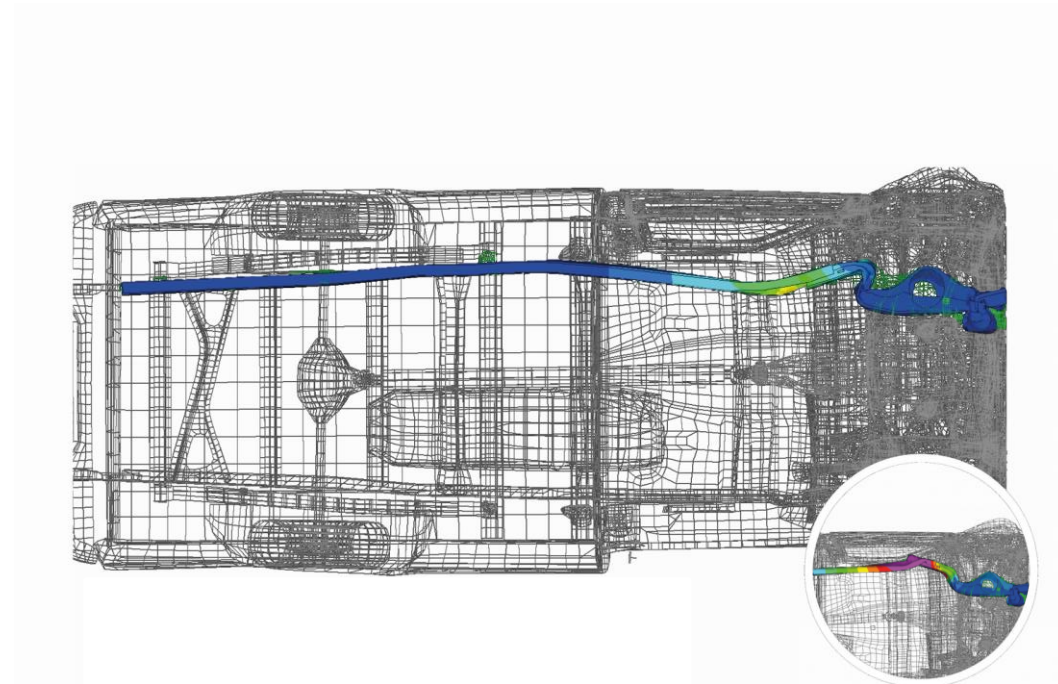

Process to improve optimization with combined robustness analysis results



Dominik Borsotto, Lennart Jansen, Clemens-August Thole

Dominik Borsotto

Agenda

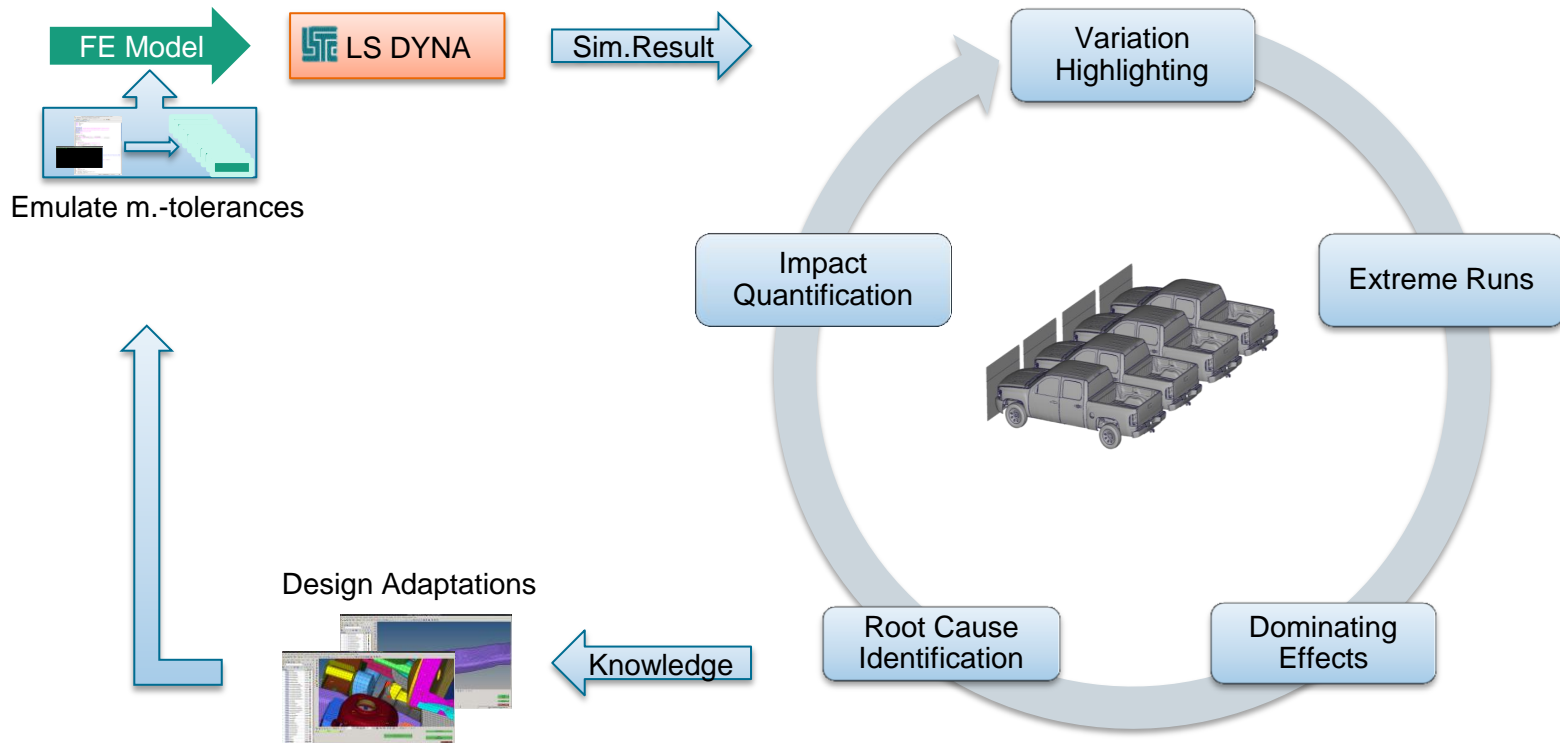
Introduction

Combined Optimization & Robustness Analysis

Introduction

Robustness Workflow

DIFFCRASH



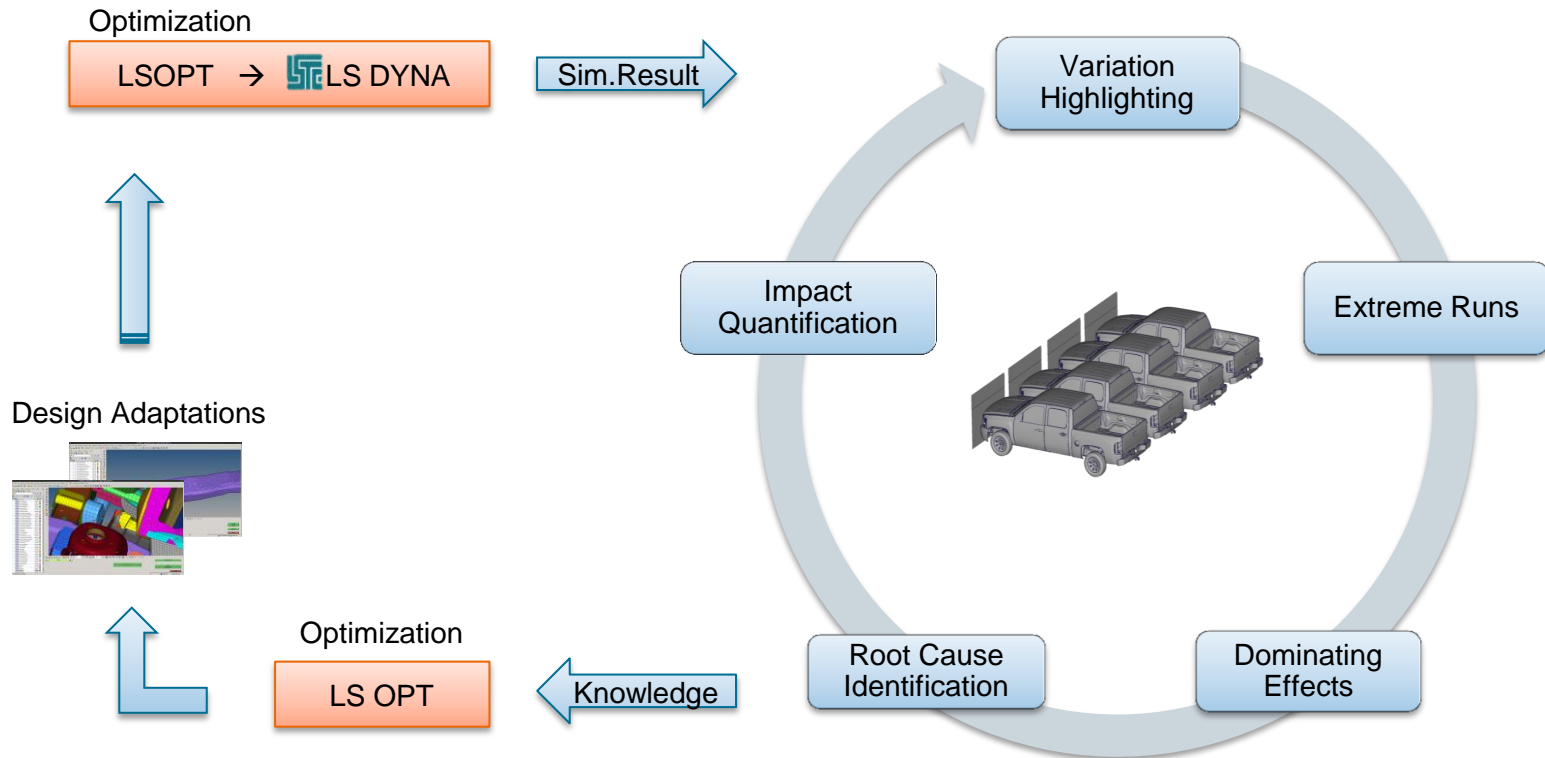
"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT"

<http://www.ncac.gwu.edu/vml/models.html>

Introduction

Robustness & Optimization Workflow

DIFFCRASH



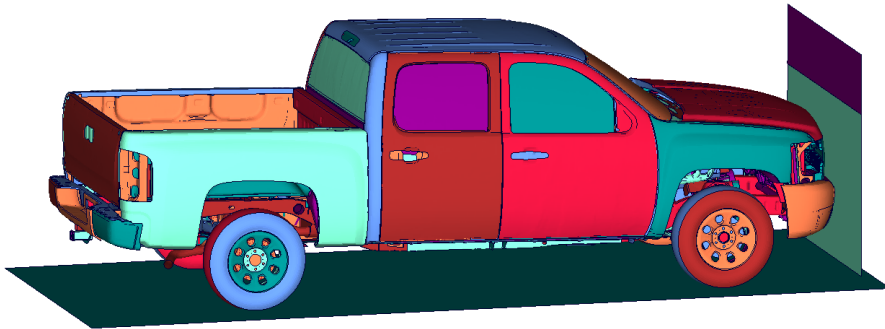
