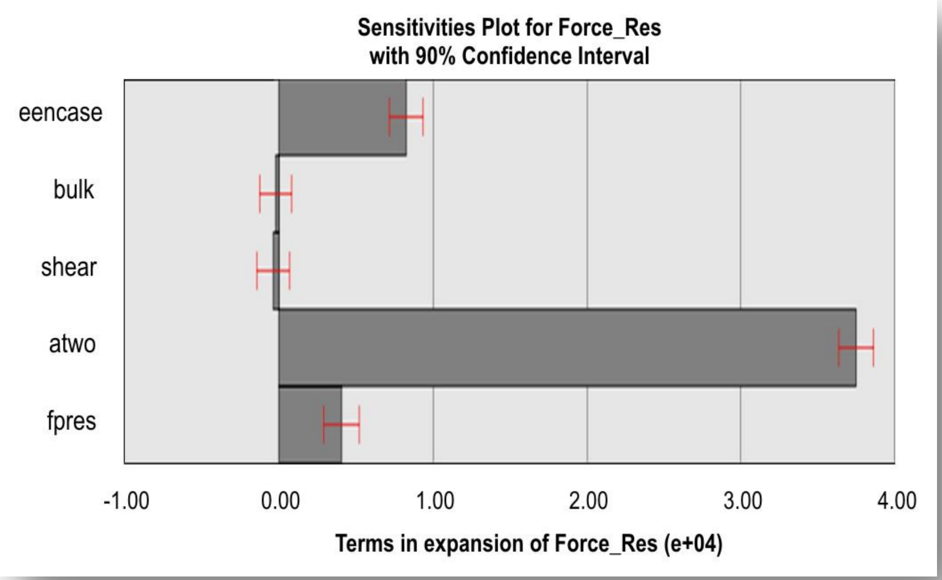
decomposition 2 – slice type

```
decomposition {
    numproc 32
    RZ -3.5 SX 200
    show }
```

Model Preparation - ANOVA

- Select suitable design parameters. Use many variables at the beginning if you are not sure which of them contribute the most to the changes in response.

- Stop after first iteration and scan for insignificant variables by performing ANOVA.

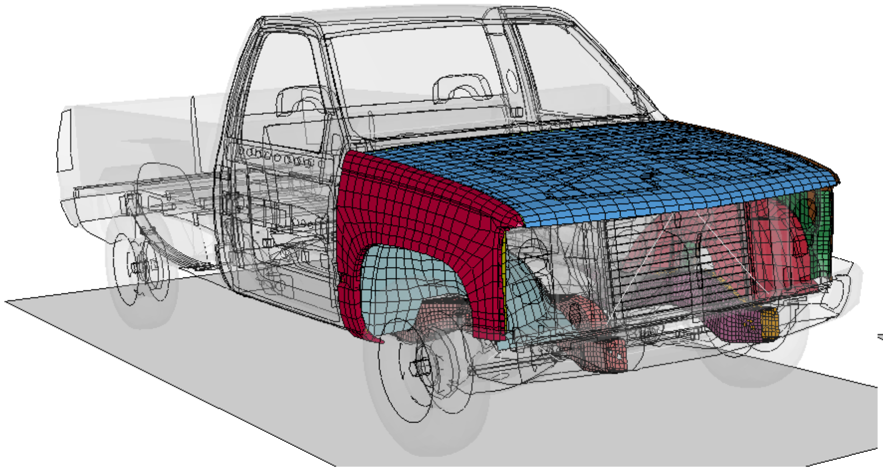


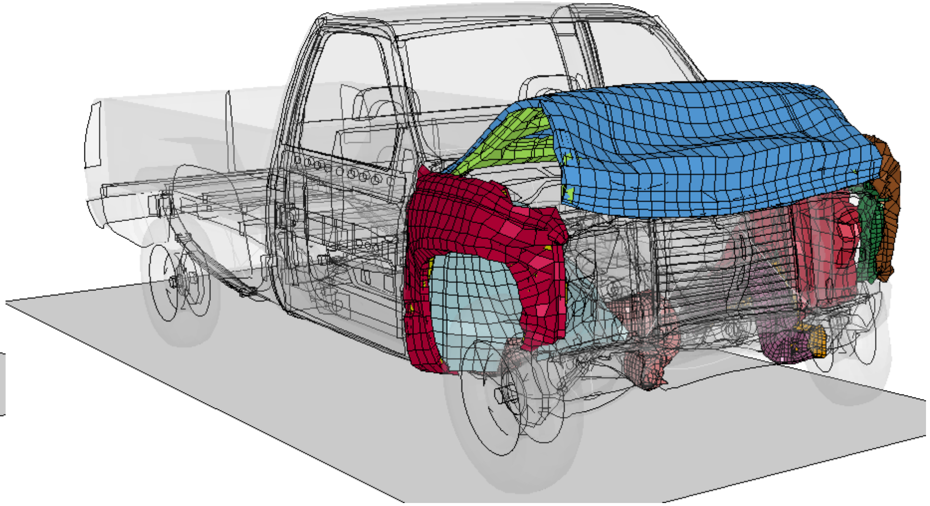
Design Optimization Process – Model Preparation

- Choose a design space by setting absolute bounds on the design variables. Be sure that the simulation is stable for these values.
- Choose suitable initial range. Too small region may require many iterations to converge to global optimum. Too large region may exhibit large accuracy error.
- Choose appropriate order of design approximation when using polynomial response surfaces.
- In many cases it takes only 2 to 3 iterations to achieve reasonably optimal design. An improvement can be achieved within one iteration.

Problem Description

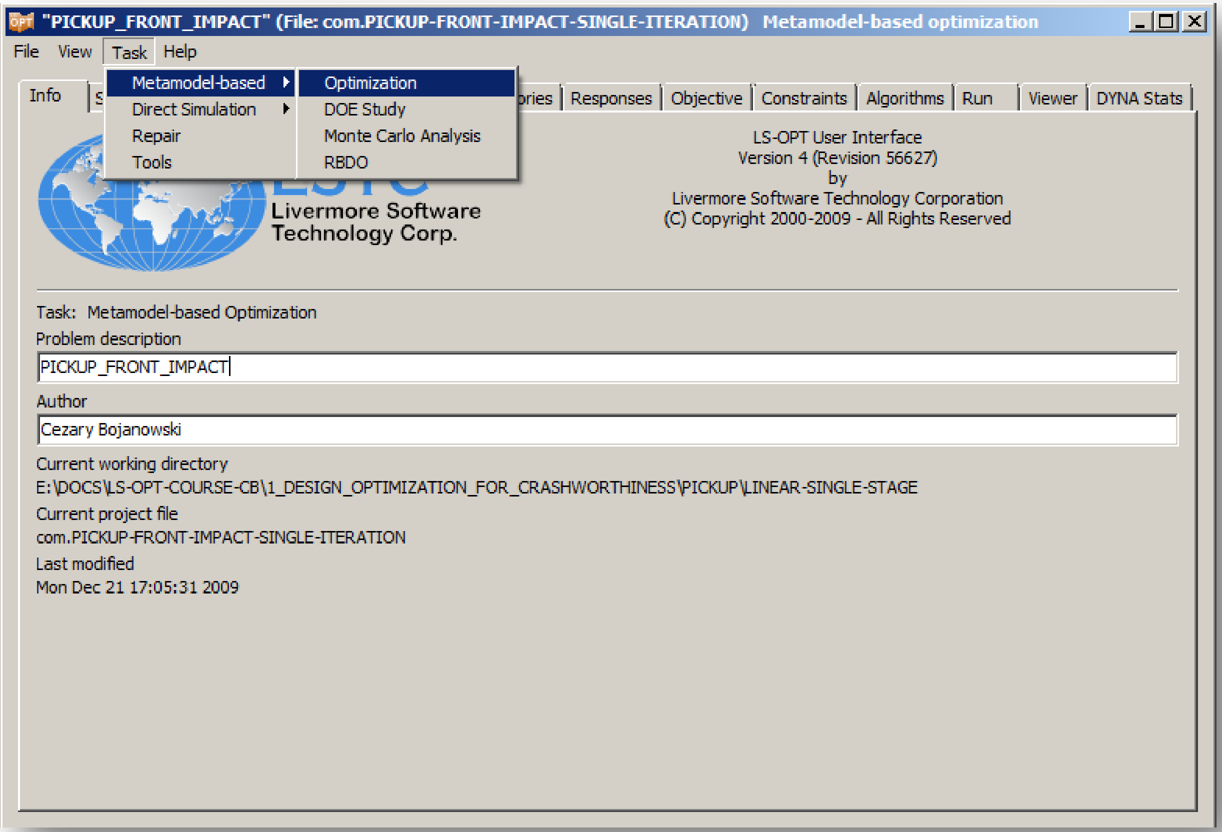
- Frontal impact of the C2500 Pickup truck (58,354 elements)
- Objective: Maximize the internal energy to mass ratio (for selected 12 parts)
- Variables: thicknesses of 12 parts of the model
- Constraints: bounds on mass





