

Topology Optimization

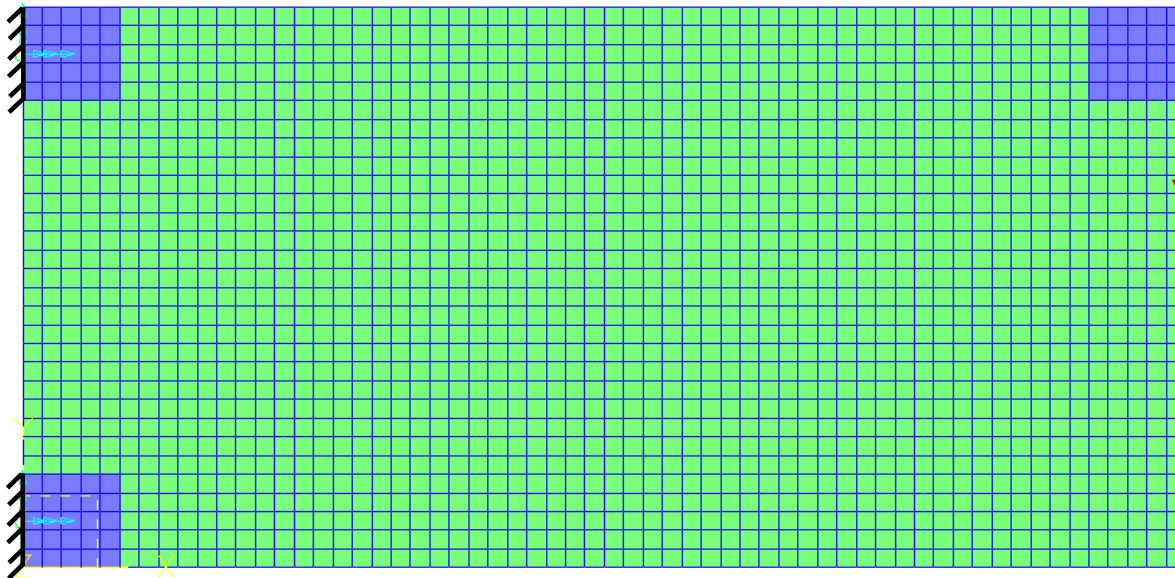


**ENGINEERING CENTER STEYR
GmbH & Co KG**

FEMFAT User Meeting, 13th May 2005

Topology Optimization

Example: FE-Model Biegebalken



$F = 200\text{N}$
oscillating, $N = 1.000.000$

1800 shell elements 5x5x10mm

■ design area, 1725 elements

■ frozen area, 75 elements

Topology Optimization

Workflow

- **FE-Modell** ⇒ **Biegebalken.dat** ✓
- **Parameter File** ⇒ **TOSCA.gui**

Topology Optimization

Group Definition

The screenshot shows the TOSCA GUI interface for defining optimization groups. On the left, a tree view shows the project structure under 'Optimization Task'. The 'GROUP_DEF' folder is expanded, and 'frozen_elements' is selected. The main window displays the 'GROUP_DEF' dialog with the following details:

- ID_NAME:** frozen_elements
- Type:** Element
- Format:** List
- Data:** 2000-2074

Buttons at the bottom include 'Modify', 'Create', 'Close', and 'Delete'. The status bar at the bottom indicates 'GROUP_DEF command loaded in editor' and 'Queue is empty'.

Topology Optimization

Definition loadcases and controller input

The screenshot shows the TOSCA GUI interface for defining loadcases and controller inputs. The interface is divided into several sections:

- Command List:** A list of commands on the left side of the main window, including `CTRL_INPUT` and `CTRL_LC`, which are circled in red.
- Definition Area:** The main area where the user defines the parameters for the selected command. It shows the definition for `CTRL_LC` and `CTRL_INPUT`.
- Annotations:** Two arrows point from text labels to the definition area:
 - "definition damage loadcase" points to the `CTRL_LC` definition.
 - "definition controller input" points to the `CTRL_INPUT` definition.