"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT"

<http://www.ncac.gwu.edu/vml/models.html>

Optimization: Chevrolet Silverado

DIFFCRASH

Chevrolet Silverado



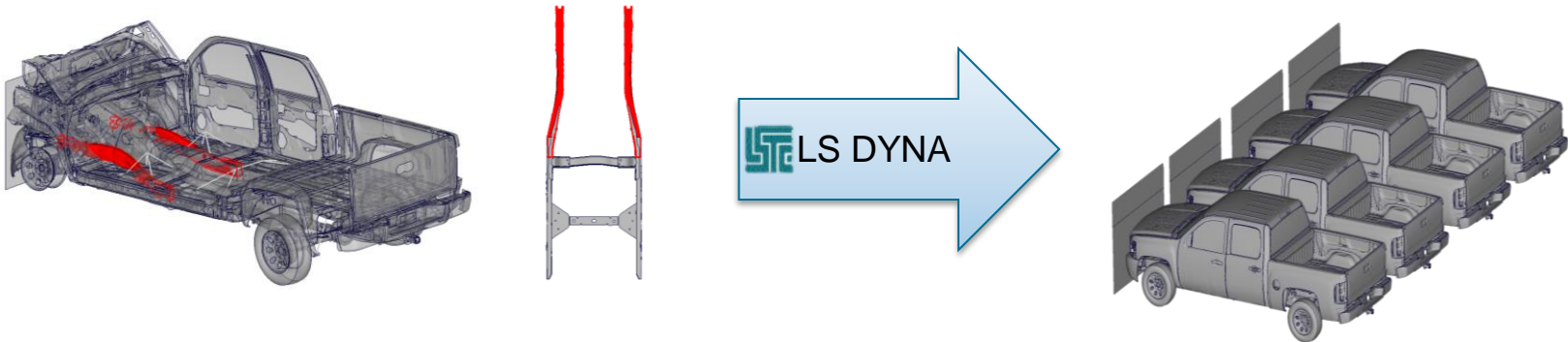
Model	Chevrolet Silverado
Year	2007
Number of Parts	679
Finite-Elements	929,131

"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT"

<http://www.ncac.gwu.edu/vml/models.html>

Optimization: Dataset

77 Simulation runs with random thickness variations of the longitudinals

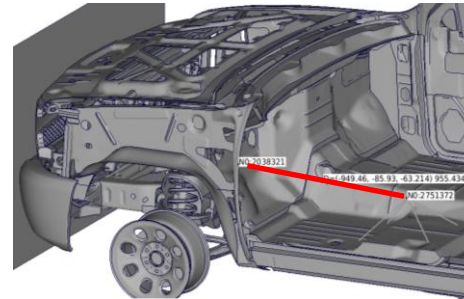
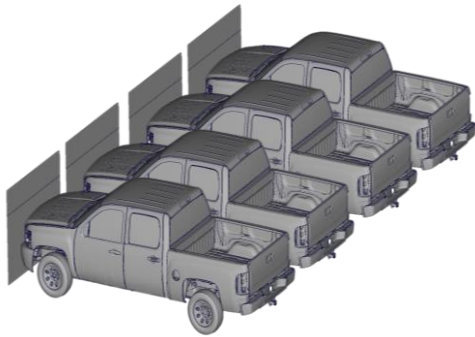


"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT"