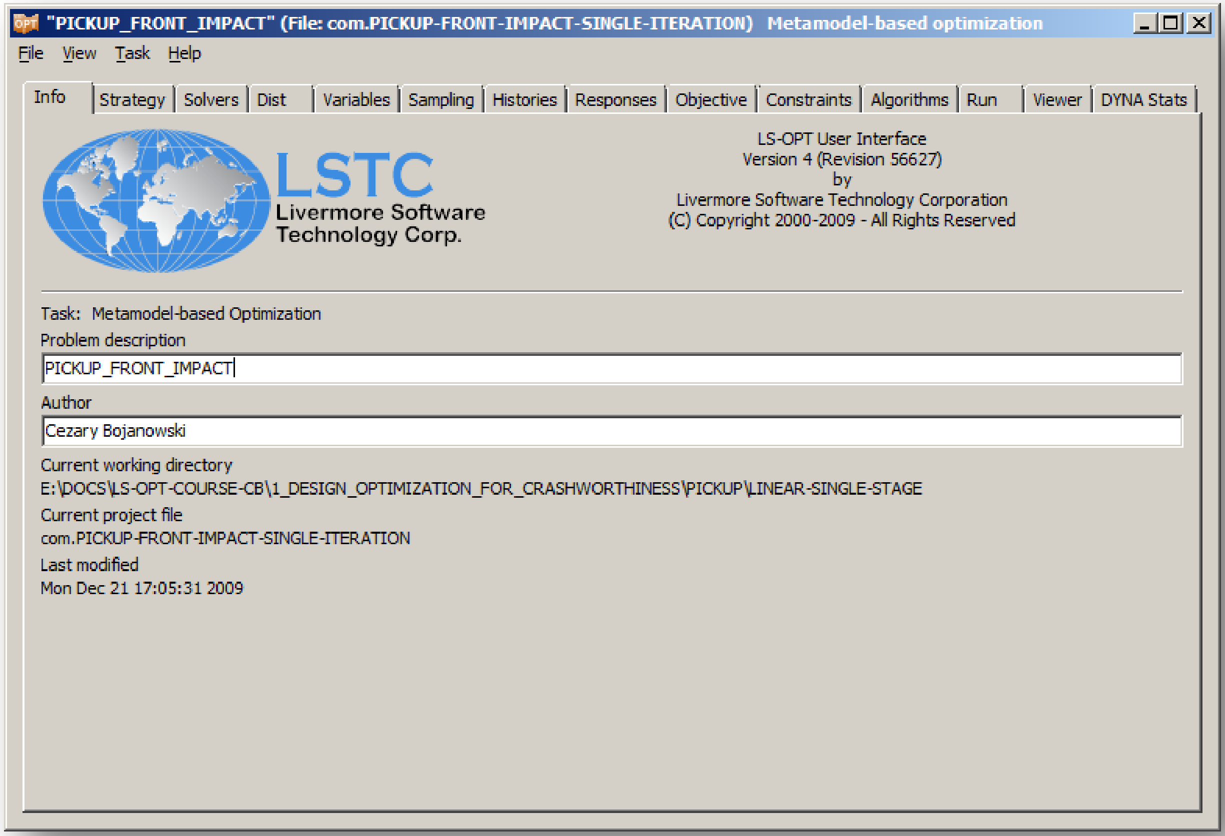
Task Selection

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



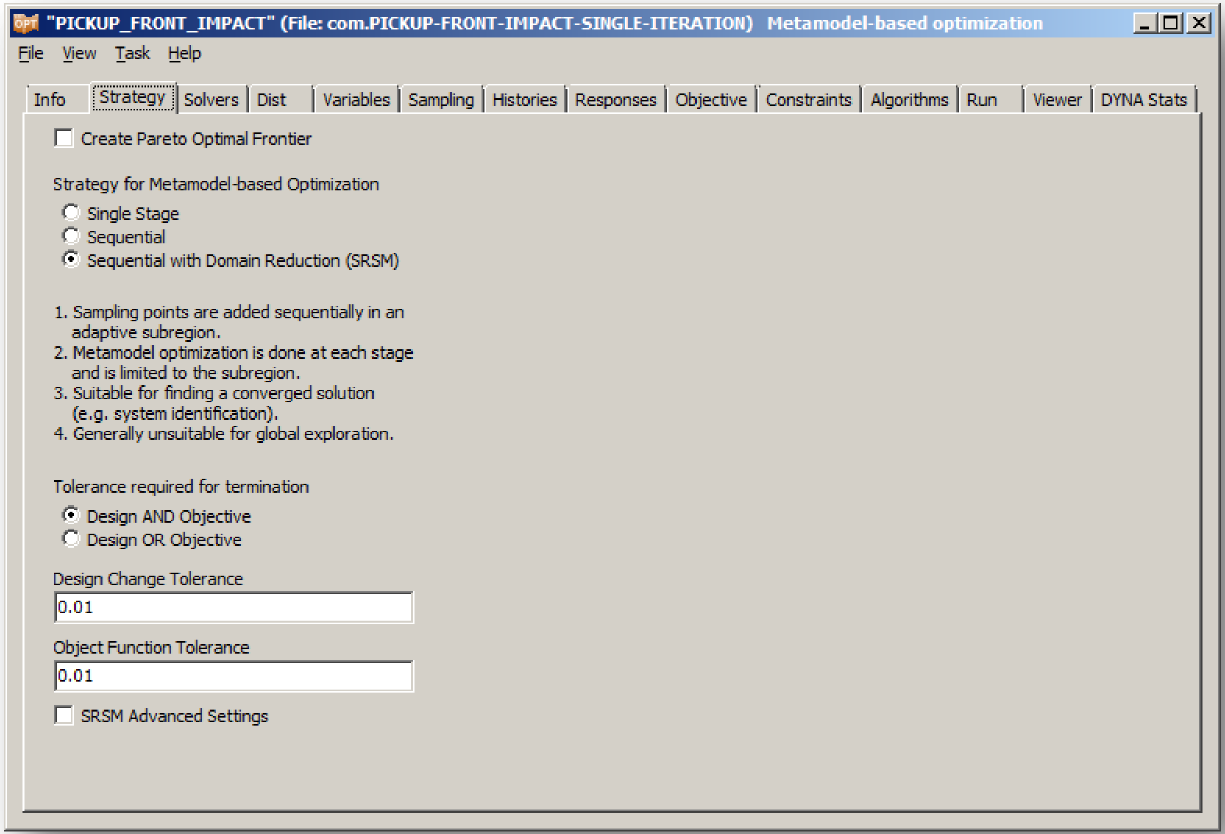
Info Tab

- Type in the description of the problem and the name of the Author



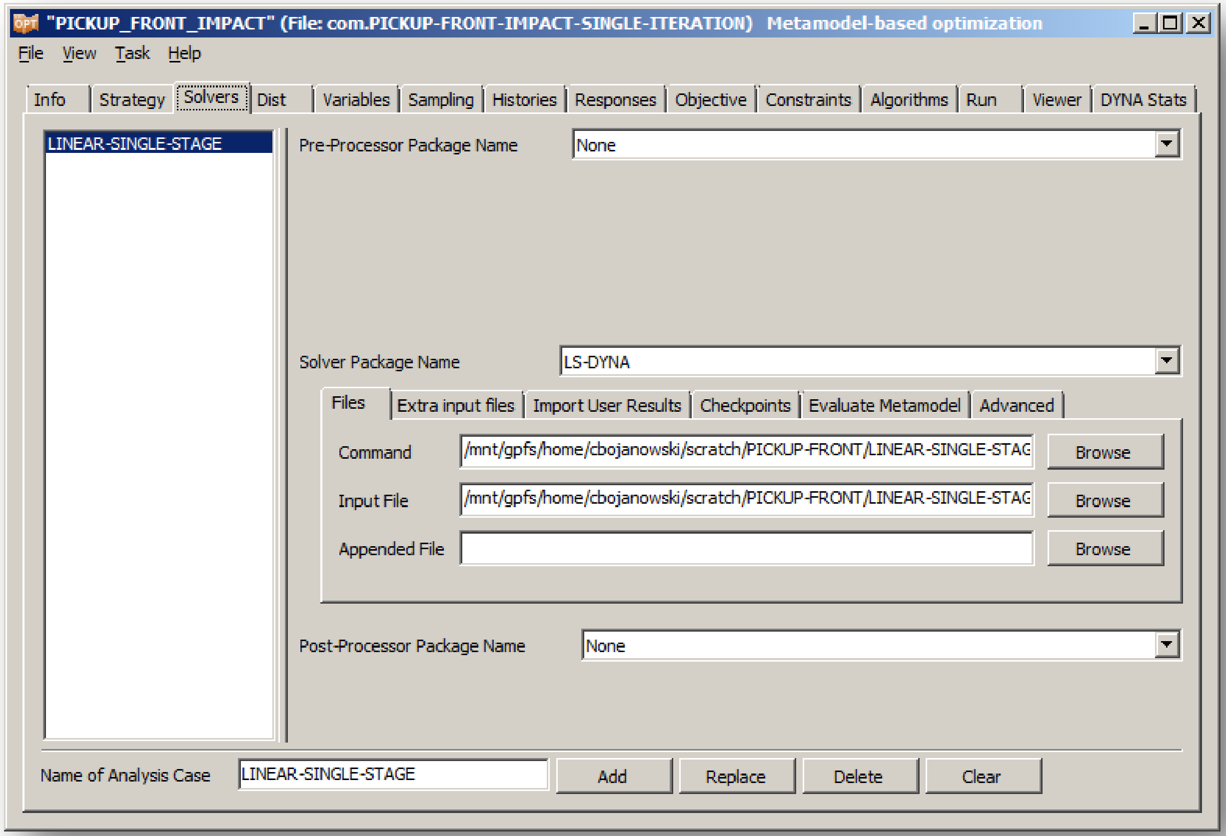
Strategy Tab

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



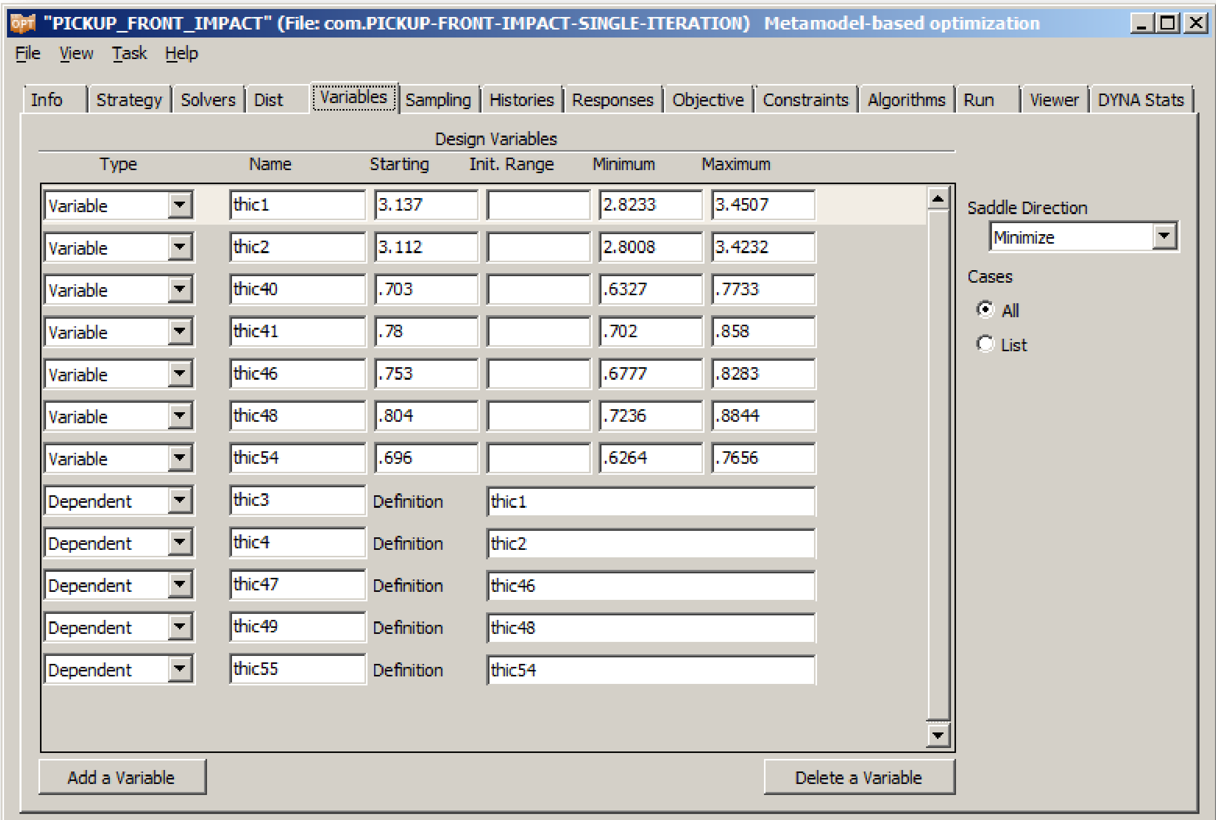
Solvers Tab

- 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 `Combine.k` file
- Type `LINEAR-SINGLE-STAGE` in the Name of Analysis Case field and hit Add



Variables Tab

- In the Variables panel Add seven variables:
  - thic1 with starting value of 3.137 with lower bound 2.8233 and upper bound 3.4507
  - thic2 with starting value of 3.112 with lower bound 2.8008 and upper bound 3.4232
  - thic40 with starting value of 0.703 with lower bound 0.6327 and upper bound 0.7733
  - ...

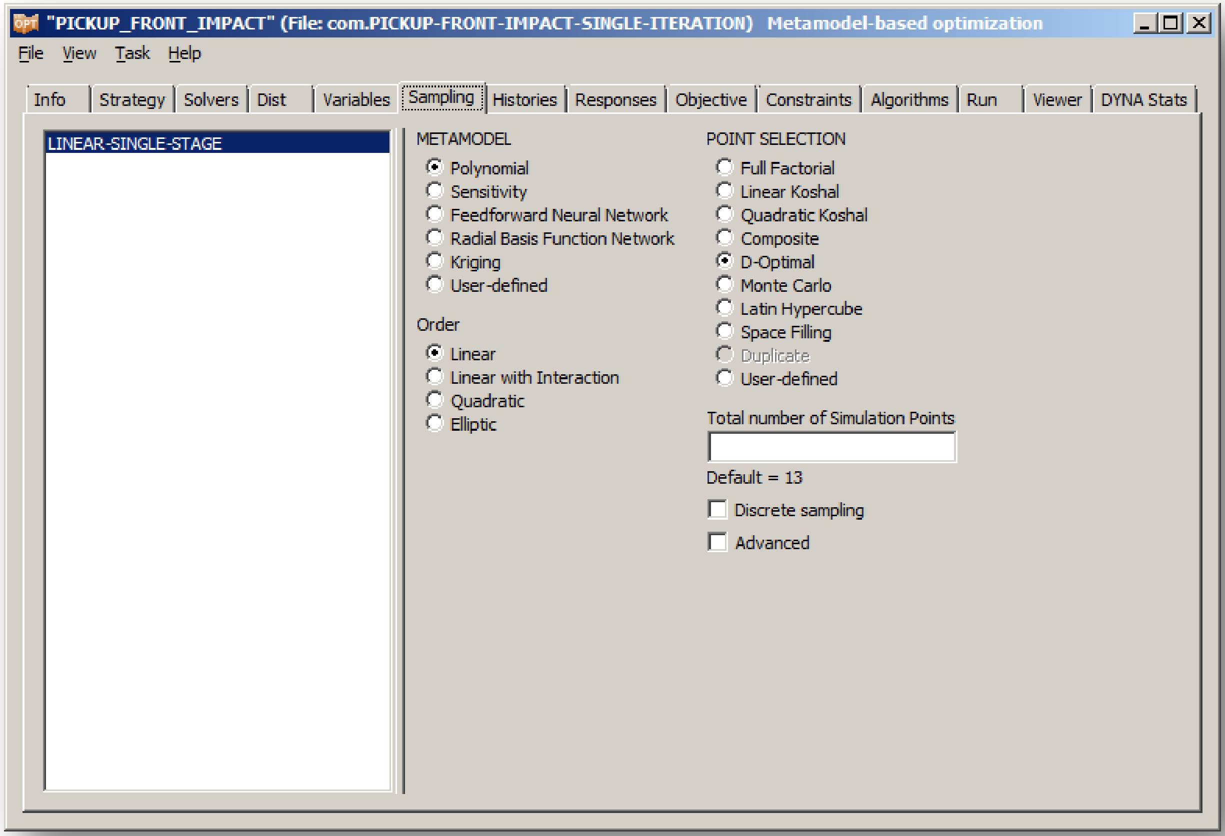


Variables Tab

- In the Variables panel Add seven variables:
  - ...
  - thic41 with starting value of 0.78 with lower bound 0.702 and upper bound 0.858
  - thic46 with starting value of 0.753 with lower bound 0.6777 and upper bound 0.8283
  - thic48 with starting value of 0.804 with lower bound 0.7236 and upper bound 0.8844
  - thic54 with starting value of 0.696 with lower bound 0.6264 and upper bound 0.7656
- And five Dependent varaibles:
  - thic3 defined as thic1
  - thic4 defined as thic2
  - thic47 defined as thic46
  - thic49 defined as thic48
  - thic55 defined as thic54

