Integrating *RBF Morph* and *LS-DYNA* into *ANSYS Workbench* and *Mechanical* for car bonnet crash optimisation

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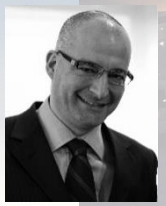
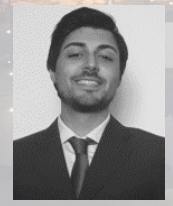
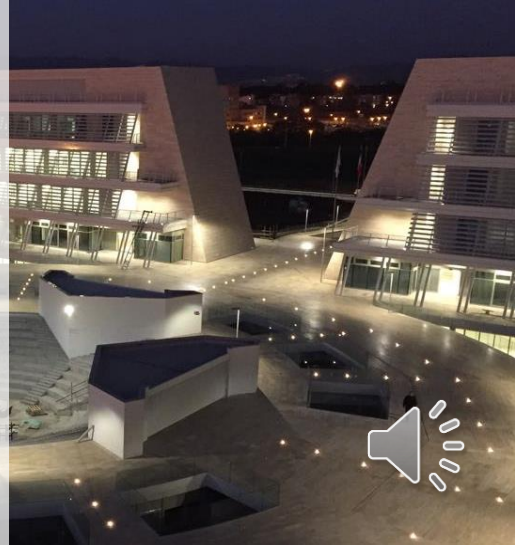






University of Rome Tor Vergata

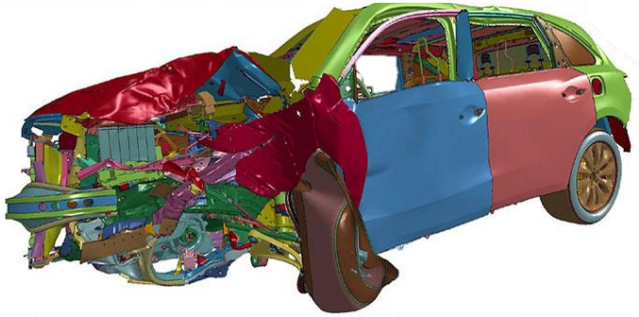
- Department of Enterprise Engineering composed by 90 full time employees, 80 contract researchers. Research team, from Machine Design Group, involved in **several national and international research projects**.

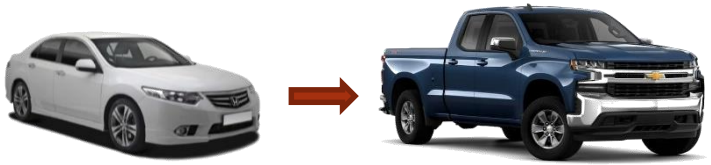
Focus on:

- Structural and fluid dynamic shape optimization (**automotive**, nautical, aerospace, biomedical, energy).
- Static and dynamic **F**luid **S**tructure **I**nteraction.
- Advanced use of **R**adial **B**asis **F**unctions (image analysis of deformations, flow fields interpolation).
- Large-scale **high-fidelity** numerical simulations of flows in complex geometric configurations.
- **R**educed **O**rder **M**odels and Digital Twin.

Outline

- **RBF Morph** software overview: solutions for **shape modification and optimization**
- Mesh morphing needs for **crashworthiness** in the automotive industry
- **RBF Morph** in ANSYS Mechanical and **LS-DYNA**: a study based on the explicit solver
- Industrial example: exploring how a **car bonnet** can be reshaped ready to simulate a crash test
- Conclusions





RBF Morph partnership

- Partnership between **University of Rome "Tor Vergata"** and **RBF Morph**: academic and industrial synergy

- RBF Morph is Technical Partner of ANSYS Inc. since 2009.

