

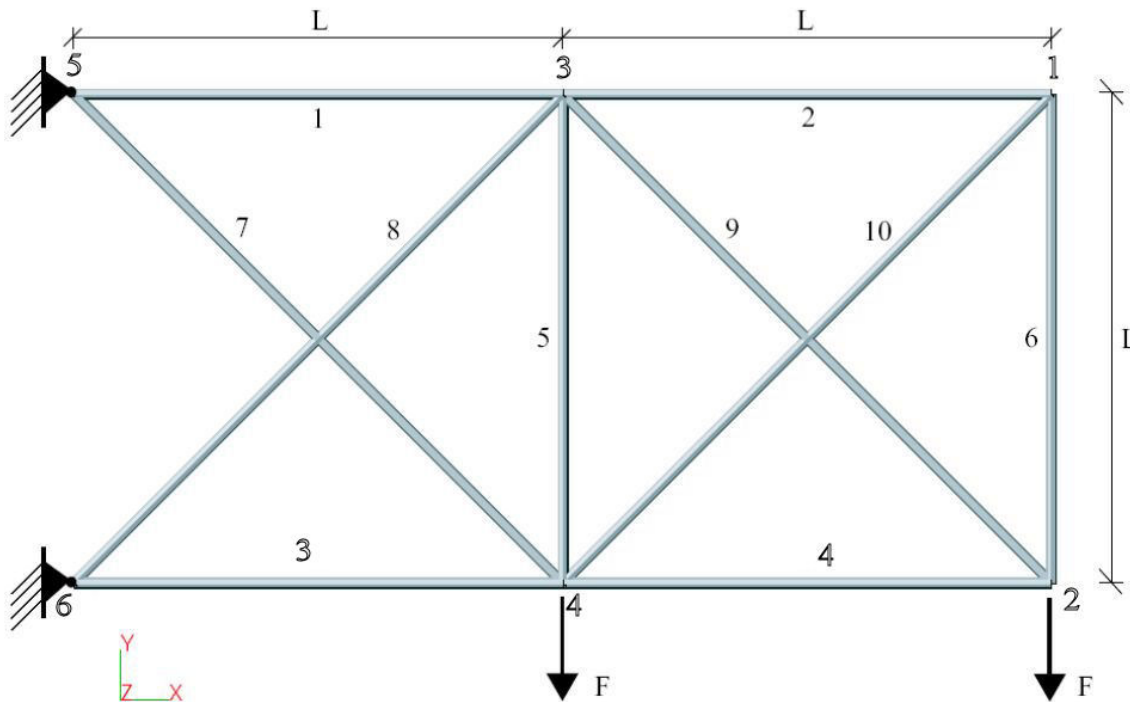
optiSLang—ANSYS Tutorial

10 bar truss example — Part 1

Single Object Optimization using ES and ARSM



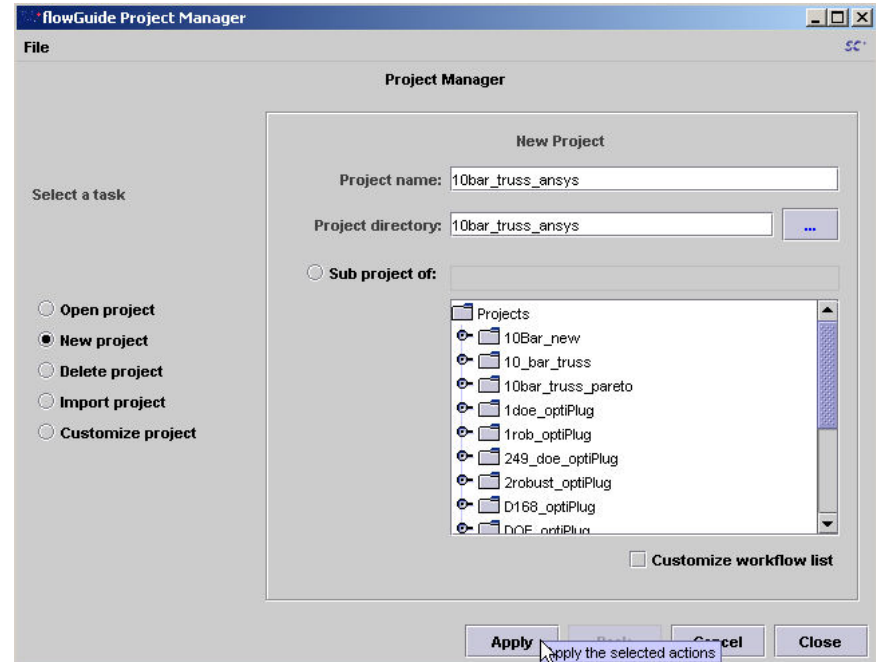
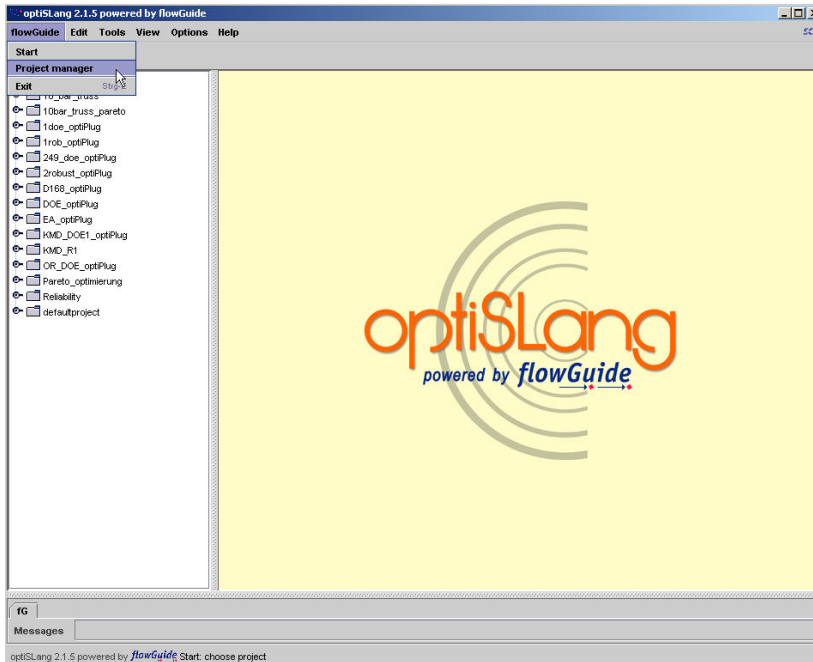
Problem description



- Max stress limit is 25000 psi, use this as the initial stress constraint.
- Displacement constraint is 20 in.
- The aim is to minimize the mass of the whole structure
- ANSYS will be used as the computational solver

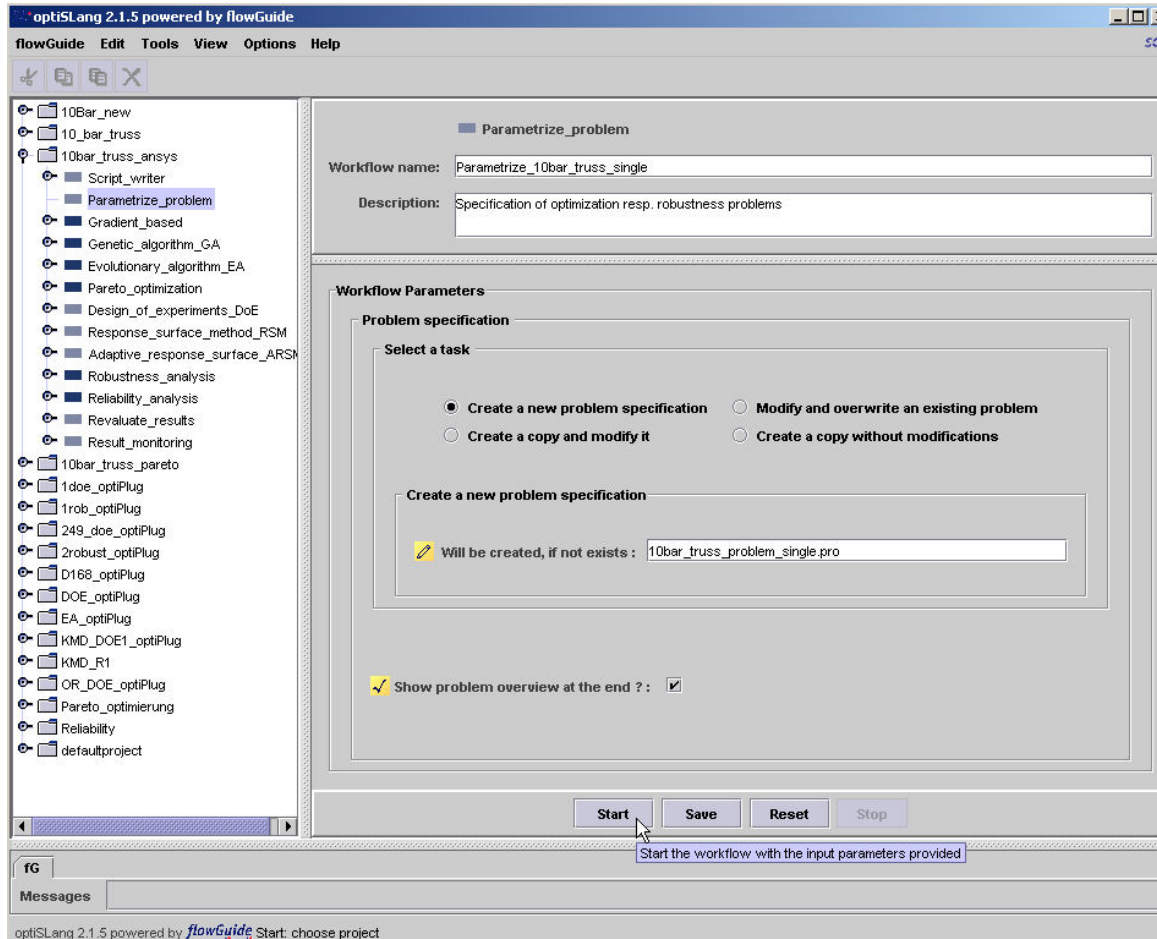
- Linear rod elements
- Element length $L=360$ in; load $F_y=100000$ lb
- Young's modulus $1 \cdot 10^7$ psi; density $0,1$ lbs/in³
- 10 design variables: cross-sectional areas of the rod elements
- 3 basic response: mass of the structure, max_displacement, max_stress
- 12 additional responses: stress_1...stress_10 and disp_2 and disp_4

Create project: 10bar_truss_ansys



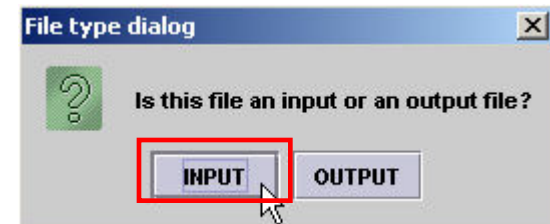
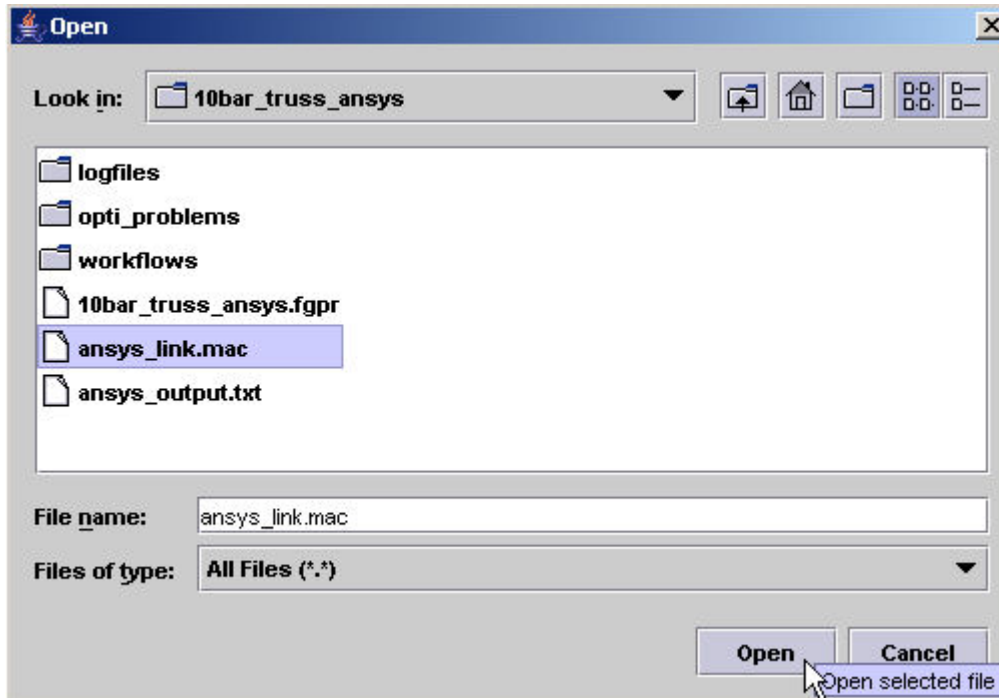
- | Start: Project manager
- | Create: new project, e.g. “10bar_truss_ansys”
- | Define project name
- | Create your Project directory: “10bar_truss_ansys”
- | Copy the input file: “ansys_link.mac” and the output file: “ansys_output.txt” into your directory “10bar_truss_ansys”

Parameterize the problem



- Create a new “Parameterize problem”
- Define the workflow name, e.g. “Parameterize_10bar_truss_single”
- Define the problem specification name, e.g. “10bar_truss_problem_single.pro” or “10bar_New.pro”
- Highlight “Show problem overview at the end?”
- Start the Workflow