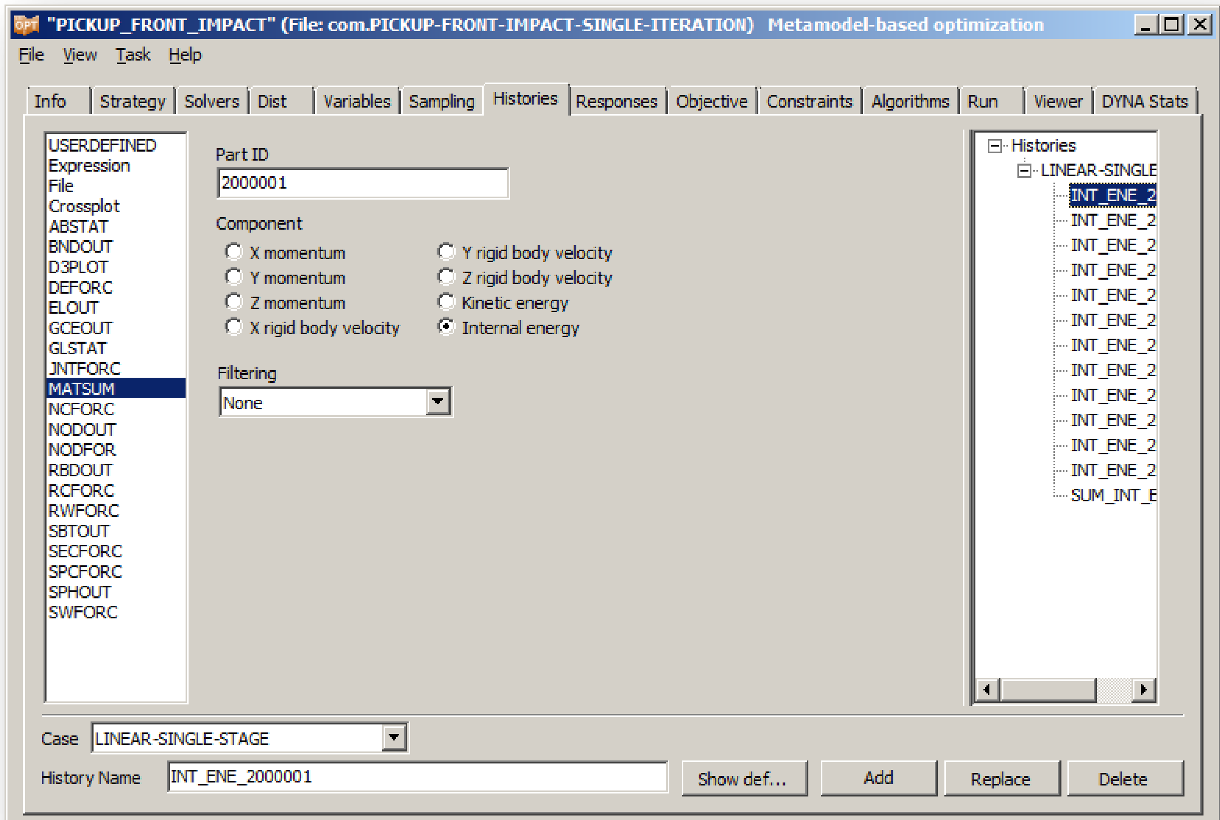
Sampling Tab

- In the Sampling panel select Polynomial Metamodel with Linear order
- For Point Selection choose D-Optimal criterion
- Leave the default number of Simulation Points



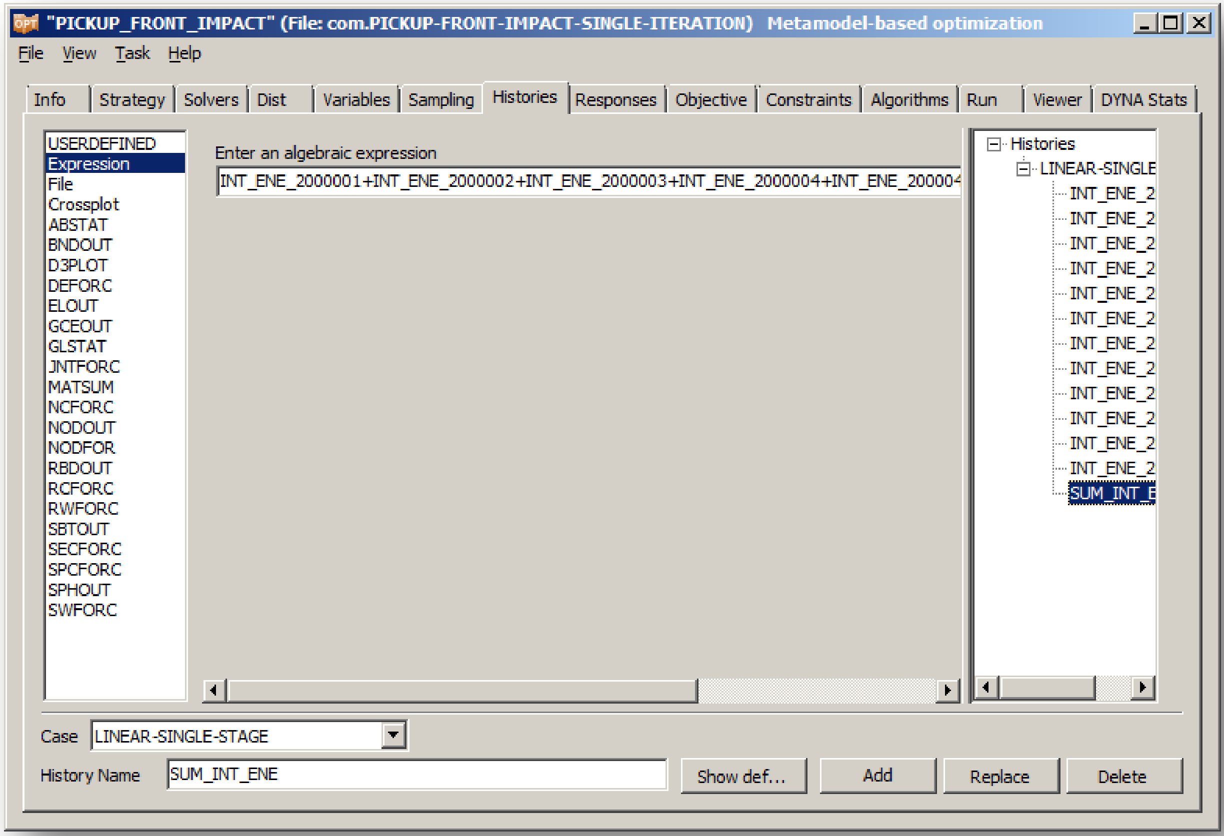
Histories Tab

- In the Histories panel from the right window select MATSUM file
- For Part ID identifier type 2000001
- For the component choose Internal Energy
- Name the History as INT_ENE_2000001
- Repeat the same for parts:
  - 2000002
  - 2000003
  - 2000004
  - 2000040
  - 2000041
  - 2000046
  - 2000047
  - 2000048
  - 2000049
  - 2000054
  - 2000055



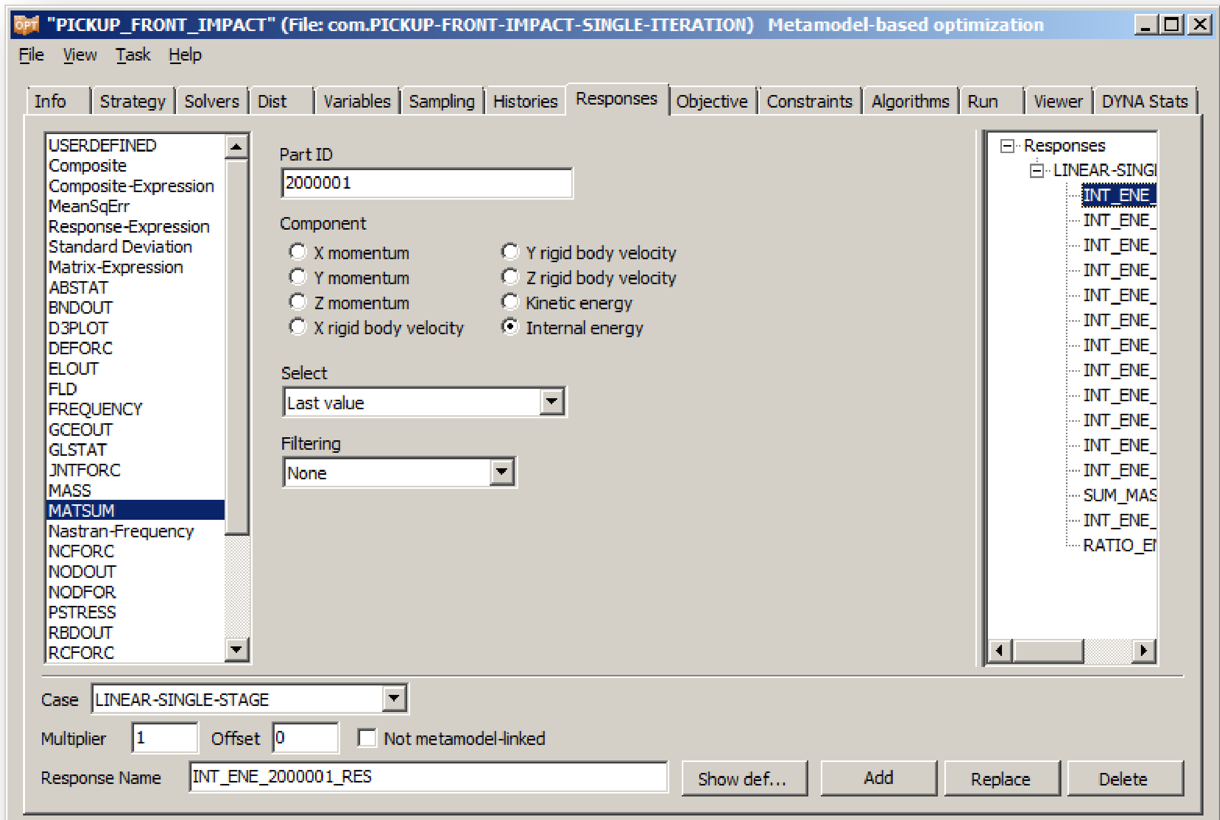
Histories Definitions

- In the Histories panel from the right window select `Expression`
- For the algebraic expression type `INT_ENE_2000001 + INT_ENE_2000002 INT_ENE_2000003 + INT_ENE_2000004 + INT_ENE_2000040 + INT_ENE_2000041 + INT_ENE_2000046 + INT_ENE_2000047 + INT_ENE_2000048 + INT_ENE_2000049 + INT_ENE_2000054 + INT_ENE_2000055`
- Name it as `SUM_INT_ENE`
- Press Add



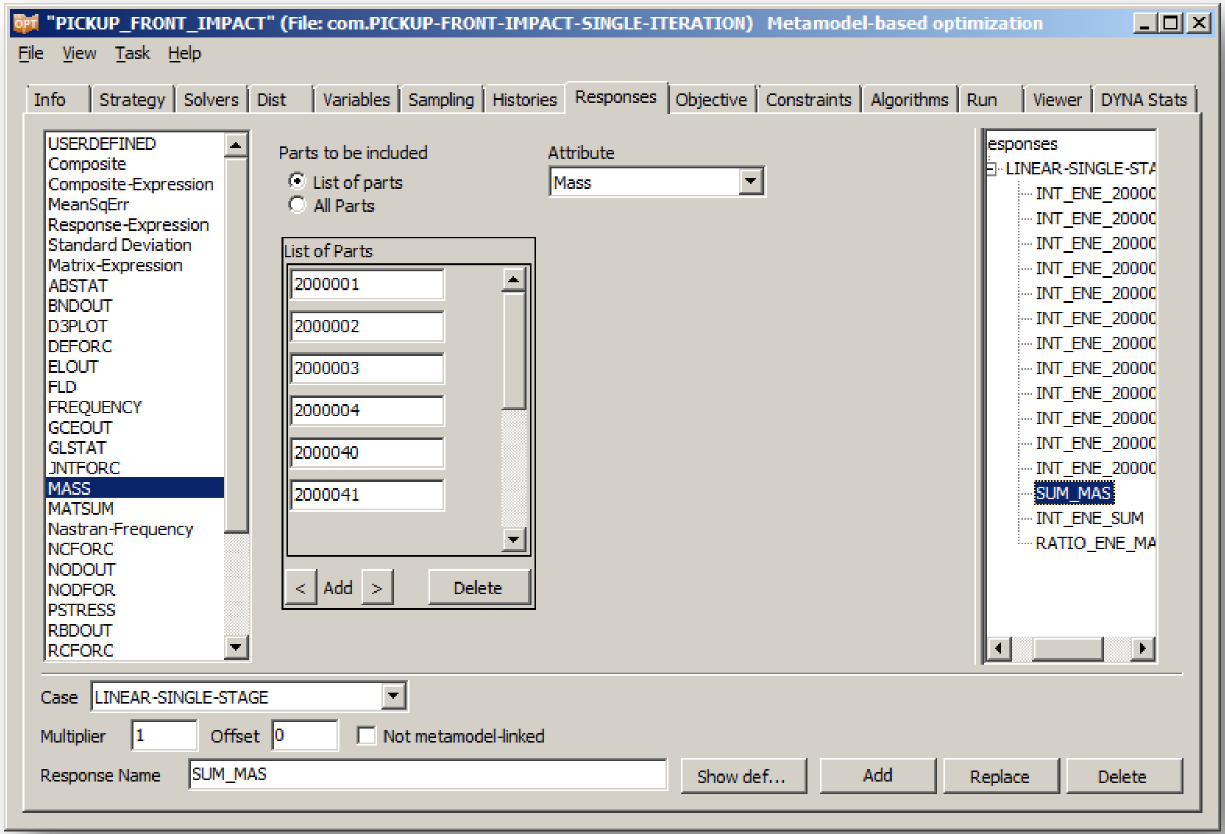
Responses Definitions

- In the Responses panel from the right window select MATSUM file
- For Part ID identifier type 2000001
- For the component choose Last value of Internal Energy
- Name the Response as INT_ENE_2000001_RES
- Repeat the same for parts:
  - 2000002
  - 2000003
  - 2000004
  - 2000040
  - 2000041
  - 2000046
  - 2000047
  - 2000048
  - 2000049
  - 2000054
  - 2000055



