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Optimization of Influence Parameters on Thermal Buckling of Hybrid Composite Plates with Cutout Using Genetic Algorithm

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ABSTRACT: Optimization in the design and maintenance of many engineering systems, economic and even social has been used to minimize the cost or maximize profits. In the buckling analysis, the hybrid composite plates with cutout, the effective parameters on buckling are the cutout geometry, fiber angle, cutout size to plate size ratio, bluntness of cutout corners, and rotation angle of cutout. Therefore, in this study, using genetic algorithm method an attempt has been made to introduce the optimum parameters to achieve the Maximum amount of critical buckling temperature of hybrid composite plate with polygonal cutouts in different boundary conditions and stacking sequences, which are subject to uniform temperature rise. The cutouts in this study are circular, pentagonal, and hexagonal. The solving method used to analyze this study is the finite element based on the energy method. Also, the theory used in this paper is the first-order shear deformation theory. The results presented in this case show that by choosing the appropriate shape of cutout and the optimal selection of parameters affecting buckling, the plate's resistance to thermal buckling can be increased. It was also found that stacking sequences and boundary conditions have a significant effect on the critical buckling temperature of a hybrid composite plate with cutout.

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1- Introduction

In different industries, for easy access to various engineering systems, inspection of damages, transmission of pipes carrier fuel, and decreases weight use from perforated plates. These types of plates in various thermal environments are often exposed to thermal loads, which can result in thermal buckling. Therefore, looking at the thermal buckling behavior of plates containing cutouts in order to achieve effective and efficient design seems necessary. For a plate without cutout under uniform heat loading, the stress field is the uniform throughout the plate, so that analytical buckling solutions can easily be obtained. The presence of cutout on the plate causes the stress field to become uneven. Hence, for a plate with cutout buckling analysis is extremely difficult and various numerical methods for analyzing such plates have been developed. The genetic algorithm (GA) uses biological evolution inspired methods. Therefore, a random search is the basis of its work. A large number of numerical and analytical studies have been carried out to check the buckling of the plates under thermal and mechanical loads, but limited studies have been done to optimize the parameters affecting the buckling of such plates with different algorithms. The study of buckling structures has a very long history. Shaterzadeh et al. [1] analyzed the thermal buckling of multilayered composite plates with circular cutout using finite element method and first order shear deformation theory. Optimization of multilayer banding for maximizing buckling load using an ant colony optimization method, used by Aymerich and Serra [2]. Vosoughi et al. [3] calculated the maximum buckling load of reinforced composite plates by combining finite element method and improved genetic algorithm method.

2- Methodology

A four-layer hybrid composite plate with a cutout in its center is assumed. This plate is under increasing uniform temperature. The displacement field is considered in accordance with the first-order shear deformation theory. Because the existence of a cutout on the plate prevents the creation of a uniform square element, therefore, the tetrahedral elements are used to model the finite element of the problem. On the other hand, due to the integration problems of the tetrahedral elements, an isoparametric elemental formulation is used according to reference [4]. After writing the relation of potential energy in terms of the displacement parameters in accordance with the principle of minimum potential energy, in equilibrium, the energy potential derivative of the whole system respected to vector displacement is equal to zero. Then, the matrixes of the stiffness and thermal force vector are calculated for each element and finally assembled for the entire structure. After calculating the pre-buckling

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displacement vector, using the geometric stiffness matrix, it can obtain the temperature of the buckling. This procedure is used in the genetic algorithm. The genetic algorithm is based on Darwin's evolutionary theory, and the solution to the problem solved by the genetic algorithm is gradually improving. The genetic algorithm begins with a set of answers that are displayed through chromosomes. This set of answers is called the primitive population. Then a good number of pairs of chromosomes are selected based on their fitness to be used later. Chromosomes that have high levels of compliance can be selected several times in the production process, while chromosomes whose levels of fitness are low may never be selected. In the sequel, the crossover operates with the probability of crossover on the parent's chromosomes and, by combining them, produces new chromosomes (sons). Then, the mutation operator with the probability of mutation on the chromosomes derived from the combination action is performed, and by changing the genes of these chromosomes, a way to enter new information. The new population is then selected to enter the next step of the algorithm. This is done by comparing the fitness of chromosomes and selecting more suitable chromosomes. Eventually, all new population will be evaluated. If the termination conditions are provided, the algorithm ends, otherwise the population will be used as the initial population for the next step.