<http://www.ncac.gwu.edu/vml/models.html>

Optimization: Goals

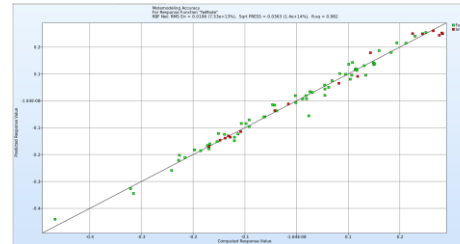
DIFFCRASH



Maximize node distance



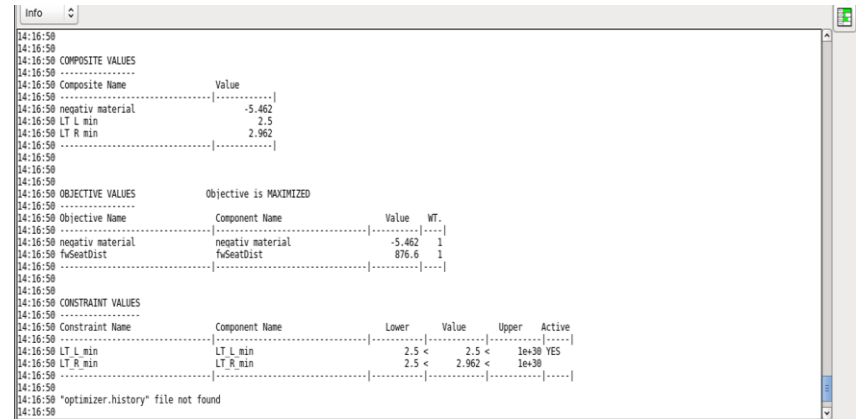
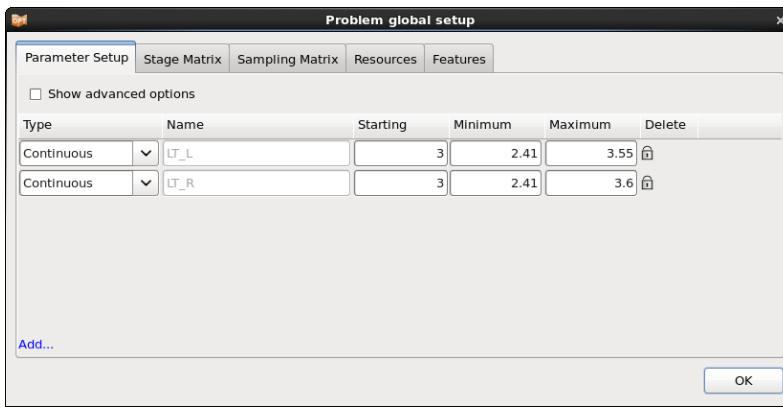
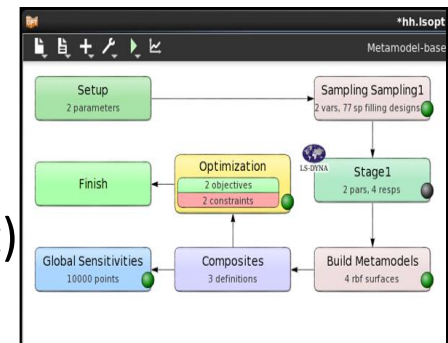
Minimize thicknesses (material)



Provide accurate metamodel

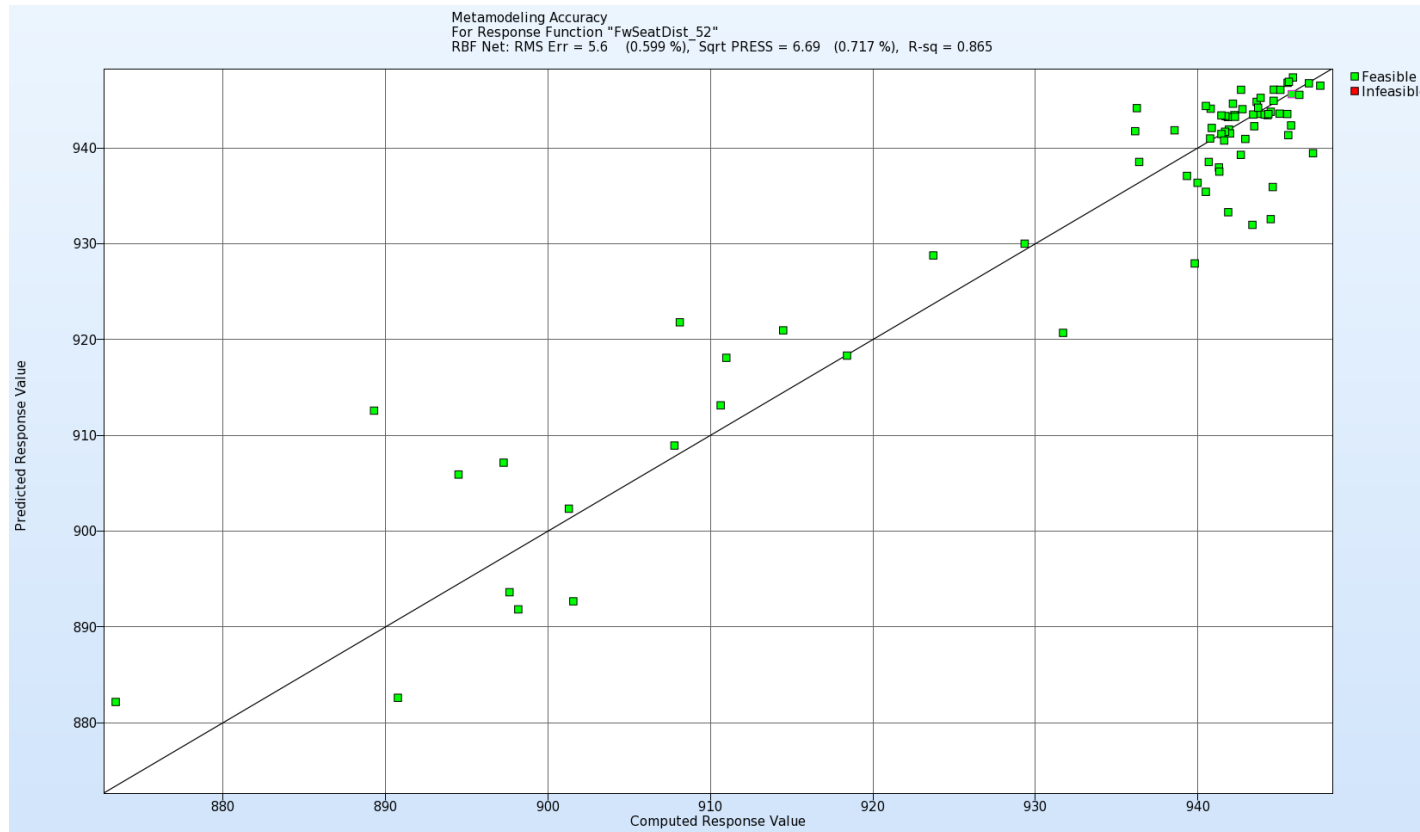
Optimization: LSOPT

- Metamodel optimization
- Input variables: longitudinal thicknesses
- Maximize node distances (between firewall and seat)
- Minimizing the sum of the thicknesses



