



Optimization Study of Bumper Structure

Agenda

- Scope of the study
- Design
- Process Automation
- Analysis Workflow
- DoE
- Optimization
- Conclusions

Optimization of Bumper Structures

- Absorb as much energy as possible
- Must have high strength
- Should be light
- Should be has long lifetime



Ref:<https://arabakocu.com.tr/index.php/2020/09/17/tampon-demiri/>



Ref:<https://forums.overclockers.co.uk/threads/broken-bumper-is-this-an-mot-failure.18367911/>

Design

Design parameters:

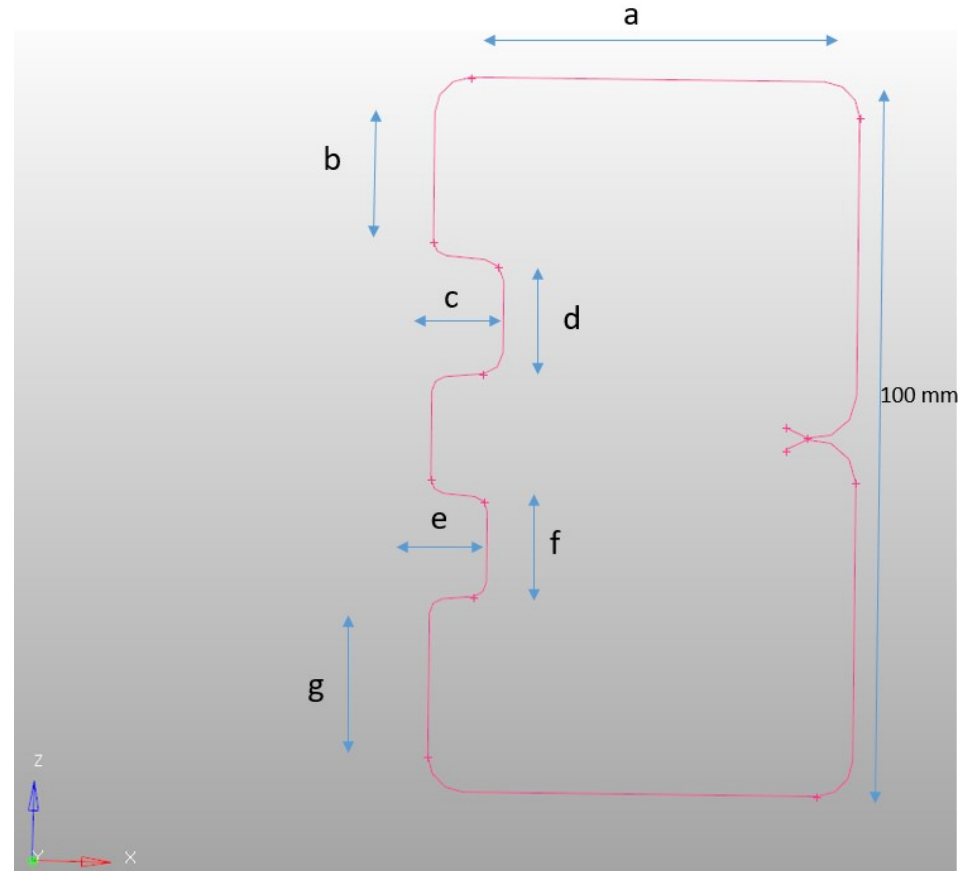
- a, b, c, d, e, f, g (dimensions)
- Profile thickness

Outputs:

- Mass
- Max. stress

Optimization goals:

- Minimum mass
- Max. Stress < Yield stress



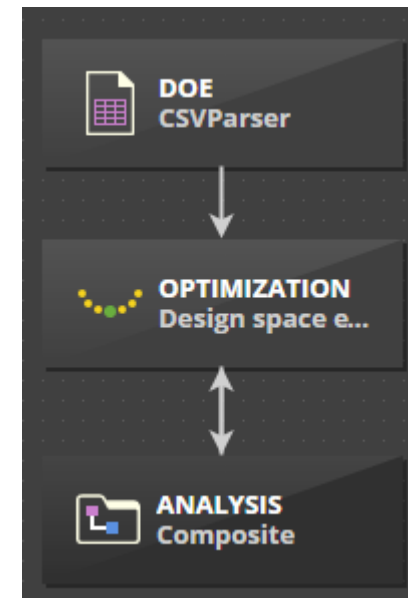
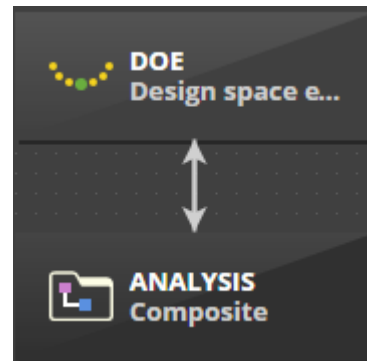
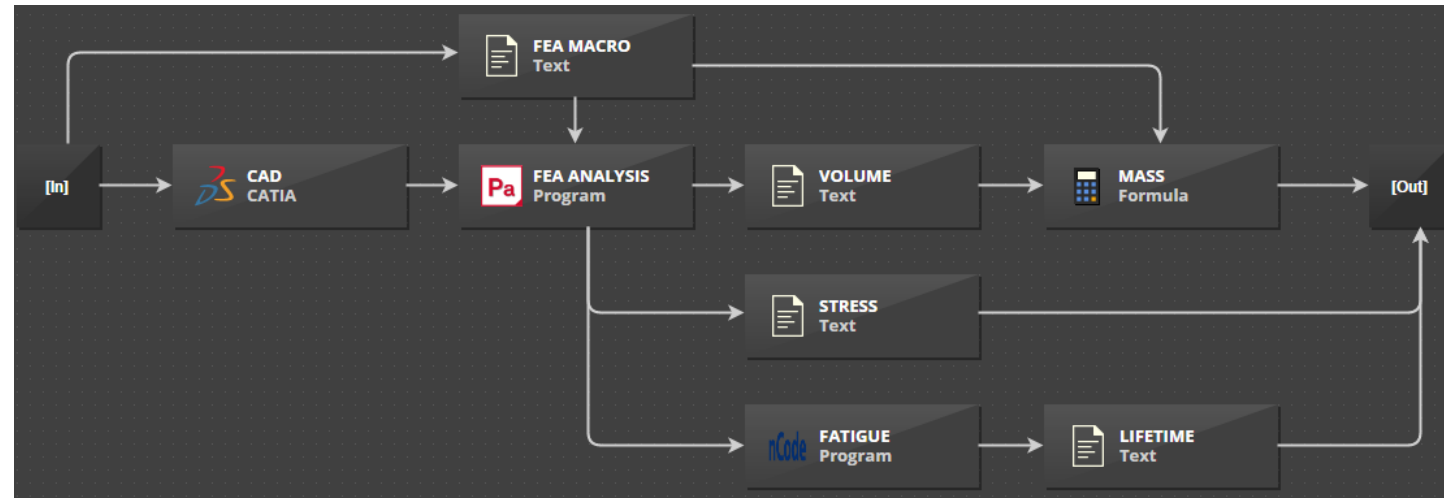
Process Automation

