Higher Efficiency by Optimization

Integrating Simulation-based Structural Optimization into the Product Development Process

Content

GOAL: EFFICIENT PRODUCT SOLUTIONS FOR RAPID MARKET ENTRY

Today's product development teams are facing more and more challenges. New product strategies and solutions have to meet conflicting goals such as shortage of engineering resources, stricter regulatory requirements, and the need for greater cost efficiency within an ever shorter timeframe.

And, there are additional questions to ask: What are your competitors doing? Are there alternative technologies that could be employed? Are there better ways to design our current products that we haven't considered before? Keeping all this in mind and finding the right strategies prepares you to gain and maintain a better competitive position in the marketplace with the development of innovative and sustainable high quality products.

In today's changing engineering world, it is crucial to adapt the product development process to meet these growing demands. Modeling and simulation already plays an important role to help understand and validate potential designs within the development process. However, in order to realize continuing product improvements and get innovative, sustainable design concepts within a shorter development cycle, the consequent use of simulation methods along with structural optimization technology offers a better approach. When companies bring traditional stress analysis and structural optimization solutions together, market entry for components and products is realized more rapidly and efficiently.

The bottom line is: Why not use the computer to help you not only simulate and validate your existing design, but also help you identify new and more optimal design possibilities?

SIMULATION-BASED STRUCTURAL OPTIMIZATION AS AN INTEGRAL PART OF PRODUCT DEVELOPMENT

Structural optimization based on widespread simulation methods, e.g. FEA, brought together with the existing engineering know-how can be used for the optimization of mechanical properties by finding the optimal component geometry. This combination offers an innovative solution to fulfill increasing demands for lightweight, stiff, durable and sustainable components and products.

A typical structural optimization task, e.g. for lightweight design, is weight reduction while maintaining stiffness requirements. Another application is use of optimization to reduce strain/stress for critical load cases to increase robustness. Both applications are of interest for many industries, e.g. Transportation and Energy, to name just two.

Choosing the right optimization method for each development stage

Computational structural optimization offers various methods - each targeting different product development phases, e.g. for the concept phase or design improvements in a later stage.

Topology Optimization

Early in the product development process topology optimization can be used to get a design proposal that already considers product and production requirements. The possibility to shorten the overall development time begins with an optimized design proposal or design improvement. In this early phase the overall development time can be considerably reduced as a result of less iteration between design and prototype. As a consequence of numerical optimization, fewer physical prototypes are necessary.

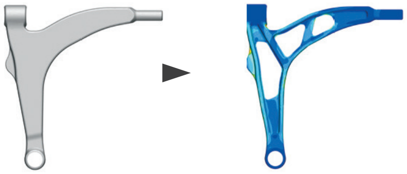


Figure 1: Topology optimization – Innovative, lightweight design concepts

Sizing

The possibility to obtain optimal designs without changing the general shape of the geometry is called sizing or topometry. This approach is seeking for perfect geometry sizes for the considered structure and its load conditions. Thereby an optimum relation between weight, stiffness, and dynamic behavior should be found, to gain material savings and take advantage of increased safety and comfort. Sizing allows for even complex geometries and challenging load conditions to obtain optimal design parameters/variables. A typical sizing application example is the optimization of lightweight vehicle bodies by optimal choice of sheet metal thickness.

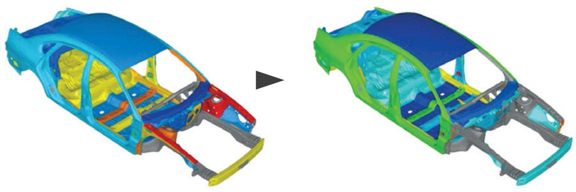


Figure 2: Sizing optimization—Best static and dynamic behavior through optimized sheet thicknesses

Shape optimization

Shape optimization is an optimization method used during later product design phases. In these cases, local stress or strain peaks are reduced - often by just small local changes to the original design - to improve existing designs and achieve a higher reliability and durability with an increased lifespan. This technique plays an important role to increase the length between regular maintenance cycles and reduce costs as the example below from the Wind Energy industry shows.