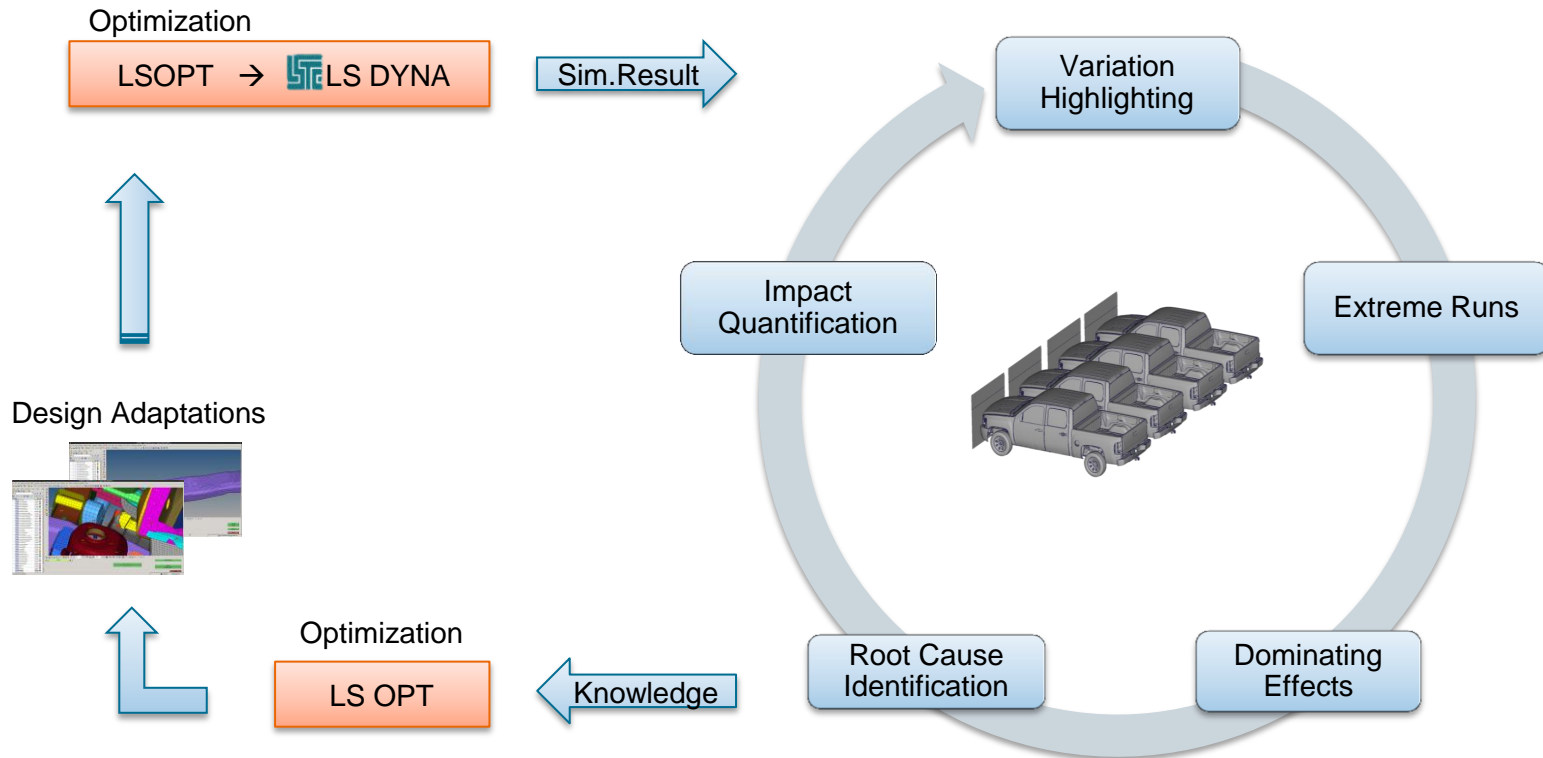
Optimization: Meta Model Quality Node Distance

DIFFCRASH



Robustness Analysis:

DIFFCRASH



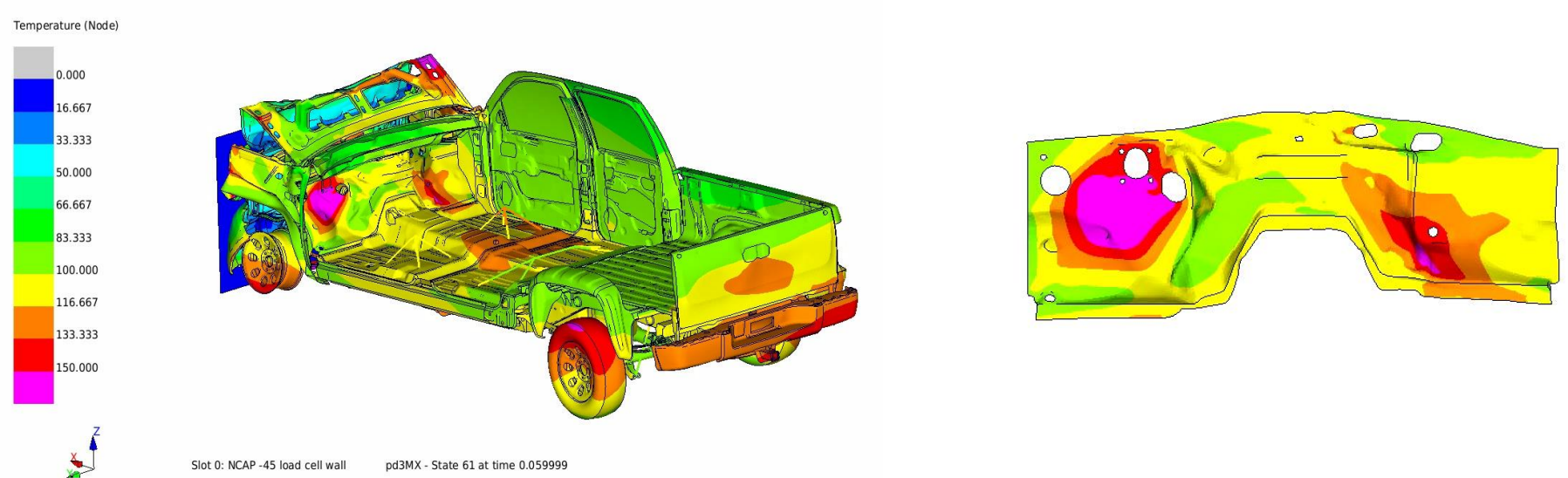
"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT"

<http://www.ncac.gwu.edu/vml/models.html>

Robustness Analysis: DIFFCRASH

DIFFCRASH

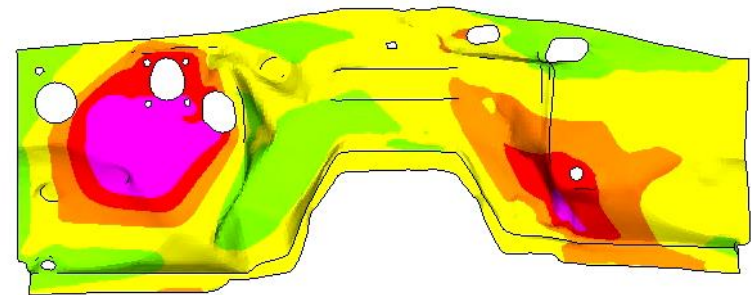
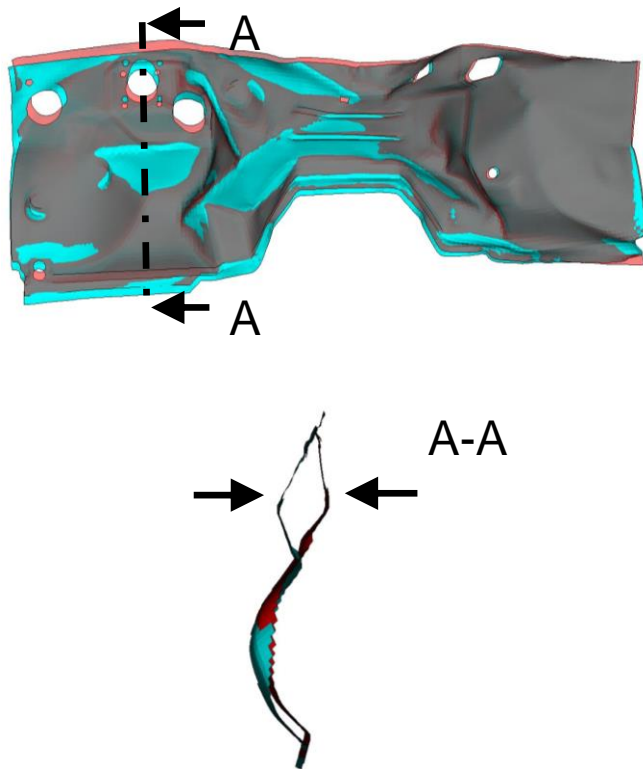
Scatter Overview