Choose input file

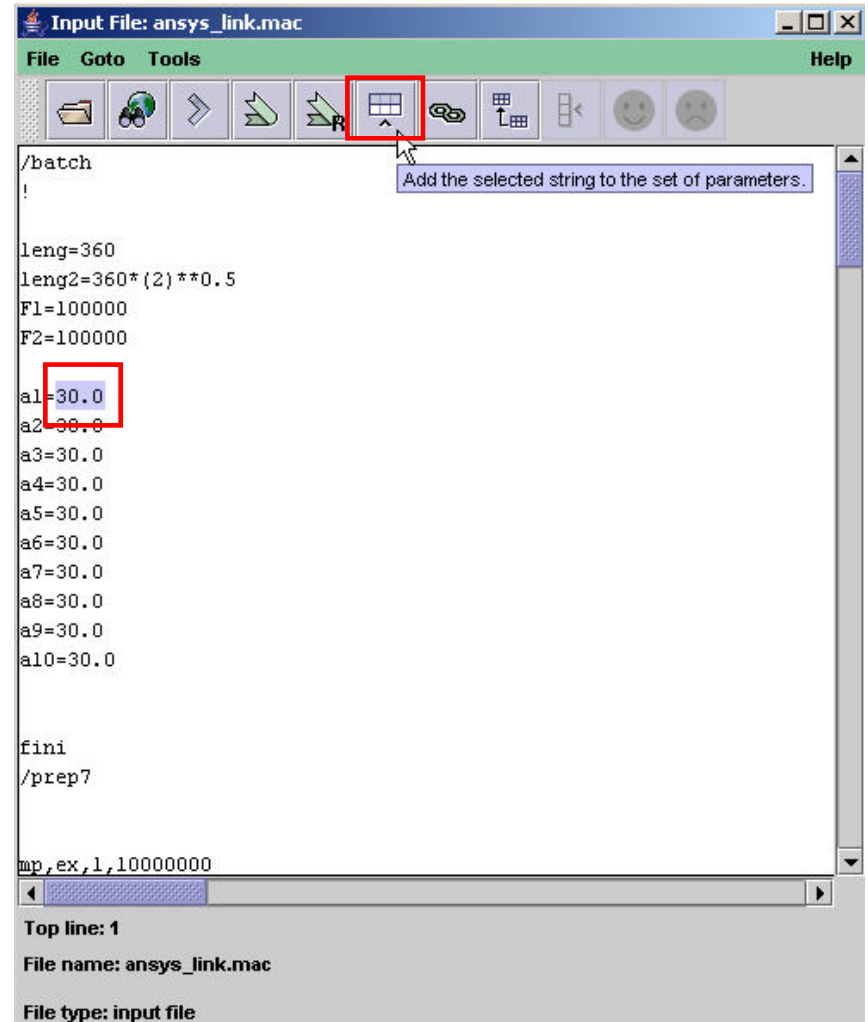


- Open dialog of the file browser window
- Choose input file “ansys_link.mac”
- Specify file type as INPUT

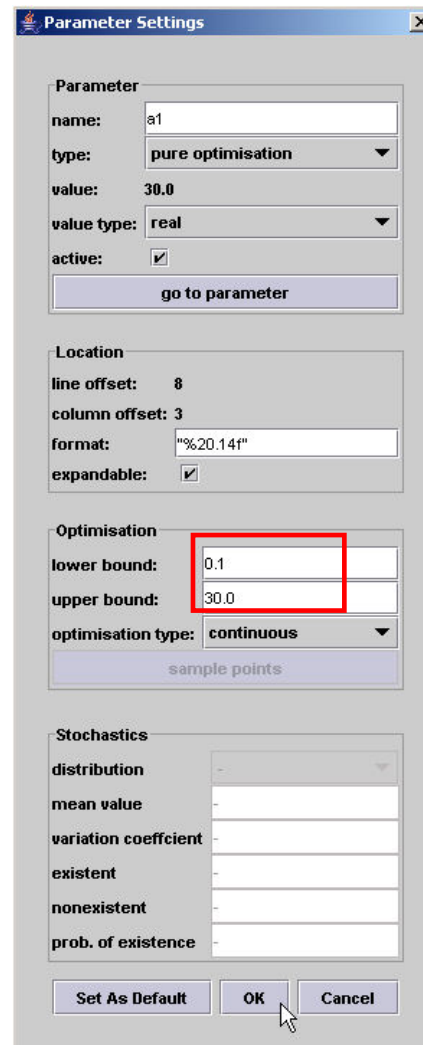
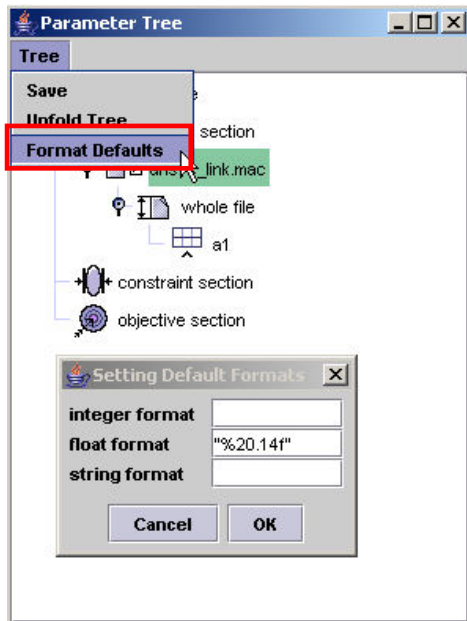
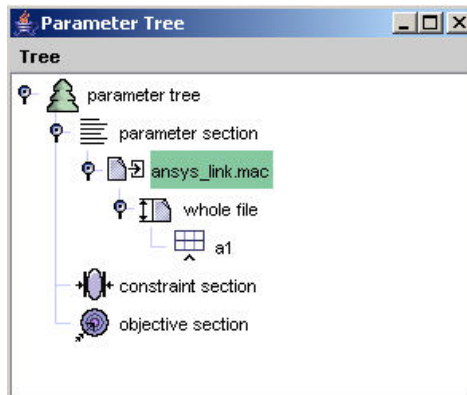
Input file ansys_link.mac

Parsing design parameter

- Mark the parameter value
- Click on parameter button
- Define parameter name as a1

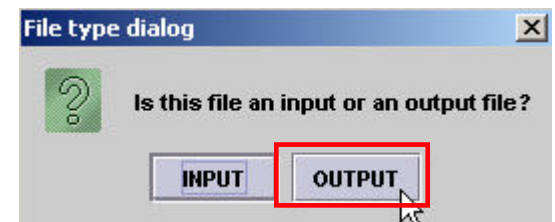
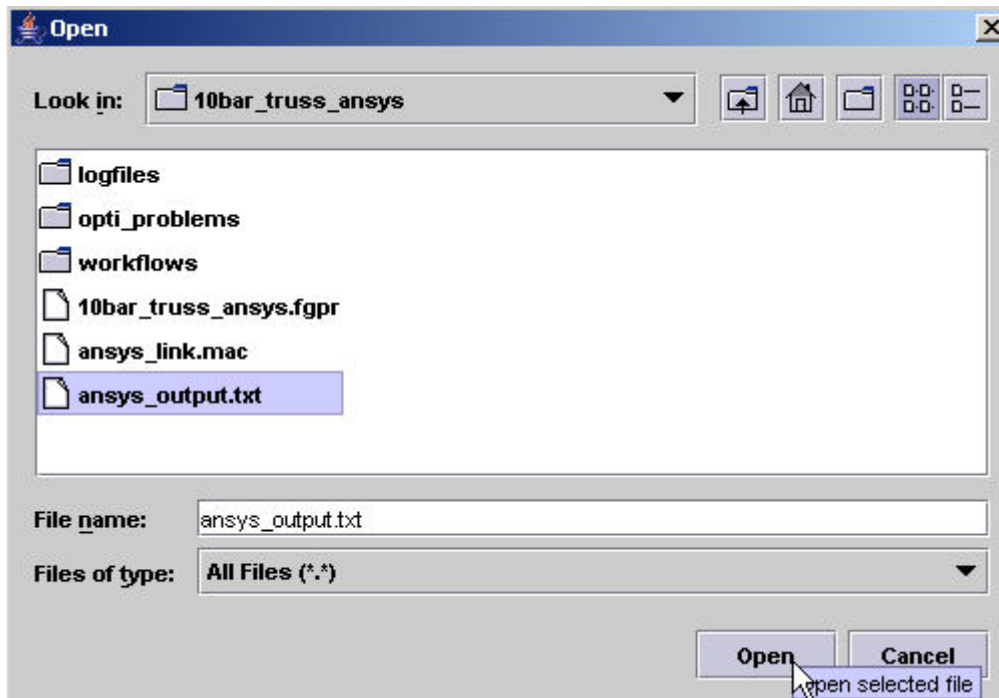


Parameter settings



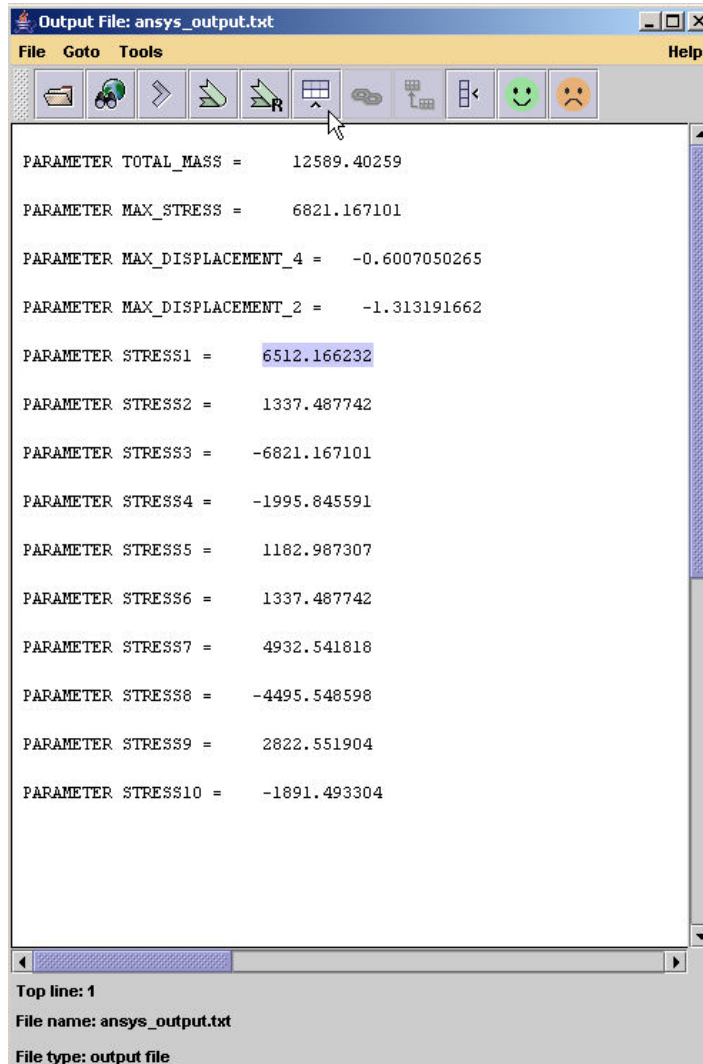
- Define the design parameter properties by double-click on it
- Use expandable format
- Set format defaults
- Define the lower to 0.1 and upper bound to 30
- Click on “Set as default”
- Define the additional 9 design parameters in the same manner

Choose output file



- Open dialog of the file browser window
- Choose output file “ansys_output.txt”
- Specify file type as OUTPUT

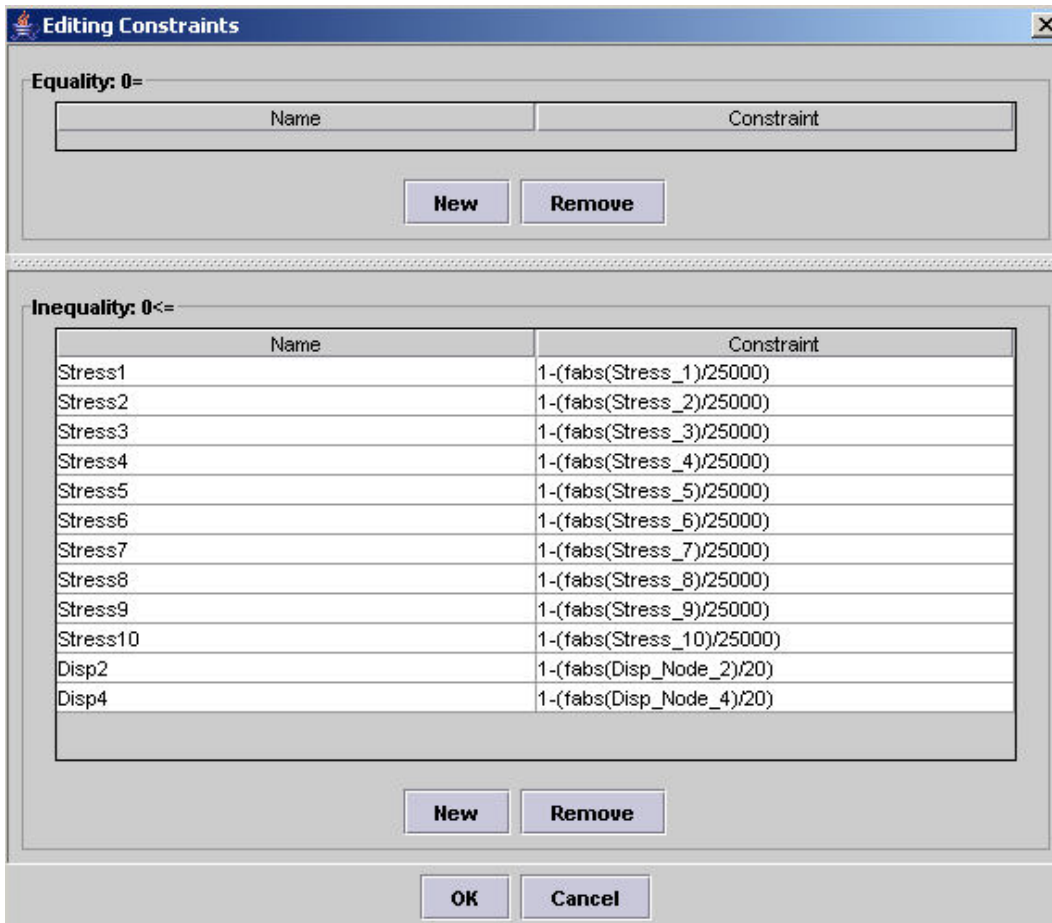
Parsing of the responses



Parsing response parameter

- Mark the parameter value of the response "Total_Mass"
- Click on parameter button
- Define parameter name as Mass
- Define the responses "Stress1"... "Stress10" and "Max_Displacement_2" and "Max_Displacement_4" in the same manner

