LS-OPT® Pro Status 2023R1

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Overview

- Integration with Ansys Products
  - LS-OPT Metamodels
  - Twin Builder
- LS-DYNA Fields
- Mode Tracking with topologically different designs
- Conclusion

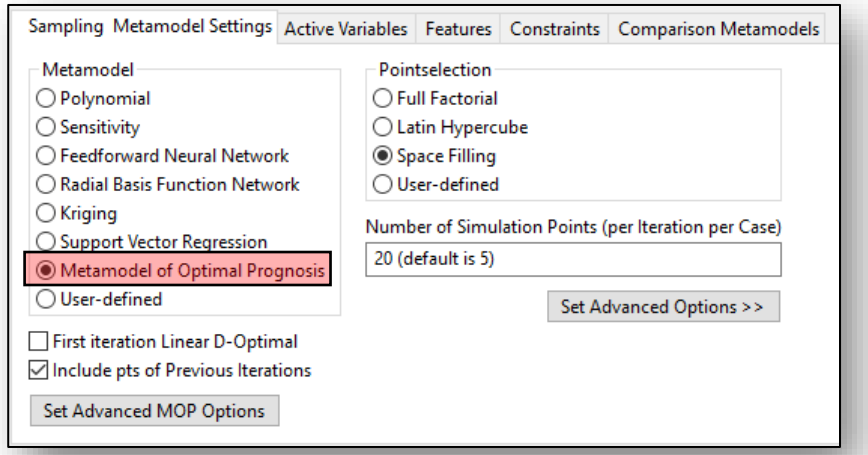
Integration with Ansys Products: Metamodel Enhancement

Integrating LS-OPT features into Ansys products

Metamodels and LS-DYNA Interface

- **LS-OPT → optiSLang**
  - ***Extractor (LS-DYNA interface)(.exe)***
    - Features:
      - LS-DYNA responses and histories, Crash Injury criteria, Calibration tools, General Mathematical expressions, keyword parsing (variable substitution)
      - GUI
    - LS-Reader integration (d3plot). Supported by LSPP group.
    - In current version (2022R2)
  - ***LS-OPT Metamodels***
    - Feedforward Neural Networks, Radial Basis Function Networks, Kriging, Support Vector Regression
    - *Status :* Delivered library. Integration process under way**.**

- **optiSLang → LS-OPT**
  - ***MOP2: Only optiSLang metamodels***
    - **Metamodel of Optimal Prognosis: automatically selects the metamodel**
    - Benchmark comparison on crash examples (next slide)



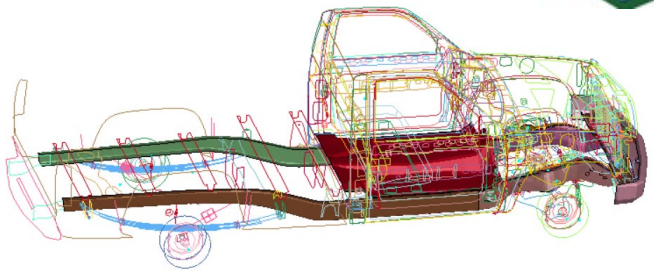
LS-OPT GUI

  - ***MOP3: optiSLang + LS-OPT metamodels***
    - *Broadens the library of metamodels*
    - *Scheduled release :* ***July 2023***

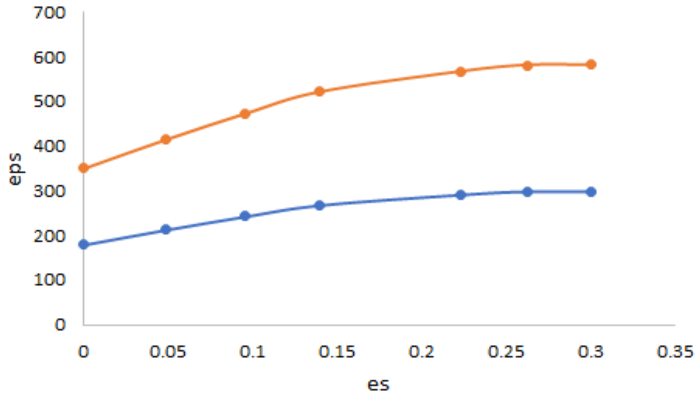
MOP: Comparison to Existing Metamodels (22 variable truck)

