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

2.4 - Parameter Identification

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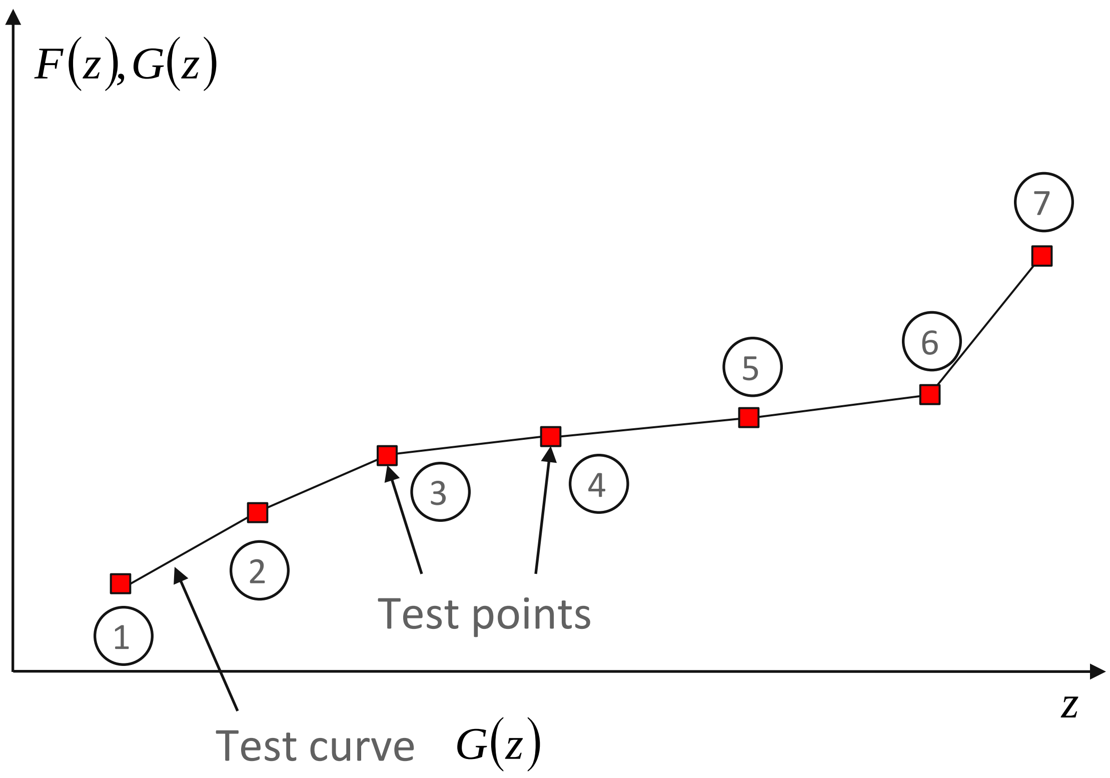
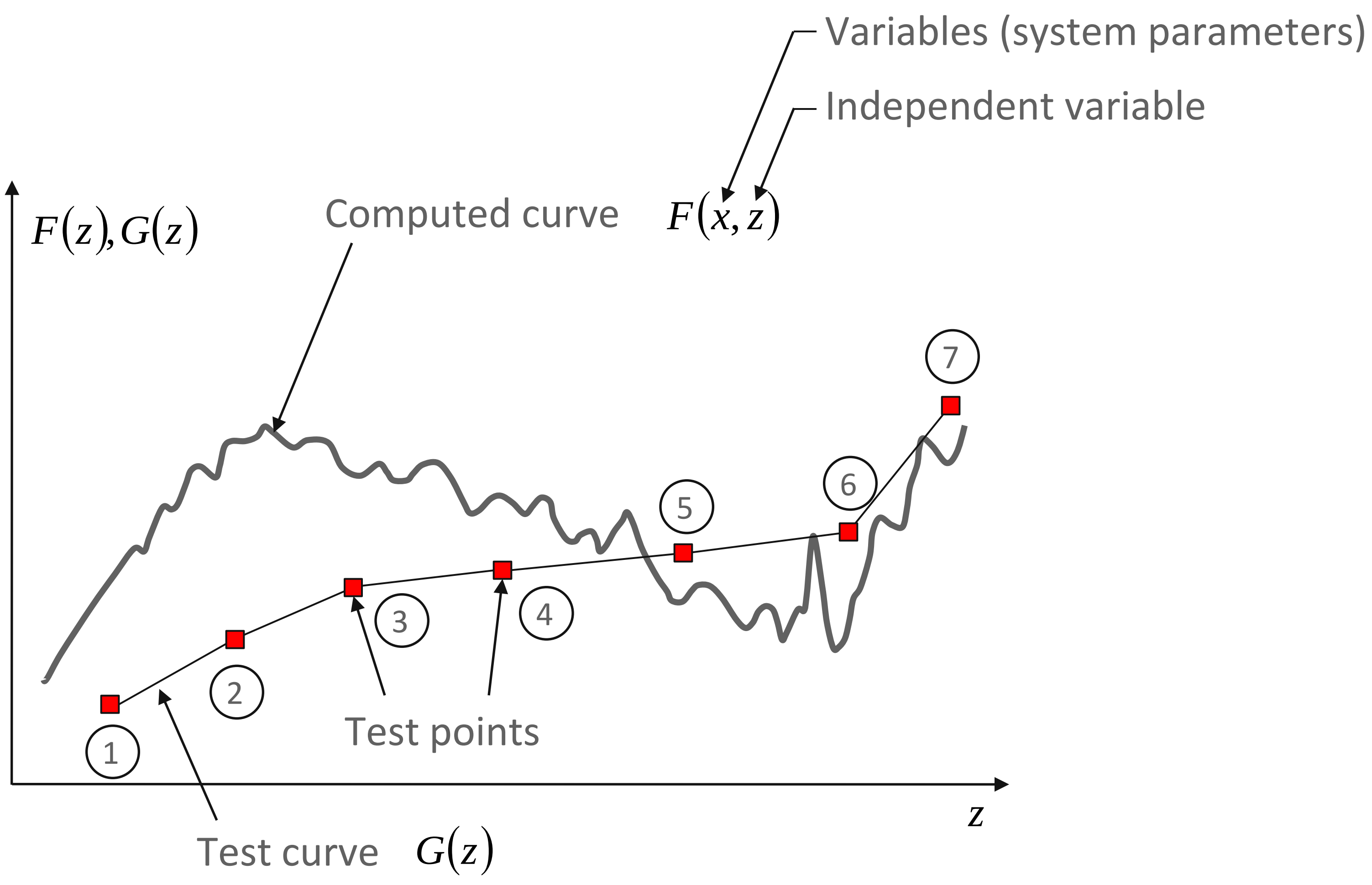
Parameter Identification Using Response Surfaces

- The material identification is in essence a non-linear optimization process
- It uses experimentally measured data to determine the parameters describing some constitutive model of a material
- A non-linear simulation is performed with the model parameters as input
- The deviation of the simulated performance from that measured, also called distance function is used as a criterion for minimization.
- Two approaches for system identification can be used within LS-OPT depending on the formulation of the problem:
  - Mean Squared Error (MSE)
  - Min-Max formulation

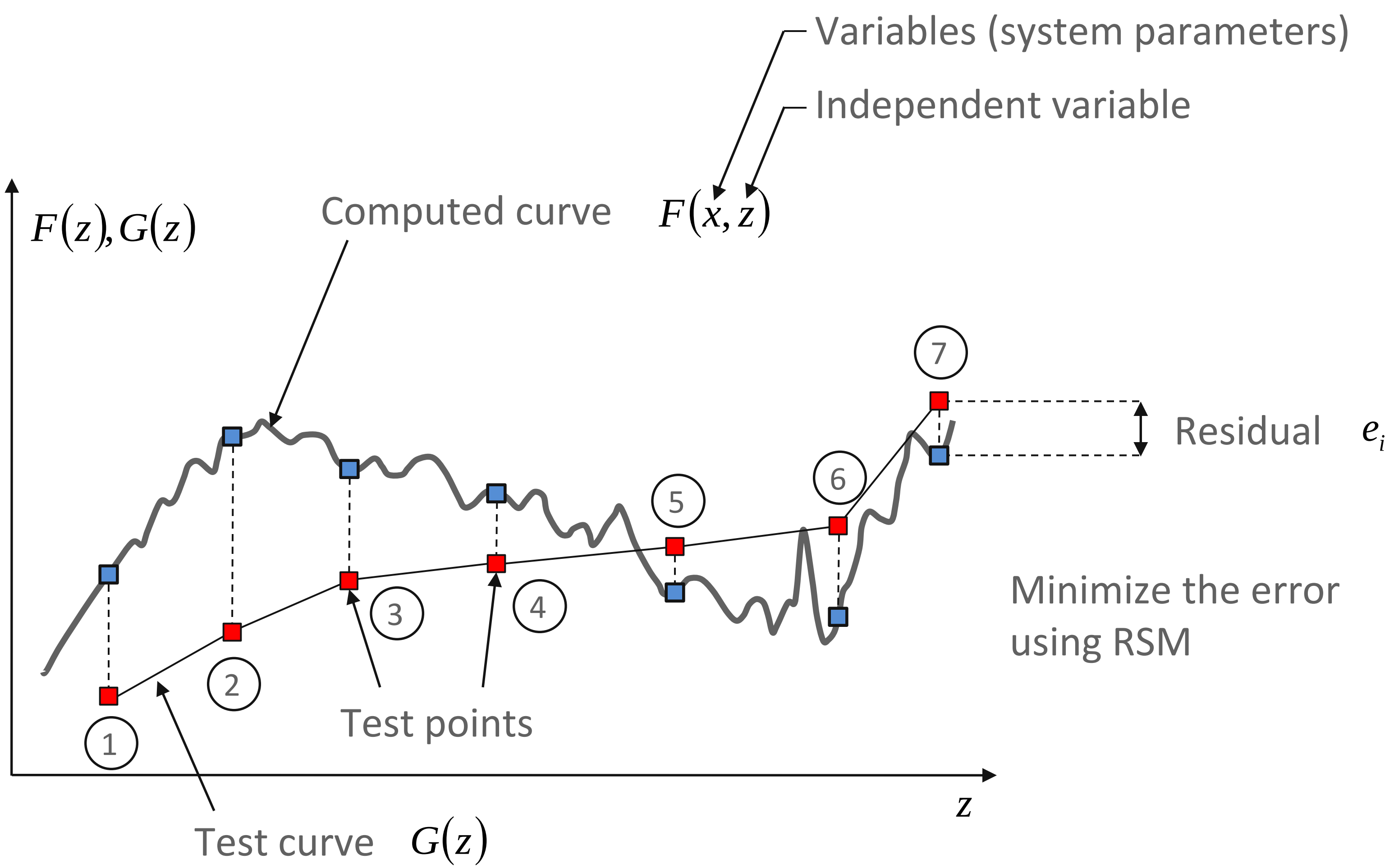
Problem Formulation



Problem Formulation



Problem Formulation



Mean Squared Error

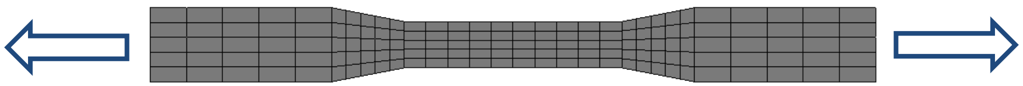
- If an overall fit is required without distinguishing any specific features, a Least Squares Residual approach is used.
- Based on this approach, in LS-OPT Mean Squared Error function is defined as:

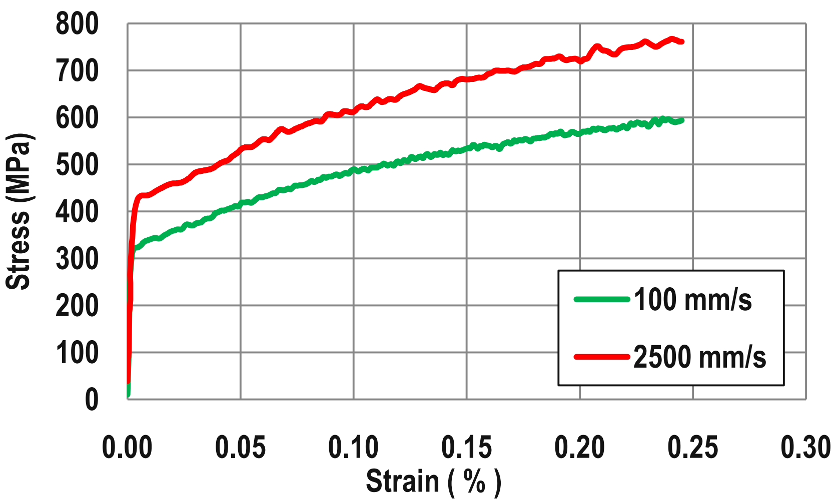
$$\varepsilon = \frac{1}{P}\sum_{i=1}^{P} W_i \left(\frac{F_i(x) - G_i}{s_i} \right)^2 = \frac{1}{P}\sum_{i=1}^{P} W_i \left(\frac{e_i(x)}{s_i} \right)^2$$

P	Number of regression points
$F_i(x)$	Simulated value
G_i	Test value at regression point
e_i	Residual
W_i	Weight applied to the square of the scaled residual (importance factor)
s_i	Scale factor for residuals (error normalization)

Example

- Given: results of two tensile tests with
- different loading speeds.