Geometry Preparation Steps;

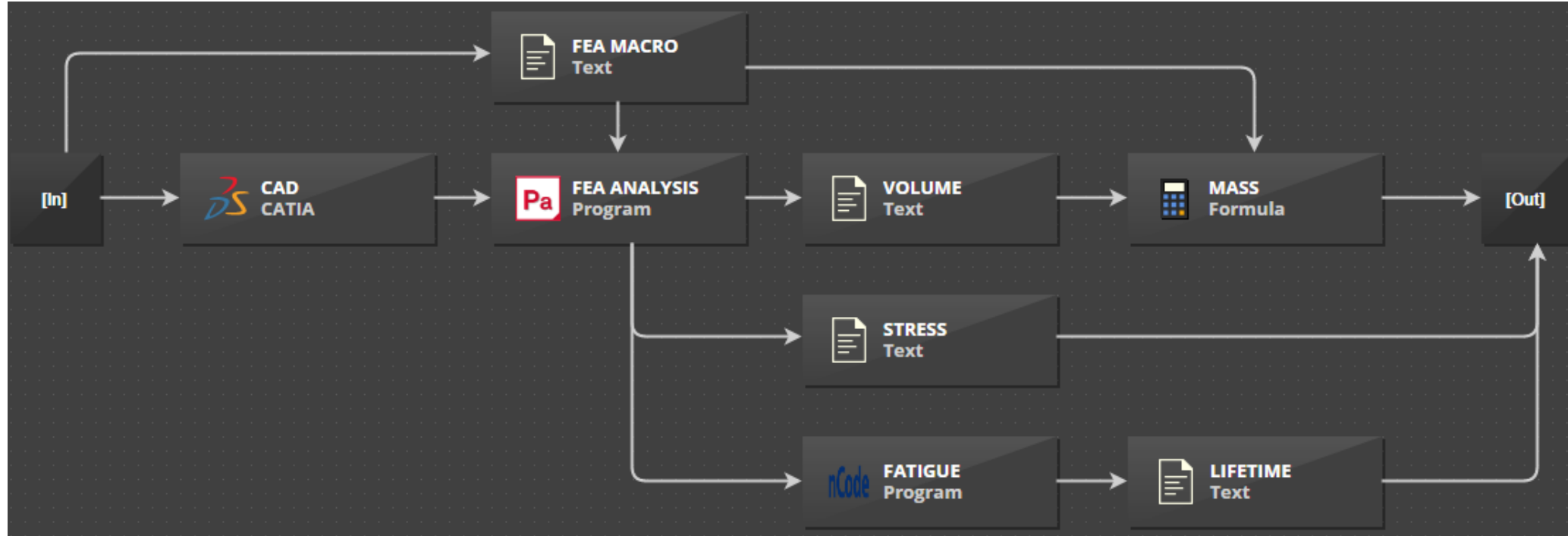
- Preparing the bumper profile in Catia

Linear Solving Steps;

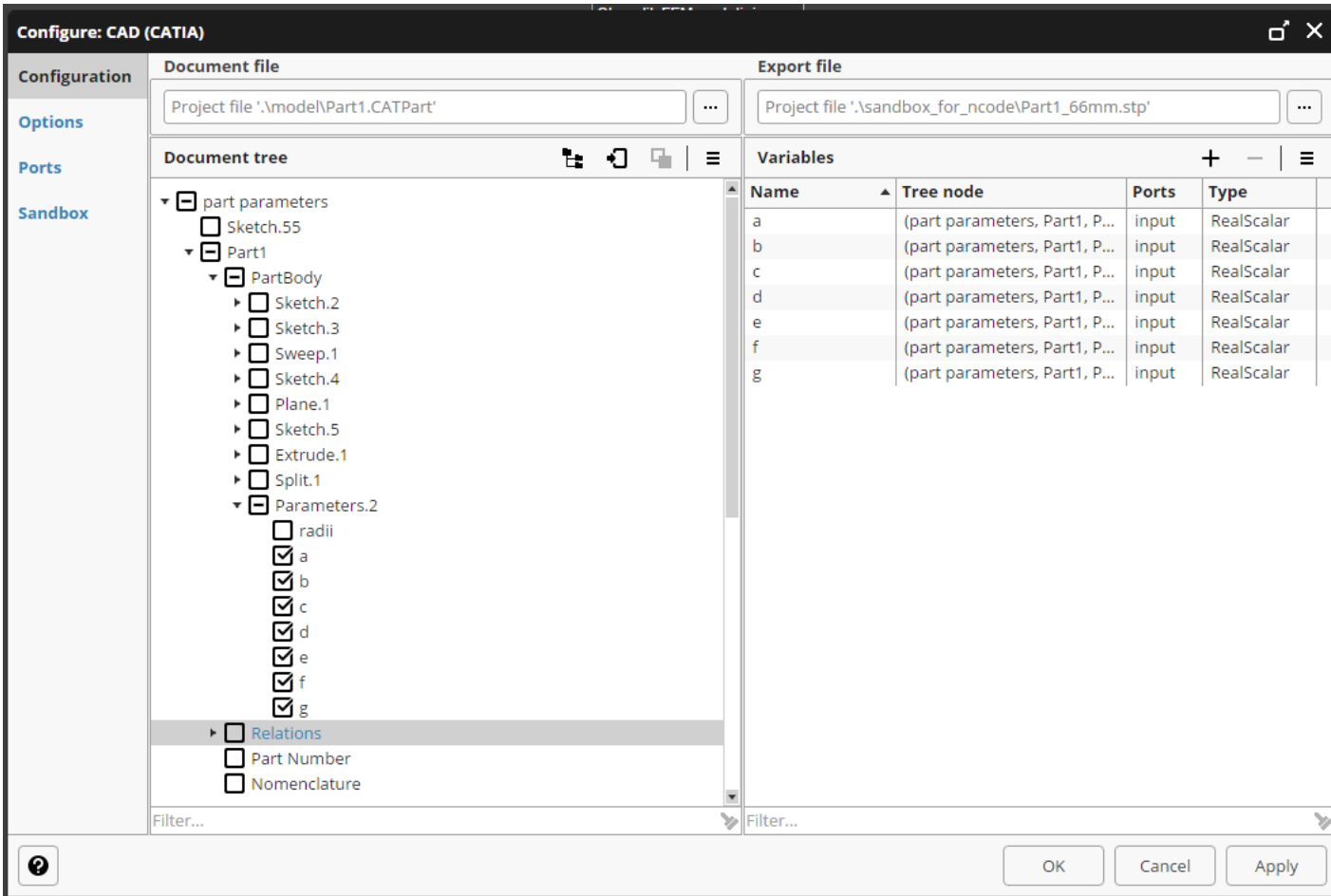
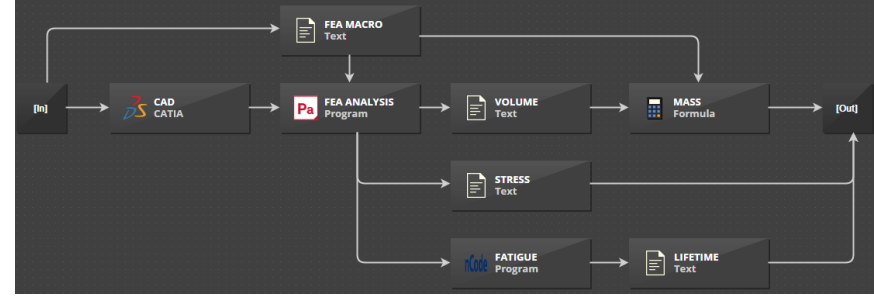
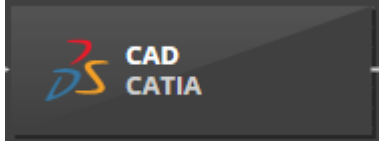
- Preparation of the automated FEM model (SOL101)
- Preparation of the automated Fatigue analysis model
- Creating pSeven Workflow
- Analyzing with pSeven
- DoE (Design of Experiment)
- Optimization
- Post-Process of the outputs