	LS-OPT			oS - MOP	
	RBF Predicted	NN Predicted	Kriging Predicted	MOP Predicted	MOP Model
t1, m1	2.510, 349.5	2.510, 349.7	2.510, 327.6	2.510, 348.1	
t2, m2	2.398, 315.4	2.398, 279.6	2.398, 336.3	2.398, 349.3	
t3 , m3	2.510, 340.5	2.510, 293.4	2.510, 329.1	2.510, 348.6	
t4, m4	2.399, 292.6	2.399, 269.7	2.399, 310.9	2.399, 336.4	
t5, m5	2.721, 180.5	2.721, 300.6	2.721, 333.8	2.721, 291.8	
t6, m6	2.721, 275.2	2.721, 180.1	2.721, 255.5	2.721, 328.2	
t10, m10	2.162, 298.5	2.162, 180.2	2.162, 283.5	2.162, 246.5	
t11, m11	2.927, 330.2	3.600, 299.2	2.667, 350.0	3.040, 308.1	
t12, m12	2.948, 330.3	3.257, 330.0	3.350, 267.1	2.499, 223.1	
t64, m64	1.010, 190.6	1.010, 180.1	1.010, 218.6	1.027, 183.8	
t73, m73	1.593, 345.5	1.593, 349.8	1.593, 270.3	1.593, 182.3	
N1_disp	725.5	723.1	722.6	724.4	Kriging
RMS	9.22	8.00	9.22	9.27	
N2_disp	722.3	725.7	723.1	724.7	Kriging
RMS	8.77	7.72	8.83	8.99	
Stage1_pulse	6.818	6.03	6.598	5.869	Linear
RMS	0.0646	0.0624	0.105	0.122	
Stage2_pulse	20.3	21.09	21.03	21.09	Linear
RMS	0.377	0.378	0.432	0.532	
HIC	1.148e+05	7.93e+04	9.56e+04	1.089e+05	Kriging
RMS	2.76e+05	7.09e+05	2.83e+05	2.86e+05	
scl_mass	0.8006	0.8001	0.8006	0.8051	
scl_disp	0.9984	0.9991	0.997	0.9994	
scl_stage1_pulse	0.9019	0.7976	0.8728	0.7763	
scl_stage2_pulse	0.9577	0.9947	0.9918	0.9946	

min *mass (11 parts, 22 variables)*
s.t. *displacement ≤ 1*
stage1_pulse ≤ 1
stage2_pulse ≤ 1



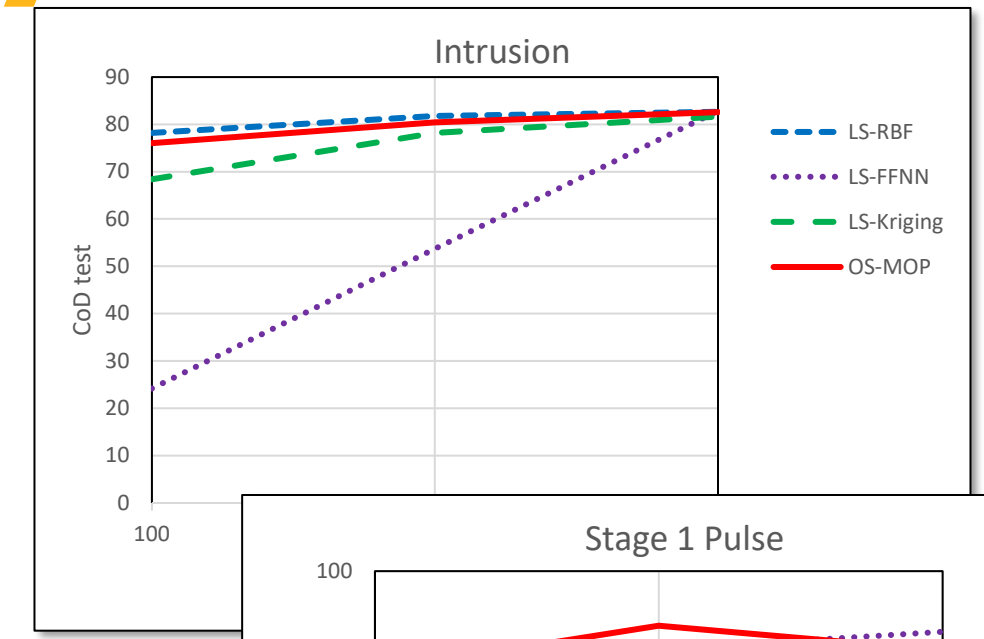
Design Parts (Thickness variables)

