GENETIC ALGORITHM BASED OPTIMIZATION OF COMPOSITE LAMINA

Avaya Kumar Baliarsingh Asst. Professor,
Biswajit Nayak Professor,
Biswajit Mallick Student
Department of Mechanical Engineering Einstein Academy of Technology and Management
Bhubaneswar, Khurdha Odisha, India

Abstract **:** Composite materials are realized by combining at least two organic or inorganic materials. Composites are highly used on industrial design. The light weight makes them key elements to reduce weight and reduces operating costs in some domains like aeronautics. Genetic algorithms(GA) are heuristic stochastic methods that explore a reduced set of tentative solutions, performing a guided search procedure that evaluates few solutions. The dynamics in GA provide optimal solutions to complex optimization problems when an analytical technique does not work. In this paper, results of optimization of a stiffened composite panel subject to a set of shear and axial loads. The modified GA is proposed to simultaneously minimize the cost and weight of a composite plate under different combinations of axial loading. Two materials with one significantly stronger, but more expensive than the other are used. The optimization techniques is implemented by using convex combinations of cost and weight objective functions into a single value for laminate fitness. To obtain optimal set of designs, the influence of cost and weight on the overall fitness of a laminate configuration was adjusted from one extreme to the other by adjusting the scale factors accordingly. The performance of the proposed configurations are evaluated via nonlinear finite element simulation. The goal is to find the optimal configuration that keeps the principal strains under a given threshold. The proposed method significantly reduce both the weight and iterations required for the optimization.

Index Terms— Composite lamina, GA, Ansys Parametric Design Language, Composite box wing

1.INTRODUCTION

Composites are highly-used on several industrial domains like spacecraft, civil or aircraft design. Their popularity is due to their excellent mechanical properties as well as their available freedom to tailor material properties. Most practical laminate designs require combinatorial optimizations because the ply orientations are usually restricted to small set of discrete values. In spite of this discretization, composite optimizations often have multiple solutions with similar performance. This kind of problems are one of the most complex and expensive to solve. Moreover, its large number of design variables contributes to having multiple local optima. This optimization process is also hardened with the addition of several structural constraints. In order to check some of these constraints (i.e. maximum strain values), a finite element simulation is usually executed. This simulation is highly time-consuming and therefore its number of executions should be reduced to a minimum.

During the last years, Genetic Algorithms (GAs) have been used for a variety of optimization problems. One of their main advantages is the capability to treat multimodal functions, finding its multiple optima and giving the possibility chooses one solution (design) or another. Also, GAs does not use any gradient information during the searching process, in contrast to numerical optimization procedures. Hence, GAs are a compromise between expensive brute force search strategies and numerical approaches**.**

2. GENETIC ALGORITHMS

The idea of a genetic algorithm was thought to have been conceived by John Holland at the University of Michigan in the 1970s. Holland was interested in applying the laws of natural selection towards the development of artificial systems rather than systems that are based on some reasoning process. These artificial systems could be constructed using computer software and applied to various disciplines which emphasize design, optimization and machine learning. Gas represent potential solutions for the problem as chromosomes. Chromosomes can be sequences of bits (bit streams), of other types of data (e.g. real numbers) or even more complex structures (sometimes referred as Genetic Programming or GP). Each chromosome encodes one individual. The set of chromosomes (individuals) under evaluation by the

algorithm is called population. A GA performs a heuristic search over the vast solution space of possible chromosomes to find the most appropriate individual.

A GA starts from an initial population of chromosomes and evolves it in an iterative procedure with the following steps: (i) computing the quality (fitness function) of the individuals in the present population, (ii) selecting the best individuals from this population, (iii) mating pairs of individuals to generate new ones, (iv) performing random mutations (changes) on some of the new individuals, and finally (v) all the new individual and the individuals from the previous generation (iteration) conform the population for the next generation, selecting them based on fitness or similar criteria.

2.1 Basic structure of genetic algorithms

GAs are probabilistic algorithms that utilize the processes of natural selection by mimicking the concept of survival of the test. The main element of a GA is the organism which usually consists of a fixed number of chromosomes.