Maximum variation of node position in [mm]

Robustness Analysis: Mode information

DIFFCRASH

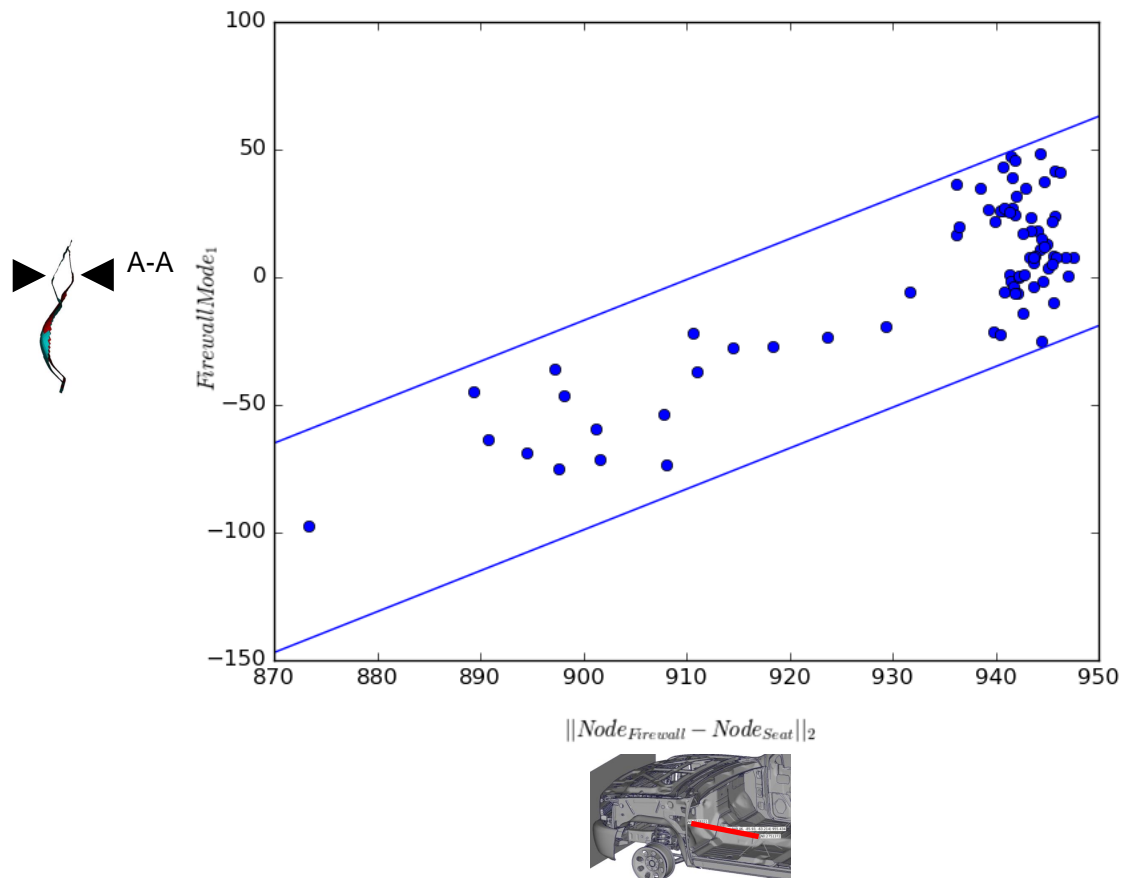


→ Intrusion information

→ Replacement for node distance?

Robustness Analysis: Mode information

DIFFCRASH



LS-OPT – Mode as objective and variable



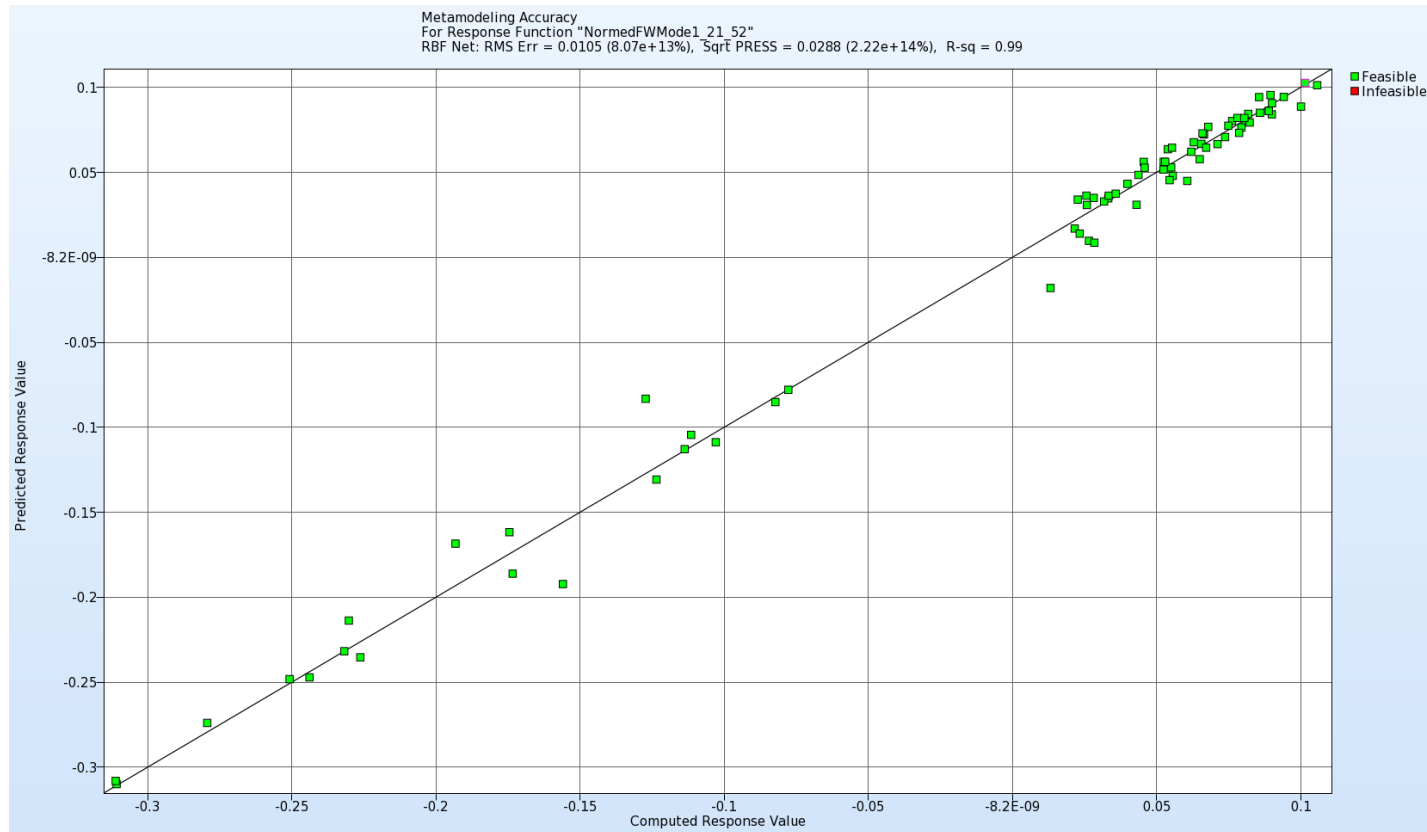
- Firewall mode (intrusion)
- Input variables: longitudinal thicknesses
- Maximize node distances (between firewall and seat)
- Minimizing the sum of the thicknesses