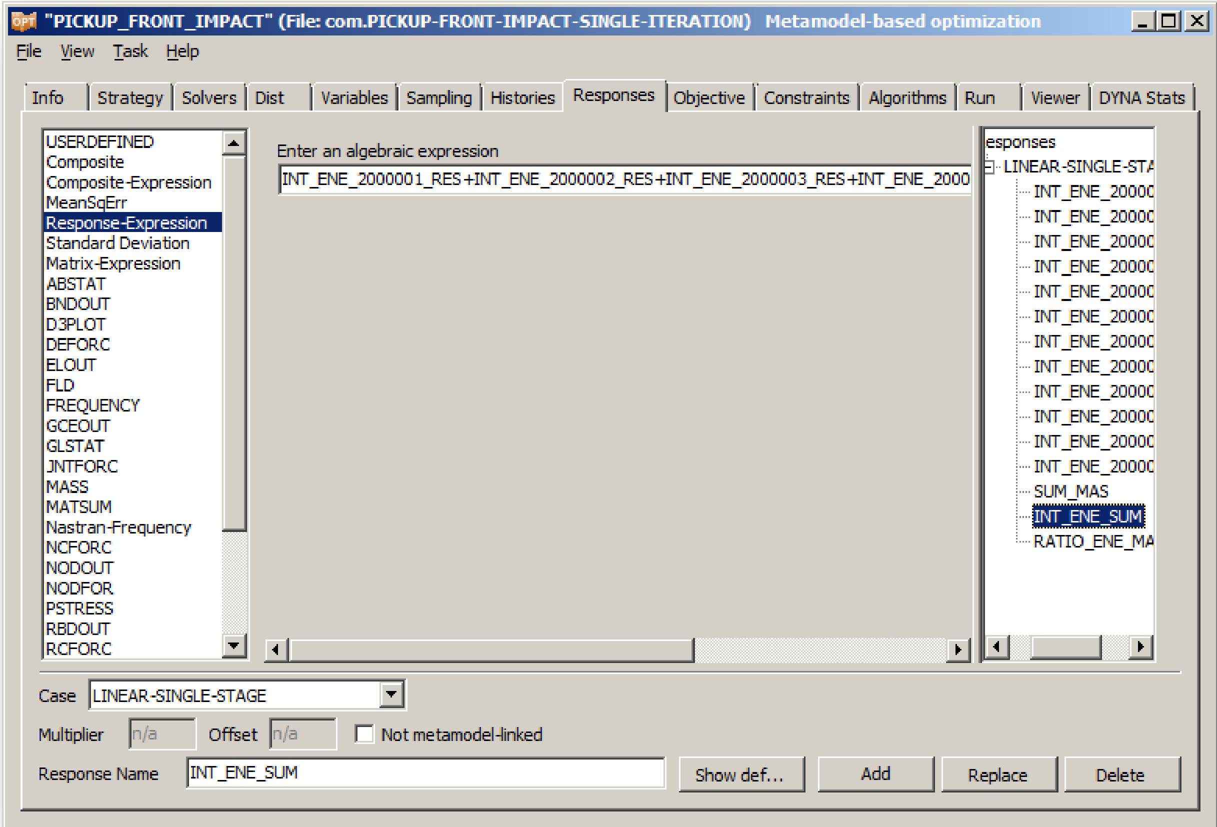
Responses Definitions

- In the Responses panel from the right window select MASS file
- For Parts to be included Add parts: 2000001, 2000002, 2000003,2000004, 2000040, 2000041, 2000046, 2000047, 2000048, 2000049, 2000054, 2000055
- Name the Response as SUM_MAS



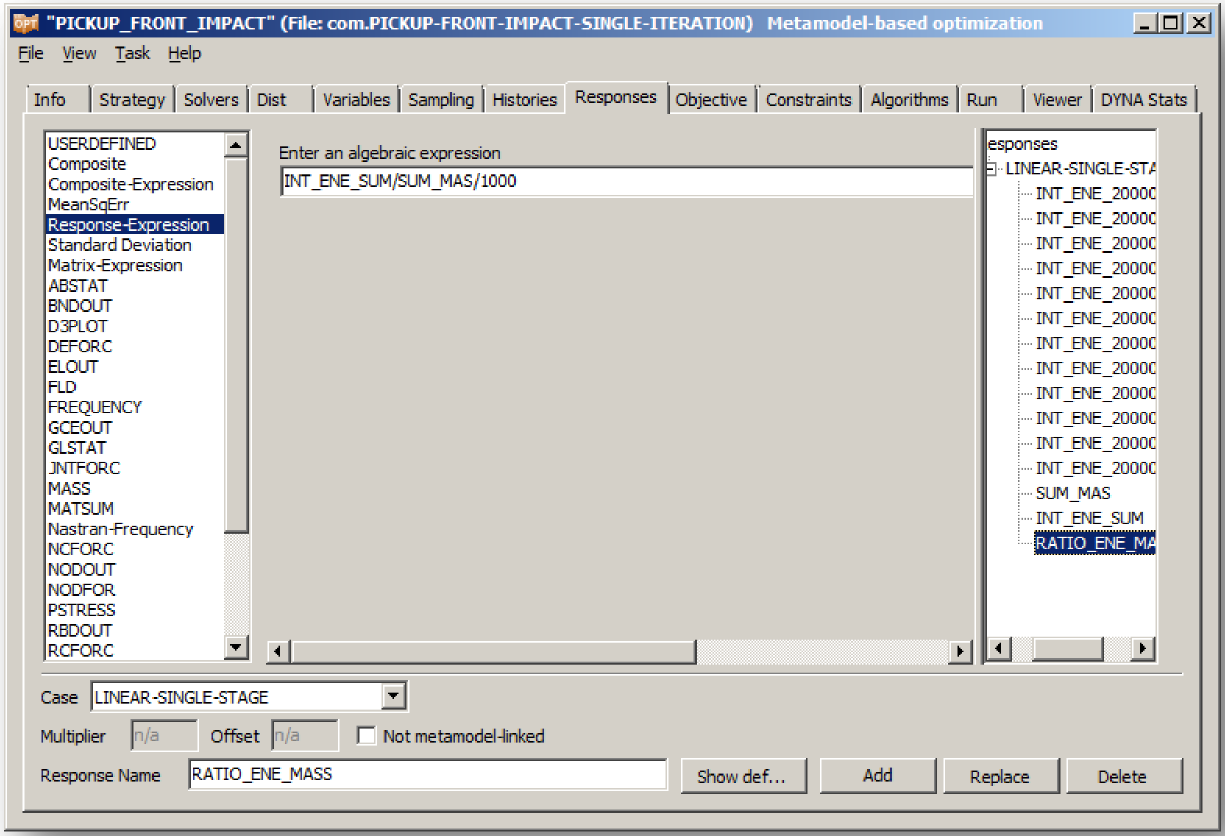
Responses Definitions

- In the Responses panel from the right window select Response-Expression
- For the algebraic expression enter INT_ENE_2000001_RES + INT_ENE_2000002_RES INT_ENE_2000003_RES + INT_ENE_2000004_RES + INT_ENE_2000040_RES + INT_ENE_2000041_RES + INT_ENE_2000046_RES + INT_ENE_2000047_RES + INT_ENE_2000048_RES + INT_ENE_2000049_RES + INT_ENE_2000054_RES + INT_ENE_2000055_RES
- Name it as INT_ENE_SUM
- Press Add



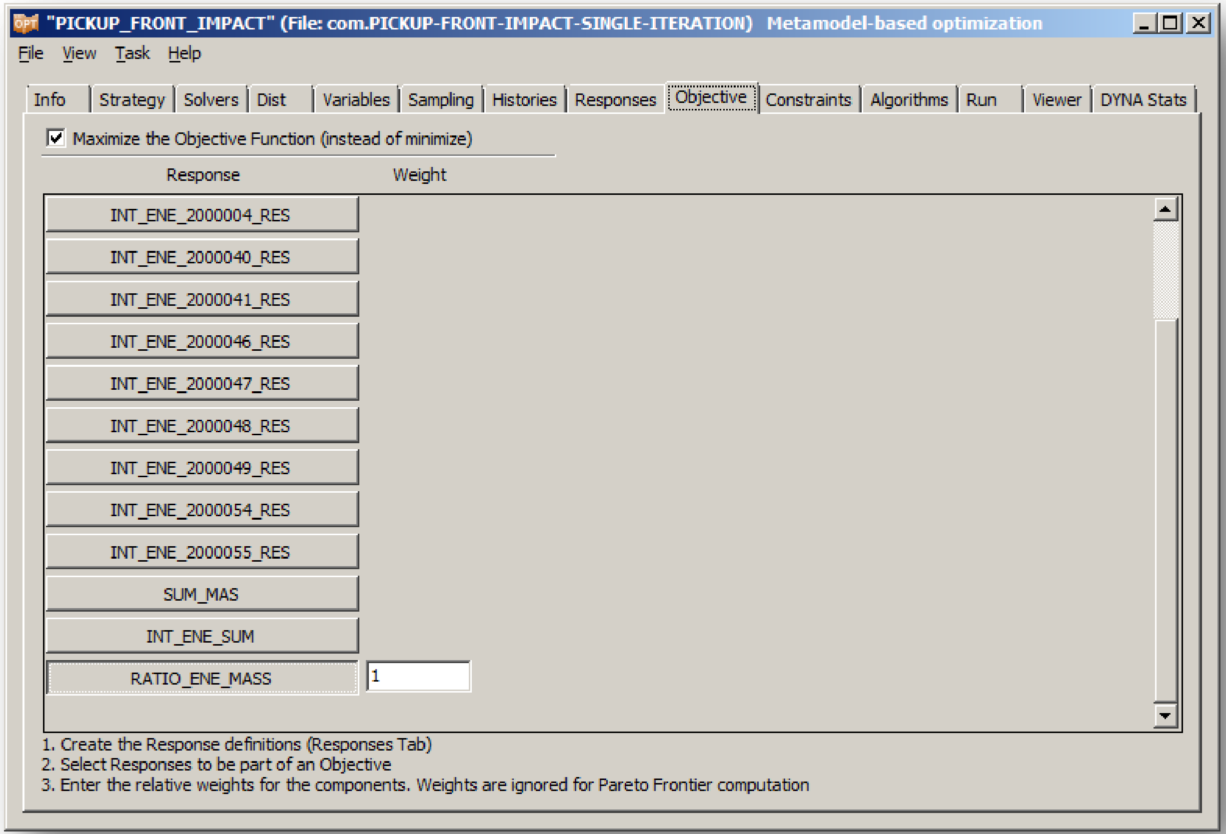
Responses Definitions

- In the Responses panel from the right window select Response-Expression
- For the algebraic expression type INT_ENE_SUM/SUM_MAS/1000
- Name it as RATIO_ENE_MASS
- Press Add



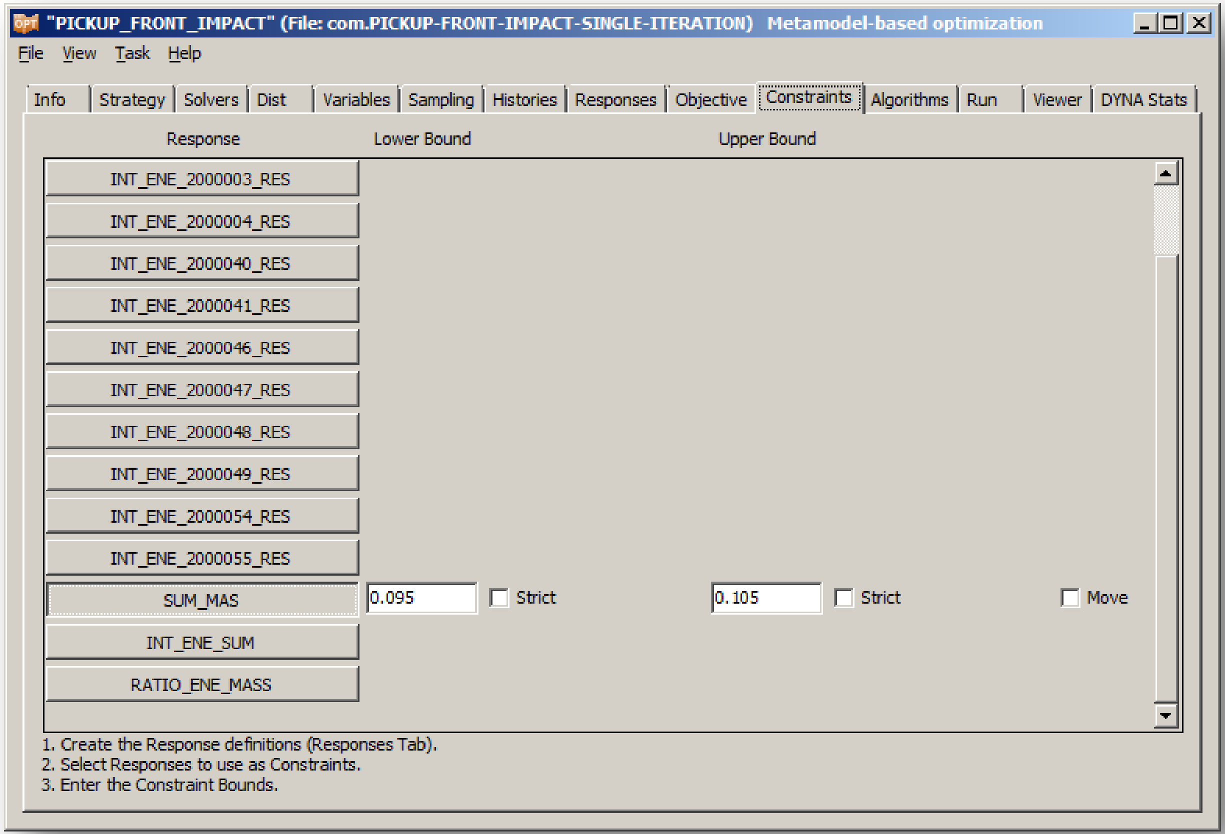
Objectives Tab

- In Objectives panel select to maximize the RATIO_ENE_MASS with default weight 1.0