In turn, each chromosome may consist of one or many genes. Typically, each gene of a chromosome is coded using a binary alphabet, showing whether a gene is active (represented by a 1) or inactive (represented by a 0). Other representation has used general alphabets with many more elements or multiple gene alphabets for different types of genes. The complexity of an organism can be controlled by the length and number of chromosome and gene strings, and the size and number of gene alphabets. A genetic algorithm is usually made up of a group of organisms commonly referred to as a sub-population or population of organisms. If more than one group of organisms exist, then each group is called a sub-population. A group of sub-populations is called a population. Such terminology is often used when discussing parallel genetic algorithms. A parallel GA invokes several sub-another to improve the performance
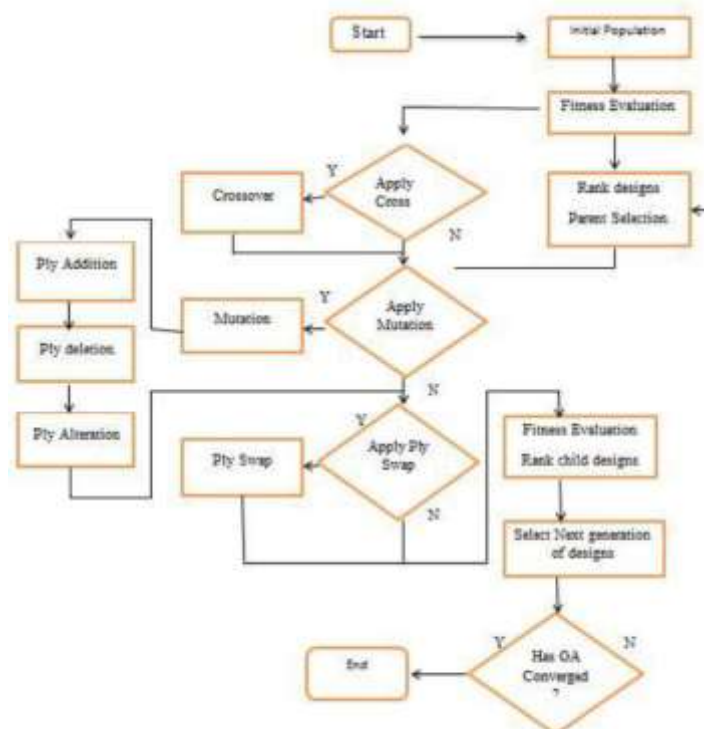

Fig. 1 Structure of Genetic Algorithm

3.APPLICATIONS OF GENETIC ALGORITHM IN AEROSPACE

Genetic algorithm are used in the following fields

☐ Airfoil pressures ☐

- ▢ Genetic Algorithms in Aerodynamics ▢
- ▢ Genetic Algorithms in Multidisciplinary
  - ▢ Design
- ▢ Optimization ▢
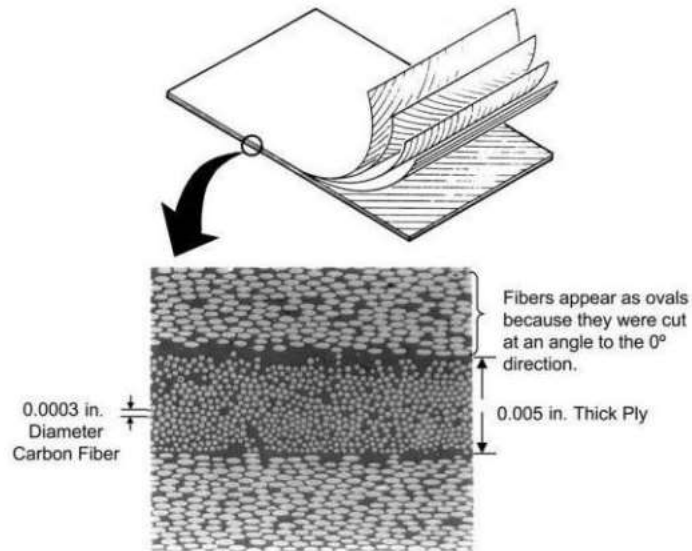 - ▢ Genetic Algorithms in Propulsion ▢
  - ▢ Genetic Algorithms in Structures ▢

Fig. 1.2 Cross section of a cross-plied carbon/epoxy laminate

4 IMPLEMENTATION OF GENETIC ALGORITHM TO COMPOSITE LAMINATE STRCTURES

Procedure of GA algorithm

i) Algorithm need following inputs were taken for

a) No of layer

b) No of Materials

c) No of thickness

d) No of Layer Orientation

e) Enter the material properties

After crossover

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For example two materials (M1,M2), two thickness(5mm,10mm) and two angles (0,45)

crossover operation

The best sequence1 (parent 1)

