



## A Survey of Optimization Techniques for Composite Wings for Light Aircraft

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### ABSTRACT

*In most aerospace flying conditions, a well-designed wing is essential for improved aircraft flight performance. Although much study has been done on light aircraft wing design for various mission profiles, and many useful tools for optimizing the wing have been established, there has been a growing interest in reducing weight and cost while increasing effectiveness in recent years. As a result of these needs, multi-objective aircraft wing optimization algorithms have been developed. The goal of this study is to provide a general overview of recent advances in multi-objective wing optimization algorithms and heuristic approaches for flight missions. The gradient-based approaches, genetic algorithm-based design methods, finite element methods, vortex lattice method, and structural static analysis method are discussed as useful optimization procedures for light aircraft wings. Furthermore, the wing optimization concept was discussed along with various optimization procedures. The major characteristics of various optimization strategies, such as their benefits and drawbacks, are summarized. Recent use of the optimized wing was given considerable attention. Finally, some conclusions have been reached, and future research into smart wing optimization strategies has been discussed.*

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### INTRODUCTION

Composite materials were first used in commercial aircraft radar domes in the 1940s. In terms of corrosion resistance and stiffness to weight ratio, composite materials consistently outperform isotropic materials. The National Aeronautics and Space Administration (NASA) manufactured a huge quantity of composites for research in 1975. Since then, the BOEING Company has made composites a priority in its products.[1].

Composites were used for the main and load-bearing structures. A composite device developed for stiffness has a better safety factor than its metallic counterpart. The good fatigue behavior of composites is due to this feature, which allows airlines to save money on maintenance. Another advantage is the ability to tailor composites to a specific purpose, this can be done by altering the fiber angle distribution or unifying the

shape, resulting in a reduction in the number of components.

In aircraft design research, weight reduction is among the top objectives. As a result, efforts are concentrated on improving the performance of various aircraft elements, particularly the wing. The appropriate structural design of an aircraft wing is crucial to the plane's performance, including achieving a high stiffness/weight ratio and absorbing unpredictable stresses like gusts and maneuvering circumstances. The traditional approach of structural optimization was to reduce structural mass by modifying member sizes or shell thickness while maintaining the geometry of a model. As a result, various studies on structural optimization have been conducted in recent years. [2] Proposed a closed-form analytical solution for minimal weight analysis and design. The configuration shape composed of Hex-cell and square-cell honeycomb core sandwich and

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panels made of composite material subjected to in-plane uniaxial compressive loads. The methods ensure minimal weight while also allowing for comparisons between different material systems and honeycomb sandwich construction with other panel architectures. A research which adopted the layup optimization of laminated plates under buckling load and discovered the minimum weight configuration of a laminated fiber-reinforced composite plate under in-plane and transverse loading was adopted [3]. Buckling load and transverse deflection are both limited and each ply's fiber orientation and thickness are treated as design variables. An unconstrained minimization methodology is used to carry out optimization studies. The optimum weight configuration results in a special thickness distribution of the plies with pre-assigned fiber orientation used in most research, and the stability constraint is active at low aspect ratios while the deflection constraint is active at high aspect ratios. [4] Presented a combined procedure for the aerodynamic and structural optimization of a high-speed civil transport wing. Primary goal of the procedure is the determination of the jig shape of the wing necessary so that it deforms into its optimum shape in cursive flight. The wing structure is sized subject to strength, buckling, and aero elastic constraints.

Various analyses have been performed with different material configurations and structural-concepts as discussed in section 2. A new technique for optimization problem of structures at various loading, upon application discovered the optimal piece-wise constant design of an elastic tube made out of a non-homogeneous anisotropic material [5]. A two-level optimization procedure for wing design subject to strength and buckling constraints and the design variables are found to be the orientation of ply and the number of plies of each orientation [6]. The genetic algorithms and response surface method were used to continue the optimization.

The aim of this review paper therefore, is to develop an optimization program by considering different criteria such as aerodynamic, performance and weight criteria for the preliminary design stages of aircraft design.

#### MAJOR OPTIMIZATION TECHNIQUES

There are various optimization methods used in the aerospace industry. The following sections provide an analysis of some of these various methods used to optimize composite wings in light aircraft as highlighted in

**Table 1.**

**Table 1:** Overview of various optimization techniques for composite wing for light aircraft.

Classification	Technique	Reference	Content	Advantages	Disadvantages
Heuristic	Finite Element	[7]	Modelling and Ply orientation	Ply orientation of [0/90/+45/-45/90/0] was achieved	The wing leading edge has lesser Von-mises stress and trailing decreases towards the wingtip.
Heuristic	Optimization Method by Vortex Lattice Method and Structural Static Analysis Method	[8]	The research covers both aerodynamic and structural design.	Composite mass saving of (32%) was achieved instead of isotropic material for the taper wing and (23%) for the	