Defining the constraints



Editing Constraints

Equality: 0=

Name	Constraint
------	------------

New Remove

Inequality: 0<=

Name	Constraint
Stress1	1-(fabs(Stress_1)/25000)
Stress2	1-(fabs(Stress_2)/25000)
Stress3	1-(fabs(Stress_3)/25000)
Stress4	1-(fabs(Stress_4)/25000)
Stress5	1-(fabs(Stress_5)/25000)
Stress6	1-(fabs(Stress_6)/25000)
Stress7	1-(fabs(Stress_7)/25000)
Stress8	1-(fabs(Stress_8)/25000)
Stress9	1-(fabs(Stress_9)/25000)
Stress10	1-(fabs(Stress_10)/25000)
Disp2	1-(fabs(Disp_Node_2)/20)
Disp4	1-(fabs(Disp_Node_4)/20)

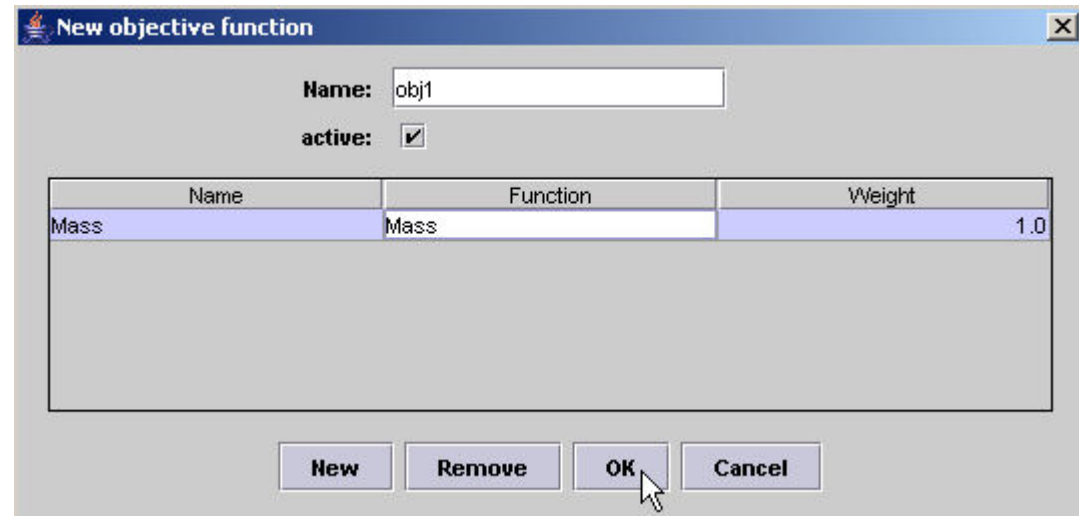
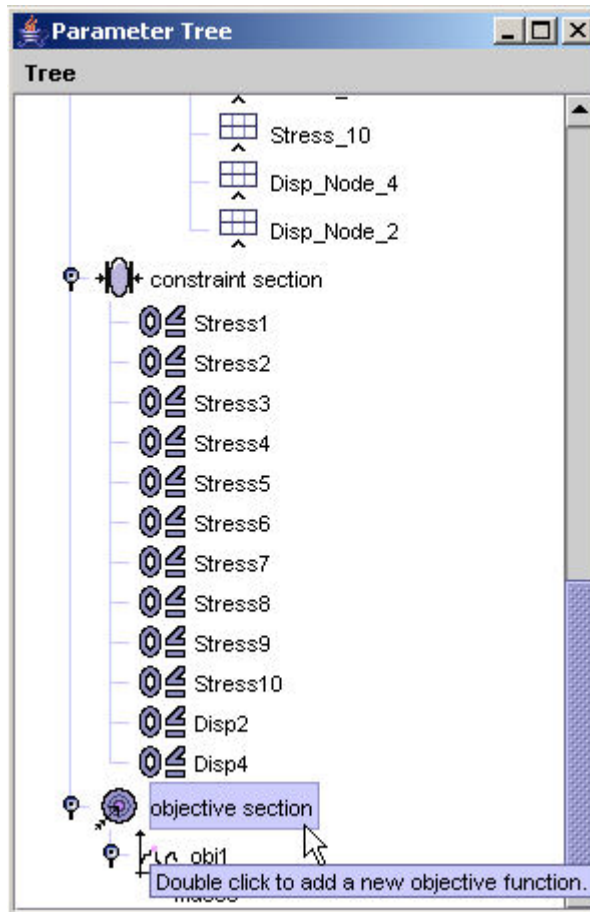
New Remove

OK Cancel

- Double-click on constraint section to define the constraints. Add them with “New”.
- $\text{Stress}(X) = 1 - (\text{fabs}(\text{Stress}_X) / 25000)$
for $x = 1 \dots 10$
- $\text{Disp2}(4) = 1 - (\text{fabs}(\text{Disp_Node2}(4) / 20))$

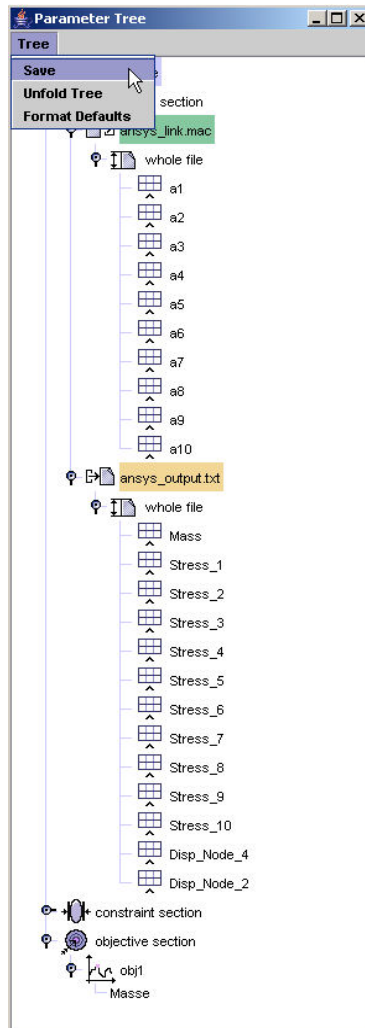
We include the “fabs” function to get the absolute values of our parameters

Definition the objective function



- Double-click on objective section and define a new objective function
- This minimizes the mass of the structure

Final parameter tree



- Ten design parameters to vary
- Thirteen responses
- Twelve inequality constraints
- One objective with one objective term
- Save the parameter tree end exit the parametrize section

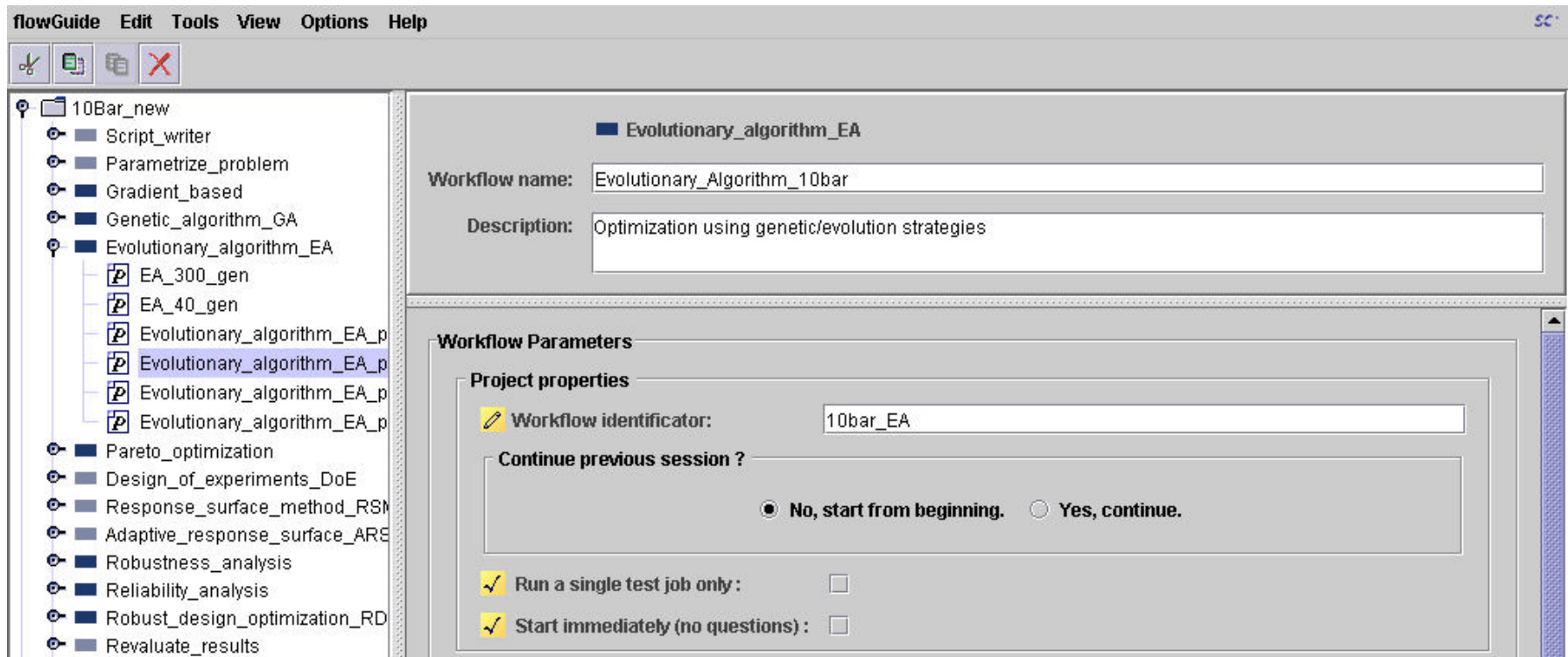
Write the “call_ansys.bat” file

Use a text editor to write this script or modify the included script file

```
@echo off
REM script: call_ansys.bat
REM generated by optiSLang
REM start a program
"C:\Program Files\Ansys Inc\v110\ANSYS\bin\intel\ansys110" -b -i ansys_link.mac -o out.txt
del file.*
exit 0
```

Before you write the script – locate where your ANSYS program has been installed and modify the path, otherwise this script would not work!

Workflow of the evolutionary algorithm I



- Create a new workflow of “evolutionary_algorithm”
- Define “Workflow name” and “Workflow identifier” like shown above!

Workflow of the evolutionary algorithm II

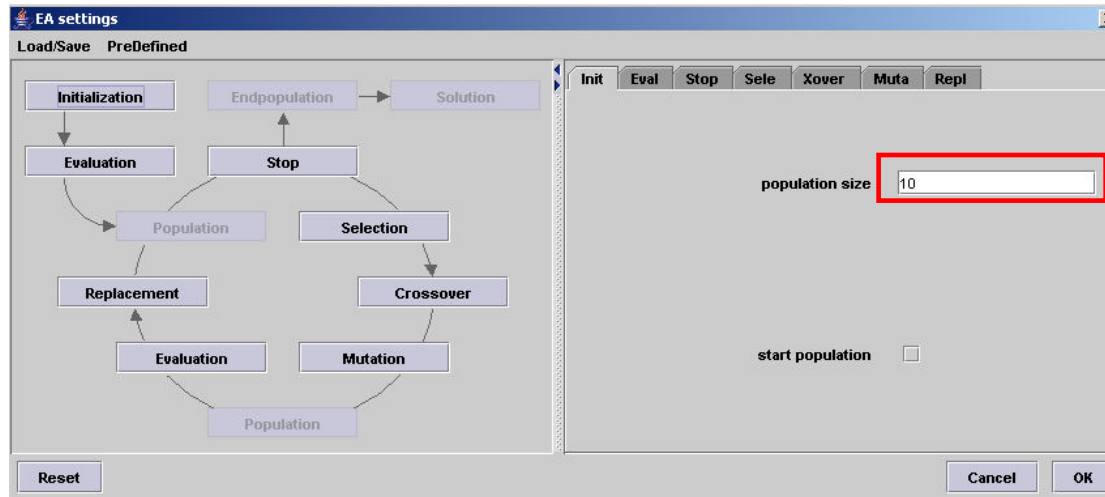
The screenshot displays a software interface for configuring an evolutionary algorithm workflow. It is organized into several sections:

- Optimization problem:** Includes a text field for "problem specification file" (D:\TMP_Veiz10_bar_neuopti_problems10Bar_New.pro) and a checkbox for "show problem overview".
- Optimization strategy:**
 - Evolution parameter set:** Features radio buttons for "Create resp. Modify" (selected) and "Use previously defined". Below, a "Create resp. Modify" section has a text field for "Will be created, if not present in project directory" (evolution_parameters.set).
 - Constraints:** Includes a spinner for "How many designs may violate the input constraints ? (%)" (100) and a checkbox for "Do not solve designs which violate input constraints ?".
 - Scaling:** Includes a checkbox for "Scale terms and objectives" and radio buttons for "no scaling" (selected), "automatic scaling", "use existing factors", and "show scale dialog".
- Solver control:**
 - command line to execute:** Features radio buttons for "Run a single command (found in PATH)" and "Run a script file" (selected).
 - Run a script file:** Includes a "select a file" text field (D:\TMP_Veiz10_bar_neu\call_ansys.bat) with a browse button.
 - Execution parameters:** Includes spinners for "maximum number of parallel runs" (1), "idle time before starting a run (sec)" (0), and "maximum runtime of a single job (min)" (5). A checkbox for "do not solve duplicated designs twice" is checked.
- Monitoring:** Includes checkboxes for "Show monitoring during calculation progress ?" and "Show postprocessing after calculation has finished ?" (checked).