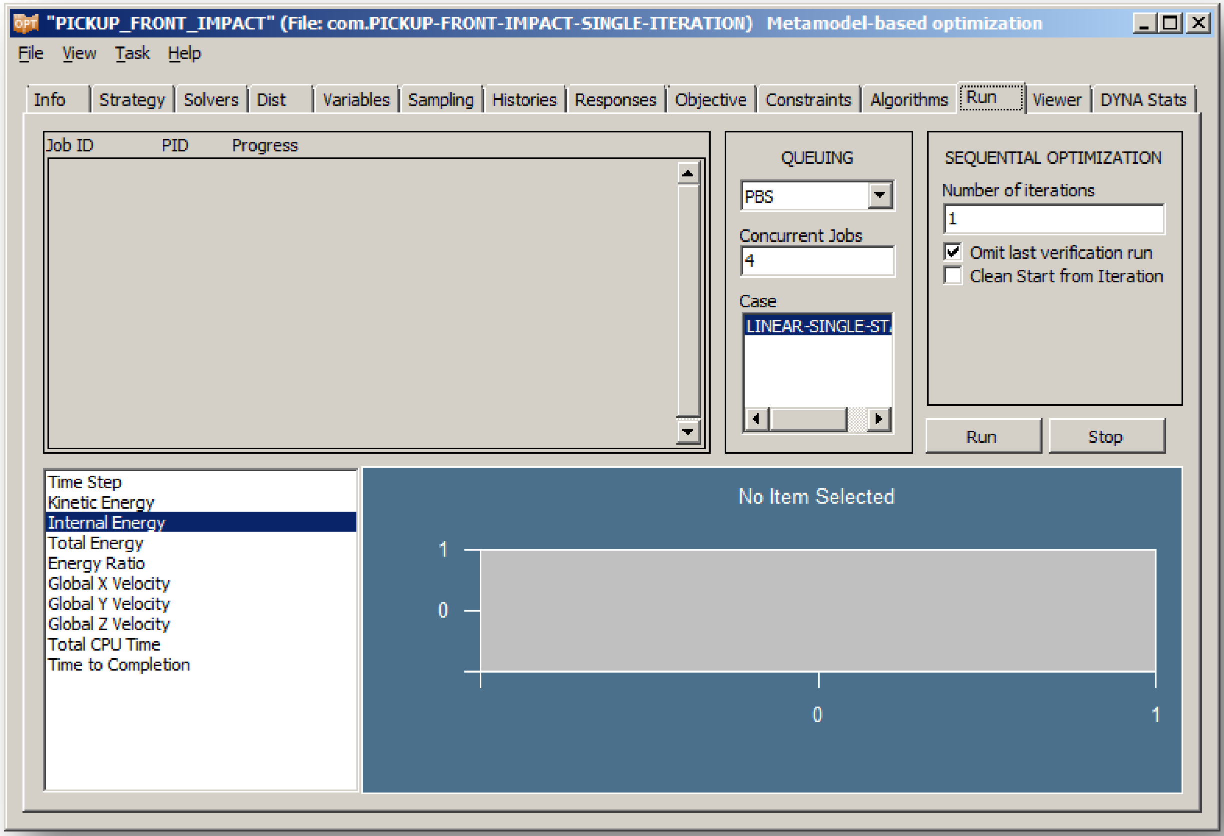
Constraints Tab

- From Responses select SUM_MAS
- For lower bound type -0.095 and the Upper bound +0.105



Run Tab

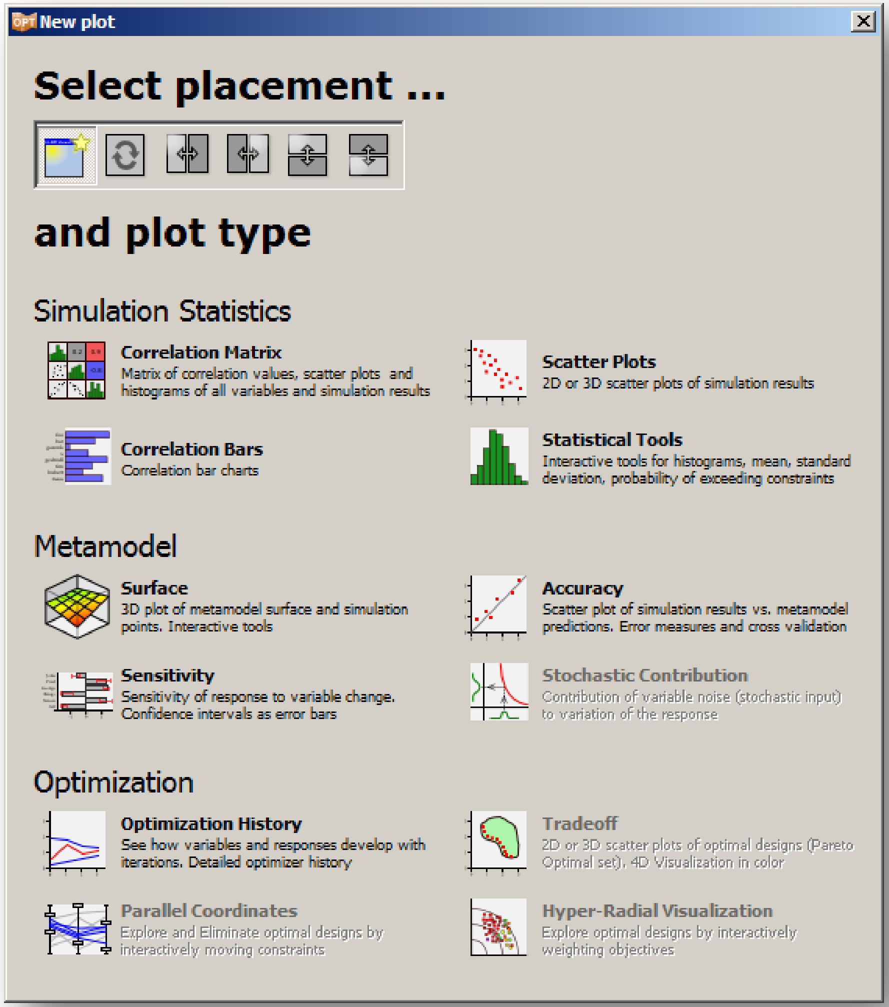
- Select PBS for QUEUING software (TRACC cluster users)
- For Concurrent Jobs enter 4
- For Number of Iteration enter 1 and
- Check Omit last verification run and Clean Start from iteration 1
- Hit Run to start simulations



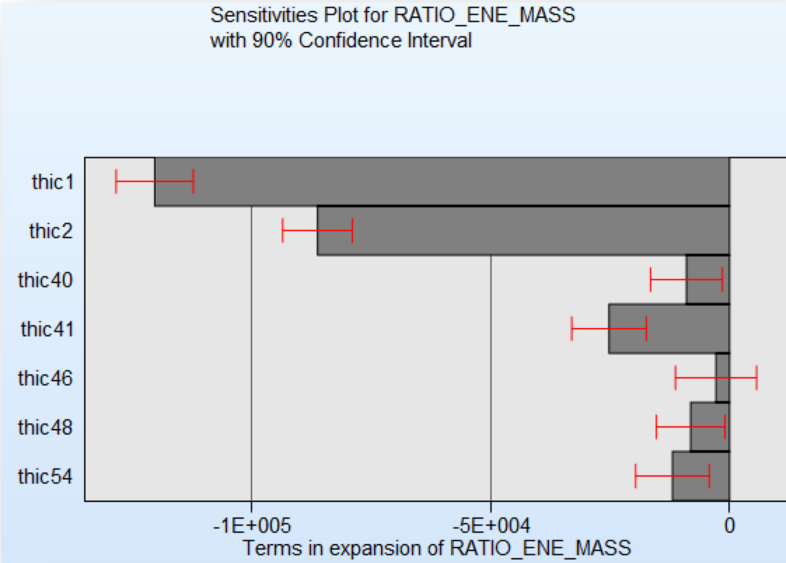
Viewer

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

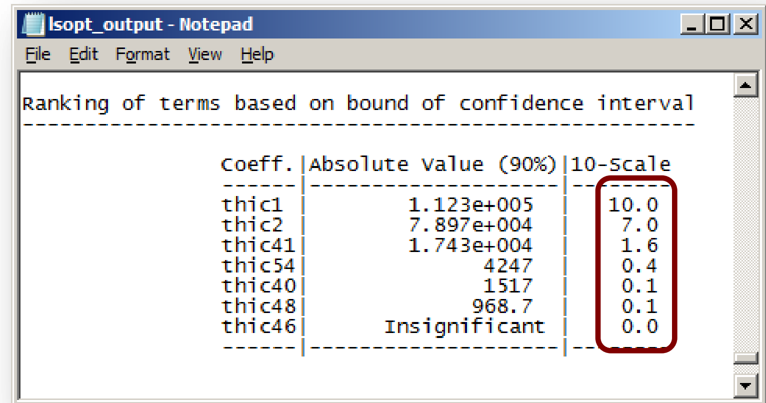
- See the sensitivities of responses:
  - Sum of the mass
  - Sum of the internal energies
  - Ratio of the internal energy to mass (objective)