CTRL_LC Definition:

```

CTRL_LC
ID_NAME      = I_C_DAMAGE
LC_OPER      = ADD, 0
LC_NORM      = ORIGINAL
LC_SET       = ALL,,
END_
    
```

CTRL_INPUT Definition:

```

CTRL_INPUT
ID_NAME      = CTRL_INPUT_DAMAGE
LC_COMB      = MAX
GLOBAL_OPER  = MULT, 1.0
HYPO        = DAMAGE_IC
CTRL_LC     = I_C_DAMAGE
END_
    
```

OBJ_FUNC Definition:

```

OBJ_FUNC
ID_NAME      = minimize_sum_energy
TARGET      = MIN
DRESP       = DRESP_SUM_ENERGY
END_
    
```

Buttons at the bottom include `Modify`, `Create`, `Close`, and `Delete`.

Topology Optimization

Definition controller input

```
GROUP_OPER = Sum
EL_GROUP   = opt_elements
END_

CTRL_LC
  ID_NAME   = LC_DAMAGE
  LC_OPER   = ADD, 0
  LC_NORM   = ORIGINAL
  LC_SET    = ALL,,
END_

CTRL_INPUT
  ID_NAME   = CTRL_INPUT_DAMAGE
  LC_COMB   = MAX
  GLOBAL_OPER = MULT 1.0
  HYPO     = DAMAGE_LC
  CTRL_LC   = LC_DAMAGE
END_

OBJ_FUNC
  ID_NAME   = minimize_sum_energy
```

requires FEMFAT onf_601 resultfile

Topology Optimization

Workflow

- FE-Modell ⇒ Biegebalken.dat ✓
- Parameter File ⇒ TOSCA.gui ⇒ Biegebalken.par ✓
- FEMFAT job File ⇒ FEMFAT gui

Topology Optimization

- According actual stress results read from actual op2 – file

Stress Data

File Format: **NASTRAN OP2**

Data Location: At Nodes on Element Averaged at Nodes

Data Type: Amplitude/Mean Upper/Lower

Stress Amplitude Mean Stress Constant Stress Temporary Stress Dataset

Note: If there is no mean stress, amplitude stress will be copied to mean stress

Input File: ...

Number of Element Stress Data found: 0

Data Operations

Delete Stress Dataset

Multiply Factor: **150.00000**

Copy Stress Amplitude Mean Stress Constant Stress

Add Temporary Stress Dataset

Current Dataset

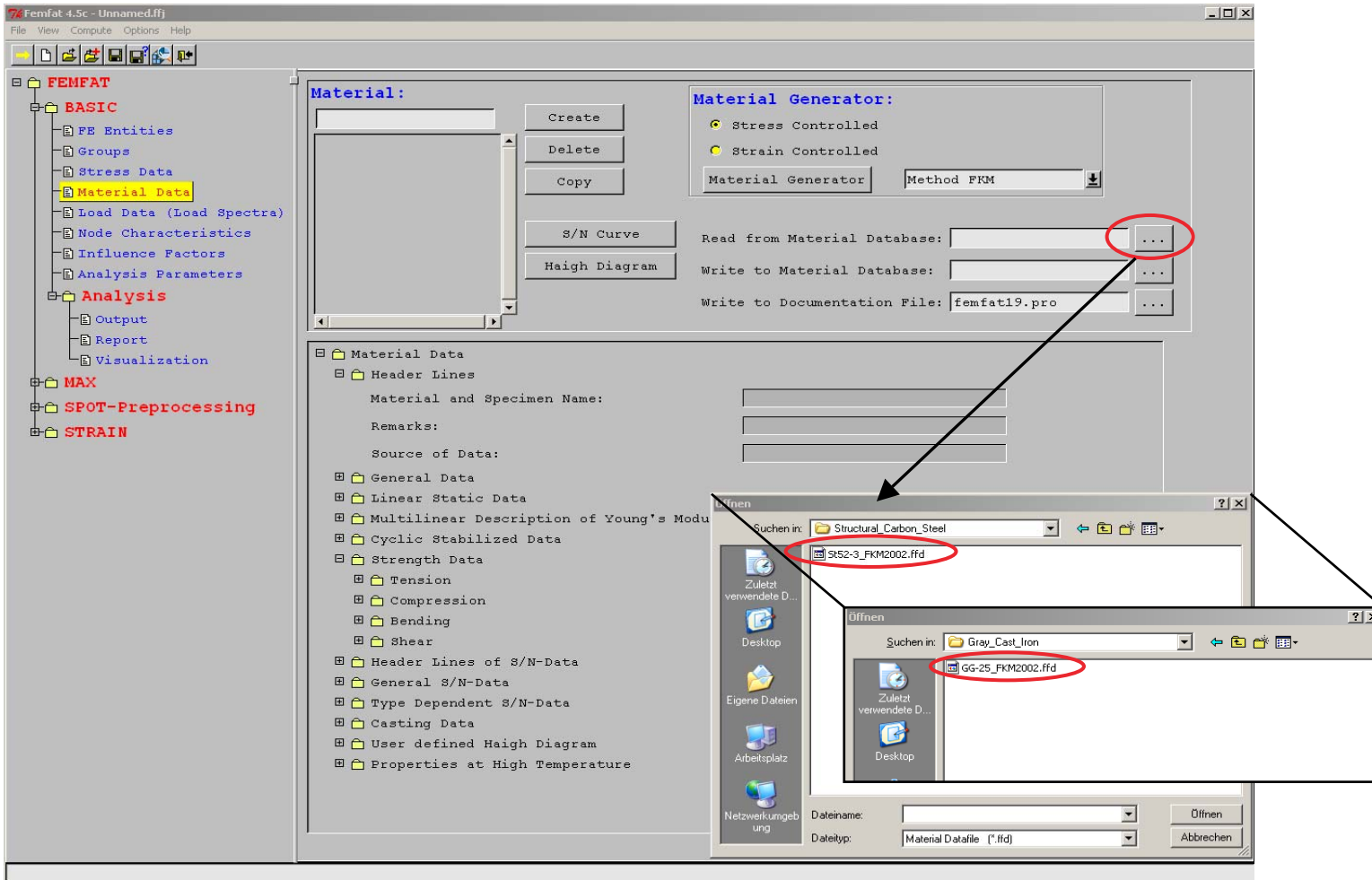
Element with Highest Max. Principal Stress:

