Increasing Efficiency of the Design Process with an Isogeometric Analysis Plugin for Siemens NX by Analyzing the CAD Model Directly

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1 Design-through-Analysis process

The bottleneck for today’s integrated CAD and CAE tools or for the design-through-analysis process in general is the fact that for each product at least two different geometry representations are used. On the one hand side there is the CAD model and on the other hand side there is the finite element mesh, both representing the same object. The conversion between CAD model and FE model are named meshing and CAD reparameterization, respectively. These operations are error prone, time consuming and cannot fully be automatized. The current approach in industry to close the gap between CAD and CAE is to use more sophisticated and highly specialized tools. In consequence taking benefits out of new algorithms and tools becomes harder and harder.

A completely new approach to overcome the problem of different geometric models is to use one model for both, which means to use the CAD model directly for the analysis. The corresponding approach is called *Analysis in Computer Aided Design* (AiCAD) [2]. The AiCAD concept is based on *isogeometric B-Rep analysis* (IBRA) [2], a new finite element technique. IBRA uses CAD models, especially NURBS based B-Rep models, instead of finite element meshes for approximating solution fields.

The AiCAD concept is realized in the integrated CAD/CAE/CAM software *Siemens NX 9.0* [3] with a plugin, which extends the CAD tool by the missing analysis functionalities. For the *isogeometric B-Rep analysis* itself the software CARAT++, developed at the Chair of Structural Analysis of the Technische Universität München, is used.
In the following the basic steps necessary for the AiCAD concept within *Siemens NX 9.0* are briefly summarized. As an example a surface CAD model of an oil sump is used (see Fig. 1).

2 Geometric Modeling

The first step of a design-through-analysis process is the geometric modeling of the product. This can be done within any CAD program, whereby all standard modeling functionalities in CAD can be used. Fig. 1 shows the surface CAD model of an oil sump in *Siemens NX 9.0* [3].

Fig.1: Example of a typical surface CAD model visualized in Siemens NX 9.0 [3]

3 Analysis

The second step is to perform an analysis on the CAD Model. A prerequisite for any analysis is the application of analysis related data on the geometry model, e.g. supports, loads, material, etc. In integrated CAD/CAE/CAM tools these are usually applied directly on the CAD model. Fig. 2 shows exemplarily the surface CAD model of Fig. 1 with analysis related data.

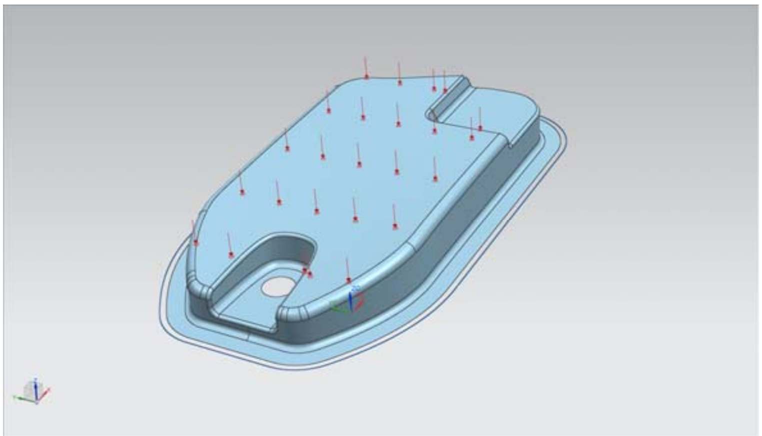

Fig.2: CAD model with analysis related data, e.g. supports (represented as additional curve), loads, etc.

After the analysis modeling the analysis itself needs to be performed. Usually for structural analysis the finite element method (FEM) is used. Today's CAE tools in industry mostly use the classical finite element analysis (FEA).

3.1 Classical Finite Element Analysis (FEA)

Classical finite element analysis uses linear or quadratic polynomials defined over non-overlapping subdomains (the elements) for the geometrical description of an object and for approximating solution fields. Since the geometry of the product usually is created in CAD with CAD basis functions a geometry conversion is necessary, named meshing.

3.1.1 Meshing

The meshing operation is not easy at all and cannot be done always fully automatically. In addition it is time consuming and often several meshing steps with human interaction are necessary. Thus the meshing step costs a lot of money.

