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# Design Optimization with Parametric Geometry Variation

H. Müllerschön

H. Zimmer, M. Schäfer

E. Arvelo

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  - Optimization in automotive development process: Merits, Limits, State of the Art
  - software products for design optimization with parametric geometry variation
- Case Study
  - SFE CONCEPT model
  - Optimization setup
  - Optimization results

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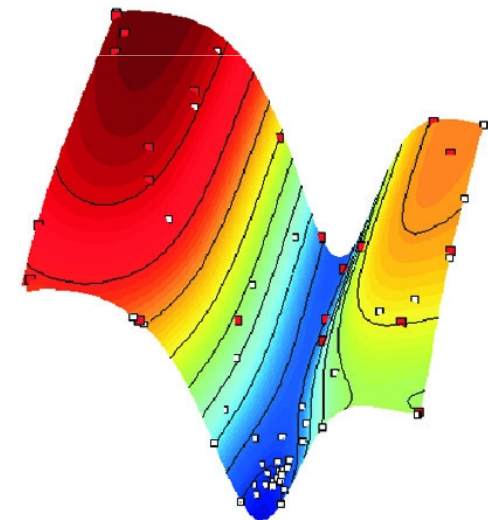
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# Introduction – Optimization in automotive development process

# Optimization in automotive development process

Application of mathematical optimization – state of the art, merits and limits

- Optimization
  - Size-/Shape Optimization
  - Topology Optimization
  - System-/Parameter Identification
  - Reliability Improvement
- Design Exploration
  - Study of design changes
- Sensitivity Studies
  - Parameter / Variable Screening
- Robustness Analysis
  - Consideration of uncertainties
  - Evaluation of reliability



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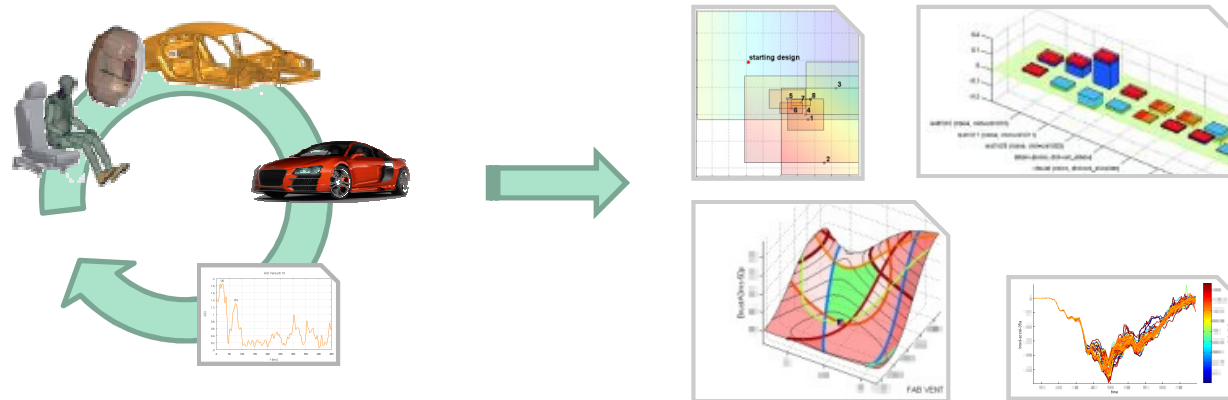
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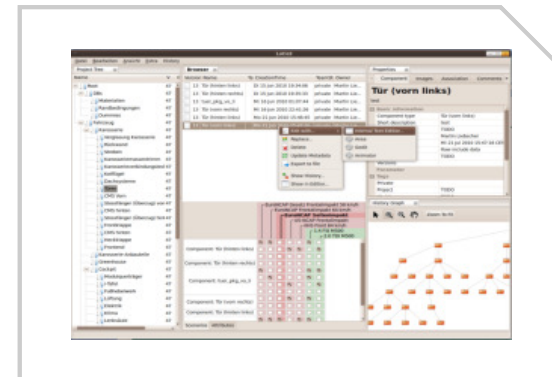
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# Optimization in automotive development process

- Integration in development process



- Integrated Optimization in Simulation Data Management Systems (SDM) – Future?
- Multi Disciplinary Optimization (MDO) ?
- Consideration of Design Constraints



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# Introduction Software Products for design optimization with parametric geometry variation

# SFE Concept - Overview

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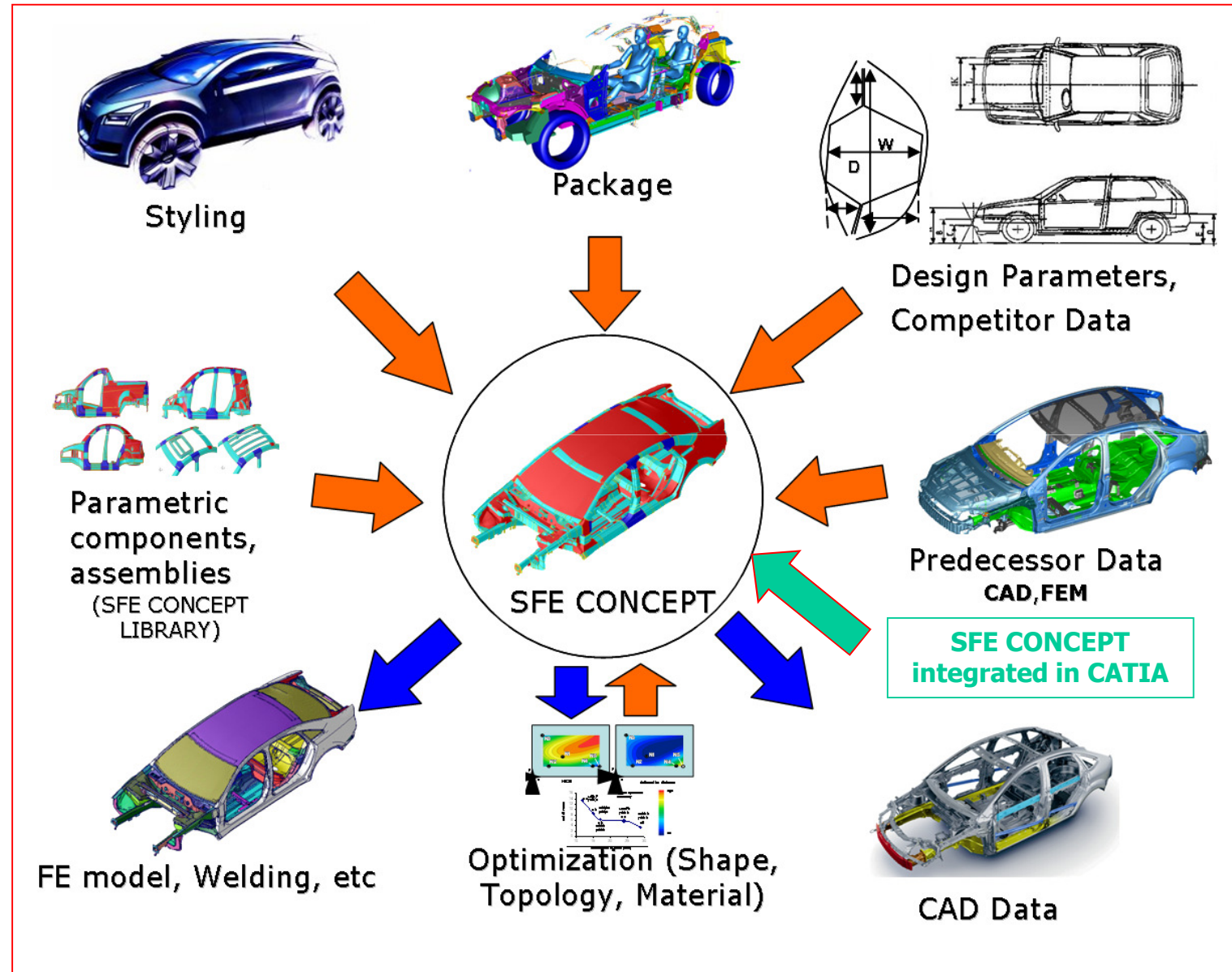
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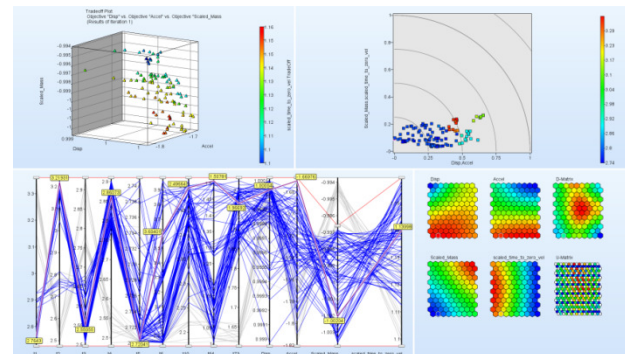
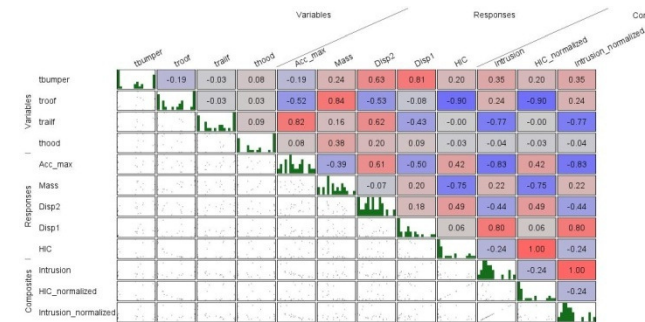
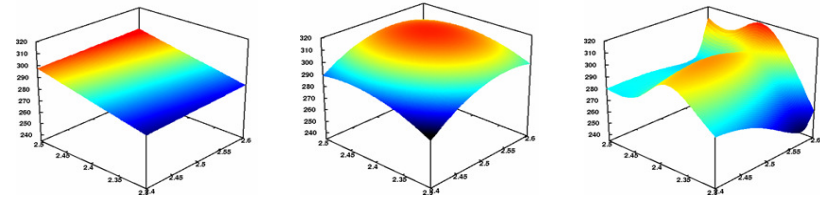
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# LS-OPT- Overview

## LS-OPT – Optimization Software – Overview

- Very effective optimization algorithms customized for crash applications
- Meta-Models
  - Polynomials
  - Radial Basis Functions
  - Neural Nets (FFNN)
- Genetic Algorithm (MOGA->NSGA-II)
- Multidisciplinary optimization (MDO)
- DOE-Studies (Sensitivity Analysis)
- Stochastic/Probabilistic Analysis
- Reliability Based Design Optimization (RBDO)
- Parameter- / System Identification