Element Label:	Location:	Sigma xx:	Sigma yy:	Sigma zz:	Sigma xy:	Sigma yz:	Sigma xz:	Max. Principal Stress:
0	On Solid	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]	0.000e+000 [N/mm ²]

150 for steel
50 for gray cast iron

Topology Optimization

- Material: FEMFAT material dataset .ffd imported



Topology Optimization

- Load: generate collective load

The screenshot shows the Femfat 4.5c software interface. The 'Load Data' dialog is open, showing a list of load data items. The 'LoadData New Dialog' is also open, showing the 'General Load Spectrum Specification' dialog. The 'LoadData New Dialog' has the following fields:

- Load Data Label: 1
- Name of Measure Object: Rechteckskollekt
- Designation of Measure Section:
- Channel designation:
- Unit of Channel:

The 'Load Data' dialog shows a list of load data items, with '1 - Rechteckskollekti' selected. Below it, a table shows the number of load cycles (N) for step 1 as 1000000.

Step	N	Fact. Ampl	Fact. Mean
1	1000000	1.0000	1.0000

N loadcycles

Topology Optimization

- Output: results have to be written in onf600 or onf601-format

Permanent Scratch | Output Settings | Output Modification | Module Specific Output

Output File

File Type: TOSCA ONF 601
 File Write Mode: Write
 File Name: al/en/Biegebalken_601.onf ... Write

Output Setting

Maximum Number of Outputs: 6 Reset Delete All

Output Results Selected:

Col	Result	Group
1	6th Root(Safety Factor A - Damage)	Main

Main | Stress | Gen. Factors | Surface | Miscellaneous | HEAT

Main Results

Result	Column
Safety Factor A - Damage - Degree of Multiaxiality:	0
Safety Factor B:	0
Inverse(Safety Factor A - Damage - Degree of Multiaxiality):	0
Inverse(Safety Factor B):	0
Relative Stress Gradient:	0
SPOT - Detailed Result:	0
Log10(Safety Factor A - Damage - Degree of Multiaxiality):	0
Log10(Inverse Safety Factor A - Damage - Degree of Multiaxiality):	0
6th Root(Safety Factor A - Damage):	6

required for optimization

Topology Optimization

Workflow

- FE-Modell ⇒ Biegebalken.dat ✓
- Parameter File ⇒ TOSCA.gui ⇒ Biegebalken.par ✓
- FEMFAT job File ⇒ FEMFAT gui ⇒ Biegebalken.ffj ✓
- TOSCA configuration File ⇒ TOSCA home path

