STOCHASTIC IDENTIFICATION IN THERMOMECHANICAL STRUCTURES USING EVOLUTIONARY ALGORITHMS

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1. Introduction

The thermomechanical processes belong to coupled problems in which interaction between mechanical and thermal field is considered. It is very convenient for identification, because measuring both quantities: displacements and temperatures simultaneously is more effective than measuring only one with the use the same numbers of sensor points [2].

The identification problem can be formulated as the minimization of some objective functional (fitness function) which depends on measured and computed state fields such as displacements, strains or temperature. In order to obtain the unique solution of the identification problem one should find the global minimum of the objective functional.

In the present paper the parameters of thermomechanical systems are modelled by random variables with a Gaussian probability density function. The applications of evolutionary computation to such problems require some modifications of the algorithm. Genes should be modelled by random numbers and the potential solutions of the optimization problem are represented by stochastic individuals in the form of random vectors. Modified evolutionary operators of mutation, crossover and selection are proposed.

2. Stochastic identification problem

The aim of the stochastic identification is to find a random vector $\mathbf{X}(\gamma)$:

(1) $$\mathbf{X}(\gamma) = [X_1(\gamma), X_2(\gamma), \ldots, X_i(\gamma), \ldots, X_n(\gamma)]$$

which minimizes an objective function $F(\gamma) = F[\mathbf{X}(\gamma)]$ subjected to m constrains $P[g_j(\mathbf{X}) \geq 0] \geq p_j, \quad j = 1, 2, \ldots, m$

where: (Γ, $\mathcal{F}$, P) is a probability space, Γ is a space of elementary events, $\mathcal{F}$ is σ-algebra of subset of the set Γ, P is the probability defined on $\mathcal{F}$.

In order to solve the identification problem an evolutionary algorithm (EA) is used. Each individual is a multidirectional vector consisting of random variables (genes) with the Gaussian density probability function. Each gene is represented by the two moments: (i) the mean value m_i and (ii) standard deviation σ_i .

The evaluation of the fitness function can be done by solving the stochastic boundary-value problem, for instance: stochastic boundary element method SBEM [1] or the stochastic finite element method SFEM [3].

The original stochastic problem can be also reduced to the series of the deterministic one. In this work for each individual several direct problems are solved on the basis of input random variables. The moments of the displacement and temperature fields are evaluated on the basis of the 200 deterministic tasks. An fitness function is expressed by minimization of the following functional:

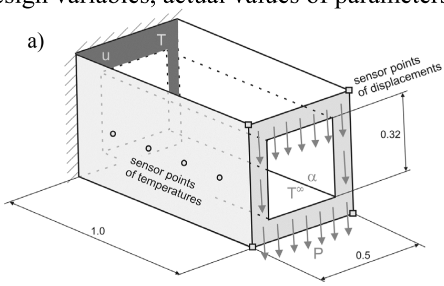
(2) $$\min : \left[F(\mathbf{x}) = \sum_j w_j \sum_i \left(x_i - \hat{x}_i \right)^2 \right]$$

where: x_i - the measured quantity (temperature or displacement), $\hat{x}_i$ - quantity computed for the structure with the parameters generated by the evolutionary algorithm, w_j – is appropriate weight. Direct problems of thermoelasticity for the identification task are solved by means of the finite element method (FEM) [5].

3. Numerical example

In this example thermal boundary conditions are identified. It is assumed that identified ambient temperature T^∞ and heat convection coefficient α are random variables. The structure under thermomechanical loading presented in Figure 1a is considered. One surface of the box is supported, whereas on the opposite load P is applied. On the supported surface of the structure the temperature T is applied. The third type thermal boundary condition (convection) is specified on the internal surface (identified random variables T^∞ and α). The stochastic fitness function is evaluated on the basis of measured displacements and temperatures in boundary sensor points, which are random variables with the Gaussian distribution. Table in Figure 1b contains limitations of the design variables, actual values of parameters and obtained results.

a)



b)

	$\alpha \left[W / m^2\,°C \right]$		T^∞[°C]	
	m	σ	*m*	σ
Min	1.00	0.01	0.20	0.01
Max	9.00	0.50	90.00	0.50
Actual	5.00	0.20	48.00	2.00
Found	4.78	0.17	47.54	1.74

Figure 1. a) Geometry of the structure. b) The results of the stochastic identification

4. Conclusions

An effective intelligent technique based on the stochastic evolutionary algorithm has been presented. This approach can be applied in the optimization and the identification of systems that are in the random conditions. The obtained results demonstrate good accuracy comparing to exact solution. Numerical computations of thermoelasticity problems using finite element usually is time consuming, especially with more complicated models.

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6. References

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