Stacking Sequence Optimization Based on Deflection and Stress using Genetic Algorithms and Finite Difference for Simply Supported Square Laminate Plate Under Uniform Distributed Load

Asst .Prof Dr. Nabil H. Hade
College of Engineerin
Mechanical Eng. Dept
Baghdad University
nabilhha@yahoo.com

Dr. Louay Sabah Yousuf
College of Engineering
Mechanical Eng. Dept
Baghdad University
louaysabah79@yahoo.com

Abstract

In this paper, the optimization and increasing of the stiffness of squareplate, numerical simulation of laminate composite plate using genetic algorithms with finite difference analyses, in which applied to the design variables of the objective functions of the stacking sequence are studied. The plates have been evaluated with actual condition of problem such as distributed load,under simply supported boundary condition with different number of layers (5, 10, 20, 30, 50) and different stiffness ratios (E1/E2) 5, 10, 20, 30, 50. The effects of fiber orientation, number of layers and stiffness ratios on the deflection and stress response of symmetric of classical laminated composite plate subjected to uniformly pressure load (flexural loading) are presented. The maximum deflection and stress are the major parameters that were taken into account in the plate design. Then obtain the optimal suitable stacking sequence orientation of composite plate that gives a small maximum deflection and maximum stress of central point of the plate which represent the main aim in this work. The results were compared with ANSYS software results and obtain a good agreement.

Keywords: composite laminate,genetic algorithms,finite difference.

Introduction

Genetic algorithms are heuristic stochastic methods that explore a reduced set of tentative solutions, performing a guided search procedure that evaluates few solutions, in several orders of magnitude smaller than the whole search space. A methodology is implemented to design symmetrically laminate composite rectangular plates with eight layers using genetic algorithms with the finite element method. The optimal design variables of the objective functions are four, fiber orientations,laminae thicknesses, load distributions, and various combinations of (clamped, simply supported and free), to minimize weight and deflection (stiffness maximization) of fiber reinforced structures, [1, 2, 3]. On the other hand the Tsai-Hill failure criterion is taken as the fitness function to design variables optimization of stacking sequence (ply orientation angles) and laminate failure margines of symmetric composite laminates subjected to various loading and boundary conditions using genetic algorithms with the finite element method based on shear deformation theory to reduce the number of the criteria. The results show that the optimization via a genetic algorithm can find the global optimal solution leading to a substantial decrease in the failure index, [4, 5]. Moreover several changes and improvements to the standard genetic algorithms have been applied to design optimization of stacking sequence of a stiffened composite panel against buckling under a set of shear and axial loads using nonlinear finite element simulation to reduce weight, cost, and the number of analyses required for the optimization, [6, 7].A numerical free vibration response with nine nodded quadrilateral isoparametric element of rectangular plates with simply supported edge conditions is used in the presence of elliptical cutouts to design parameters like orientation of the ellipse with respect to the references axis, aspect ratio of the cutout, orientation of plies, thickness of plies and material of the plies. The results illustrated that genetic algorithms is available tool for optimum design of laminated composite plates with cutouts, [8].An optimization procedure is proposed to determine the optimal stacking sequence of laminated composite rectangular graphite-epoxy plates for critical buckling load maximization and flexural stiffness under several different loadings, such as uniaxial compression, shear, biaxial compression, and the combination of shear and biaxial loadings. Also, a genetic algorithm finds the global solution without requiring auxiliary derivatives of the objective function, [9, 10, 11].In this work it can be derived the analytical solution of general orthotropic equation at the same time the researchers do not studied it briefly and solve the orthotropic equation using finite difference method to design the stacking sequence optimization of composite plate, which reduce the maximum deflection and stress using genetic algorithms.

Analytical Procedure

Consider a plate of a total thickness (h) composed of (N) orthotropic layers with the principal material coordinates of kth lamina oriented at an angle θ_k to the laminate coordinate, x. the kth layer is located between the points z = z_k and z = z_{k-1}in the thickness direction as shown in Fig. 1. It can be used ***Kirchhoff hypothesis*** theory with the aiding to classical laminate plate theory (CLPT). For general orthotropic material and layers oriented arbitrarily with respect to the laminate coordinates,the Hook's law relations are, [12]:

$$\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix}^{(K)} = -z * \begin{bmatrix}\overline{Q}_{11}\overline{Q}_{12}\overline{Q}_{16}\\ \overline{Q}_{12}\overline{Q}_{22}\overline{Q}_{26}\\ \overline{Q}_{16}\overline{Q}_{26}\overline{Q}_{66}\end{bmatrix}^{(K)} * \begin{Bmatrix}\dfrac{\partial^2 w}{\partial x^2}\\ \dfrac{\partial^2 w}{\partial y^2}\\ 2 * \dfrac{\partial^2 w}{\partial x\,\partial y}\end{Bmatrix} \quad (1)$$

Which:

$$\begin{Bmatrix}M_{xx}\\ M_{yy}\\ M_{xy}\end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix} * z * dz \quad (2)$$