Topology Optimization

TOSCA configuration File

```
##### NASTRAN #####
if (${fe_solver} eq "nastran") {
  $ENV("tosca interface") = "${tosca}/nastran";
  if (${Client->isWin}) {
    $(fe_solver_exe) = "D:/FEMFAT-SCHULUNG/Topo_Opti/Gray_Cast_Iron/nastran_start.bat";
    $(fe_solver_call) = "${fe_solver_exe} ${modelname}.${inp_ext} notify=no old=no";
  }else{
    $(fe_solver_exe) = "/sc301/ffischer/OPTIMIERUNG/EXAMPLE_BIEGEBALKEN_TOPO/GRAY_CAST_IRON/nastran_start";
    $(fe_solver_call) = "${fe_solver_exe}";
  }
  # ${modelname}.${inp_ext} batch=no notify=no old=no";
}
$(res_ext) = "xdb";
$(solver_add_call) = "";

add_move_per_iter_list("first_last", "SAVE.f06", "*.f06");
add_move_per_iter_list("ever", "SAVE.f04", "*.f04");
add_move_per_iter_list("ever", "SAVE.xyz", "*.xyz");
add_move_per_iter_list("ever", "SAVE.mnf", "*.mnf");
add_move_per_iter_list("ever", "SAVE.mtx", "*.mtx");
add_move_per_iter_list("ever", "SAVE.txt", "*.cut.txt");
add_move_per_iter_list("first_last", "SAVE.${res_ext}", "${modelname}.${res_ext}");

add_copy_solver_info_list("ever", "SAVE.${inp_ext}", "${modelname}.${inp_ext}");
```

NASTRAN Configuration

FEMFAT Configuration

```
##### FEMFAT #####
)elseif (${life_solver} eq "femfat") {
  $(life_interface) = "${tosca}/femfat";
  $(life_ini) = "tosca_femfat.ini";

  if (${Client->isWin}) {
    $(life_solver_exe) = "D:/FEMFAT-SCHULUNG/Topo_Opti/Gray_Cast_Iron/femfat_start.bat";
  }else {
    #UNIX Version
    $(life_solver_exe) = "/sc301/ffischer/OPTIMIERUNG/EXAMPLE_BIEGEBALKEN_TOPO/GRAY_CAST_IRON/femfat_start";
  }
  add_move_per_iter_list("first_last", "SAVE.601_dma", "${modelname}_601.onf");
  add_move_per_iter_list("first_last", "SAVE.pro", "${modelname}.pro");

  if (${fe_solver} eq "nastran"){
    add_move_per_iter_list("first_last", "SAVE.op2", "*.op2");
  }

  $life_solver_call = "${life_solver_exe}";
}
#####
```

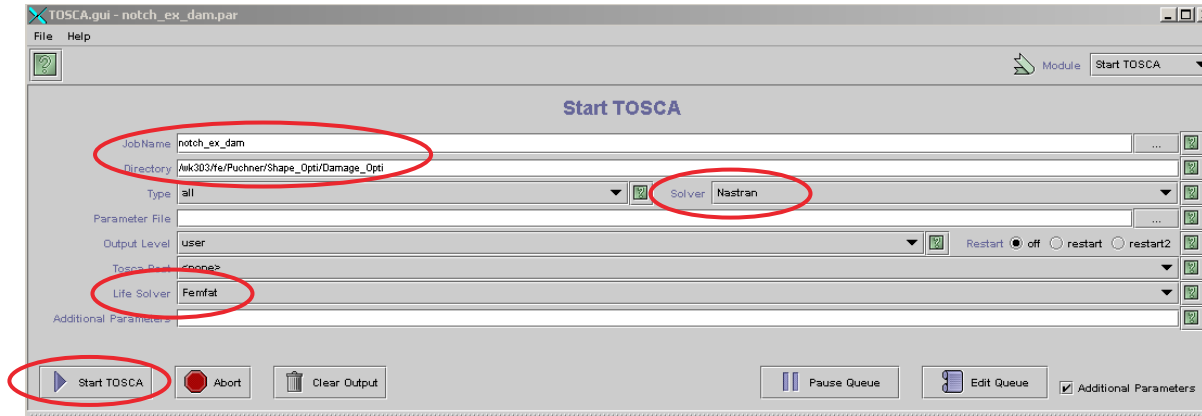
Topology Optimization

Workflow

- FE-Modell ⇒ Biegebalken.dat ✓
- Parameter File ⇒ TOSCA.gui ⇒ Biegebalken.par ✓
- FEMFAT job File ⇒ FEMFAT gui ⇒ Biegebalken.ffj ✓
- TOSCA configuration File ⇒ TOSCA home path ⇒ Biegebalken.cfg ✓
- Start optimization