Sensitivities



Sensitivities for RATIO_ENE_MASS from `lsopt_output` file

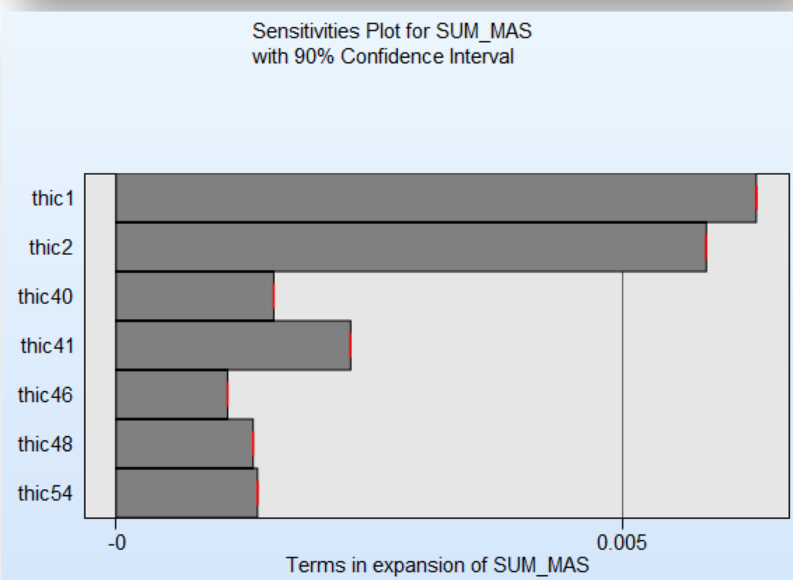


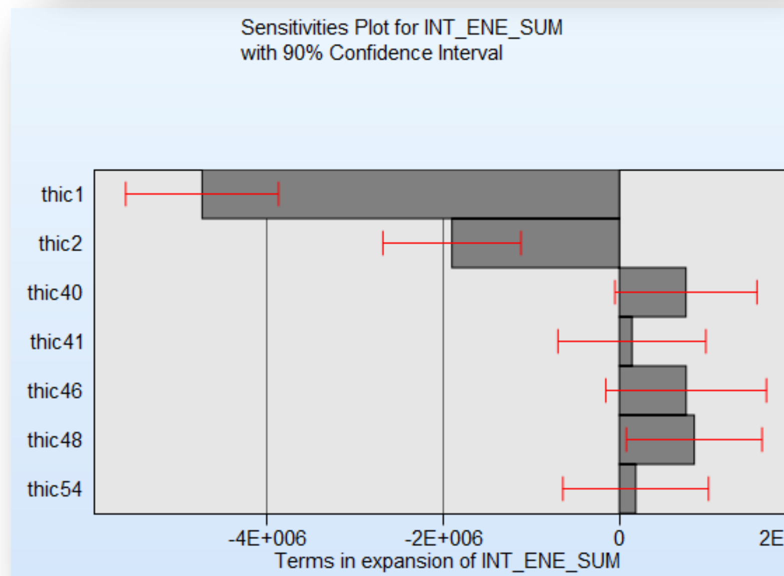
lsopt_output - Notepad

File Edit Format View Help

Ranking of terms based on bound of confidence interval

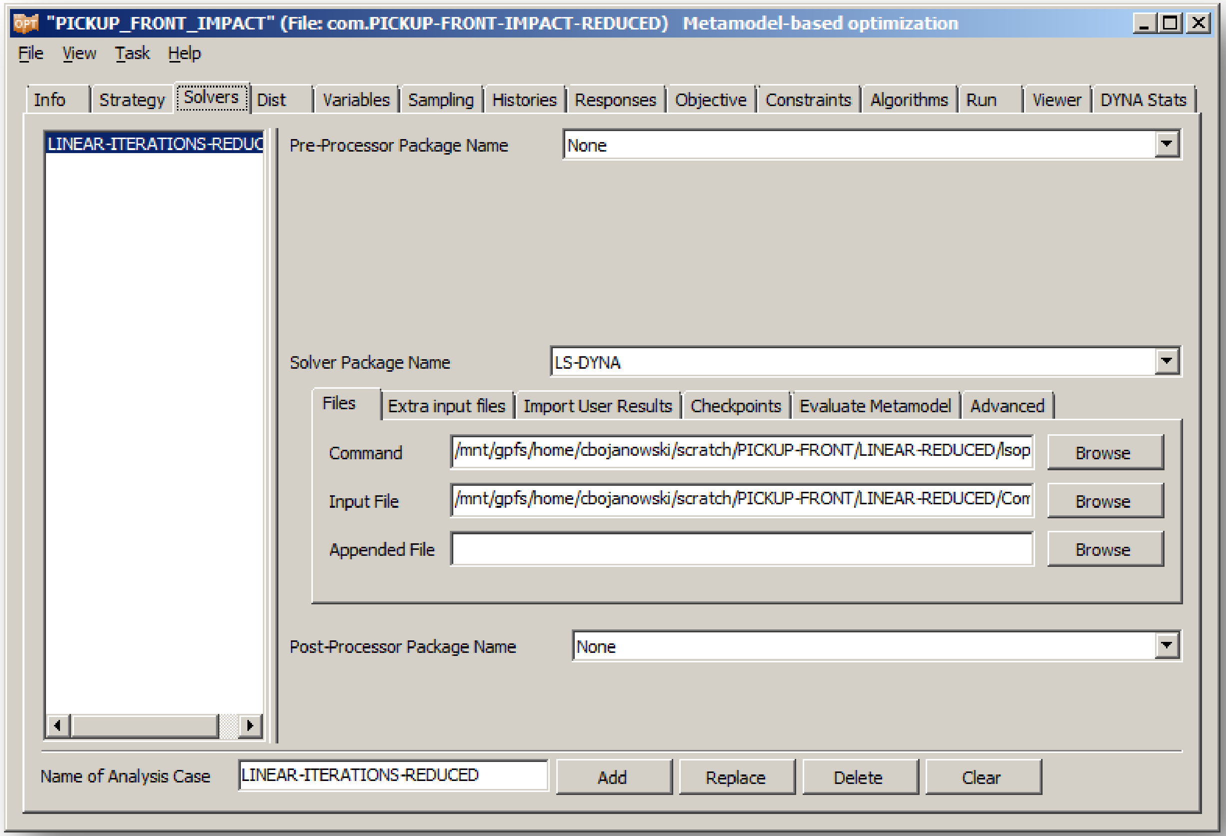
Coeff.	Absolute Value (90%)	10-Scale
thic1	1.123e+005	10.0
thic2	7.897e+004	7.0
thic41	1.743e+004	1.6
thic54	4247	0.4
thic40	1517	0.1
thic48	968.7	0.1
thic46	Insignificant	0.0





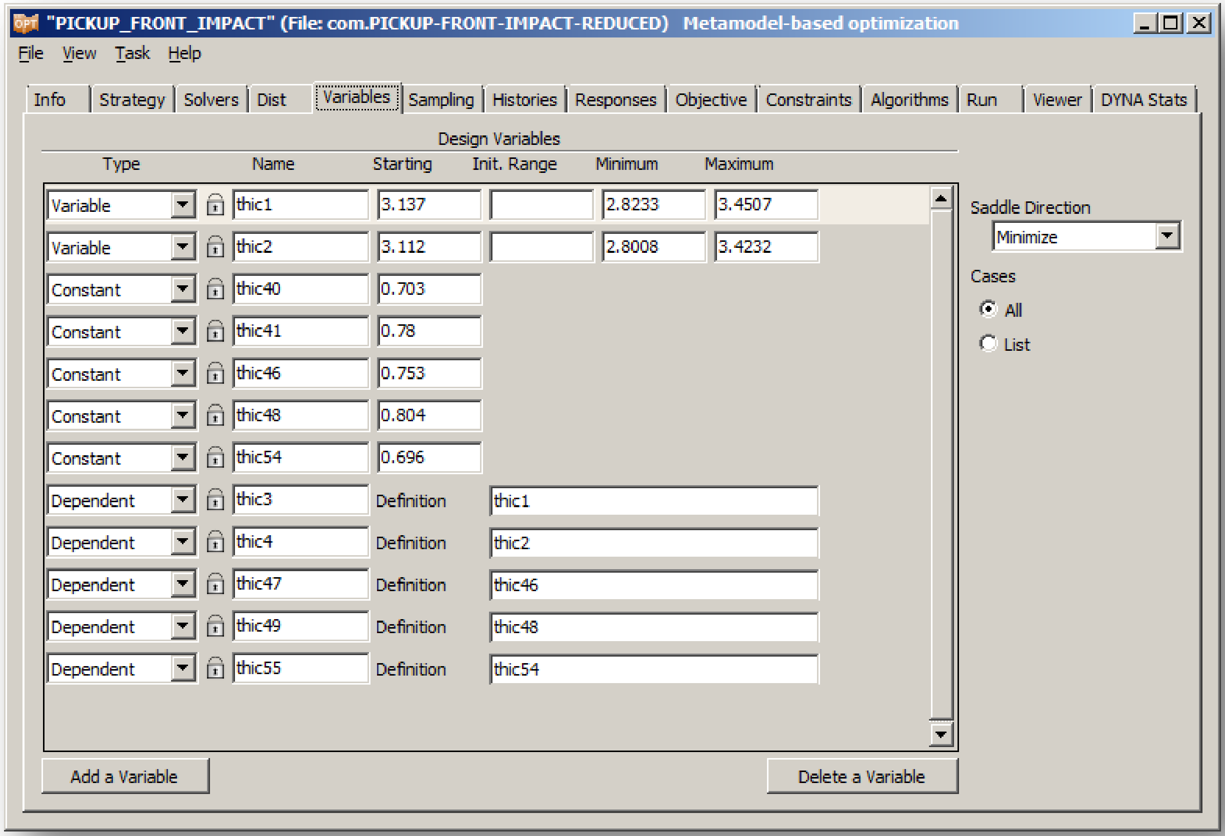
Solvers Tab

- Copy the input files to another folder
- 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 again locate the `Combine.k` file
- Type `LINEAR-ITERATIONS-REDUCED` in the Name of Analysis Case field and hit Replace



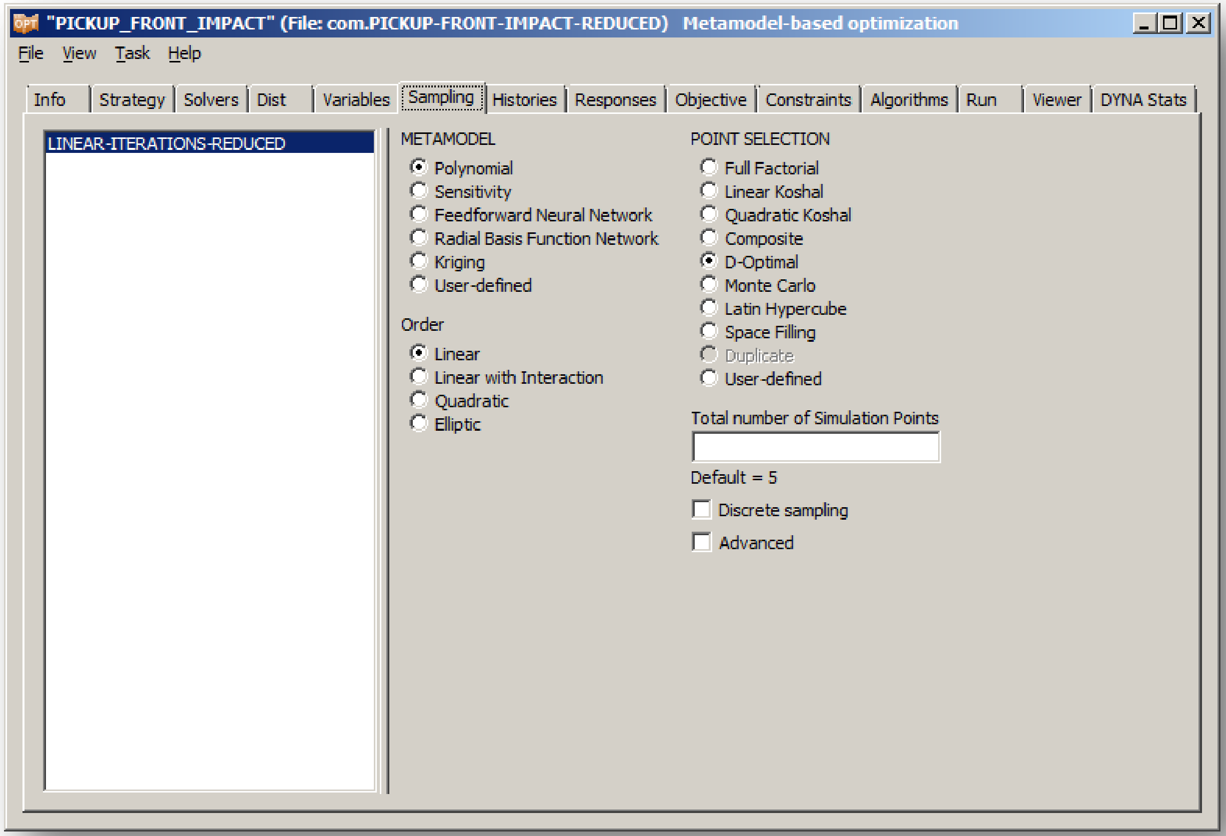
Variables Tab

- In the Variables panel change Type of the variables to Constant for:
  - thic40, thic41, thic46, thic48, thic54



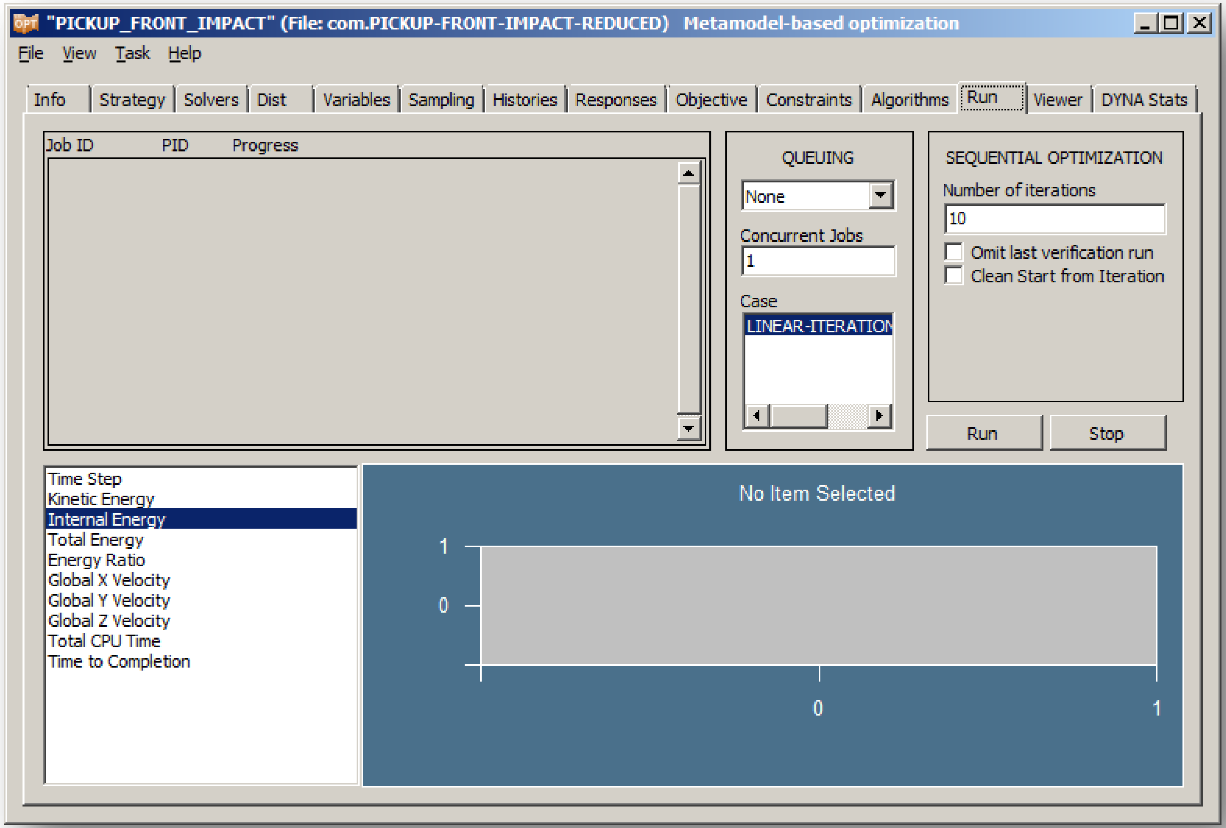
Sampling Tab

- In the Sampling panel leave Polynomial Metamodel with Linear order
- The default number of simulation points per iteration will drop from 13 to 5



