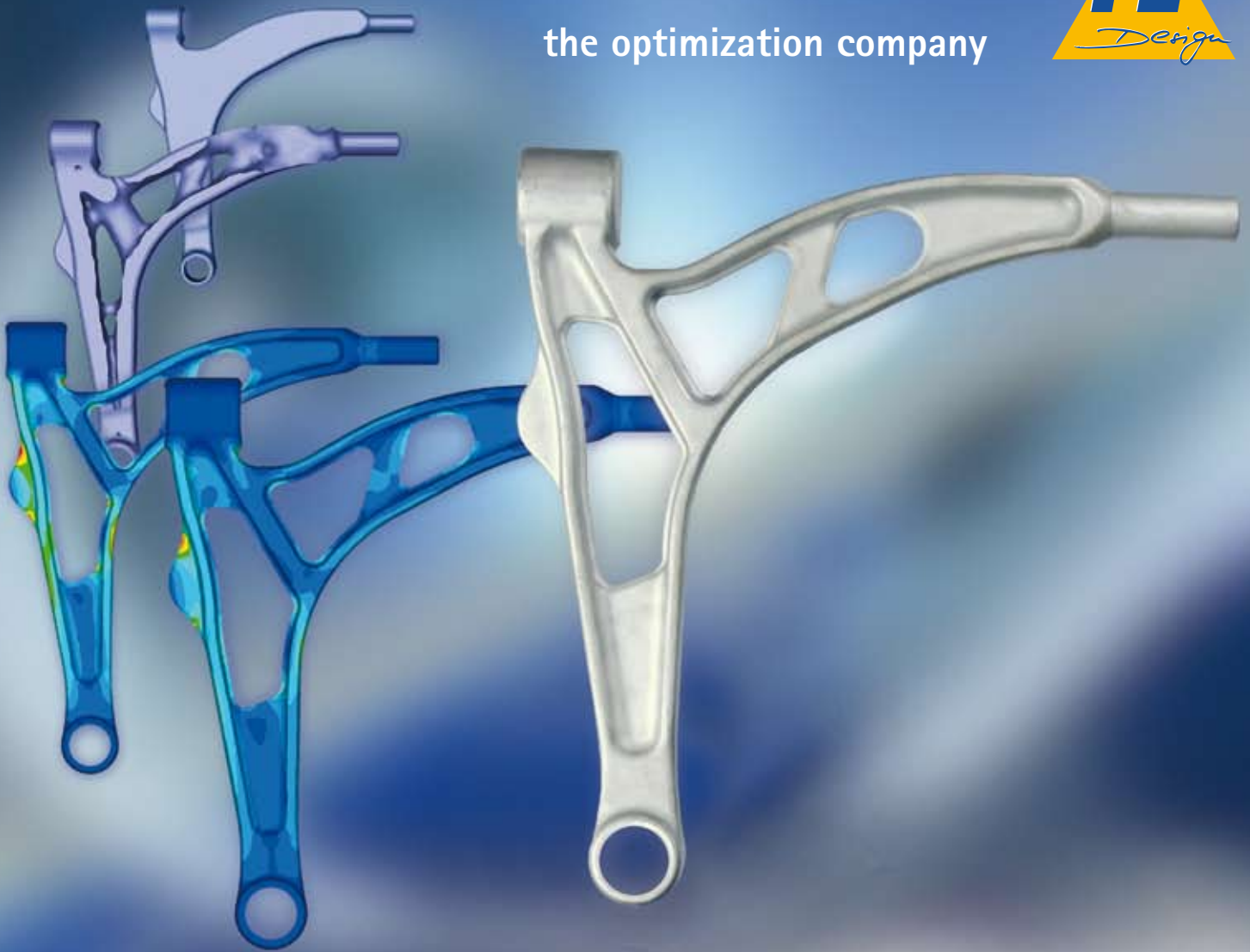




the optimization company



the optimization system



FE-DESIGN is an industry leading full-service **optimization solution provider** that enables customers to develop products **faster, better, safer and cheaper** by providing best-in-class **optimization technology, software and services** and integrating them into the **virtual product development process.**

TOSCA Structure – The Optimization Suite for Structural Optimization

Why

New competitive products have to meet growing and challenging demands of the market. They must for example be light-weighted, resource-efficient, durable, stable, robust, or having low noise emission. At the same time, products must be introduced quickly and on-time to the market and for global customers. These demands can only be met if structural optimization tools are used in addition to established CAE, CAD, DMU and PDM systems – from simulation to optimization. Variation analyses and performance improvements can be identified on the digital prototype at a very early project stage. Therefore, the number of required prototypes can be reduced which leads to significant time and cost savings.

