AUTOMOTIVE CAE COMPANION

Knowledge for Tomorrow's Automotive Engineering

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carhs

Empowering Engineers

Reshaping Automotive Components with Advanced RBF Mesh Morphing

Automotive industry is relying more and more on Computer Aided Engineering and high-fidelity simulations are today trusted enough to reduce drastically the number of physical prototypes that are often limited to the final validation stage of the new product. FEA (CSM) is well established for structural analysis so that the strength, the durability, the comfort and the crashworthiness of automotive components can be anticipated. CFD (usually VOF) is widely adopted for external aero, internal flow, cooling. Just to name a few of the daily applications performed by design engineers in the automotive industry.

There is a growing demand for optimization tools. All the automotive companies are striving for improved products for many different reasons: competition, regulations, greener and safer products. But optimization is not enough because we need robustness and we want to be sure that component will preserve the initial specifications within a certain range for the whole life. Digital twins (powered by AI and reduced models) and digital shadows (replica of as built parts) are emerging technologies, strictly connected to CAE, and intended to target not a generic part, but a specific actual one. There is furthermore another important driver: additive manufacturing is today a main stream technology which opens new solution for the design and new challenges for the maintenance.

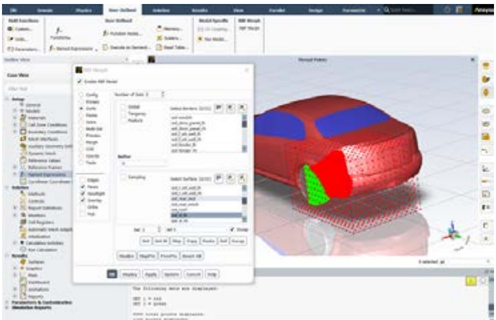

Figure 1: The RBF Morph Fluids software is integrated in the CFD solver Ansys Fluent. The RBF set-up for changing the boat tail angle of the car is represented. The morphing action is localized in the Domain box, the red points on the tail are controlled to change its angle, the green points allows preserving the shape of the wheel. The right side of the car receives the same morphing action with a symmetry constraint.

In this landscape shape control is a paramount and advanced mesh morphing provides a good help. Mesh morphing is a technology that allows to reshape an existing CAE model ready to run (a CFD model complete of initial data and boundary conditions, an FEA model with loads and constraints ready to run) by updating the position of the mesh nodes (all the nodes or for local subset). The use of radial basis functions [1] makes mesh morphing precise and effective allowing to have the full control of surfaces (up to be node-wise) and volumes (gently propagating the deformation of surfaces into the full solid mesh).

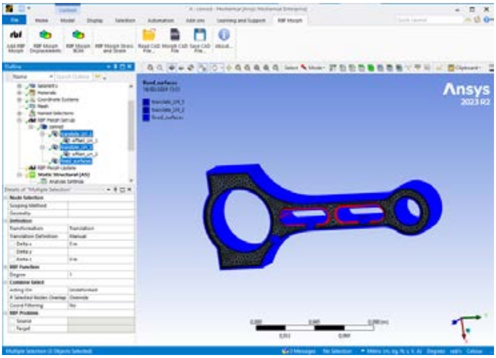

Figure 2: The RBF Morph Structures software is integrated in the FEA solver Ansys Mechanical. The RBF set-up for changing the size of the lightening holes of the connecting rod is represented. The holes are controlled making their position and size parametric (A,B) the external surface (C) is constrained.

The software RBF Morph, the first industrial solution on the market based on RBF mesh morphing, offers advanced RBF mesh morphing for fluids and structures [2,3]. The UI, available as a Stand Alone software, as a Fluent Add-On and as an ACT Extension for Mechanical, is represented in figures 1 and 2.

Mesh morphing can be used mainly in two ways: parameter-based, parameter-free. Adding parameters to an existing CAE model (changing of a thickness, a length, and angle) allows to enable parameter-based optimizations making the original CAE model parametric.

Figure 3: The automated workflow enabled by mesh morphing. New CAE variations are automatically generated making the baseline CAE model parametric. Design exploration and generation of synthetic big data to train reduced order model are substantially simplified with respect to the conventional approach based on parametric CAD and remeshing.

The ability of generating shape variations with parameters (figure 3) allows to enable optimization according to zero-order methods (the shape parameters are used as input) and/or to local methods (steepest descent gradient when derivatives of KPI versus input parameters are available). The same orchestration tools can be used for robust design (in this case instead of input parameters we have their uncertainty focused). Last, but not least, the ability to create variations allows to generate synthetic big data ready to train AI so that reduced order models can be defined and deployed.

Mesh morphing is adopted for parameter-free situations as well. This is occurring for shape optimization cases in which the results computed by the CAE solver (local stress, flow results, adjoint sensitivities) are used to locally reshape surfaces adding in this case packaging and manufacturing constraints. There are other scenarios that can be targeted: non conformal parts can be studied by morphing the baseline CAE onto the actual shape, evolution of the shape due to the working scenario (erosion, repair, snow deposition, fauling).