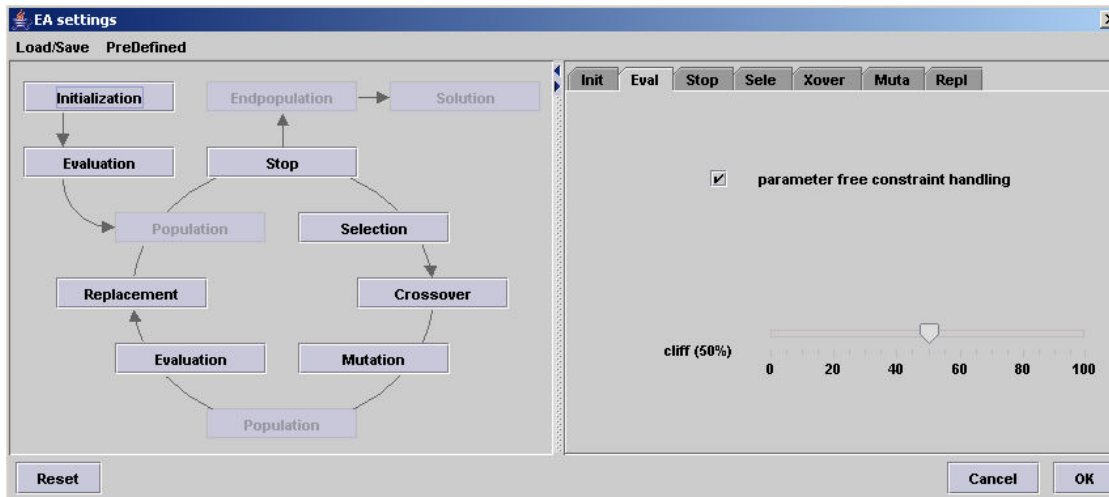
At the bottom, there are four buttons: "Start", "Save", "Reset", and "Stop".

- Use predefined optimization problem (*.pro)
Select the script bat file "call_ansys.bat" for starting the solver
- Save your settings
- Start the Workflow