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Classification	Technique	Reference	Content	Advantages	Disadvantages
				rectangle wing	
Optimization	Gradient base method	[9]	Wing stiffness optimization	Wing stiffness optimization	
		[10]	Classical lamination theory	Laminate stiffness, Stress Concentration and Structural integrity	
Optimization	3 D	[11]	Strength and stiffness to the weight of the materials	Achieving a very lightweight and rigid structure.	The thin profile of components made of CFRP can lead to structural instability/buckling
Optimization	Shape liked	[5]	Section property changes despite a discrete model, there is possibility of reducing weight with continuous thickness	The method saves design time, weight and cost	The model was design using aluminum material. Which has less strength compared to composite.
Algorithm	Genetic algorithm	[12]	The empirical formulas and genetic algorithm	It gave consistent results for wing weight estimation	It used a low order program.
Algorithm	Multi-Objective	[13]	Weight of multi-laminate	Weight saving of 54% was	Incorrect selection of weight vectors



Classification	Technique	Reference	Content	Advantages	Disadvantages
	Evolutionary Algorithm Optimization Based on Pareto Concept		aerospace structure by classical Genetic Algorithm	achieved in the laminate structure.	implies algorithm can bring down assembly weight but at the cost of violation of design limits.

### Gradient-Based Optimization

The problems encountered in structural design of aircraft wings involves achieving the lowest possible weight and highest possible stiffness, within constraints imposed by geometry and dimensions required for aerodynamic performance, maintenance access and tolerance fit for accessories. Other equally important considerations are cost and ease of manufacturing.

Optimization problems are mostly presented mathematically as a set of functions made up of the objective function and one or more constraint functions. Gradient Based Optimization Methods are applied if the objective and constraint functions are continuous and differentiable within the boundary of the design space

[9] Applied gradient based optimization in showing the effect of manufacturing constraints on the  $h_1 \Delta V_1^A + h_2 \Delta V_2^A + h_3 \Delta V_1^D + h_4 \Delta V_2^D + h_5 \leq 0$

$$h_1 = \det \begin{vmatrix} 1 & V_{21}^A & V_{11}^D & 1 & V_{22}^A & V_{12}^D & 1 & V_{23}^A & V_{13}^D & V_{21}^D & V_{22}^D & V_{23}^D & 1 & V_{24}^A & V_{14}^D & V_{24}^D & | \end{vmatrix} \quad (2)$$

$$h_2 = \det \begin{vmatrix} V_{11}^A & 1 & V_{11}^D & V_{12}^A & 1 & V_{12}^D & V_{13}^A & 1 & V_{13}^D & V_{21}^D & V_{22}^D & V_{23}^D & V_{14}^A & 1 & V_{14}^D & V_{24}^D & | \end{vmatrix} \quad (3)$$

$$h_3 = \det \begin{vmatrix} V_{11}^A & V_{21}^A & 1 & V_{12}^A & V_{22}^A & 1 & V_{13}^A & V_{23}^A & 1 & V_{21}^D & V_{22}^D & V_{23}^D & V_{14}^A & V_{24}^A & 1 & V_{24}^D & | \end{vmatrix} \quad (4)$$

$$h_4 = \det \begin{vmatrix} V_{11}^A & V_{21}^A & V_{21}^D & V_{12}^A & V_{22}^A & V_{22}^D & V_{13}^A & V_{23}^A & V_{23}^D & 1 & 1 & 1 & V_{14}^A & V_{24}^A & V_{24}^D & 1 & | \end{vmatrix} \quad (5)$$

$$h_5 = -\det \begin{vmatrix} V_{11}^A & V_{21}^A & V_{11}^D & V_{12}^A & V_{22}^A & V_{12}^D & V_{13}^A & V_{23}^A & V_{13}^D & V_{21}^D & V_{22}^D & V_{23}^D & V_{14}^A & V_{24}^A & V_{14}^D & V_{24}^D & | \end{vmatrix} \quad (6)$$

The manufacturing constraint equation was derived as

$$|\Delta V_{K(N) \rightarrow (N-X)}^A| \leq 2 \left( \frac{X}{N} \right) \quad (7)$$

$V^A$  is the A-Matrix of the composite ply layout normalized by the total thickness T. This is expressed as

structural design of composite wing panels for optimal stiffness. In this research work, laminate parameters were proposed and formulated using the Classical Lamination Theory (CLT) [10]. In deriving thickness in the longitudinal direction, two design rules were applied as constraints. These are limitation of taper slope, and ply continuity rule based on the premise that discontinuities in longitudinal ply arrangement and non-tapered variation of thickness will result in eccentricity of laminate stiffness, stress concentration and a compromised structural integrity. In addition, an approximation of Tsai-Wu failure criterion was applied as failure constraints. The linear constraint model applied was based on the equation representing the constraints for hyperplanes forming the convex hulls.

$$V_{[1,2,3,4]}^A = \frac{1}{T} \sum_{k=1}^N (Z_k - Z_{k-1}) [(2\theta_k), (4\theta_k), (2\theta_k), \sin(4\theta_k)] \quad (8)$$

$$V_{[1,2,3,4]}^D = \frac{1}{T^3} \sum_{k=1}^N (Z_k^3 - Z_{k-1}^3) [(2\theta_k), (4\theta_k), (2\theta_k), \sin(4\theta_k)] \quad (9)$$

X is the number of plies removed while N is the total number of plies.

