Multi-objective optimization tool – validiation and extension.

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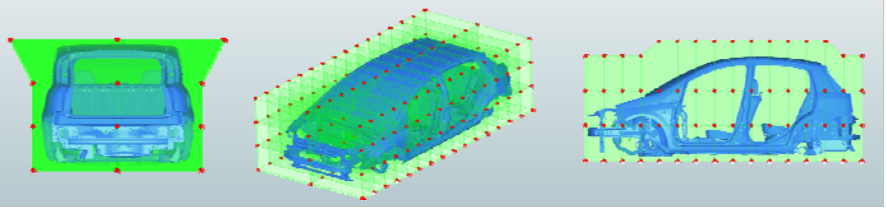
AGENDA

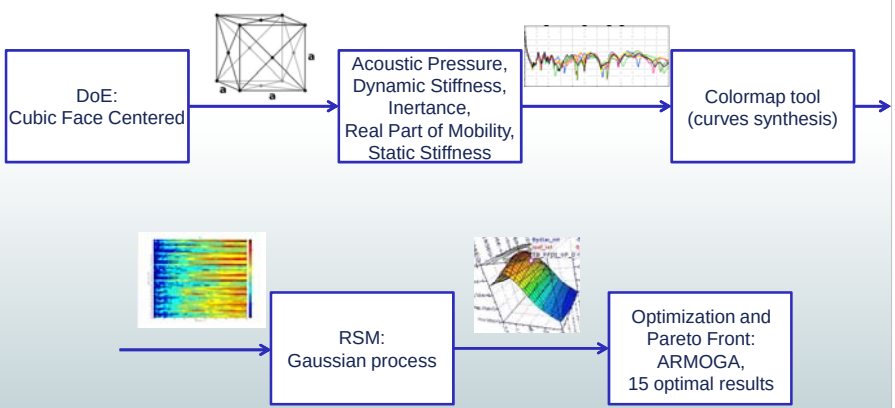
1. **Introduction.**
2. **Optimal solutions for basic structure.**
3. **Results for different structures.**
4. **Correlation between obtained results.**
5. **Decreasing acoustic pressure by increasing stiffness (different optimization approaches).**
6. **CFD DoE.**
7. **Work in Progress and conclusions.**

Introduction

- Goal for the multi-objective optimization tool:
  - Decreasing the time of development,
  - Concurrent optimization design for different fields of engineering (NVH, Strength Calculations, CFD).
- Technique used: FE model morphing:
  - 7 parameters (B-pillar rotation, roof translation and rotation, front translation, etc.),
  - Parameters boundaries,
  - Constraints (ergonomics: visibility and accessibility).

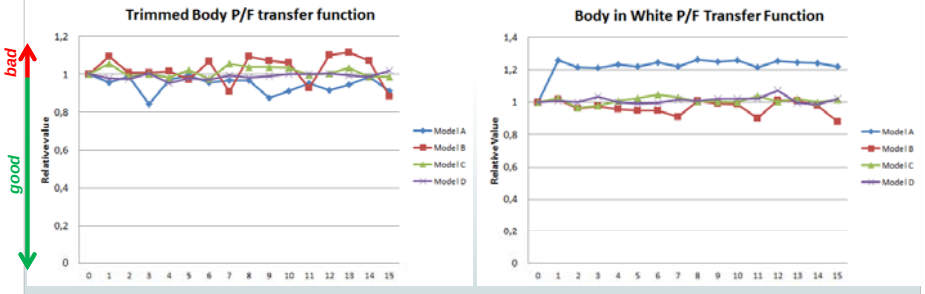


Optimal solutions for basic structure



Results for different structures (1)

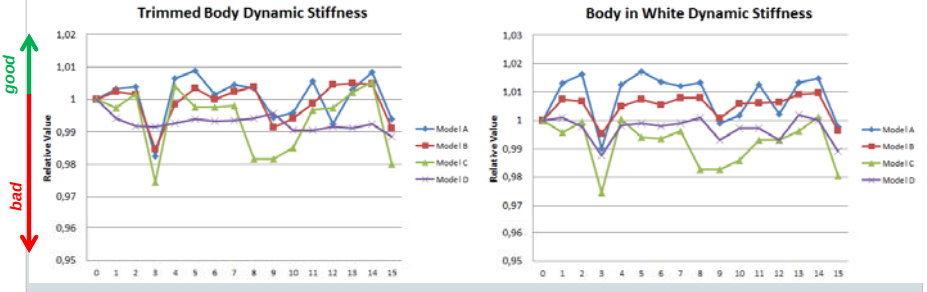
Results for P/F Transfer Function, for 4 models and 15 morphing attempts:



$$relative\ \ value = \frac{value\ after\ morphing}{basic\ value}$$

Results for different structures (2)