Subflows of the evolutionary algorithm

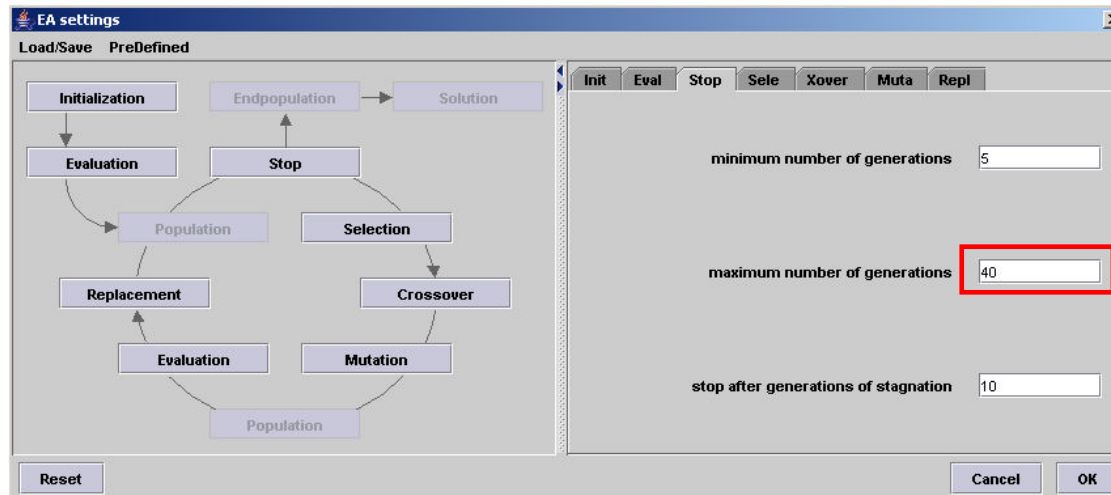


- Specify the Population size (μ) to 10

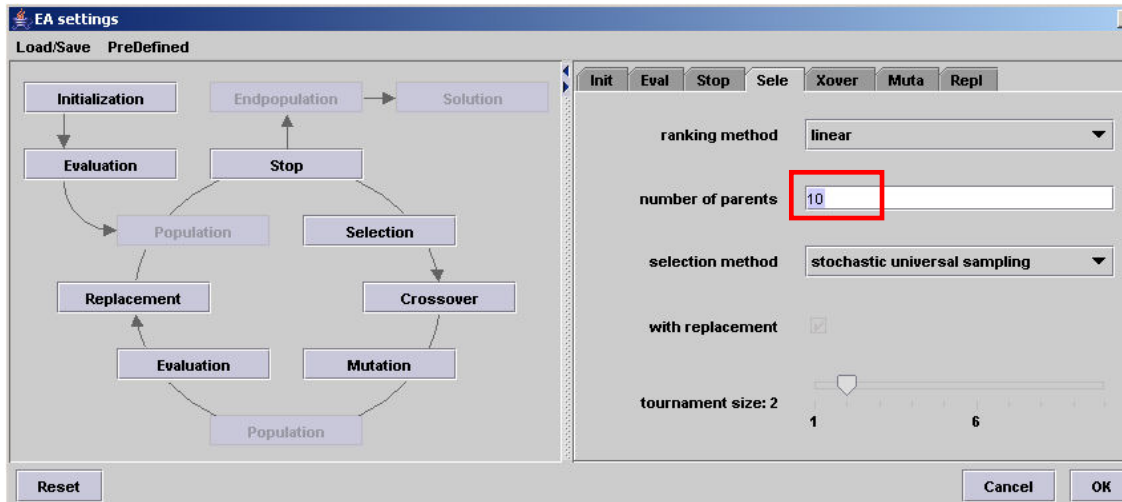


- Choose the constraint handling method

Subflows of the evolutionary algorithm

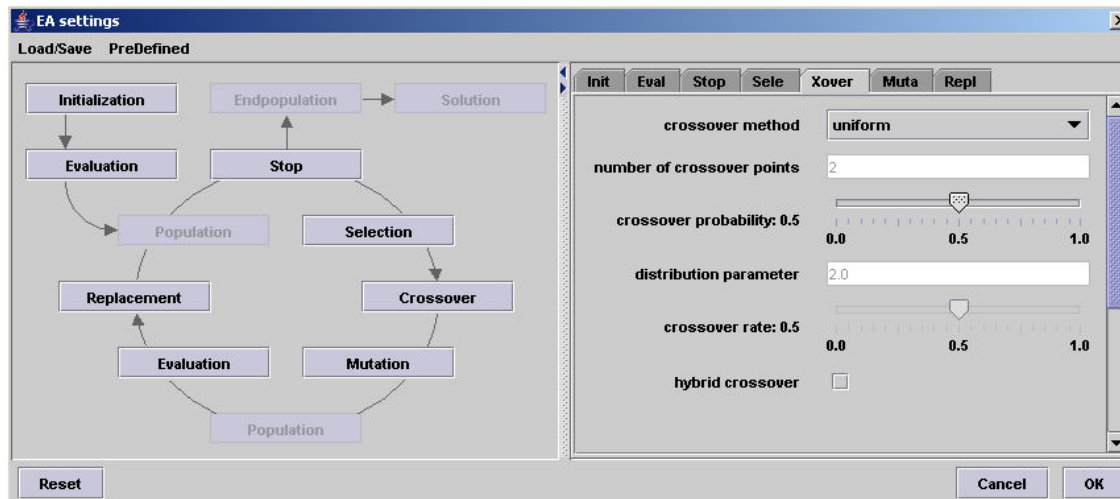


- Specify maximum number of generations to 40

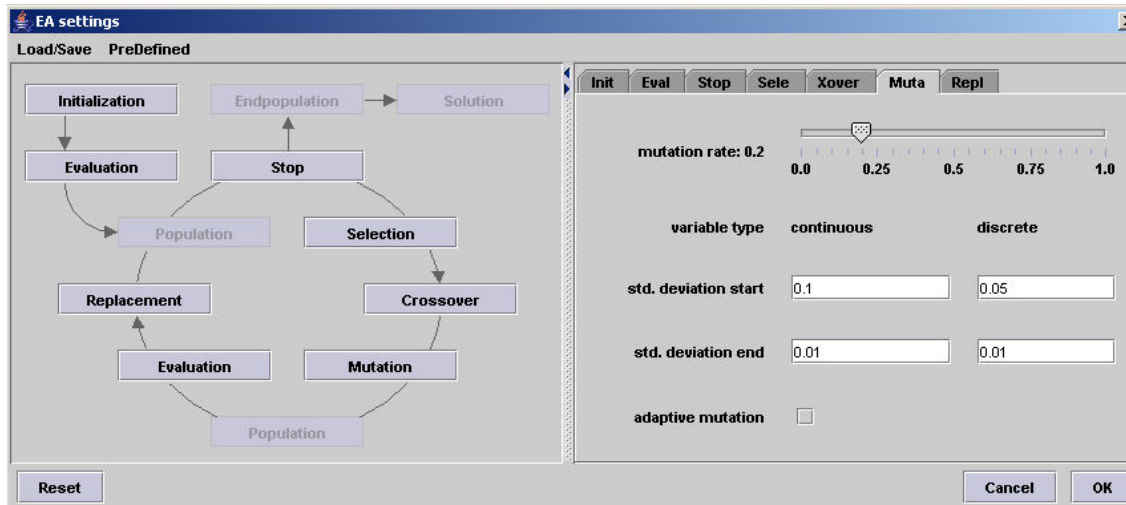


- Customize the parent selection method
- Set the number of the parents to 10

Subflows of the evolutionary algorithm

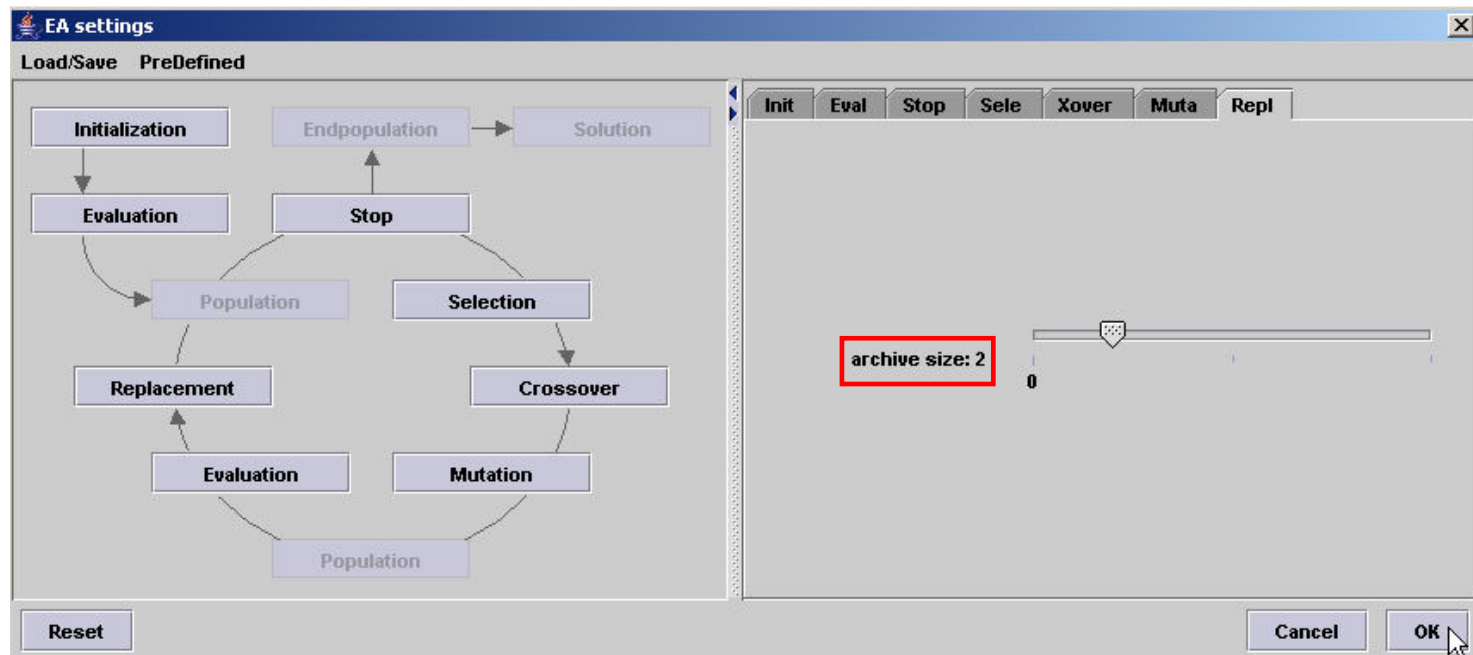


- Choose the crossover method and corresponding parameters

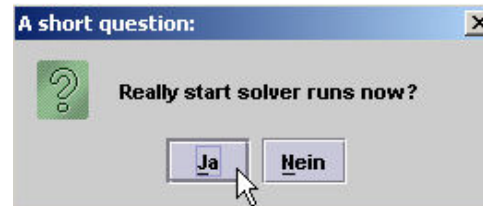


- Specify mutation parameters

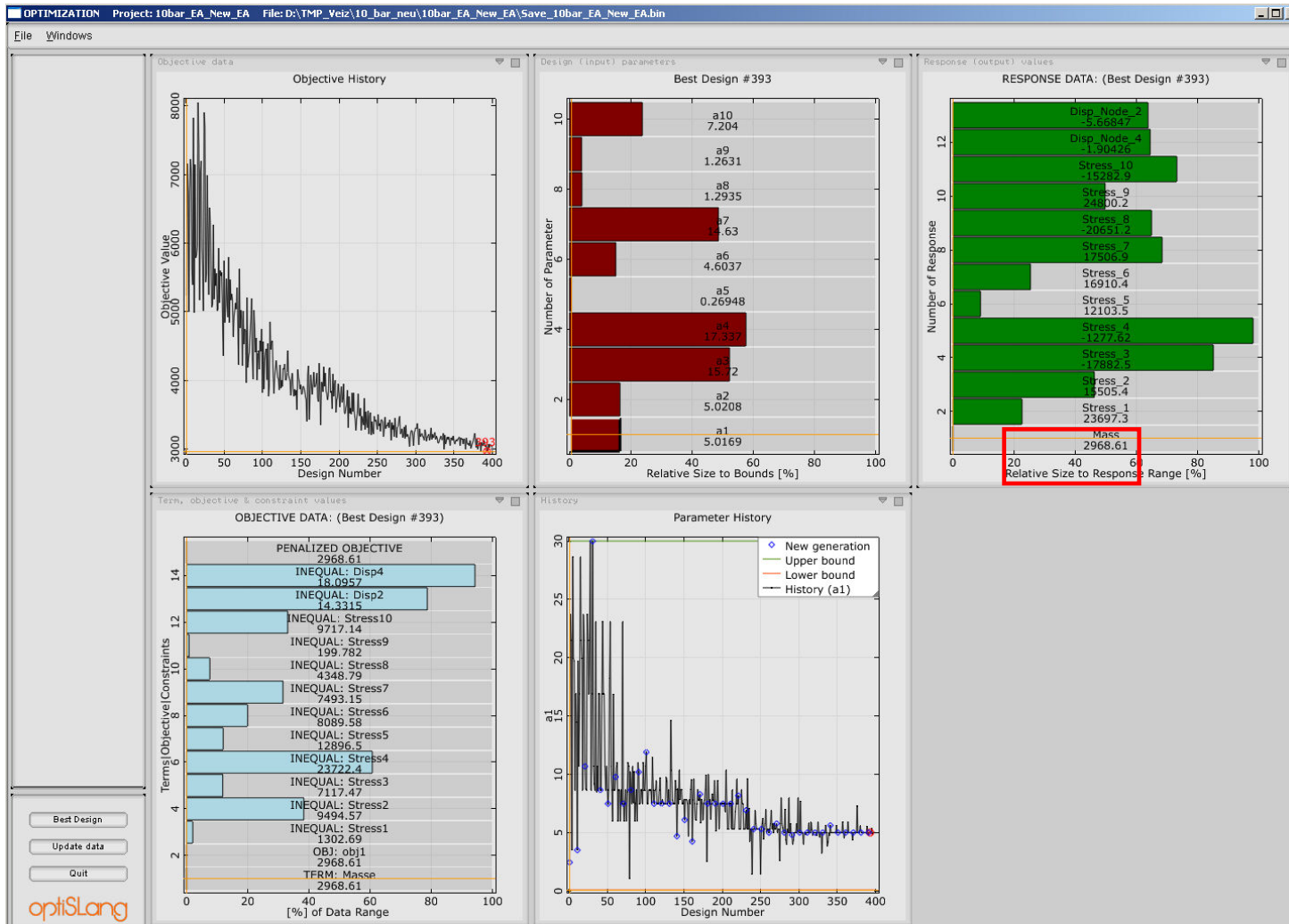
Subflows of the evolutionary algorithm



- Specify the archive size to 2



Postprocessing EA



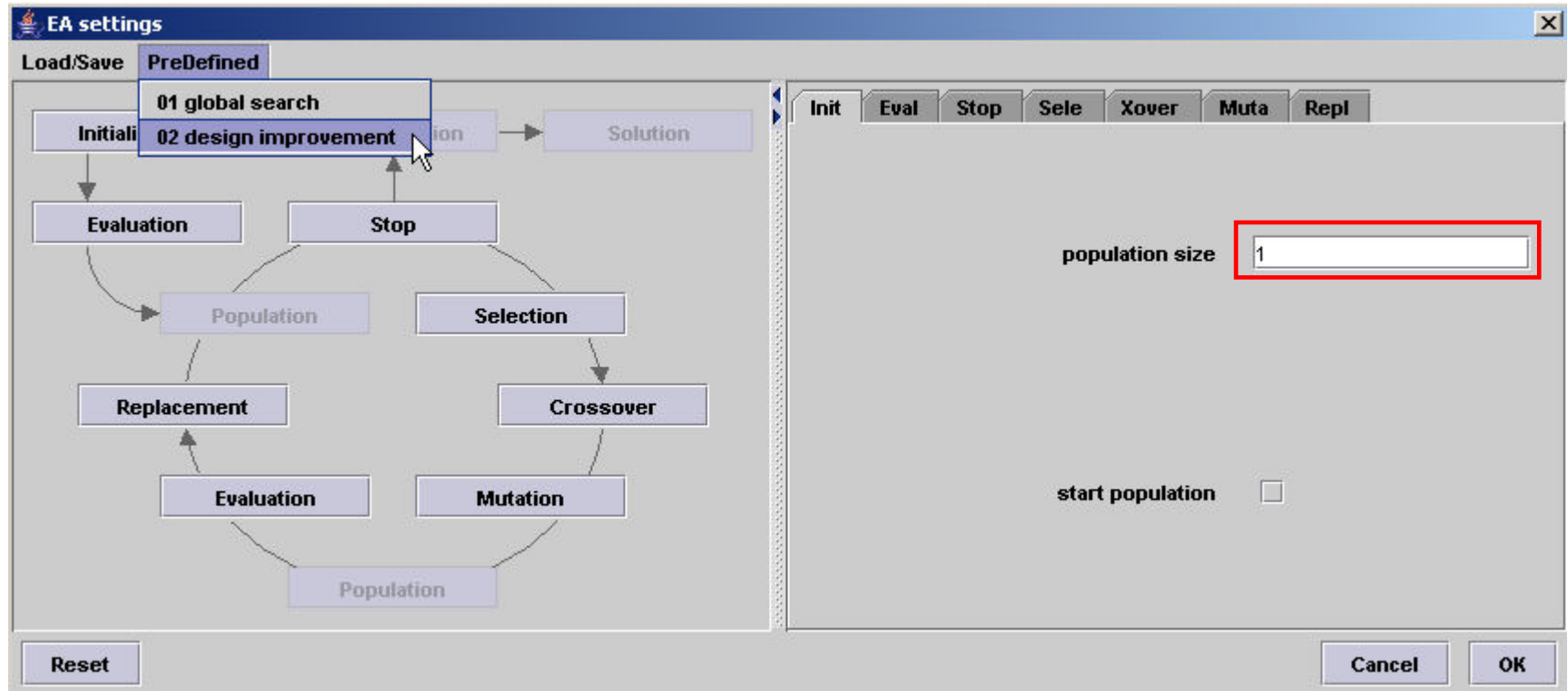
- Initial mass: 12589,4
- First optimization (evolutionary algorithm) mass: 2968,6

Design improvement of a pre-optimized structure

The screenshot shows a software interface for configuring an evolutionary algorithm workflow. At the top, the title bar reads "Evolutionary_algorithm_EA". Below it, there are two text input fields: "Workflow name:" with the value "Evolutionary_algorithm_Design_Improvement" and "Description:" with the value "Optimization using genetic/evolution strategies". A horizontal separator line follows. Below the separator is a section titled "Workflow Parameters". Inside this section, there is a sub-section "Project properties" which contains a "Workflow identifier:" field with the value "10bar_Improve". Below this is a "Continue previous session ?" section with two radio buttons: "No, start from beginning." (selected) and "Yes, continue.". Further down are two checked checkboxes: "Run a single test job only:" and "Start immediately (no questions):", each followed by an unchecked checkbox. The bottom section is titled "Optimization problem" and contains a "problem specification file:" field with the path "D:\TMP_Veiz\10_bar_neu\opti_problems\10Bar_New.pro" and a browse button "...". Below this is a checked checkbox "show problem overview:" followed by an unchecked checkbox.

- Define “Workflow name” and “Workflow identifier”, e.g. “EA_10bar_truss_improve”
- Use the predefined optimization problem(*.pro)
- Select the script bat file “call_ansys.bat” for starting the solver
- Save settings
- Start the flow

Settings for the Evolution Strategy (ES)

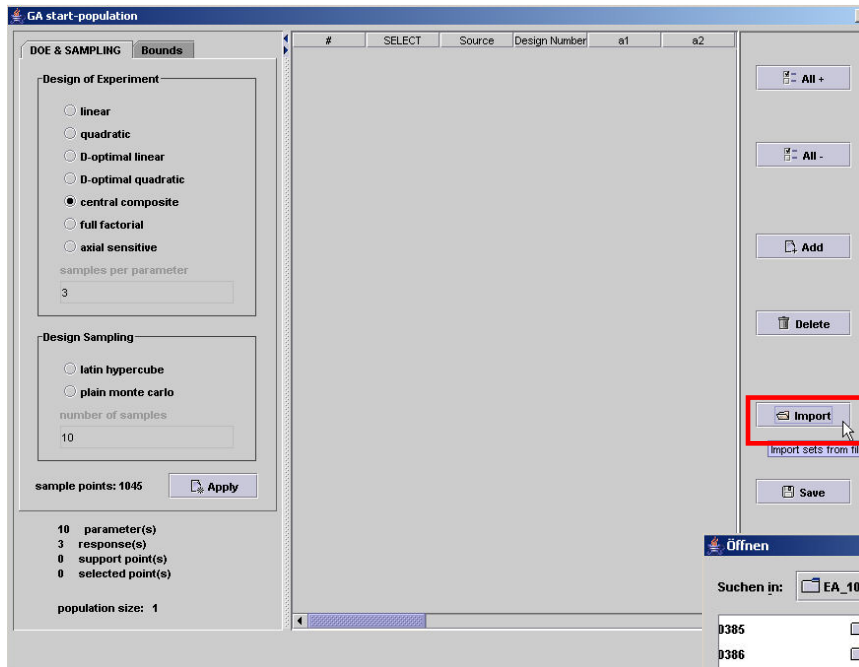


EA settings: Select PreDefined → design improvement

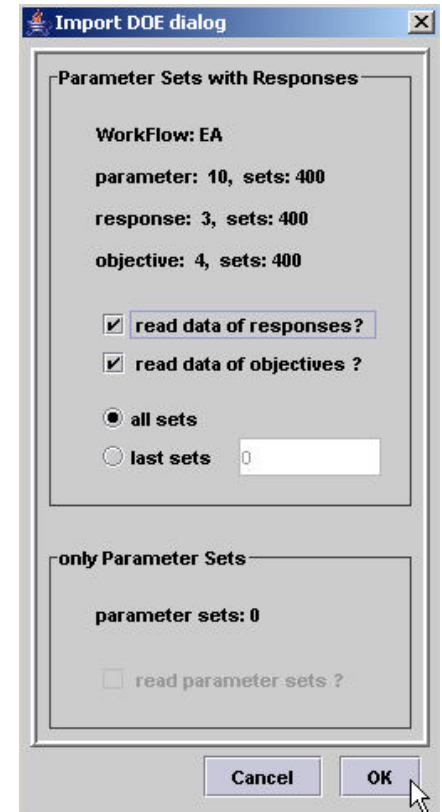
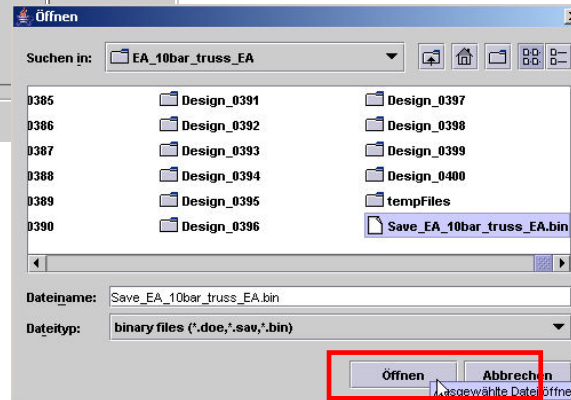
Settings for the Evolution Strategy (ES)

- Population size (μ) 1
- Start population yes
- Constraint handling parameter free
- Max. number of generations 40
- Ranking method linear
- Number of parents (λ) 5
- Seletion method stochastic universal sampling
- Crossover method copy/ no crossover
- Mutation rate 0.2
- Standard deviation start 0.02
- Adaptive mutation yes
- Archive size $1 \rightarrow (1+5)\text{strategy}$

Subflows of the evolutionary algorithm



- Import existing result file from the EA strategy



File import dialog:
Import the file e.g.