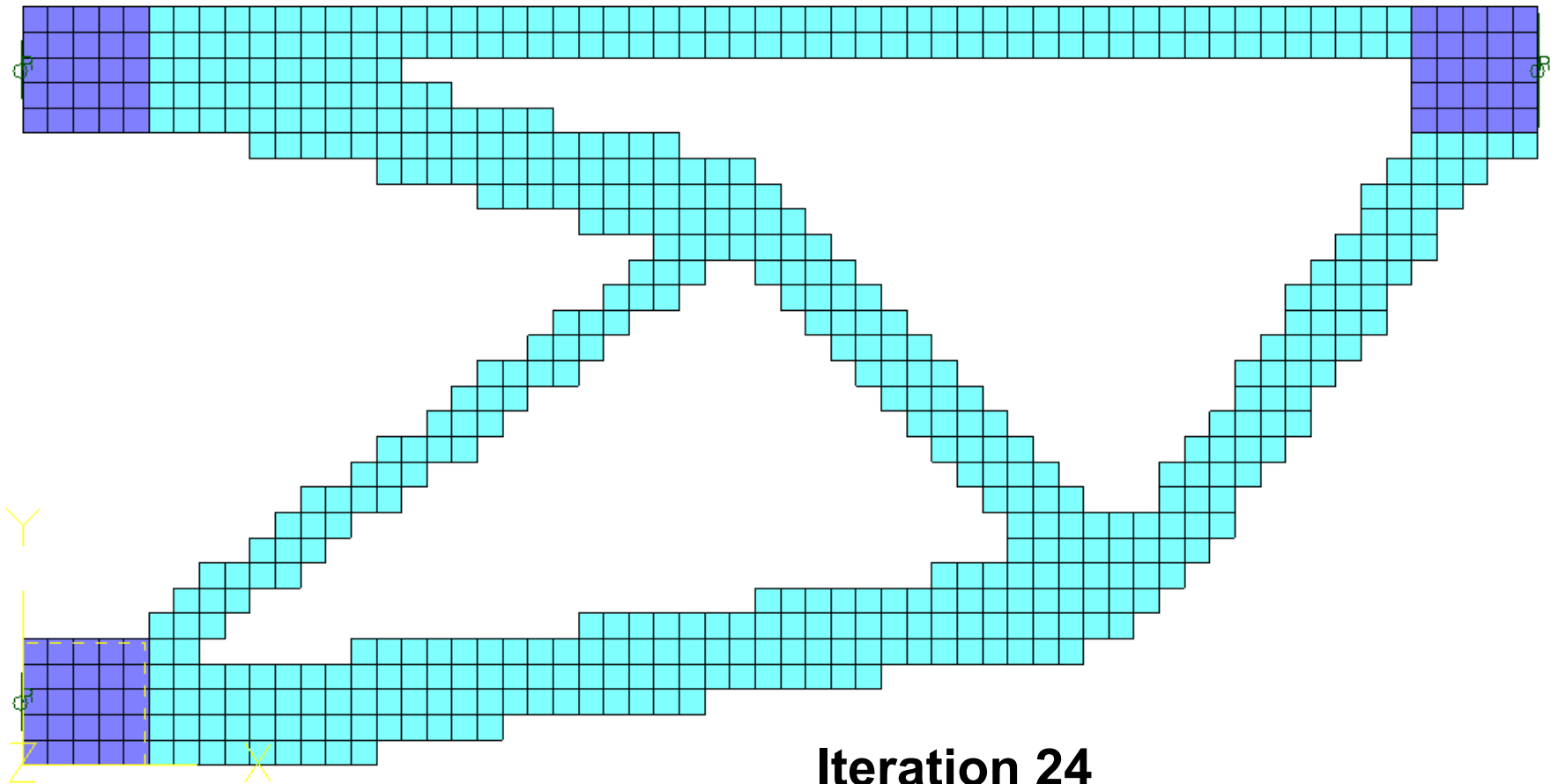
Topology Optimization

Start optimization



Topology Optimization

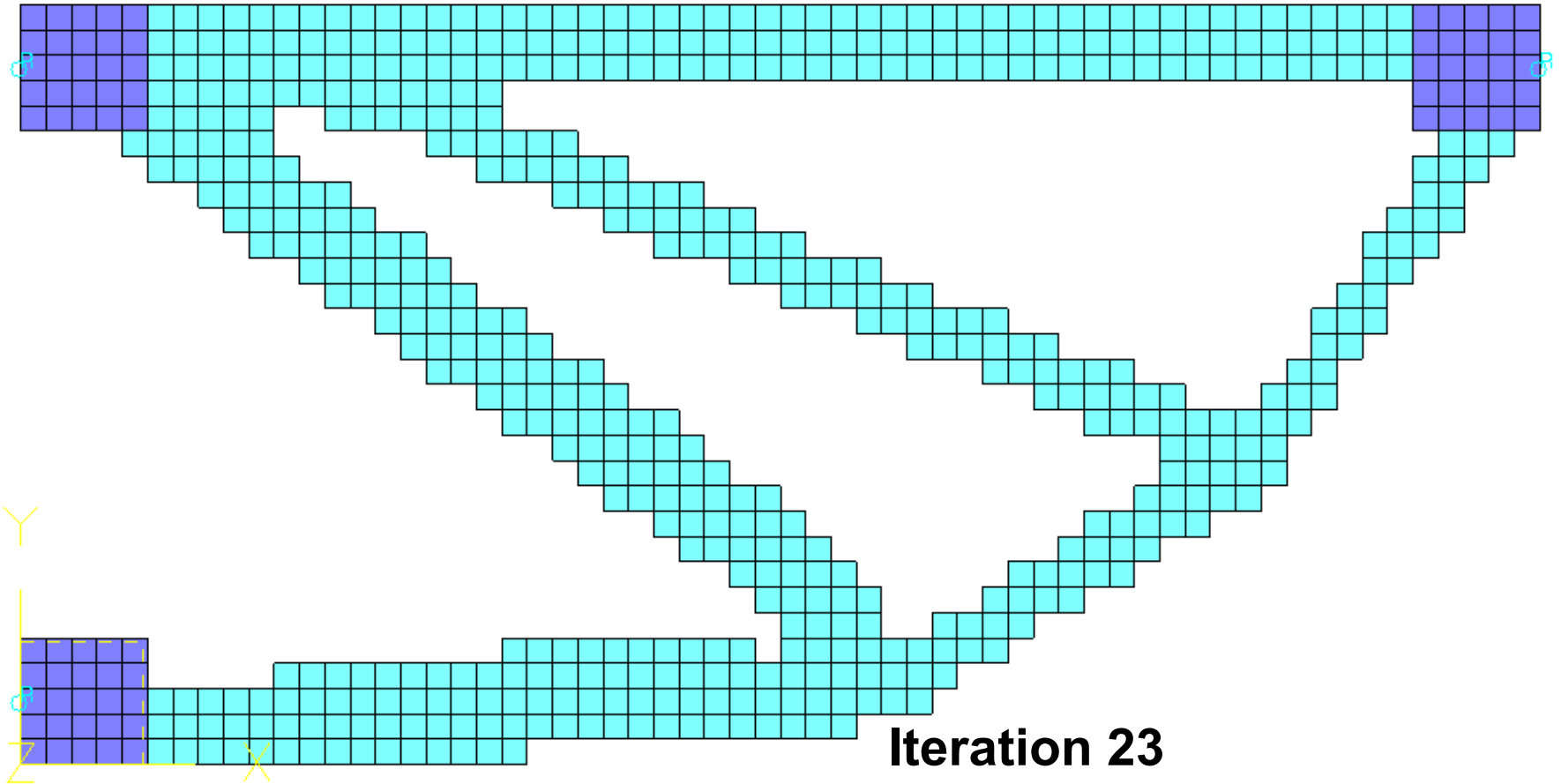
Result optimization with St52_3



Iteration 24
30 % Volume of Startmodel

Topology Optimization

Result optimization with GG-25



Topology Optimization

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- FE-Modell ⇒ Biegebalken.dat ✓
- Parameter File ⇒ TOSCA.gui ⇒ Biegebalken.par ✓
- FEMFAT job File ⇒ FEMFAT gui ⇒ Biegebalken.ffj ✓
- TOSCA configuration File ⇒ TOSCA home path ⇒ Biegebalken.cfg ✓
- Start optimization ✓