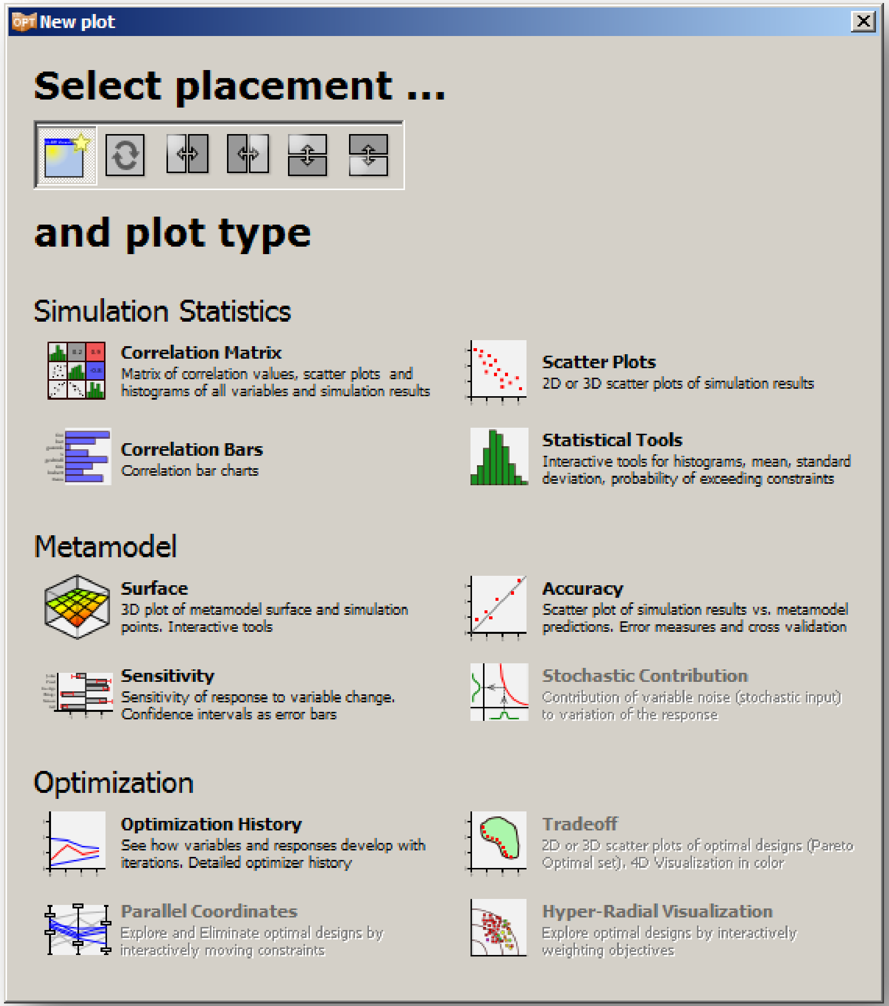
Run Tab

- Select PBS for QUEUING software (TRACC cluster users)
- For Concurrent Jobs enter 4
- For Number of Iteration enter 10 and
- Check Omit last verification run and Clean Start from iteration 1
- Hit Run to start simulations



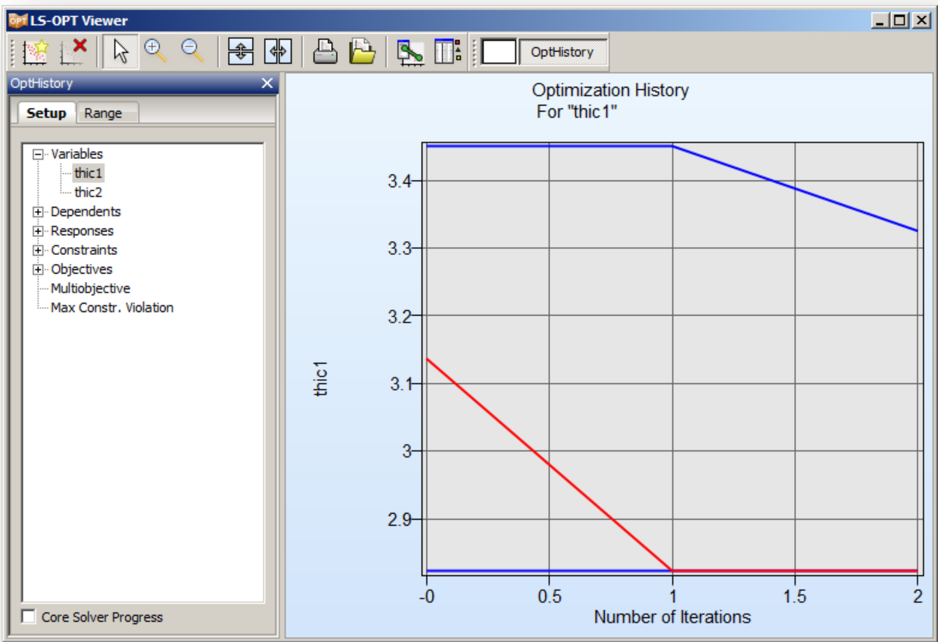
Viewer

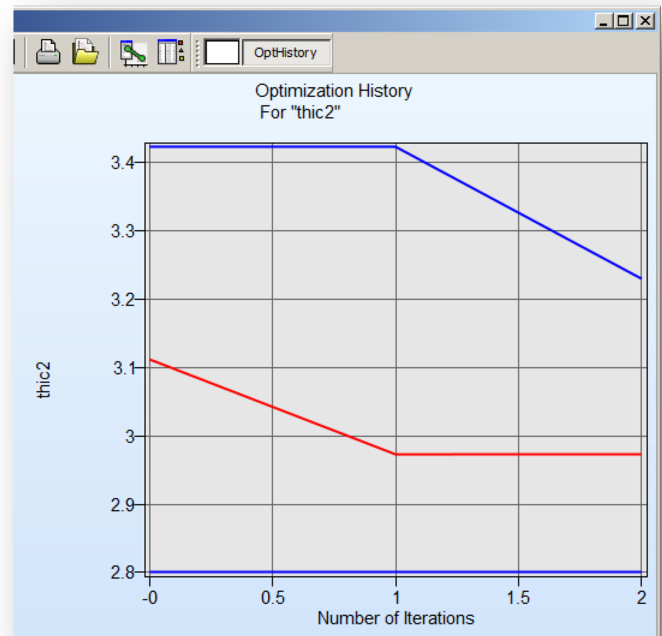
- Go to Viewer panel and the viewer options should pop up automatically
- From Optimization menu select Optimization History
- New window should appear



Optimization History

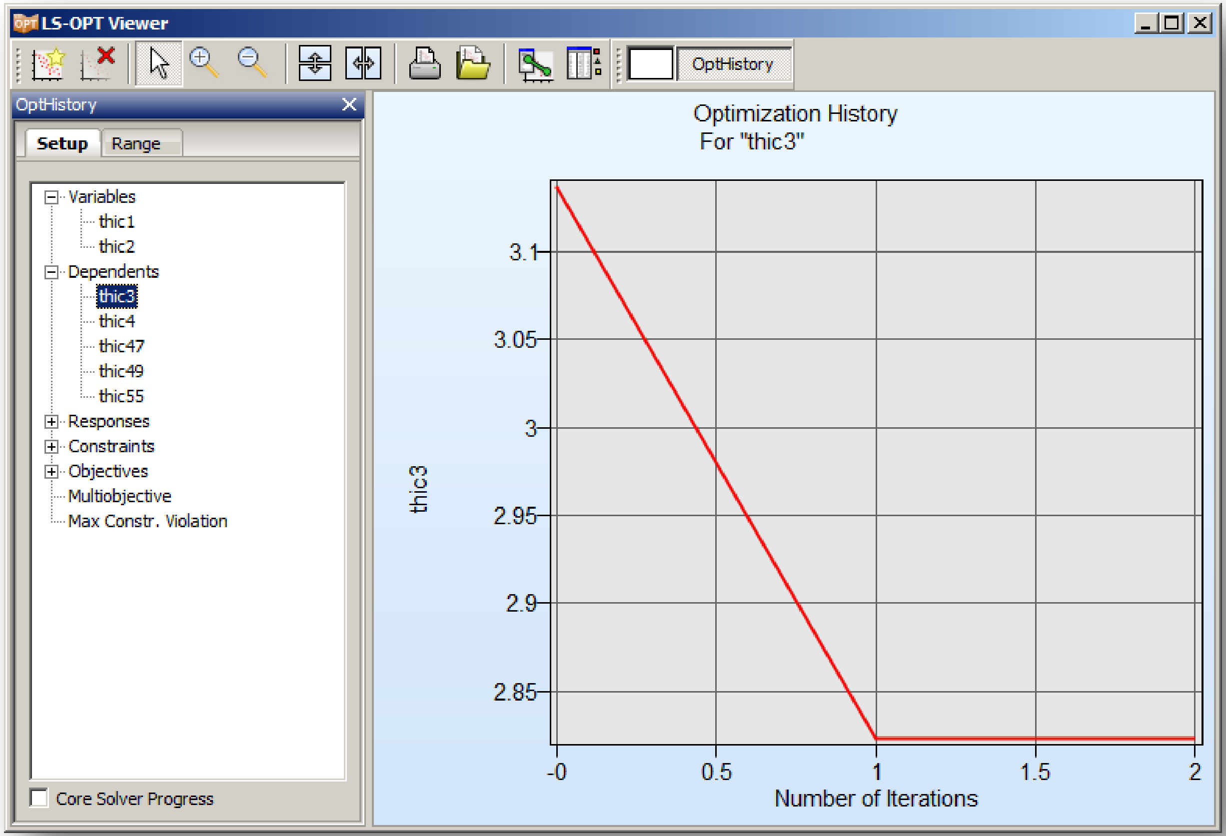
- Select the variable `thic1` and `thic2`
- The problem became easy and the number of simulations was reduced considerably





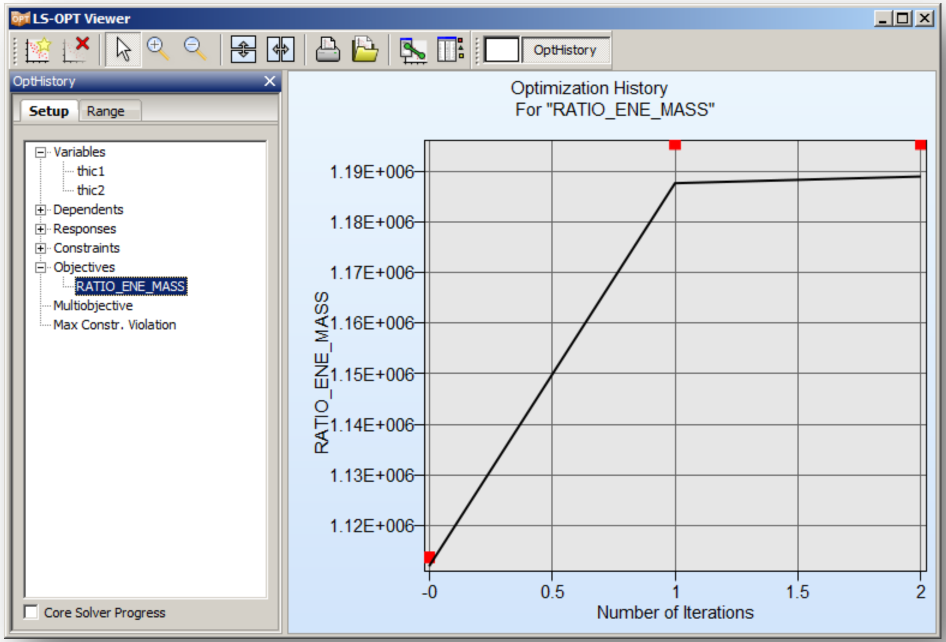
Optimization History

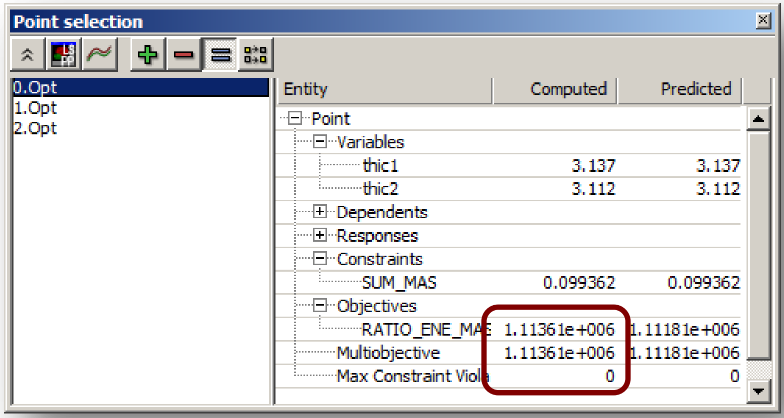
- The Dependents follow the history of the Independent Design Variables

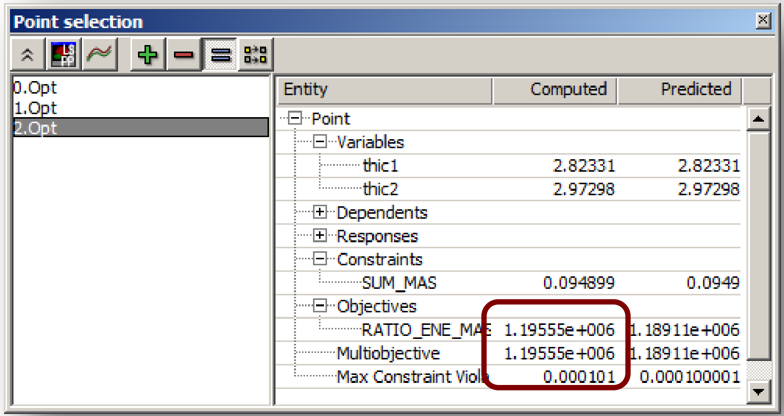


Optimization History

- Select RATIO_ENE_MASS from objectives list to see its optimization history
- Click on the graph to see exact values of the responses