After simplification to obtain:

$$\begin{Bmatrix}M_{xx}\\ M_{yy}\\ M_{xy}\end{Bmatrix} = -\sum_{K=1}^{N} \begin{bmatrix}\overline{Q}_{11}\overline{Q}_{12} & 2 * \overline{Q}_{16}\\ \overline{Q}_{12}\overline{Q}_{22} & 2 * \overline{Q}_{26}\\ \overline{Q}_{16}\overline{Q}_{26} & 2 * \overline{Q}_{66}\end{bmatrix} * \begin{Bmatrix}\dfrac{\partial^2 w}{\partial x^2}\\ \dfrac{\partial^2 w}{\partial y^2}\\ \dfrac{\partial^2 w}{\partial x\,\partial y}\end{Bmatrix} * \frac{(z_K^3 - z_{K-1}^3)}{3} \quad (3)$$

The plate equation under flexural loading is:

$$\frac{\partial^2 M_{xx}}{\partial x^2} + \frac{\partial^2 M_{yy}}{\partial y^2} + 2 * \frac{\partial^2 M_{xy}}{\partial x\,\partial y} + P_o = 0 \quad (4)$$

Put equ. (3) intoequ. (4) to obtain:

$$D_x * \frac{\partial^4 w}{\partial x^4} + 2 * H_1 * \frac{\partial^4 w}{\partial x^2\,\partial y^2} + 2 * H_2 * \frac{\partial^4 w}{\partial x^3\,\partial y} + 2 * H_3 * \frac{\partial^4 w}{\partial x\,\partial y^3} + D_y * \frac{\partial^4 w}{\partial y^4} = P_o \quad (5)$$

Where:

$D_x = \sum_{K=1}^{N} \overline{Q}_{11} * \frac{(z_K^3 - z_{K-1}^3)}{3}$, $H_1 = \sum_{K=1}^{N} (\overline{Q}_{12} + 2 * \overline{Q}_{66}) * \frac{(z_K^3 - z_{K-1}^3)}{3}$

$H_2 = \sum_{K=1}^{N} 2 * \overline{Q}_{16} * \frac{(z_K^3 - z_{K-1}^3)}{3}$, $H_3 = \sum_{K=1}^{N} 2 * \overline{Q}_{26} * \frac{(z_K^3 - z_{K-1}^3)}{3}$

$$D_y = \sum_{K=1}^{N} \overline{Q}_{22} * \frac{(z_K^3 - z_{K-1}^3)}{3}$$

By using the central finite difference method shown in Table (1) to evaluate the deflection in eq. (5) at these mesh pivotal points (m, n) illustrated in Fig. 2 as below, [13]:

$$\left(\frac{\partial^4 w}{\partial x^4}\right)_{m,n} = \frac{1}{\Delta x^4}\left(w_{m+2,n} - 4 * w_{m+1,n} + 6 * w_{m,n} - 4 * w_{m-1,n} + w_{m-2,n}\right)$$

$$\left(\frac{\partial^4 w}{\partial y^4}\right)_{m,n} = \frac{1}{\Delta y^4}\left(w_{m,n+2} - 4 * w_{m,n+1} + 6 * w_{m,n} - 4 * w_{m,n-1} + w_{m,n-2}\right)$$

$$\left(\frac{\partial^4 w}{\partial x^2\,\partial y^2}\right)_{m,n} = \frac{1}{(\Delta x^2 \Delta y^2)} * \left[4 * w_{m,n} - 2 * \left(w_{m+1,n} + w_{m-1,n} + w_{m,n+1} + w_{m,n-1}\right) + w_{m+1,n+1} + w_{m+1,n-1} + w_{m-1,n+1} + w_{m-1,n-1}\right] \qquad 6$$

$$\left(\frac{\partial^4 w}{\partial x^3\,\partial y}\right)_{m,n} = \frac{1}{4 * (\Delta x^3 \Delta y)}\left[w_{m+2,n+1} - w_{m+2,n-1} - 2 * w_{m+1,n+1} + 2 * w_{m+1,n-1} + 2 * w_{m-1,n+1} - 2 * w_{m-1,n-1} - w_{m-2,n+1} + w_{m-2,n-1}\right]$$

$$\left(\frac{\partial^4 w}{\partial x\,\partial y^3}\right)_{m,n} = \frac{1}{4 * (\Delta x\,\Delta y^3)}\left[w_{m+1,n+2} - w_{m-1,n+2} - 2 * w_{m+1,n+1} + 2 * w_{m-1,n+1} + 2 * w_{m+1,n-1} - 2 * w_{m-1,n-1} - w_{m+1,n-2} + w_{m-1,n-2}\right]$$