Analysis Workflow

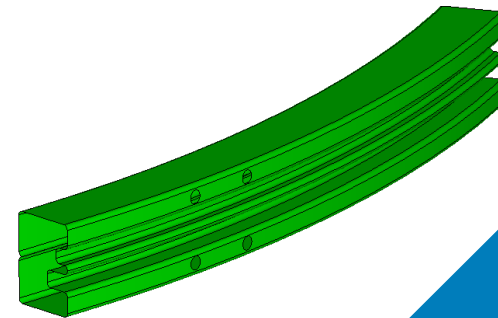


CAD Integration

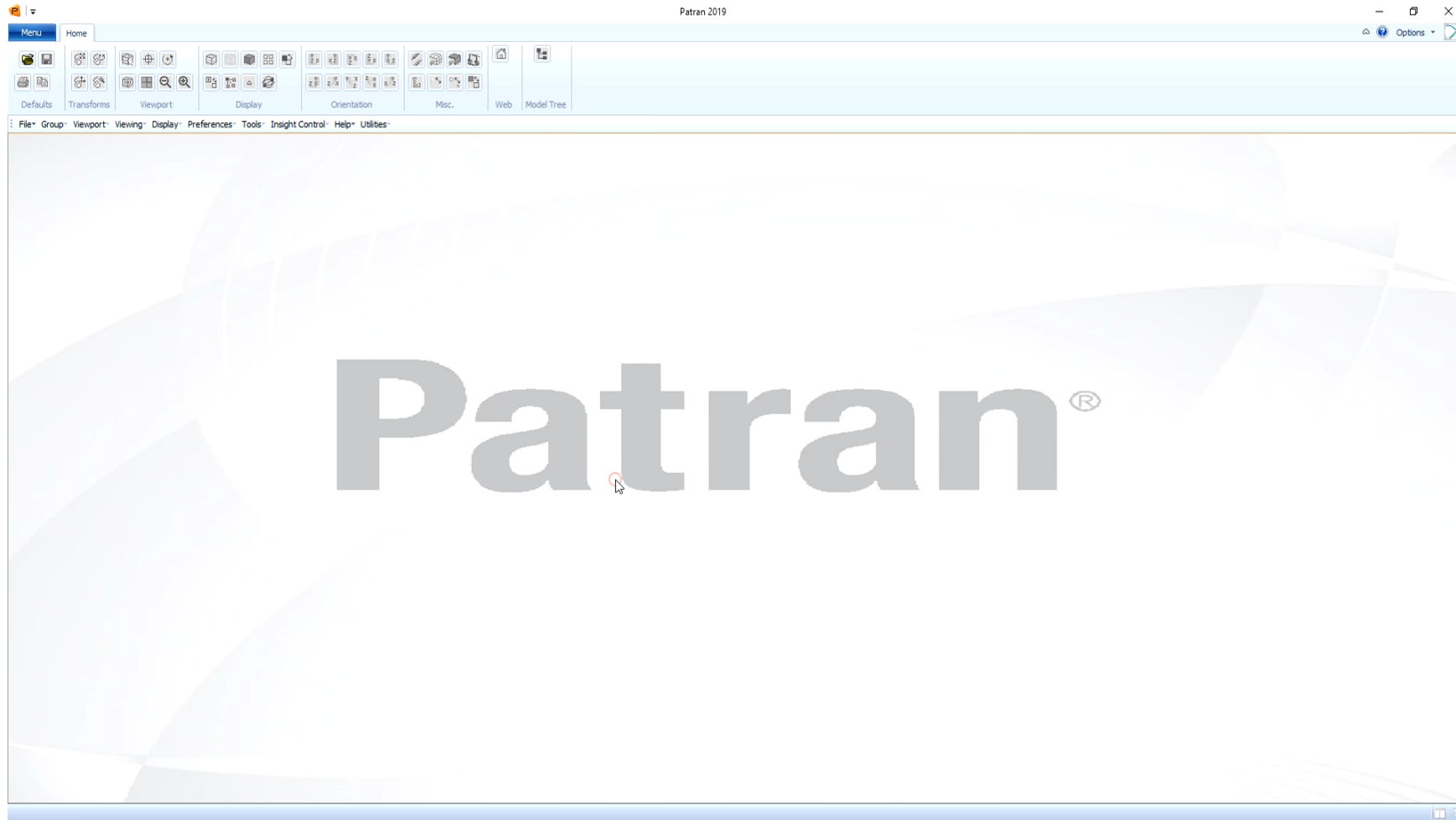
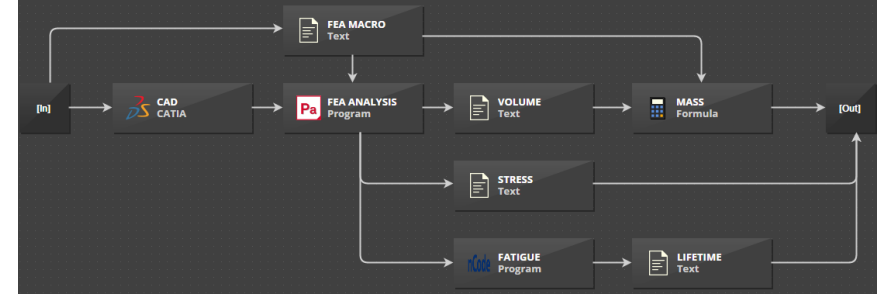


Modeling of the bumper design was done in CATIA software as 3D Shell model.