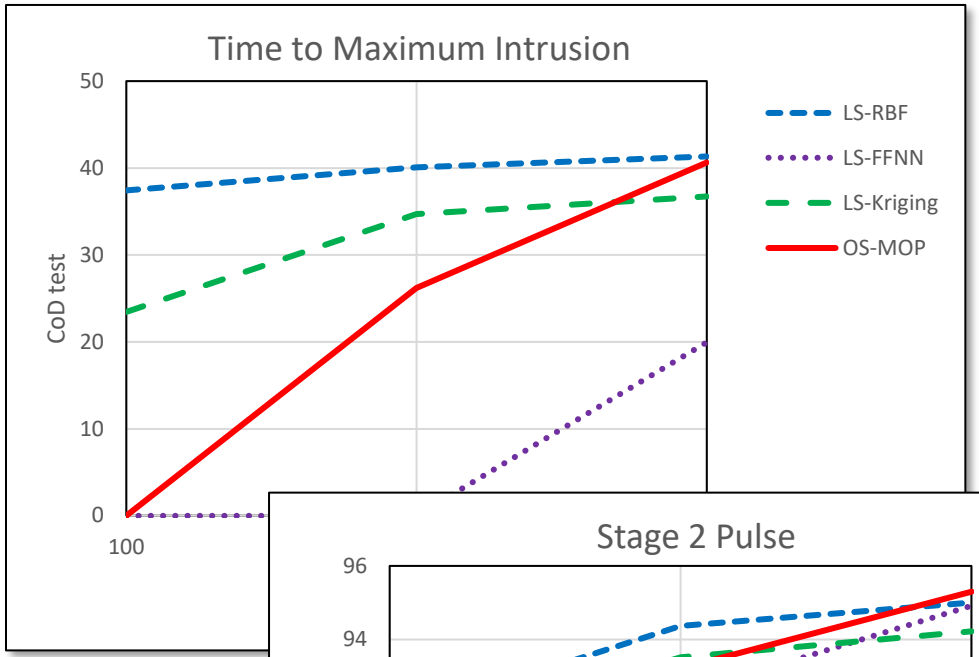


Continuous Part Material Variables

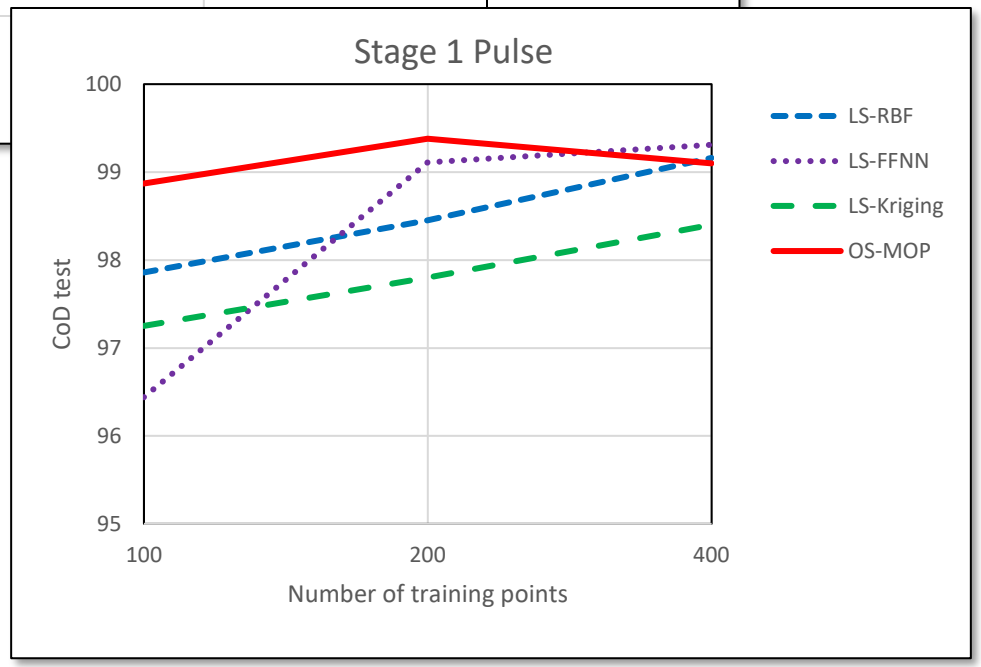
Metamodel construction using ***800*** points
RMS error evaluated using ***1200*** test points

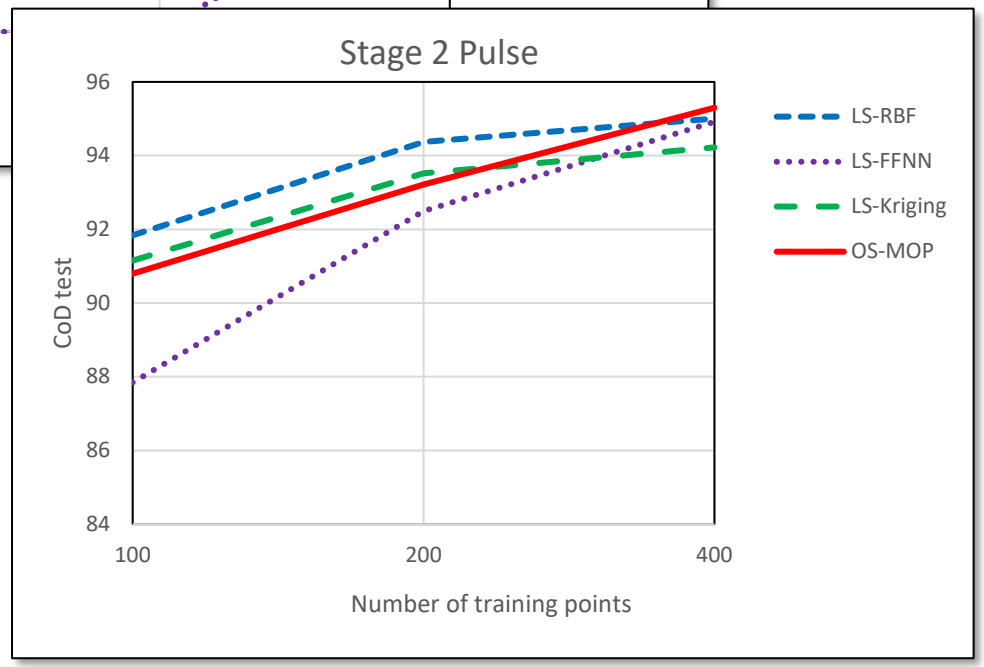
LS-OPT models vs. MOP2: *Sampling rate dependency (22 var.)*





LS=LS-OPT
OS=optiSLang





Analysis by:
Lars Gräning
Thomas Most
(Ansys-Dynardo)

Comments: LS-OPT metamodels vs. MOP: Sampling dependency

- ***In general, LS-OPT metamodels have the potential to improve accuracy for a selection/aggregation system such as MOP***
- ***MOP3, which will include LS-OPT metamodels, also has additional metamodels such as GARS (Genetic Aggregation Response Surface).***
- ***MOP is consistent in selecting the best metamodel on a response-by-response basis. It's an adaptive system which adjusts to the best metamodel every iteration, every response.***

Reduced Order Modeling

Ansys

ROM Techniques in Twin Builder

Goal: Build field approximations for calibration in the material testing and health care areas.

