OPTIMIZATION OF THERMAL MICROACTUATORS RELATED TO MULTIPLE CRITERIA

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1. Introduction

The problems of optimal design of MEMS (Micro Electro Mechanical Systems) structure attract more and more attention in the recent years. MEMS structures are mainly micro sensors and micro actuators, which are commonly used in telecommunication, automotive, aviation or medical industry. Many of them combines both measurements and actuation elements [3] [8]. Designer of such structures have to consider many technical aspects and restrictions. Among the various types of microactuators, most commonly used are: thermal, electrostatic and piezoelectric. For the first group as an material, polycrystalline silicon is used. It utilizes the Joule heating effect, due to the high value of electrical resistance of the silicone. The most commonly used in practice are: U-Beam microactuators (folded toggle) and V-Beam microactuators (shevron type). For such structures, deformation, maximum displacement, generated force or maximal value of equivalent stresses strongly depend on its geometry. Optimal design of complex structures such as microactuators, requires consideration of many criteria, which depends on the quantities like: the mass of the system, the distribution of stress, the temperature, the displacement, the dynamic characteristics, etc. In practice, this requires coupling of appropriate multi-criteria optimization methods and different numerical simulation techniques. The problems of optimal design of thermal actuators have been considered by many researches, e.g. [4] [5] [9]. In order to efficiently optimize such structures, proper optimization techniques have to be applied, especially when more criteria have to be taken into account [1]. Optimization taking into account one criterion with other criteria formulated as a restriction or weighting sum optimization method, can be found in vast of papers. The present paper proposes methodology of multiobjective optimization of thermal actuators which is more effective, when many criteria (more than three) are considered.

2. Multiobjective optimization algorithm

The metaphors of the game theory and immunology are used to solve the problems of multiobjective optimization using IMGAMO (Immune Game Theory Multi-Objective Algorithm). Each player has its own objective (a payoff function in the Nash equilibrium). The strategy for a particular player is the optimum solution for this player's problem remembering that other players also play their best strategies. The solution of the optimized problem consists of several parameters, each of which is assigned to one of the players. Each player optimizes only its parameters (its strategy) taking the rest of them as constant. The rest of the parameters are set by taking the best solutions from the other players. Solutions from all players should establish the solution of the problem. Then all players use the immune algorithm to optimize their objectives. IMGAMO algorithm was tested on several benchmark problems (ZDT and DTLZ problems). The results of multiobjective optimization are compared to the results obtained by NSGA2 nad SPEA2 algorithms [2] [11]. The metrices of general distance (GD) and spread of the Pareto optimal solutions (S) are used for comparison between algorithms. For the bi-objective optimization results obtained by IMGAMO and NSGA2 or SPEA2 algorithms are comparable, whereas for higher number of criteria (up to 7) IMGAMO gives significantly better results. Details of the algorithm have been described in [6].

3. Formulation of the problem

In order to simulate numerically electrothermal actuators, a coupled electrical, thermal, and mechanical analysis has to be solved. Such problem is described by the appropriate partial differential equations. The equations with arbitrary geometries and boundary conditions are solved by Finite Element Method [12]. This problem is weakly coupled and it requires solving electrical, thermal and mechanical analysis separately. The coupling is carried out by transferring loads between the considered analyses and by means of staggered procedures. FEM commercial software MSC Mentat/Marc is adapted to solve the coupled boundary-value problem.

Shevron-type microactuator is modelled and optimized. Several design variables are responsible for the shape of the beam. It concerns: shape of the beams (which are modelled by means of NURBS parametric curves), pre-bending angle, radii of connection between beams and anchors or central shafts.

Five different functionals are defined. Such functionals are related to the: mass of the structure, equivalent stress, maximum deflection of the actuator, total heat generated by the actuator and buckling safety factor.

Proposed approach allows to obtain a set of Pareto-optimal solutions as a result of a single optimization task run. Visualization of such a set, for two or three criteria is not a major problem, it leads to the form of curves or surfaces. Performing optimization task for larger number of criteria entails necessity of proper visualization of the results. One of the more popular methods is the projection of each pair of criteria and present them in the form of a matrix (Scater-plot matrix). For the large number of criteria this method of visualization can be ineffective. In present paper more convenient way to visualize the results of the optimization is the used - Self-Organizing Maps (SOM) [10]. This concept is based on Kohonen neural networks [6].These networks can also be used to visualize the vector of design variables for optimal solutions.

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4. References

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