Self-adaptative genetic algorithm for minimum thickness design of composite laminate

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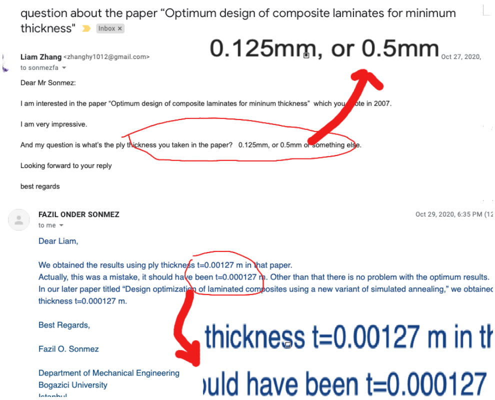
Content

1. Classic Lamination Theory
2. Self-adaptative Genetic Algorithm
3. Experiment and result

1. Inspiration

- Paper: "Optimum design of composite laminates for minimum thickness"(Computers and Structures)
- Design Variable: Fiber orientation angles: [-90, 90], and layer thickness
- Search Method: Simulated annealing algorithm
- Constraint: safety factor > 1

- the search process wasn't presented
- the convergence speed, and the search cost
- GA is a better alternative



question about the paper "Optimum design of composite laminates for minimum thickness" Inbox ×

0.125mm, or 0.5mm

Liam Zhang <zhanghy1012@gmail.com> Oct 27, 2020,
to sonmezfa

Dear Mr Sonmez:

I am interested in the paper "Optimum design of composite laminates for mininum thickness" which you wrote in 2007.

I am very impressive.

And my question is what's the ply thickness you taken in the paper? 0.125mm, or 0.5mm or something else.

Looking forward to your reply

best regards

FAZIL ONDER SONMEZ Oct 29, 2020, 6:35 PM (12
to me

Dear Liam,

We obtained the results using ply thickness t=0.00127 m in that paper.
Actually, this was a mistake, it should have been t=0.000127 m. Other than that there is no problem with the optimum results.
In our later paper titled "Design optimization of laminated composites using a new variant of simulated annealing," we obtained
thickness t=0.000127 m.

Best Regards,

Fazil O. Sonmez

Department of Mechanical Engineering
Bogazici University

thickness t=0.00127 m in th
uld have been t=0.000127

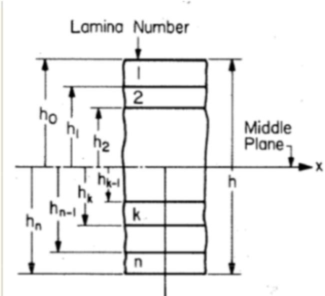
2. Methdology

- modifying selection strategy: in order to handle the constraint search
- Self-adaptative mutation direction of fiber orientation and laminate thickness: random change the length, and the angle in the laminate.
- the self-adaptative parameters don't refer to parent's proportion, mutation probability.

2. Classic Lamination Theory

θ
-θ
$\cdots$
θ
-θ

Figure 1: Model for Angle ply laminate



$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{11} & B_{12} & B_{16} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} k_x \\ k_y \\ k_{xy} \end{bmatrix}$$

$$\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ B_{12} & B_{22} & B_{26} \\ B_{16} & B_{26} & B_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + \begin{bmatrix} D_{11} & D_{12} & D_{16} \\ D_{11} & D_{12} & D_{16} \\ D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{bmatrix} k_x \\ k_y \\ k_{xy} \end{bmatrix}$$

2. Self-adaptative GA: selection operator

- acitve group: individual is used to increase the diversity of the population
- potential group: individual doesn't fulfill constraint
- proper group: individual meet constraint

2. Self-adaptative GA: mutation operator

$$\text{md} = [CT_1, \cdots, CT_{n-1}, CT_n] - [ICV_0, \cdots, ICV_{n-1}, ICV_n]$$

- md means mutation direction.
- CT_i denotes the i-th constraint, such as weight, safety factor.
- ICV_i denotes individual's i-th constraint value, such as, weight, safety factor of current individual.

2. Self-adaptative GA: mutation operator

- length mutation $=$

$$\begin{cases} LMC * [0, \sum_{i=1}^{N} md_i] & \text{if } \sum_{i=1}^{N} md_i > 0 \\ LMC * [\sum_{i=1}^{N} md_i, 0] & \text{if } \sum_{i=1}^{N} md_i < 0 \end{cases}$$

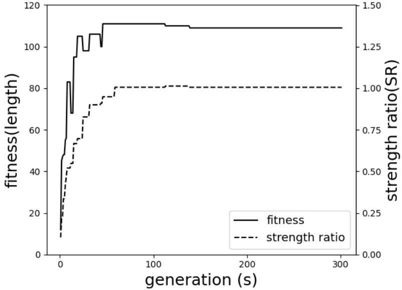
  LMC stands for length mutation coefficient, it's a positive integer.

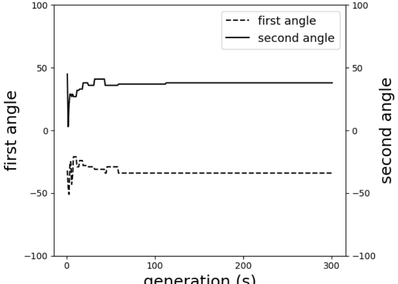
- angle mutation $=$

$$\begin{cases} AMC * [0, \sum_{i=1}^{N} md_i] & \text{if } \sum_{i=1}^{N} md_i > 0 \\ AMC * [\sum_{i=1}^{N} md_i, 0] & \text{if } \sum_{i=1}^{N} md_i < 0 \end{cases}$$

  AMC stands for angle mutation coefficient, it's sign is unclear.

Result: Loading $N_x = 10, N_y = 5$ MPa m





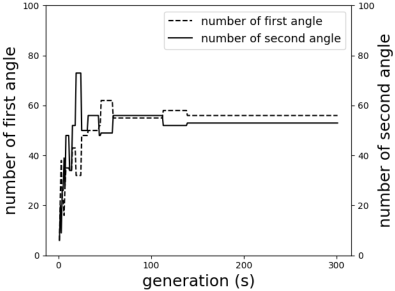


Figure 3: Two distinct angles in the laminate

Result: Loading $N_x = 10, N_y = 5$ MPa m

Table 1: Comparison with the results of DSA

Loading	Akbulut and Sonmez's[?] Study				Present Study			
$N_x/N_y/N_{xy}$ (MPa m)	Optimum lay-up sequences	laminate thickness	TW	MS	Optimum lay-up sequences	laminate thickness	TW	MS
10/5/0	$[37_{27}/\text{-}37_{27}]_s$	108	1.0068	1.0277	$[33_{29}/\text{-}39_{25}/\text{-}\bar{3}9]_s$	109	1.0074	1.0246
20/5/0	$[31_{23}/\text{-}31_{23}]_s$	92	1.0208	1.1985	$[33_{22}/\text{-}31_{24}]_s$	92	1.0055	1.2065
40/5/0	$[26_{20}/\text{-}26_{20}]_s$	80	1.0190	1.5381	$[29_{18}/\text{-}21_{23}/\text{-}\bar{2}1]_s$	83	1.0034	1.7350
80/5/0	$[21_{25}/\text{-}19_{28}]_s$	106	1.0113	1.2213	$[\text{-}20_{27}/21_{25}/\bar{2}5]_s$	105	1.0029	1.2063
120/5/0	$[17_{35}/\text{-}17_{35}]_s$	140	1.0030	1.0950	$[\text{-}18_{34}/17_{36}]_s$	140	1.0000	1.0898