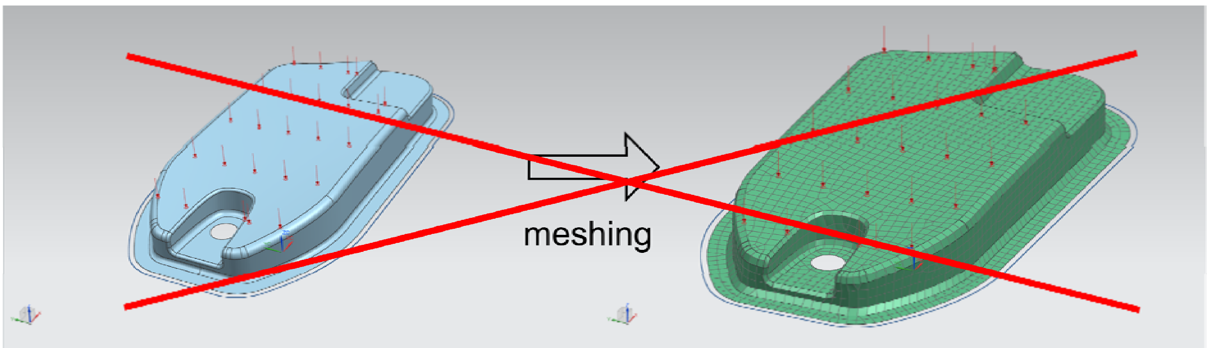

Fig.3: For the proposed AiCAD concept based on IBRA no meshing is necessary

4 Analysis in Computer Aided Design (AiCAD)

The AiCAD concept follows a completely new approach, and uses a refined CAD model for approximating solution fields. The CAD refinement is a standard CAD functionality and can be performed easily within the CAD program. The refinement is only necessary to improve the solution quality. Within AiCAD the meshing can be avoided by using CAD models instead of finite element meshes for approximating solution fields (see Fig. 3).
For approximating the solution with CAD models the classical finite element analysis needs to be replaced by the isogeometric B-Rep analysis (IBRA) [2].

4.1.1 Isogeometric B-Rep analysis (IBRA)

Isogeometric B-Rep analysis is a finite element technique [2], which uses NURBS based B-Rep models instead of finite element meshes for approximating solution fields. IBRA is an extension of the isogeometric analysis (IGA), introduced by T. Hughes *et al.* [1]. In contrast to IGA, IBRA uses in addition to the basis functions also the entire B-Rep (boundary representation) description of the CAD model for the analysis.
NURBS based B-Rep models represent one of the standard formats used in CAD. For the proposed oil sump example the NURBS based Kirchhoff-Love shell formulation [4] is used as mechanical property.

4.1.2 Preprocessing

The preprocessing of IBRA can be done exactly in the same way as for the classical finite element analysis as long as all analysis related data are applied on the CAD model. This means for the user there is no difference for the analysis modelling. The only difference is that with IBRA no meshing is necessary.

4.1.3 Postprocessing

The results of IBRA can be directly visualized in CAD tools, since IBRA outputs are based on a standard CAD format (NUBRS based B-Rep models). Fig. 4 shows the deformed CAD model for a static analysis with the boundary conditions illustrated in Fig. 3. For the postprocessing again all CAD functionalities can be used. Fig. 5 shows as an example of a curvature analysis color plot on the deformed CAD geometry. In the same way also stresses can be plotted onto the CAD model.