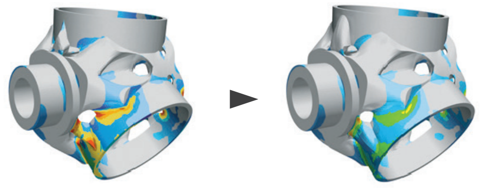


Figure 3: Shape optimization—Improved designs for more durability and strength

Bead optimization

Another optimization method is bead optimization. Bead optimization is used to improve the static and dynamic properties of shell structures. Thus efficient bead pattern layouts with increased stiffness and reduced noise can be created. To get an efficient bead layout just by intuition is difficult as so many load cases have to be regarded. The use of bead optimization leads to efficient structures in a minimum of time as well as savings in time-consuming trial-and-error processes - in comparison to conventional approaches.

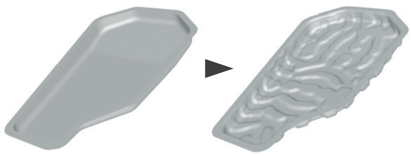


Figure 4: Bead optimization—Efficient bead patterns for increased stiffness and reduced noise

Maximum efficiency increase by the integration of optimization (into the product development process)

These examples show how structural optimization can help to meet the needs of today's streamlined product development processes. In combination with existing engineering expertise, real innovations can be found in the shortest time possible with fewer resources needed.

In addition to a reduction of resources and higher efficiency, another key parameter of optimization is efficient manufacturability. The simulation-based structural optimization is not only a smart engineering tool to support the development and improvement of products, optimization tools must also consider the production process by integration into the complete process to realize a rapid market entry.

Regarding the time and cost factor in an optimized development process

Improved and/or innovative products in sustainable design can be developed in less time by using structural optimization. Not only the number of development cycles can be reduced but also the number of prototypes because the consistent use of optimization leads to sophisticated solutions already in earlier product development stages.

The use of simulation-based structural optimization pays off in every respect: lower costs for optimized, innovative products within a shorter development time.

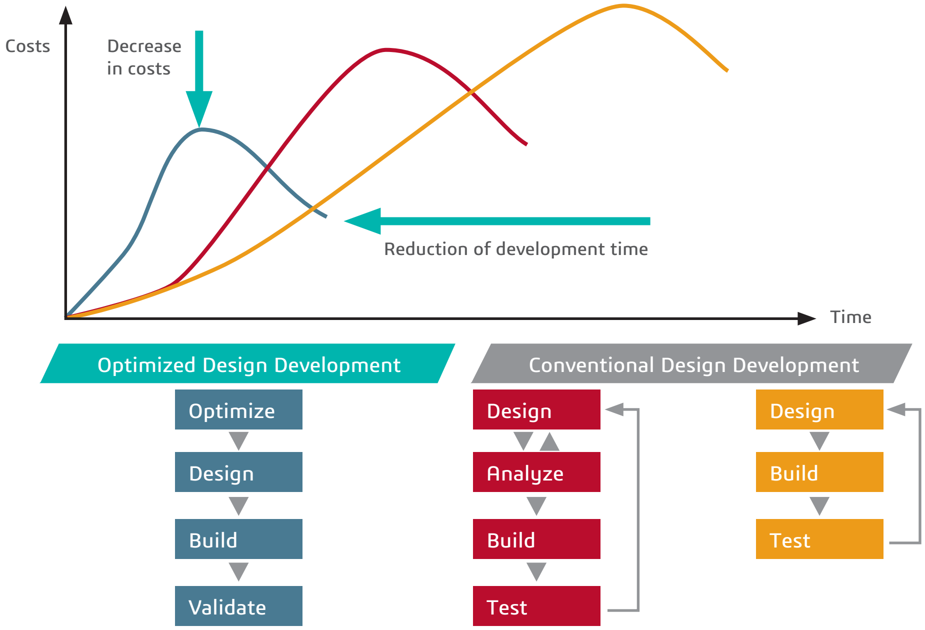


Figure 5: Comparison of conventional design process with optimized design process using simulation-based structural optimization methods