RBF Morph ACT Extension for Mechanical
Target Application: Meshing

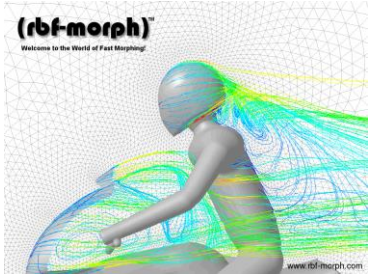
- Software line composed by Fluent add-on, Standalone RBF Morph, RBF Morph ACT extension for Mechanical and **LS-DYNA Workbench extension**

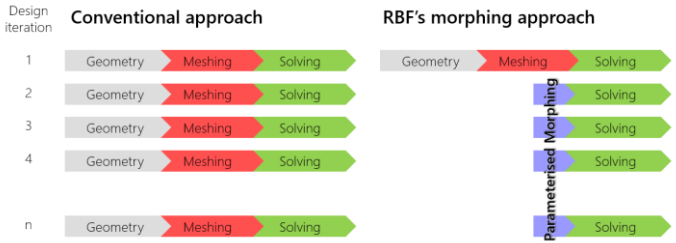
http://www.rbf-morph.com/

RBF Morph makes the CAE model **parametric** with respect to the **shape.**

Works for **any size of the mesh.**

Shape parameters can be steered with the **optimizer of choice.**





RBF mesh morphing

Mesh morphing is a technique to change the shape of a computational grid by updating only the surface nodal positions. The morphing here proposed is based on Radial Basis Function (RBF).

- **Radial Basis Functions** (RBF) are a mathematical tool capable to interpolate in a generic point in the space a function known in a discrete number of points. They are used to drive mesh morphing (smoothing) from a list of source points and their displacements:
  - ➡ Surface shape changes
  - ➡ Volume mesh smoothing
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing.

$$\begin{cases} s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\ s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^y + \beta_2^y x + \beta_3^y y + \beta_4^y z \\ s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^z + \beta_2^z x + \beta_3^z y + \beta_4^z z \end{cases}$$

$$\boldsymbol{x}_{node_{new}} = \boldsymbol{x} + \begin{bmatrix} s_x(\boldsymbol{x}) \\ s_y(\boldsymbol{x}) \\ s_z(\boldsymbol{x}) \end{bmatrix}$$

Biancolini, M. E. (2017). Fast radial basis functions for engineering applications. Springer International Publishing.

Morphing in the automotive industry

- Explore **shape variants** without recreating a new model: **reuse** the FEA model of a similar car at early-stage design of a new car.

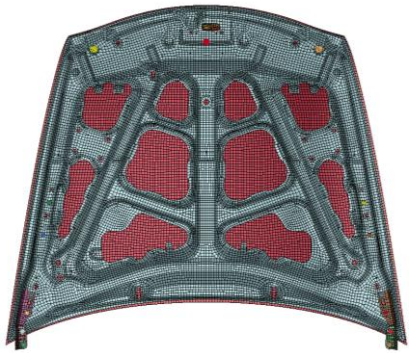
Starting with an available model, can the hood of a different car be easily replicated?

- The study of a **new bonnet shape** for a vehicle in production can start from the modification of a model previously realized and of which the CAD-design and/or the **computational grid** are already **available**.

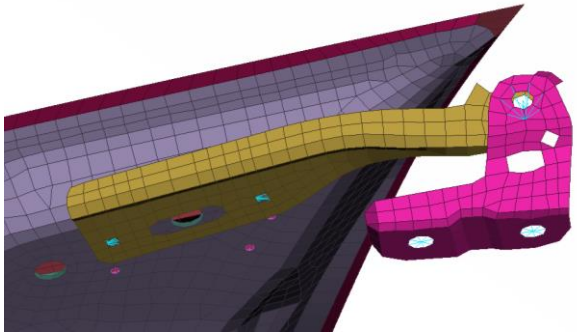
- Even more, sometimes there is the necessity to adapt the shape of one model to a completely different one to study its **properties** and its **crash behavior**.

Morphing in the automotive industry

The use of mesh morphing involves a substantial **saving of time**; in fact, the realization of the new computational grid and the preparation of the FEM model are avoided. Building a new FEM model using a re-meshing approach can be complex and wasteful.