The mathematical model above was tested with and without assembly constraints on a generic wing box, using VErSO (Virtual Environment for Structural Optimization). Optimization results presented as Span-wise distribution of panel thickness show that the panel thickness is more at the wing roots in the case where assembly constraints were applied than when it was not considered. However, towards the leading edge, the difference in thickness observed in the two scenarios is not significant. Although the paper concluded that the weight of the wing designed with assembly constraints has slightly higher mass, the impact of the constraint scenarios on stiffness and strength of the panel were not clearly discussed. Also, the impact of the limitations of Gradient Based Optimization method and the VErSO tool were not stated.

$$f_{fitness} = \frac{1}{C_l \times C_d} \quad (10)$$

Where  $C_l$  is coefficient of lift

$C_d$  is coefficient of drag

The general purpose of this optimization problem is to obtain a wing with minimum drag which will provide the required lift coefficient within

### Genetic Algorithm Based Design Optimization

Due to many parameters, having only fast design tools is not enough to make a successful and reliable design in a short time. Therefore, optimization programs are needed together with rapid analysis methods [12].

Method: low order analysis methods were used which is preferred in order to make the program foldable in terms of cost and time. Hence, an analysis program developed by Sivanandam & Deepa, (2008) using Vortex Ring Method (VRM) for aerodynamic analysis while general performance formulas were used for performance calculation and statistical weight estimation formulas for weight estimation.

Result: The results obtained from the aerodynamic analysis of individuals produced by genetic algorithm are evaluated by the equation for the fitness value, which is given by:

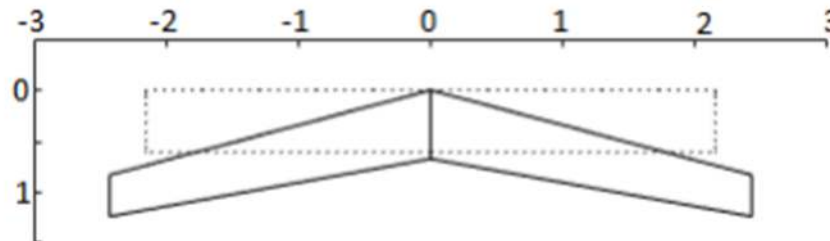


Figure 1: Optimized Wing. [12]

As seen from the results of the optimized wing in figure 1, the optimization variables are directed to the limit values of hereditary genes. The reason for this is that the information obtained from the low-order

the limits given. Figure 1 shows the wing optimization, where the dashed line is the initial wing.

aerodynamic method is limited. This is part of the limitations with using this method for optimization and in order to solve this, adding new methods to the program which will limit the geometric characteristics of the individual that is going to be

optimized. That's why weight and performance tools were added to the program in order to obtain reasonable results from the program since the design of an aircraft is a multidisciplinary field. In aircraft design, the weight is always a limiting factor. In addition, aircraft weight is one of the

most important parameters affecting the performance of aircraft. The USAF formula in Equation 1 was used for estimating wing weight of the RQ\_7B aircraft as in [12]. The USAF equation depends on the variables, such as taper, aspect ratio, and sweep angle.

$$W_{wing} = 96948 \left( \left( \frac{W_0 \times n_z}{10^5} \right)^2 \left( \frac{AR}{\cos \alpha_{swp}} \right)^{0.57} \times \left( \frac{S}{100} \right)^{0.61} \times \left( \frac{1+\lambda}{2 + \frac{t}{c_{wing}}} \right)^{0.36} \times 1 + \left( \frac{V_{cruise}}{500} \right)^{0.5} \right)^{0.993} lb \quad (11)$$

Case study of RQ-7B the estimated wing weights of with these formulas are compared in Figure 2

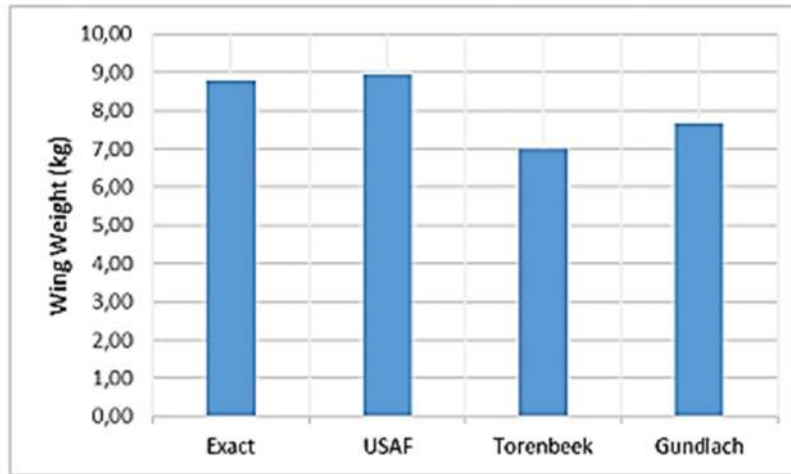


Figure 2: Wing weight estimation comparison [12]