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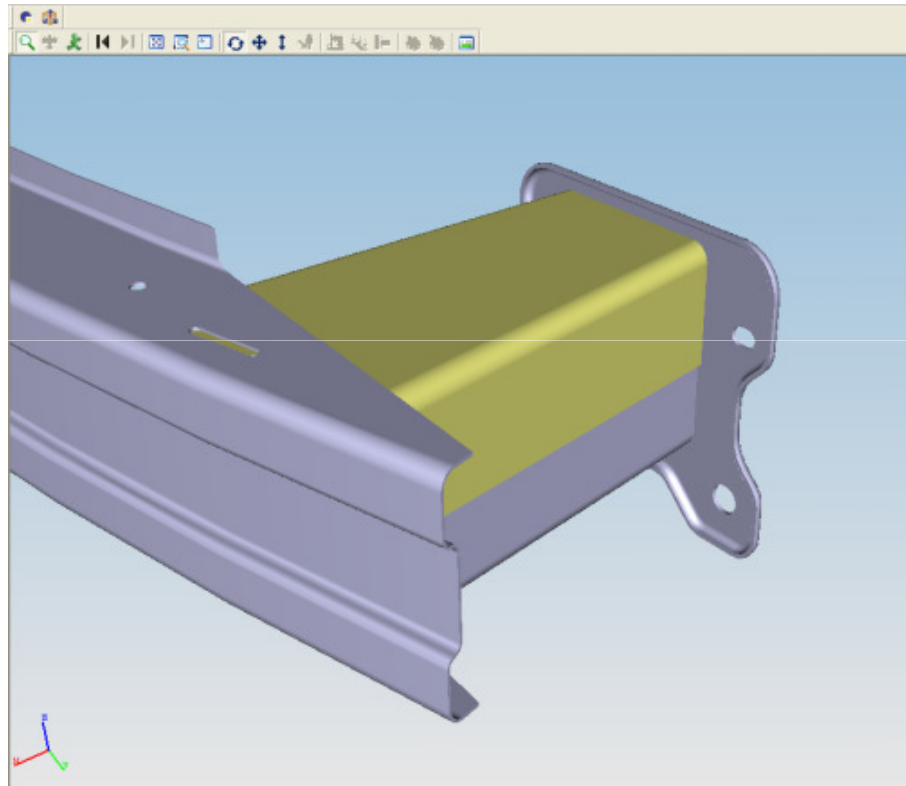
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# Case Study Description

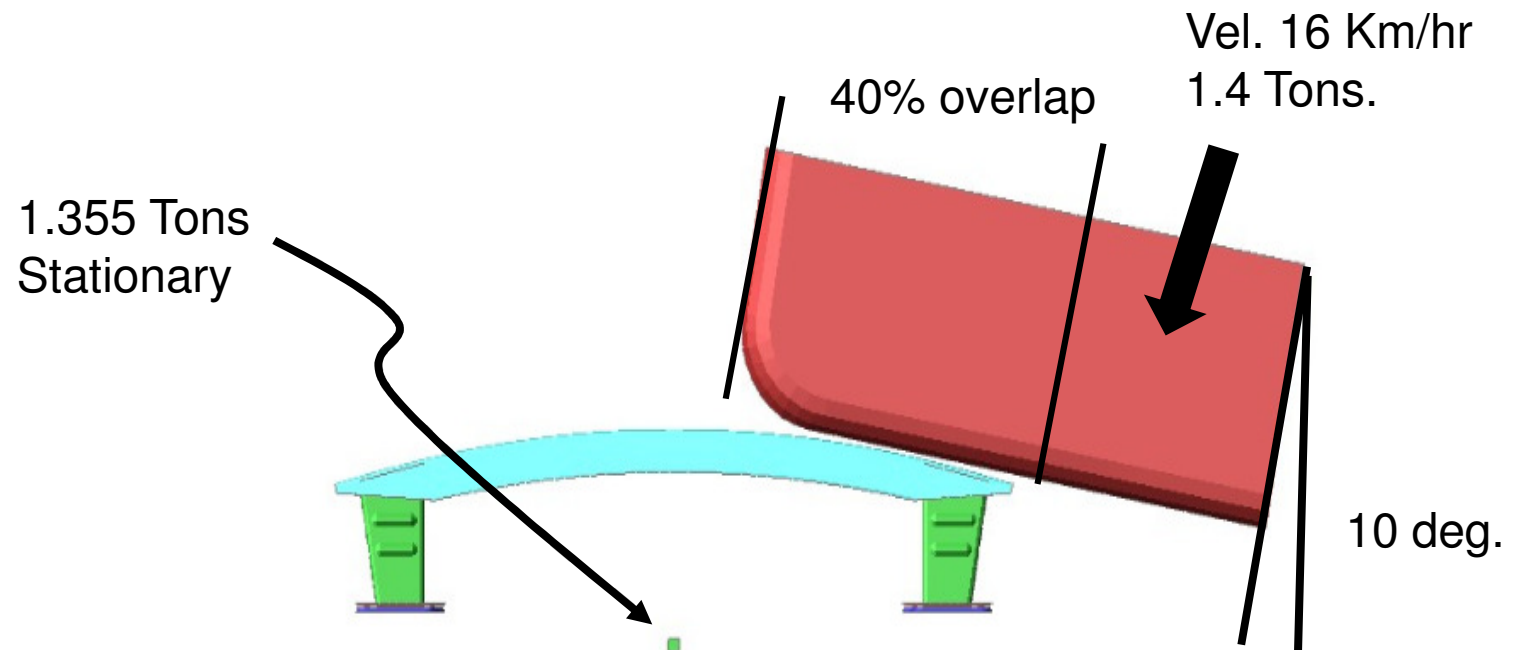
# The Geometry

- CAD representation of low speed crash absorber



## The Loading Case

- Simulation model capture the AZT (Alliance Center of Technology) rear impact test
- Important for insurance rating



## Case Study Objective

- Create the parameterised geometry model and to define the variables
- Formulation of optimization problem:

Energy absorption without violation of

- Max peak load of 90 KN
- Max deformation of 90 mm

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# Modelling Process Overview

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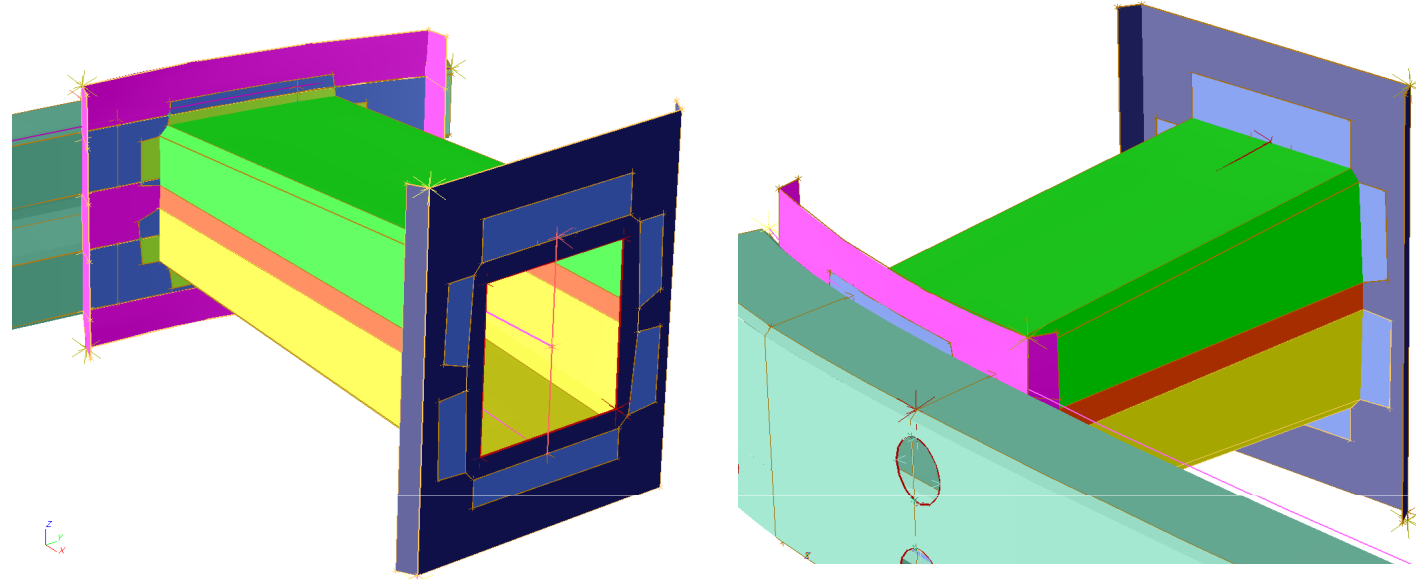
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# Crashbox