Total no layer = 5

Position 1 2 3 4 5

Material = M1 M2 M1 M2 M1

Sequence

[Young's modulus poisons ratio, shear modulus, density]

Thickness = 5 5 10 10 5

ii) Enter the Thickness in mm

Sequence

iii) Enter the Layer Angle

Angle = 45 0 0 0 45

a) Reproduction (iteration 1)

Sequence

In this process laminate design variables are randomly generated and results were stored for different combinations.   The best sequence 2 (parent 2)

Total no layer = 5

b) Crossover (iteration 2)

The best sequence from previous iteration was selected based on high fitness

Fitness[i] =1-stress[i]/stress [max]

or

Fitness[i] =1-volume[i]/volume [max]

In this iteration, laminate sequence were randomly changed from one sequence (parent1) to another sequence (parent2) for producing new sequences (child1 and child2).This concept is applicable for material, angle and thickness sequences.

Sequence1 Sequence2

Before crossover

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Position 1 2 3 4 5

Material = M2 M2 M1 M1 M1

Sequence

Thickness = 5 5 10 5 5

Sequence

Angle = 45 0 45 0 0

Sequence

After cross over (child 1)

Total no layer = 5

Position 1 2 3 4 5

Material = M1 M2 M1 M1 M1
Sequence

Thickness = 5 5 10 5 5

Sequence

Angle = 45 0 0 0 0

Sequence

After cross over (child 2)

Total no layer = 5

Position 1 2 3 4 5

Material = M2 M2 M1 M2 M1

Sequence

Thickness = 5 10 10 10 5

Sequence

Angle = 45 0 45 0 45

Sequence

The above process is called single point crossover with right side shifting

Crossover operations are classified into

1. Single crossover with right shifting

2. Single crossover with left shifting

3. Single crossover with left to right cross shifting

4. Single crossover with right to left cross shifting

The best results from above four operations were stored.

c) Mutation (iteration 3)

   The best sequence from previous iteration was selected based on high fitness. In this process variables are randomly exchange in between the single sequence itself. It is shown in below.

Sequence1

Before Mutation After Mutation

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The above process is repeated for all best sequences and result was stored.

d) Addition (iteration 4)

The best sequence from previous iteration was selected based on high fitness. In this process variables are added randomly in the best sequence .It is shown below

Sequence1

Before Addition After Addition

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The above process is repeated for all best sequences and result was stored.

e) Deletion(iteration 5)

The best sequence from previous iteration was selected based on high fitness. In this process variables are deleted randomly in the best sequence. It is shown in below

Sequence1

Before Deletion After Deletion

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The above process is repeated for all best sequences and result was stored.

f) Alteration (iteration 6)

The best sequence from previous iteration was selected based on high fitness. In this process variables are altered randomly in the best sequence. It is shown in below

Sequence1

Before Alteration After Alteration

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The above process is repeated for all the high fitness sequences and result was stored. This is called generation. Finally the overall best result from above six operations was plotted and stored. The same process was repeated for 50 numbers of generations. .
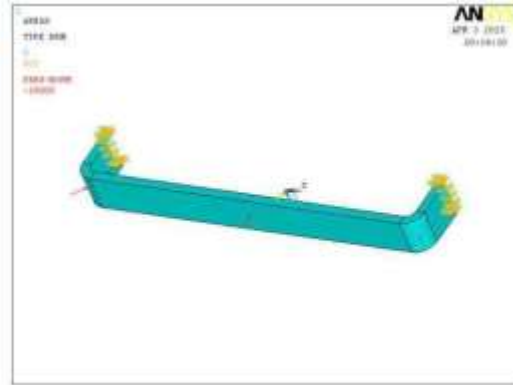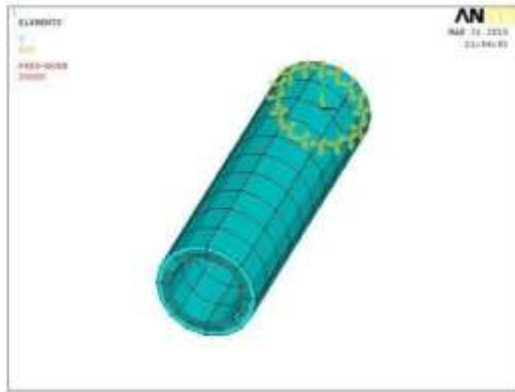
5 MESHED MODELS
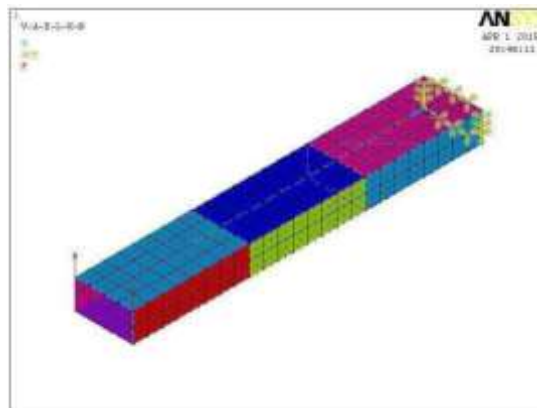

