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Sizing and Topology Optimization of Trusses by Development of Algebraic Force Method and Parallel Genetic Algorithm

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Abstract

Many researches have been carried out in structural topology optimization using the traditional stiffness method in last decades. Similarly, the force method has been employed to optimize the trusses due to its speed and efficiency. In this paper as the first feature, the algebraic force method formulation is developed such that it is possible to utilize it in the topology optimization. The force method has two advantages over the conventional stiffness method. Firstly, number of equations should be solved in the force method is the same as the degree of static indeterminacy in place of the total degrees of freedom used in the stiffness method, resulting in increasing of the optimization speed. Secondly, the matrices corresponding to particular and complementary solutions are formed independently of the members' mechanical properties. In developed version, these matrices are formed only once for intact truss and used numerous times for trusses of the same topology. Second feature of this study is usage of a cluster of parallel personal computers due to genetic algorithm capability in parallelism. Each processor or island optimizes independently with own parameters and operators, resulting in diversity of solutions and escaping the local optimum.

Keywords: algebraic force method, topology optimization, distributed parallel genetic algorithm.

1. INTRODUCTION

In this research the force method formulation is developed and used to analyze trusses with different topologies. First advantage of this method is that the number of equations to be solved is the same as the degree of static indeterminacy of the structure which is much less than those of the traditional stiffness method (active degree of freedom) for usual trusses, thus increasing the speed of optimization [1]. The second (and main) advantage of using this method lies in the fact that the matrices corresponding to the particular solution B_0 matrix and the complementary solutions B_1 matrix are formed independent of the mechanical properties of truss members. Therefore these matrices can be formed only once and used numerous times in the process of a sequential analysis [2]. This can be done provided the topology of the truss under investigation does not change. Whereas in topology optimization of trusses, it is required to analyze trusses in which some member(s) has/have not participated. Therefore, the force method has not yet been used for such trusses.

In this study, the formulation has been developed such that one can use the force method for analysis of trusses with different topologies, resulting in increasing the computational speed by avoiding the repetition of the analysis.

Two groups of formulations are usually employed to find the optimal topology of trusses under different static loading conditions. The first utilizes mathematical programming [3–7] and the second consists of random based search methods. The genetic algorithm (GA) can be considered one the most popular method among the second group [8–11]. The main difference between the abovementioned methods is that mathematical programming approaches require the calculation of the gradients of the objective function and constraints, while the second approaches search for global optimum in a logical manner, without using the gradients. Also the superiority of GA becomes apparent for non-convex design spaces or for discontinuous objective functions. However, the parameters of GA such as population size, cross-over rate, mutation rate etc should be carefully tuned and appropriate penalty and fitness functions have to be selected in order to avoid local optimums. The high number of operations is the most important drawback of GA.

In this study, as the second feature, the distributed parallel genetic algorithm (DGA) is employed to overcome the mentioned difficulties.