The screenshot displays the LS-OPT 5.2.0 interface. The top part shows a workflow diagram with the following steps: Setup (4 parameters), Sampling (4 vars, 77 sp filling designs), Optimization (2 objectives, 3 constraints), Stage (4 pars, 2 resps), Global Sensitivities (10000 points), Composites (3 definitions), and Build Metamodels (2 dof surfaces). The bottom part shows the output log with the following tables:

```
12:31:15 COMPOSITE VALUES
12:31:15 -----
12:31:15 Composite Name      Value
12:31:15 -----
12:31:15 negativ_material      -5.824
12:31:15 StandardComposite1    2.5
12:31:15 StandardComposite2    3.324
12:31:15 -----
12:31:15
12:31:15 OBJECTIVE VALUES      Objective is MAXIMIZED
12:31:15 -----
12:31:15 Objective Name        Component Name      Value  WT.
12:31:15 -----
12:31:15 fWMode                 negativ_material   -5.824  1
12:31:15 -----
12:31:15
12:31:15 CONSTRAINT VALUES
12:31:15 -----
12:31:15 Constraint Name      Component Name      Lower  Value  Upper  Active
12:31:15 -----
12:31:15 StandardComposite1  StandardComposite1  2.5 < 2.5 < 1e+30 YES
12:31:15 StandardComposite2  StandardComposite2  2.5 < 3.324 < 1e+30
12:31:15 fWMode                 negativ_material    0.2661 < 0.2716 < 1e+30
12:31:15 -----
12:31:15
12:31:15 "optimizer.history" file not found
12:31:15
```

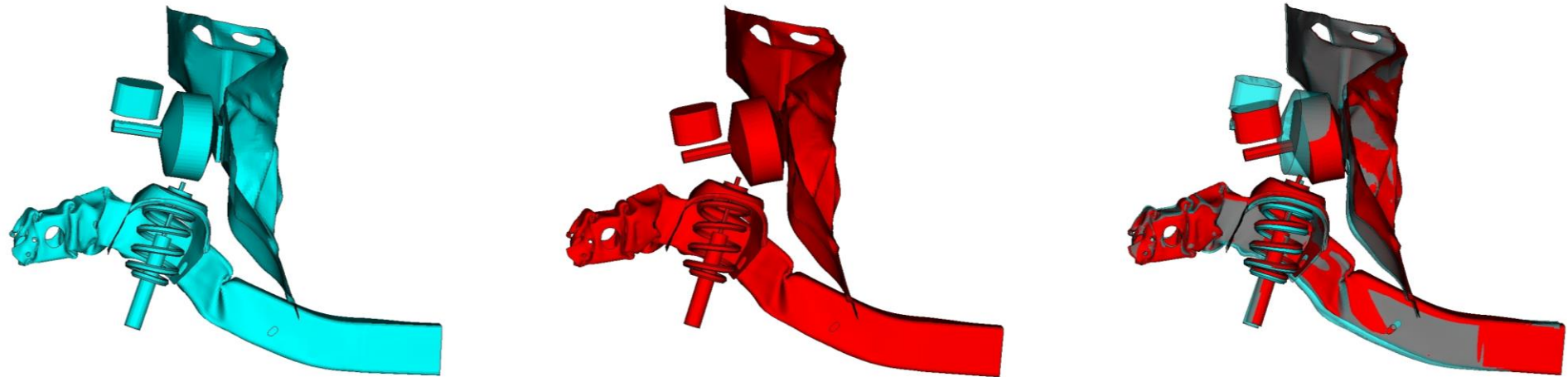
Optimization: Quality of the Meta Model Firewall Mode

DIFFCRASH



Robustness Analysis: Mode information

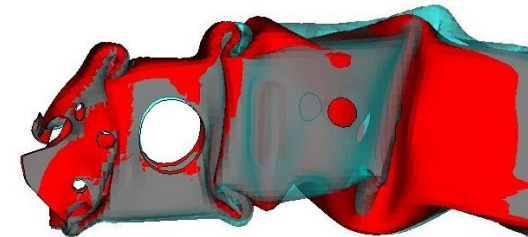
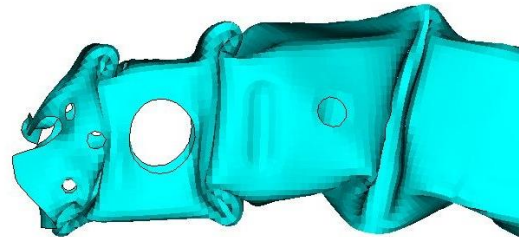
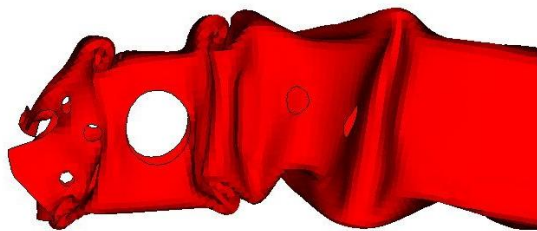
DIFFCRASH