Initial model

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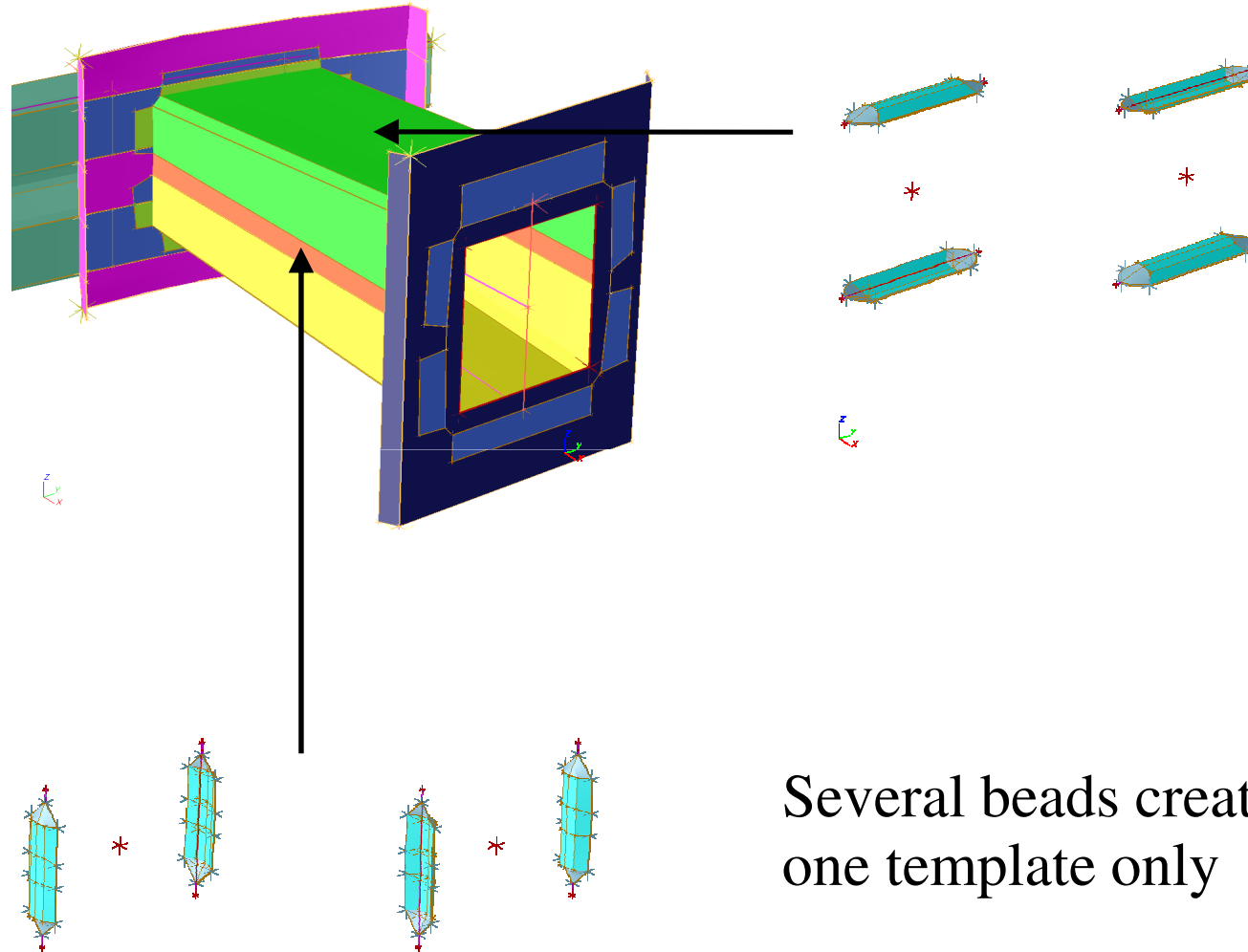
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# Crashbox beads



Several beads created from  
one template only

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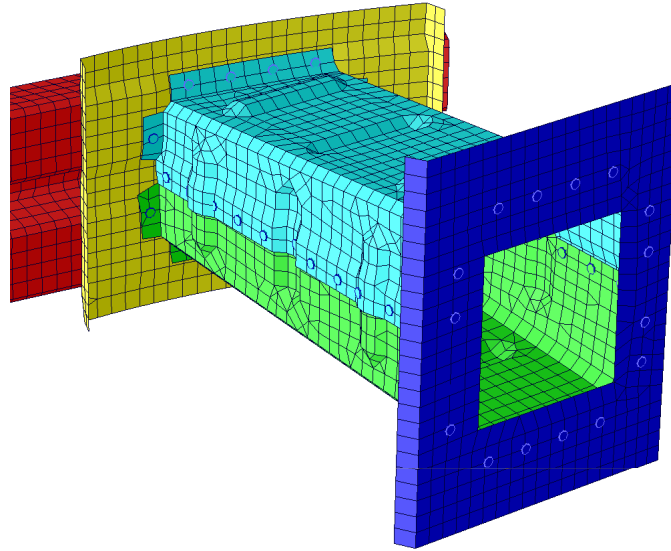
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# Crashbox



New variant



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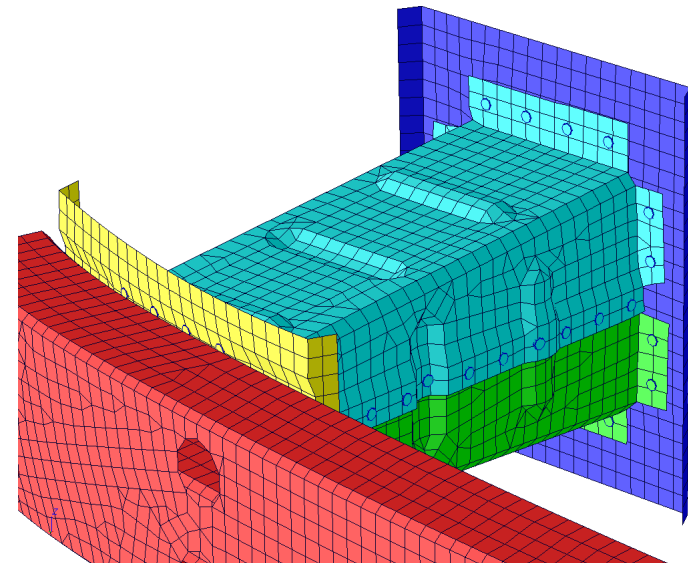
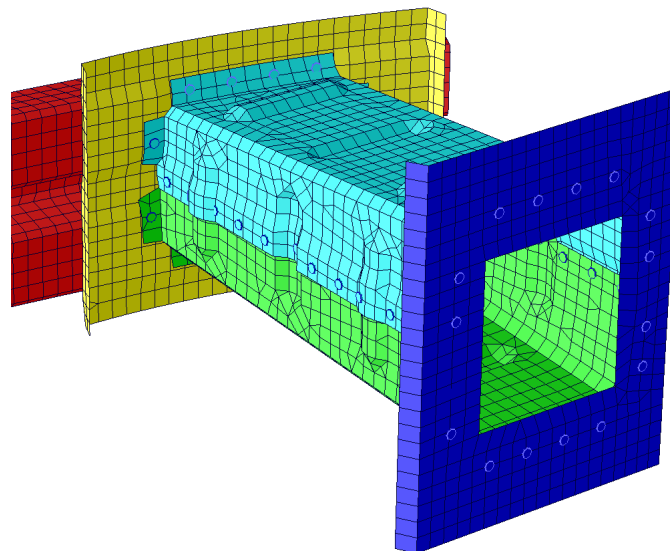
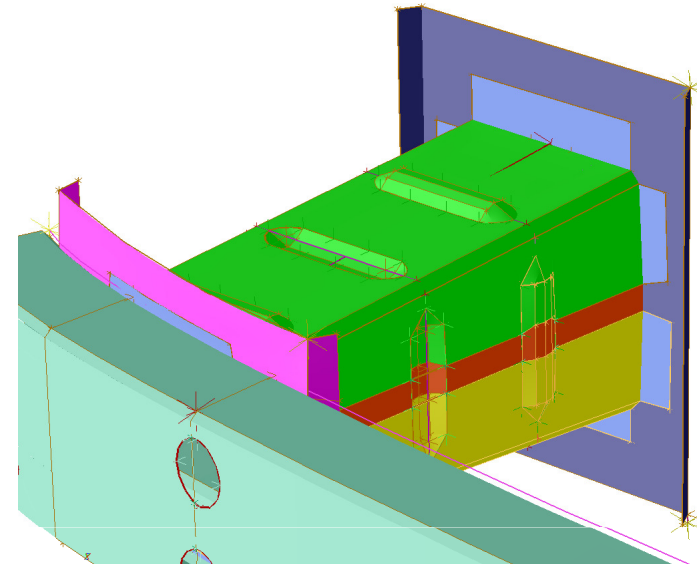
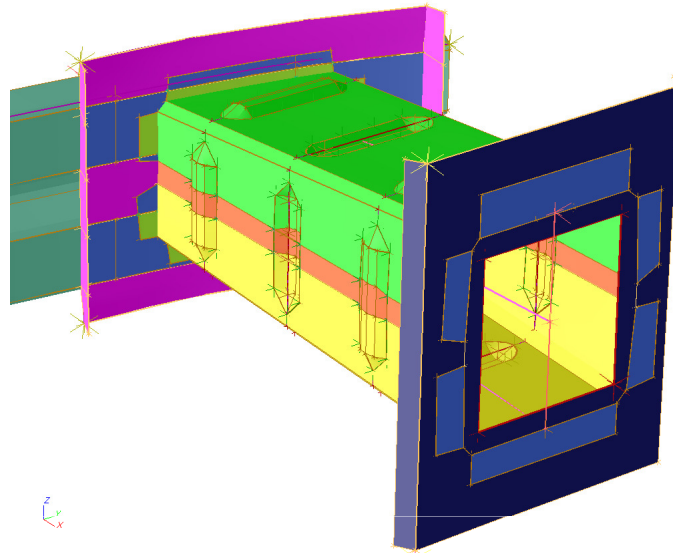
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# Crashbox



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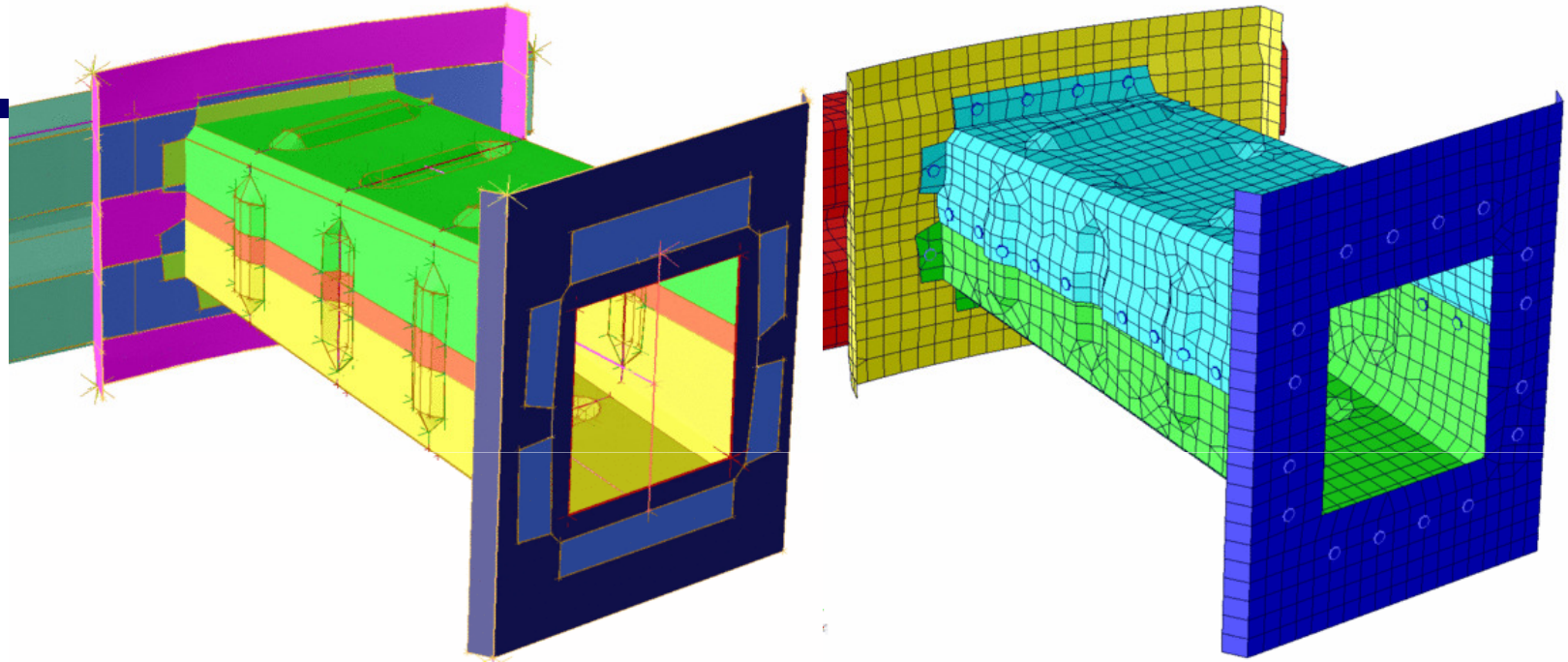
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# Crashbox



