Schnelle Optimierung in der Strukturakustik

Mostafa Ranjbar[1], Steffen Marburg[2], Hans-Jürgen Hardtke[3]
[1] *Islamic Azad University, Pardis Branch, Iran, Email: Mranjbar@pardisiau.ac.ir*
[2] *LRT4, Institut für Mechanik, Universität der Bundeswehr München, 85577 Neubiberg, Germany*
[3] *Institut für Festkörpermechanik, Technische Universität Dresden, 01062 Dresden, Germany*

Introduction

Passive noise control describes methods to optimize structures numerically with respect to various acoustical and structural properties such as root mean square level of the structural particle velocity, the radiated sound power etc. These techniques can be applied during the design phase of a machine or machine component, since they use a finite element (FE) model of the structure [1].

Although the structural acoustic optimization processes are time consuming, but there is no guarantee in order to achieve the desired optimum after a number of objective function evaluations [2]. Therefore, finding the efficient optimization methods in terms of convergence rate, accuracy and robustness for structural acoustics application is still an open field [3].

This article presents a comparative study on optimization in structural acoustics. The detailed description and further explanations can be found in [4].

Methods

A combination of a commercially available finite element software package and additional user-written programs is used to modify the shape of a square plate made of steel. The structure's local geometry modification values at the selected surface key-points are considered as design variables. The allowable ranges of design variables are limited between -10 and +10 millimeters.

The objective of the optimization includes the minimization of the root mean square level of structure borne sound. The optimization process continues automatically until the predefined maximum number of function evaluations is reached.

The optimization procedure is tested on the finite element model of the rectangular plate. The model has 400 elements and 1681 nodes. The constant modal damping value is 0.03. The element type is the 8-node rectangular finite elements with quadratic shape functions of ANSYS, ie, ANSYS element type (SHELL93) [5].

There are three uniform harmonic pressure excitations on the surface of plate. All of them act at the same amplitude and phase and are uniform over the frequency range of 0-100 Hz. The excitation pressures act at the locations where presumably all relevant mode shapes of the structure in the frequency range of interest are excited.

A statistical approach is followed for the comparison of seven different optimization methods. These methods are Method of Feasible Direction (MFD), Method of Moving Asymptotes (MMA), Mid-Range Multi-Points Method (MMP), Method of Simulated Annealing (SA), Tabu Search Method (TS), Limited memory Broyden-Fletcher-Goldfarb-Shanno algorithm for Bound constrained optimization (L-BFGS-B) and Newton Method (NM).

A set of initial designs including of 1000 design points are selected uniformly on the allowable design space.

Results

It is shown in Table 1 that all of considered optimization methods could produce significant improvements of the objective function. This holds for all of the optimization algorithms employed. These methods can be used for numerical optimization in structural acoustics and it can be expected to achieve acceptable results after a certain number of function evaluations.

Table 1 presents the success rates for seven optimization methods, three selections of M, as the number of objective function evaluations, and five different levels of objective function improvements. It is obvious that all these local methods are quite successful to decrease the objective function. However, only one method, i.e. MMA, was capable to always gain an improvement of at least 5 dB. MMA turns out to be very successful up to at least 15 dB improvement.

Note that even after 200 function evaluations, every second MMA run reached an impact of 15 dB and more. In this sense, MMA is a very reliable optimization method. However, even the L-BFGS-B and SQP seem to be reliably supply reasonable gains after only 100 function evaluations. However, it does not seem reasonable to let them run longer since further improvement is rather low. MMP appears as a remarkable method. Therefore, if there's time limitation on the computation time of the optimization process, then, it is recommended to use the fast methods, such as MMA. This method can produce good results in comparison to other optimization methods.

Finally, some modified geometries resulting from MFD, SA and SQP methods are shown in figures 1, 2, 3.

Table 1: Success rate (in %) of optimization methods after fixed number of objective function evaluations.

M	Method	Success Rate for Minimum Gain of				
		5 dB	10 dB	15 dB	20 dB	25 dB
100	L-BFGS-B	85	68	34	0	0
	MFD	72	30	6	1	0
	MMA	100	74	30	3	0
	MMP	61	34	16	8	4
	SQP	83	68	31	0	0
	NM	58	34	1	0	0
	SA	25	6	0	0	0
200	L-BFGS-B	86	68	36	1	0
	MFD	83	43	9	3	0
	MMA	100	82	53	8	0
	MMP	64	39	17	13	7
	SQP	83	68	31	7	0
	NM	60	35	1	1	0
	SA	46	9	2	0	0
500	LBFGSB	86	68	39	2	0
	MFD	83	47	14	5	0
	MMA	100	91	70	15	0
	MMP	69	50	23	20	9
	SQP	83	68	31	12	0
	NM	63	38	4	4	2
	SA	82	15	3	0	0

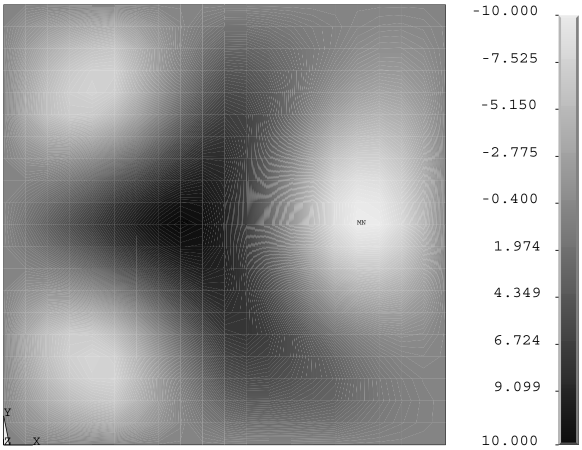

Figure 1: Best modified geometry by MFD.

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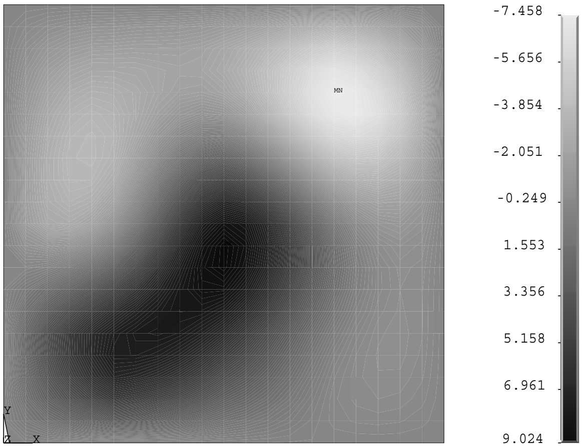

Figure 2: Best modified geometry by SA.

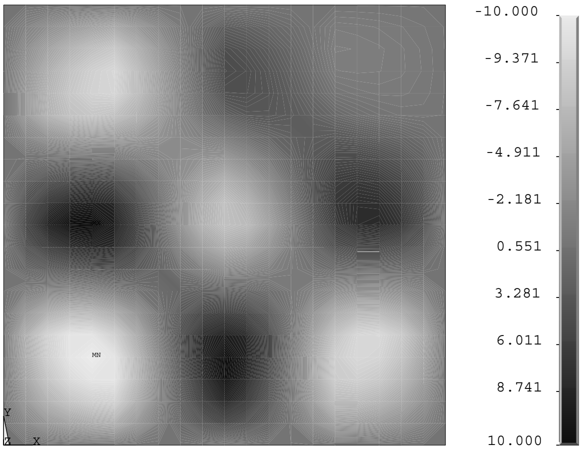

Figure 3: Best modified geometry by SQP.

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