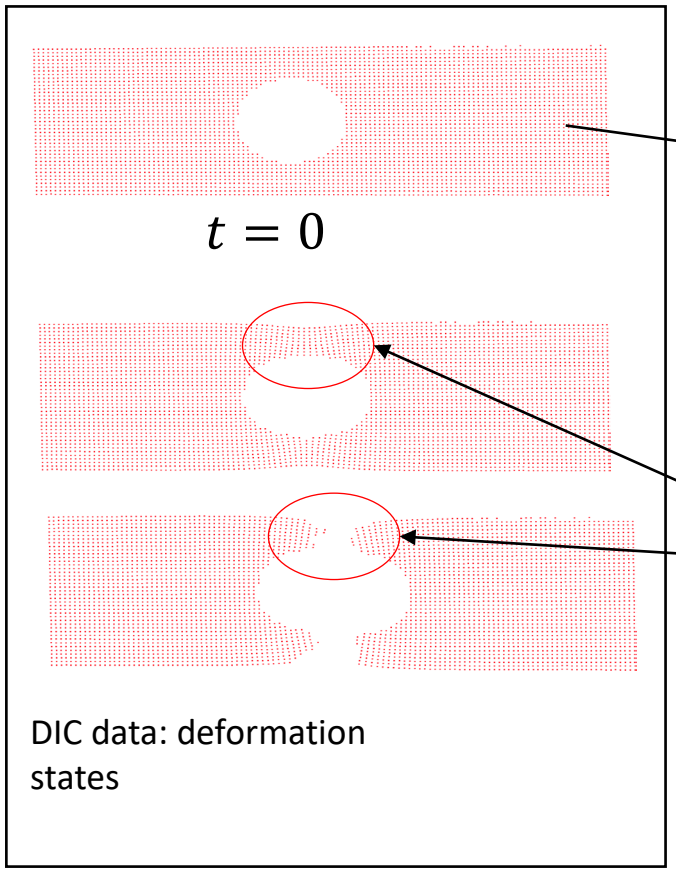
Ansys Twin Builder uses **blackbox solver agnostic** techniques for creating **Reduced Order Models** for **Non-Linear Systems** such as produced by LS-DYNA:

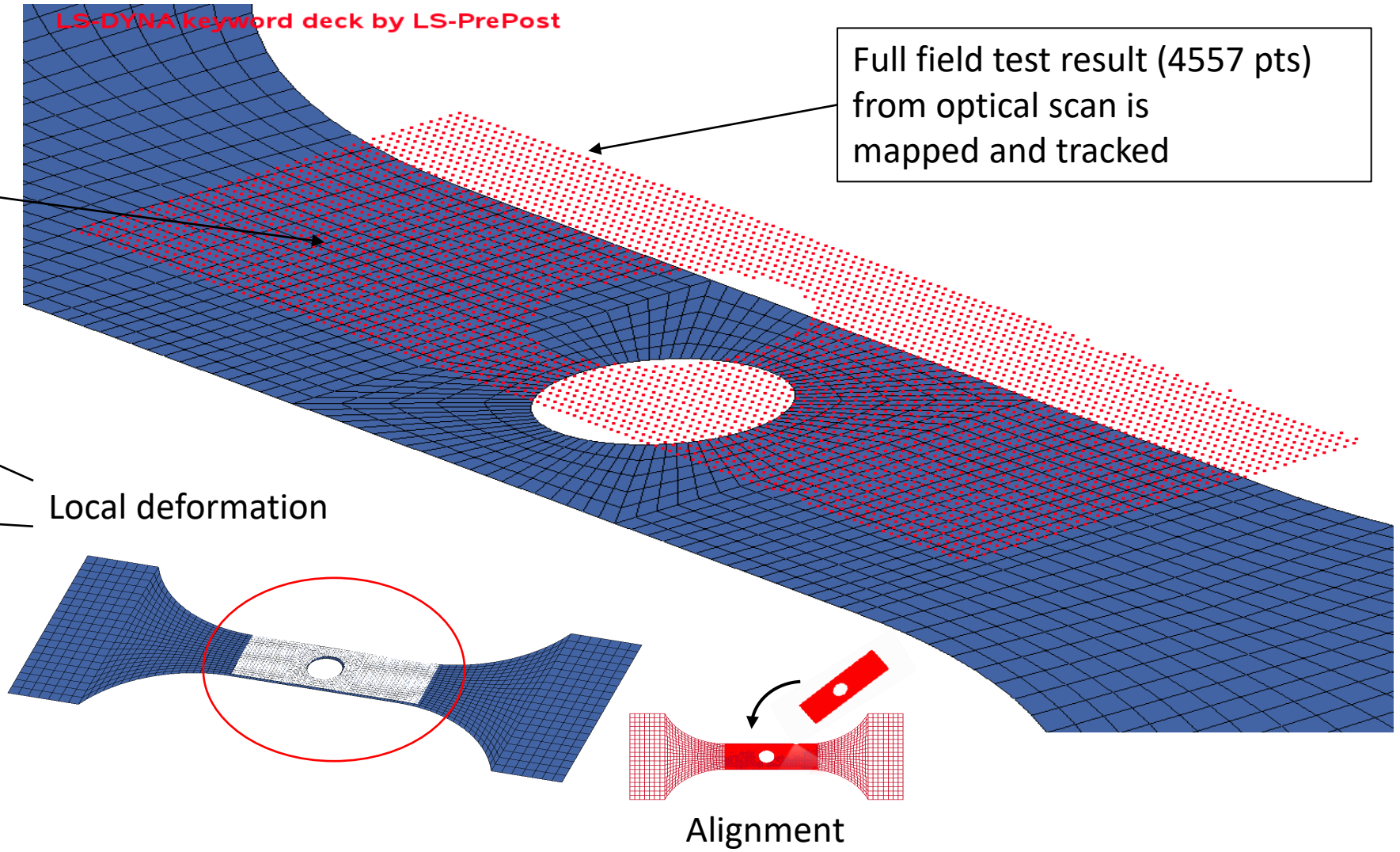
- Reduction :
  - Projection methods on subspaces: **SVD** and **POD** [PCA, Karhunen–Loève Transform] – Eigenvalue Analysis
- Machine learning :
  - Advanced **Interpolation** (Polynomial, Kriging, SVR, GARS) → Static ROM Builder
  - **ODE identification** using **Patented Optimization Method** → Dynamic ROM Builder

