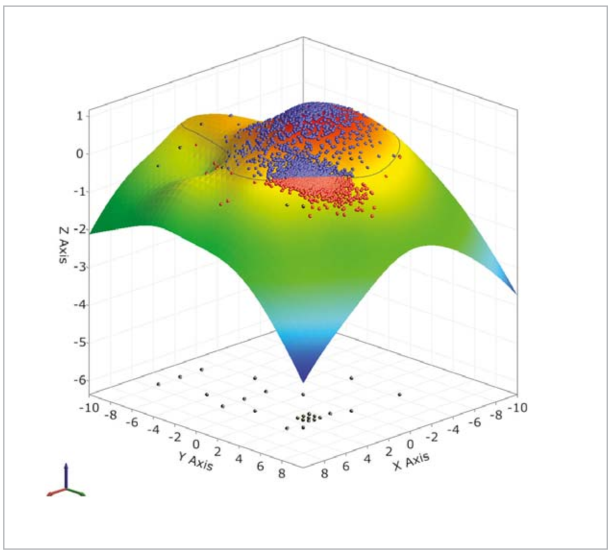
APPLICATIONS FOR FATIGUE-RELATED OPTIMIZATION

Reliability-based fatigue analysis and Robust Design Optimization (RDO) with optiSLang®.

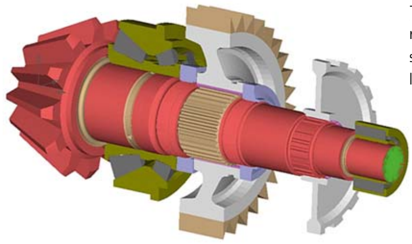
Application Areas

optiSLang is one of the most efficient software tools for tasks regarding sensitivity analysis, optimization, reliability evaluation and robustness evaluation. optiSLang is successfully applied for fatigue-related optimization and robustness problems in a wide range of industrial sectors including automotive, electronics and consumer products. Due to its balanced approach of robust analysis, optimization and pre-/post-processing capabilities, optiSLang offers efficient and computationally affordable solutions in the following application areas:

- Robustness evaluation of fatigue life predictions
- Identification and quantification of variability sources effecting fatigue life and fatigue strength
- Robust fatigue-design optimization
- Fatigue-based risk and reliability analysis (cumulative and instantaneous risk analysis, lifetime distributions)
- Decision support for operation and inspection times in order to warrant product reliability and integrity
- Optimized planning of fatigue tests for cost-effective and robust parameter estimation



Adaptive response surface for estimating the probability of exceeding nominal lifetime



Typical industrial application: reliability analysis of a pinion shaft to ensure the nominal lifetime

Modeling Issues

Variability in physical properties and manufacturing processes has to be explicitly taken into account in virtual simulation in order to avoid non-robust design solutions and, consequently, customer dissatisfaction or warranty claims. optiSLang offers most realistic modeling capabilities for uncertainties in fatigue analysis like:

- Variability of material properties (fracture toughness, material strength, etc.)
- Uncertainties in usage of time and initial fatigue quality-Probabilistic fatigue load descriptors (time- or frequency - domain)
- Stochastic damage evolution laws (crack growth, damage accumulation, parameter uncertainties)
- Maintenance, inspection and testing uncertainties

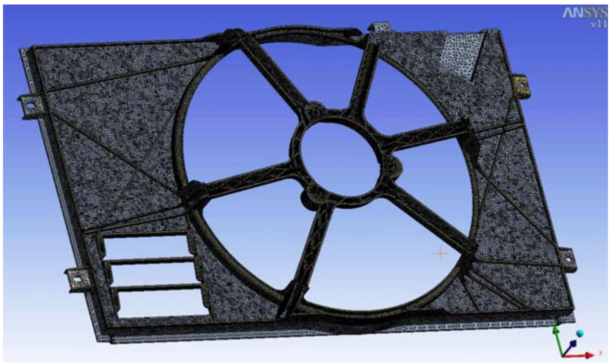
Method Overview

Deterministic approaches are unable to take into account above uncertainties without leading to over-designed and cost-ineffective design solutions. The necessity of assessing and improving the robustness of a particular solution requires methods based on reliability analysis and design optimization with probabilistic models. optiSLang supplies the user with generally applicable and reliable methods:

- Simulation-based global sensitivity analysis and robustness evaluation
- Failure rate and lifetime distribution estimators
- First-order reliability method and advanced Monte Carlo simulation procedures
- Surrogate model builder
- Efficient optimization strategies (adaptive response surface, evolutionary algorithms) suitable for fatigue reliability problems

Application Example

Project goal: A typical application case is the robust design optimization of an automotive fan shroud. Primary goal of the project was to effect significant weight savings under fatigue constraints. As reference, the best engineering design solution so far was taken. The shroud was modeled with ANSYS DesignModeler. Design criteria were evaluated utilizing ANSYS non-linear static analysis. The fatigue requirements of the molded shroud were formulated in terms of plastic stresses and strains.



Finite element mesh of initial layout of automotive fan shroud

Optimization: For optimization, a set of 94 CAD parameters were chosen as design variables. Performing a global sensitivity analysis using 100 latin hypercube samples, six input parameters have been selected as being either most effective in weight savings or most sensitive to fatigue requirements. For this reduced set, a weight saving of 13% was achieved with optiSLang's adaptive response surface method after only 50 design evaluations. The weight was further reduced to 15% by utilizing optiSLang's evolutionary algorithm with 100 additional design evaluations.

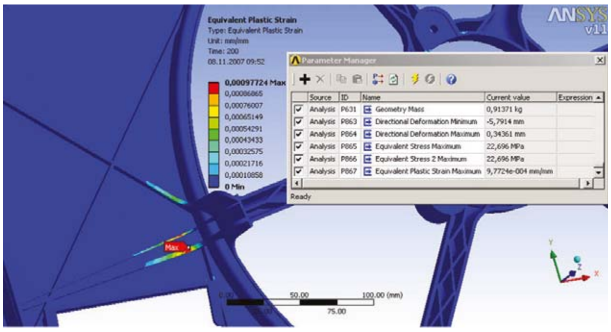
Robustness: The optimized design solution was assessed in terms of robustness. Since the molding process causes thickness as well as material uncertainties, we modeled 61 CAD tolerances and material values as random variates. Using 70 latin hypercube samples, the 3-sigma values of the maximum strains and stresses were checked and the critical tolerances were identified. After a satisfying step with small design modifications, the 3-sigma robustness was reached.

Project result: With optiSLang's optimization and robustness algorithms, the weight of the fan shroud was reduced by 15% with warranted robustness. Today, the fan shroud is in production and has proven its successfulness. The amount of weight savings was a positive surprise to the design department and shows the high potential of CAE-based robust design optimization.

Key Issues Addressed

optiSLang's combination of robustness evaluation and optimization procedures allows the user to gain reliable understanding of the fatigue performance of virtual products by addressing key issues like:

- Which environmental conditions induce the largest fatigue damage?
- To what degree does resistance model uncertainty influence fatigue life?
- To what degree does load uncertainty (amplitude, number of cycles, extreme events, etc.) influence fatigue life?
- Which components/details dominate fatigue life time?
- How to make a design robust against uncertainties?
- Which parameters or parameter uncertainties need further investigation?
- How to maintain and inspect most cost-efficiently?



Identification of design details affecting most fatigue lifetime