IMPLEMENTATION OF SIMULATION-BASED OPTIMIZATION WITH SIMULIA TOSCA STRUCTURE

The optimization suite SIMULIA Tosca Structure, a solution for efficient product development with simulation-based structural optimization, has been successfully applied in various industries for many years. It is offered as an open solution and due to its choice of different methods can be applied across various industries to answer to industry specific requirements. The range of applications stretches from lightweight design for engines, efficient, comfort-optimized hearing aids up to optimized plastic bottles for daily use. SIMULIA Tosca Structure offers the following modules for different stages of the product development process:

- Tosca Structure.topology
  Topology optimization to get optimal initial design proposals already at early stages of the product development process.
- Tosca Structure.sizing
  Sizing optimization to optain an optimal relation between weight, stiffness and dynamic behavior through optimized sheet thicknesses.

- Tosca Structure.shape
  Shape optimization to minimize stress, strain and damage for increased durability and strength.
- Tosca Structure.bead
  Bead optimization to get efficient bead layouts for improved static and dynamic properties of shell structures.

Optimization based on FEA simulations

Each structural optimization with SIMULIA Tosca Structure is based on the simulation model of the component to be optimized. The simulation method used is the Finite Element Analysis (FEA). With this method the component or design space for the component is described, loads and boundary conditions are considered and the component behavior within its operating conditions simulated. The idea of structural optimization is to change the component's geometry to get improved component design performance. With SIMULIA Tosca Structure this is done in a fully automated, iterative process. For this purpose a simulation is first run to provide a baseline result. Based on these results the component geometry is changed by mathematical models and the algorithms of optimization. The behavior of this new component geometry is then simulated again and re-analyzed in an iterative process until an optimum design is found. Compared to conventional methods this can be done - even for industrial large scale models - in a much shorter time and with much less effort.

Integration of structural optimization into existing CAE environments

As SIMULIA Tosca Structure is an open solution, structural optimization can be seamlessly integrated into existing CAE environments. Typically CAE environments are heterogeneous. By supporting all industry standard FEA solvers no changes to the existing CAE environment are necessary. SIMULIA Tosca Structure - as an additional CAE tool – fits into the existing CAE environment. This allows the use of the existing simulation models and of course the engineering experience within each company for the benefit of the optimization result and time.

Definitions of candidate geometry as well as the potential design space including functional areas that cannot be changed during the optimization can be defined by the known FEA preprocessors of the existing CAE environment. The interactive optimization authoring is done in one of the user interfaces Abaqus/CAE, Tosca ANSA environment (TAe) or Tosca Structure.gui. For direct definition of the optimization task within the ANSYS Workbench, Tosca Extension for ANSYS Workbench is available.