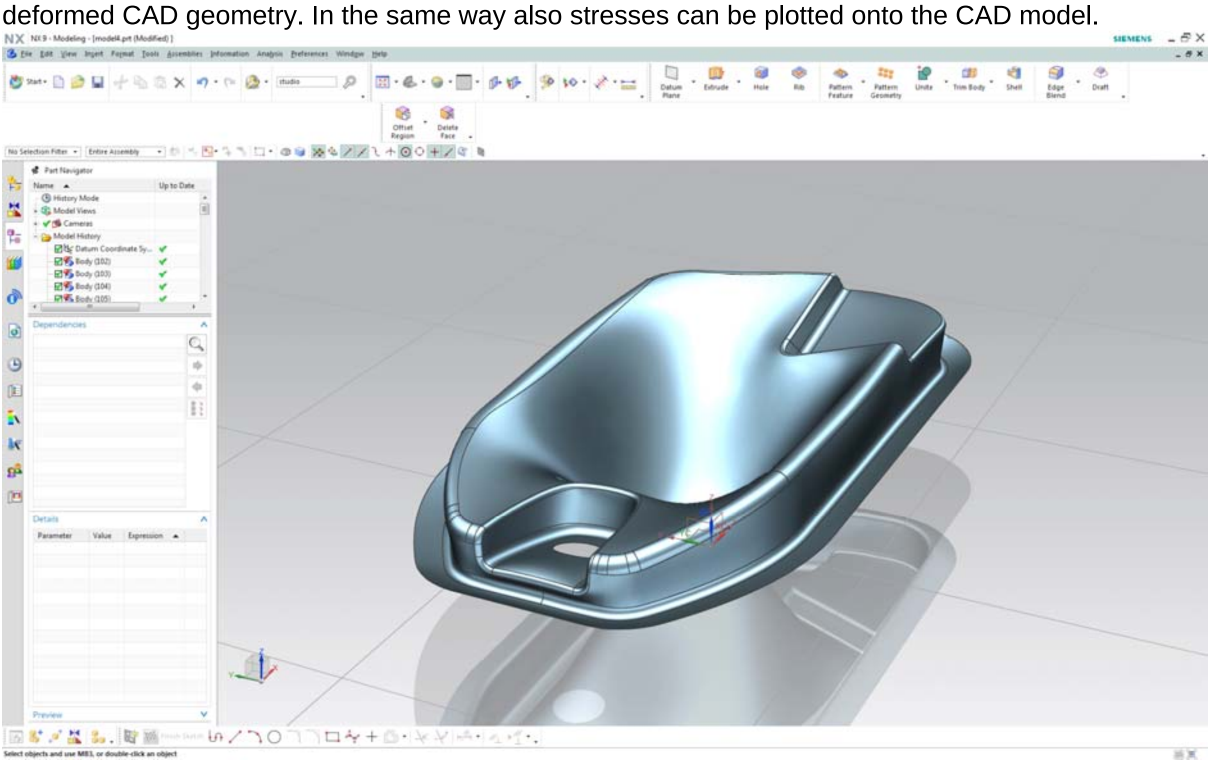

Fig.4: For the proposed AiCAD concept based on IBRA no meshing is necessary

5 Summary

A new approach for unifying CAD and CAE is realized within the integrated CAD/CAE/CAM software *Siemens NX 9.0* [3] using the AiCAD concept [2]. Instead of bridging the gap between CAD and CAE with more sophisticated tools, algorithms, etc. the proposed concept uses just one model for CAD and CAE thus omitting the gap. This can be realized by replacing the classical finite element analysis with the isogeometric B-Rep analysis [2] for the CAE part. IBRA uses CAD models, especially NURBS based B-Rep models, instead of finite element meshes for approximating solution fields.

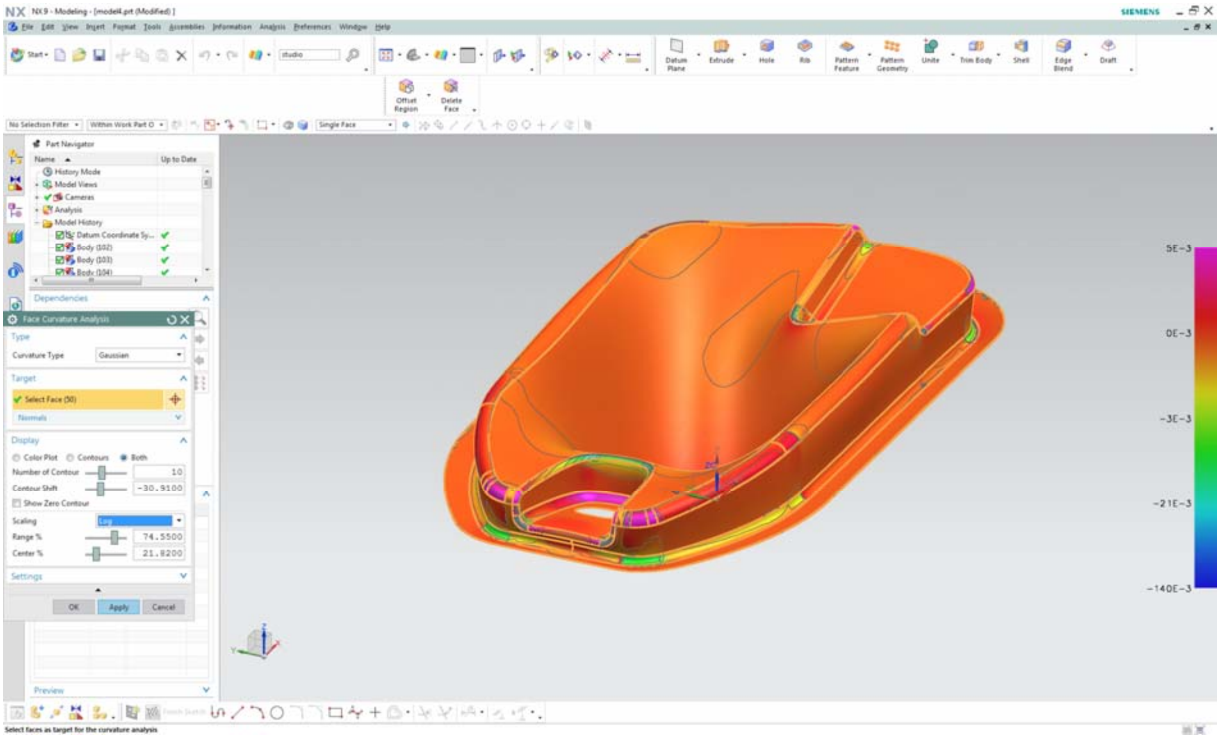

Fig.5: Curvature analysis with color plot on the deformed CAD model

6 Literature

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