As seen from Figure 2, the USAF method gives the closest result for the RQ-7B aircraft. The empirical formulas given in the review were applied to RQ-7B Shadow aircraft and the results were compared with the actual structural weight values. As a result of comparison, it was observed that USAF formulation gave consistent

results for wing weight estimation. A genetic algorithm code was also developed for performance calculation by using the already known performance formula (integrated with aerodynamic analysis, weight estimation and performance programs.

$$W_{wing} = 96948 \left( \left( \frac{W_0 \times n_z}{10^5} \right)^2 \left( \frac{AR}{\cos \alpha_{swp}} \right)^{0.57} \times \left( \frac{S}{100} \right)^{0.61} \times \left( \frac{1+\lambda}{2 + \frac{t}{c_{wing}}} \right)^{0.36} \times 1 + \left( \frac{V_{cruise}}{500} \right)^{0.5} \right)^{0.993} \quad (12)$$

The limitation of this paper is that it uses a low order program which gives reasonable results but an optimal one can be used for better results as a future research work.

### Baseline 3-D Wing Box Optimization

This work uses a two-phase process to achieve optimization of the 3D Model of wing. The first phase is to develop the design of the baseline wing box by generating a model of the wing using Computer Aided Three Interactive Application

(CATIA) based on the reference aircraft. The 3D methodology flow chart is shown in Figure 4. Two studies were conducted to determine the best configuration of spars and ribs and thereafter, the layout for the baseline design was determined.

The second phase generate the lift loss versus mass plot aimed at achieving a very light weight and rigid structure. The desired material can be selected by referring to the specific strength and the specific modulus. These are factors which compare the strength and stiffness

to the weight of the materials. In cases where high strength and very low weight are required, a high specific strength is suitable. In cases where a high stiffness and low weight are concerned, a high specific modulus is suitable. This implies that the

best material to use is Carbon Fiber Reinforcement Plastic (CFRP) as shown in Figure 5, which offers the best overall values for specific strength and specific modulus [11].

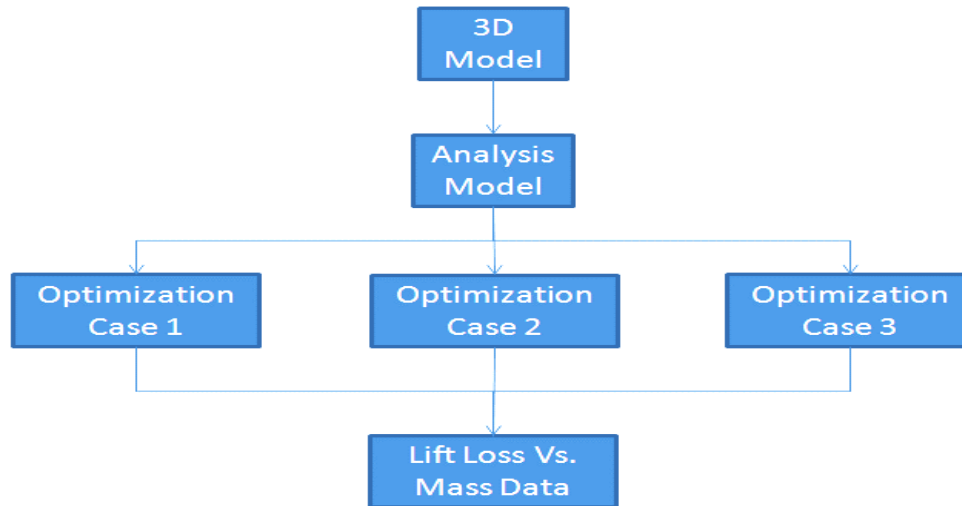


Figure 4: Methodology flow chart

Phase two also finds the relationship between lift-loss and mass by optimizing the wing box structure at three allowable deflections cases. Then, for each deflection case, the lift loss is calculated. Finally, the values of minimum mass and the lift loss at each tip deflection are compared to reveal the relationship between lift-loss and mass exploded model of the 3D wing structure as shown in Figure 5

The wing box is made of 3 structural members which include the wing skin, spars, and ribs as illustrated in Figure 5. The wing skin can

aid in the reaction of bending moments, but it primarily carries shear loading. Skin panels are located on the top and bottom of the wings. The Spars and skin are members that run along the span of the wing which carry bending and shear loads. The ribs run across the spars and provide form to the wing covers, as well as prevent buckling of the wing covers. Two studies were conducted to determine the best configuration of spars and ribs. Thereafter, the layout for the baseline design is determined [11].