For square plate $\Delta x = \Delta y = \lambda$

Put the above expressions in eq. (6) into eq. (5) to obtain:

$$\frac{D_x}{\lambda^4}\left(w_{m+2,n} - 4 * w_{m+1,n} + 6 * w_{m,n} - 4 * w_{m-1,n} + w_{m-2,n}\right) + \frac{2 * H_1}{\lambda^4}\left[4 * w_{m,n} - 2 * \left(w_{m+1,n} + w_{m-1,n} + w_{m,n+1} + w_{m,n-1}\right) + w_{m+1,n+1} + w_{m+1,n-1} + w_{m-1,n+1} + w_{m-1,n-1}\right] + \frac{H_2}{2 * \lambda^4}\left(w_{m+2,n+1} - w_{m+2,n-1} - 2 * w_{m+1,n+1} + 2 * w_{m+1,n-1} + 2 * w_{m-1,n+1} - 2 * w_{m-1,n-1} - w_{m-2,n+1} + w_{m-2,n-1}\right) + \frac{H_3}{2 * \lambda^4}\left(w_{m+1,n+2} - w_{m-1,n+2} - 2 * w_{m+1,n+1} + 2 * w_{m-1,n+1} + 2 * w_{m+1,n-1} - 2 * w_{m-1,n-1} - w_{m+1,n-2} + w_{m-1,n-2}\right) + \frac{D_y}{\lambda^4}\left(w_{m,n+2} - 4 * w_{m,n+1} + 6 * w_{m,n} - 4 * w_{m,n-1} + w_{m,n-2}\right) = P_{om,n} \qquad 7$$

And the central finite difference for distributed load is, [13]:

$$P_{om,n} = \frac{1}{36}(P_{m-1,n-1} + 4 * P_{m,n-1} + P_{m+1,n-1} + 4 * P_{m-1,n} + 16 * P_{m,n} + 4 * P_{m+1,n} + P_{m-1,n+1} + 4 * P_{m,n+1} + P_{m+1,n+1})$$

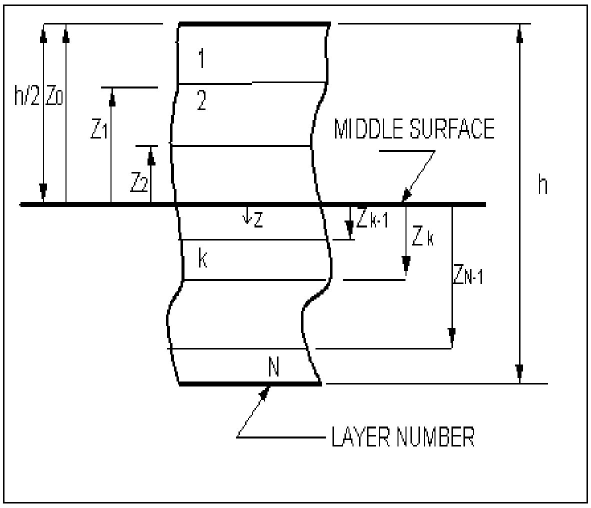

Fig. 1 Geometry of an N-Layered Laminate, [12].

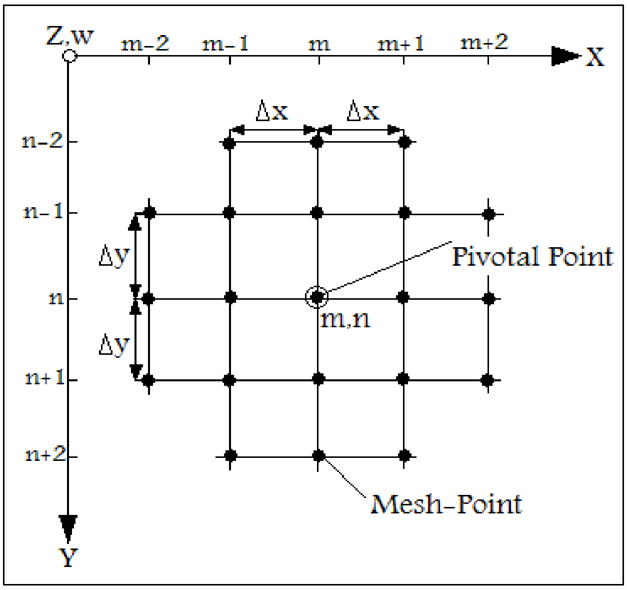

Fig. 2 Finite Difference Meshes Type, [13].

Table (1) Schematic Representation of Central Differences, [13].

