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An evolutionary search technique to determine natural frequencies and mode shapes of composite Timoshenko beams

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ABSTRACT

Natural frequencies and mode shapes of composite Timoshenko beams are determined by a diversity guided evolutionary algorithm (DGEA) with different boundary conditions. After applying boundary conditions, frequency equation is obtained in determinant form. Then, natural frequencies and consequently mode shapes are obtained using DGEA where the absolute value of determinant is the subject of optimization. Advantages of employing DGEA are: first, all natural frequencies are produced in a simple run, second, its simplicity for implementation and third, the procedure is not computationally prohibitive. Results clearly show the applicability of the proposed method for obtaining natural frequencies and mode shapes.

1. Introduction

In addition to the effect of rotary inertia, Timoshenko included the effect of transverse shear deformation on the vibratory motion of the beam (Timoshenko, 1922). Since then, the expression Timoshenko beam has become universally well-known. There are several applications of this type of beam in which composite and metallic beams are employed (Banerjee, 2001; Younesian et al., 2005; Muscolino and Palmeri, 2007). One of the advantages of using Timoshenko beam is when higher natural frequencies and mode shapes become important. Furthermore, fibrous composites have usually very low shear moduli which result in low shear rigidity of the beam. Many of the developed solution techniques are computationally prohibitive. In recent years, in order to reduce time complexity, some successful attempts have been performed by the advances in symbolic computation. The added advantage of these methods is to derive the explicit form of frequency equation and mode shapes that have been reported for both composite and metallic beams (Banerjee, 2001). Despite these advantages, symbolic computation tools may not be available to every researcher. Moreover, there exist some computational methods that are not computationally prohibitive. These methodologies are special optimization algorithms that give multiple solutions simultaneously in numerical form without explicit derivation (Ursem, 2003). Therefore, the problem of locating natural frequencies and mode shapes can be formulated in a form suitable for optimization task and eventually using a numerical technique to extract numerical results. In the following, the growing interest of applying these methods are described and introduced briefly.

In recent years, optimization algorithms have been widely utilized in many engineering problems. The attention of researchers is due to the power of these algorithms to solve problems for which no analytic method is available, e.g.; complicated non-linear differential equations. One category of these algorithms, which have been successfully employed in several complex engineering optimization tasks, is called Evolutionary Algorithms (EAs) (Ursem, 2003; Adam, 2004). The methodologies, in which EAs are used for solving non-linear equations, are generally similar to each other. Therefore, developing a methodology in this field is useful for applying to similar cases. On the other hand, in spite of the power of EAs in finding global optimum of a function, some of the real world optimization problems are multimodal (Ursem, 2003). An algorithm that keeps track of multiple optima simultaneously has the ability to spread out the search and thereby discover different optima in one run (Ursem, 2003). The central concept in most research on EAs for multimodal optimization has been to maintain the genetic diversity of the algorithm's population (Thomsen and Rickers, 2000; Thomsen et al., 2000; Ursem, 2000; Ursem, 2002). Genetic diversity is important because a diverse population allows the algorithm to better exploit the crossover operator when creating new solutions. diversity guided evolutionary algorithm (DGEA) is an EA that has been introduced by Ursem. This algorithm uses a diversity measure to alternate between exploring and exploiting behavior (Ursem, 2002). One simple run of this algorithm results in a final popula-