3- Results and Discussion

With reference to Fig. 1 it can be seen that for pentagonal cutouts, the rotation angle of 135° and 157.5°, for hexagonal cutouts, the rotation angle of 157.5° and 0° respectively leads to the highest and lowest critical buckling temperature. An interesting result is that the rotation angle of 157.5° for the pentagon cutouts is the worst and for the hexagonal cutouts the best position is the cutout position. In addition, plates with pentagonal cutouts have a better position than the plate with hexagonal cutouts against thermal buckling.

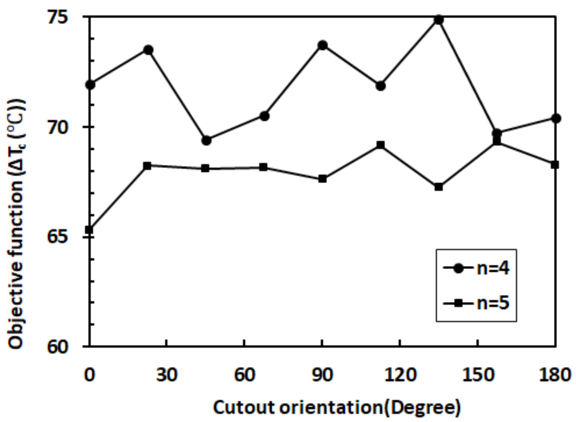
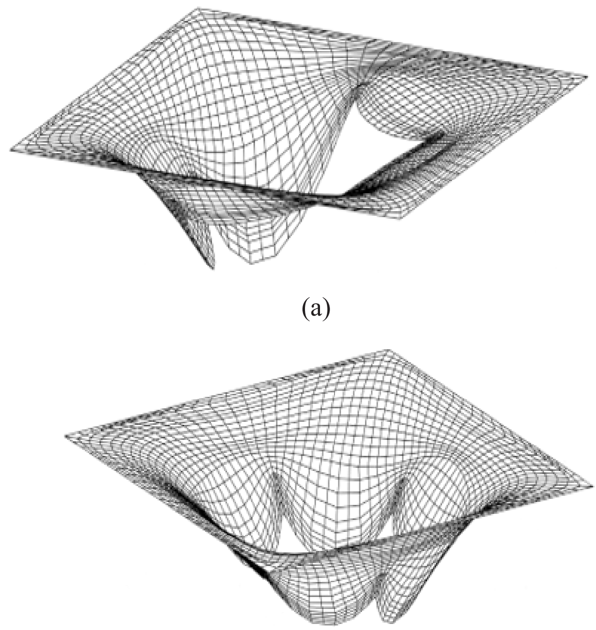


Fig. 1. Variation of the objective function to different values of cutout orientation

The resistance of the hybrid composite plate to thermal buckling increases with increasing ratio of D/a. As the cut-out size increases, the domain of tension stresses near the hole increases, which causes more resistance against buckling. Boundary conditions on the edge of the hybrid composite plate under thermal buckling load have a significant effect on the values of the critical buckling temperature. The plate with boundary conditions of four clamped edges has a greater resistance to thermal buckling than a plate with simply supported boundary conditions. This is because, for the CCCC boundary condition, all the edges of the plate are tighter. The mode shape of buckling of the plate with a pentagonal and hexagonal central cutout for fully clamped boundary conditions is shown in Fig. 2.



(a)

(b)

Fig. 2. Buckling mode shape of the plate with central cutout (a) Pentagon cutout (b) Hexagonal cutout

It is found that the symmetrical hybrid composite plate with a stacking sequence of [B B B B] has more resistance to thermal buckling than the other stacking sequences, and the composite plate with a stacking sequence of [G B B G] has the lowest resistance to thermal buckling.

4- Conclusions

In this paper, to achieve the maximum value of the thermal buckling load, the optimal design variables affecting the thermal buckling load are obtained for different stacking sequences and boundary conditions using the GA. The objective function in the GA is the maximum value of the critical buckling temperature.

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