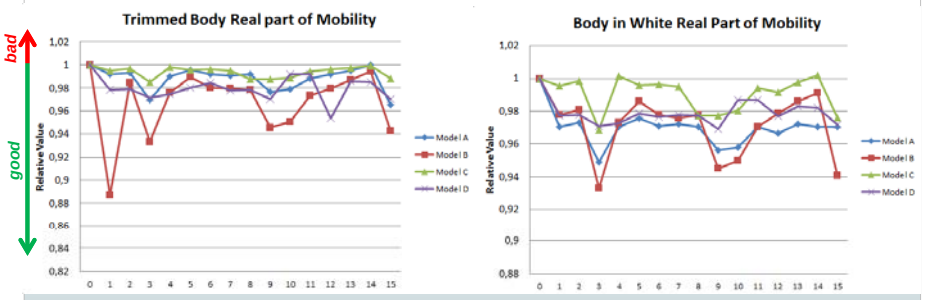
Results for Dynamic Stiffness , for 4 models and 15 morphing attempts:



$$relative\ \ value = \frac{value\ after\ morphing}{basic\ value}$$

Results for different structures (3)

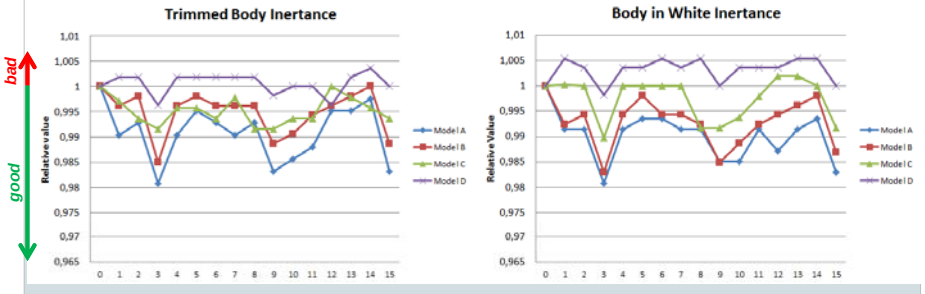
Results for Real Part of Mobility, for 4 models and 15 morphing attempts:



$$relative\ \ value = \frac{value\ after\ morphing}{basic\ value}$$

Results for different structures (4)

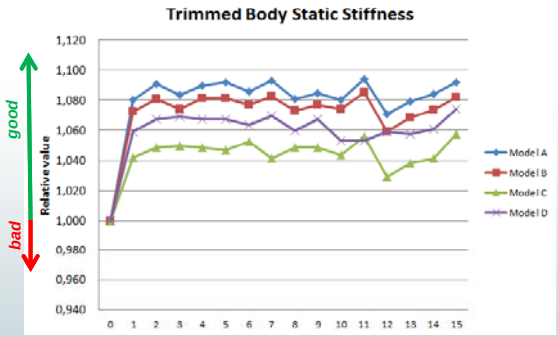
Results for Inertance, for 4 models and 15 morphing attempts :



$$relative\ \ value = \frac{value\ after\ morphing}{basic\ value}$$

Results for different structures (5)

Results for Static Stiffness, for 4 models and 15 morphing attempts :



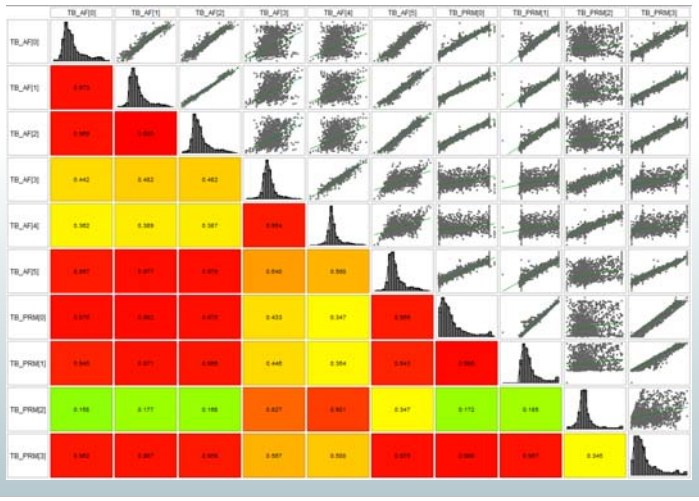
$$relative\ \ value = \frac{value\ after\ morphing}{basic\ value}$$