Fig.3 Meshed model of multi panel hollow cylinder

Fig. 5 Meshed model of multi panel wing box structure

6 RESULT & DISCUSSION

The APDL programme is written for the optimization of following components using composites. For the given load all the possible ply angle combinations are analyzed and the best combinations are selected after over 100 iterations. The result is explained below.
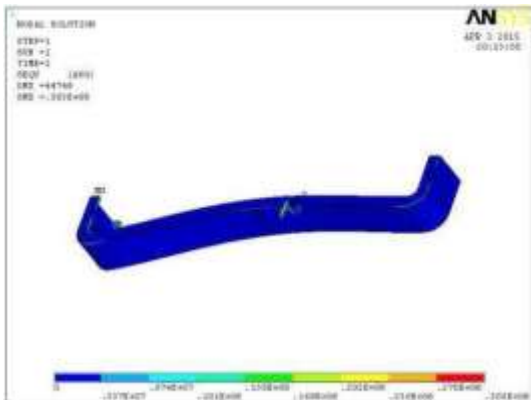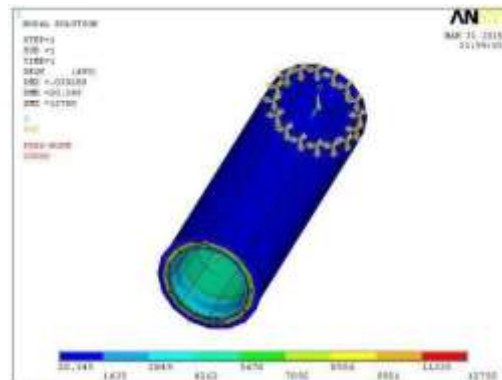

Fig. 4 Meshed model of multi panel bumper

Fig 6 Stress distribution over a hollow cylinder

Panel No.	No. of layer	Angle sequence (degree)	Material sequence	Thickness sequence	Volume (mm³)	Vonmises stress (N/mm²)
1	4	45 -45 45 90	2 1 2 1	10 5 5 10		
2	5	0 -45 45 0 -45	1 1 2 2 2	10 10 10 5 5		
3	3	45 0 45	2 1 2	5 10 5		
4	2	-45 0	1 2	10 5		
5	5	90 -45 0 45 -45	2 1	5 10		
6	4	90 45 0 -45	1 1 1 2	5 5 5 10	76547845.33	21809
7	3	90 -45 0	2 2 1	5 5 10		
8	3	-45 0 90	1 2 1	5 10 5		
9	4	0 45 0 90	1 2 1 2	10 10 5		
10	4	0 45 -45 45	2 2 2 1	10 10 10 5		

Table 1 Optimum stress of the fittest Box Wing laminas

7 CONCLUSION

This work presents the results obtained applying genetic algorithms to the configuration of composite material of panels design. The problem is defined by several manufacturing and design constraints (layer symmetry, maximum number of layers, fixed number of possible orientations and some parameters of certain structural components, such as horizontal and vertical frames). The performance and characteristics of the proposed configurations are evaluated via nonlinear finite element simulation. The algorithm is controlled by a programmable state machine which selects among two different representation schemes and two finite element simulation model (linear vs. nonlinear).

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