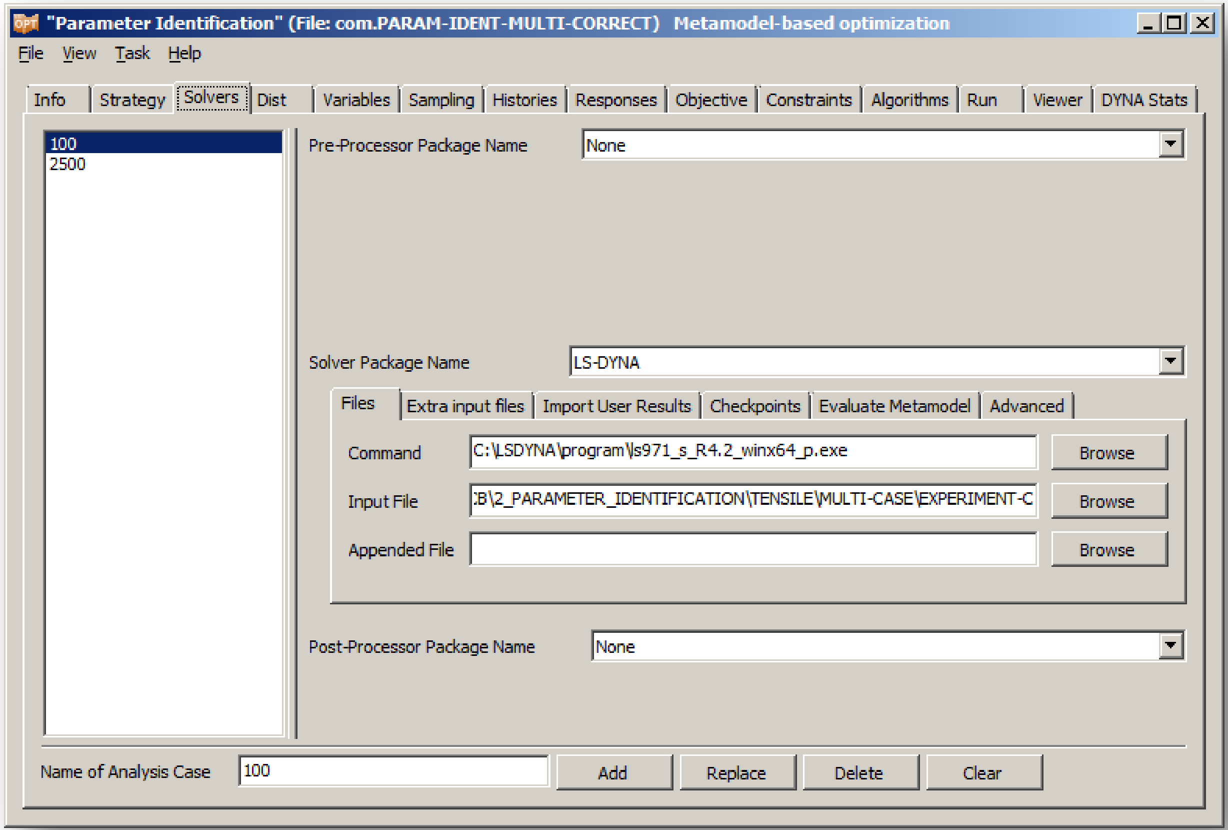


- find unknown C and P strain rate parameters for a given steel.

$$\sigma_y\left(\varepsilon_{eff}^p, \dot{\varepsilon}_{eff}^p\right) = \sigma_y^s\left(\varepsilon_{eff}^p\right)\left[1 + \left(\frac{\dot{\varepsilon}_{eff}^p}{C}\right)^{\frac{1}{P}}\right]$$

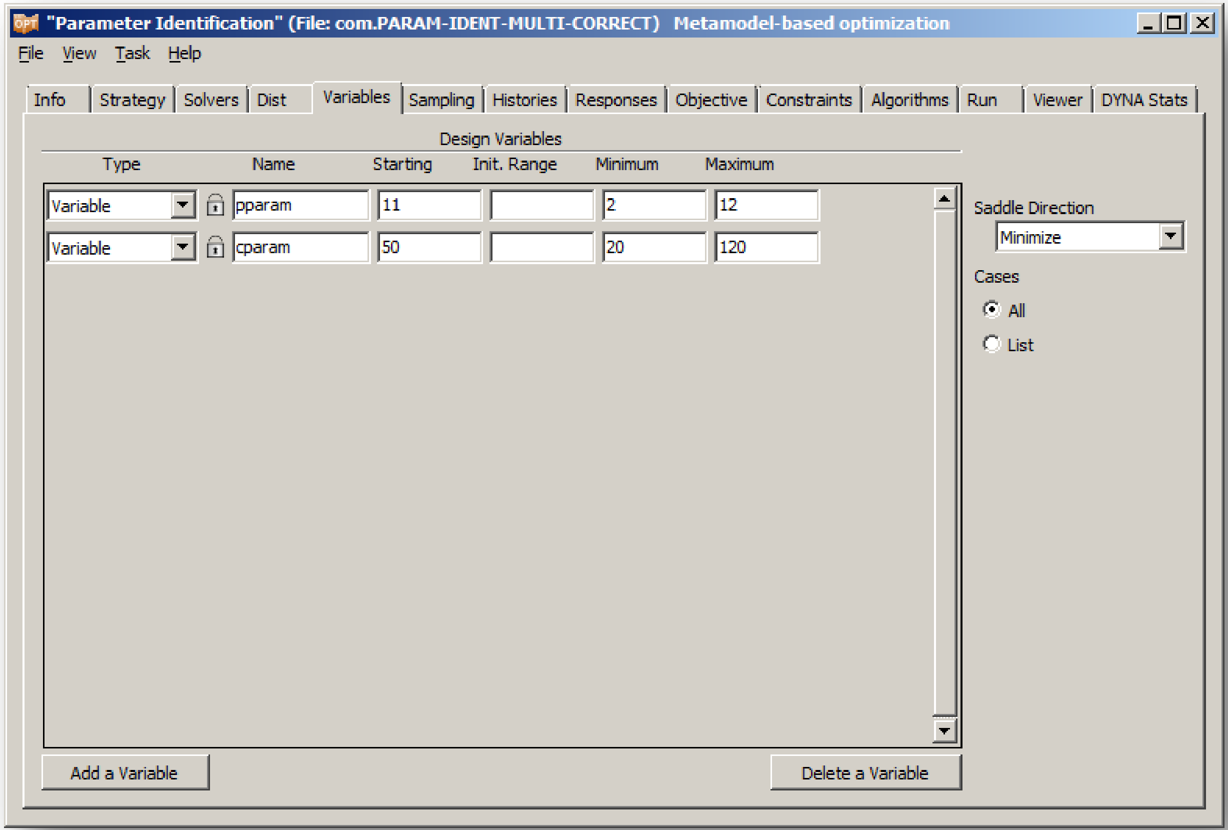
Solvers panel

- Command: specify path to lsoptscript generated for this case
- Input File: find path to EXPERIMENT-C40P5-V_100.k file
- Name of Analysis Case: 100
- Hit Add button to save it
- Repeat the same steps for case with file EXPERIMENT-C40P5-V_2500.k



Variables panel

- Add Variable: `pparam` with starting value `11`, lower bound `2` and upper bound `12`
- Add Variable: `cparam` with starting value `50`, lower bound `20` and upper bound `120`