“Save_EA_10bar_truss_EA.bin”

Subflows of the evolutionary algorithm

GA start-population

DOE & SAMPLING Bounds

Design of Experiment

- ☐ linear
- ☐ quadratic
- ☐ D-optimal linear
- ☐ D-optimal quadratic
- ☒ central composite
- ☐ full factorial
- ☐ axial sensitive

samples per parameter

3

#	SELECT	Source	Design Number	obj1	obj2
380	☒	IMPORT[1]: S...	380	1693.850972	9.8730072
357	☐	IMPORT[1]: S...	357	1744.567788	9.2358929
378	☐	IMPORT[1]: S...	378	1747.489789	11.026841
336	☐	IMPORT[1]: S...	336	1751.453973	10.475121
340	☐	IMPORT[1]: S...	340	1757.081441	10.475121
397	☐	IMPORT[1]: S...	397	1758.654237	9.7646078
399	☐	IMPORT[1]: S...	399	1764.538191	9.7646078
339	☐	IMPORT[1]: S...	339	1764.608446	10.526335
390	☐	IMPORT[1]: S...	390	1766.853961	9.7646078
347	☐	IMPORT[1]: S...	347	1771.323483	10.475121
386	☐	IMPORT[1]: S...	386	1772.377213	9.8934881
396	☐	IMPORT[1]: S...	396	1776.826672	10.475121
394	☐	IMPORT[1]: S...	394	1783.479744	11.026841
383	☐	IMPORT[1]: S...	383	1790.865647	9.8730072
349	☐	IMPORT[1]: S...	349	1794.07576	10.237887
375	☐	IMPORT[1]: S...	375	1795.554791	10.475121
278	☐	IMPORT[1]: S...	278	1797.015544	8.9336886

All +

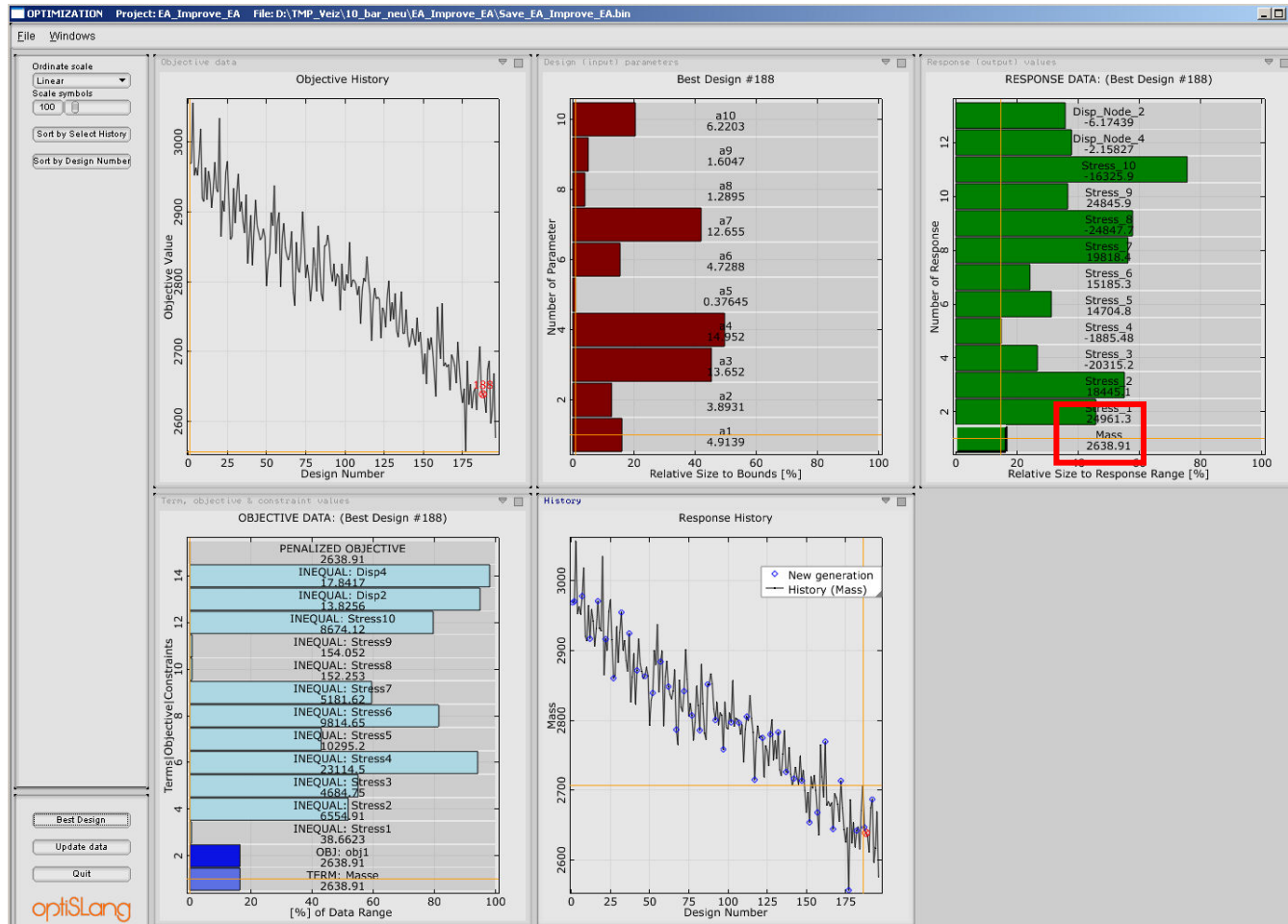
All -

Add

I Start population dialog

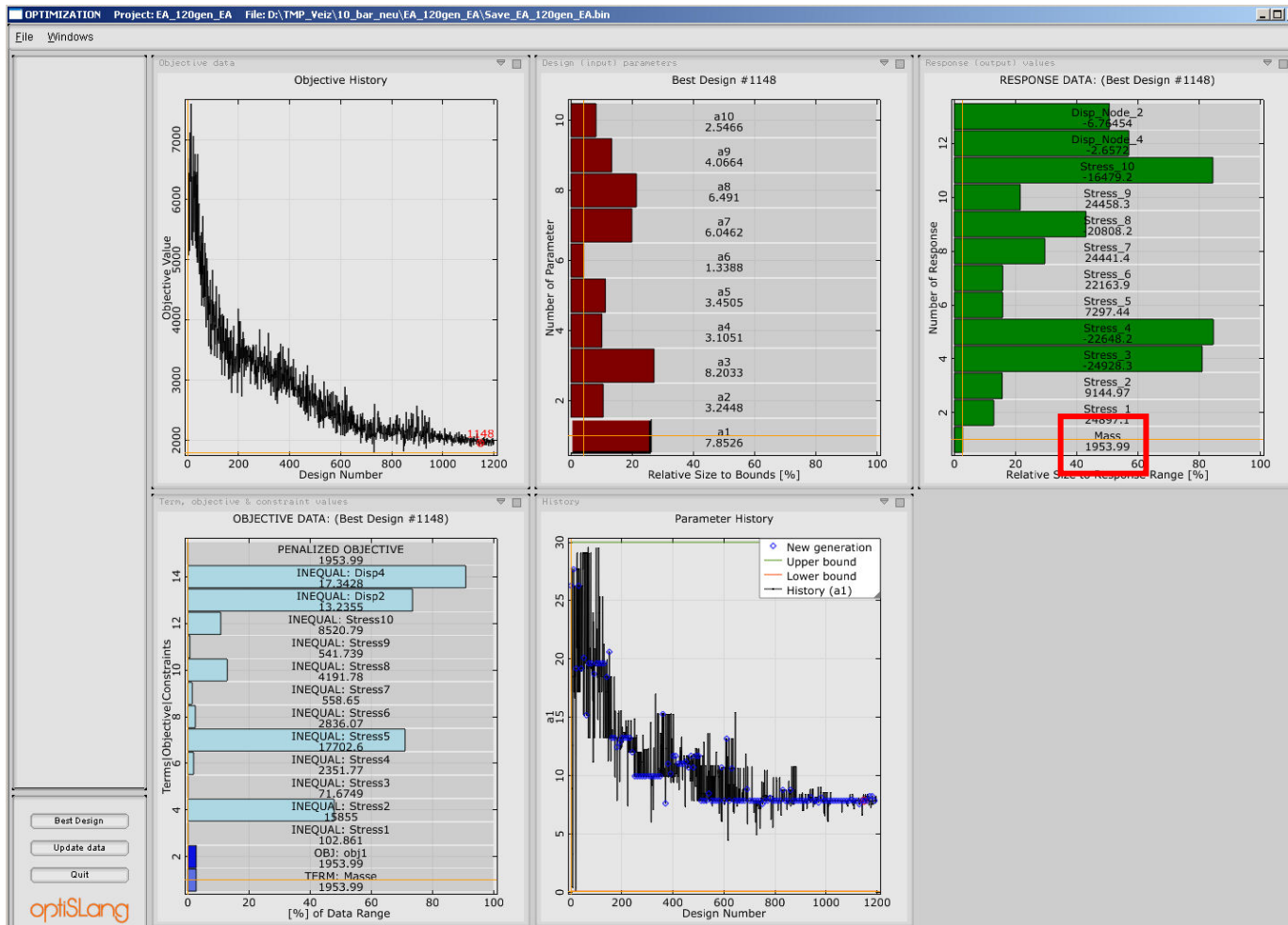
- Revalue objective and constraints
- Sort designs by objective in ascending order
- Select best feasible solution as start design

Postprocessing for the design improvement



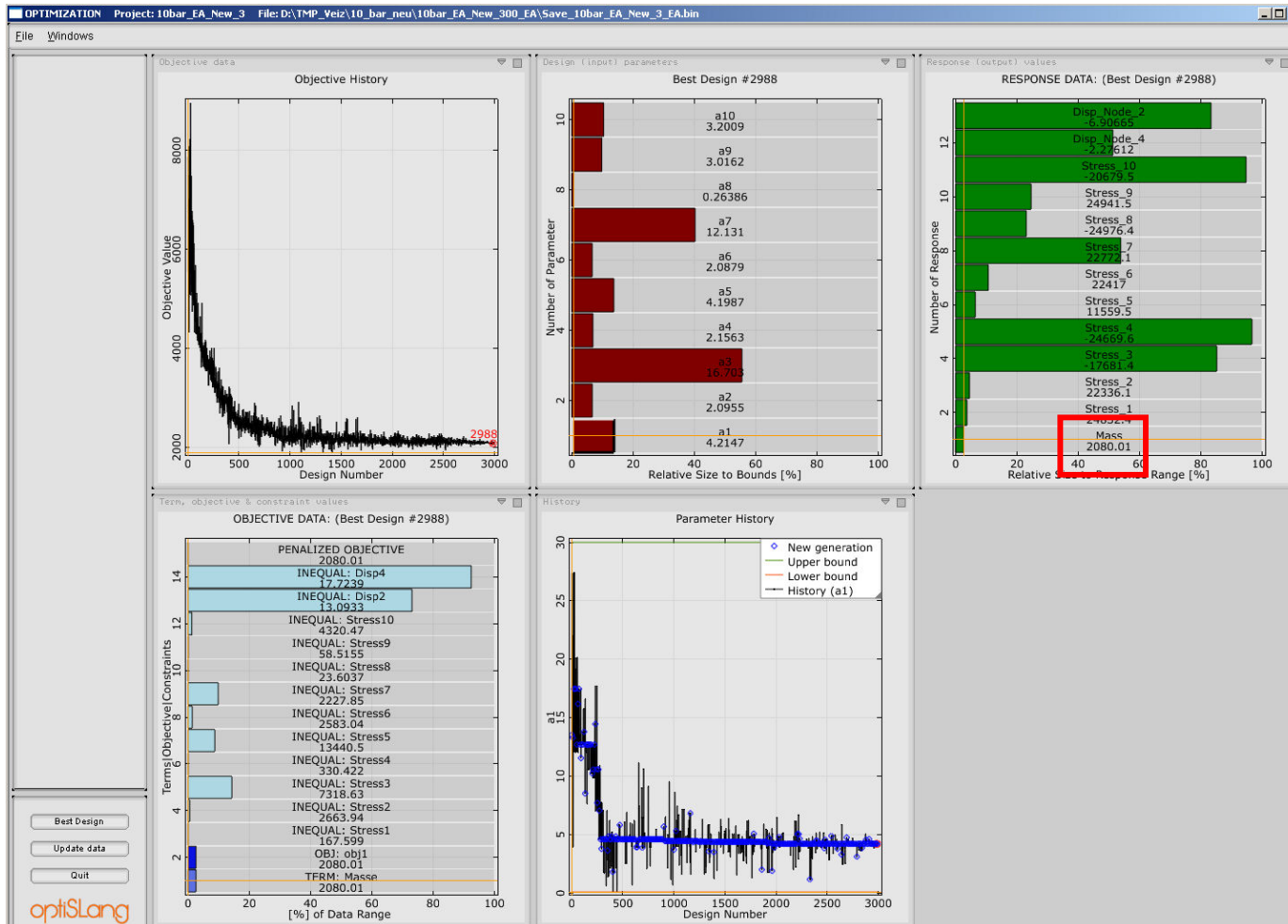
- Initial mass:
12589,4
- First optimization (EA),
mass: 2968,6
- Second optimization (evolution strategy),
mass: 2638,9