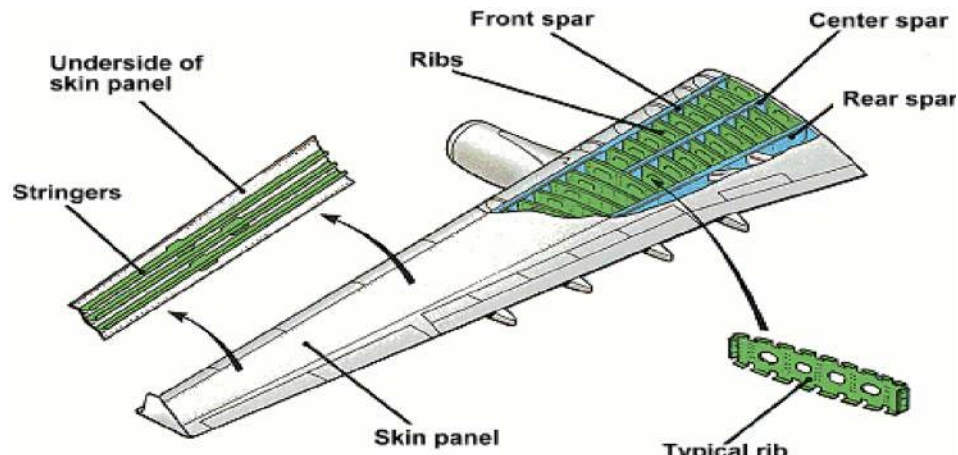


Figure 5: Structural components of a wing box with labels [11].

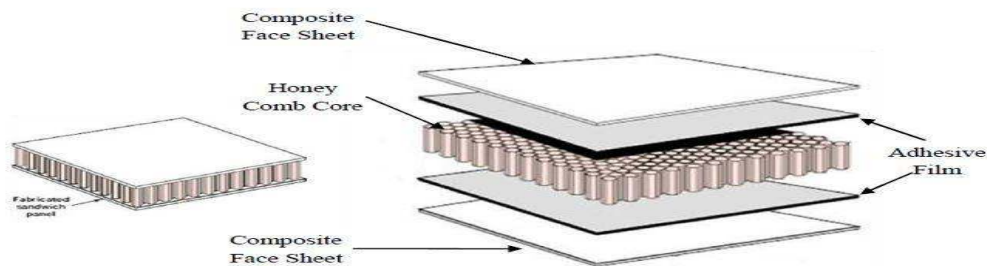


Figure 6: Diagram of sandwich composite [11].

There are two ways to use composites, in monolithic structure, or in sandwich composite structures. Monolithic indicates that the layup is purely the composite material. Since the strength to weight ratio is very high, this requires less material. The thin profile of components made of CFRP can lead to structural instability, or buckling. In order to prevent buckling, the moment of inertia of the wing structure can be increased by the addition of a core material, which leads to sandwich composites.

A sandwich composite material consists of face sheets made of a highly stiff and very strong composite material, a lightweight core

material, and adhesive film to hold the two together as shown in Figure 6. The role of the face sheets is to take in-plane loads. Since the face sheet has such high specific modulus and specific mass, it may only require a few plies which make it susceptible to buckling. The role of the lightweight core material is to make the layup more stable by increasing its thickness, which inherently increases the moment of inertia. The second role of the core material is to carry out-of-plane shear loads. Generally, in high stress conditions, a material that is formable and poses high shear strength is mostly used.



## Normalized Comparison of Aviation materials

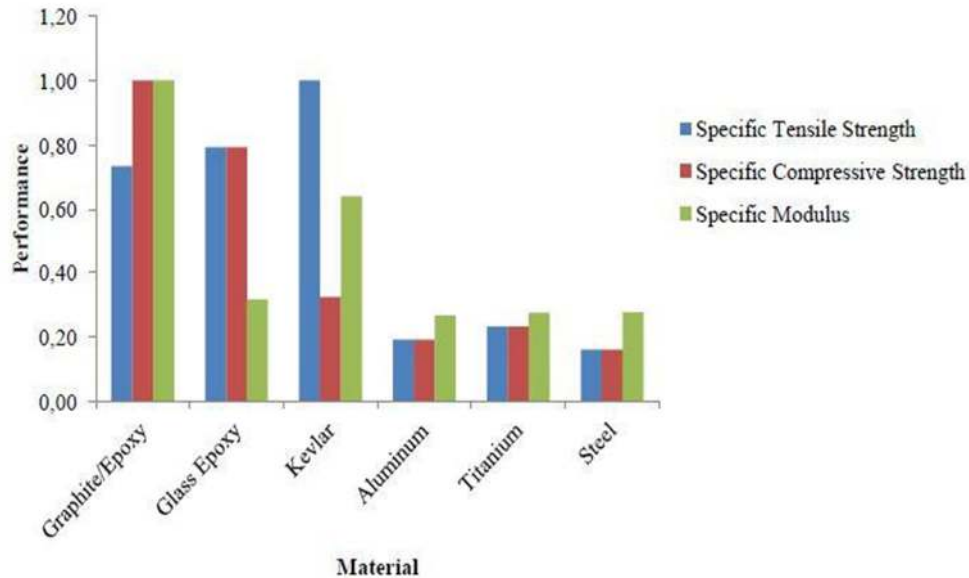


Figure 7: Comparison of aerospace materials [11].