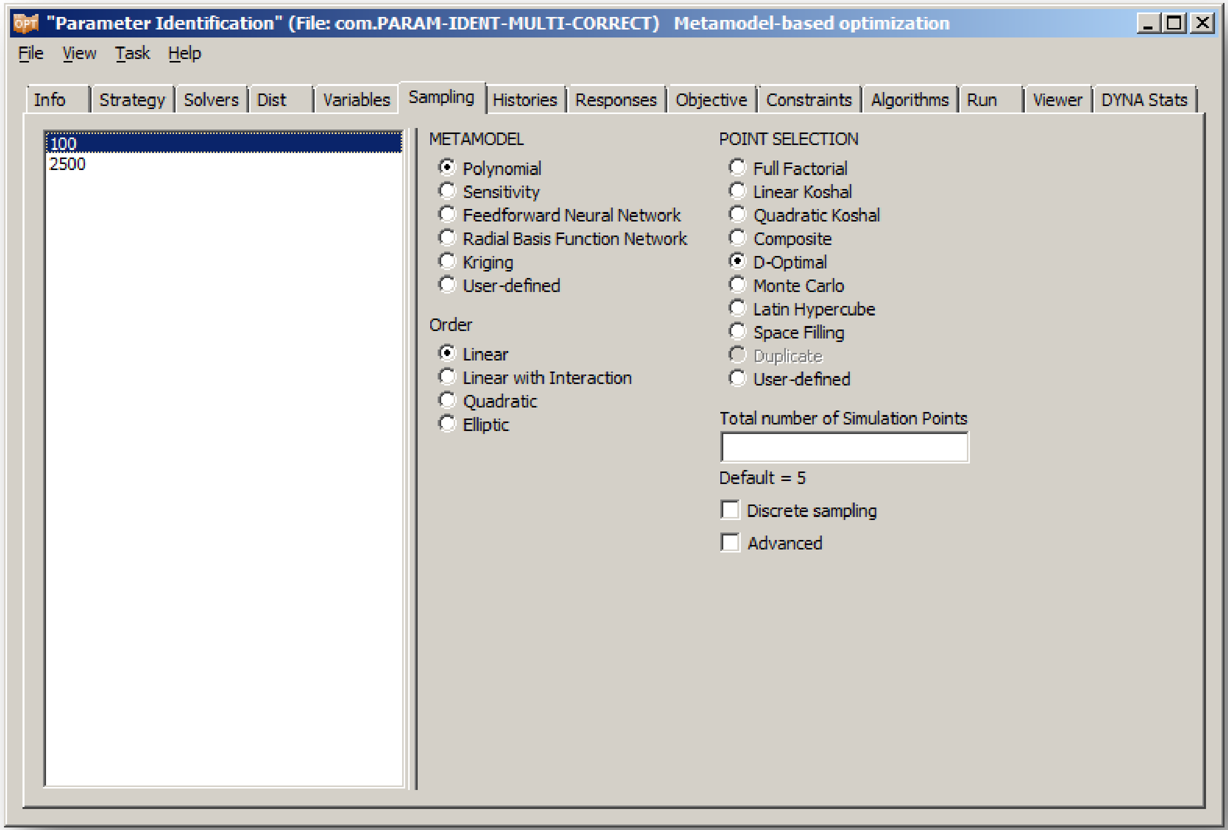
Variables in the k-file

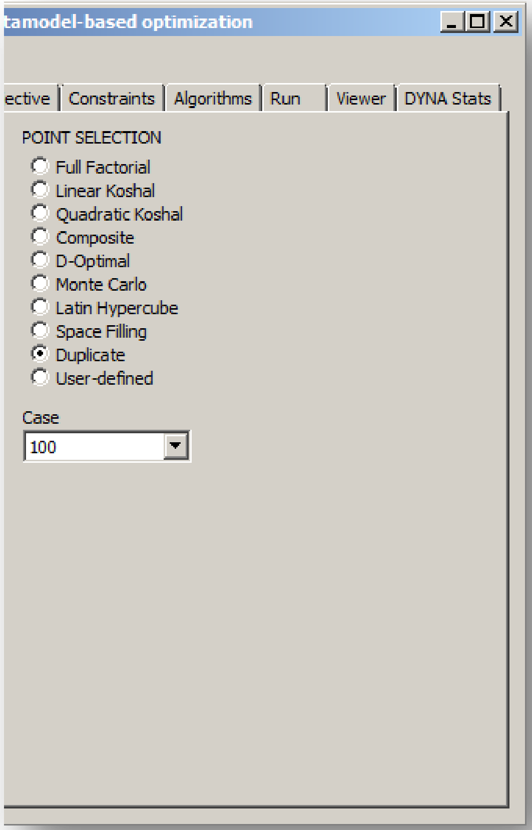
```
*PARAMETER
rpparam,11
rcparam,50
...

*MAT_PIECEWISE_LINEAR_PLASTICITY_TITLE
STEEL_24
$#     mid        ro         e        pr      sigy      etan      fail
   tdel
         2 7.8000E-7 2.0700E+5  0.280000 200.00000     0.000  0.250000
   0.000
$#       c         p      lcss      lcsr        vp
   &cparam   &pparam        13         0 -1.000000
```

Sampling panel

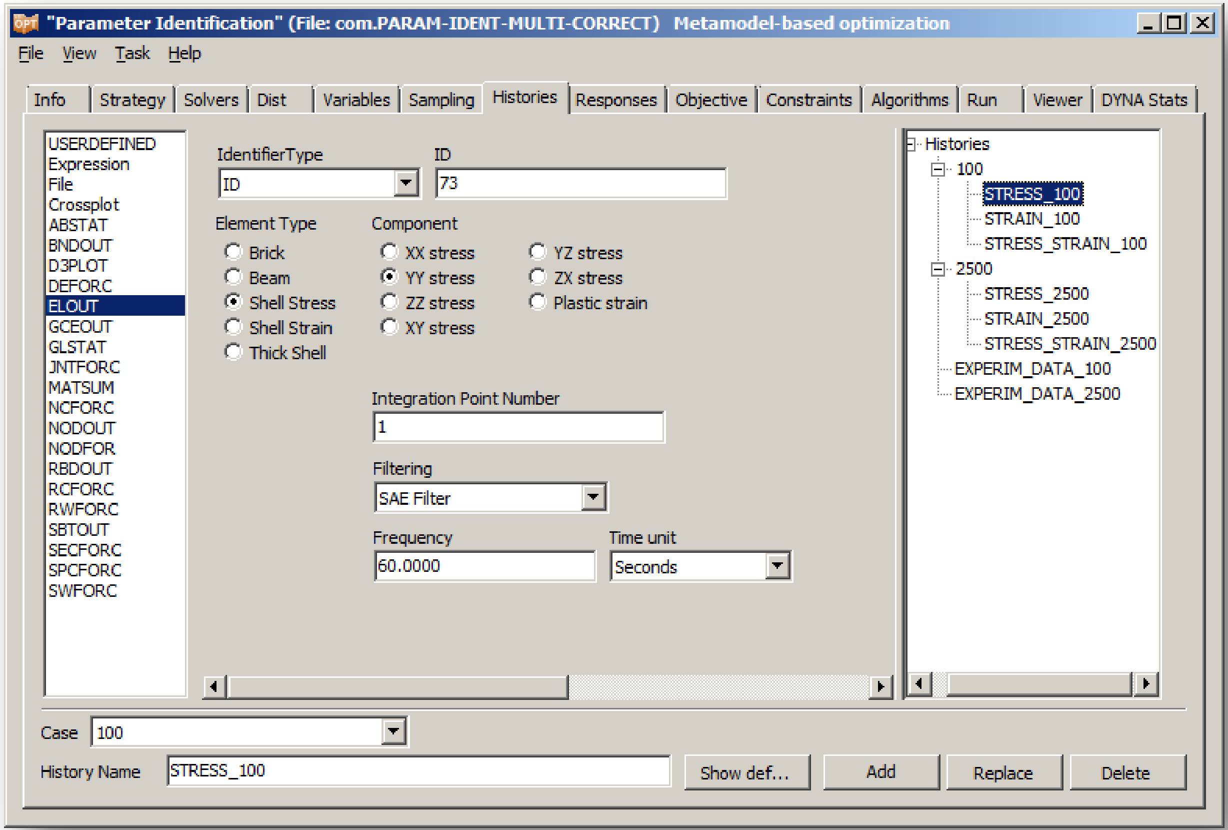
- For case 100 select Metamodel Polynomial
- Order Linear with D-Optimal Point Selection method
- For case 2500 choose Duplicate Point Selection from Case 100





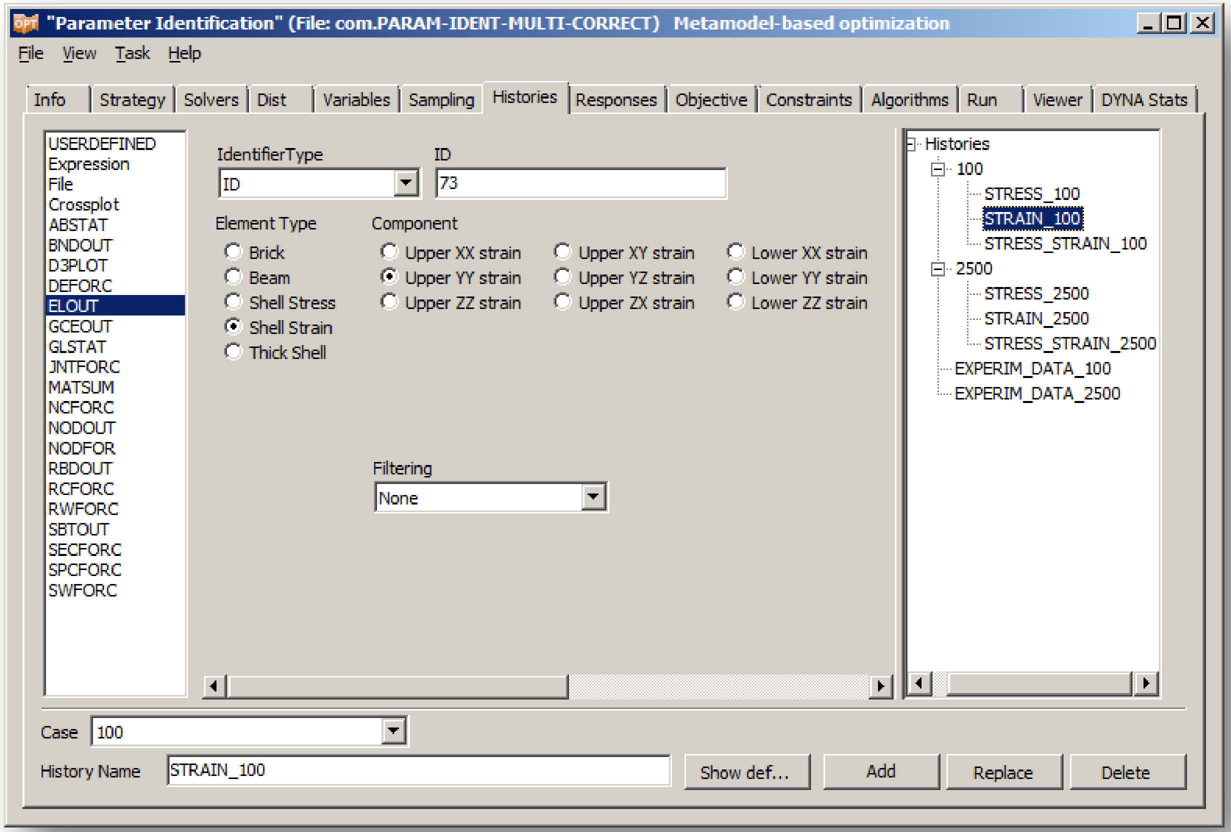
Histories panel

- Select ELOUT on the left window
- Select Identifier Type ID and type 73 (for element ID# 73)
- For Shell Stress in Element Type choose YY stress component
- Choose SAE Filter with 60 Hz frequency
- Name the variable STRESS_100 and hit Add



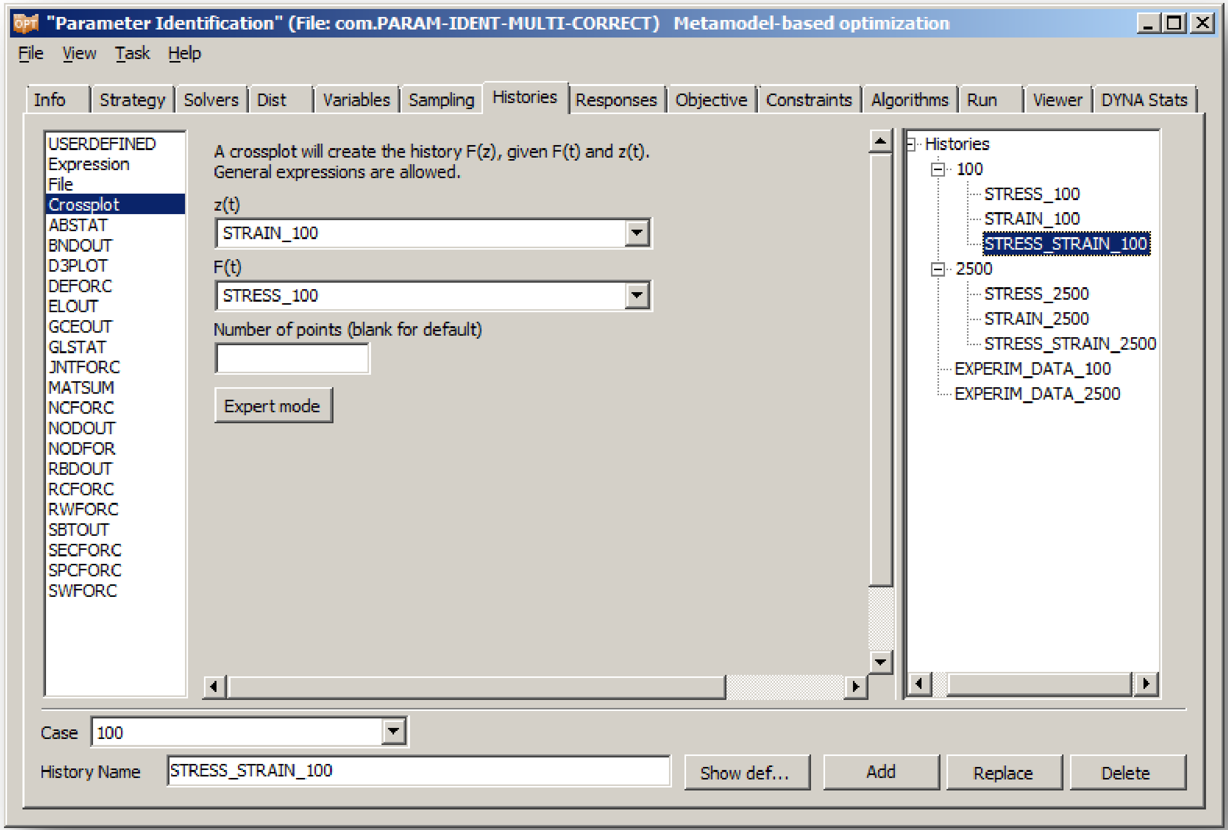
Histories panel

- Select ELOUT on the left window
- Select Identifier Type ID and type 73 (for element ID# 73)
- For Shell Strain in Element Type choose Upper YY strain component
- Name the variable STRAIN_100 in History Name field and hit Add