Structural optimization using TOSCA Structure helps to find optimized design proposals in a very early phase of the product development cycle and dramatically reduces the overall development costs and time.

How

TOSCA Structure uses the existing CAD/CAE design and simulation environment for enhanced structural optimization objectives. The easy and seamless integration of TOSCA Structure into an established CAE-infrastructure saves previous investments and enables to leverage it for advanced applications.

Pre

The users of TOSCA Structure stay in their familiar preprocessing environment. Any FEA preprocessor that is able to generate finite element solver input decks that are supported by TOSCA Structure may be used for preprocessing of the component to be optimized. The intuitive preprocessing is enhanced by the preprocessing GUI capabilities of several commercial preprocessors and by the interactive graphical optimization setup environment of TOSCA Structure itself. Additional optimization wizards help the user to generate easily and quickly optimization input sets or to manage input decks from several FEA solver.

Optimization

TOSCA Structure has interfaces to all main commercial finite element solvers (Abaqus, Ansys, MSC.Nastran, MSC.Marc, NX.Nastran, Permas). This enables the users to stay in their familiar and preferred finite element solver environment for enhanced optimization objectives. Many solver specific features are supported by the optimization system which significantly reduces the time to set up the optimization task. All design changes preformed by TOSCA Structure during an iterative optimization loop are validated automatically by the finite element solver. The many years of knowledge in using a valid finite element system as well as an established FEA environment and workflow provide and leverage the best qualifications to execute structural optimization with TOSCA Structure with a minimum of additional efforts.

Post

TOSCA Structure is generating native finite element postprocessing information with the relevant optimization results for the visualization and evaluation of the optimization results.

Examples of the Industrial Use of TOSCA Structure

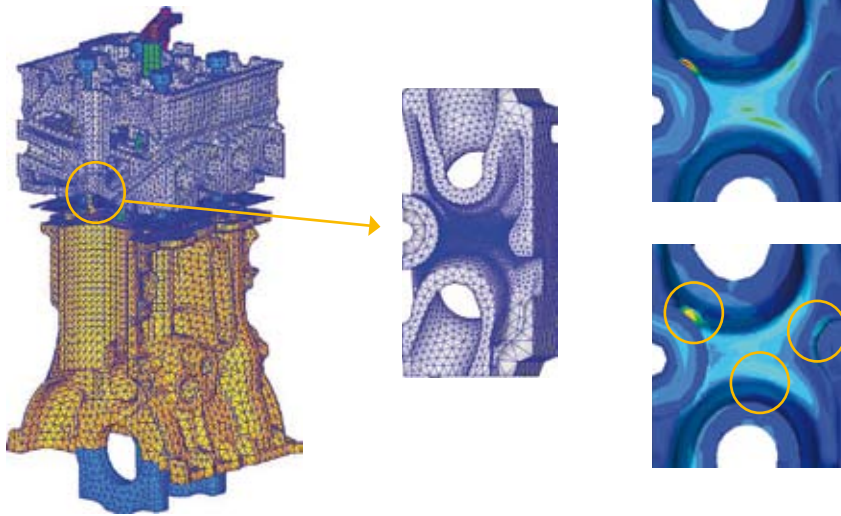
High Cycle Fatigue Optimization with ABAQUS, FEMFAT and TOSCA Structure

(with courtesy of FEV Automotive Motorentechnik GmbH)

The optimization of engine components is a challenging task as different analysis disciplines are combined in the analysis procedure. The thermal and mechanical analysis is carried out with the FE-program Abaqus. The program Femfat is used for the determining the operating safety. The program TOSCA Structure is applied for the shape optimization. Each optimization step of TOSCA Structure starts the above mentioned programs automatically and executes a complete analysis cycle of coupled thermal mechanical analysis and fatigue strength analysis. The results of each complete analysis lead to a modified geometry aiming to fulfill the design target.