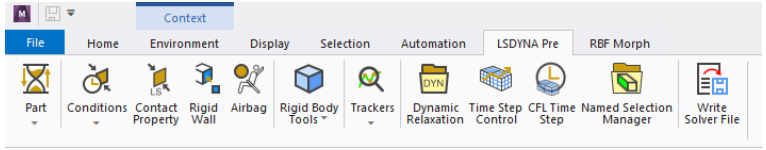


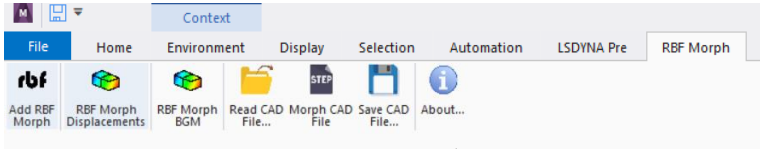
- In general, some **requirements** about the perfect matching between style surface and morphed FEM must be satisfied :
  - Same platform (hinges, connections).
  - Keep same cross section.
  - Geometrical constraints (preserve welding).
  - Discontinuities are not acceptable.
- The **quality of the computational grid** must be preserved.



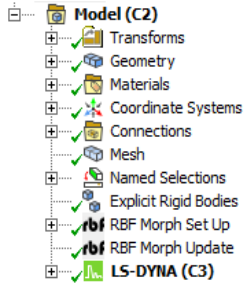
RBF ACT extensions

To apply mesh morphing, **ACT RBF Morph** is used: this is directly integrated in the Workbench interface for Ansys Mechanical and **LS-DYNA extension**.





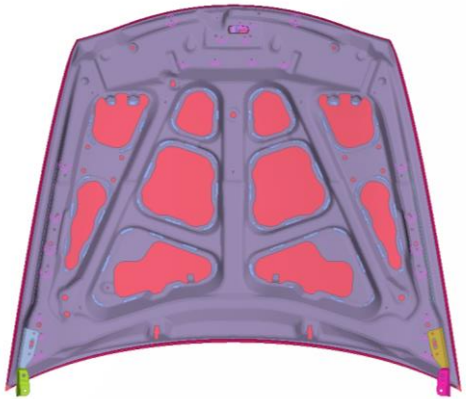
- Direct shape changes within the Ansys Workbench Environment
- Ability to quickly edit LS-DYNA keyword files
- Flexible and easy to use with a consistent ANSYS-like user interface

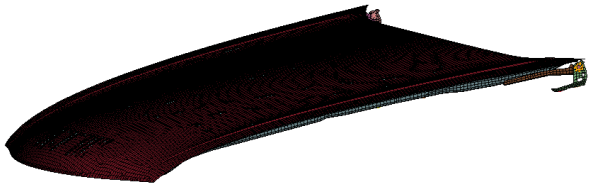


! Take advantage of both Mechanical's implicit solver and LS-DYNA's explicit one !