Result of the EA after 120 generations



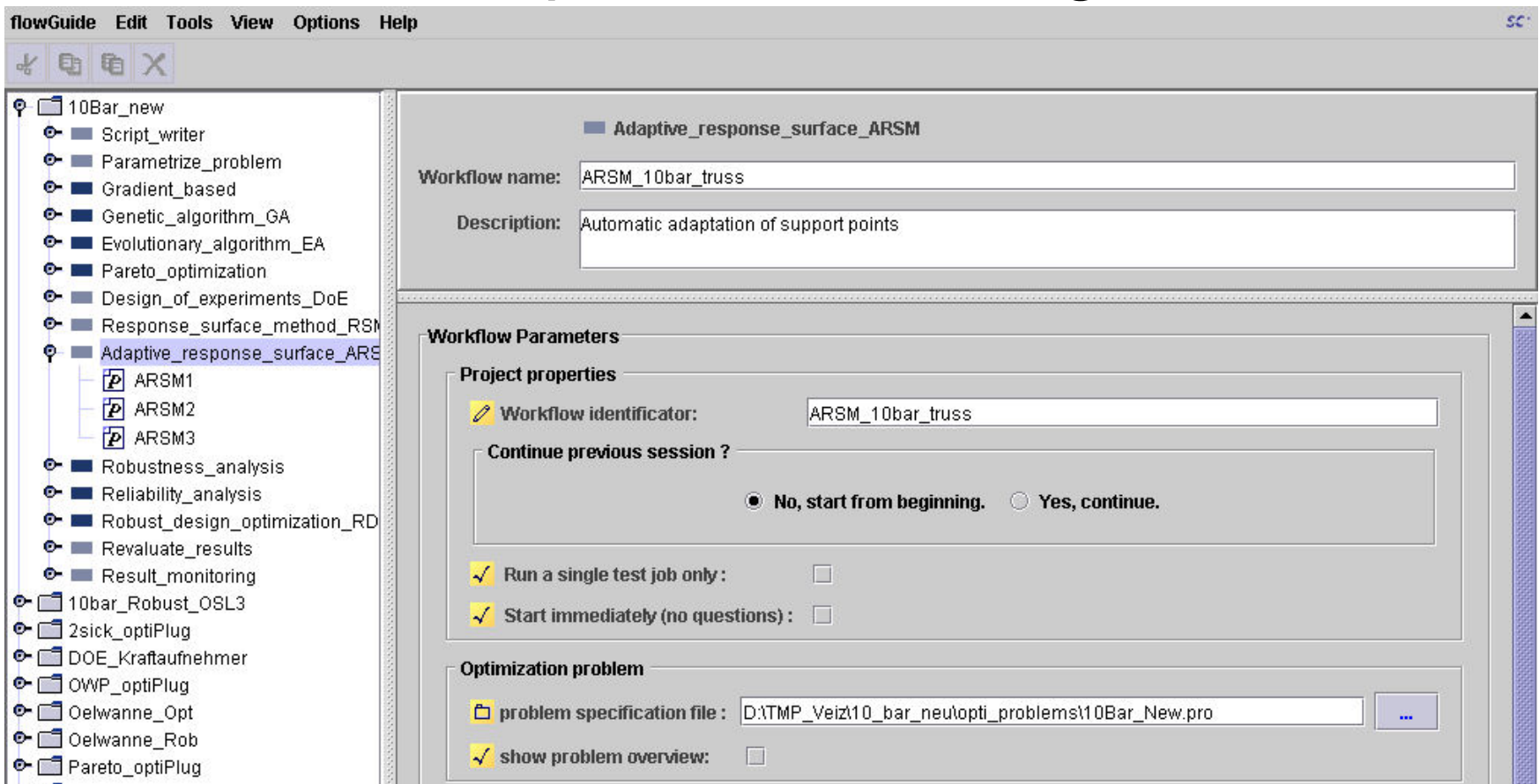
- Initial mass: 12589,4
- EA result after 120 generations mass: 1954

Result of the EA after 300 generations



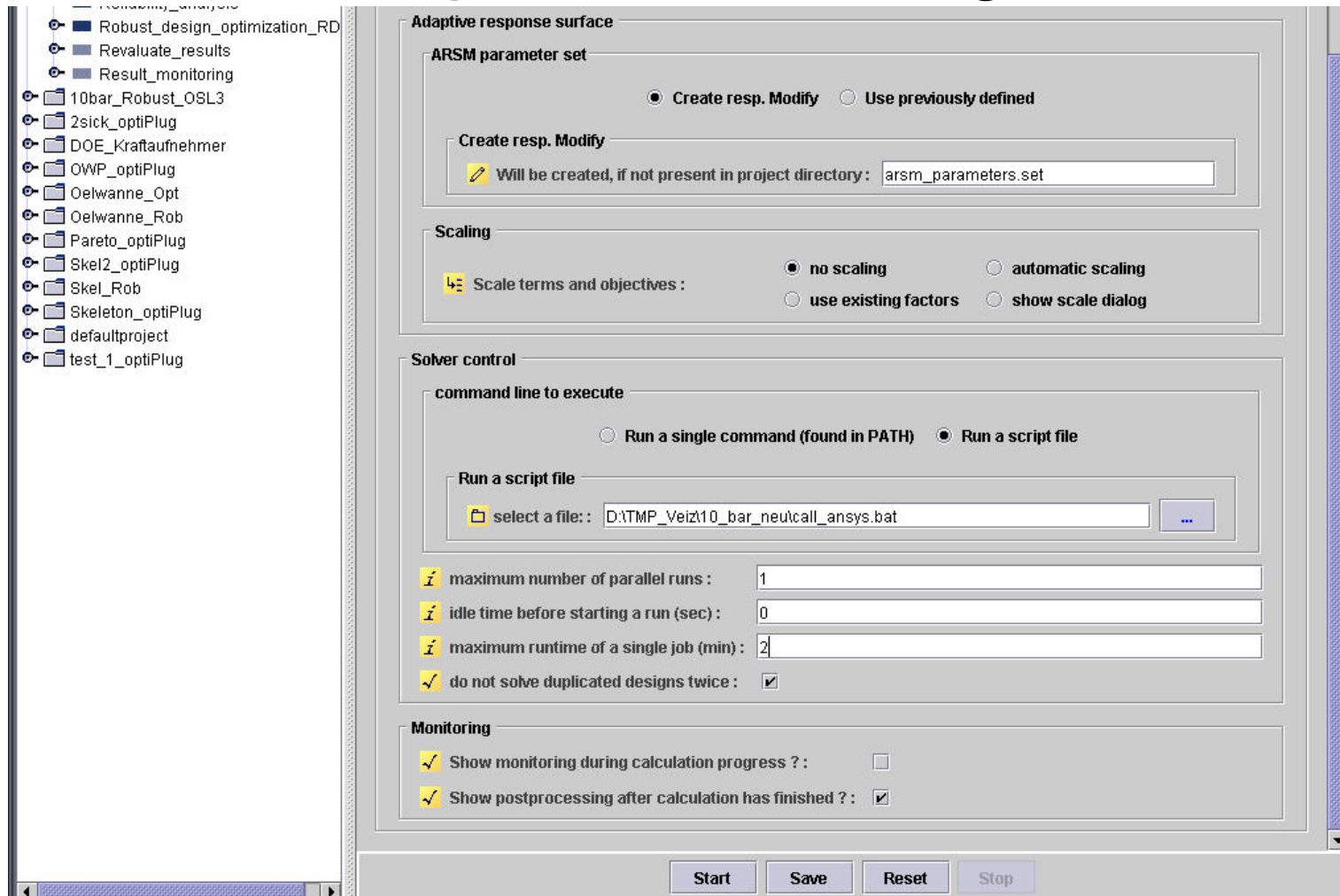
- Initial mass: 12589,4
- EA result after 300 generations mass: 2080

Workflow optimization using ARSM I



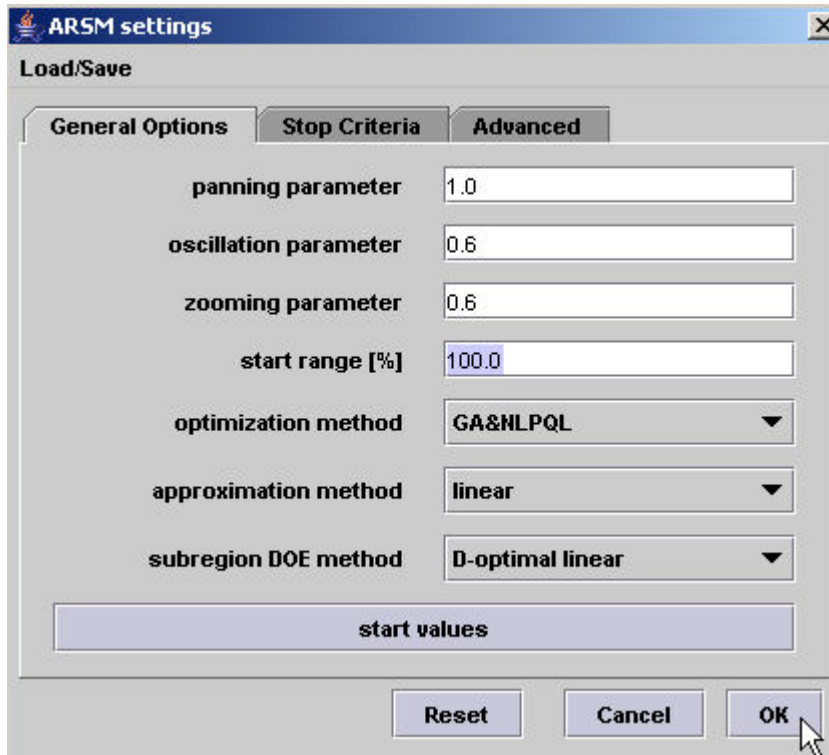
- Create a new workflow of “ARSM”
- Define “Workflow name” and “Workflow identifier”, e.g. “10bar_ARSM”
- Use predefined optimization problem (*.pro)

Workflow optimization using ARSM II



- Select the script bat file “call_ansys.bat” for starting the solver
- Save the setting and start the flow