$y_m^{(k)}$	Coefficient	First Error Term
y'_m	[-1 +1] $\frac{1}{2(\Delta x)}$	$-\frac{1}{6}(\Delta x)^2 y'''_m$
y''_m	[+1 -2 +1] $\frac{1}{(\Delta x)^2}$	$-\frac{1}{12}(\Delta x)^2 y^{IV}_m$
y'''_m	[-1 +2 -2 +1] $\frac{1}{2(\Delta x)^3}$	$-\frac{1}{4}(\Delta x)^2 y^{V}_m$
y^{IV}_m	[+1 -4 +6 -4 +1] $\frac{1}{(\Delta x)^4}$	$-\frac{1}{6}(\Delta x)^2 y^{VI}_m$
Point	m-2 m-1 m m+1m+2	ϵ_1

The square plate with mesh points for simply supported boundary conditions can be shown in Fig. 3:

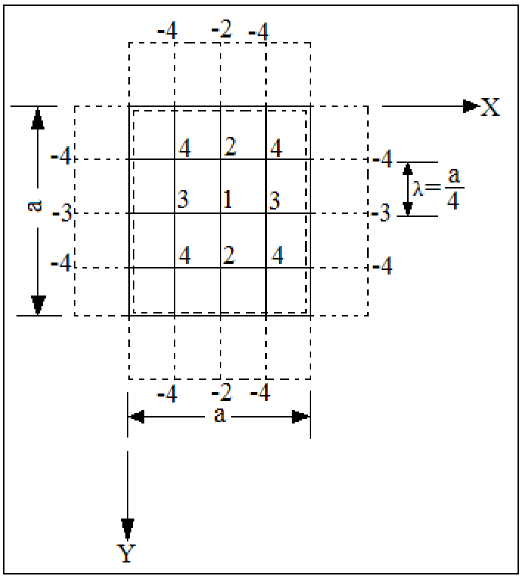

Fig. 3 Numbering of Mesh-Points For Simply Supported Square Plate (a*a).

By applying eq. (7) on points (1, 2, 3, 4) in Fig. 3 it can be obtained:

For point (1):

$$D_x * (6 * w_1 - 8 * w_3) + 2 * H_1 * (4 * w_1 - 4 * w_3 - 4 * w_2 + 4 * w_4) + D_y * (6 * w_1 - 8 * w_2) = \frac{P_o * a^4}{256}$$

For point (2):

$$D_x * (6 * w_2 - 8 * w_4) + 2 * H_1 * (4 * w_2 - 4 * w_4 - 2 * w_1 + 2 * w_3) + D_y * (6 * w_2 - 4 * w_1) = \frac{P_o * a^4}{256}$$

For point (3):

$$D_x * (6 * w_3 - 4 * w_1) + 2 * H_1 * (4 * w_3 - 2 * w_1 - 4 * w_4 + 2 * w_2) + D_y * (6 * w_3 - 8 * w_4) = \frac{P_o * a^4}{256}$$

For point (4):

$$D_x * (6 * w_4 - 4 * w_2) + 2 * H_1 * (4 * w_4 - 2 * w_2 - 2 * w_3 + w_1) + \frac{H_2}{2} * (2 * w_3 - 2 * w_1) + \frac{H_3}{2} * (2 * w_2 - 2 * w_1) + D_y * (6 * w_4 - 4 * w_3) = \frac{P_o * a^4}{256}$$

Genetic Algorithmsin Composite Laminates Optimization

Real composite material structures optimization problems depends on a reliable structural analysis. Even for simple geometric configurations, the determination of the mechanical behavior is difficult in the case of composite materials. It happens because of the complex mechanisms like coupling between extension, bending and torsion deformations, depending on the stacking sequence. The available closed mathematical formulations introduce much simplification on the analysis or, in many cases; they are not able to predict the structural behavior, mainly for complex geometries. These make necessary to use numerical methods that can predict satisfactorily the structure response for a given design load [14].

GAs is probabilistic optimization methods that seek to mimic the biological reproduction and natural selection process through random, but structured, operations. The design variables are coded as genes and grouped together on chromosomes strings that represent an organism (possible solution on the design space), what allow GAs to manipulate discrete variables. Instead of working with just one search point in the design space, GA uses a population of designs that, by reproduction operations, evolve through successive generations. Many search points dispersed in the design space prevent the GA to get stuck in a local optimum area, and avoiding a premature convergence of the process. New possible designs (organisms) are generated by applying genetic operators on existing population organisms (mimicking the natural genetic mechanisms). The evolution of successive generations towards the optimization objectives is achieved by using concept of survival of the fittest (where fittest organisms have more chances to reproduce and continue in the next generation) what mimic the natural selection process. The organism fitness is obtained directly from an objective function that uses simple structure information. No gradient evaluation is necessary to perform the search by GA [14]. Basic Genetic Algorithm may be decomposed into the following steps:

– Create a starting population. Usually a set of random chromosomes are created.

– Repeat the following until some termination criterion is met:

• Evaluate each chromosome using a fitness function.

• Select pairs of chromosomes using some scheme such as random selection or fitness-biasedmethods.

• Apply crossover on the pairs of chromosomes selected and mutation on individuals.

• Create a new population by replacing a portion of the original population with the chromosomes‘produced’ in the previous step, [15].