### Shape-linked Optimization of Wing Components

An optimization technique called shape-linked optimization, which is different from the traditional optimization method, is introduced in this paper. The research introduces an updated wing optimization design in an effort to adopt continuous structure changes and shapes while optimizing for a lighter weight of the structure [15]. The approach described in their research has demonstrated that it could be capable of reducing weight with continuous thickness and section property changes despite being a discretized model. In addition, the element deletion was also shown to benefit from weight reduction. Unlike previous design efforts where the structures are traditionally partitioned to a lot of zones with

numerous design variants, this work represents a very simple and highly efficient approach with parametric expressions, coming from fewer variables. The proposed approach performs fully automatic modelling and loading. The parametric wing model as a primary design offers a good starting point for more detailed structural analysis. In a word, this approach is expected to widely be applied to most of the aircraft parts, such as horizontal tails, a vertical tail, and a fuselage. The method saves design time, weight and costs. The result shows that almost all of the parts of the wing are defined as functions, which expresses continuous changes of thickness of the skin, properties of spars, stiffeners and optimal results tend to be integrative processing, as shown in Figure 8.

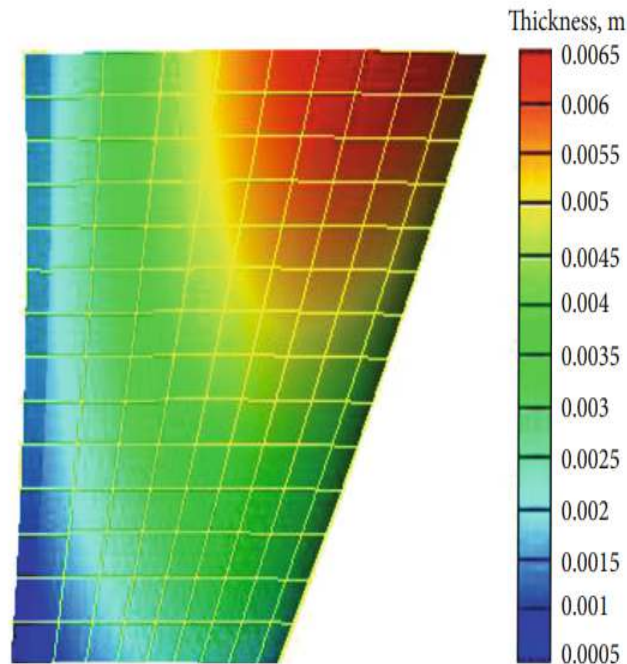


Figure 8: Thickness Distribution of the Upper skin [15].

The limitation of their research is that the model was designed using an Aluminum material as a model. Finally, their work revealed that weight can be reduced by section reduction and continuous thickness changes.

#### **Optimization Method by Vortex Lattice Method and Structural Static Analysis Method**

Vortex Lattice and Structural static Analysis based optimization concept was conducted on the wings of two unmanned aircraft. Two types of wings for unmanned airplanes were chosen; the first wing was the taper designed at ( $M = 0.71$ ) and the other wing was rectangular designed at ( $M = 0.21$ ). The research covers both the aerodynamic and structural design. The aerodynamic study was achieved by using the vortex lattice method and the structural analysis was achieved by using the Ansys 5.4 package where isotropic and composite materials were used. From the results, the mass saving of (32%) when composite material is used instead of isotropic material for the taper wing and (23%) for the rectangle wing. The optimum design for each wing was obtained

according to the mass, stress and displacement. The research focused on comparing a wing composed of composite and isentropic material and the other wing made from isotropic material in a bid to achieve an optimum strength to weight ratio.

The major deductions obtained by the two optimization methods (vortex latex method and structural static analysis) includes;

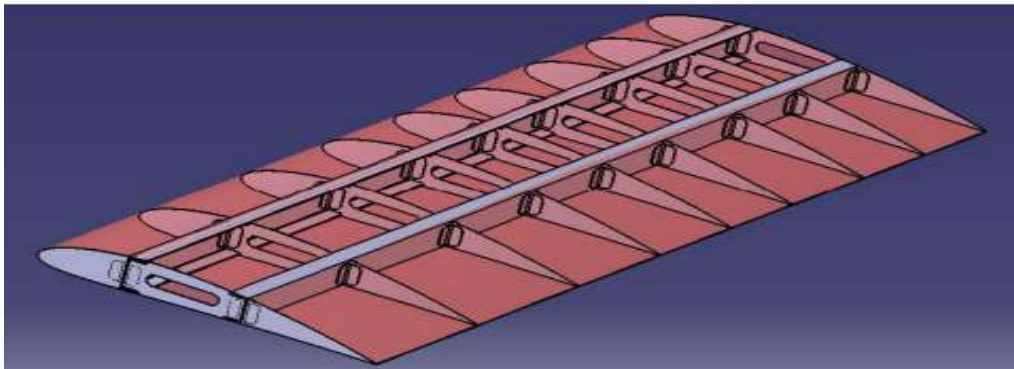
1. From the aerodynamic results it can be noticed that the lift coefficient increases with the increase in Mach number at the same angle of attacks due to the compressibility.
2. From the structural results it is noticed that increasing the skin thickness is considered as an important factor in reducing the stress and displacement levels compared to the increase of cross section area of beam and number of layers.
3. Increasing the ribs span wisely does not change Von-Mises stress distribution for all wings.
4. In case of using composite material in the design of the skin of the wing it can be noticed that the changing in fiber orientation