ARSM settings



ARSM settings

Load/Save

General Options Stop Criteria Advanced

panning parameter 1.0

oscillation parameter 0.6

zooming parameter 0.6

start range [%] 100.0

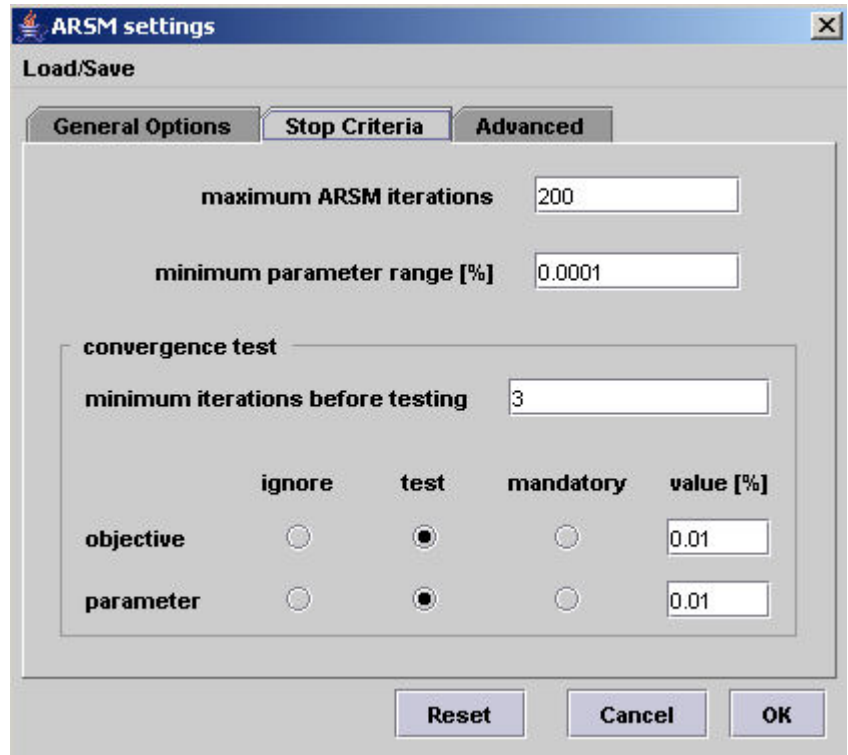
optimization method GA&NLPQL

approximation method linear

subregion DOE method D-optimal linear

start values

Reset Cancel OK



ARSM settings

Load/Save

General Options Stop Criteria Advanced

maximum ARSM iterations 200

minimum parameter range [%] 0.0001

convergence test

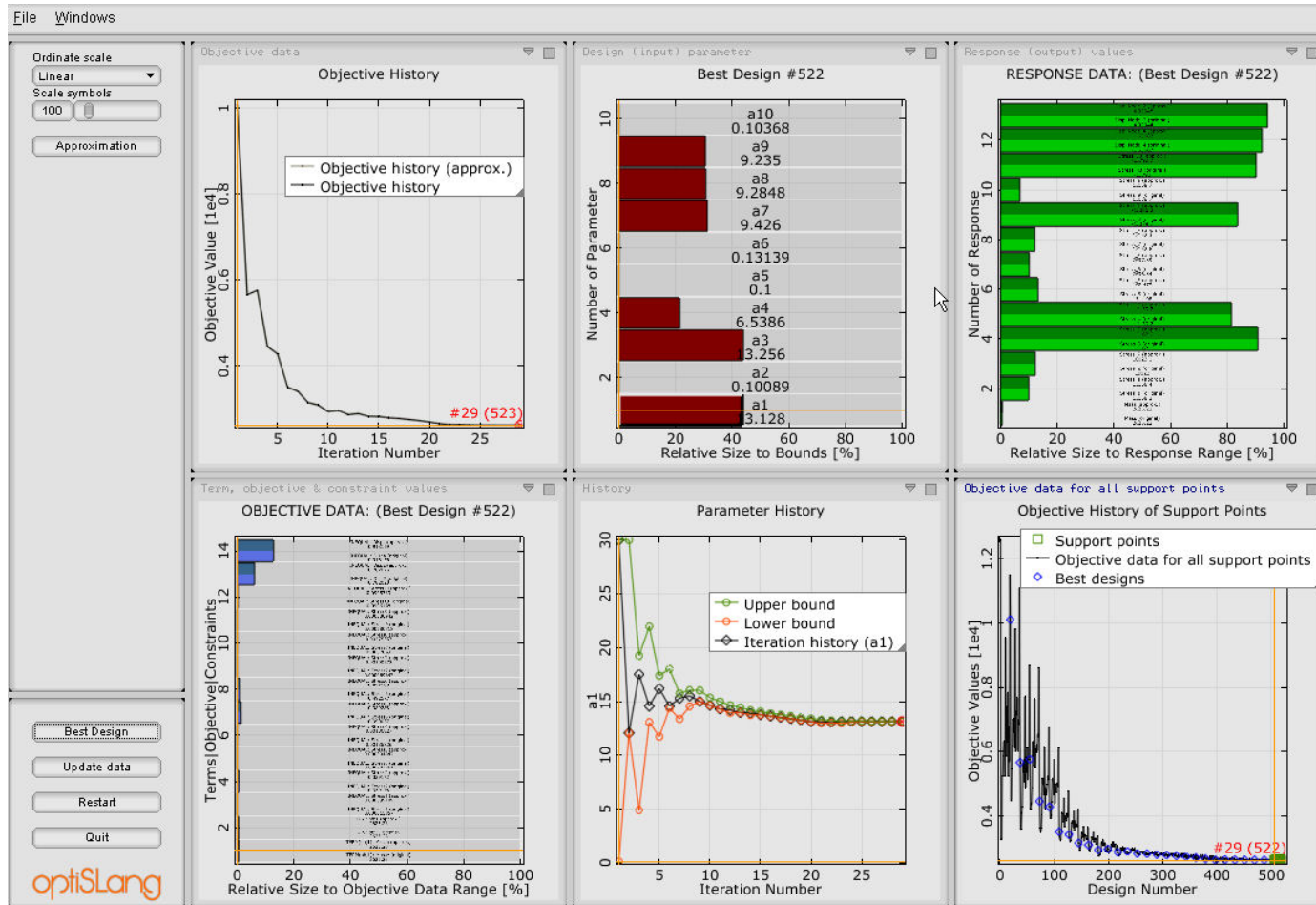
minimum iterations before testing 3

	ignore	test	mandatory	value [%]
objective	☐	☒	☐	0.01
parameter	☐	☒	☐	0.01

Reset Cancel OK

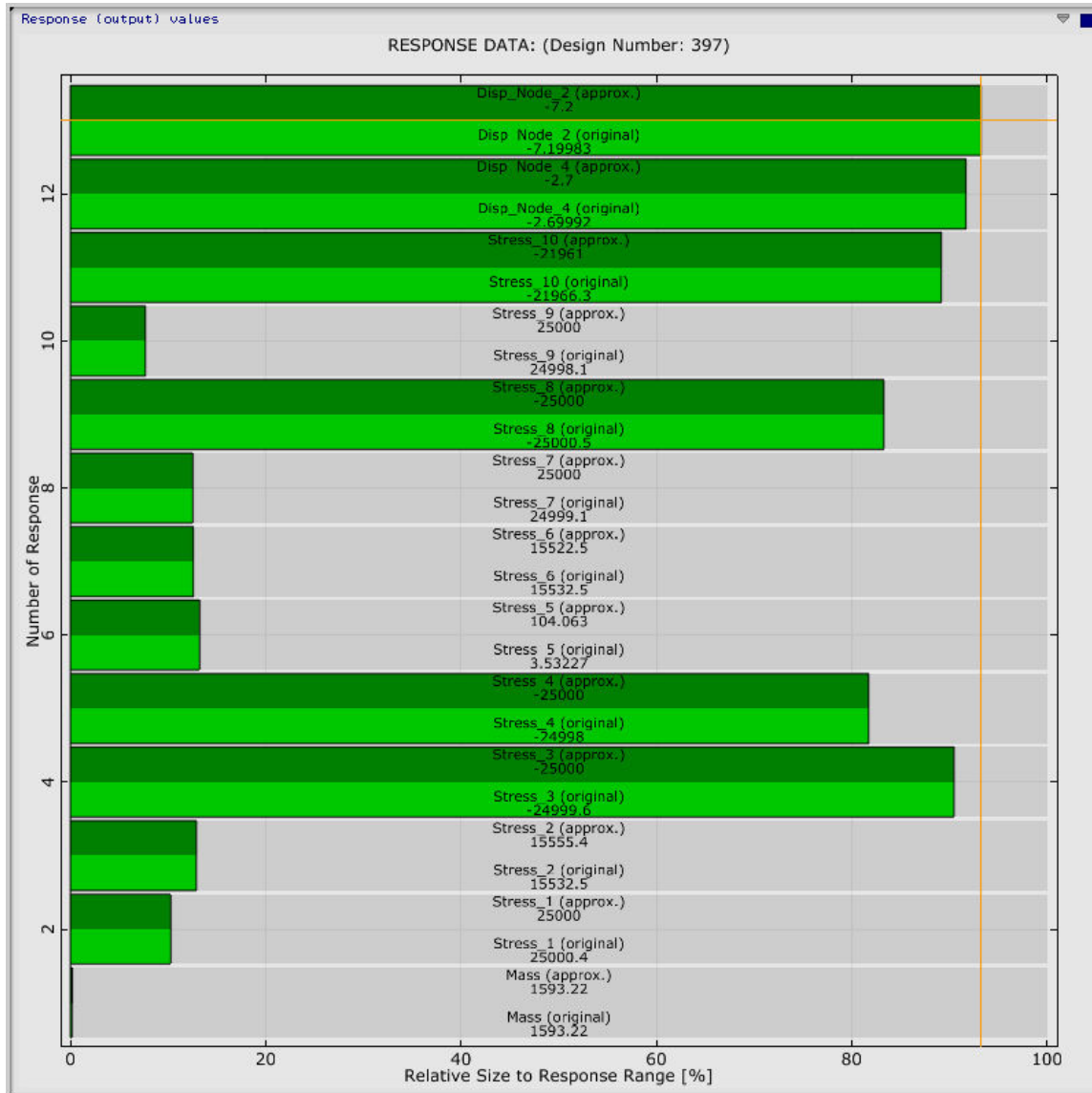
- Change the Settings as shown above:
- Optimization method to “Ga&NLPQL”
- Start range [%] to 100.0

Postprocessing ARSM



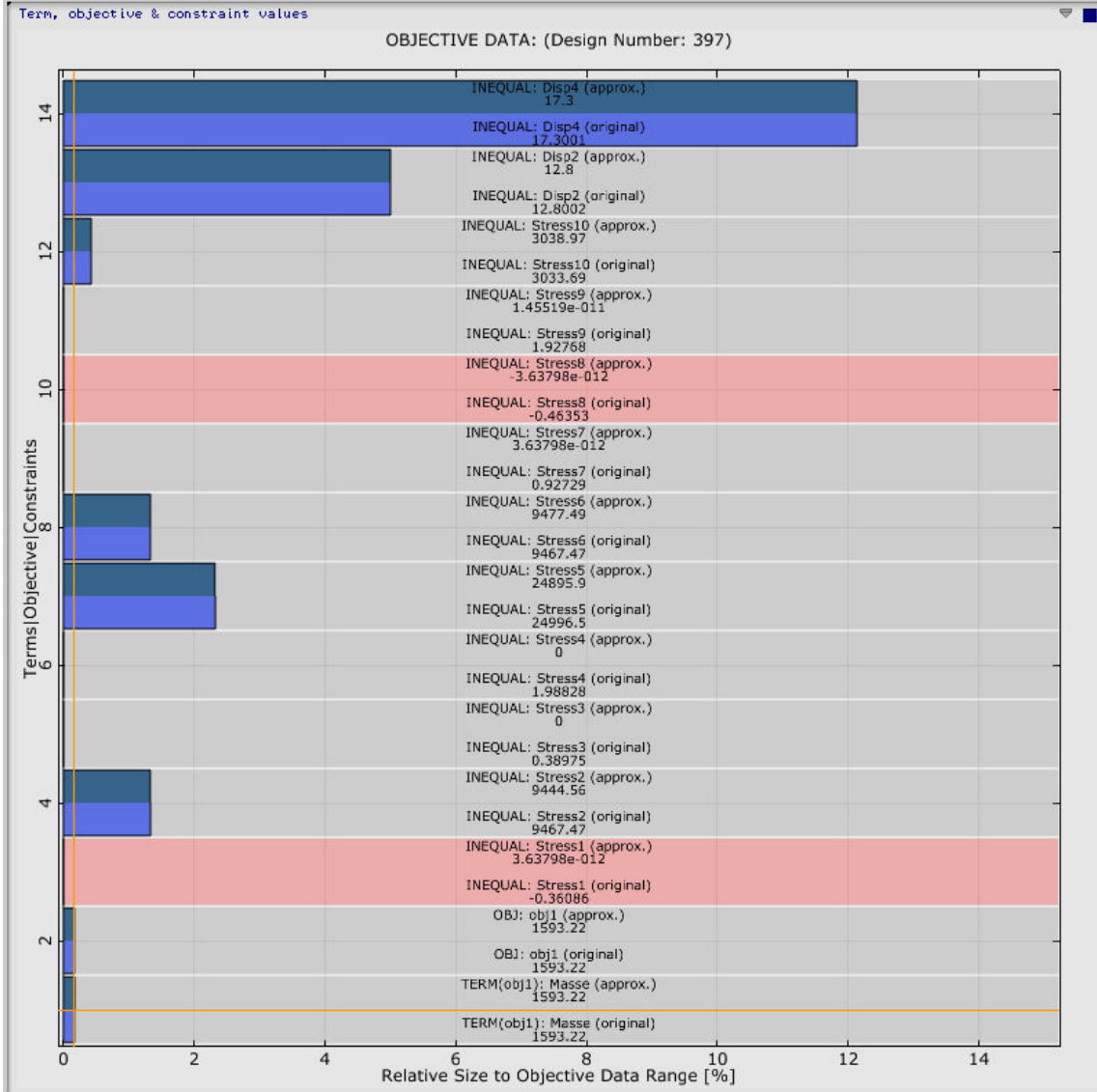
- Initial mass: 12589,4
- ARSM result after 522 designs for the mass: 2625
- The Response Data and the Objective Data is shown on the following pages

Postprocessing ARSM



- Initial mass:
12589,4
- ARSM result after
397 designs for the
mass: 1593,22

Postprocessing ARSM



- You see that in two cases the stress constraint is slightly violated. The magnitude of this is negligible!

Comparing the methods

	Initial Values		Reference Calculation		EA (40 generations)		EA (Improvement)		EA (120 generations)		EA (300 generations)		ARSM	
Units	US	SI	US	SI	US	SI	US	SI	US	SI	US	SI	US	SI
Mass	12589,4 lb	5710,5 kg	1593,2	722,7	2968,6	1346,6	2638,9	1197,0	1954	886,3	2080	943,5	1593,2	722,7
A1	30 sq.in	19354,8 mm ²	7,94	5122,6	5,01	3232,3	4,91	3167,7	7,85	5064,5	4,21	2716,1	7,94	5122,6
A2	30 sq.in	19354,8 mm ²	0,1	64,5	5,02	3238,7	3,89	2509,7	3,24	2090,3	2,09	1348,4	0,1	64,5
A3	30 sq.in	19354,8 mm ²	8,06	5200,0	15,72	10141,9	13,65	8806,4	8,2	5290,3	16,7	10774,2	8,06	5200,0
A4	30 sq.in	19354,8 mm ²	3,94	2541,9	17,34	11187,1	14,95	9645,1	3,1	2000,0	2,15	1387,1	3,94	2541,9
A5	30 sq.in	19354,8 mm ²	0,1	64,5	0,27	174,2	0,38	245,2	3,45	2225,8	4,2	2709,7	0,1	64,5
A6	30 sq.in	19354,8 mm ²	0,1	64,5	4,6	2967,7	4,73	3051,6	1,34	864,5	2,09	1348,4	0,1	64,5
A7	30 sq.in	19354,8 mm ²	5,75	3709,7	14,63	9438,7	12,66	8167,7	6,04	3896,8	12,13	7825,8	5,75	3709,7
A8	30 sq.in	19354,8 mm ²	5,57	3593,5	1,29	832,3	1,29	832,3	6,49	4187,1	0,26	167,7	5,57	3593,5
A9	30 sq.in	19354,8 mm ²	5,57	3593,5	1,26	812,9	1,6	1032,3	4,07	2625,8	3,02	1948,4	5,57	3593,5
A10	30 sq.in	19354,8 mm ²	0,1	64,5	7,2	4645,2	6,22	4012,9	2,55	1645,2	3,2	2064,5	0,1	64,5
Disp. Max	-1,31 in	-33,4 mm	-7,2	-182,9	-5,67	-144,0	-6,17	-156,7	-6,76	-171,7	-6,91	-175,5	-6,99	-177,5
Stress Max	6821 psi	47 Mpa	25000	172,4	24800	171,0	24961	172,1	24897	171,7	24796	171,0	25000	172,4
Designs					400		196		1200		3000		397	

Conclusion

- Best method for this problem is the ARSM.
- It is fast and achieves highest reduction of the mass.
- Now, start a robustness analysis to check wheather you have developed a robust design.
- Perform a reliability analysis to determine the probability of failure for your design.