Taper horizontal modification

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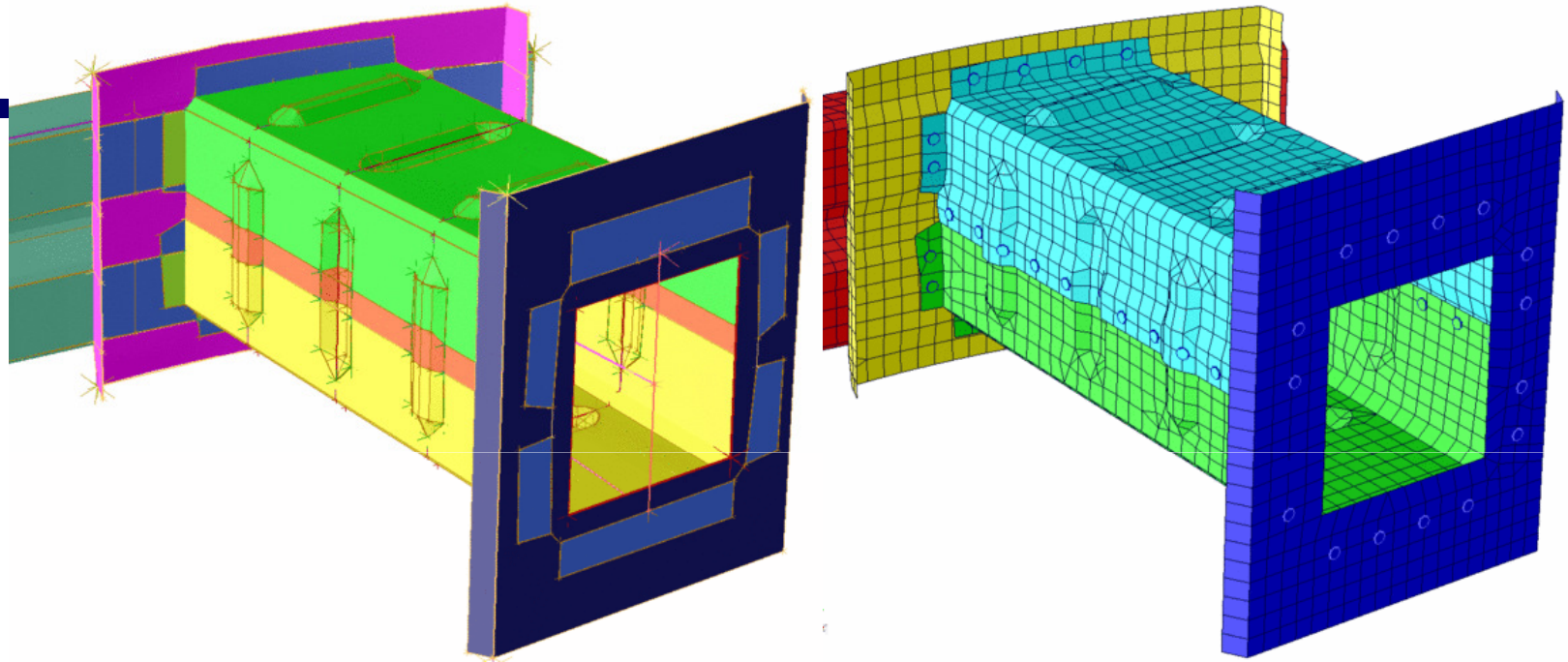
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# Crashbox



Taper vertical modification



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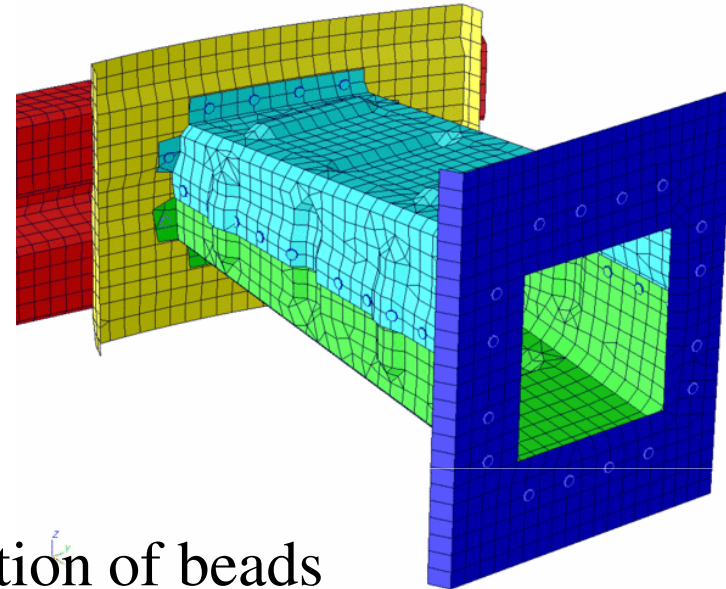
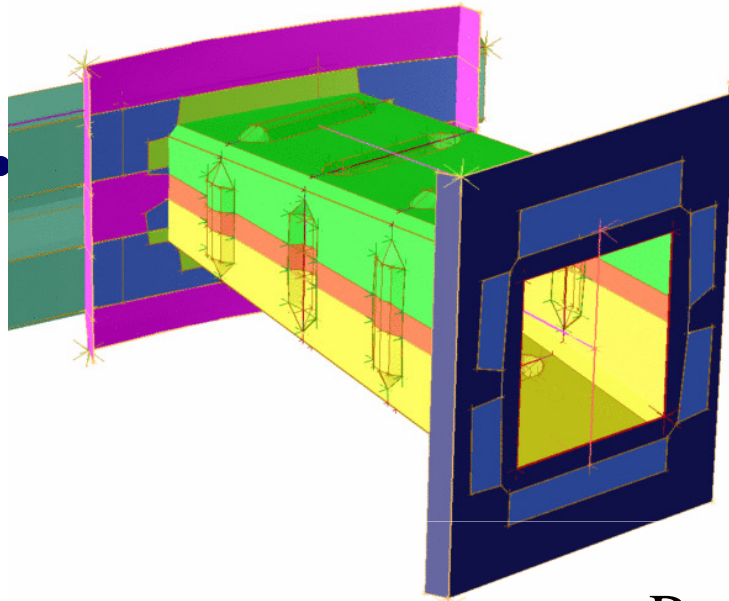
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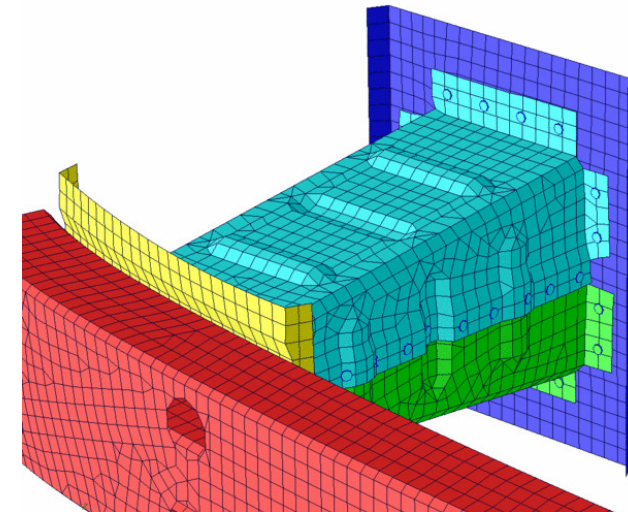
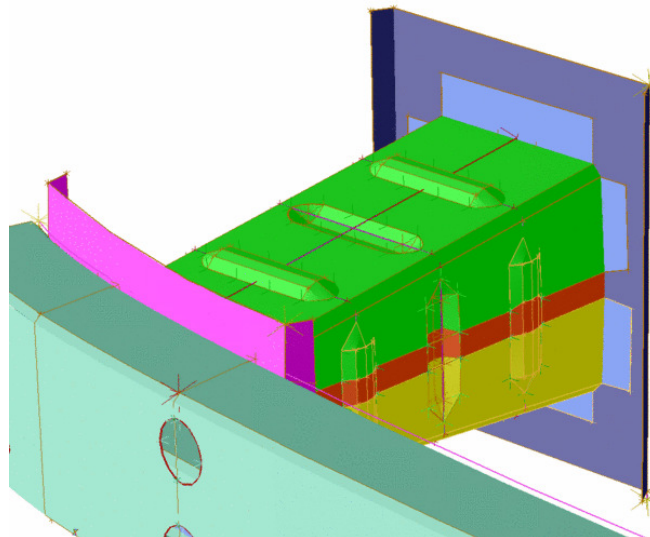
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# Crashbox