Firewall scatter mode at power-brake

Robustness Analysis: Mode information

DIFFCRASH



Dominating firewall scatter mode at longitudinal rail

LS-OPT – Mode as objective and variable



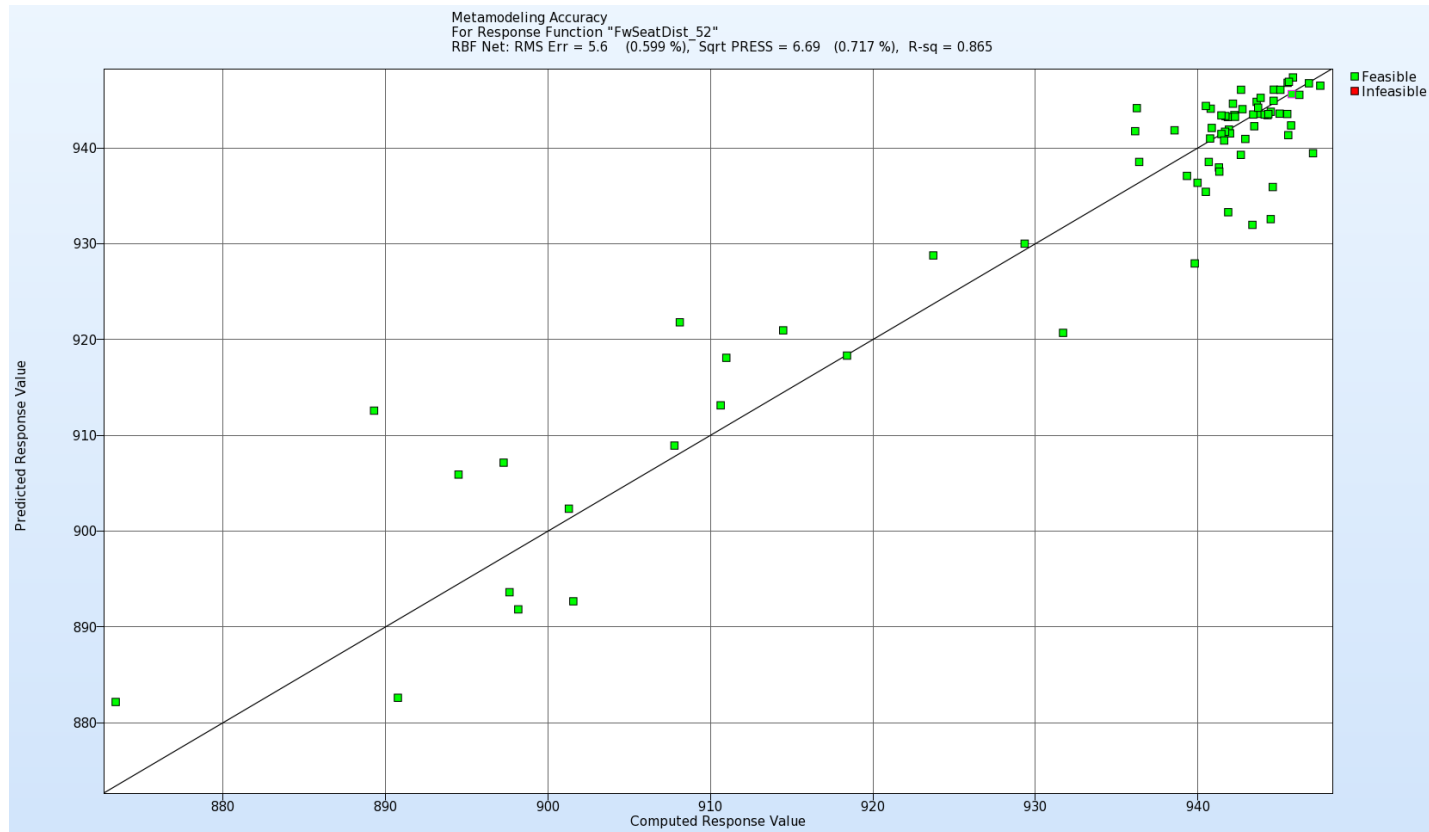
- Firewall mode (intrusion)
- Variables: Brake booster & left longitudinal buckling modes
- Possibility to choose best specification of the modes for our objectives.

The screenshot displays the LS-OPT 5.2.0 software interface. The top part shows a workflow diagram with the following steps: Setup (4 parameters) leads to Sampling (4 vars, 77 sp filling designs), which leads to Optimization (2 objectives, 3 constraints). Optimization leads to Finish. Optimization also leads to Stage (4 pars, 2 resps), which leads to Build Metamodels (2 ref surfaces), then Composites (3 definitions), and finally Global Sensitivities (10000 points). The bottom part shows the Output (I) window with the following log:

```
02:31:15
02:31:15 COMPOSITE VALUES
02:31:15 -----
02:31:15 Composite Name      Value
02:31:15 -----
02:31:15 negativ_material      -5.824
02:31:15 StandardComposite1    2.5
02:31:15 StandardComposite2    3.324
02:31:15 -----
02:31:15
02:31:15
02:31:15 OBJECTIVE VALUES      Objective is MAXIMIZED
02:31:15 -----
02:31:15 Objective Name         Component Name      Value  Wt.
02:31:15 -----
02:31:15 fWMode                 negativ_material    -5.824  1
02:31:15 -----
02:31:15
02:31:15 CONSTRAINT VALUES
02:31:15 -----
02:31:15 Constraint Name        Component Name      Lower  Value  Upper  Active
02:31:15 -----
02:31:15 StandardComposite1    StandardComposite1  2.5 <  2.5 <  1e+30  YES
02:31:15 StandardComposite2    StandardComposite2  2.5 <  3.324 <  1e+30
02:31:15 fWMode                 fWMode             0.2716 <  0.2716 <  1e+30
02:31:15 -----
02:31:15
02:31:15 'optimizer.history' file not found
02:31:15
```

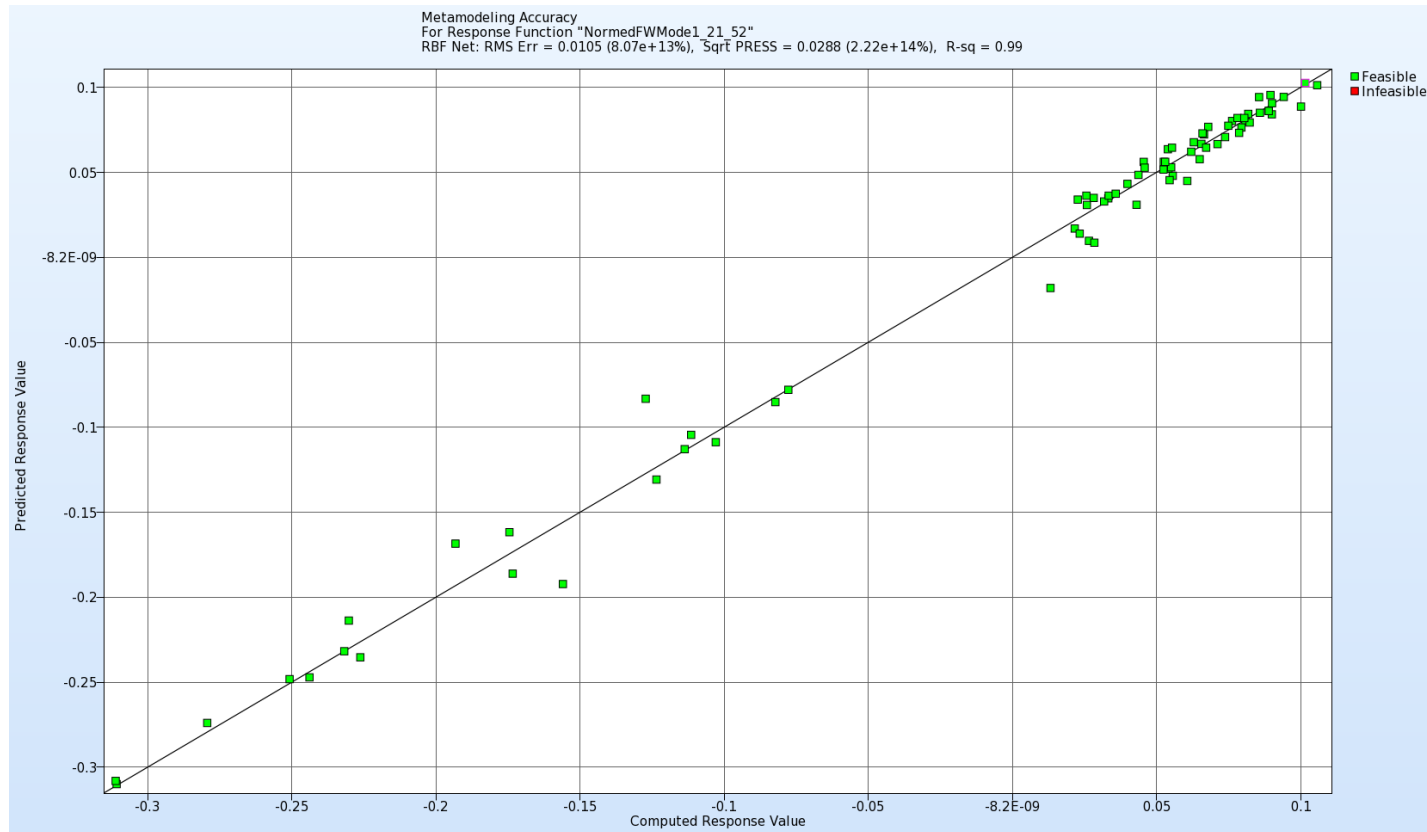
Optimization: Quality of the Meta Model Node Distance