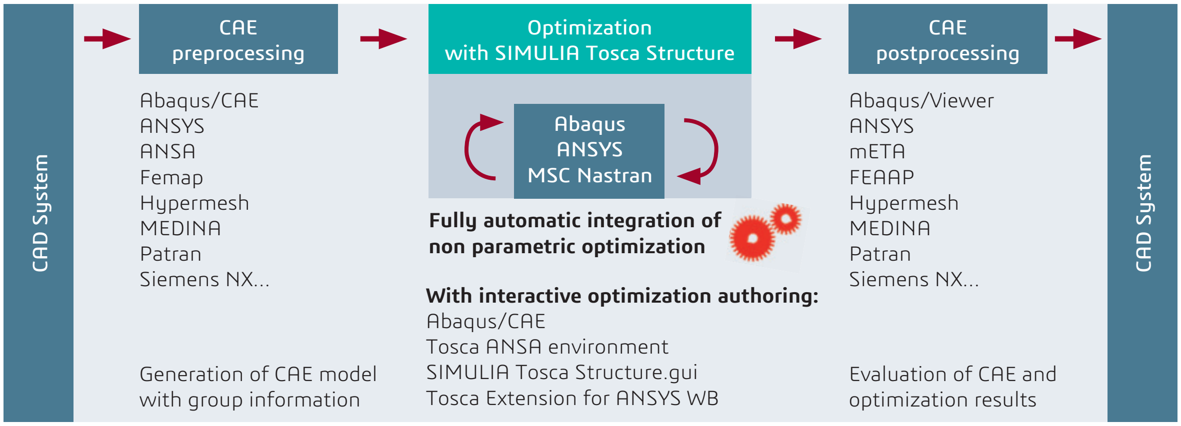


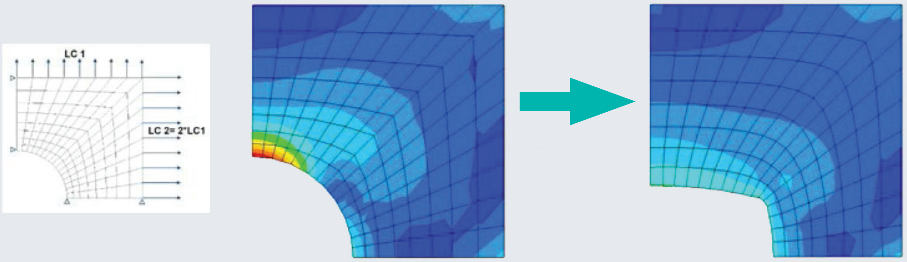
Figure 6: Optimization suite SIMULIA Tosca Structure seamlessly integrated into existing CAE environment

Getting realistic results by a non-parametric optimization approach

SIMULIA Tosca Structure uses a non-parametric approach describing the geometry. This method directly utilizes the geometric description within the Finite Element models. Thus no complex parameterization of the geometry is necessary and the existing FEA simulation models can be directly used. Furthermore the non-parametric approach offers the most flexible and detailed geometry description in comparison to the parametric approach. This way the most complete form flexibility can be guaranteed and no geometry will have to be excluded within the optimization. This results in truly innovative designs.

The simple example of a notch can be used to illustrate the difference between parametric and non-parametric optimization. With the parametric approach the notch is modelled circular and would be described through the radius – a single number. A variation of this parameter will maintain the basic circular shape as the notch is made bigger or smaller. A non-parametric approach, however, allows both the size and shape of the notch to be modified and optimized This will be the better option to choose in this case in order to keep the notch strain at a minimum.

INFOBOX: Non-parametric optimization



The parameterization of component geometries is highly complex and changes only parameters like radii while keeping the shape of the geometry (described by the radii). In case of having the freedom to change the design, the non-parametric approach in Tosca offers optimized geometries without complex and time-consuming parameterization. In addition, the non-parametric approach also allows for the full optimization potential to be explored. This effect is shown on a notch example. The possibility to change the shape using the notch radii as a parameter is very limited. Using non-parametric optimization, the notch geometry can be altered by freely changing element positions resulting in a more optimal reduction of notch stresses compared to the parametric approach.

Solutions for challenging optimization tasks

In addition to the optimization of static, dynamic and thermo-mechanical issues SIMULIA Tosca Structure as a customer-oriented software solution also offers solutions for nonlinear analysis and durability. These solutions are of strategic importance for a lot of industries like the Transportation industry, especially in the areas of Powertrain and Chassis, just to name two examples.

In the case of nonlinear analysis this means that Tosca can be used to optimize FEA models that include nonlinearities like plastic material behavior, large deformations and contact. These capacities are frequently used in applications in nearly all industries, including Transportation and Life Science industries.

A new additional capacity is the Tosca Structure.morph functionality to accelerate design decisions by quickly changing mesh geometry. There will be no intermediate CAD modifications necessary and geometry changes can be directly applied on the existing FE-mesh. Thus various manufacturable design alternatives can be analyzed and evaluated to judge different design opportunities.

Consideration of complex manufacturing requirements for an efficient integration into the manufacturing process

Another focus is on the aspect of manufacturability. By regarding manufacturing restrictions and symmetries already in the optimization process, the design proposal or optimized design will fit the chosen or available production process, including these constraints.

This way, economically feasible designs can be created in an early stage of the product development process. Last but not least this is the basis for an increase in efficiency of product and process. SIMULIA Tosca Structure offers the most comprehensive choice of manufacturing restrictions.

