Abaqus Topology Optimization Module (ATOM)

Nonlinear Structural Optimization for Improved, Rapid Product Design

Overview

In the race to get new and innovative products to market faster, manufacturers face many challenges, including globalization, cost reductions, and shorter development cycles. In addition, the products must also meet safety, reliability, environmental and maintenance objectives.

ATOM delivers powerful solutions for performing topology and shape optimization for single parts and assemblies, while leveraging advanced simulation capabilities such as contact, material nonlinearity, and large deformation. This enables engineers to meet the structural requirements of a part assembly while saving time and reducing costs.

Linear vs. Nonlinear

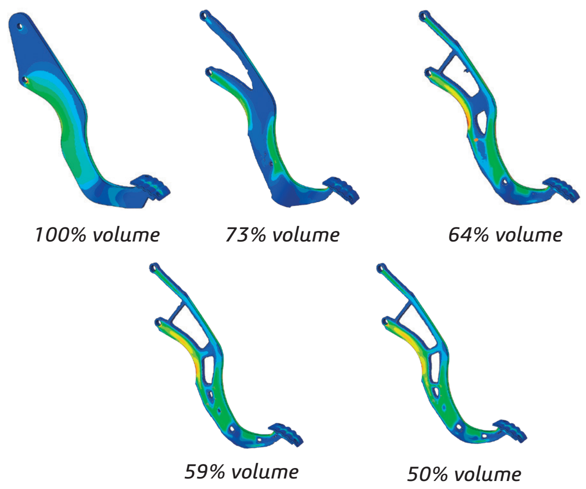
When performing topology optimization on a brake pedal, the brake pedal geometry, pin joints for boundary conditions, and pressure loading on the pedal need to be taken into account with a small amount of deformation expected.

Both the linear and nonlinear topology optimizations resulted in a 50% reduction in part weight.

The linear topology optimization provided a peak stress of 168 MPa with a lateral displacement of 1.7mm.

Comparatively, the nonlinear topology optimization solver resulted in a structure with 30% less lateral displacement (1.2mm) and 10% lower peak stresses (150 MPa).

ATOM, a nonlinear topology optimization solver, took out-of-plane warping effects into account, resulting in a manufacturable design which will meet the most stringent standards, while outperforming the results of a linear topology optimization.



This nonlinear brake pedal example shows the progression of a topology optimization as it attempts to maximize the stiffness while reducing the volume by 50% during 31 design cycles.

ATOM Highlights

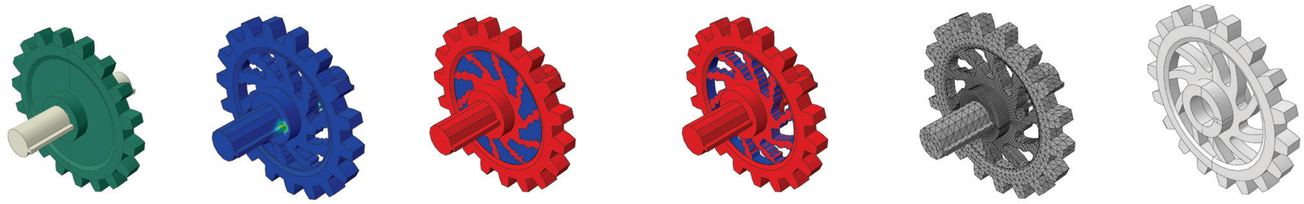
Features

- Topology and shape optimization for material nonlinearity and contact
- Generation of smoothed output for CAD input
- Model parameterization is not required
- Utilizes the Abaqus/Standard nonlinear solver
- Pre and postprocessing provided in Abaqus/CAE

Benefits

- Shorter design cycle enables faster time-to-market
- Lower production costs due to weight savings
- Better part-life estimates with targeted peak stress
- Improved product quality with lower failure rates

Structural optimization is an iterative process that helps to refine designs and produce components that are lightweight, rigid and durable.



Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Original Geometry	*Mises Stress*	*Material Distribution*	*Material Distribution with Soft Elements Removed*	*Extracted Surface*	*New Topology Geometry*

This image illustrates the setup and postprocessing of the topology optimization of a spur gear and shaft assembly in the new Abaqus Topology Optimization Module.

Topology Optimization

Topology optimization begins with an initial design, which is assumed to be the maximum physical extent of the component, and determines a new material distribution by changing the density and the stiffness of the elements in the initial design while continuing to satisfy the optimization constraints.

ATOM provides users with a choice of objective function terms and constraints, including:

Optimization Design Responses

Volume, mass, compliance, displacements, rotations, reaction forces, reaction moments, internal forces, natural frequencies, center of gravity, moments of inertia, results from frequency response analysis (amplitudes, phases, velocities and accelerations), acoustic measures (surface velocities, sound pressure)

Manufacturing Restrictions

Demolding constraints for casting and forging

Symmetry Restrictions

Rotational, cyclic, planar and linked condition

Material Sizing Restrictions

Minimum, maximum and envelope sizing for wall thickness

Shape Optimization

Shape optimization begins with a finite element model and minimizes stress concentrations using the results of a stress analysis to modify the surface geometry of a component until the required stress level is reached. Shape optimization then attempts to position the surface nodes of a selected region until the stress across the region is constant.

ATOM provides users with a choice of objective function terms and constraints including:

- Minimization of combinations of equivalent stress values
- Shape optimization of contact surfaces for homogeneous contact stress
- Maximization of selected natural frequencies
- Specification of a volume constraint
- Mesh-independent manufacturing constraints for casting, forging, stamping, extrusion and drilling
- Minimum and maximum member size
- Rotational and planar symmetry
- Penetration checks to neighboring parts
- Mesh smoothing in each design cycle ensure optimization solution stability

Optimized Design Proposal

ATOM provides transformation, smoothing, and data reduction of the optimization results. CAD-neutral data can be exported in either .STL or .INP formats as a surface mesh. This can be used to reconstruct parametric geometry if needed.