Position of beads



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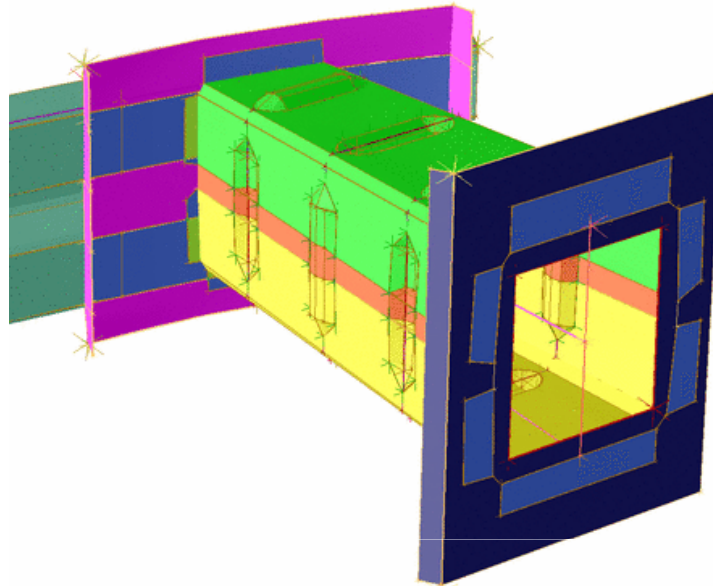
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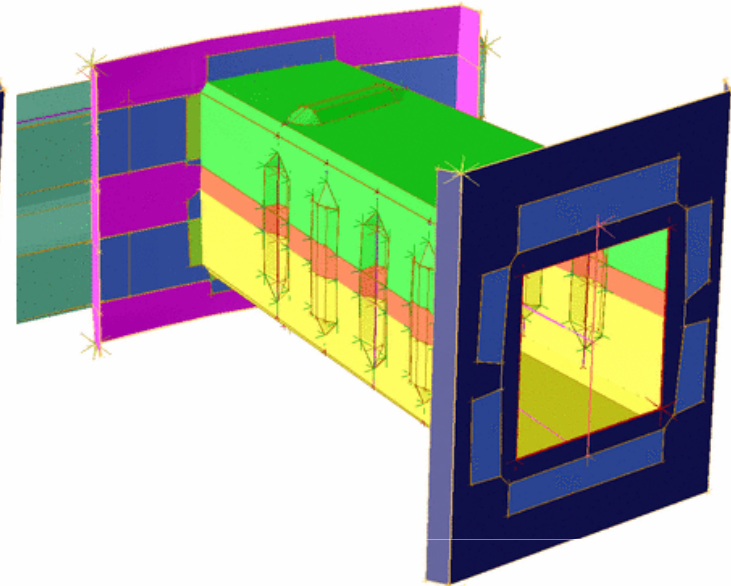
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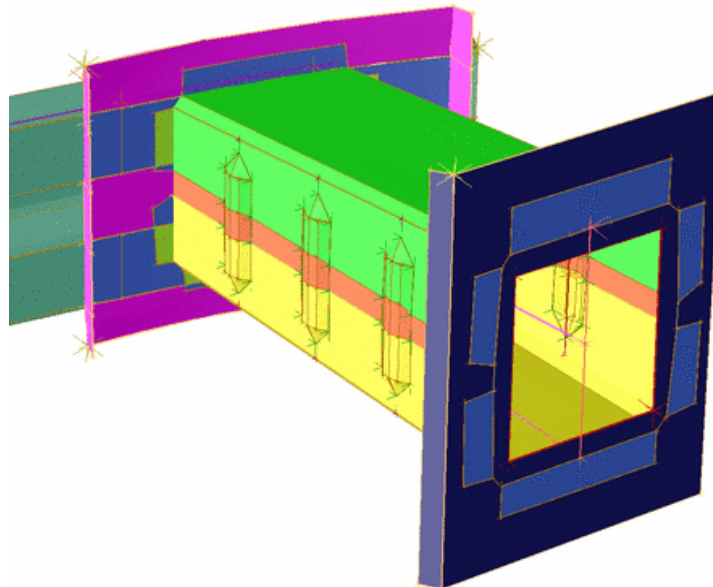
# Randomly created topologies



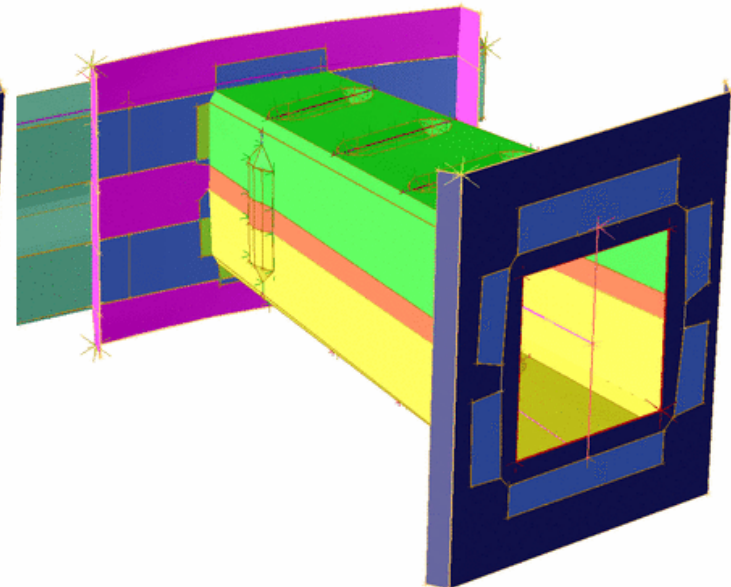
CRASHBOX\_var11



CRASHBOX\_var12



CRASHBOX\_var13



CRASHBOX\_var14



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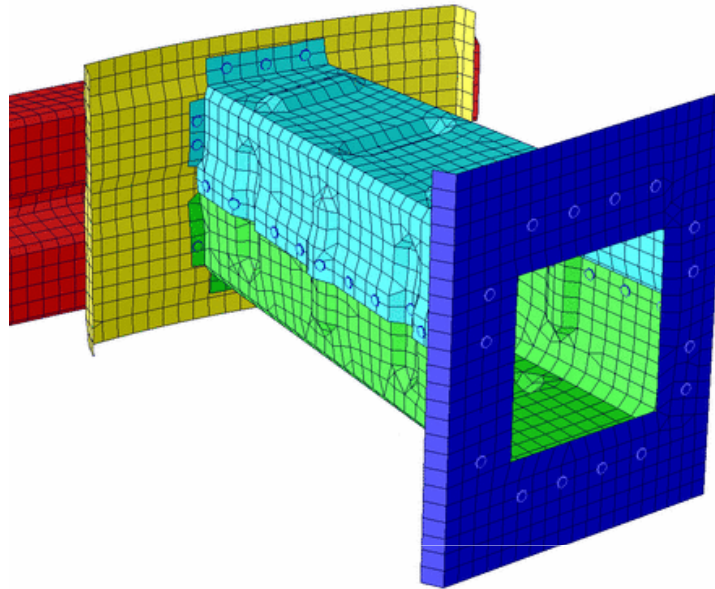
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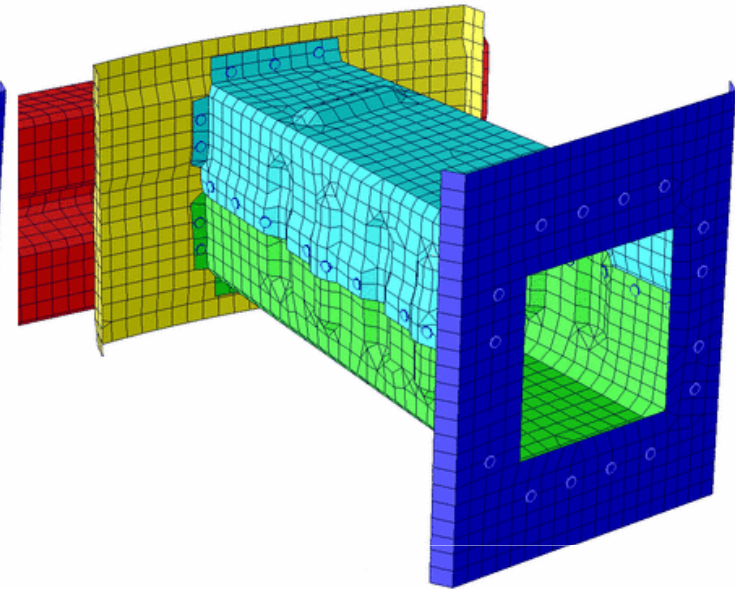
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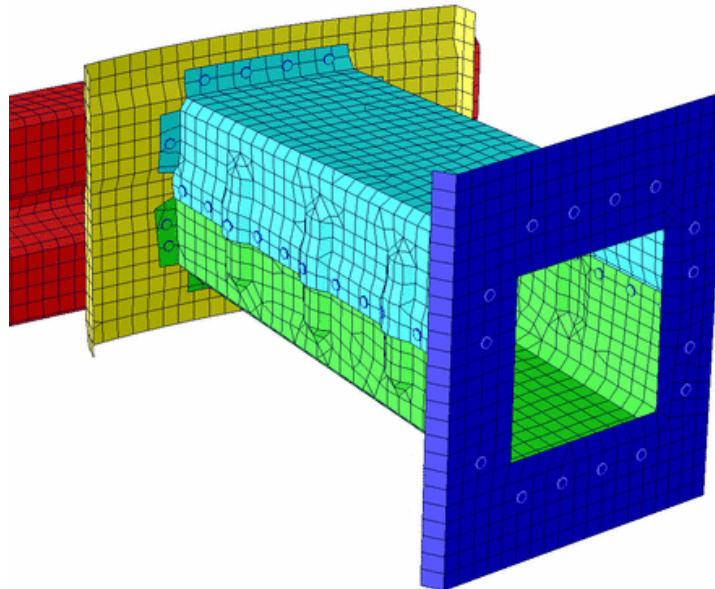
# Randomly created topologies



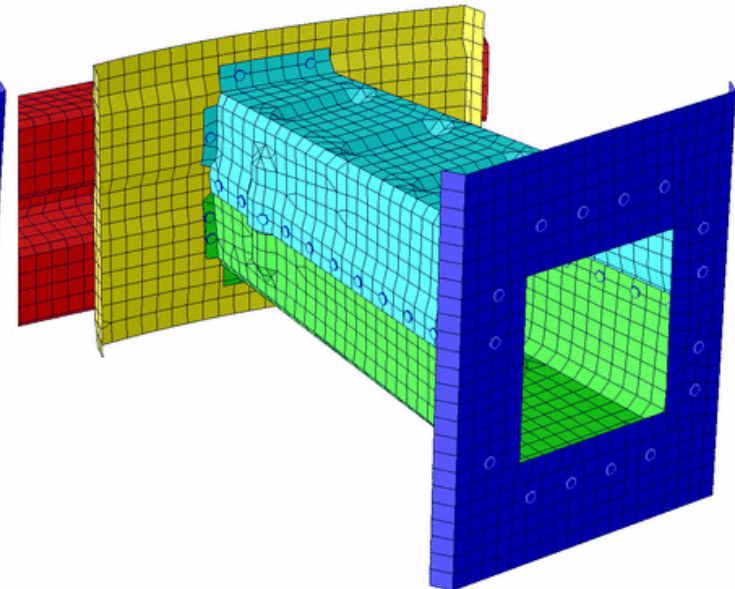
CRASHBOX\_var11



CRASHBOX\_var12



CRASHBOX\_var13



CRASHBOX\_var14

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# Optimization Setup

# SFE Optimisation Setup

- Closed loop for structural optimization using SFE CONCEPT, LS-DYNA and LS-OPT

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Optimization (1): Crush-Can\_3\_row\_initiator\_20100826...