AVAILABLE MANUFACTURING RESTRICTIONS

- Frozen areas 
- Minimum member size
- Maximum member size 
- Demold control 
- Stamping 
- Symmetries 

APPLICATION EXAMPLE: TOPOLOGY OPTIMIZATION OF A PLANET CARRIER WEIGHT REDUCTION BY MORE THAN 30%

Background

Higher ecological and economical standards require more advanced and lighter transmissions to promote better fuel economy and lower emissions. Voith a competent partner for OEM and transport services determined that one way to meet these challenges was to enhance the efficiency of its transmissions. Voith targeted weight reduction through material savings as a primary route to increase efficiency. To find the optimum geometry of automatic transmission components – in this case a planet carrier – Voith turned to topology optimization with SIMULIA Tosca Structure.

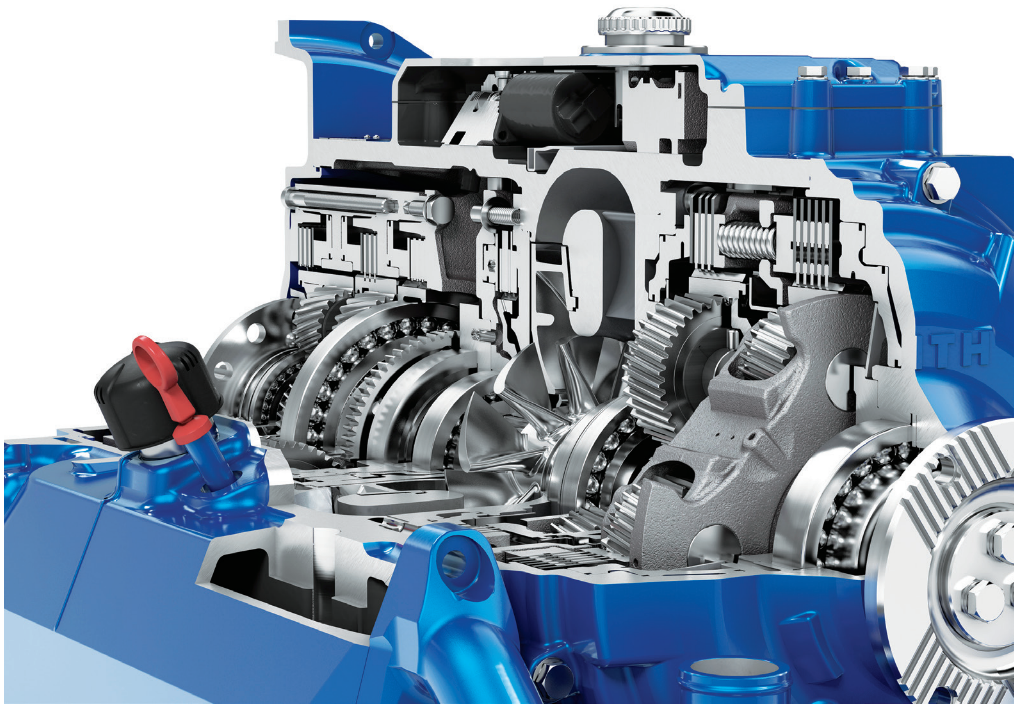


Figure 7: Optimized planet carrier within the DIWA automatic transmission of Voith

Topology optimization using SIMULIA Tosca Structure.topology

Starting with CAD data of the carrier, the engineers first used SIMULIA Tosca Structure to define the available design space by subtracting functional areas and joint spaces to connecting areas. Restrictions placed on the optimization ensured that any design or manufacturing requirements are kept. In this case the functional stiffness of the planet carrier – required to guarantee bearing durability and equal load on the tooth flanks – was maintained.

SIMULIA Tosca Structure then automatically identified areas that did not contribute to the structural efficiency and removed the materials within these areas that were not essential. Because requirements for the manufacturing process were taken directly into account during optimization, the design proposal could then be easily transferred to Voith's CAD system where modifications were made in order to meet further casting parameters.

Weight savings also provide manufacturing benefits

The new design of the planet carrier generated significant savings in material, with a weight reduction of more than 30%. The more compact size of the revised planet carrier permits an additional component to be placed in the molding box, allowing the same number of castings to be produced with fewer casting runs. Voith's experience with Tosca Structure shows that even designs that have already been manually optimized still contain significant optimization potential. The updated design of the planet carrier maintained the required stiffness and lifetime, achieved considerable material and weight savings, and resulted in more economical production.