Ansys Twin Builder and Reduced Order Models, by *Valéry Morgenthaler (Ansys Twin Builder)*

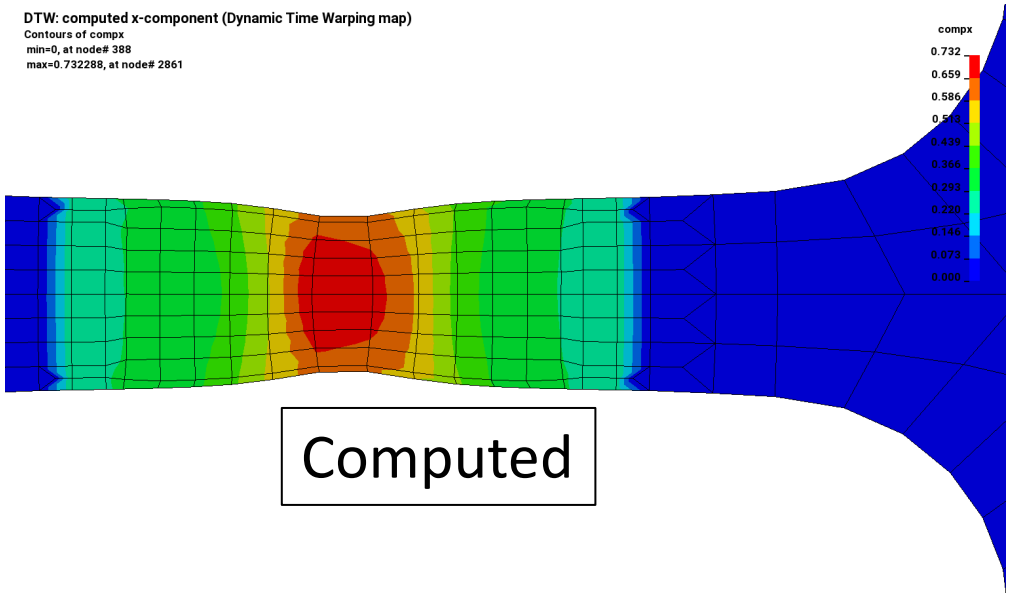
How does LS-OPT used fields? Digital Image Correlation (DIC)