The CATIA block in pSeven allows you to access the parameters and feature tree in a .catpart.

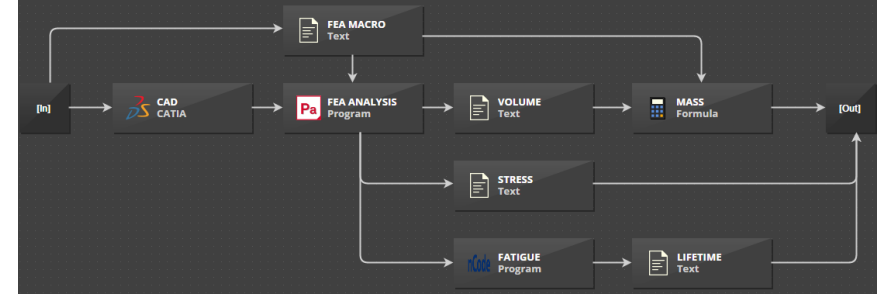


FEA Model & Analysis



- With Patran macro (.ses) ;
- Importing .stp file
 - Creating 2D mesh
 - Defining the thickness
 - Defining loads
 - Defining report contents

FEA Model & Analysis



Configure: FEA MACRO (Text)

Configuration

Input file: Project file: \model_for_ncode\webinar_ses_r04.ses.01

Options

Ports

Sandbox

Template file: Use input file

```

67 "0.3", "7.85e-9", "" ]
68 STRING asm_delete_surface_deleted_ids[VIRTUAL]
69 asm_delete_surface( "Surface 11", asm_delete_surface_d
70 $# 1 Surface Deleted: Surface 11
71 elementprops create( "shell", 51, 25, 35, 1, 1, 20, [1
72 4118, 4119, §111, 4401, 4402, 4403, 4404, 4405, 4406,
73 9, 1, 1, 1, 1, 1, 4, 4, 1, 1, 1, 1, 1, 1, 4, 4], ["m:m
74 "", "", "", "", "", "", "", "", "", "", "", ""], "Surf
75 $# Property Set "shell" created.
76 loadsbcs_create2( "fix", "Displacement", "Nodal", "",
77 "Surface 5:17:4.5 5:17:4.6 5:17:4.7 5:17:4.8"], "Geome
78 "<0 0 0>", "<0 0 0>", "< >", "< >", ["", ""],
79 $# Load/BC set "fix" created.
80 loadsbcs_create2( "load", "Total Load", "Element Unifo
81 "Surface 1:3.2 5.2 15.2 17.2 20:23.2 27.2 4.3 6:10.3 1
82 "3 24:26.3"], "Geometry", "Coord 0", "1.", ["< >",
83 ] )
84 $# Load/BC set "load" created.
85 ui_exec_function( "mesh_seed_display_mgr", "init" )
86 INTEGER fem_create_mesh_surfa_num_nodes
87 INTEGER fem_create_mesh_surfa_num_elems
88 STRING fem_create_mesh_s_nodes_created[VIRTUAL]
89 STRING fem_create_mesh_s_elems_created[VIRTUAL]
90 fem_create_mesh_surf_4( "Hybrid", 49664, "Surface 10",
91 "1.0"], "Quad4", "#", "#", "Coord 0", "Coord 0", @
92 fem_create_mesh_surfa_num_nodes, fem_create_mesh_surfa
93
  
```

Operations

- 1 Set frame start: search for "elementprops_create", match 1..
- 2 Set frame start: search for "m", match 2 times
- 3 Write to file: variable thickness, line 0, field 5
- 4 Reset the working frame
- 5 Set frame start: search for "Poisson Ratio", match 1 time, m..
- 6 Read from file: variable density, line 0, field 3

Variables

Name	Ports	Type	Test value
density	output	RealScalar	7.8500e-9
thickness	input	RealScalar	

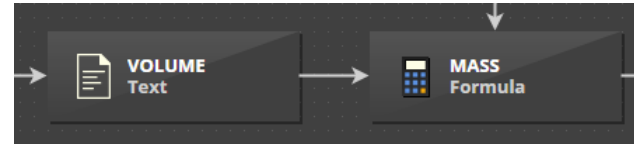
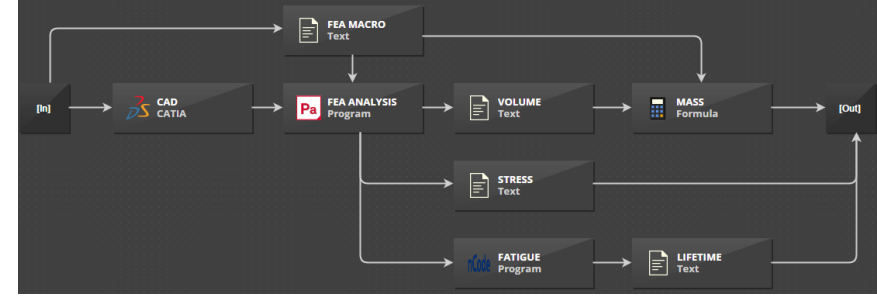
Output file: Temporary file without initial data; write to port 'output'

OK Cancel Apply

With Text block;

- Data read from macro file (density)
- Change data (thickness) within the macro file

Mass Calculation



Configure: VOLUME (Text)

Configuration

Input file: Read from port 'input'

Template file: \\model_for_ncod...

Operations

- 1 JQ Set frame start: search for "Scalar Properties..
- 2 ∞ Read from file: variable volume, line 0, field 0

Variables

Name	Ports	Type	Test value
volume	output	RealScalar	771.5815

Output file: Temporary file without initial data; write to port 'ou...'

Filter...