Especially, the pre-tensioning forces of the cylinder head bolts and the pulsating gas forces exert mechanical stresses on the cylinder head, which at the same time is also subject to very high thermal loads. During manufacturing, assembly and engine operation the component is subject to further stresses.

The submodeling technique of Abaqus is used in the automatic optimization procedure to reduce the calculation time and have a good accuracy. For this optimization, the safety factors in the critical areas could be increased by approximately 40%.



Comparison of HCF-results of base and optimized structure: Significant increase of safety factor after 15 optimization loops with TOSCA Structure

Structural Optimization of Cast Main Frames of Wind Turbines (with courtesy of Suzlon GmbH)

In the course of rapid development of wind turbines the demand for increased operating efficiency has steadily grown during the last years. Rising turbine capacities as well as severe competition require reduction of component mass while shortening time of development. To make allowance for this tendency sophisticated calculation methods using numerical optimization procedures are increasingly employed. Wind turbines are affected by a variety of different load conditions and a large number of load cycles during operation. Special emphasis has to be put on the main frame, which is of particular importance in carrying the rotor loads.

At Suzlon, one of the leading wind turbine manufacturers worldwide, an approach was established using topology optimization and casting simulation tools at main frame development.

As a result the employment of structural optimization procedures lead to innovative lightweight rib structures, which are adapted to the loads in almost ideal manner. The fast conversion of the generated design proposals into cost effective casting components require extensive integration of calculation, design and manufacturing.

With the implementation of TOSCA Structure optimization technology in the design phase significant benefits could be achieved, e.g. considerable reduction of mass and development cycles. At present first optimized main frames for different turbine capacity have gone into series production at Suzlon. Compared to conventional main frames a mass reduction of 20% to 40% can be achieved.



Topology optimization leads to 25% mass reduction with the new design

Topology and Shape Optimization of a Forged Control Arm with Elasto-Plastic Material Behavior

(with courtesy of Otto Fuchs KG)

The combined approach of topology and shape optimization is considered for the layout of a control arm. In the first step the design space is generated. A topology optimization determines the design having the minimum weight for a given displacement constraint. A forging constraint is applied in the topology optimization for avoiding undercuts in the design proposal. Afterwards, TOSCA Structure.smooth is used to generate a smoothed surface and IGES cutting splines in order to generate a new finite element model for validation.

For the following finite element analysis a non-linear material behavior is applied. One discovers different areas of high plastic deformation in the validation run. Consequently, a shape optimization is executed for reducing the plastic deformation. During the shape optimization, the forging constraint has to be fulfilled and the maximum design space that was defined for topology optimization should not be exceeded. Additionally, a volume constraint is applied. The shape optimization leads to a feasible component after 10 design cycles.



Complete design cycle of topology and shape optimization of a control arm with manufacturing restrictions for forged components

Topology and Shape Optimization of a Machine Support

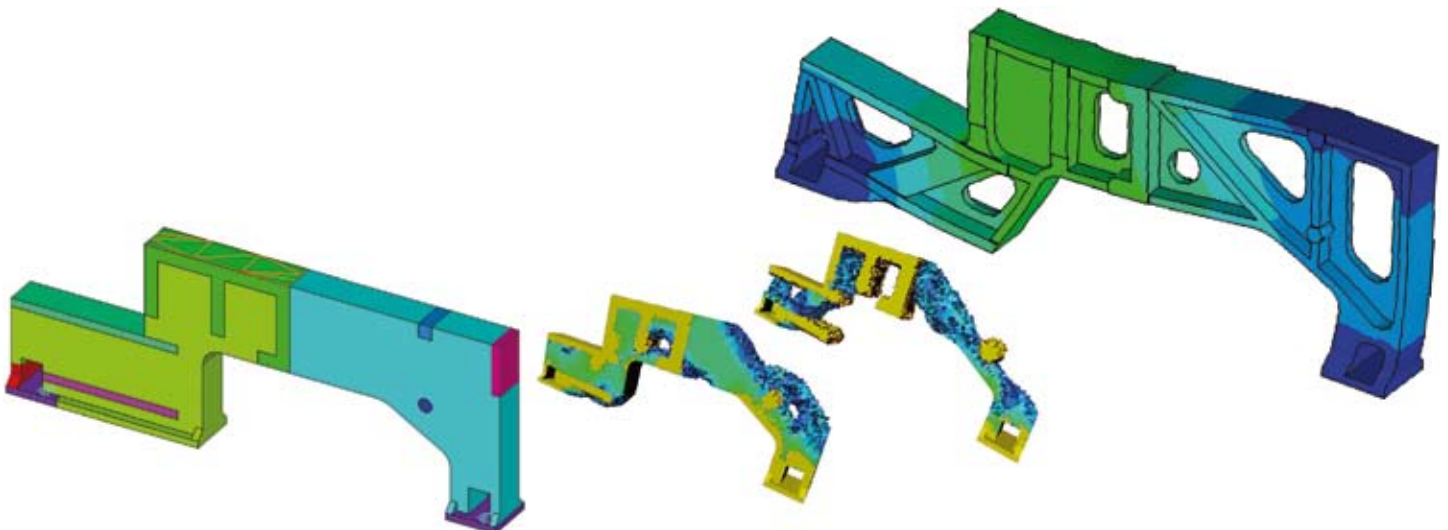
(with courtesy of Heidenreich und Harbeck AG)