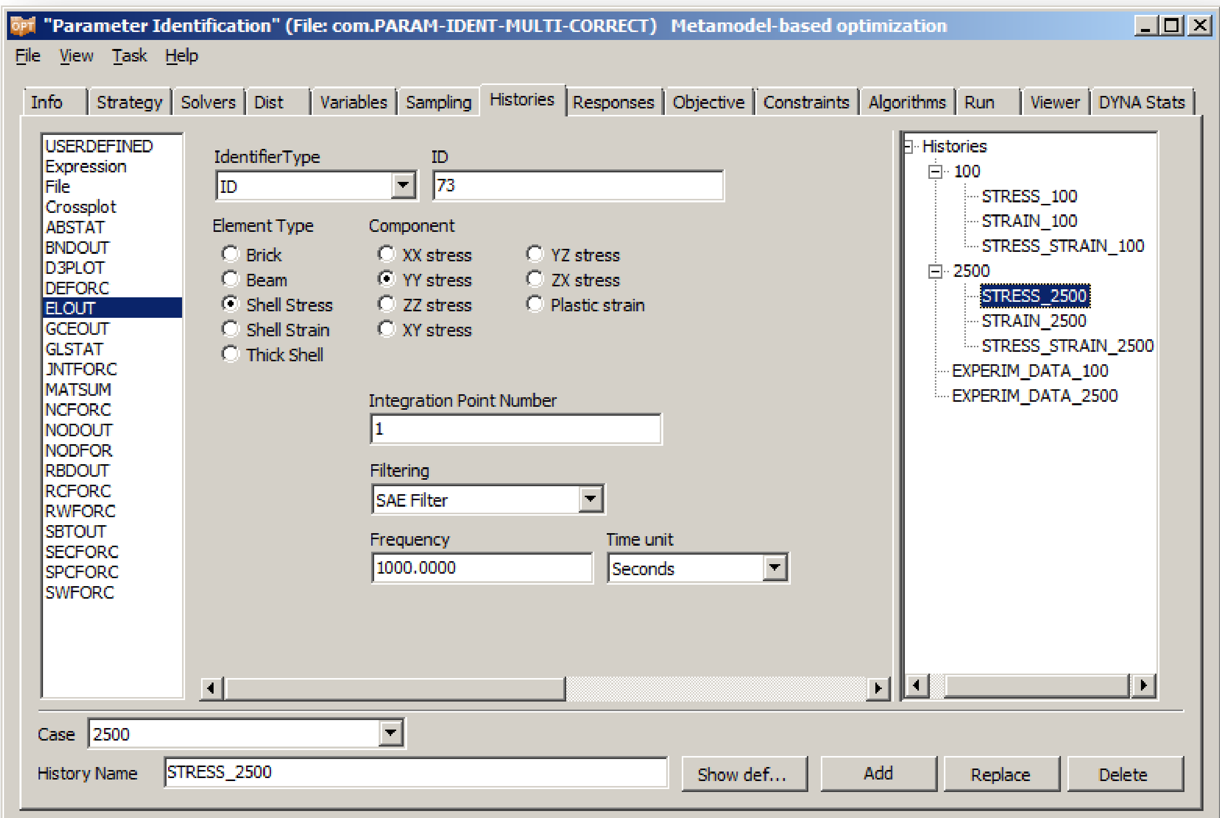
Histories panel

- Select crossplot from left window
- As z(t) – independent variable select STRAIN_100
- As F(t) select STRESS_100
- That would create stress vs. strain curve;
- Type STRESS_STRAIN_100 in History Name field and hit Add



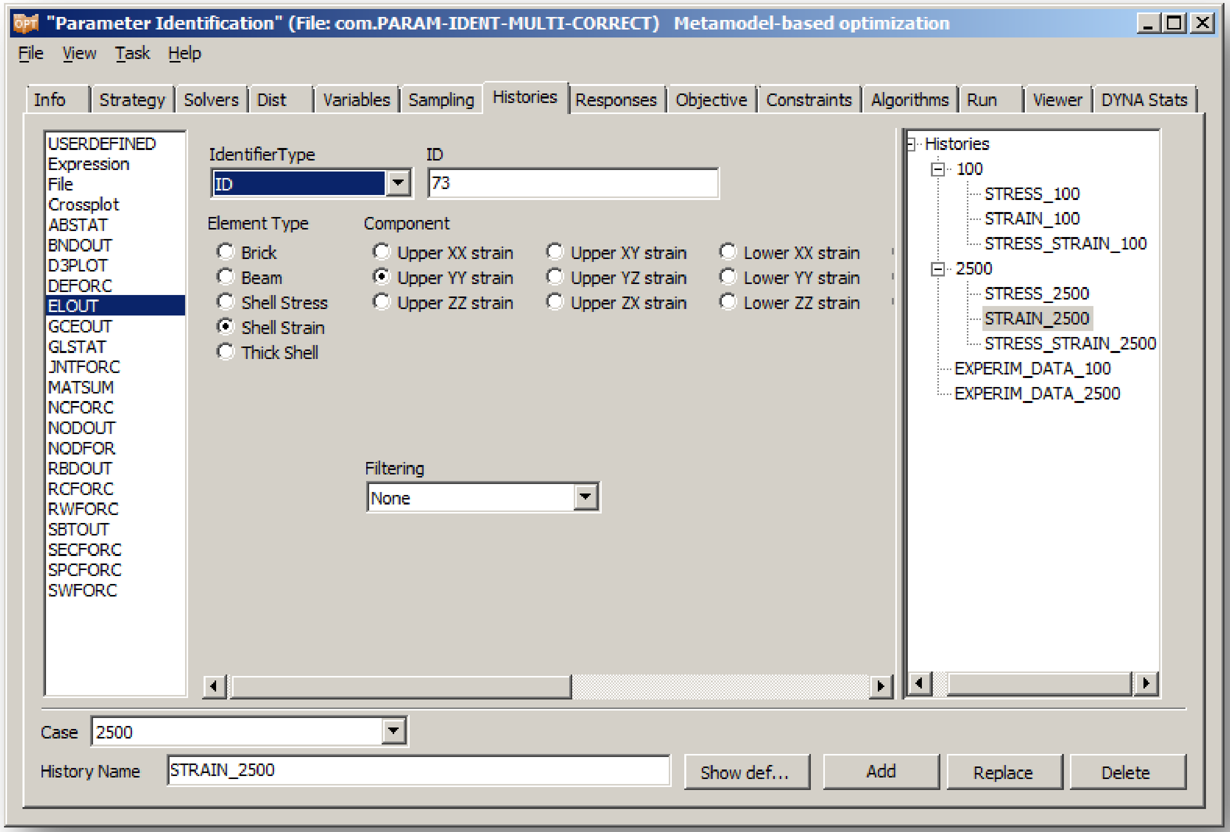
Histories panel

- From the Case menu at the bottom select 2500
- Repeat the same procedure to create STRESS_2500, STRAIN_2500, STRESS_STRAIN_2500
- For STRESS_2500 use SAE Filter with frequency 1000 Hz



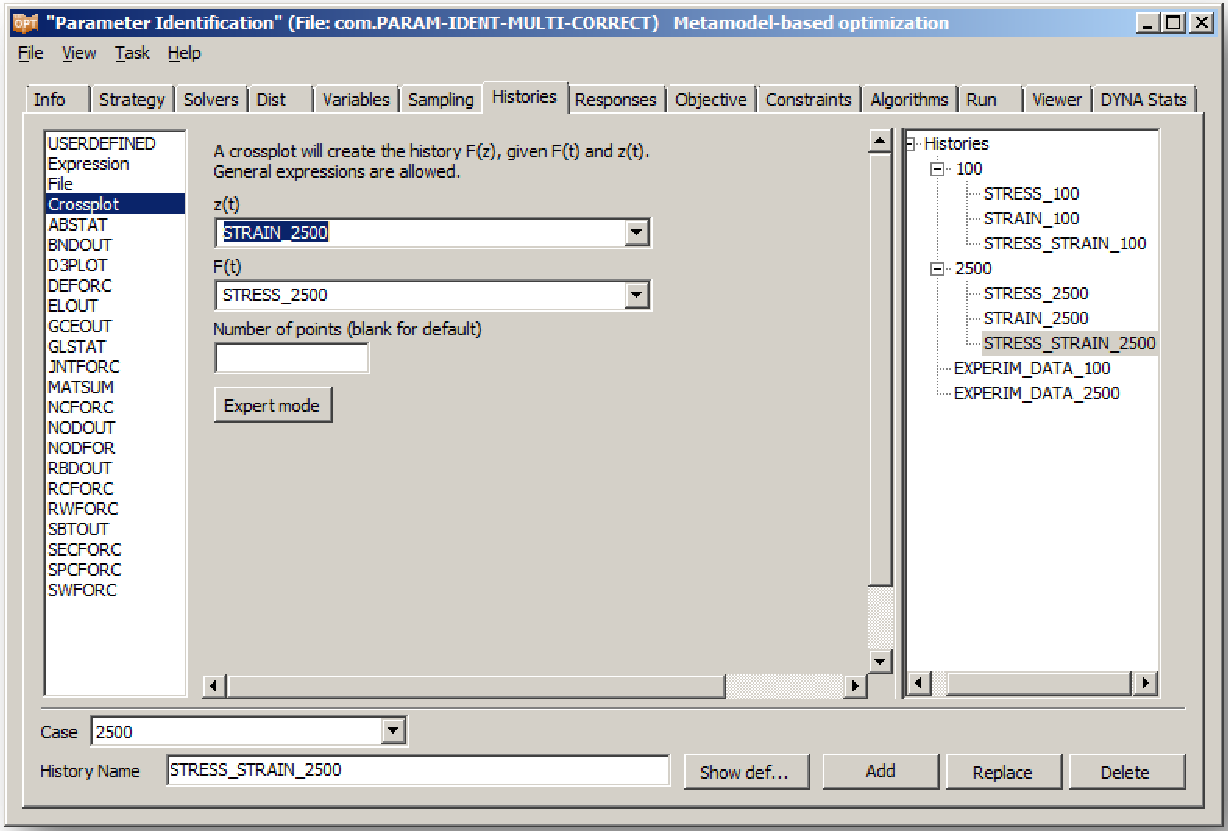
Histories panel

- Select ELOUT on the left window
- Select Identifier Type ID and type 73 (for element ID# 73)
- For Shell Strain in Element Type choose Upper YY strain component
- Name the variable STRAIN_2500 in History Name field and hit Add