DIFFCRASH



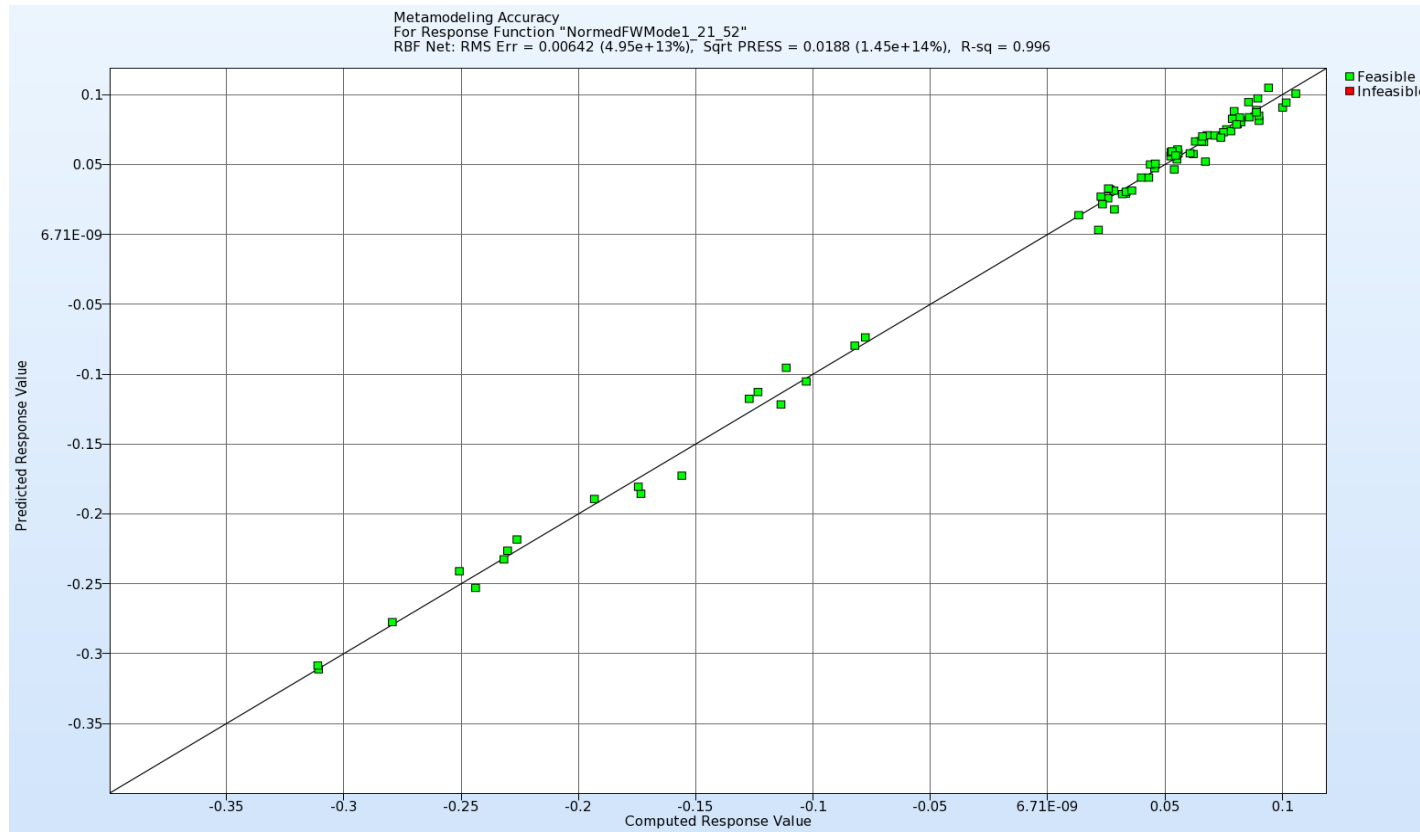
Optimization: Quality of the Meta Model Firewall Mode

DIFFCRASH

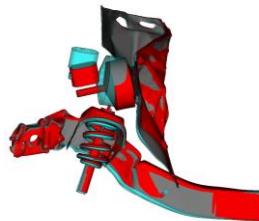
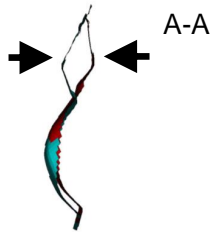
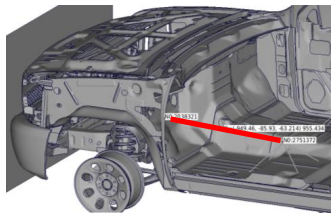


Optimization: Meta-Model Accuracy Firewall/BreakBooster

DIFFCRASH



Robustness Analysis: Mode information



$$LSDYNA (D_1, D_2)$$

$$intrusion(LSDYNA (D_1, D_2))$$

$$\alpha_{FW} (D_1, D_2) \cdot M_{\alpha_{FW}}$$

$$\beta_{FW} (D_1, D_2) \cdot M_{\beta_{FW}}$$

...

$$intrusion(\bar{f} + \alpha_{FW} (D_1, D_2) \cdot M_{\alpha_{FW}} + \beta_{FW}(D_1, D_2) \cdot M_{\beta_{FW}} \dots)$$

$$intrusion(\bar{f} + \alpha_{FW} (D_1, D_2, \mathbf{I}_{BB}) \cdot M_{\alpha_{FW}} + \beta_{FW}(D_1, D_2, \mathbf{I}_{BB}) \cdot M_{\beta_{FW}} \dots)$$

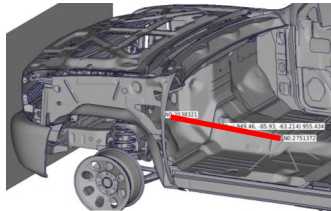
$\alpha_{FW} (D_1, D_2)$
 $\beta_{FW} (D_1, D_2)$
 $M_{\alpha_{FW}}$
 $M_{\beta_{FW}}$
 D_i

Metamodel of 1st FW Mode
 Metamodel of 2nd FW Mode
 1st FW Mode
 2nd FW Mode
 Thicknesses

$intrusion$
 \bar{f}

Function to determine intrusion
 Average simulation result

Robustness Analysis: Mode information



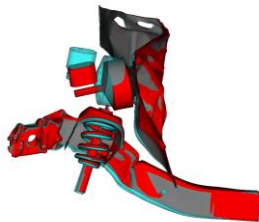
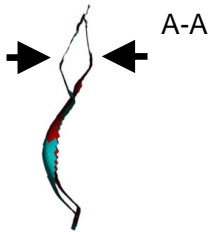
Modes describe geometrical deformation of an area compared to single points

Less prone to local effects (e.g creasing)

Modes can be used as additional input variables as well as objectives

Describing effects, modes allow a classification (preferred behavior vs bad behavior)

This enables us to use a combined optimization with robustness knowledge



Thank you for your attention!

Dominik Borsotto