Design Model: DESMOD\_1

Model name: DESMOD\_1

Create Copy Delete Rename

Design variables:  
Status: 8 Desvars defined.

Define...

Optimization:  
Define parameters  
Start Stop  
Show history

File export for: ☒ LS-OPT ☐ Export

End

Optimization: Design model - DESMOD\_1

Current definitions:

DesignVariableName	Type	LowerB.	CurrentV.	UpperB.	DiscreteV
XPOS1_INITIATOR_TOP	Continuous	-15	0	10	
XPOS1_INITIATOR_SIDE	Continuous	-40	0	10	
CAN_WALL_THICKNESS	Continuous	-2	0	7	
INITIATOR_WIDTH	Continuous	-7	0	8	
INITIATOR_DEPTH	Continuous	-4	0	4	
SPACING_TOP	Continuous	-5	0	2	
SPACING_SIDE	Continuous	-5	0	2	
CAN_WALL_TAPER	Continuous	0	1	1	

Add... Delete Details

Design variable type: ☒ Continuous ☐ Binary ☐ Discrete

Set current value / bounds of selected design variable:

Set lower bound: 0.00 Set upper bound:

Discrete values:

LS-OPT Input & Link Files





# LS-OPT Optimisation Setup

Linking files to run SFE CONCEPT  
in batch mode

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Pre-Processor Package Name

User-Defined

Command

C:\SFE\CONCEPT\v4.2.2.3\bin\concept.cmd -a -b C:\X\

Input File

\_Crush-Can\_1\_row\_initiator\_20100826\_full.DESMOD\_1.mac

LS-OPT file from SFE

Type	Name	Starting	Init. Range	Minimum	Maximum	Save
Variable	XPOS1_INITIATO	0.		-50.	0.	
Variable	XPOS1_INITIATO	0.		-65.	0.	
Variable	CAN_WALL_THIC	0.		-2.	7.	
Variable	INITIATOR_WIDT	0.		-7.	8.	
Variable	INITIATOR_DEPT	0.		-4.	4.	
Variable	CAN_WALL_TAPE	1.		0.	1.	
Discrete Var	mat_id	1.	Values	1 2		

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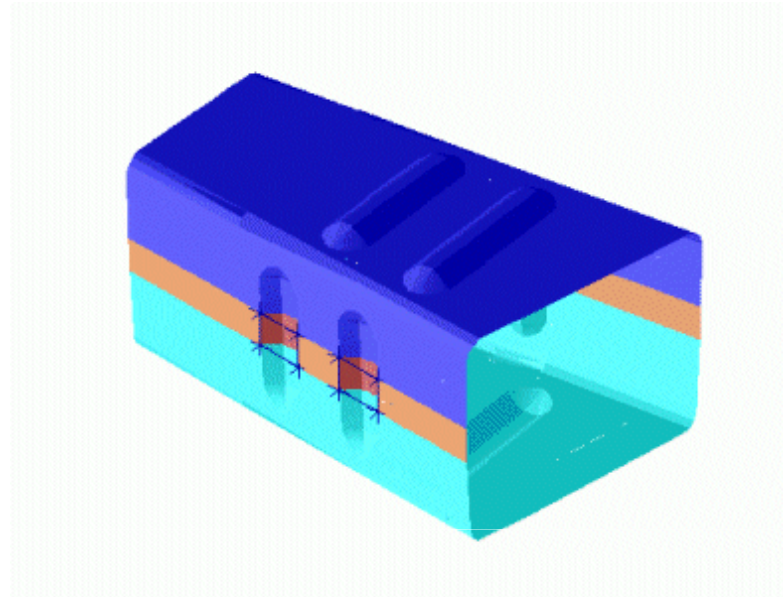
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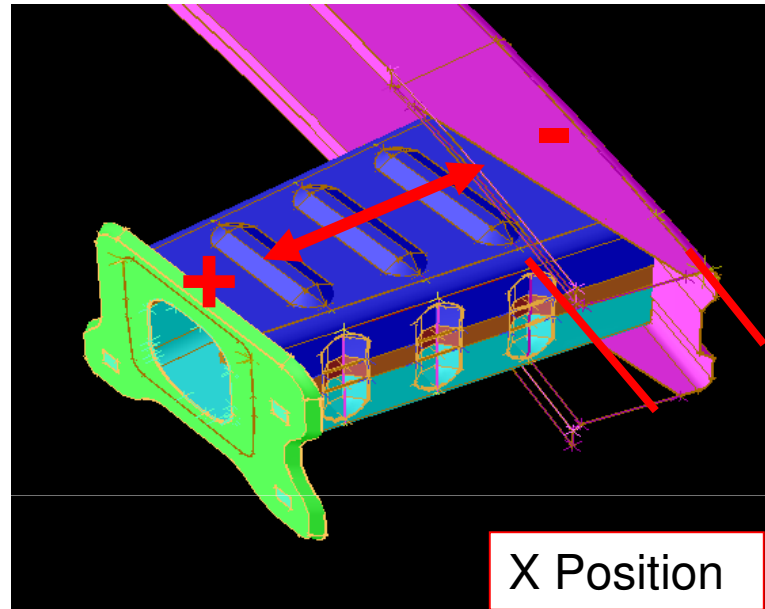
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# Variables for all variants



Description	Lower	Nominal	Upper
Can wall thickness	1.6mm	1.8mm	2.5mm
Can material	H340LAD	H340LAD	+30%
Can outer wall taper	0°	10°	10°
Depth of initiators	2mm	6mm	10mm
Width of initiators	15mm	22mm	30mm
Number of rows of initiators	1	3	3

# Variables specific to number of beads



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	Single Row			Two Rows			Three Rows		
Description	Lower	Nominal	Upper	Lower	Nominal	Upper	Lower	Nominal	Upper
<b>X-position of top initiator</b>	-50mm	0/92mm	+50mm	-15mm	0/48mm	40mm	-15mm	0/48mm	40mm
<b>X-position of side initiator</b>	-60mm	0/92mm	+50mm	-38mm	0/48mm	40mm	-38mm	0/48mm	40mm
<b>Spacing between initiators top</b>	-	-	-	-5mm	0/44mm	15mm	-5mm	0/44mm	5mm
<b>Spacing between initiators side</b>	-	-	-	-5mm	0/44mm	15mm	-5mm	0/44mm	5mm

# Optimisation Strategy

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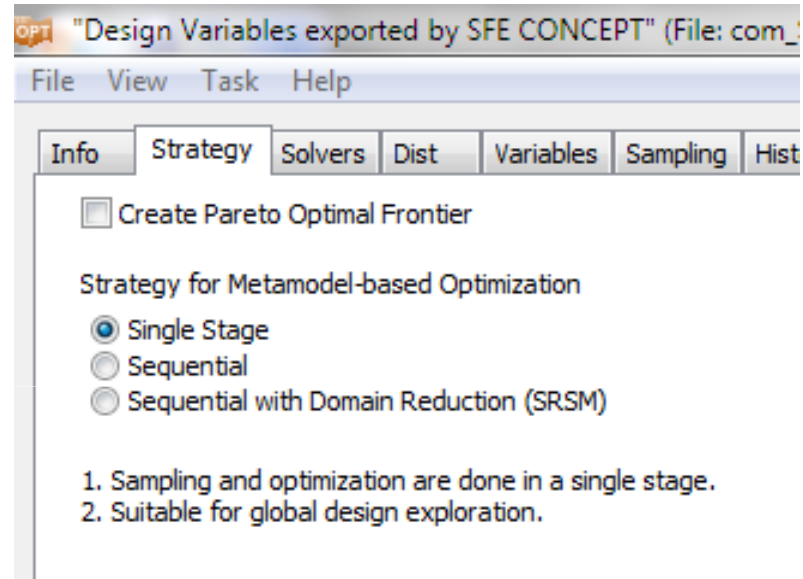
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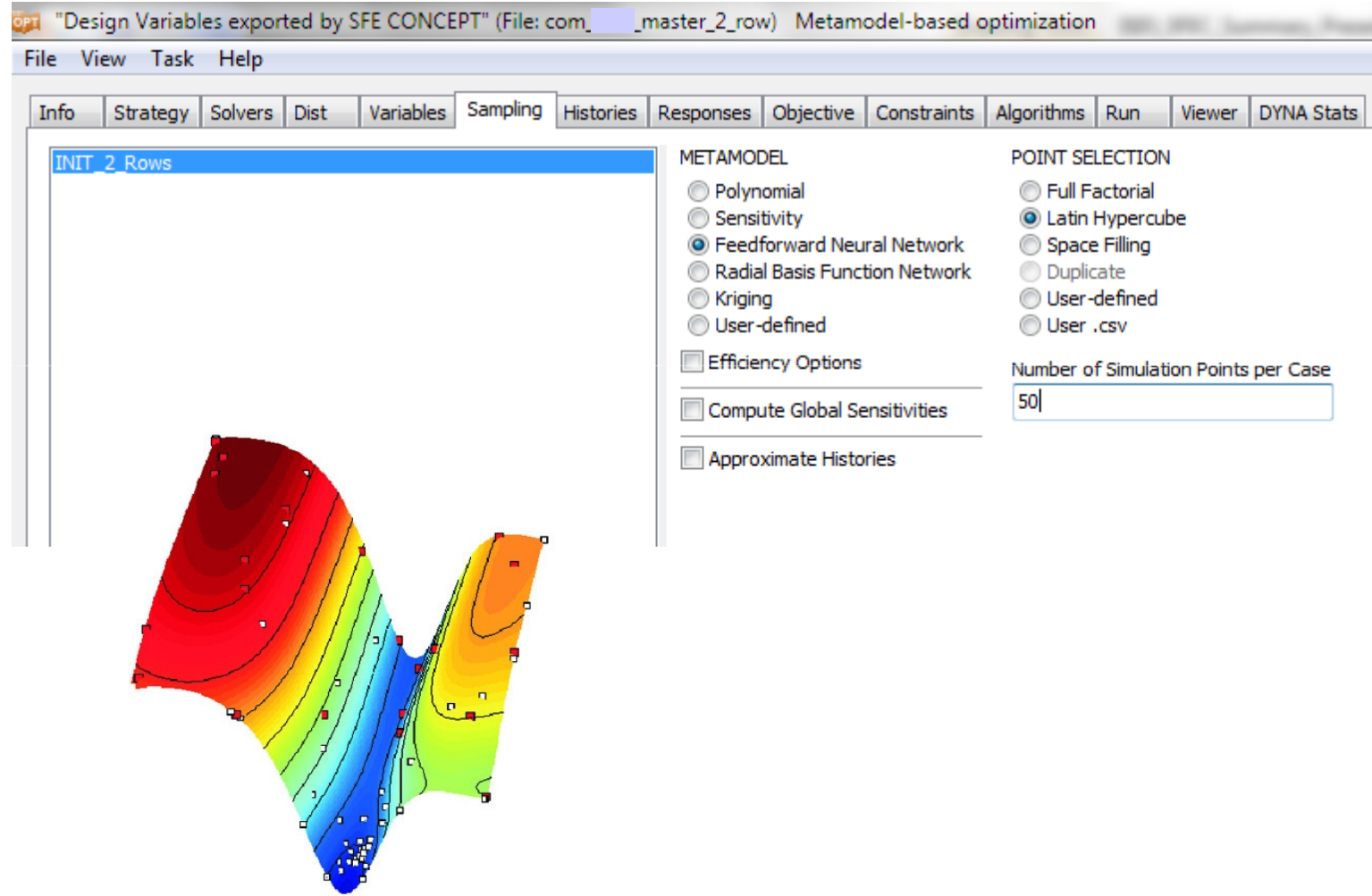
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# Metamodel and Sampling