Correlation (1)

- Objectives dependencies can be used to reduce:
  - Time of analysis,
  - Complexity of multi-objective approach:
    - More accurate surrogate approach,
    - Complexity of choosing optimal solution,
    - Time of optimization process.
- Two sets of data were examined: DoE and RS's
  - Similar results → RS can be trusted,
  - Acoustic Pressure is strongly correlated with Static Stiffness,
  - Real Part of Mobility is correlated with Inertance.

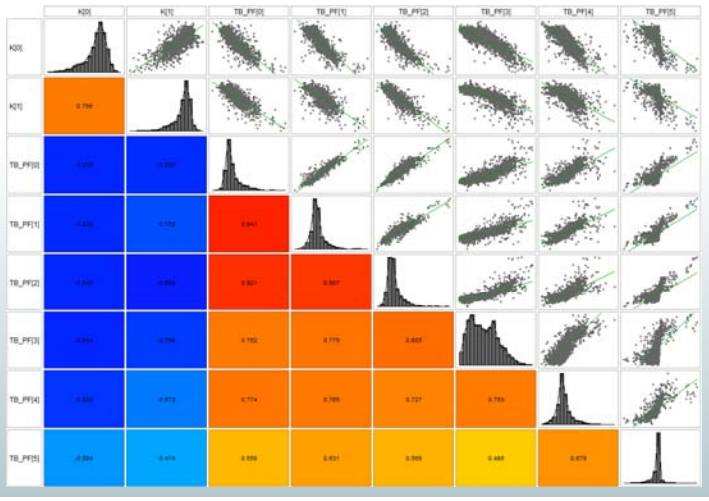
Correlation (2)

Real Part of Mobility and Inertance (similar for TB and BiW).



Correlation (3)

Static Stiffness and Acoustic Pressure (similar for TB and BiW):



Decreasing acoustic pressure by increasing stiffness (1)

Because of the found correlation between static stiffness and acoustic transfer function, an attempt of minimizing the noise inside of the car, by finding a solution characterized by the highest stiffness coefficients values was undertaken.

Three separate approaches were used:

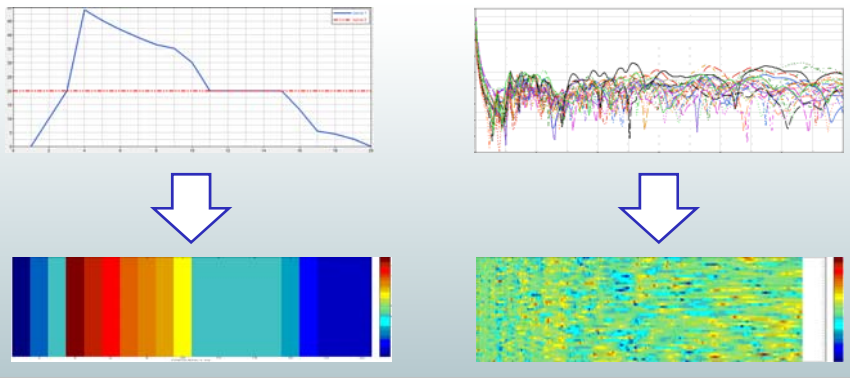
- RSM (Gaussian Process → ARMOGA),
- Non-dominated Sorting Genetic Algorithm 2 (NSGA 2),
- Combined method using GA and RSM (NSGA 2 → Gaussian Process → ARMOGA)

	K_{tors} predicted	K_{tors} analysis	ΔK_{tors} [%]	K_{bend} predicted	K_{bend} analysis	ΔK_{bend} [%]	P/F analysis	Time of computations
BASIC	-	1	-	-	1	-	1	-
RSM	1,002	1,271	21,214	1,056	1,138	7,25	0,797	~2days
GA	-	1,225	0	-	1,145	0	0,858	~3days
GA + RSM	1,198	1,256	0,046	1,160	1,156	0,003	0,807	~2days

Relative values (both: predicted and from analysis) are regarded to results obtained from the basic structure.