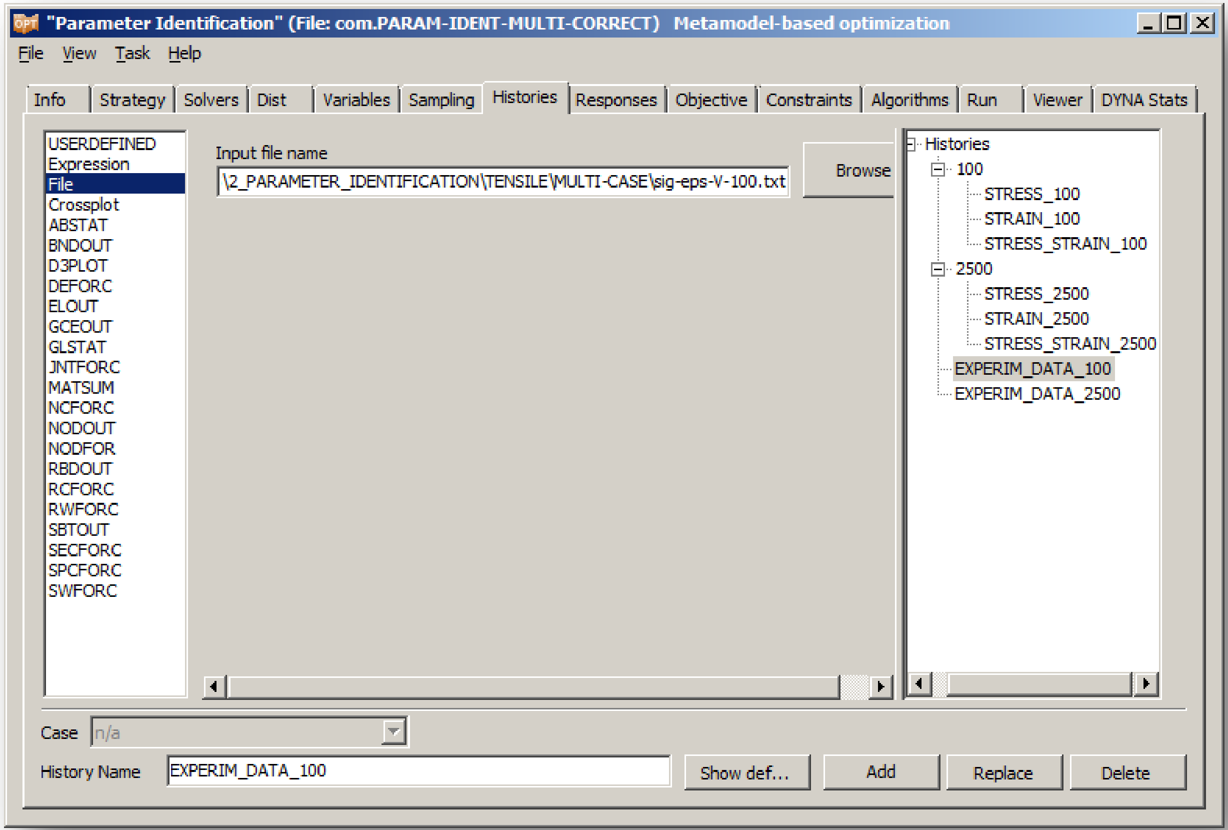
Histories panel

- Select crossplot from left window
- As z(t) – independent variable select STRAIN_2500
- As F(t) select STRESS_2500
- That would create stress vs. strain curve;
- Type STRESS_STRAIN_2500 in History Name field and hit Add



Histories panel

- From left window select File based History
- Browse to `sig-eps-V-100.txt` file for Input file name
- Type `EXPERIM_DATA_100` in History Name and hit Add
- This will save the “experimental” data as history in LS-OPT



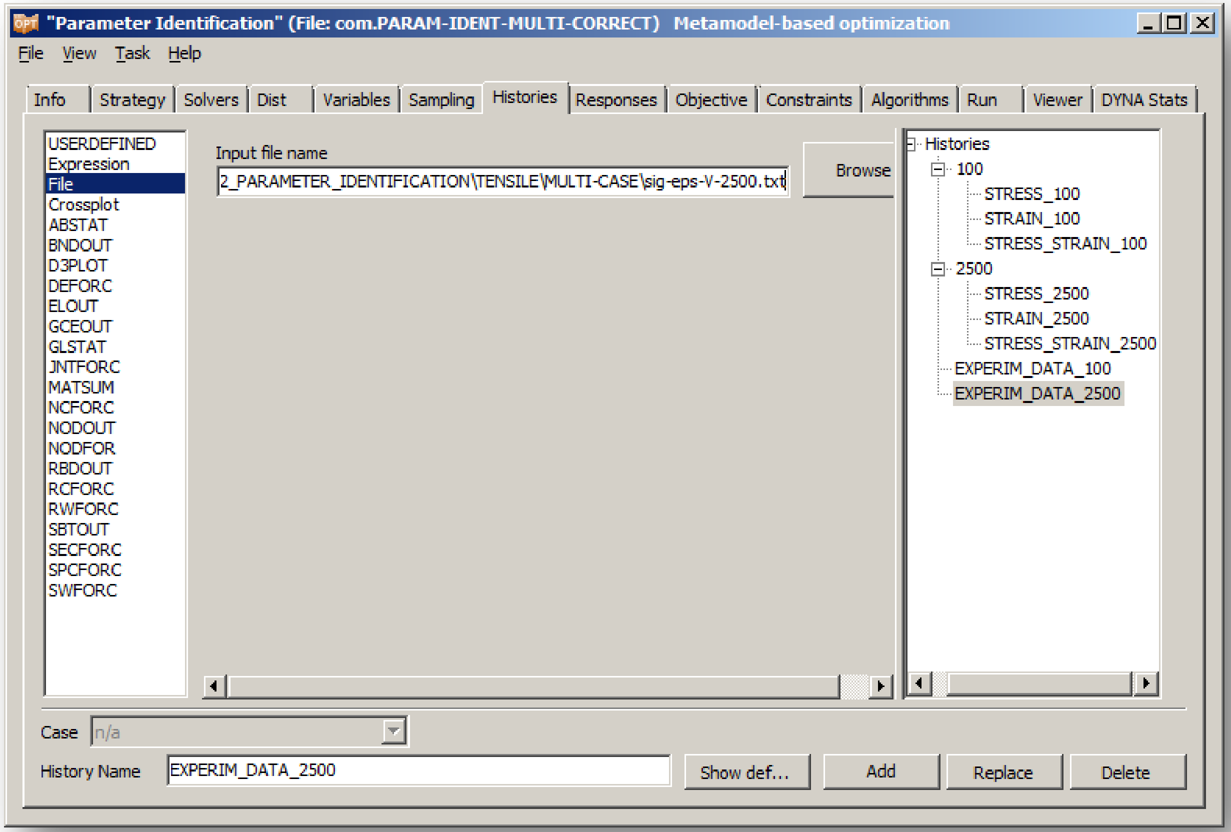
Histories - txt File

- `sig-eps-V-100.txt` file contains “experimental” data
- Is built as files produced from LS-PREPOST

```
Curveplot
Exiperiment Data
upper surface Y-strain
Y-stress
Element id
1  #pts=50001
* Minval=  -4.227777e+001 at time=        0.246730
* Maxval=   6.392031e+002 at time=        0.249200
       0.000000e+000       1.024795e+001
       0.000000e+000       1.061309e+001
       0.000000e+000       1.098138e+001
       0.000000e+000       1.135281e+001
       0.000000e+000       1.172739e+001
       0.000000e+000       1.210511e+001
       ................................
```

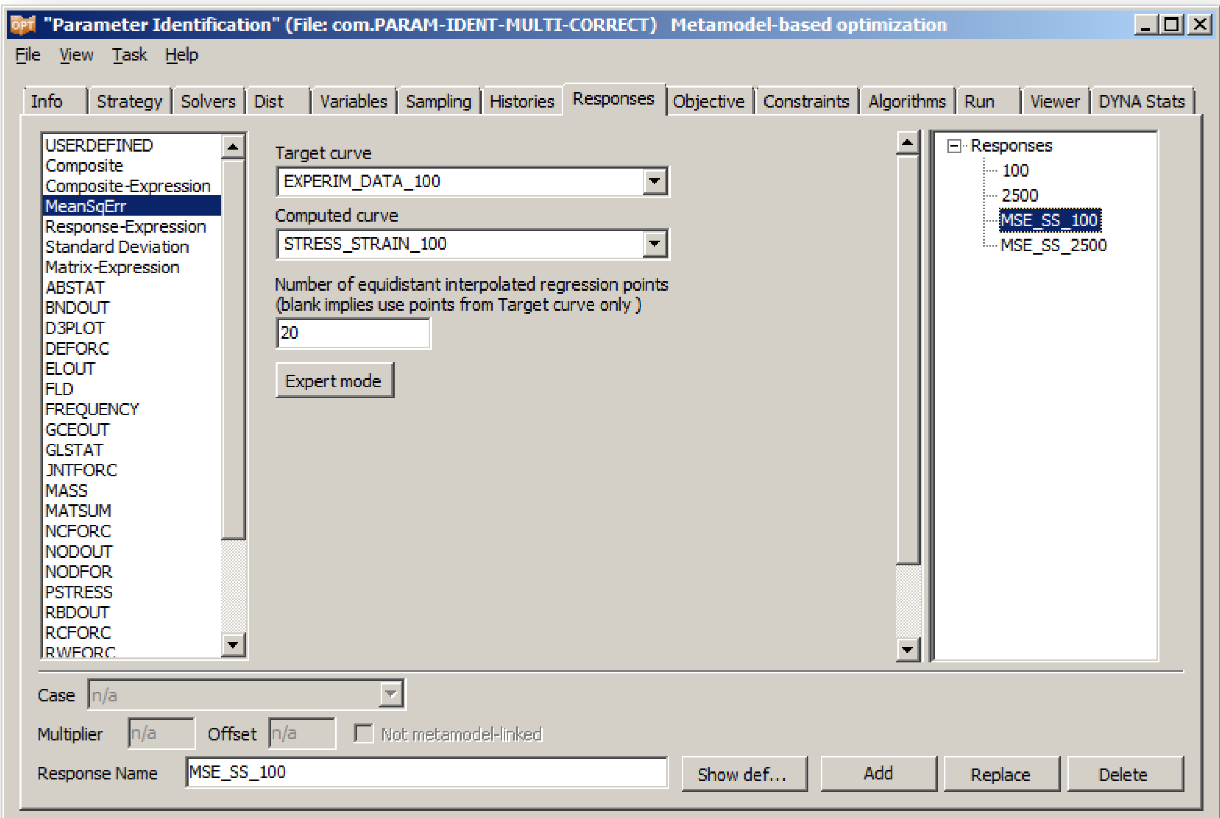
Histories panel

- From left window select File based History
- Browse to `sig-eps-V-2500.txt` file for Input file name
- Type `EXPERIM_DATA_2500` in History Name and hit Add
- This will save the "experimental" data as history in LS-OPT