The first example described is about crashworthiness [4]. In this study both the aforementioned approaches are adopted demonstrating advanced mesh morphing for the quick evaluation of crash performances of a car bonnet (figure 4). The existing LS-DYNA model of the Honda Accord is firstly morphed to represent a new car (in the example the Chevrolet Silverado), then parameters are added so that the desired level of deceleration are achieved. In the first morphing action the new style is used as a target, then parameters are added so that the shape is changed and variations of the explicit transient job are submitted getting the desired KPI.

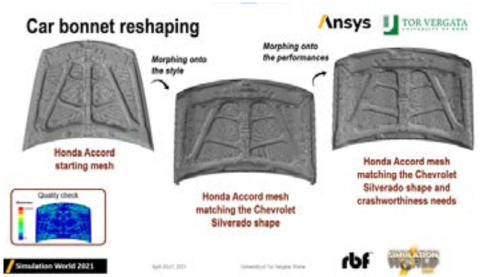

Figure 4: In the picture a solution presented at Ansys Simulation World 2021 by the University of Rome Tor Vergata is shown. The study demonstrates how an existing FEA model for LS-DYNA (the bonnet of a car complete of external style surface, internal structures, welds and interfaces with the chassis) can be transformed to represent a different car and then controlled to match its crashworthiness' requirements.

The second example is about flow optimization, in the specific the shape of a Formula 3 F3-19 Dallara [5] is controlled with the aim of reducing drag force (figure 5). 14 design parameters are introduced to control the front wing end plate, the mirror and the bargeboard. The adjoint solver is in this case exploited to compute the derivatives of the KPI (drag) with respect to the high number of parameters. It's worth to notice that a single run (CFD + adjoint) allows to compute all the 14 derivatives. A local optimization method allows in this case to go for the optimum.

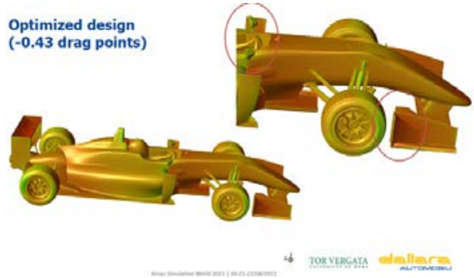

Figure 5: In the picture a solution presented at Ansys Simulation World 2021 by Dallara is shown. The study demonstrates how shape sensitivity map computed by the adjoint CFD solver of Ansys Fluent can be used to compute and combine the effect of 14 different local shape modifications getting a good reduction of the overall drag.

The third (figure 6) and fourth (figure 7) applications here presented are about powertrain optimization showing how the same BGM method [6] can be used to improve the durability of an internal combustion engine [7] and of an electric motor [8].

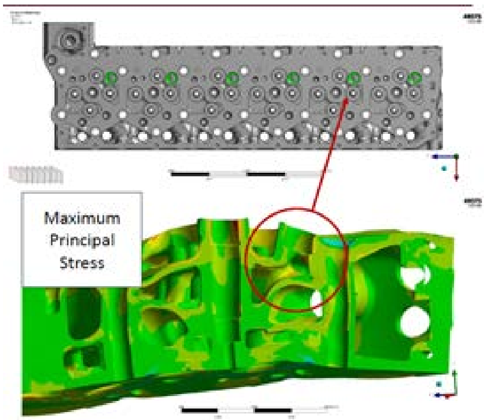

Figure 6: This picture shows how Cummins Inc. reduced the stress on the head of an internal combustion engine.

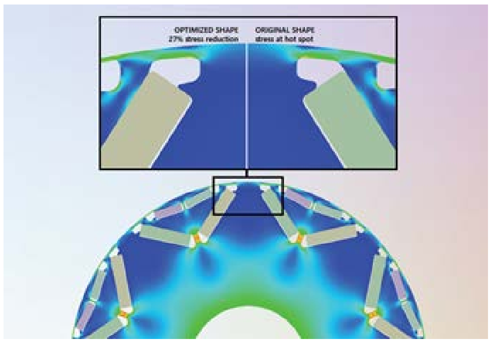

Figure 7: The picture shows how the pockets of the rotor of a Tesla-like electric motor are reshaped to reduce the stress.

For the thermal engine the mitigation of a hotspot in the engine head in a district close to the exhaust valve housing is conducted under a complex multi-physics analysis where the intake and exhaust flows, the liquid coolant flow and the thermos-structural analysis of the block are conducted at the same time. The shape evolves by adding/removing material according to the local level of stress on surfaces getting a 15% reduction of the hot-spot stress. The same BGM approach is used for the rotor of an electric motor. In this case the structural analysis is coupled with an EM one. The shape of the pocket is changed getting a 27% stress reduction.