OK Cancel Apply

```
0 .....
1 *                               MASS PROPP
2 .....
3 MSC.Patran 2019
4 File: D:\bg\db.db
5 Date: 07-Sep-20
6 Time: 15:35:07
7
8 Scalar Properties:
9   Volume
10  771.581543
11 Center of Gravity in Coordinate Frame:
12   Comp. Ref. Cartes. Frame 0
13   X      -1.105747  -1.105747
14   Y      16.117081  16.117081
15   Z      1.968599   1.968599
16 Principal Inertia Quantities:
17   Pr. Inertias Rad. of Gyr.
18   0.000551    9.542081
19   0.000549    9.523161
20   0.000023    1.951985
21 Inertia Tensor in Coordinate Frame:
22   Comp. Ref. Cartes. Frame 0
23   XX      0.002116   0.002116
24   YY      0.000086   0.000086
25   ZZ      0.002130   0.002130
26
```

Configure: MASS (Formula)

Configuration

Formula designer

Name: Formula

mass = volume*density*1e6

New... =

Variables

- density
- volume

Responses

- mass

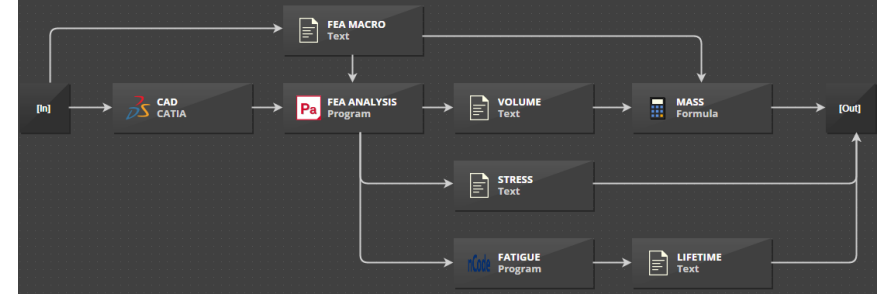
Functions

- Abs
- Chi
- Cl
- DiracDelta
- Ei

Insert

OK Cancel Apply

Reading Stress



Configure: STRESS (Text)

Configuration

Input file
Read from port 'input'

Options

Ports

Sandbox

Template file: `.\model_for_ncode\vm_stress.rpt`

```
0
1
2
3
4
5          MSC.Patran 25.0.638960 Wed I
6          Load Ca
7          Result
8
9
10
11
12
13
14
15
16  -Source ID--Entity ID---Sub ID----von Mises--
17  Min:      1      1287      0      0.007003
18  Max:      1      40448     0      4327.934570
19
20
```

Output file
Temporary file without initial data; write to port 'output'

Operations

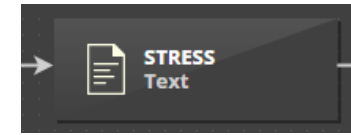
- Set frame start: search for "Source ID", match 1 time
- Set frame start: search for "Max", match 1 time
- Read from file: variable max_stress, line 0, field 4

Variables

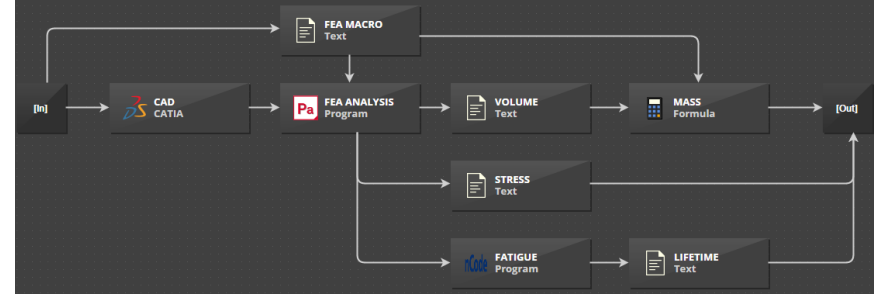
Name	Ports	Type	Test value
max_stress	output	RealScalar	4327.9346

Filter...

OK Cancel Apply



Lifetime Calculation



Configure: LIFETIME (Text)

Configuration

Input file: Read from port 'input'

Template file: \model_for_ncode\vb_out.csv

```
0
1
2
3 Material Group,Property ID,Material ID,Damage,Me
4
5 ,MaterialGroup,PropertyId,MaterialId,Damage,Mean
6
7 repeats
8
9 g,huge,huge,double,double,double,double
10
11 entities,1,1,2.682E-5,0.2753,0,-2.449,3.729E4
12 entities,1,1,2.574E-5,0.2178,0,-4.541,3.885E4
13 ties,1,1,2.471E-5,0.2801,0,0.0412,4.047E4
14 entities,1,1,2.411E-5,0.09201,0,-0.6072,4.148E4
15 entities,1,1,2.325E-5,0.1581,0,0.8332,4.301E4
16 ties,1,1,2.279E-5,0.1994,0,3.376,4.388E4
17 entities,1,1,2.182E-5,0.1102,0,-5.232,4.582E4
18 ties,1,1,2.052E-5,0.2068,0,-2.738,4.874E4
19 ties,1,1,2.024E-5,0.09496,0,0.229,4.94E4
20
```

Output file: Temporary file without initial data; write to port 'output'

Operations

- Set frame start: search for "Bottom", match 1 time
- Read from file: variable critical_life, line 0, field 10

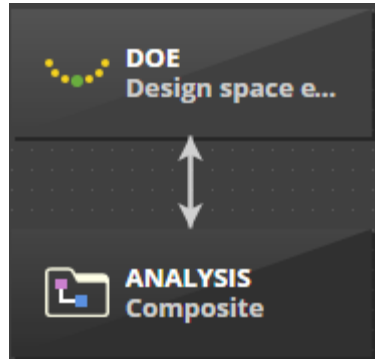
Variables

Name	Ports	Type	Test value
critical_life	output	RealScalar	37290.0

Buttons: OK, Cancel, Apply

- Fatigue analysis is performed using the outputs of the Nastran solver.
- Result output is taken from nCode software in .csv format.
- The critical lifetime value is read from the .csv file.

Design of Experiment



Configure: DOE (Design space exploration)

Technique: Latin hypercube sampling Options: All options are default.

Variables

Name	Type	Size	Lower bound	Upper bound	Levels	Hints
thickness	Continuous	1	1.0	3.0		
a	Continuous	1	50.0	75.0		
b	Continuous	1	10.0	17.0		
c	Continuous	1	20.0	45.0		
e	Continuous	1	20.0	45.0		
d	Continuous	1				Constant Value: 17
f	Continuous	1				Constant Value: 19
g	Continuous	1				Constant Value: 17

Filter...

