Free Material Optimization

Find the best material within a given domain able to carry the given loads. The material properties can vary from point to point; the only constraint: physical availability.

MOPED (Material Optimization in Engineering Design): software package for free material optimization of general two-dimensional structures, including graphical postprocessing. Single- and multiple-load, 2D and 3D problems. Large-scale convex nonlinear program (300,000 var., 100,000 quadr. constr.). Semidefinite program (60,000 var., 20,000 LMI constr.).

Global Stability Constraints

Elastic instability is often of critical importance when designing a real-world structure, like a bridge or an aircraft. Such structures may fail not as a result of high stresses, but owing to insufficient elastic stability.

Global stability constraints formulated as a nonconvex matrix inequality

\[ A(t) + G(t; u) \preceq 0 \]

where \( t \) is the design and \( u \) the state variable, \( A(t) \) the stiffness matrix and \( G(t; u) \) the geometry stiffness matrix.

Optimal design problem: nonconvex semidefinite program.

PENNON

General-purpose code for large scale nonlinear and semidefinite programming

- Convex NLP: generalized Augmented Lagrangian method based on PBM algorithm by Ben-Tal/Zibulevsky
- Convex SDP: via special penalty function for matrix inequalities; treatment of different data sparsity patterns
- Nonconvex NLP: based on trust region algorithm for inexact unconstrained minimization steps
- Nonconvex SDP, in particular BMI: combination of above
- Combination of NLP and SDP constraints: so far the only optimization code of this kind

Independent benchmarks by H. Mittelmann (http://plato.la.asu.edu/bench.html):

PENNON is one of the fastest codes for convex NLP and SDP, particularly for large sparse problems.

SDP version implemented on the NEOS server: http://www-neos.mcs.anl.gov

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Applications

Airbus A380, design of “leading edge”

Weight saving of up to 17%, compared to traditional design.

Design of rear fuselage of cargo aircraft

Problems with up to 100,000 finite elements.

2D model problems with stability constraints

First solve problems with vibration constraints → linear SDP with

\[ A(t) + \lambda M(t) \preceq 0 \quad (\lambda \ldots \text{min. allowed eigenfrequency}, M \ldots \text{mass matrix}) \]

initial design min. weight result + vibration constr.

Robust structural design (w.r.t. small random loads)

Ben-Tal/Nemirovski: LARGE scale SDP, numerically unsolvable. Cascading: solve a sequence of “small” multiple-load problems with most dangerous loads.

Robust FMO design

min. compliance FMO design robust strains stresses

http://www2.am.uni-erlangen.de/~kocvara/pennon/ ... /moped/ http://www.penopt.com/