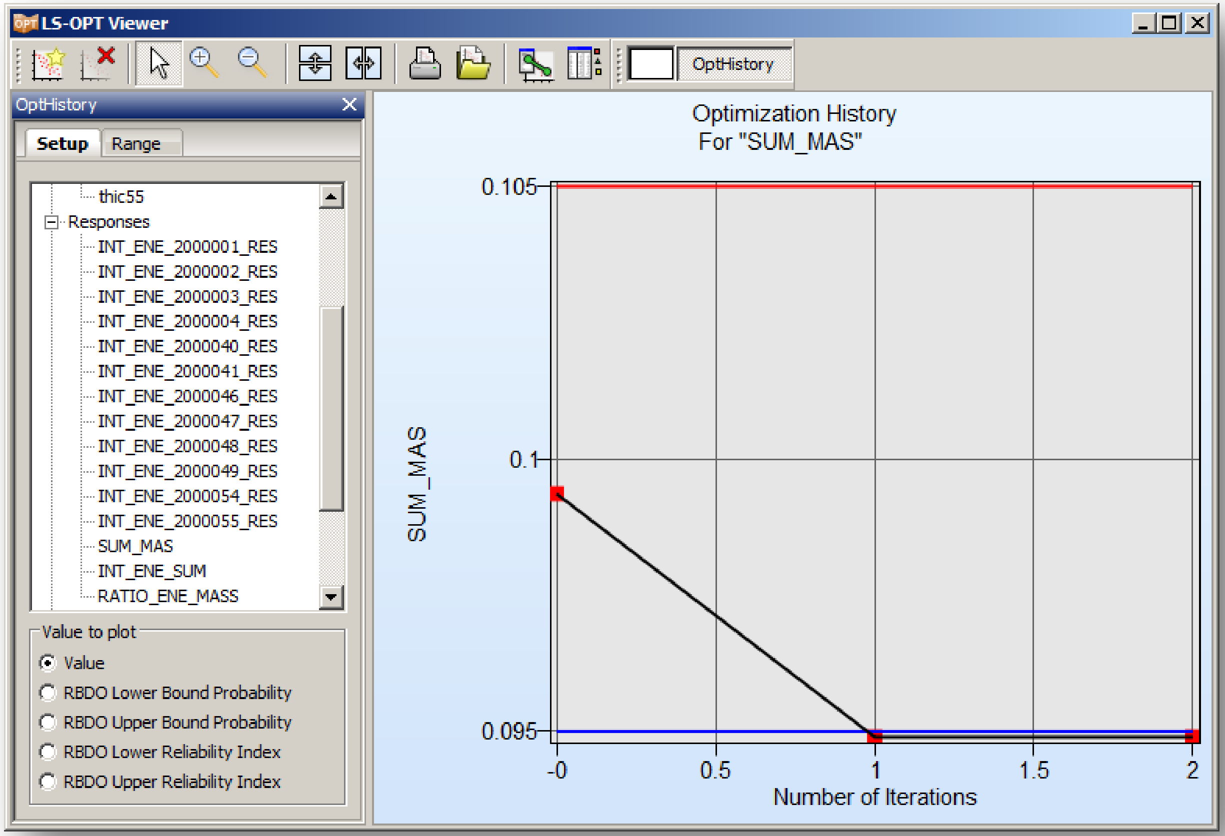




- The value of the objective increased 7.36 % in the optimization process

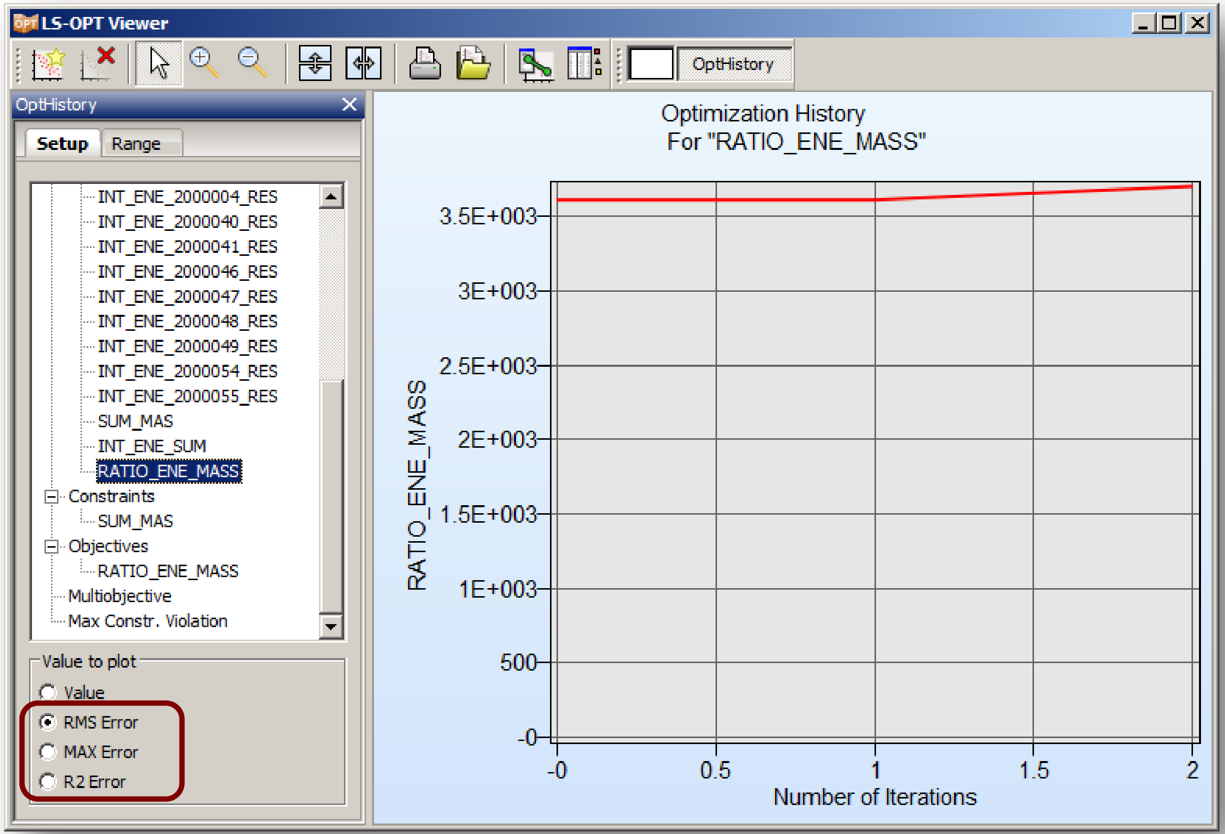
Optimization History - Modeling Errors

- Select SUM_MAS from objectives list to see its optimization history
- Click on the graph to see exact values of the responses



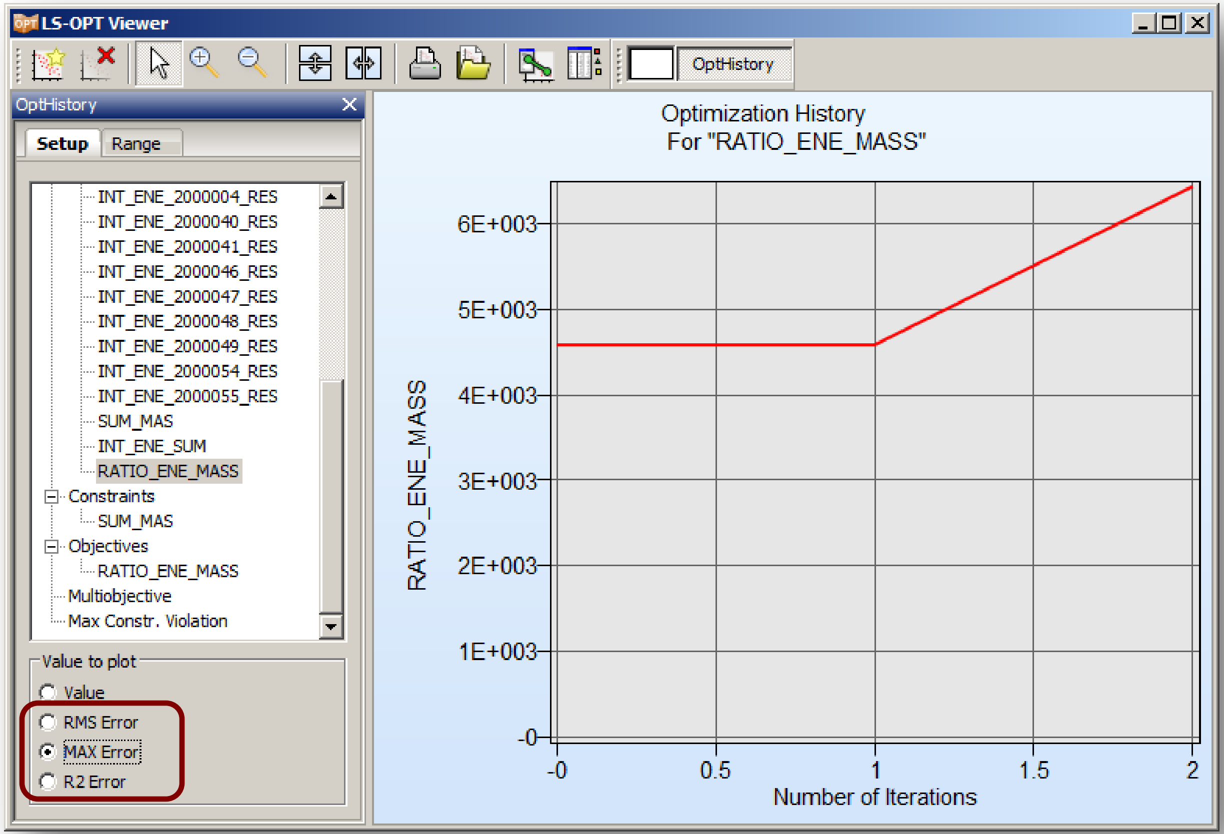
Optimization History - Modeling Errors

- Select again RATIO_ENE_MASS from objectives list to see its optimization history
- Select RMS Error value to plot
- When the region of interest is shrinking, the modeling errors may increase



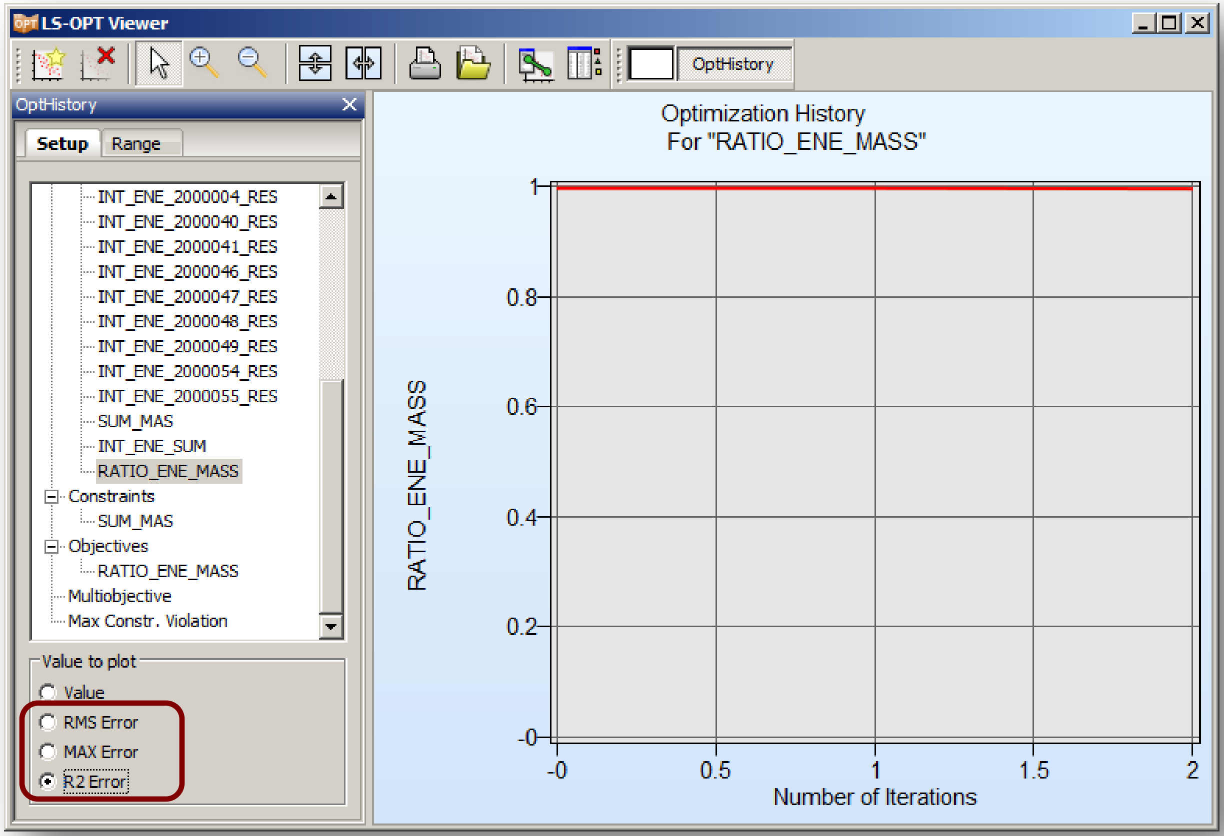
Optimization History - Modeling Errors

- Select again RATIO_ENE_MASS from objectives list to see its optimization history
- Select MAX Error value to plot



Optimization History - Modeling Errors

- Select again RATIO_ENE_MASS from objectives list to see its optimization history
- Select R2 Error value to plot
- R2 Error represents ability of the model to capture the variability of the real response



Metamodel Accuracy

- Go to Viewer panel and Restart Viewer
- From Metamodel menu select Accuracy
- Display accuracy of the metamodeling of RATIO_ENE_MASS response
- Locate the error parameters in the lsopt_output.1 file