In this work a computer code written in MATLAB following the basic genetic algorithm operators (crossover) in real coded. Table (2) shows the values of some parameters need to be use in GA operators. It can be convert the calculation of deflection and stress for finite difference equation to the objective function in stacking sequence and it can be found the maximum and minimum values with aiding of genetic algorithms program. In the genetic algorithm program it be taken to the program the upper and lower limits of stacking sequence orientation between (-90 and 90) and the program merged the sequence randomly and obtained the suitable stacking sequence that gives a minimum deflection and a minimum stress

Table (2) Parameters used in different GA operators

parameter	value
Population size	100
Number of Elitism	2
Crossover probability P_c	0.95
Mutation probability P_m	0.05

NumericalResults

It can be taken the best iteration ofstacking sequence distributions from the genetic algorithms program of the design variables in the objective functions of the stacking sequence.For comparison a static analysis was carried out with ANSYS Program software. The linear elastic general orthotropic model is used to investigate the maximum deflection and maximum stressof central point of the plate. For this problem, the (SHELL 99) element is used. This element is used for the two-dimensional modeling of shell structure and is defined by eight nodes having six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes.

Results

It can be applied the finite difference equations and compared with ANSYS software to the plate made from carbon fiber and epoxy matrix (high modulus) for volume fraction($\upsilon_f = 0.6$) and having the following specifications:

$P_o = 1000\ \frac{N}{m^2}, a = 0.4\ m, h = 0.004\ m, E_1 = 100\ E9\ Pa., E_2 = E_3, G_{12} = G_{13} = 0.5 * E_2, \nu_{12} = \nu_{13} = 0.25$, [16], $G_{23} = \frac{G_m}{(1-\upsilon_f)*(1-\frac{G_m}{G_{f23}})}$, $\nu_{23} = \upsilon_f * \nu_{f23} + \upsilon_m * \left(2 * \nu_m - \nu_{12} * \frac{E_2}{E_1}\right)$, [17];but showed a good agreement. If a body has one plane of material properties isotropy, i.e. a plane in which the properties are the same in all directions at a point, then the material is said to be transversely isotropic. The other mechanical properties against stiffness ratio can be shown in Table 3.

Table 3 Mechanical Properties Against Stiffness Ratio.

E_1/E_2	G_{12} (GPa.)	G_{13}(GPa.)	G_{23}(GPa.)	ν_{12}	ν_{13}	ν_{23}
5	10	10	4.092	0.25	0.25	0.458
10	5	5	4.092	0.25	0.25	0.468
20	2.5	2.5	4.092	0.25	0.25	0.473
30	1.667	1.667	4.092	0.25	0.25	0.474
50	1	1	4.092	0.25	0.25	0.477

(1) The effect of number of layers:

The number of layer (5, 10, 20, 30, 50) does not affect much more on the value of central normal deflection and central stress in (x, and y) directions with keeping thickness constant. In this problem it can be taken five symmetric layers about z-axis.

(2) The effect of stiffness ratio (E_1/E_2):

Table 4 Verification Test of Deflection Variation with Stiffness Ratio (E_1/E_2).

E_1/E_2	Deflection (m)		
	F.D.M	ANSYS	Error (%)
5	4.516 E-4	4.593 E-4	1.676 %
10	5.712 E-4	5.8 E-4	1.517 %
20	6.577 E-4	6.68 E-4	1.542 %
30	6.926 E-4	7.042 E-4	1.647 %
50	7.232 E-4	7.376 E-4	1.952 %

Note: error = (ANSYS Values – F.D.M Value) / ANSYS Values.

Table 4 shows the variation of deflection vs. stiffness ratio with the aiding of finite difference method and ANSYS software before using genetic algorithms. The central deflection increases with the increasing of stiffness ratio because the stiffness of this material will be decreased. Results show a good agreement between the present F.D.M and ANSYS.

E_1/E_2	Normal Stress (σ_{xx})			Normal Stress (σ_{yy})		
	F.D.M	ANSYS	Error (%)	F.D.M	ANSYS	Error (%)
5	1.22 E6	1.31 E6	6.87 %	5.14 E6	5.79 E6	11.22 %
10	7.65 E5	8.22 E5	6.93 %	6.27 E6	7.17 E6	12.55 %
20	4.36 E5	4.7 E5	7.23 %	7.07 E6	8.16 E6	13.35 %
30	3.05 E5	3.29 E5	7.294 %	7.39 E6	8.55 E6	13.56 %
50	1.91 E5	2.06 E5	7.281 %	7.66E6	8.9 E6	13.93 %

Table 5 Verification Test of Stress in (x, and y) Directions Varies with Stiffness Ratio (E_1/E_2).

Table 5 shows the variation of stress in (x, and y) directions vs. stiffness ratio with the aiding of finite difference method and ANSYS software before using genetic algorithms. The stress in the x-direction decrease; but in the y-direction the stress increase with the increasing of stiffness ratio until reached the steady state value because at plate middle point the moment value in the x-direction has been decreased adversely to the moment value in the y-direction. The error of normal stress is very high when compared with the error of deflection because the stress depends upon the derivation of the deflection in numerical solutions. In the design it can be taken the stress in y-direction because it has a high value of stress. Also results show acceptable agreement between the FDM and ANSYS.