(Courtesy of Voith GmbH)

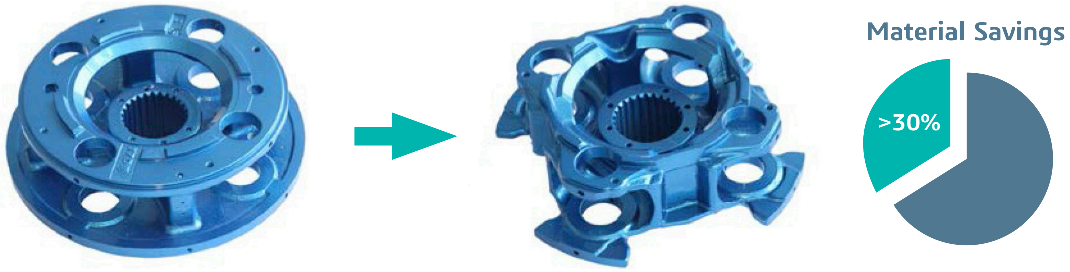


Figure 8: Optimization result of the Voith planet carrier using SIMULIA Tosca Structure

NO CONTRADICTION: SHORTER DEVELOPMENT CYCLES FOR INNOVATIVE PRODUCTS

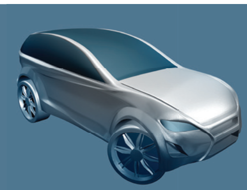
Confronted with constantly increasing environmental and economic demands simulation-based optimization offers a solution for significant efficiency increase throughout the product development process. Following a holistic approach an established and consequent use of structural optimization leads to improved, innovative and sustainable products as well as more efficient development and production processes.

Last but not least everyone benefits from participation in the process of simulation-based optimization. Engineers profit from a powerful tool to fulfill today's high product expectations and gain increasing efficiency. Product managers and executives profit from a shorter product development with less prototypes needed and product improvements as well as innovations in an early phase of product development. In addition they get new perspectives for the development, production and application. Simulation-based optimization delivers solutions getting the best possible performance and cost.

OUTLOOK

Only a holistic approach which ensures the integration of structural optimization into the product development process will lead to higher efficiency. Thus, creating optimal designs already in early product development stages foster a shorter time-to-market. As an additional consequence calculation and optimization will also be getting closer to CAD design for an overall stronger integrated development process.

OVERVIEW: INDUSTRIAL APPLICATION EXAMPLES OF SIMULIA TOSCA STRUCTURE

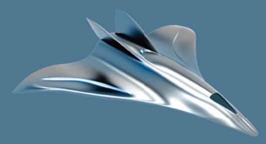


TRANSPORTATION & MOBILITY

Applications:
Brake
Wheel Carrier
Wishbone
Exhaust Muffler
Turbocharger Housing

ARCHITECTURE ENGINEERING & CONSTRUCTION

Applications:
Telehandler Axle
Tractor Lever
Machine Slide
Machine Housing



AEROSPACE & DEFENSE

Applications:
Engine and Gearing Components

ENERGY, PROCESS & UTILITIES

Applications:
Drive-Shaft
Hub
Machine Slide
Rotary Blades

MARINE & OFFSHORE

Applications:
Drive-Shaft
Crankshaft
Crankcase

LIFE SCIENCE

Applications:
Implants
Measuring Technique

INDUSTRIAL EQUIPMENT

Applications:
Cylinder Head
Oil Pan
Turbocharger Housing

CONSUMER GOODS & CONSUMER PACKAGED GOODS

Applications:
Beverage Bottles
Packaging
Household Appliance

FIND MORE APPLICATIONS ON OUR WEBSITE

www.3ds.com/tosca

FE-DESIGN was acquired by Dassault Systèmes expanding SIMULIA's offering to provide the most complete design optimization solution in the market.

The SIMULIA Tosca optimization product suite will enhance Dassault Systèmes' **3D**EXPERIENCE platform's realistic simulation applications (SIMULIA), providing even better optimization solutions for sustainable design, and deliver them in a way suitable for a wider audience.

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