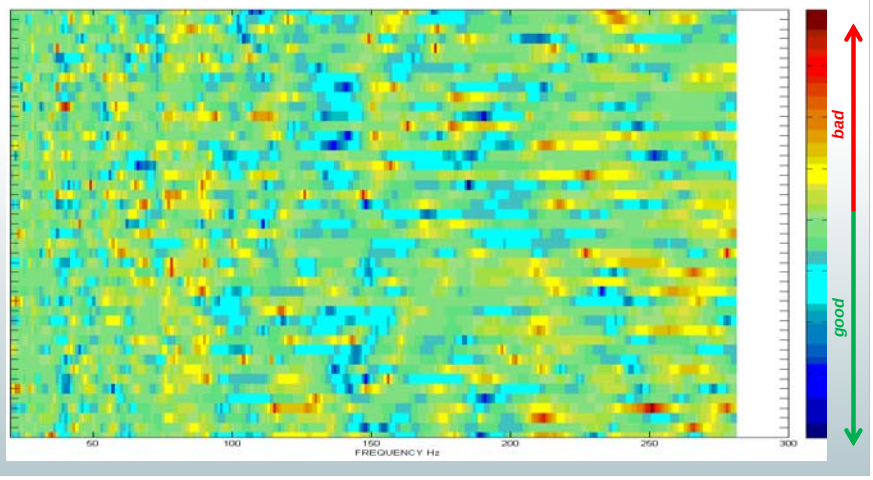
Decreasing acoustic pressure by increasing stiffness (2)

- Explanation of colormap algorithm:
  - Highlighting differences between curves or target,
  - One curve is a target,
  - Automatic color scale.



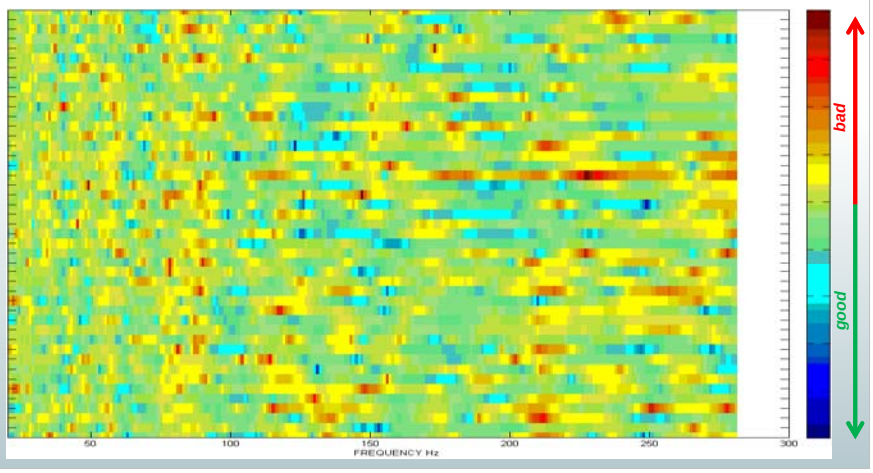
Decreasing acoustic pressure by increasing stiffness (3)

Colormap comparison of P/F curves obtained from the model morphed accordingly to RSM → ARMOGA optimizator and the basic structure.



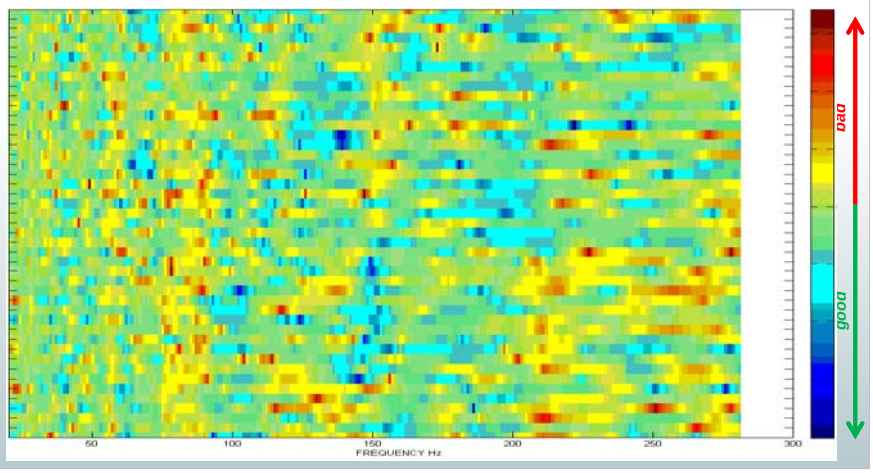
Decreasing acoustic pressure by increasing stiffness (4)

Colormap comparison of P/F curves obtained from the model morphed accordingly to NSGA 2 attempt and the basic one.