Table 6 Deflection, Stress in (x, and y) Directions, and Stacking Sequence Varies with Stiffness Ratio (E_1/E_2) Using Deflectionin a Fitness Function with theGenetic Algorithms Optimization.

E_1/E_2	Deflection (m)	Stress (σ_{xx}) Pa.	Stress (σ_{yy}) Pa.	Stacking Sequence (Degree)
5	2.8457 E-4	4.2238 E6	4.1643 E6	-45.96,-45.14,-45.73
10	2.8461 E-4	4.2643 E6	4.1251 E6	-49.62,-45.19,-45.13
20	2.8459 E-4	4.1407 E6	4.2481 E 6	-44.94,-44.13,-45.48
30	2.8458 E-4	4.174 E6	4.2143 E6	-48.99,-45.05,-44.76
40	2.846 E-4	4.1699 E6	4.219 E6	-41.57,-45.81,-44.92
50	2.8454 E-4	4.1862 E6	4.2011 E6	-44.41,-45.41,-44.72

Table 6 shows the deflection, stress in (x, and y) directions and stacking sequence varies with stiffness ratio using deflection genetic algorithms optimization. The deflection in Table 6 has been decreased when it was compared with the deflection in Table 4 for a suitable stacking sequence orientation distribution. It can be noticed that the value of deflection and stress in (x, and y) directions remain constant with the increasing of stiffness ratio when using deflection genetic algorithms optimization because the distribution of stacking sequence orientation approximately still constant for each value of stiffness ratio. Results show the maximum reduction in central deflection when using genetic algorithm was (60.65%) in

$\frac{E_1}{E_2} = 50$ and minimum reduction was (36.98%)with $\frac{E_1}{E_2} = 5$. The optimum stacking sequence orientation is (-44.41,-45.41,-44.72) for $\frac{E_1}{E_2} = 50$ and that gives a maximum reduction in central deflection.

Table 7 Deflection, Stress in (x, and y) Directions, and Stacking Sequence Varies with Stiffness Ratio (E_1/E_2) Using Deflection and Stress (σ_{xx}) in a Fitness Function with the Genetic Algorithms Optimization.

E_1/E_2	Deflection (m)	Stress (σ_{xx}) Pa.	Stress (σ_{yy}) Pa.	Stacking Sequence (Degree)
5	3.6938 E-4	2.2793 E6	8.6035 E6	-36.91,-47.48,-80.08
10	3.939 E-4	2.1659 E6	9.4 E6	-47.25,-46.98,-87.49
20	3.9917 E-4	2.1642 E6	9.5375 E6	-46.57,-49.05,-89.26
30	4.0055 E-4	2.1671 E6	9.5711 E6	-50.52,-48.79,-89.6
40	4.4868 E-4	2.3427 E6	1.0705 E7	-51.45,-51.6,-89.99
50	4.5278 E-4	2.3745 E6	1.0805 E7	77.59,80.18,89.23

Table 7 shows the deflection, stress in (x, and y) directions, and stacking sequence varies with stiffness ratio using deflection-stress (σ_{xx}) genetic algorithms optimization. Both deflection and stress in y-direction increase gradually with the increasing of stiffness ratio until reached the steady state value when using the deflection-stress (σ_{xx}) genetic algorithms optimization because stacking sequence has been changed for each value of stiffness ratio; but the stress in x-direction remain constant because the moment in x-direction at middle point approximately still constant and that is mean the change in the stacking sequence distributions for each value of stiffness ratio does not affect on the value of stress in x-direction. Results show the maximum reduction in central deflection when using genetic algorithm was (37.39%) in $\frac{E_1}{E_2} = 50$ and minimum reduction was (18.206%) with $\frac{E_1}{E_2} = 5$. The optimum stacking sequence orientation is (77.59, 80.18, 89.23) for $\frac{E_1}{E_2} = 50$ and that gives a maximum reduction in central deflection.

Table 8 Deflection, Stress in (x, and y) Directions, and Stacking Sequence Varies with Stiffness Ratio (E_1/E_2) Using Deflection and Stress (σ_{yy}) in a Fitness Function with the Genetic Algorithms Optimization.				
E_1/E_2	Deflection (m)	Stress (σ_{xx}) Pa.	Stress (σ_{yy}) Pa.	Stacking Sequence (Degree)
5	3.6269 E-4	8.3646 E6	2.3258 E6	-46.8,-44.23,-12.63
10	3.9126 E-4	9.3236 E6	2.1716 E6	-46.31,-42.62,-4.02
20	3.966 E-4	9.4725 E6	2.1635 E6	-43.37,-43.82,-1.65
30	3.9767 E-4	9.4995 E6	2.1633 E6	-42.71,-43.35,-1.12
40	3.9804 E-4	9.5077 E6	2.1646 E6	-46.32,-44.18,-0.9
50	3.9867 E-4	9.5231 E6	2.1646 E6	-38.61,-43.54,-0.6