The last two automotive examples reported (figure 8 and figure 9) are related to motorbikes. Shape parameters can be added to the CFD model so that drag and lift can be finely controlled. In the example the mock up model of a MotoGP is parametrized and an improvement of 23% in downforce, together with a 3.5% drag reduction is achieved [9]. Structural optimization of the wheel rim of a Ducati Panigale [10] is conducted considering the stress at critical braking getting a lighter and less stressed (-21%) version of the component.

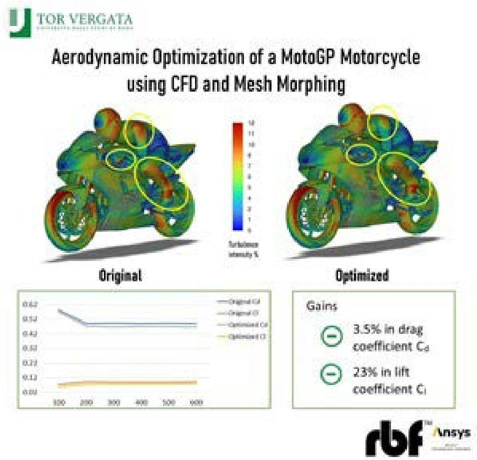

Figure 8: The picture shows how mesh morphing allows to reduce the drag and increase downforce of motoGP motorbike.

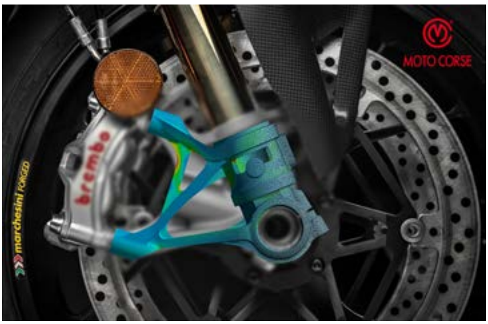

Figure 9: This picture shows how Moto Corse company managed to reduce the weight of the front wheel hub for a Ducati Panigale motorbike.

References

[1] Biancolini, M.E. Fast Radial Basis Functions for Engineering Applications (2017), Springer pp. 1-357.

[2] RBF Morph Fluids web page https://www.rbf-morph.com/add-on-ansys-fluent/

[3] RBF Morph Structures web page https://www.rbf-morph.com/act-module/

[4] Marco Evangelos Biancolini, Leonardo Geronzi. Integrating RBF Morph and LS-DYNA into Ansys Workbench and Mechanical for car bonnet crash optimization. Ansys Simulation World 2021. https://www.rbf-morph.com/wp-content/uploads/2021/04/RBF-Morphand-LSDYNAintoAnsysWorkbenchandMechanical.pdf

[5] Elisa Serioli, Corrado Groth, Simona Invernizzi, Marco Evangelos Biancolini. Fast and cost efficient CFD optimization by means of adjoint and RBF mesh morphing: a perspective from Dallara. Ansys Simulation World 2021. https://www.rbf-morph.com/wp-content/uploads/2021/04/FastandcostefficientCFDDallara.pdf

[6] Porziani, S., Groth, C., Waldman, W., Biancolini, M.E. Automatic shape optimisation of structural parts driven by BGM and RBF mesh morphing (2021) International Journal of Mechanical Sciences, 189, art. no. 105976.

[7] Porziani S., Groth C., Zhang H., Biancolini M.E. Stress mitigation of a thermal engine head block using the bioinspired BGM-FEM method. AIAS2023 6-9 September, Genova, Italy. https://www.rbf-morph.com/wp-content/uploads/2023/10/Aias2023RBFMorph_Porziani.pdf

[8] C.Groth, M.Marra, S.Porziani, M. Schubert, M.E. Biancolini. Advancing Structural Optimization of an Electric Motor Rotor through Mesh Morphing Techniques. AIAS2023 6-9 September, Genova, Italy. https://www.rbf-morph.com/wp-content/uploads/2023/10/Aias-2023RBFMorph_Porziani.pdf

[9] F. Ricci. Aerodynamic Optimization of a MotoGP Motorcycle using CFD and Mesh Morphing. BsC thesis, University of Rome Tor Vergata 2023. https://www.rbf-morph.com/wp-content/uploads/2024/01/FRicciRBFMorph_presentationeng.pdf

[10] Andrea Ridolfi, Luca Mancini, Chirianni Francesco, Felici Alessandro, Mirasoli Gabriele, Stefano Porziani, Marco Evangelos Biancolini. Ottimizzazione di un componente motociclistico attraverso il biological growth method. A&C. Analisi e Calcolo. 2020. https://www.rbf-morph.com/wp-content/uploads/2021/05/Analisiecalcolo2021.pdf

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