Space-time data

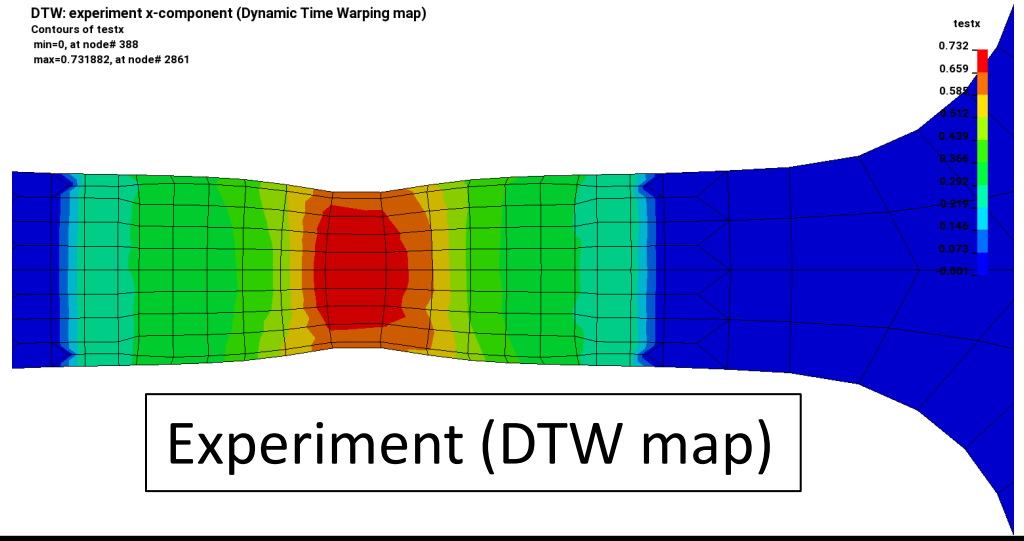




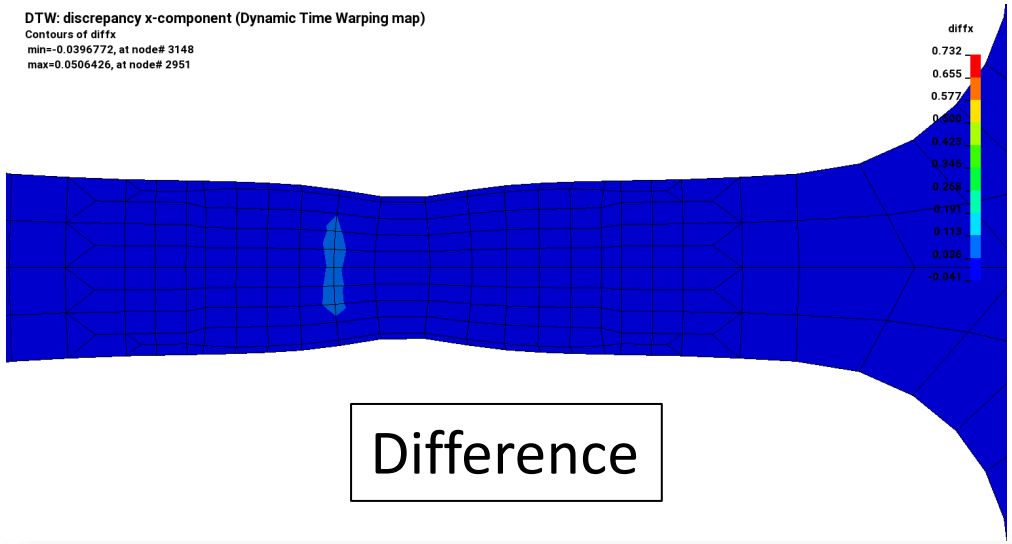
Material Calibration (DIC): Optimal Strain Contours (Dynamore)



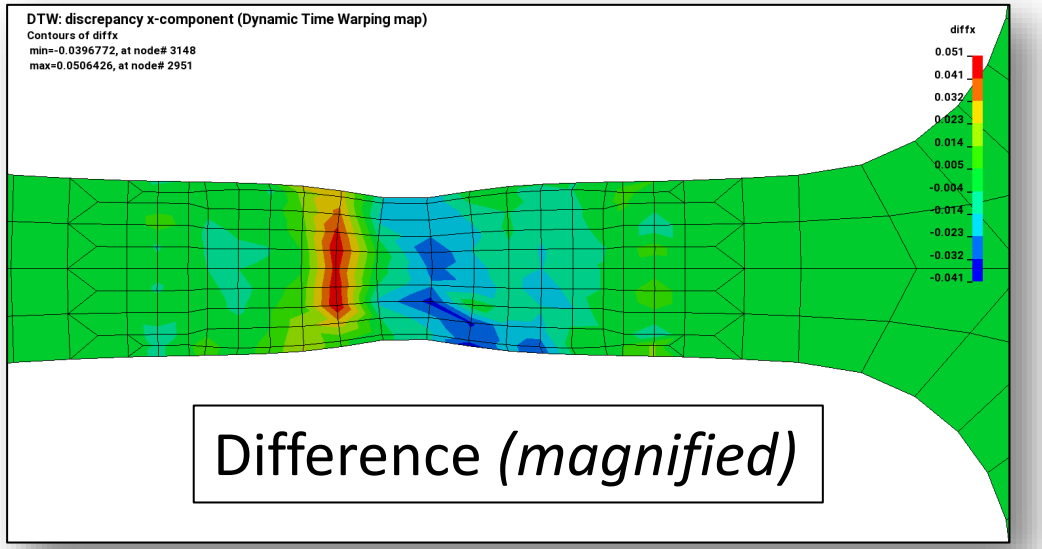
Computed



Experiment (DTW map)