Car bonnet reshaping

- Starting from a LS-DYNA keyword file of the **Honda Accord 2011** model





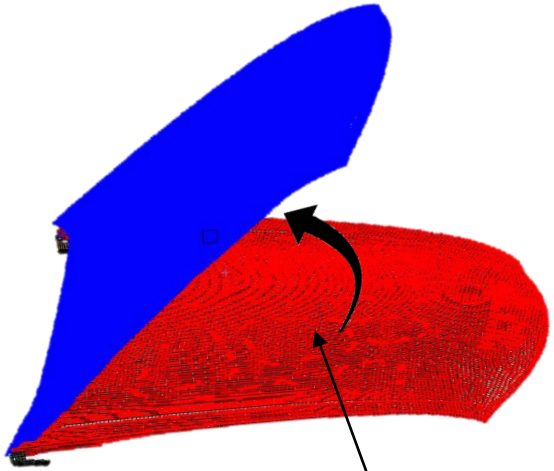
3 Solid bodies and 11 Surface bodies

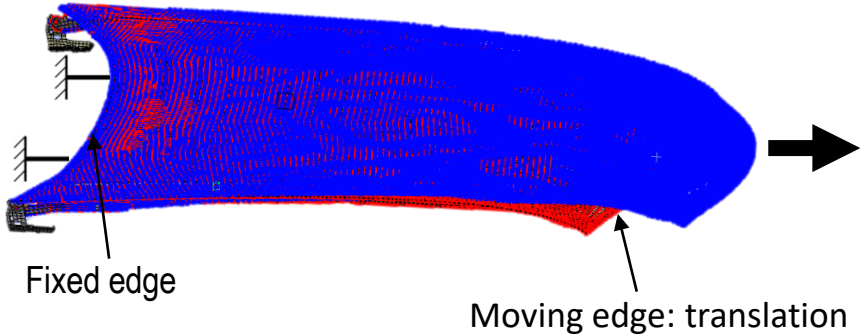
Solid elements: 1440
Surface elements: 37512