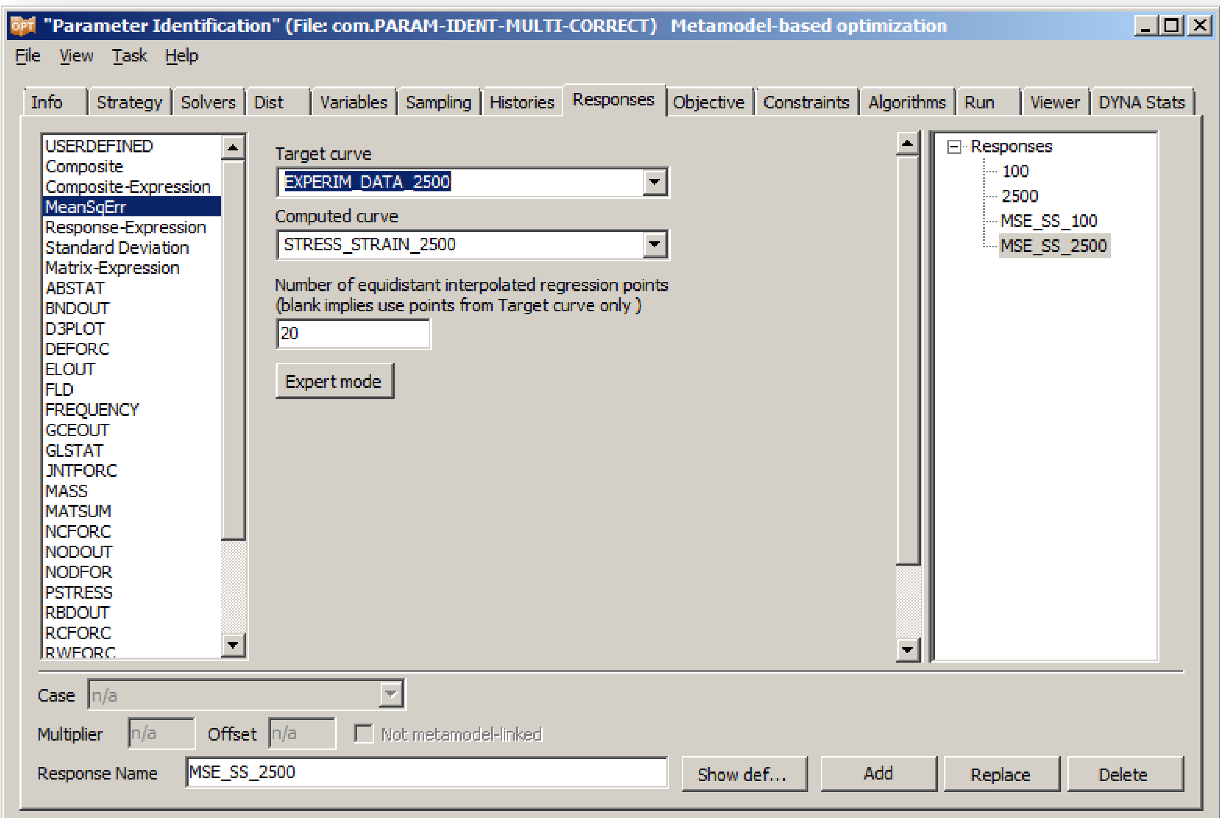
Responses panel

- From left window – responses types select MeanSqErr
- For Target curve select `EXPERIM_DATA_100`
- For Computed curve select `STRESS_STRAIN_100`
- Type `20` for Number of equidistant regression points
- Enter the Response Name: `MSE_SS_100` and push the Add button



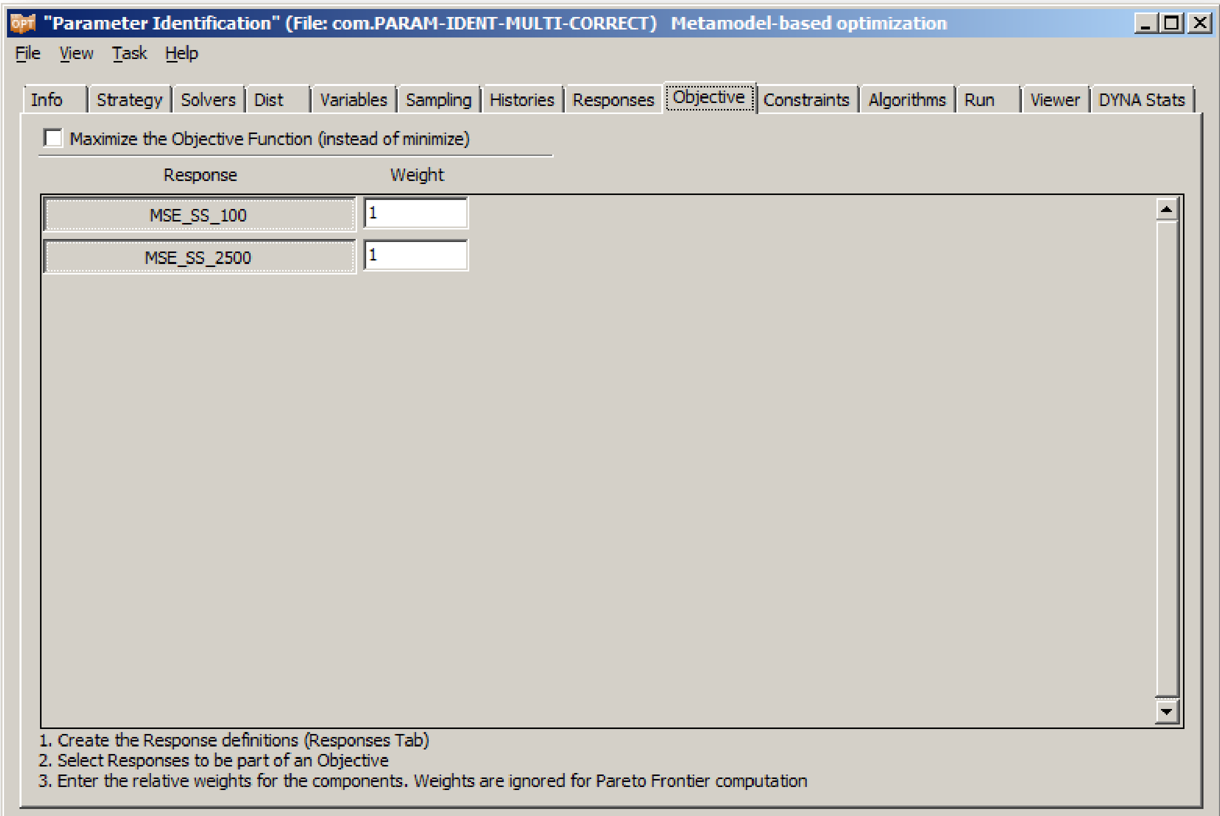
Responses panel

- From left window – possible responses types select MeanSqErr
- For Target curve select EXPERIM_DATA_2500
- For Computed curve select STRESS_STRAIN_2500
- Type 20 for Number of equidistant regression points
- Enter the Response Name: MSE_SS_2500 and push the Add button



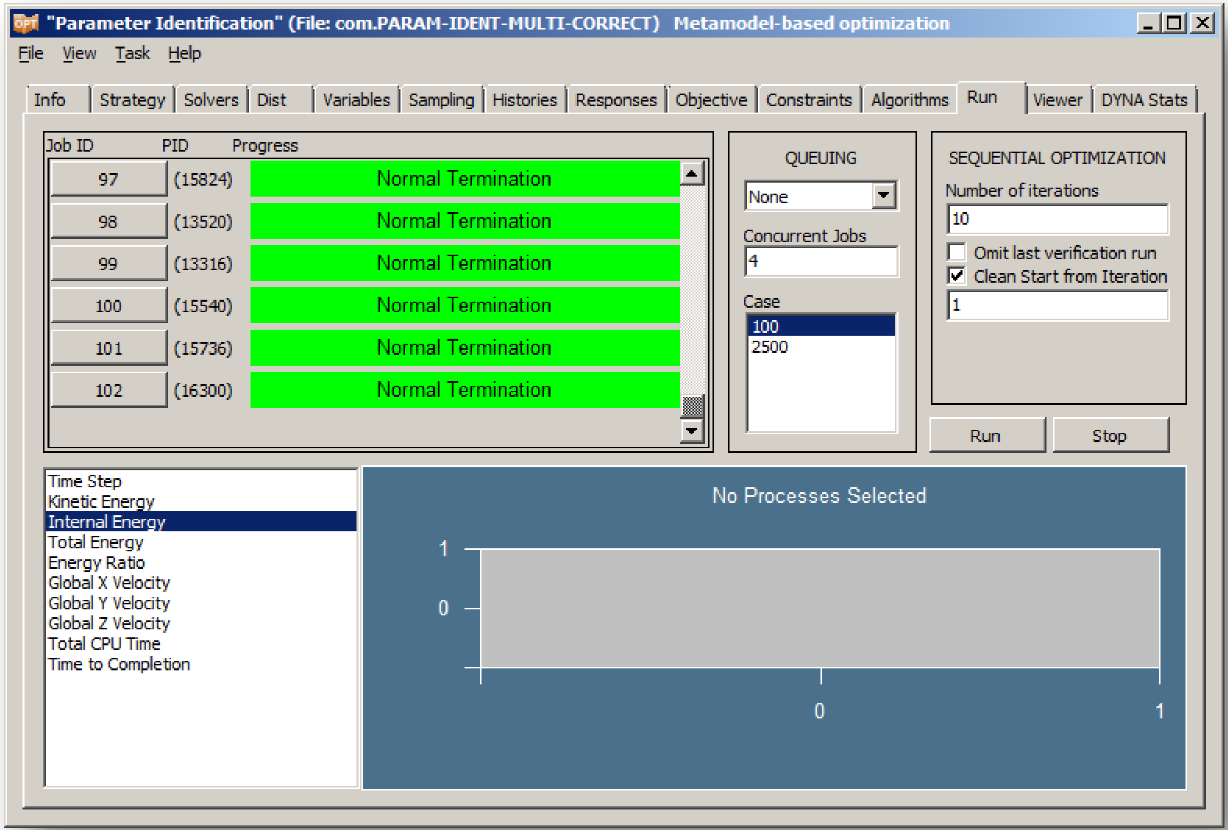
Objective panel

- In the Objective panel select MSE_SS_100 and MSE_SS_2500 as the objective functions
- Leave default weight factors equal to 1



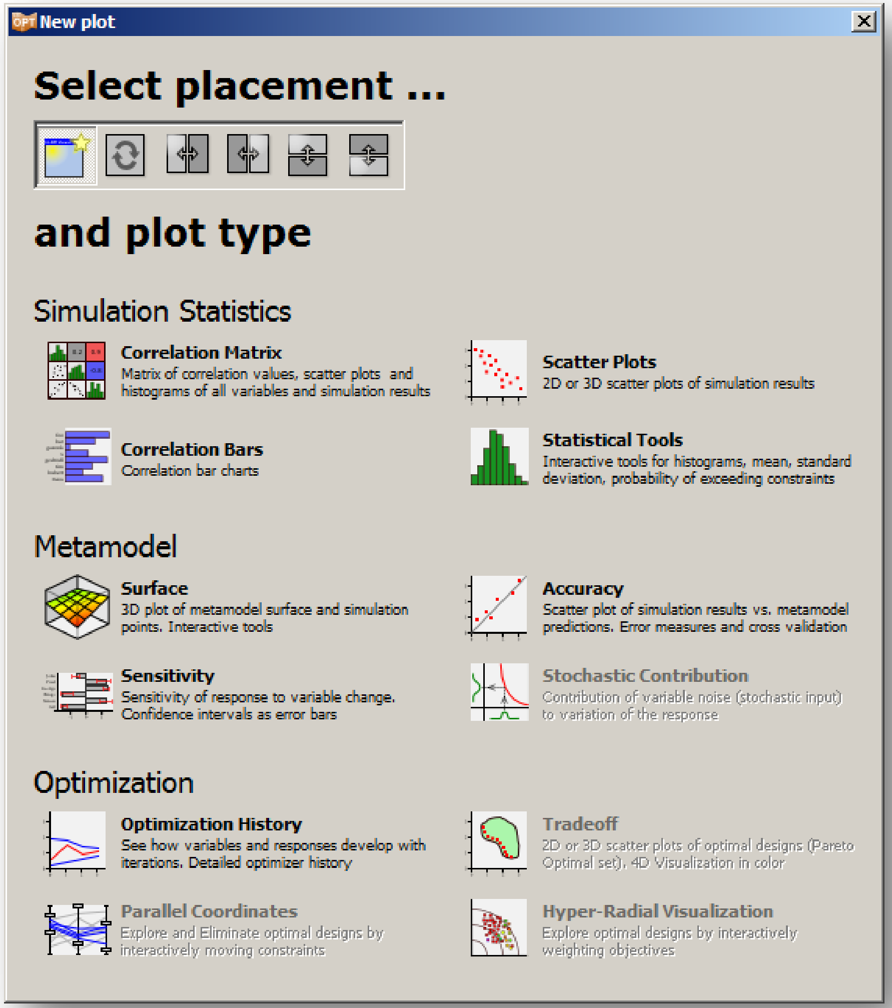
Run panel

- In the Run panel type in 10 for Number of iterations and
- If the job is run on the TRACC cluster select PBS for QUEUING
- And select desired number of Concurrent Jobs
- For desktop machine specify only number of Concurrent Jobs
- Push Run button to star the optimization process