Decreasing acoustic pressure by increasing stiffness (5)

Colormap comparison of P/F curves obtained from the model morphed accordingly to NSGA 2 → Gaussian Process → ARMOGA attempt and the basic one.



Decreasing acoustic pressure by increasing stiffness (6)

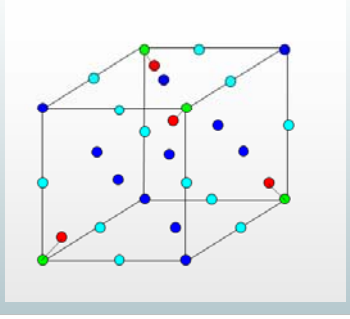
Comparison between the old approach and chosen optimization method for increasing the static stiffness, with constraints .

	K_{tors} predicted	K_{tors} analysis	ΔK_{tors} [%]	K_{bend} predicted	K_{bend} analysis	ΔK_{bend} [%]	P/F analysis	Time of computations
BASIC	-	1	-	-	1	-	1	-
RSM (P/F optimization)	1,071	1,072	0,001	1,049	1,051	0,002	0,965	~30days
GA (K optimization)	-	1,376	-	-	1,092	-	0,952	~3days

Relative values (both: predicted and from analysis) are regarded to results obtained from the basic structure.

Computational Fluid Dynamics DoE

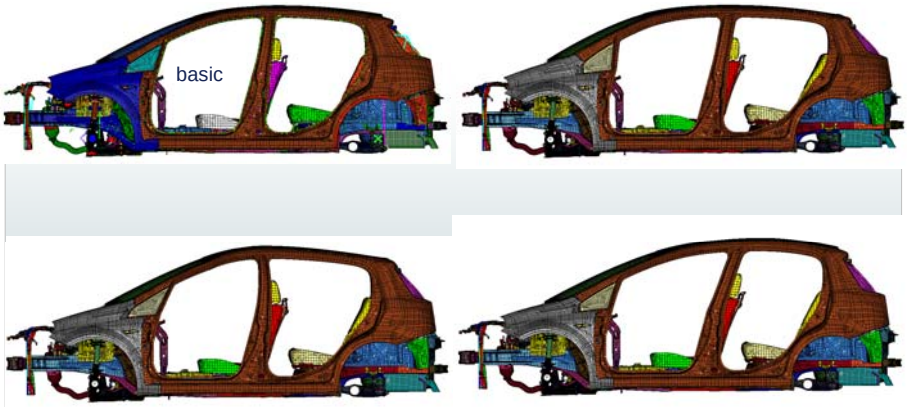
- Aim of CFD optimization:
  - Reduce the drag
- 11 parameters of global morphing (constrained by ergonomy).
- Chosen Design of Experiment:
  - Full Factorial $3^n = 3^{11} = 177147$ designs
  - Cubic Face Centered $2^n + 2n + 1 = 2071$ designs
  - Reduced Factorial: 64 (25% distance from extremes)



Parameter	Movement
1. Parameter 1	Forward/Rearward translation
2. Parameter 2	Upward/Downward translation
3. Windscreen top X	Forward/Rearward translation
4. Windscreen top Z	Upward/Downward translation
5. Middle Roof X	Forward/Rearward translation
6. Middle Roof Z	Upward/Downward translation
7. Rear Roof Z	Upward/Downward translation
8. Spoiler	Rotation
9. Parameter 9	Curvature modification
10. Parameter 10	Curvature modification
11. Parameter 11	Inward/Outward expansion

Computational Fluid Dynamics DoE

Examples of morphed structures:



Work in Progress and conclusions

- Conclusions
  - Optimal design parameters obtained for the basic structure, have not always worked in case of other tested car models,
  - Correlation have been found between static stiffness and P/F transfer function values among the results obtained for base model,
  - First test confirmed that static stiffness can be used as an objective in optimization in purpose of minimizing internal noise, but further tests have to be conducted,
  - New optimization approach, with respect to constraints have significantly decreased computational time and resulted in internal noise level improvement.
- Work in progress:
  - NVH calculations and optimization approach for CFD DoE structures,
  - Local morphing and optimization approach,

Thank you for your attention!