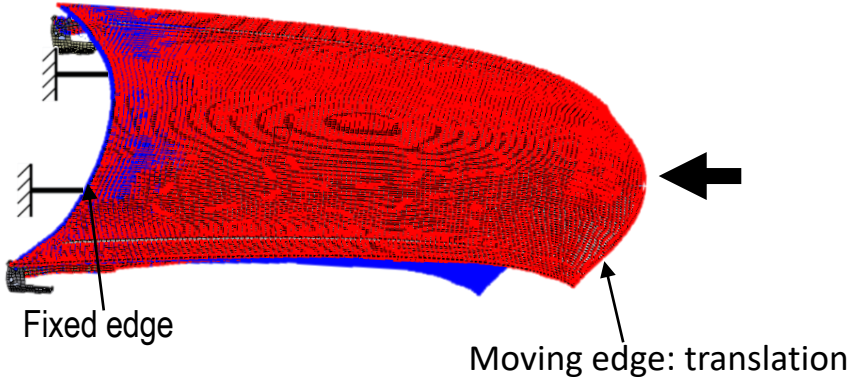
N° Elements: 38952
N° Nodes: 41979

Car bonnet reshaping

- Direct morphing of a **CAD-free** mesh

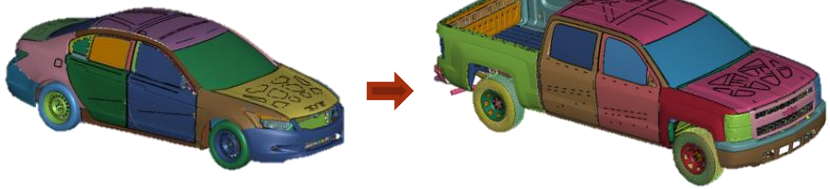


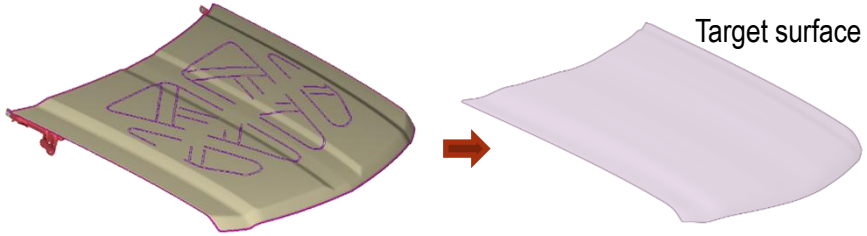


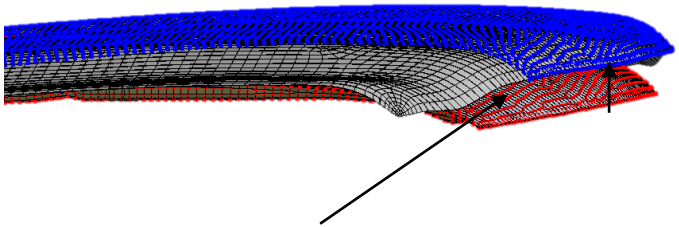


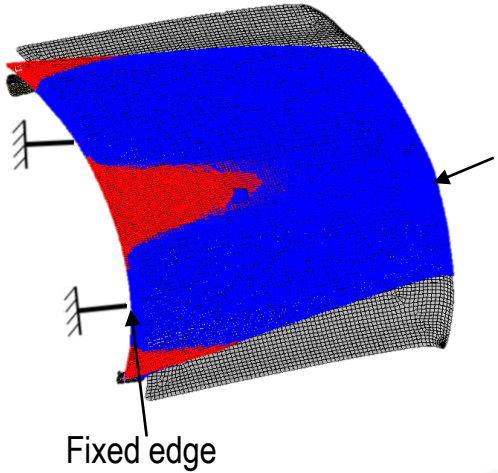
Car bonnet reshaping

- Morphing the hood of a Honda Accord onto that of a Chevrolet Silverado



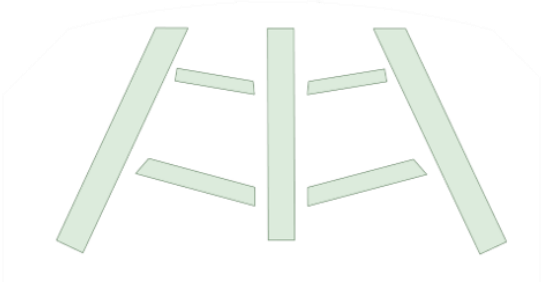


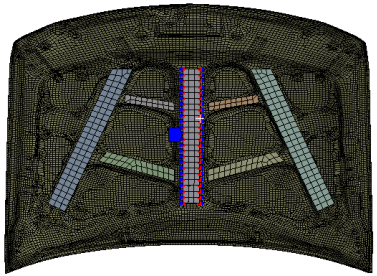




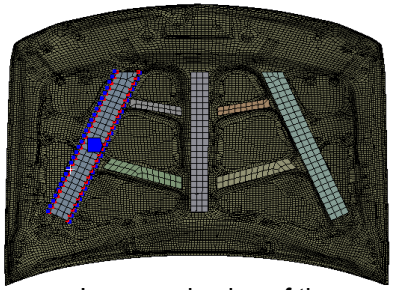
Car bonnet reshaping

- Using reconstructed support guide surfaces on the mesh to increase the size of the mesh reinforcements of the adapted Honda.
  - From a dead mesh to a supporting CAD quickly rebuilt by tracing the desired mesh shapes.
  - Perform a parametric study of component shapes and positions typical of the structural design