Difference



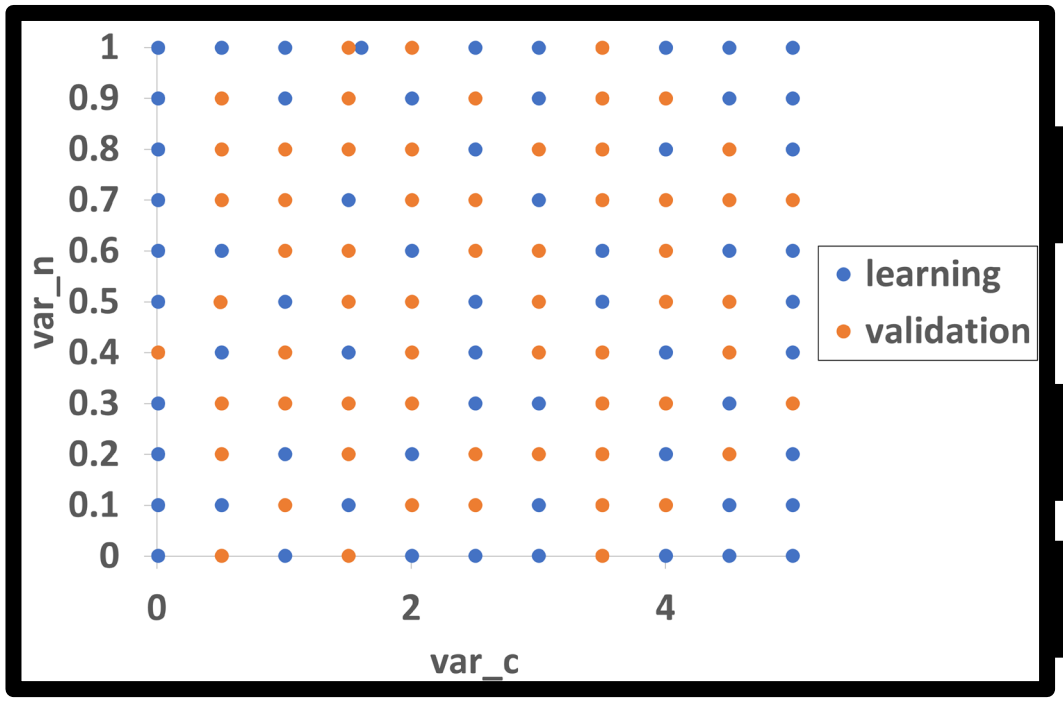
Difference *(magnified)*

LS-DYNA® Fields: LS-OPT® capabilities

- Utilizes the full-field dynamic output of *LS-DYNA (d3plot)*
- Fields and Field-histories
  - *Displacement*, *strain* and *stress*-based quantities
  - *Solids* and *shells*
  - Element-based quantities (stress, strain) are *mapped to nodes*
- Part or Part set can be selected

- Applications
  - Digital Image Correlation
    - *Fields* are mapped to *multi-histories* and *multi-responses* by inverting them
  - Input to *Twin Builder* to create Static/Dynamic ROMs for selected structural components

ROM creation with LS-OPT data export using Static ROM Builder



Converted validation data

Converted learning data

Doe.csv

Static ROM Builder Build Mode

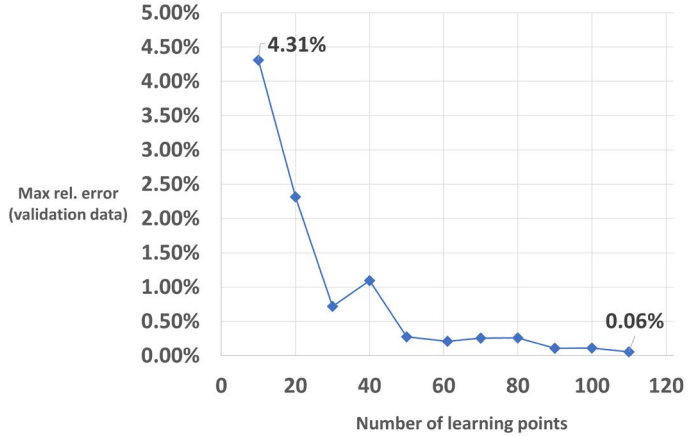
ROM

- *In collaboration with: V. Morgenthaler, C. Grivot, O. Crabbé (Ansys Digital Twin)*
- *Slide courtesy of O. Crabbé*

Fast solutions with LS-OPT/LS-DYNA/Ansys Twin Builder

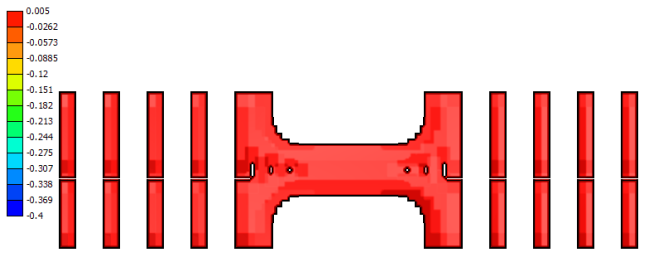
- ***Challenge: Interactive optimization using full-field LS-DYNA models***

- *Calibration example:*
  - 2 material variables: c *[0.01, 5],* n *[0.001, 1]*
  - Model: 122 samples with LS-OPT
  - 376 strain values
  - 81 time frames

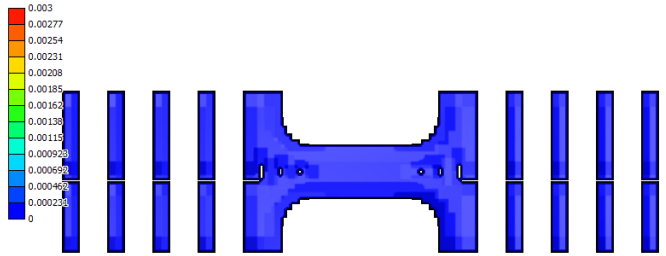


Learning point relevance

yy*-strain (LS-DYNA FE model)*



yy*-strain over time*



Error in yy*-strain over time*

Twin Builder Dynamic ROM model with material [c =0.9, n =0.509] *(TB User Interface)*

In collaboration with: V. Morgenthaler, C. Grivot, O. Crabbé (Ansys Digital Twin)
Example by DYNAmore GmbH, Stuttgart-Vaihingen, Germany

LS-OPT/LS-DYNA/Ansys Twin Builder – Outlook

- Other applications
  - Patient MRI (cardiac calibration)
  - LS-DYNA substructures
- Outlook
  - Twin Builder as solver for *LS-OPT* tasks
    2023R2 (Jul 2023)
  - LS-DYNA ROM sub-structure (future)