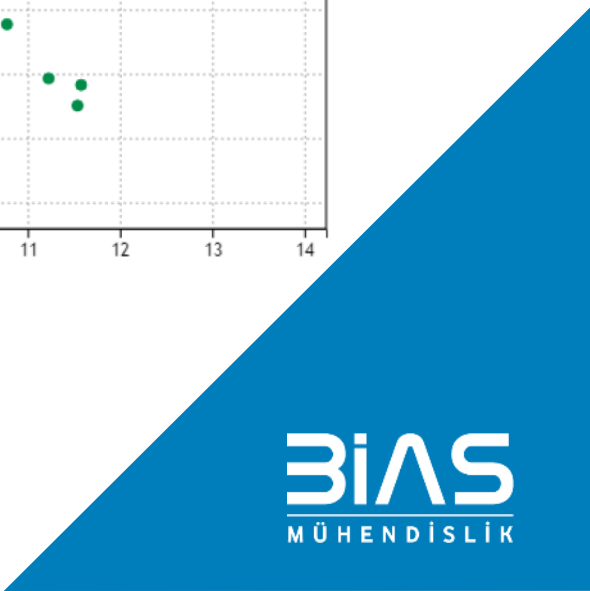
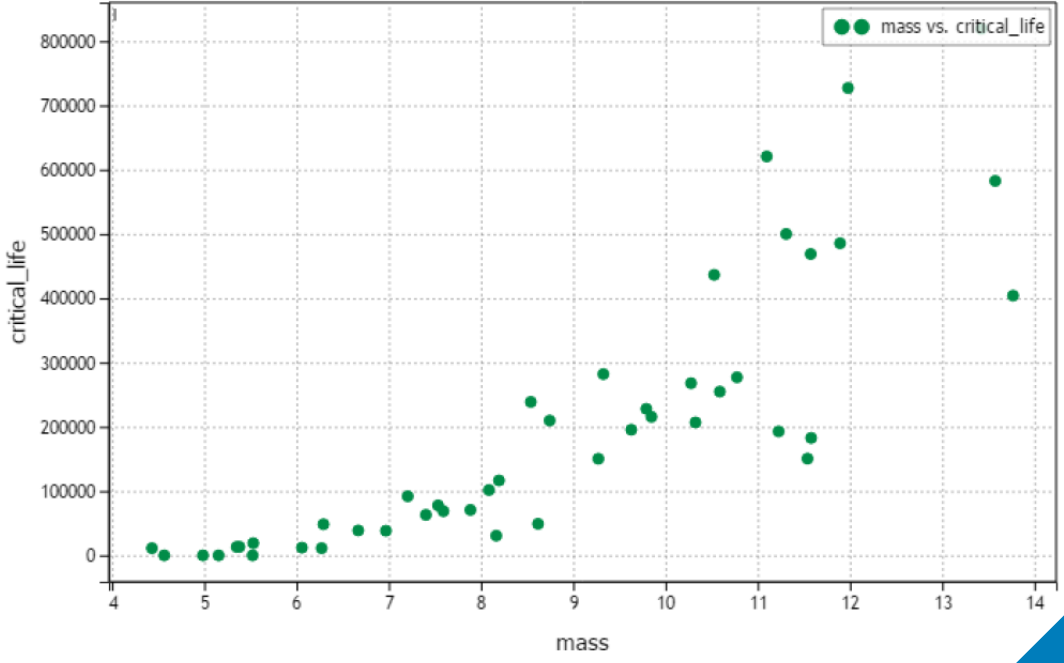
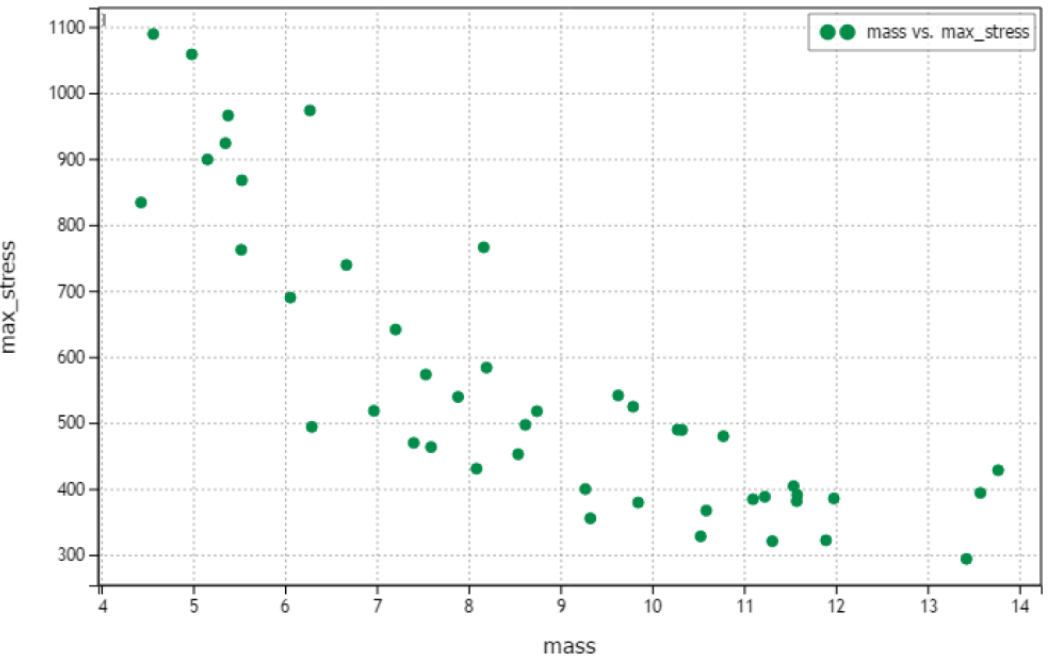
Exploration budget: Auto Study target: Auto Hints: +