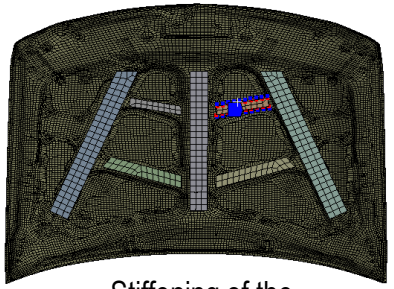




Enlargement of the central reinforcement



Increase in size of the lateral reinforcement



Stiffening of the smaller supports

Car bonnet reshaping

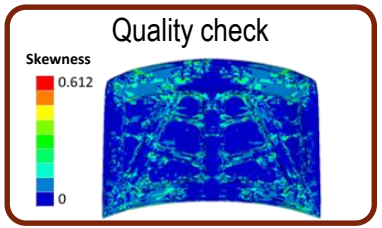
Honda Accord starting mesh

Morphing onto the style

Honda Accord mesh matching the Chevrolet Silverado shape

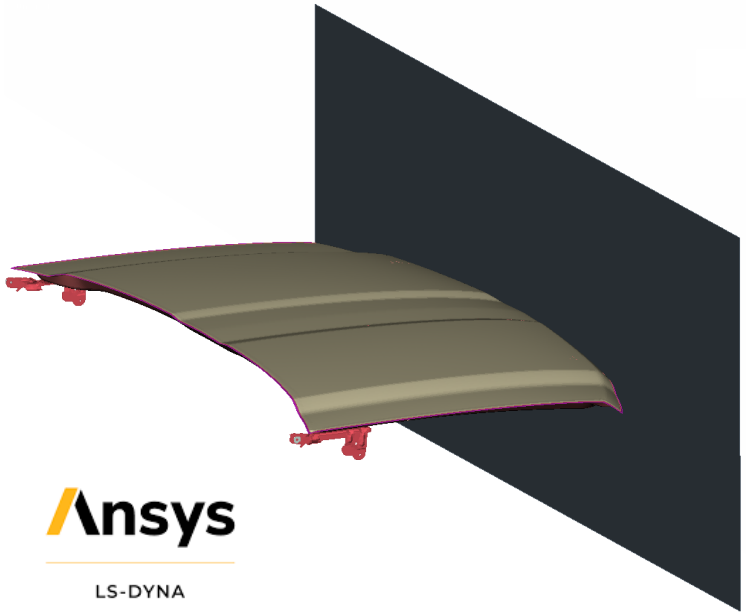
Morphing onto the performances

Honda Accord mesh matching the Chevrolet Silverado shape and crashworthiness needs

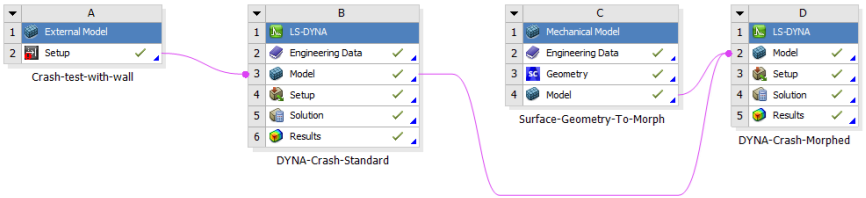


Crash test set-up

- Adding a beating mass equal to 10% of the car's weight.

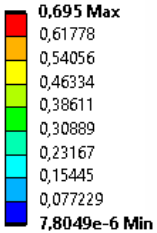


- Setting up an infinitely rigid wall: explicit rigid wall
- Preserving the connections of supports and welds
- Setting the interaction of all bodies during impact
- Imposing an impact speed of 50 km/h (31 mph)