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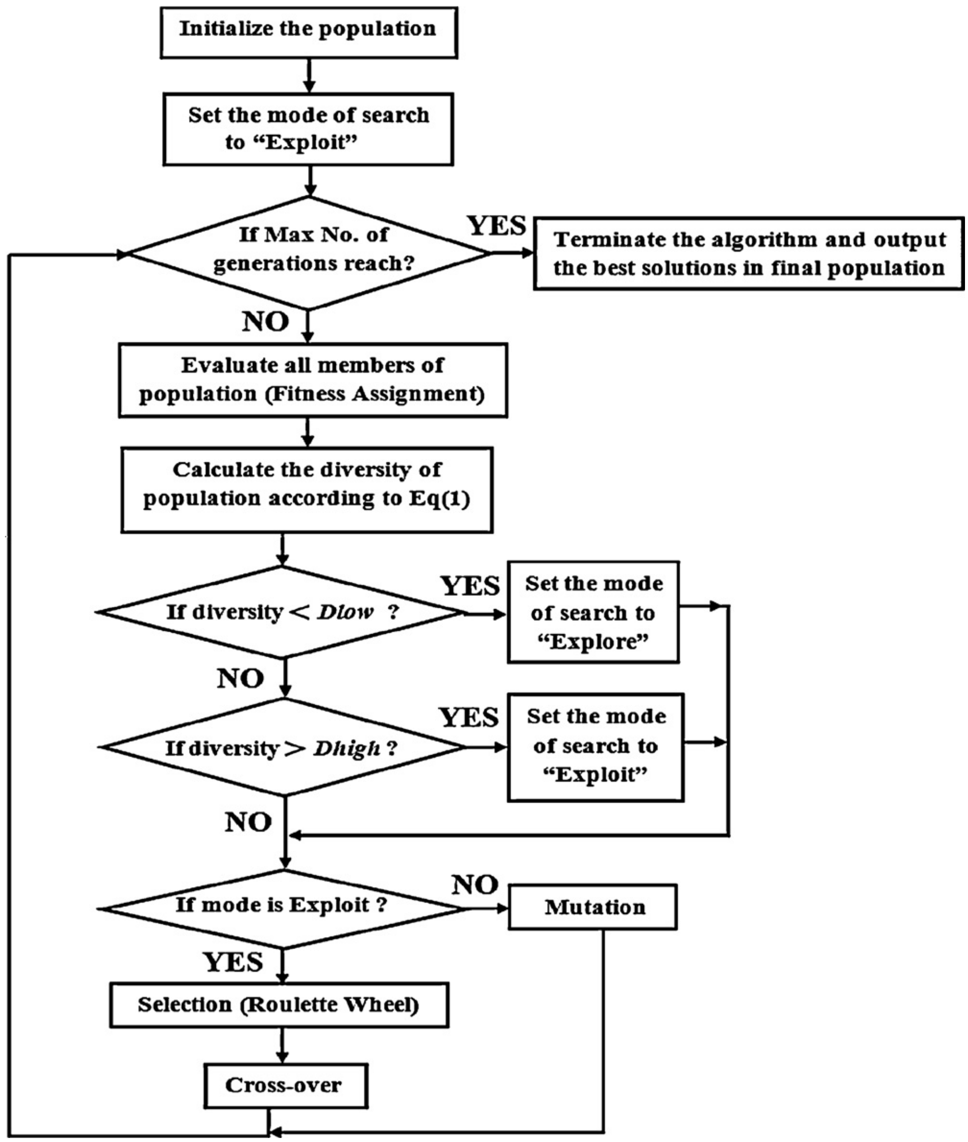

Fig. 1. Flowchart of DGEA.

tion in which different solutions with the same value of objective function exist. These solutions are multiple global optima and are calculated in a reasonable time.

In this research, the problem of finding natural frequencies and mode shapes of a composite beam is formulated as an optimization task. After that, DGEA is employed to find the natural frequencies when minimizing the determinant value of coefficient matrix is the subject of optimization. This method is not computationally prohibitive and can be used for any type of similar problem where finding all natural frequencies in a simple run is guaranteed.

2. Diversity guided evolutionary algorithm

EAs are stochastic and iterative optimization techniques inspired from Darwinian theory of evolution. One of the most well-known algorithms in this category is the so-called genetic algorithm (GA) that historically has been developed by John Holland (Adam, 2004). There are several challenging optimization problems in real world applications in terms of non-linearity and complexity. Especially in engineering and industry, there are some optimization problems with a huge search space and many local optima in which finding global optimum in a reasonable time is not possible. Furthermore, when multiple global optima exist in search space, the problem is called multimodal optimization. Solving these types of problems by simple EAs may be time consuming. One solution for this approach is to run a simple EA multiple times and hope the algorithm to converge to a distinct global optimum in each run. This solution is very time-consuming and is not possible in many real world multimodal optimization tasks. Therefore, many EAs have been specially developed for solving this type of problem in an efficient manner. The central concept in most research on EAs for multimodal optimization has been to maintain the genetic diversity of the algorithm's population. Genetic diversity is important because a diverse population allows the algorithm to better exploit the crossover operator when creating new solutions. Crossover on individuals from a fully converged population has no effect, because recombining identical individuals will not generate any new solutions. In this case, the algorithm is severely dependent on the mutation operator to escape the local optimum and further explore the search space.

Some advanced research in the field of multimodal optimization has been recently performed by Ursem (2003) and Adam (2004). He introduced DGEA in order to improve control over the population diversity (Ursem, 2002). The DGEA was developed for controlling