Responses

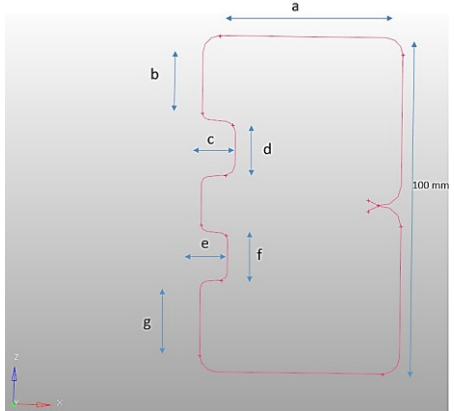
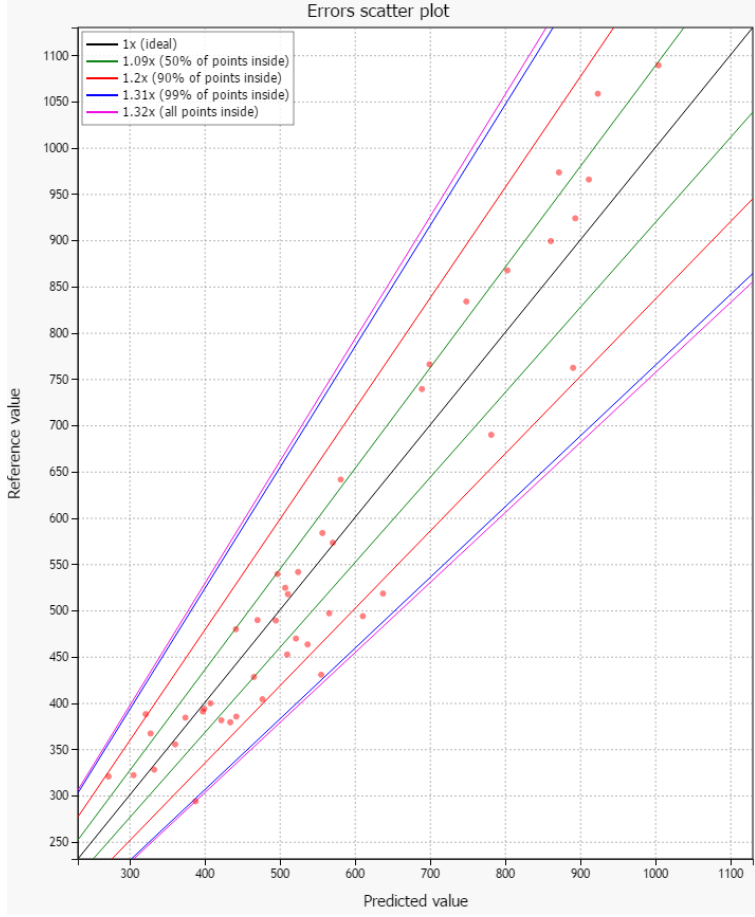
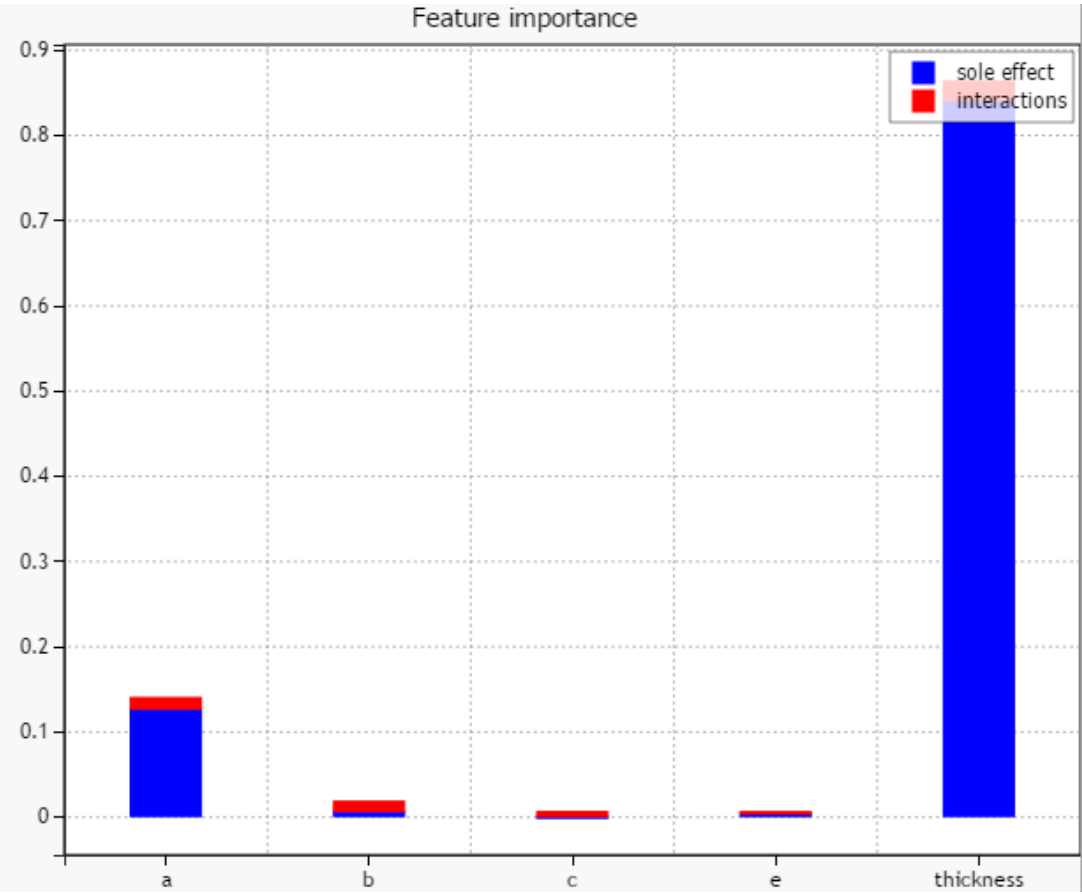
Name	Type	Size	Lower bound	Upper bound	Hints
mass	Evaluation	1			
max_stress	Evaluation	1			
critical_life	Evaluation	1			

Design of Experiment

Data	Statistics	Correlations	Dependency
index	a	b	c
25	72.250	14.130	29.250
26	64.250	16.650	38.750
27	59.250	14.550	42.250
28	58.750	14.970	40.250
29	56.250	10.350	38.250
30	67.750	13.150	20.250
31	62.750	10.910	33.750
32	54.750	11.890	22.750
33	68.750	13.570	35.750
34	60.750	14.690	41.250
35	73.750	13.990	25.750
36	64.750	15.810	21.250
37	69.250	13.290	36.250
38	57.750	13.850	26.750
39	72.750	10.770	36.750
40	52.250	11.470	33.250
41	65.750	11.330	20.750
42	63.750	10.630	24.250
43	67.250	14.270	27.250
44	57.250	16.230	23.250



Design of Experiment



Optimization

Configure: DOE (CSVParser)

Configuration

Input file
File: data_for_ncode\doe_results_45.csv ... Load

Options

Ports

Sandbox

Import

Import rows: :
Import columns: :
Preview rows count: 10
 Parse first row as header

Field delimiter

Comma
 Semicolon
 Tab
 Space
 Other:

Decimal separator

Point
 Comma

Other options

Escape character: \
Comment character: #

Preview

a	b	c	e	thickness	mass	max_stress	critical_life
55.2500	12.7300	28.2500	39.2500	1.2600	5.5242	762.1259	1.0000e-10
52.7500	13.0100	22.2500	43.2500	2.7000	11.5795	390.7308	182600.0
56.7500	12.4500	28.7500	29.2500	1.1800	4.9860	1058.3519	1.0000e-10
69.7500	16.5100	23.7500	41.2500	2.2200	10.3255	489.0666	206800.0
50.2500	14.8300	39.2500	28.7500	2.6200	11.2267	387.8684	192800.0
54.2500	15.2500	31.7500	44.7500	2.5400	11.5400	404.0050	150500.0
50.7500	11.0500	34.7500	36.2500	2.7400	10.5892	366.9860	254800.0
65.2500	11.1900	44.2500	40.2500	1.2200	5.3811	965.6518	13340.0
60.2500	11.6100	30.7500	38.2500	1.6600	6.6692	739.2115	38800.0

OK Cancel Apply

Configure: OPTIMIZATION (Design space exploration)

Technique: Surrogate-based optimization Options: All options are default.