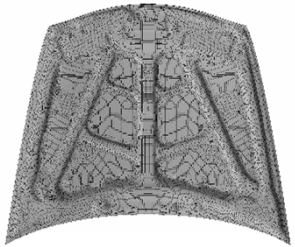


Crash test results

- Impact Deformation



Honda Accord



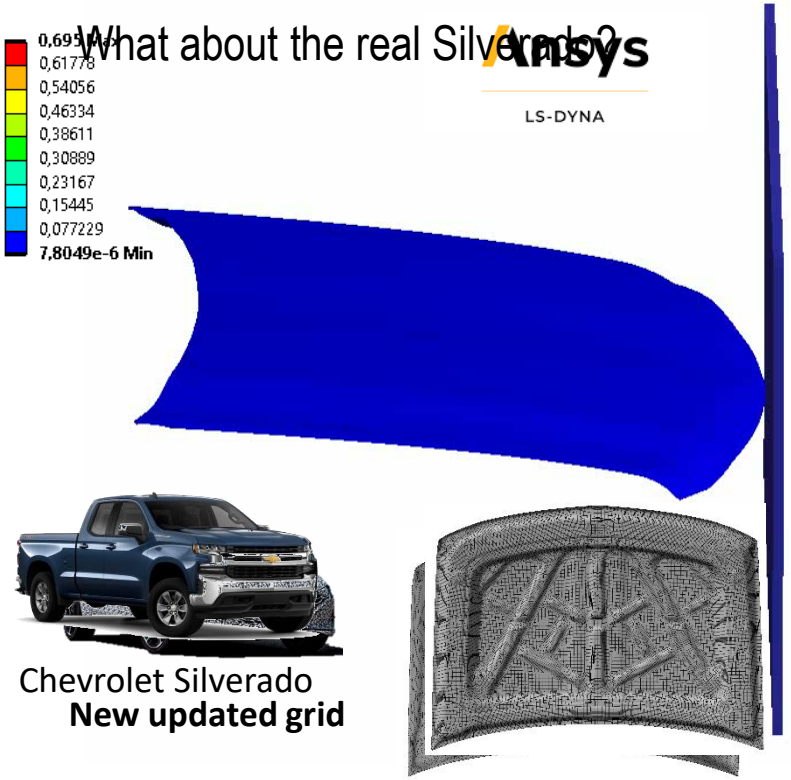
Ansys

LS-DYNA

New updated grid

Crash test results

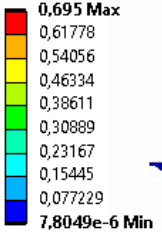
What about the real Silverado?



Chevrolet Silverado
New updated grid

Crash test results

- Impact Deformation



Ansys LS-DYNA

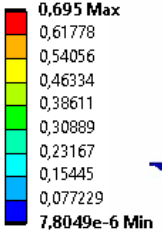
New updated grid

What about the real Silverado?

Chevrolet Silverado

Crash test results

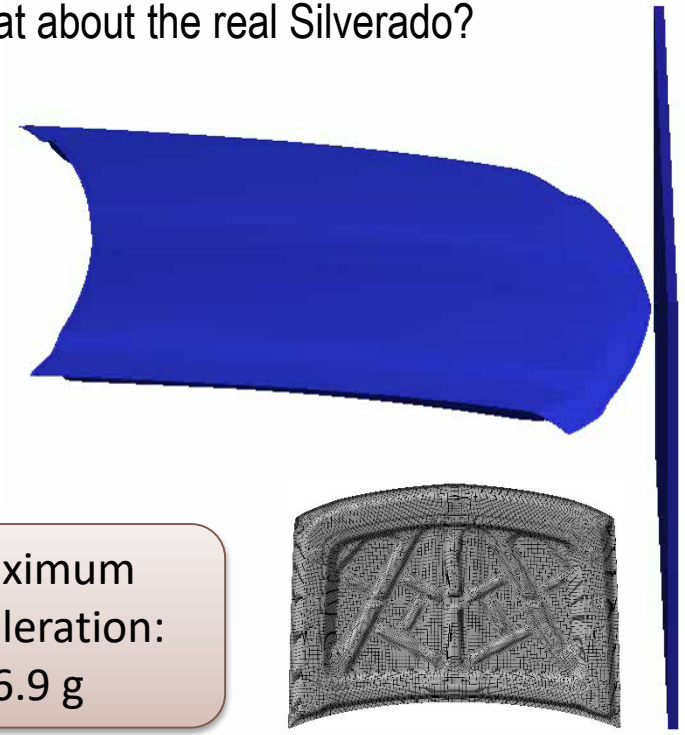
- Impact Deformation



Ansys LS-DYNA

Maximum deceleration: 7.1 g

What about the real Silverado?



Maximum deceleration: 6.9 g

Conclusions

- There is a need for advanced tools to explore **shape variants** in the crashworthiness field.
- **Mesh morphing** sounds as a good tool to reuse existing and validated FEA models.
- In this study we presented a new approach based on LS-DYNA, Ansys Mechanical and RBF Morph that allows to predict the crash of a reshaped car bonnet **without** the need of a new **FEA mesh.**
- Easy design and **shape optimization** coupled with LS-DYNA explicit solver.
- Intuitive and **same UI** of RBF Morph in Mechanical and faster morphing in **one Component Model.**
- The proposed method was able to adapt the bonnet of a sedan onto the one of a pick-up.

Thanks for the attention

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