# Optimisation by Evolutionary Algorithms of Free-Layer Damping Treatments on Plates

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## 1. INTRODUCTION

The problem of controlling or reducing vibration levels is very common in many different applications. From costly aeroplane fuselages to cheap domestic appliances the problem can be tackled with the appropriate use of free layer damping treatments (FLDT).[1] This technique, based on the distribution of layers of visoelastic material on the vibrating parts, is frequently adopted since it is cheap, efficient and easily applicable either at the design stage or in situ as a corrective measure. Due to these advantages and few limitations, not much care is taken to optimise the material distribution.

Conversely, the necessity to produce lighter and quieter products will force the designer to optimise these treatments too. Under these circumstances, the most appropriate optimisation objectives seem to be the maximisation of the achievable damping levels and the minimisation of the amount of added material.

In this work the potential of the genetic algorithm for the determination of the optimal damping material distribution on vibrating plates is tested. The selection of this optimisation procedure is dictated by the high number of control variables involved and by the nature of the energetic formulation adopted. The latter leads to multi-modal solution spaces where, unfortunately, classical search procedures, based either on the gradient or hill climbing procedures, tend to fail.

As it will be shown, further advantages of the proposed approach lay in the possibility to handle either a single or a multi-objective optimisation search (i.e. simultaneously maximising damping and minimising added weight) and to take into account constraints and boundary conditions in a easy, straightforward way.

The paper will also compare the results obtained with the evolutionary approach with the ones provided by the classical optimisation procedures like the sequential quadratic programming (SQP) and the goal programming.

## 2. THE VIBRATING PLATE

The idea to concentrate this feasibility study on platelike structures derives from the fact that many sources of noise and vibration are enclosed by panels and thus can be treated with FLDT. Furthermore since the analytical formulation of the dynamic behaviour of plates can be found in the reference[2] it is easy to verify the quality of the results obtained.

Once the characteristics of the viscoelastic material are defined, the FLDT optimisation problem is reduced to the definition of the thickness of the layer at different points or areas of the plate.[3,4] In this way the material is not spread uniformly on the structure, but it is concentrated only on those areas where it can operate more efficiently.

It is evident that the number of possible variables that can be taken into account is large and consequently the related solution space is also large.

For example, considering a rectangular plate divided in regular patches, if $x$ is the number of divisions along one side and y along the other one and for each patch, $z$ is the number of allowable material thickness combinations, the solution space has $z^{(xy)}$ possible solutions. Naturally, all these possible solutions have to satisfy the problem constraints like the maximum added weight, the maximum layer thickness, the distribution feasibility and so on.

In these conditions, it is evident that the robustness and the search speed of the algorithm are very important for industrial use of the procedure.

## 3. THE GENETIC ALGORITHMS

Genetic algorithms (GA) are search algorithms. They consist of a set of mathematical operators that mimic evolution and genetic mechanisms. They simulate concepts like the Darwinian ‘survival of the fittest’, random mating and mutation, evolution pressure, sterilisation, premature death and so on.[6] The advantages of the GA are related to their speed when compared to enumerative techniques and to the lack of the drawbacks of gradient-based search algorithms in multi-modal spaces. The GA approach differs from traditional methods because:

- they mostly work with coded parameters instead of the actual parameters;
- they search simultaneously populations of solutions instead of a single solution;
- they use fitness function information instead of derivative or other auxiliary functions; and
- they are based on probabilistic instead of deterministic rules.

In real terms, a GA search starts from the generation of a population of individuals, which is a subset of randomly chosen solutions within the search space. The initial population is coded, the fitness function is evaluated for each element of the population and the quality of the solutions is evaluated and ranked. Based on this ranking, the mathematical operators create a new population of individuals favouring solutions close to the highest ranking individuals of the previous generation and giving low chances of reproduction to the lowest ones. The random aspects of the GA provide that the search algorithm explores the whole space of solutions with-