The setup for the topology optimization of the machine support is executed based on the finite element model of the design space. The definition of the optimization task is easily defined using the TOSCA Structure wizard with many pre-defined inputs. Usually only some groups of elements like frozen areas are additionally to be defined. Experienced users need less than 5 minutes for this additional input procedure.

In several iterations geometric proposals are produced, which show maximum rigidity for the given weight. The volume reduced finite element model can be smoothed and exported in IGES format by TOSCA Structure in order to be able to work on the results in the CAD system. With extensive production know-how the developer constructs a casting design, which meets manufacturing as well as rigidity requirements at the same time.

The conventional proceeding is characterized by the fact that a lot of time is spent for modeling different versions of production-compatible components, which often must be rejected or at least strongly modified in following iterations after the first finite element analysis.

In the procedure with integrated topology optimization one starts with a simple model of the design area instead. The topology optimization supplies a conceptual design of the optimized component which does not require any manual effort in the conceptual design phase. Depending on the dimensions of the component and the number of load cases one gets this result in only few hours or days. Based on the design proposal, the complex casting usually has to be modeled only once.



Topology optimization leads to 40% increased stiffness with constant mass

TOSCA Structure.topology – New Design Ideas that Fit All Requirements

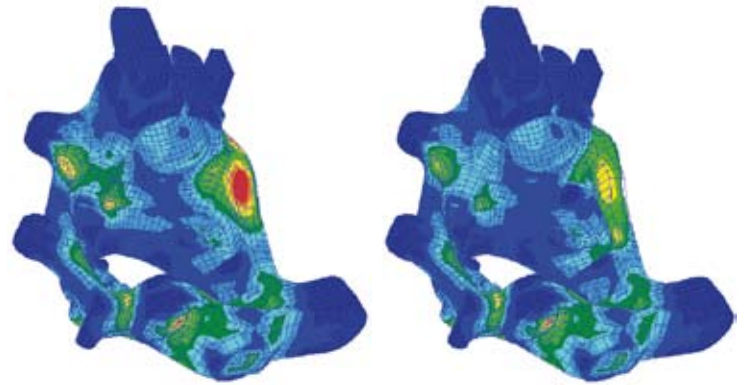
The first layout for a component is a very important step in the design phase; in all following steps it is very difficult to make changes due to the limited possibilities for alternative designs. Topology optimization delivers new design ideas under consideration of all important design requirements including the overall structural performance and also the manufacturing constraints. The ideal utilization of the used material leads to significant material savings compared to conventional designs. Several responses from the finite element analysis may be used in the definition of the objective and constraints allowing the optimization definition to be very flexible. The finite element models for the optimization may contain different solver specific features. One may carry out topology optimization e.g. in combination with non-linear finite element analysis, contact definitions, prescribed displacements and accelerations. Many other solver specific capabilities are supported by the topology optimization module of TOSCA Structure.