- and the number of layers at the same skin thickness will produce the variation in the Von-Mises stress (increase or decrease).
5. Also it was discovered that the mass saves (32%) when composite material is used instead of isotropic material for the taper wing and (23%) for the rectangle wing.
  6. It was discovered that it is desirable to use composite and isotropic materials in the design of the skin of a taper wing but undesirable to use isotropic materials in the design of the skin of a rectangle wing [8].

#### **Optimization by Finite Element Method**

The finite Element optimization aims to develop an accurate model for optimal design through designing the structure of wings that combine the composite (Skins) and isotropic materials and compare this with the same wing

made by changing the orientation of composite ply orientation in skin. The optimum design for each wing with different ply orientation can be obtained by comparing stress and displacement. Structural modelling is completed with the help of CATIA V5, each component modeled separately and assembled using Assembly workbench of CATIA V5, this assembly is then converted to IGS file. Finite element modelling is completed in MSc Patran using the IGS file as geometry, the element type used for meshing was 2D shell elements with QUAD4 element topology and different parts are connected using RBE2 connection. Static analysis done using MSc Nastran. The finite element model obtained is analyzed by applying an inertia force of 1N and then aerodynamic result (lift) is used to simulate the wing as shown in Figure 9 and Figure 10 [7].



**Figure 9:** CATIA MODEL of the Wing [7]



**Figure 10:** Finite Element of the Wing [7]

The result shows it clear that the ply orientation  $[0/90/+45/-45/90/0]$  gives the better result. So, it is considered that the ply orientation

$[0/90/+45/-45/90/0]$  is the optimized orientation. It is observed that the wing leading edge has lesser Von-Mises stress and trailing decreases towards



the wing tip and the variation in fiber orientation at the same skin thickness will produce less variation in the Von Mises stress.

### **Multi-Objective Evolutionary Algorithm Optimization Based on Pareto Concept**

The multi-objective evolutionary algorithm optimization based on Pareto concept aims to minimize the weight of multi-laminate aerospace structures by a classical Genetic Algorithm (GA) interfaced with a CAE solver. The structural weight minimization is a multi-objective optimization problem subjected to fulfilling of strength and stiffness design requirements as well. The desired fitness function connects the multi-objective design requirements to form a single-objective function by using carefully chosen scaling factors and a weight vector to get a near optimal solution. The scaling factors normalize and the weight vector prioritizes the objective functions.

The study minimized the weight of multi-laminate aerospace structures by a classical Genetic Algorithm (GA) interfaced with a CAE solver. The structural weight minimization is a multi-objective optimization problem subjected to fulfilling of strength and stiffness design requirements. The desired fitness function connects the multi-objective design requirements to form a single-objective function by using carefully chosen scaling factors and a weight vector to get a near optimal solution. The scaling factors normalize and the weight vector prioritizes the objective functions. The study further brings out the influence of mutation percentage on convergence. The optimization procedure on a transport aircraft wing torsion box has shown 29% weight reduction compared to an initial quasi-isotropic laminate structure and 54% with respect to the metallic structure. The following are the key conclusions that can be drawn.

a) The fitness function for GA optimization was established to minimize the assembly weight using scaling factors and a weight vector. The scaling factor normalizes the design criterion while the weight vector prioritizes them during optimization. In the present problem, the weight vector priority was in such a manner that assembly weight reduction should be done only when other

design parameters are within design allowable limits. However, incorrect selection of weight vectors showed that the algorithm can bring down assembly weight but at the cost of violation of design limits. This indicates that the selection of weight vectors plays a very important role towards the solution convergence.