Table 8 shows the deflection, stress in (x, and y) directions, and stacking sequence varies with stiffness ratio using deflection-stress (σ_{yy}) genetic algorithms optimization. Both stresses in (x, and y) directions increase gradually with the increasing of stiffness ratio until reached the steady state value when using the deflection-stress (σ_{yy}) genetic algorithms optimization because stacking sequence has been changed for each value of stiffness ratio; but the deflection remains constant for each value of stiffness ratio. Results show the maximum reduction in central deflection when using genetic algorithm was (44.87%) in $\frac{E_1}{E_2} = 50$ and minimum reduction was (19.68%) with $\frac{E_1}{E_2} = 5$. The optimum stacking sequence orientation is (-38.61, -43.54, -0.6) for $\frac{E_1}{E_2} = 50$ and that gives a maximum reduction in central deflection.

Table 9 Deflection, Stress in (x, and y) Directions, and Stacking Sequence Varies with Stiffness Ratio (E_1/E_2) Using Deflection-Stress (σ_{xx})-Stress (σ_{yy}) Genetic Algorithms Optimization.				
E_1/E_2	Deflection (m)	Stress (σ_{xx}) Pa.	Stress (σ_{yy}) Pa.	Stacking Sequence (Degree)
5	2.8463 E-4	4.1285 E6	4.2613 E6	-45.3,-45.082,-46.69
10	2.8465 E-4	4.099 E6	4.2916 E9	-47.223,-45.87,-46.06
20	4.3417 E-4	2.2651 E6	1.0325 E7	52.46,60.86,-90
30	4.5147 E-4	2.3642 E6	1.078E7	-79.87,82.98,88.51
40	4.5218 E-4	2.367 E6	1.0785 E7	-86.61,81.34,87.93
50	4.5356 E-4	2.3825 E6	1.08 E7	-90,82.43,86.95

Table 9 shows the deflection, stress in (x, and y) directions, and stacking sequence varies with stiffness ratio using deflection-stress (σ_{xx})-stress (σ_{yy}) genetic algorithms optimization. Both deflection and stress in y-direction increase gradually with the increasing of stiffness ratio until reached the steady state value when using the deflection-stress (σ_{xx})-stress (σ_{yy}) genetic algorithms optimization because stacking sequence has been changed for each value of stiffness ratio; but the stress in x-direction decrease because the moment in x-direction at middle point approximately decrease. Results show the maximum reduction in central deflection when using genetic algorithm was (37.28%) in $\frac{E_1}{E_2} = 50$ and minimum was (36.97%) with $\frac{E_1}{E_2} = 5$.The optimum stacking sequence orientation is (-90, 82.43, 86.95) for $\frac{E_1}{E_2} = 50$ and that gives a maximum reduction in central deflection.

Conclusions

1- The central normal deflection increases with the increasing of stiffness ratio for keeping the high modulus as constant.
2- The reduction percentages in central normal deflection due to using a genetic algorithms program are (60.655%, 37.392%, 44.874%, 37.284%) for deflection, deflection-stress (σ_{xx}), deflection-stress (σ_{yy}), and deflection-stress (σ_{xx})-stress (σ_{yy}) genetic algorithms optimization respectively of a suitable stacking sequence.
3- The reduction percentages in central stress in y-direction due to using a genetic algorithms program are (45.155%, 71.741%) for deflection, and deflection-stress (σ_{yy}) genetic algorithms optimization respectively of a suitable stacking sequence.

The best optimization are the deflection and deflection-stress (σ_{yy}) genetic algorithms optimization because they give a good reduction in a central normal deflection and central stress in y-direction.

References

1- Lino A. Costa, Pedro Oliveira, Isabel N. Figueiredo, Lu?s F. Roseiro , and Rogério P. Leal, " Structural Optimization of Laminated Plates with Genetic Algorithms", 2000.
2- M. Walker, and R. E. Smith, " A technique for the multiobjective optimization of laminated composite structures using genetic algorithms and finite element analysis", Journal of Composite Structures, Vol. 62, Issue 1, October, 2003, p.p. 123-128.
3- A. Abedian, M. H. Ghiasi, and B. Dehghan-Manshadi," Effect of a linear-exponential penalty function on the GA'S efficiency in optimization of a laminated composite panel", International Journal of Computational Intelligence 2; 1, www.waset.org, 2006.
4- J. H. Park, J. H. Hwang, C. S. Lee, and W. Hwang, " Stacking sequence design of composite laminates for maximum strength using genetic algorithms", Journal of Composite Structures, Vol. 52, Issue 2, May, 2001, p.p. 217-231.
5- Petri Kere, and JuhaniKoski, " Multicriterion stacking sequence optimization scheme for composite laminates subjected to multiple loading conditions", Journal of Composite Structures, Vol. 54, Issues 2-3, November-December, 2001, p.p. 225-229.
6- S. Nagendra, D. Jestin, Z. Gürdal, R. T. Haftka, and L. T. Watson, " Improved genetic algorithm for the design of stiffened composite panels", Journal of Computers & Structures, Vol. 58, Issue 3, p.p. 543-555, 3 February, 1996.
7- Santiago Muelas, José M. Pe?a, V?ctor Robles, KseniaMuzhetskaya, Antonio LaTorre, and Pedro de Miguel, " Optimizing the design of composite panels using an improved genetic algorithms", Journal of International Conference on Engineering Optimization, Rio de Janeiro, Barazil, 1-5 June, 2008.
8- SIVAKUMAR K., IYENGAR N. G. R., and DEB K., " Optimum design of laminated composite rectangular plates with cutouts using genetic algorithm", Indian Journal of engineering &materials sciences, Vol. 4, No. 5, 1997,p.p. 189-195.
9- C W Kim, and J S Lee, " Optimal design of laminated composite plates for maximum buckling load using genetic algorithm", Journal of Mechanical Engineering Science,Vol.219, No. 9, 2005, p.p. 869-878.