Mode tracking with topologically different designs

Ansys

LS-OPT: Mode Tracking in the Presence of Shape and Meshing Changes

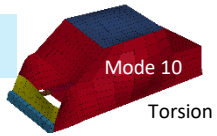
- ***Current Mode Tracking requires identical mesh*** for eigenvector comparison between designs

Reference mode — Compared mode

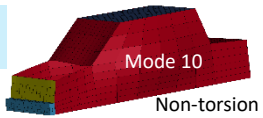
$$\max_j \frac{\{\varphi_0\}^H\{\varphi_j\}\{\varphi_j\}^H\{\varphi_0\}}{\{\varphi_0\}^H\{\varphi_0\}\{\varphi_j\}^H\{\varphi_j\}} = \max_j MAC_j$$

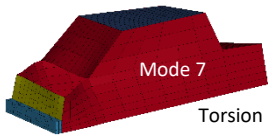
Eigenvectors φ_0 and φ_j must have same length and node order

Reference Mode 10

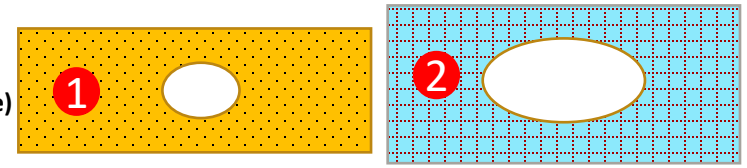


New Design

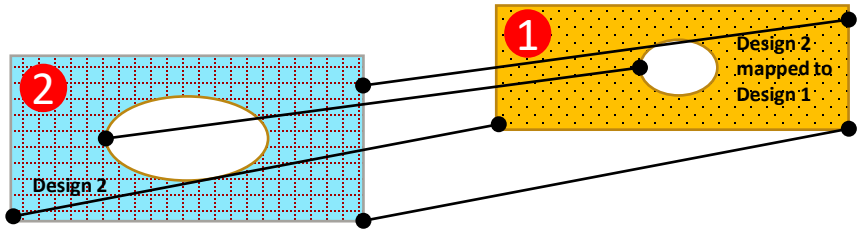


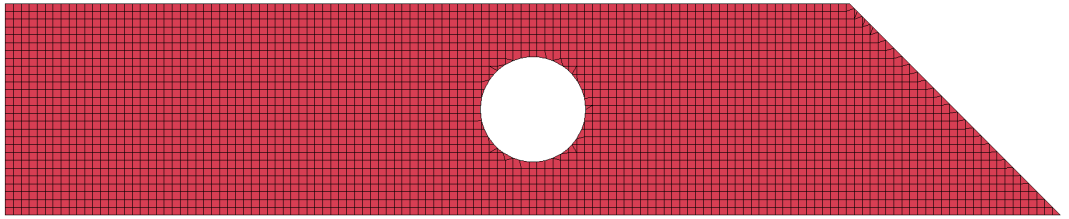


- ***New method enables MAC calculation for varying shape/mesh***
  - Eigenvectors of re-meshed designs not comparable directly

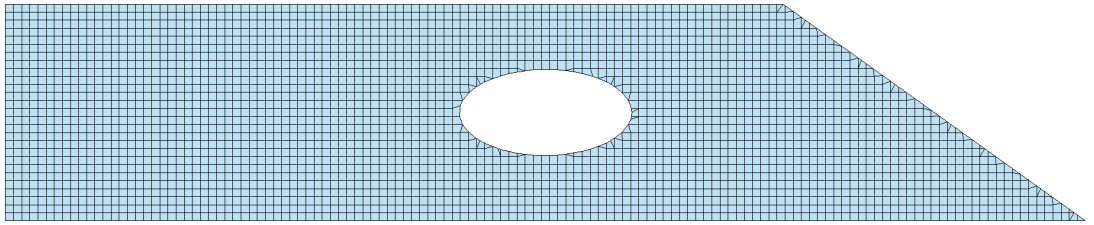


  - New mesh mapped to reference design

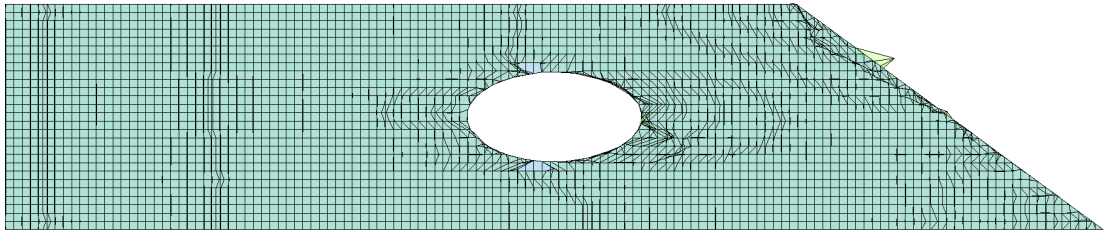




Reference Design



New Design



Reference Mesh Transformed to New Mesh

For deeper analysis and further examples see presentation and paper by Anirban Basudhar in this session

Closure

- A number of Ansys integration projects are being implemented:
  - *Metamodel selection* with MOP promises to improve both LS-OPT and optiSLang modeling capabilities
  - *Surrogate design with Twin Builder*. LS-OPT currently (2023R1) exports to TB.
    - Being extended to optimization (2023R2) and eventually as LS-DYNA surrogates
- LS-OPT is now able to *track vibration modes of topologically different designs* (both in mesh and shape)