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# Responses

opt "Design Variables exported by SFE CONCEPT" (File: con master\_2\_row) Metamodel-based optimization

File View Task Help

Info Strategy Solvers Dist Variables Sampling Histories Responses Objective Constraints Algorithms Run Viewer DYNA Stats

USERDEFINED  
GENERIC EXtraction  
Composite  
Composite-Expression  
Injury Criteria  
MeanSqErr  
Response-Expression  
Standard Deviation  
Matrix-Expression  
ABSTAT  
BNDOUT  
D3PLOT  
DBBEMAC  
DEFORC  
ELOUT  
FLD  
FREQUENCY  
GCEOUT  
GLSTAT  
JNTFORC  
MASS  
MATSUM  
NCFORC  
NODOUT  
NODFORC  
PSTRESS  
RBDOUT  
RCFORC  
RWFORC  
SBTOUT  
**SECFORC**  
SPCFORC  
SPHOUT  
SWFORC  
THICK  
Nastran-Frequency

Section ID  
1001

Component  
☐ X force    ☐ X moment    ☐ X center  
☐ Y force    ☐ Y moment    ☐ Y center  
☐ Z force    ☐ Z moment    ☐ Z center  
☒ Resultant force    ☐ Resultant moment

Select    From time    To time  
Maximum Value    0.0000    0.0100

Filtering  
None

Responses  
INIT\_2\_Rows  
SECFORC\_AV\_2\_ROW  
NODOUT1\_2\_ROW  
GLSTAT\_2\_ROW  
**SECFORC\_PK\_2\_ROW**  
NODOUT2\_2\_ROW  
DELTA\_2\_ROW

Description	Units
Peak Force	N
Average Force	N
Deformation X-axis	mm
Average Energy Absorb.	mJ

Peak Force filtered using SAE 180

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# Optimization Results

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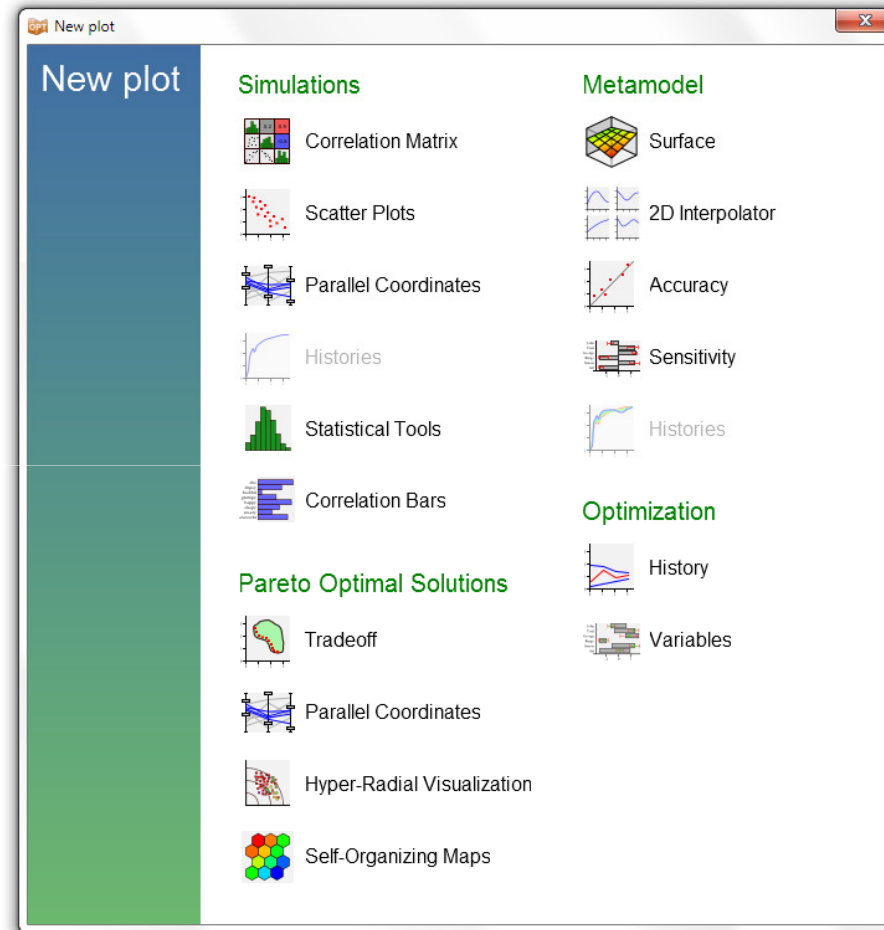
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# Post-Process





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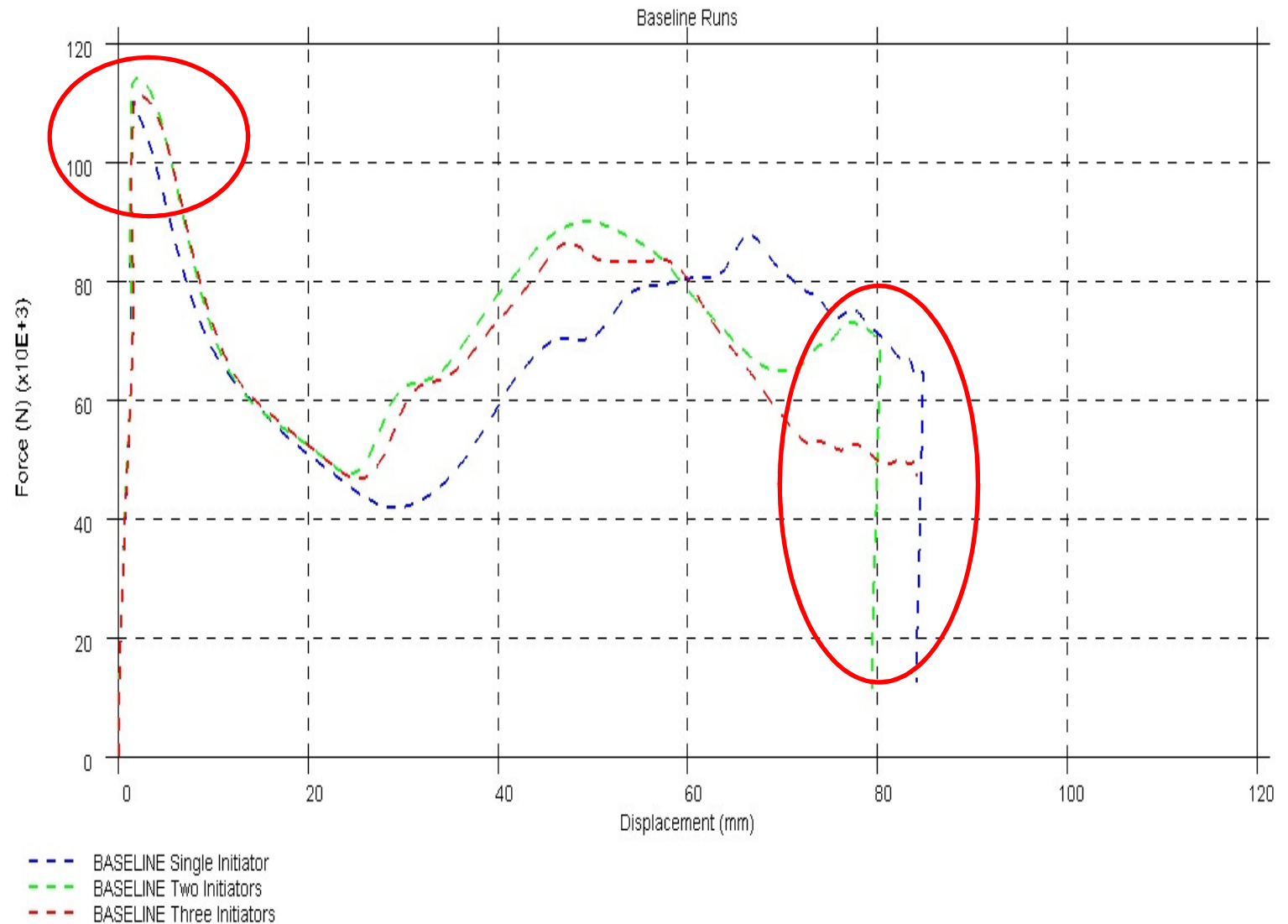
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# Baseline