Topology optimization of a tractor lever using TOSCA Structure.topology with casting restrictions leads to a clear rib layout (Images courtesy of JCB)

TOSCA Structure.shape – Find the Optimized Shape of Components

Shape optimization is mainly used in a later phase of the design process where the basic layout is fixed. In shape optimization the components surface is modified in order to reduce local stress or damage peaks. TOSCA Structure.shape is based upon a non-parametric shape optimization approach that avoids a time consuming parameterization of the input file for the optimization. For shape optimization nearly any existing finite element mesh may be used for the supported solver interfaces. Mesh independent manufacturing constraints allow the consideration of many design constraints in this design phase. Additionally, fatigue life analysis may be used to calculate the responses for shape optimization. The analysis with Femfat, Falancs, Femsite, nCode Fatigue or others is integrated after the finite element simulation so one is capable of considering use and misuse load cases simultaneously during the shape optimization process.



Shape optimization of a knuckle based upon fatigue life simulation

TOSCA Structure.bead – Determine the Optimized Location and Orientation of Bead Stiffeners

For the layout of sheet metal structures, bead stiffeners are a basic layout tool that allows to increase the sheet metals stiffness or to improve the dynamic behavior by modifying the component geometry without adding material. The selection of the correct bead pattern is often very difficult as many load cases have to be considered. TOSCA Structure.bead automatically generates the bead layout based upon the results from finite element analysis and verifies the modifications.



By bead optimization the eigenfrequencies of an exhaust muffler are increased (Images courtesy of Tenneco Automotive)

TOSCA Structure.smooth – Transfer Optimization Results to CAD and FEA

The results from TOSCA Structure are based on finite element information. TOSCA Structure.smooth enables the transfer of the optimization results back into the designer world and to generate finite element decks for a verification analysis.

Results from topology optimization are smoothed and transferred to IGES and STL for an import into standard CAD systems. Also the resulting shapes of shape and bead optimization may be transferred into IGES and STL surface representations in order to be imported into CAD systems for further processing.



Creation of slices and cutting splines for CAD import of the wishbone illustrated in the title workflow (Images courtesy of Otto Fuchs KG)

The Key Notes for Optimization Solutions with TOSCA Structure

Technology

- Leadership in technology for topology, shape and bead optimization by customer focused development and joint strategic research projects
- Special focus on optimization with large scale models, non-linear analysis, durability and manufacturing constraints
- Supporting submodeling and superelement techniques

Integration

- Support of the workflow in the preferred CAE-environment
- Use of your favorite solver guarantees high quality of calculated results
- Direct use of existing FE models in the optimization
- Pre- and postprocessing in your familiar environment
- Strong partnership with the leading CAE software vendors

Performance

- Fast, parallel and reliable FEA solvers guarantee usability of the technology even for very large models
- Fast, robust and scalable optimization algorithms in TOSCA Structure
- Gain of performance by adaptive refinement in topology optimization
- Utilization of existing IT investments

Training and Support

- Technical support hotline by experienced CAE and optimization staff
- Training onsite at customers' locations
- Introduction training courses and advanced courses at FE-DESIGN's sites

Handling

- A standard optimization problem is defined in 5-10 user clicks using the preprocessor wizard
- Easy handling for definitions of optimization problems using preprocessor GUI
- Element groups, node groups, sets, property numbers and/or material numbers defined in your preferred CAE preprocessor can directly be applied in optimization formulations
- Discussing and distributing 3D optimization results without restraints using freely distributed 3D plug-in viewer
- Postprocessing of optimization results in your preferred CAD environment

Benefits of using TOSCA Structure for the Product Development Process

- Practical conceptual designing for weight reduction considering manufacturing constraints → material savings
- Fast conceptual designing for eigenfrequency optimization → sound reduction and avoiding frequency interactions
- Reliable conceptual designing considering different structural constraints in each loadcase → feasible design for several load scenarios without time consuming trial and error process
- Combined conceptual designing for both static and dynamic properties → obtaining new design which is not intuitive
- Straightforward maximal stress reduction for complex surfaces and geometries → increasing life-span
- Increase of durability using shape optimization → fatigue resistant design
- Combined stress reduction and increase of durability → design fulfilling misuse loadcases and long life excitations
- General reduction of the development time and development cycles → cost saving

FE-DESIGN GmbH

Haid-und-Neu-Strasse 7
76131 Karlsruhe
Germany

Tel.: +49 (0)721 / 96467-0

Fax: +49 (0)721 / 96467-290

tosca_structure@fe-design.de

www.fe-design.com