- b) The LSS decides the sequence of laminate selection during optimization based on the maximum value of FI.
- c) The optimization brought out new laminates of lesser weight which are structurally strong and in compliance with set stiffness criterion. The laminated structure when compared with its metallic counterpart, showed almost 599 kg (that is, about 54%) reduction in weight
- d) The application of GA which governed FE solutions for multi-objective multi-laminate wing optimization, emerged as a highly effective tool and showed almost 201 kg (29%) of structural weight reduction and 30% less number of plies when compared to an initial quasi-isotropic laminate structure.
- e) The optimal laminate indicates that almost 50–60% ply orientations for panel, stiffener laminates are principally aligned to take care of tensile loads due to wing bending and that of the spar-web laminates are principally aligned to take care of shear loads. Therefore, present analysis suggests that without doing optimization one can use 50% plies in-line with principal load direction for panels, stiffeners and spar-web, while the spar-flange material has 50% plies with 90° orientation from the bending axis. (g) A careful choice of percentage of mutation is very important in deciding the convergence rate of the GA optimization process. The low value (1–2%) of mutation leads to local optima. On the other hand, high value (25–50%) of mutation damages the entire good characteristics of the parent strings. Thus, the new-string becomes unacceptable in iterative process

In the present study, 10% mutation was found to be a reasonable choice after a series of initial solutions. (h) the time requirement for finite element (FE) analyses on a medium range



computational facility for the present study was found to be minimal with the use of a structured global mesh. Therefore, with a well-structured global mesh along with GA, one can do an optimization of large multi-laminated aerospace structural problems in a pragmatic approach [13].

#### **FUTURE TRENDS IN COMPOSITE MATERIALS** **Smart Composite Wing Structure.**

Smart structures are those that feature sensors and actuators on the surface or integrated in the structure that can sense and take corrective action [16]. The driving force for technological advancement in successive generations has resulted in a new family of engineered materials and structures with multifunctional capabilities similar to those found in biological systems, leading to smart materials. Since the late 1970s, when the benefits of embedding optical fibres in composite materials were identified, smart materials and intelligent structures have piqued interest [17-19]. External to the sensor and actuator components is the feedback circuitry that connects sensing and actuation. Smart structural systems include smart components that perform sensing, feeding back, and other operations. As a result, the system's performance and service life improve. Active materials utilized in industrial applications include piezoelectric materials, shape memory alloys and polymers, electrostrictive materials, magnetostrictive materials, and electrorheological fluids. In intelligent composites, piezoelectric materials are Surface-bonded and static shape control of the composite wing are also being studied, with surface-mounted and embedded piezoelectric actuators spread along the wing span. The elastic deformation response to loading of the composite wing is controlled by the sequence of actuation of piezoelectric actuators inserted between the composite plies.[20]

#### **Implementation of Magnetic Microwires**

The incorporation of magnetic microwires into the composite structure allows for the measurement of stresses created in the structure after a period of operation. This measurement is carried out in a contactless manner, requiring no intervention in the structures. The efficient use of materials has always been

emphasized during the development of aeronautical structures. There is a desire to develop novel materials in order to strike the correct mix of safety, working lifespan, ecological balance, and economic efficiency. Aluminium alloys are being displaced by new advanced composite materials. Those materials, which have low specific weight, high fracture toughness, higher chemical and atmospheric resistance, and high specific strength, have found employment in aviation constructions. In contrast to traditional structural materials, composite materials have particular characteristics that make them challenging to use in practice. Apart from the manufacturing process, there is significant directional heterogeneity in mechanical properties, as well as age-related changes in composite mechanical properties. As a result, it is necessary to monitor their condition during operation, and one option for doing so is to use Magnetic microwires which could be used as contactless sensors in the future. By placing microwires in important points accessible to technical maintenance staff, non-destructive diagnostics of composite wings can be achieved, allowing the state (health, fatigue) of the composite material to be monitored. [21].

#### **CONCLUSION**

Various approximation methods were reviewed and it was observed that the gradient based model has a limitation of local solution as opposed to the global solution required, while in genetic algorithm a low order program was written which included already known parameters also the aerodynamic analysis, weight estimation and performance program was integrated. The limitation observed in this method was that a low order program was used which even though gave a reasonable result, an optimal result can be obtained by using a high order program which can be recommended for future studies.

In gradient based model which is applied if the objective function of one or more constraint functions are applied. The objective and constraint functions are continuous and differentiable within the boundary of the design space, the approach is applied in showing the effect of manufacturing constraints on the structural design of composite wing panel for





optimal stiffness. While for genetic algorithm method. This thesis has investigated a feasible structural design for the DAAP model from which to launch the optimization cases. The structure is feasible since it had only 0.94 for the failure index; this indicates that the structure has not yet failed. The model also passes buckling with a minimum value of 1.1. For the study of operability, lift loss vs. mass data has been collated and is ready for analysis. The greatest mass savings being -30%, there was only a marginal lift loss of 0.3. Reduction of weight was achieved by section reduction and continuous thickness changes using Fully Parametric Optimization Designs of Wing Components. In Optimization of Light Weight Aircraft Wing Structure, it was observed that increasing skin thickness reduces the stress and displacement levels compared to the increase in the cross-section area of beam and layers number. In Optimization of Light Weight Aircraft Wing Structure Mass saving of 32% was achieved when composite material was used instead of isotropic material for the taper wing and 23% for the rectangle wing. Therefore, the optimum optimization method in composite wing is Finite Element Analysis method due to its versatility to analyze multiple wing components variables with constant parameters.

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