Variables

Name	Type	Size	Lower bound	Upper bound	Levels	Hints
a	Continuous	1	50.0	75.0		
b	Continuous	1	10.0	17.0		
c	Continuous	1	20.0	45.0		
e	Continuous	1	20.0	45.0		
thickness	Continuous	1	1.0	3.0		

Filter...

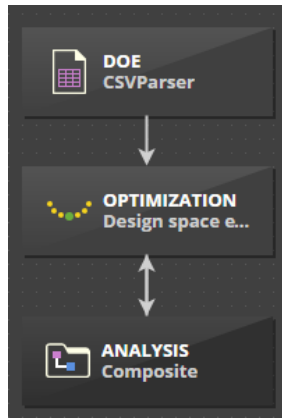
Exploration budget: Auto Study target: Auto Hints: +

Responses

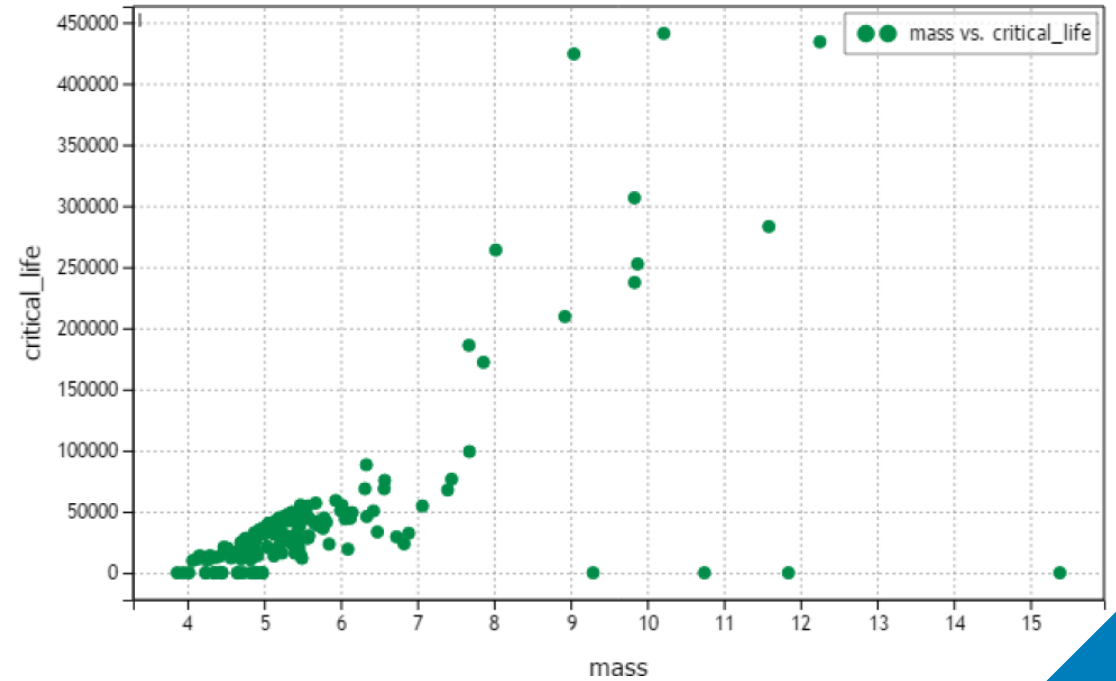
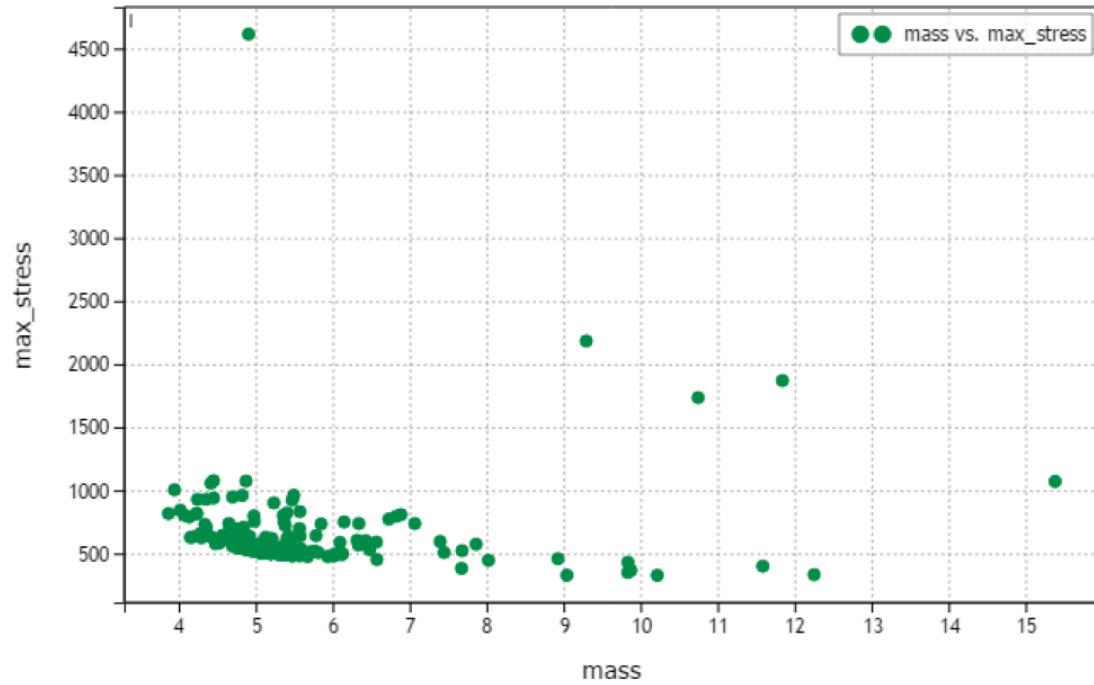
Name	Type	Size	Lower bound	Upper bound	Hints
mass	Minimization	1			
max_stress	Constraint	1		550.0	
critical_life	Constraint	1	40000.0		

Filter...

Run options Ports and parameters OK Cancel Apply



Optimization



Conclusions

- The bumper CAD file has been parameterized.
- Both the structural and fatigue analysis process have been automated.
- Integration of statistical tools into the design process was ensured.
- DoE and Optimization studies were carried out in line with the design criteria.
- The required dimensional values have been obtained for a bumper design that is both light, strength and long-lifetime.

BIAS
MÜHENDİSLİK

Yenilikçiler için Çözümler
Solutions for Innovators

THANK YOU,
ANY QUESTIONS?