10-Rodolphe Le Riche and Raphael T. Haftka, " Optimization of

laminate stacking sequence for buckling load maximization by genetic algorithm", Journal of AIAA, Vol. 31, No. 5, May, 1993.

11-Nozomu Kogiso, Layne T. Watson, ZaferGürdal, and Rophnel T.

Haftka, " Genetic algorithm with local improvement for composite

laminate design", Department of Computer Science Virginia

Polytechnic Institute and State University, 28 May, 1993.

12- J.N. Reddy," Mechanics of Laminated Composite Plates and Shells",

Book with Second Edition, 2004.

13-Dr. Rudolph Szilard, " Theory and Analysis of Plates: classical and

numerical methods", Civil Engineering and engineering mechanics

series, University of Hawaii, 1974.

14- Felipe Schaedler de Almeidaa, Armando Miguel Awrucha, "Optimizationof Composite Platesand Shells Using AGenetic Algorithmandthe FiniteElement Method",Ogeâpkec"Eqorwvcekqpcn"Xqn"ZZXK. ", p.p. 372-385, 2007.

15- KristianGuillaumier,"Generic Chromosome Representation and Evaluation for Genetic Algorithms", Department of Computer Science and AI, University of Malta, p.p. 64-67, October, 2002.

16- M. Naghipour, H.M. Daniali and S.H.A. HashemiKachapi, "Numerical Simulation of Composite Plate to be Used for Optimization of Mobile Bridge Deck", Journal of World Applied Sciences Vol. 4, No. 5, 2008, p.p. 681-690.

17- John W.Weeton, Dean M.Peters, and KarynL.Thomas, "Engineers' Guide to Composite Materials", American Society for Metals, Composite Handbook, 1987.

أمثلية السلاسل المتراكمة المعتمدة على التشوه والاجهاد باستخدام الخوارزميات الوراثية مع تحليل الفروق المحددة لصفيحة رقائقية مربعة مدعومة دعم بسيط تحت تاثير حمل موزع منتظم

ا.م.د. نبيل حسن هادي
قسم الهندسة الميكانيكية
كلية الهندسة
جامعة بغداد

د. لؤي صباح يوسف
قسم الهندسة الميكانيكية
كلية الهندسة
جامعة بغداد

الخلاصة:

في هذا البحث، ان تحقيق الامثلية مع زيادة صلابة الصفيحة المربعة، حيث ان المحاكاة العددية للصفيحة الرقائقية المركبة باستخدام الخوارزميات الوراثية مع تحليلات الفروقات المحددة، والمطبقة على متغيرات التصميم للدالات الموضوعية على زاوية دوران الطبقات المدروسة. الصفيحة تم تقييمها بالاسلوب الفعلي للمشكلة مثل الحمل الموزع، تحت شرط حد التدعيم البسيط مع اختلاف عدد الطبقات (٥، ١٠، ٢٠، ٣٠، ٥٠) واختلاف نسب الصلابة (٥، ١٠، ٢٠، ٥٠، ٣٠). ان تاثير زاوية دوران الفايبر، عدد الطبقات، ونسب الصلابة على التشوه واستجابة الاجهاد للصفيحة الرقائقية المركبة الكلاسيكية المتناظرة الخاضعة لحمل الضغط المنتظم (حمل الانحناء). ان التشوه والاجهاد الكبيرين هما احدى العناصر الرئيسية التي تؤخذ بنظر الاعتبار عند تصميم الصفيحة. وبعد ذلك يتم الحصول على امثل وانسب زوايا دوران للصفيحة المركبة والتي تعطي اقل اكبر تشوه واقل اكبر اجهاد لنقطة المنتصف للصفيحة والتي تمثل الهدف الرئيسي لهذا العمل. النتائج تم مقارنتها مع نتائج برنامج الانسيز وتم الحصول على تقارب جيد.