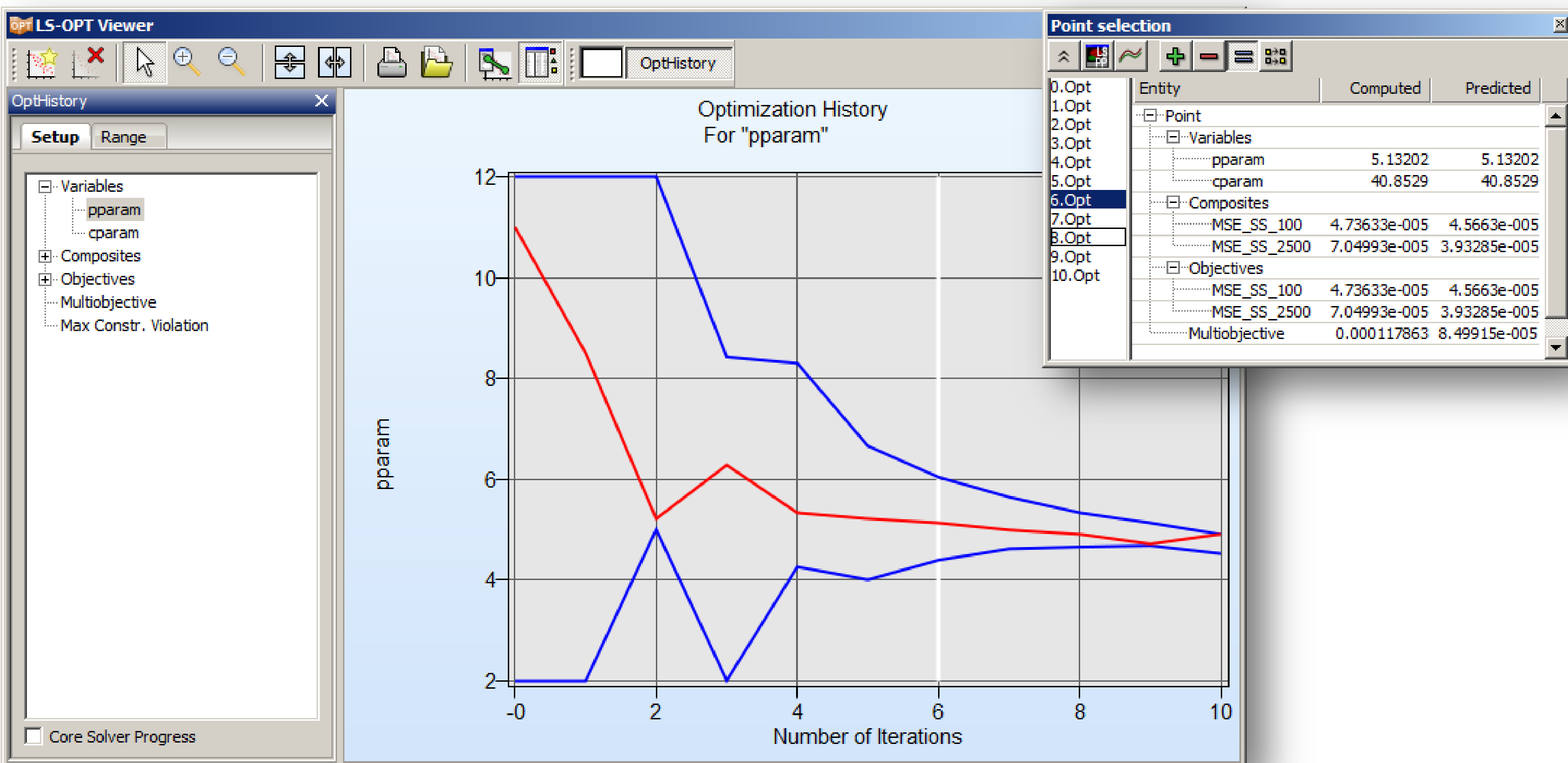
Viewer

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



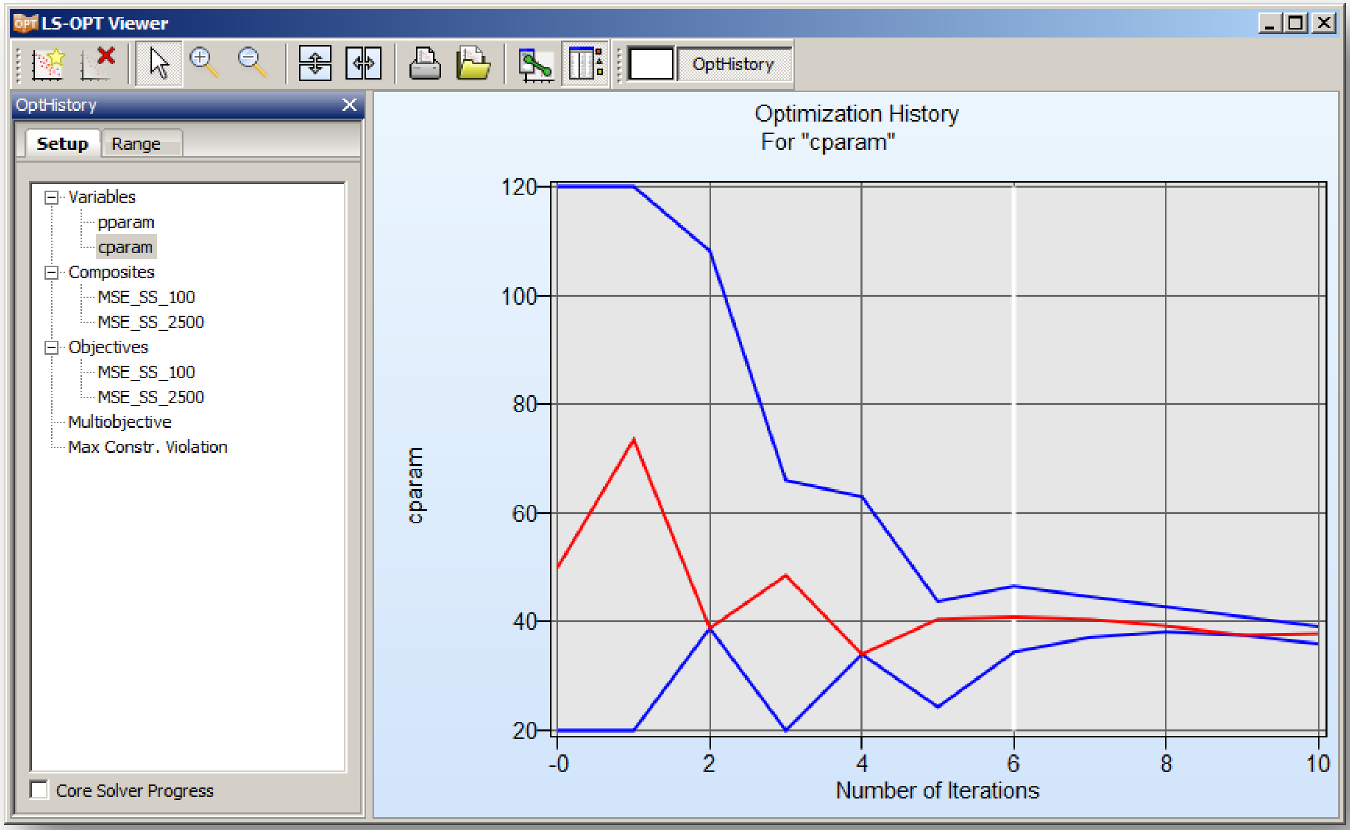
Viewer - Optimization History

- From Variables list select pparam
- Click on the plot window near iteration 6 to read Computed and Predicted values of variables and objectives