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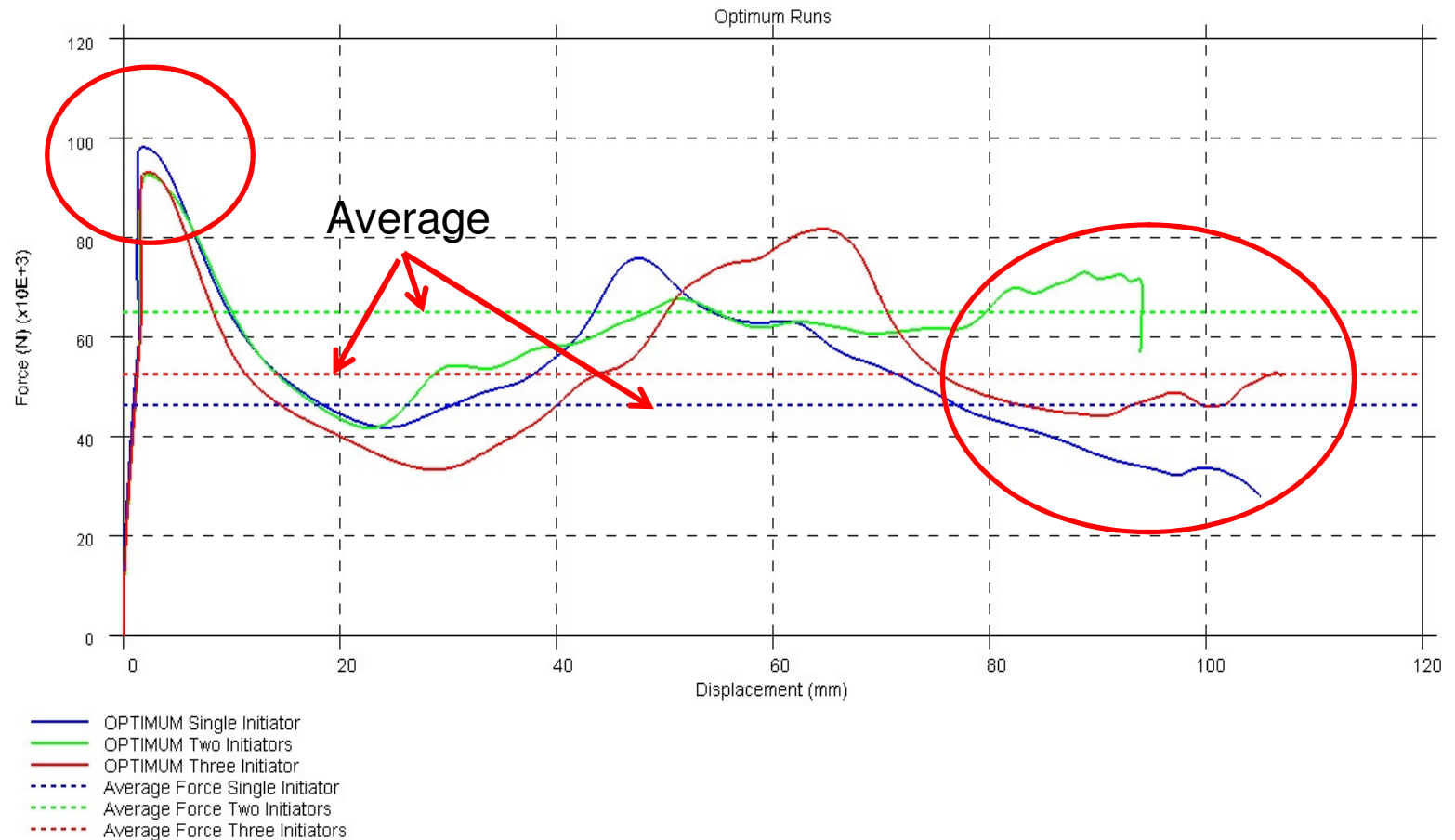
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# Optimum Comparison



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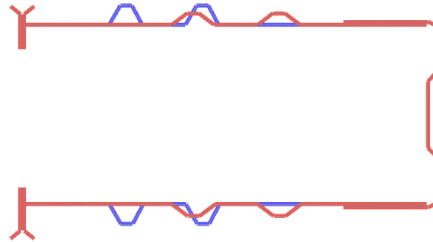
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# Two Initiators

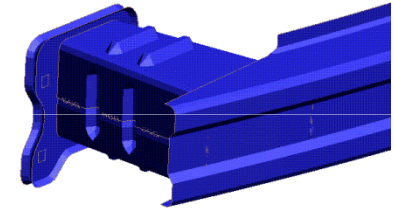
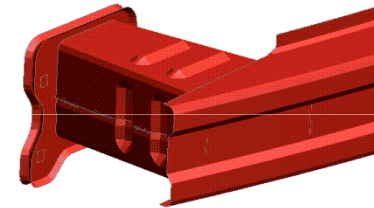
OASYS D3PLOT: Master 2 Rows of Initiators File



OASYS D3PLOT: Master 2 Rows of Initiators File

OASYS D3PLOT: Master 2 Rows of Initiators File

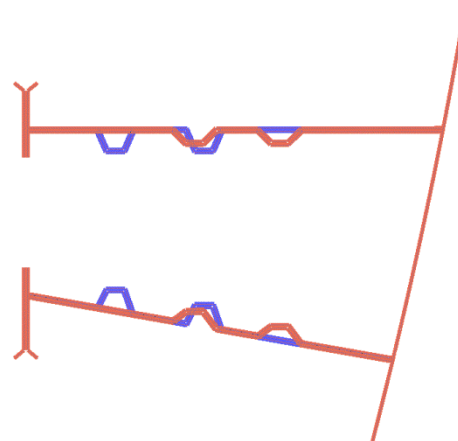
z  
x  
.000000000



z  
x  
.000000000

z  
x  
.000000000

OASYS D3PLOT: Master 2 Rows of Initiators File



y  
x  
.000000000

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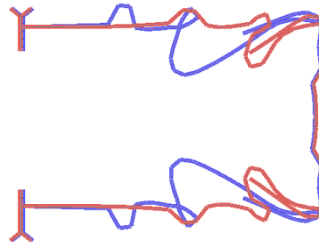
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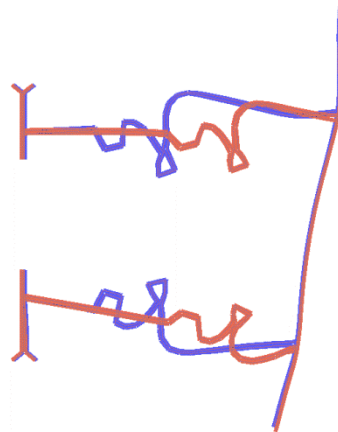
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# Two Initiators

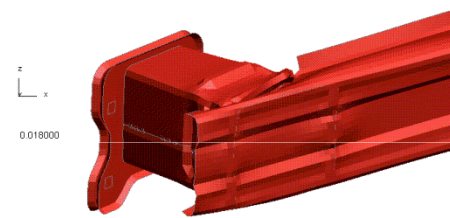
OASYS D3PLOT: Master 2 Rows of Initiators File



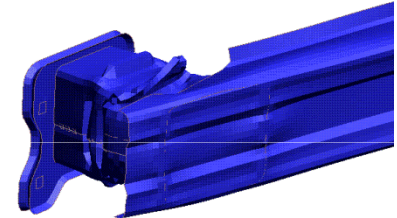
OASYS D3PLOT: Master 2 Rows of Initiators File



OASYS D3PLOT: Master 2 Rows of Initiators File



OASYS D3PLOT: Master 2 Rows of Initiators File



z  
y  
x  
0.018000

z  
y  
x  
0.018000

y  
x  
0.018000

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# Results Summary

No. Of Initiator Rows	Response	Baseline	Optimum
One	Crush (mm)	84.0	105.4
	Average Load (KN)	65.6	46.4
	Peak Force (KN)	110.3	98.4
	Energy (MJ)	5.5	5.1
Two	Crush (mm)	79	94.4
	Average Load (KN)	66.7	65
	Peak Force (KN)	114.2	92.8
	Energy (MJ)	5.6	5.3
Three	Crush (mm)	84.4	106.8
	Average Load (KN)	60.7	52.5
	Peak Force (KN)	115.0	96.5
	Energy (MJ)	5.6	5.3

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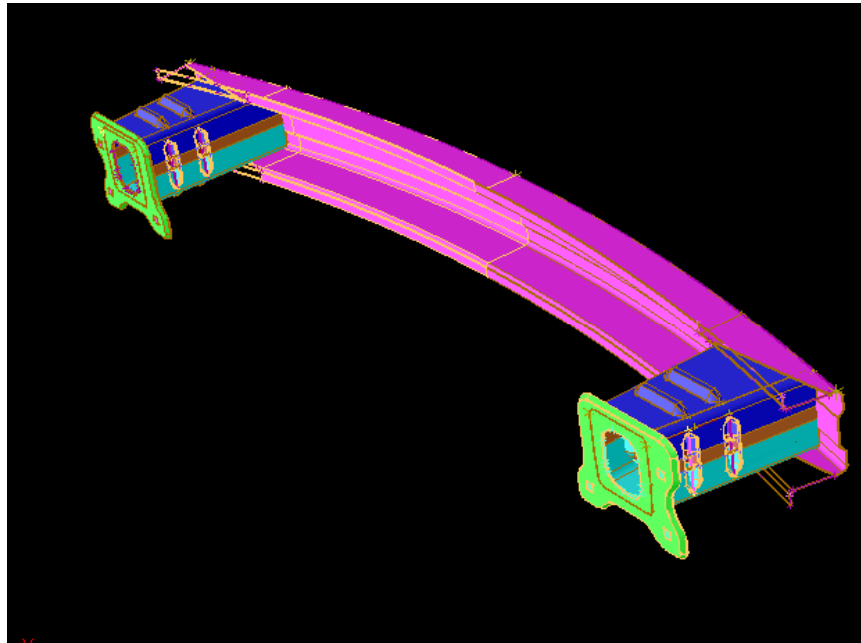
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# Two Rows Optimum



	Two Rows
Description	Nominal
X-position of top initiator	87mm
X-position of side initiator	87mm
Spacing between initiators top	39mm
Spacing between initiators side	46mm
Can wall thickness	1.6mm
Can material	H340LAD
Can outer wall taper	10
Depth of initiators	10mm
Width of initiators	18mm
Mass reduction	8%

## Conclusions Case Study

- Two initiators provide the best results
- Optimisation driven by the requirement to reduce peak force
- Welds stopped the crumpling collapse of the crush can
- 8% mass reduction was achieved with marginal compromise on crush can deformation
- Further runs are required to find the best solution
- Although design targets were not met perfectly the integration of SFE CONCEPT was successful, opening the possibility to investigate further this designs