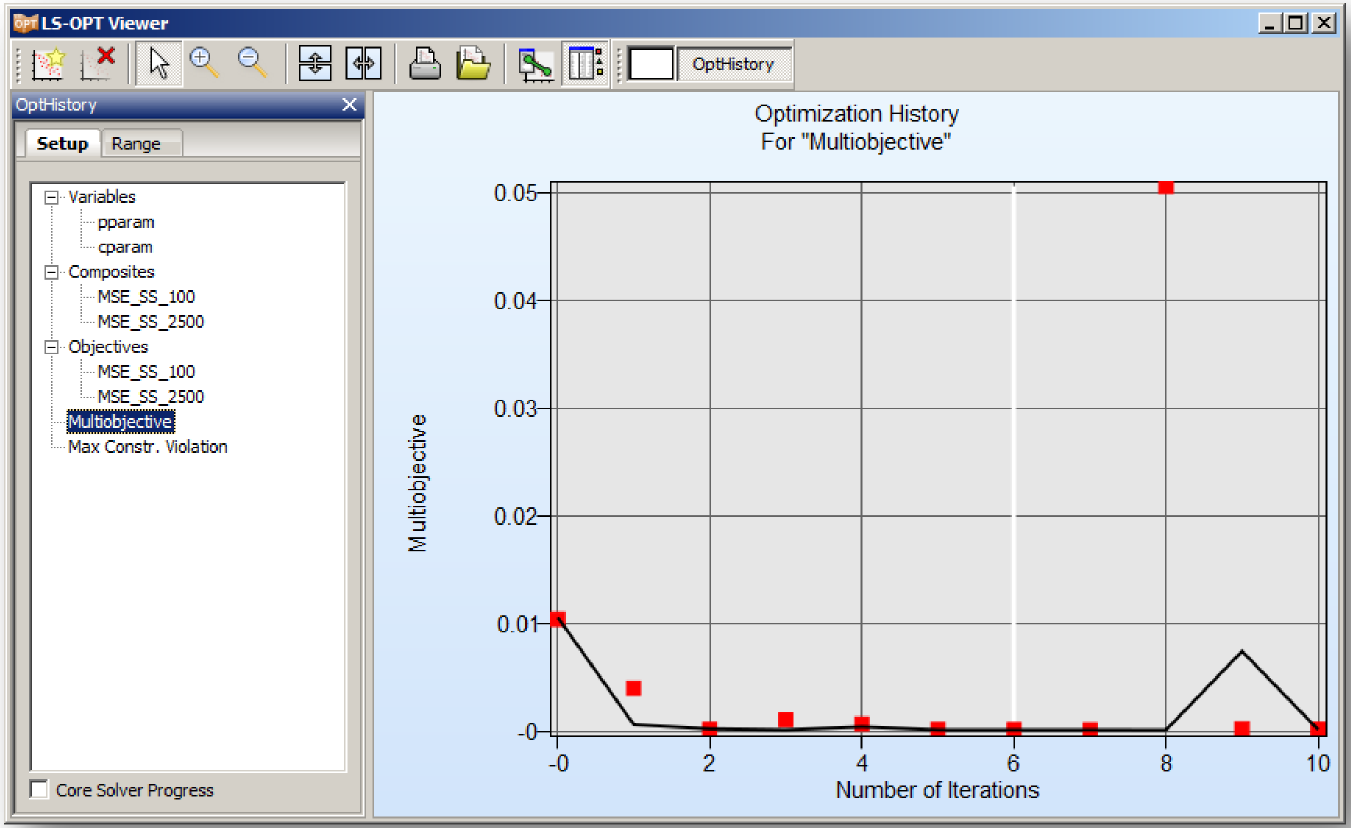
Viewer - Optimization History

- From Variables list select cparam to see its history of optimization



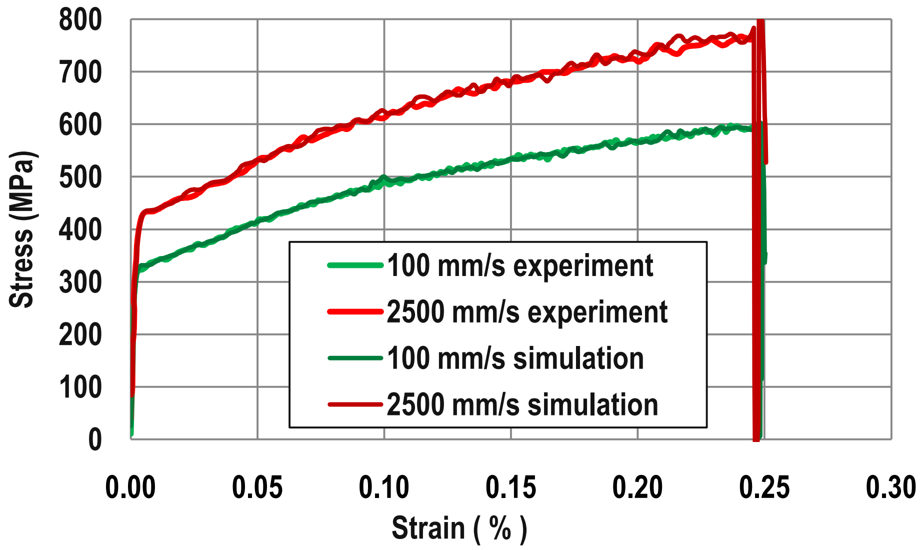
Viewer - Optimization History

- From Objectives list select Multiobjective
- Track the history of the combined error



Final results

- From folder `...\100\11.1` plot data stored in `history.2` file
- From folder `...\2500\11.1` plot data stored in `history.5` file
- Add to the graph “experimental” curves



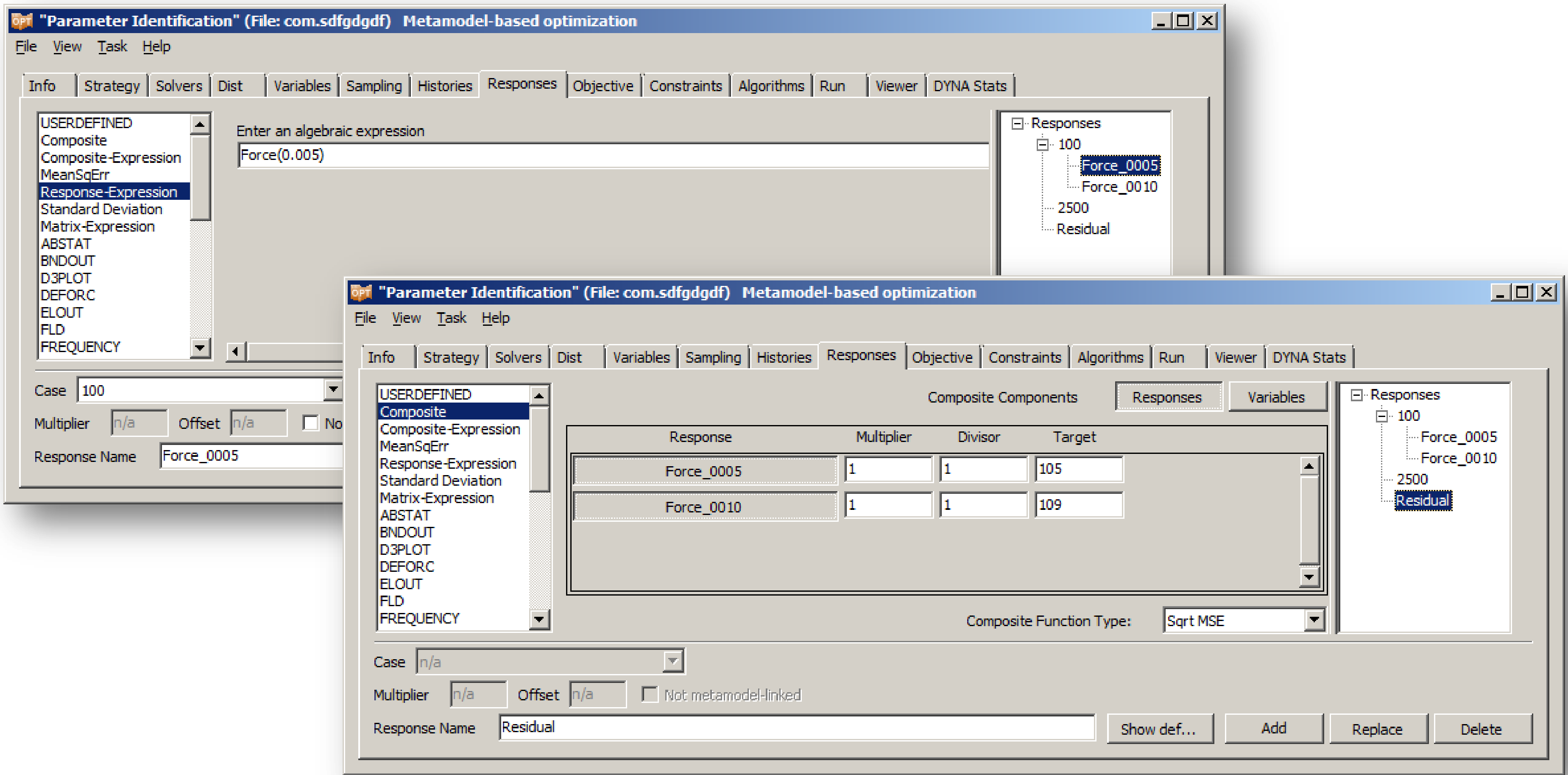
Min Max Formulation

- If certain characteristics (overshoot, discontinuity, etc) in the experiment result curve is to be matched in the simulation model then alternative -- maximum violation of a constraint approach is used:

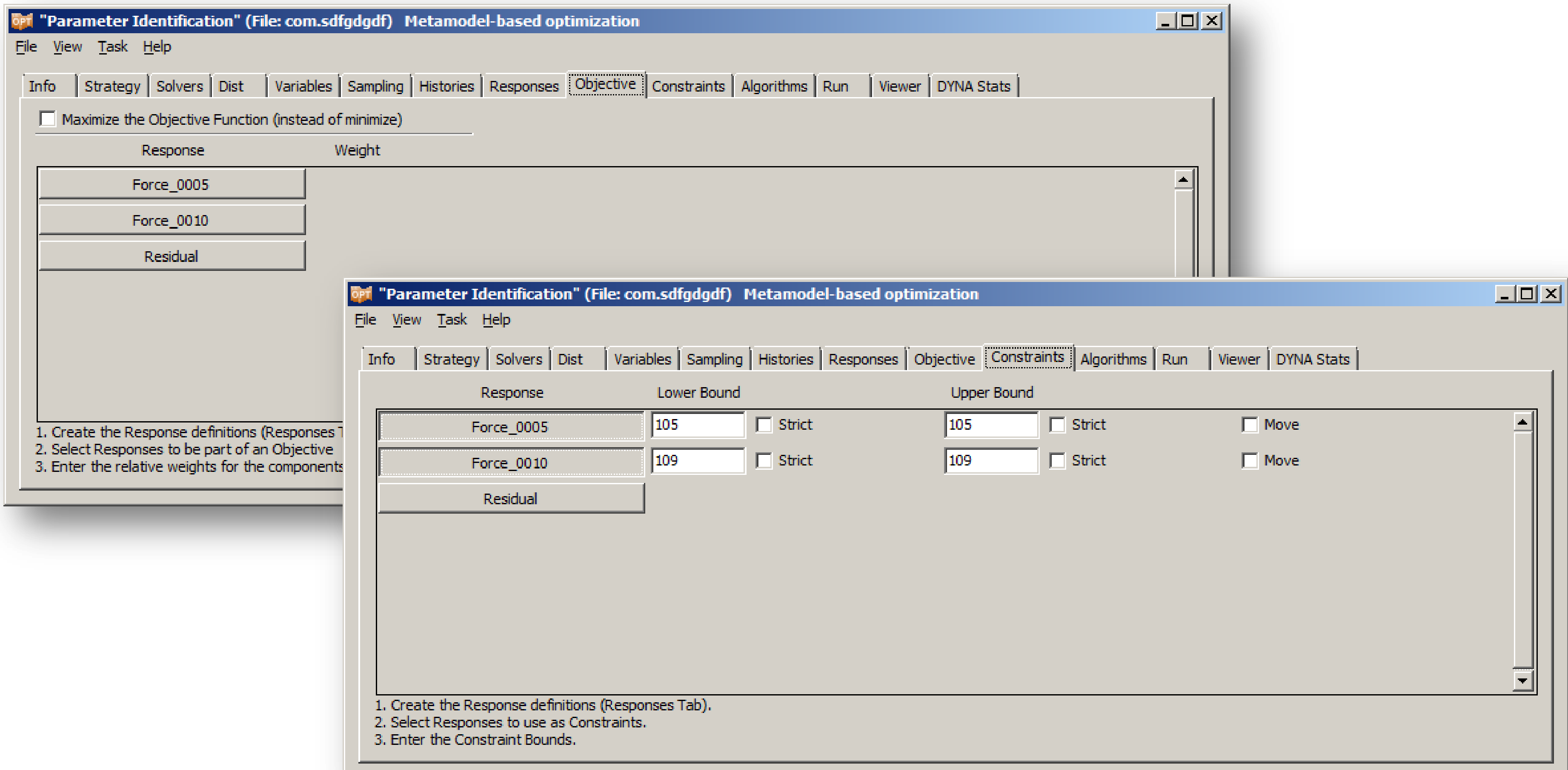
$$Minimize(Maximum \quad violation) = \min\left[\max_i \left|\frac{F_i(x) - G_i}{s_i}\right|\right]$$

P	Number of regression points
$F_i(x)$	Simulated value
G_i	Target value at regression point
s_i	Scale factor for residuals (error normalization)

Min Max Formulation - Responses



Min Max Formulation - Objective and Constraints



Min Max Formulation

- This approach is automatically activated in the LS-OPT when specifying both the lower and upper bounds to the same, targeted value.

$$\frac{F_i(x)}{s_i} = \frac{G_i}{s_i}$$

- There is no need to specify the objective function then. Optimization problem is then defined as:

$$\min e$$

$$\frac{F_i(x) - G_i}{s_i} \leq e$$

$$e \geq 0$$

e – infeasibility

```
$ COMPOSITE RESPONSES
$
 composite 'Residual' type targeted
  composite 'Residual' response
'Force_0005' 105
  composite 'Residual' response
'Force_0010' 109
$
$ NO OBJECTIVES DEFINED
$
 objectives 0
$
$ CONSTRAINT DEFINITIONS
$
 constraints 2
 constraint 'Force_0005'
  lower bound constraint
'Force_0005' 105
  upper bound constraint
'Force_0005' 105
 constraint 'Force_0010'
  lower bound constraint
'Force_0010' 109
  upper bound constraint
'Force_0010' 109
```