Preliminary analysis of hybrid laminate composite for aircraft radome application

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Abstract. The preliminary analysis of laminate composite was conducted to analyse the optimal number of layers for aircraft radome application. In this work, the ESAComp software was used for preliminary analysis to predict the displacement during the flight operation. The ESAComp is a finite element software used for preliminary and conceptual design for composite layers. Flax fibre, glass fibre and epoxy resin were applied as the hybrid composite laminate design. The laminate construction consists of flax as the center laminate and sandwiched between glass fibre. Both fibres have the same weave pattern which is twill 2/2 and 200 gsm. The material properties for each materials were obtained from technical data sheet and used as input value for ESAComp. This software was used to analyse a single ply engineering constant by conducting fibre/matrix micromechanics analysis. The value of engineering constant of single ply for each material is then used for laminate analysis. It has range from 4, 6 and 8 layers with 20%, 30% and 40% of fibre content on a flat panel with the size of 300 mm x 300 mm. The panel were fixed on each edges and under aerodynamic pressure load plus safety factor of two. Based on the result of analysis, minimum layer required is at least 6 layers if acceptance displacement is 0.1 mm. Therefore, experimental works on 6 layers hybrid laminate will be carried out to determine other requirement for aircraft radome application.

Keywords: Finite element analysis, ESAComp software, flax fibre, hybrid composite laminate, aerospace structure

1. Introduction

The Natural fibres have attracted the interest of material scientists, researchers and industries due to their specific advantages as compared to glass fibres [1]. The classification of natural fibres are broad as discussed by K. Mohanty [2] and intention of this paper is to focus on bast flax fibres. The flax fibres has an advantages such as low density, low cost, renewable and biodegradable [2]. Furthermore, most of natural fibre or specifically a flax fibre has a low dielectric property, which is suitable for aircraft radome application [3, 4, 5]. The purpose of aircraft radome is as a protection to weather radar and therefore it should has a good structural strength and radio wave can be transmitted effectively [6].
common material used for aircraft radome is a type E glass fibre [6]. Finite element analysis has been used for simulation in the aerospace and automotive industries. Both industries have recognised simulation as part of the design process to minimize the design costs and create more efficient structures. Prototyping and testing has to be performed to verify the design, nevertheless simulation is essential for standard practice throughout the design process [7]. Commonly, there are several finite element analysis software used for composite [8] and ESAComp is one of the softwares for analysis and design of composites at conceptual or preliminary stage [9, 10]. An aircraft radome wall from Beechcraft Duke 60 is used as a reference as shown in Figure 1 [11]. The Beechcraft Duke 60 aircraft radome wall construction is a thin walled radome or style c and it is fabricated from glass fibre and epoxy. The main purpose of laminate composite preliminary analysis of is to analyse the optimal number of layers for aircraft radome application using hybrid material which is flax fibre and glass fibre.

Table 1. Mechanical properties of flax fibre, glass fibre and epoxy resin [12,13]

| Properties               | Flax fibre | Glass fibre | Epoxy resin |
|--------------------------|------------|-------------|-------------|
| Density (kg/m³)          | 1500       | 2540        | 1100        |
| Young modulus (GPa)      | 50         | 73          | 3.12        |
| Shear modulus (GPa)      | 19.20      | 30          | 1.15        |
| Poisson’s ratio          | 0.40       | 0.18        | 0.35        |

Flax fibre (Figure 2a), glass fibre (Figure 2b) and epoxy resin as a matrix are used to produced hybrid laminate composite. Flax fibre is constructed at the center and glass fibre at the outer and inner layer. Both fibres have the same weaving pattern which is twill weave 2/2 and has weight per unit area of 200 gsm. Flax fibre and glass fibre were supplied from Easy Composite and Epox Amite epoxy resin from Smooth-on. The mechanical properties for each material are obtained from technical data sheet as showed in table 1.
1.1 ESAComp Analysis Setup
The ESAComp is a finite element software for composite structures with the focus on conceptual and preliminary design. Figure 3 shows an analysis flow for ESAComp.

![ESAComp Analysis Flow](image)

**Figure 3. ESAComp analysis flow**

The data in Table 1 is used in ESAComp for initial analysis to analyse the optimal number of layers for aircraft radome application. The analysis started with combined fibre and matrix to create single ply using fiber/matrix micromechanic analysis. Rules of mixture are used for ply analysis and fibre content ratio range from 20% to 40%. For laminate analysis, load response/failure option is used on flat panel with size 300 mm x 300 mm which are under pressure wind load and all edges are fixed. The assumptions of classical laminate theory are applied in the analysis to determine the displacement [14].

2. Results and discussion
The Fiber/Matrix micromechanics analysis was conducted to analyse a single ply engineering constants. The value of engineering constants were then used to determine properties of laminate. Table 2 below shows the result of value engineering constant for single ply based on rules of mixture calculation from ESAComp.

| Engineering constant | Glass/epoxy | Flax/epoxy |
|----------------------|-------------|------------|
| Density (kg/m^3)     | 1342        | 1426       |
| E1 (GPa)             | 10.50       | 14.89      |
| E2 (GPa)             | 4.10        | 4.54       |
| E3 (GPa)             | 4.10        | 5.17       |
| G_{12} (GPa)         | 1.67        | 2.24       |
| G_{31} (GPa)         | 1.67        | 2.29       |
| G_{23} (GPa)         | 1.37        | 2.80       |
| nu_{12}              | 0.332       | 0.333      |
| nu_{13}              | 0.332       | 0.333      |
| nu_{23}              | 0.5         | 0.449      |

The wind load value is calculated based on the situation of a radome during flight operation which is around 100 N. With additional a safety factor equal to two, the total wind load apply during flight operation is 200 N. Then, a composite laminate panel consist of 4, 6 and 8 layers at 20%, 30% and 40% fibre weight ratio is created. Figure 4 show an example result from ESAComp.
The total displacement result for each configuration is tabulated in Table 3. If the displacement design value is around 0.1 mm, the minimum layer required is at least 6 layers. Furthermore, Figure 5 shows the number of layers increase, the displacement is decrease due to increase of thickness of composite panel. However, the experimental works still need to be done before to verified the result it can be used in aircraft radome construction.

Table 3. Total displacement result for laminate

| Laminate | 20%wt | 30%wt | 40%wt |
|----------|-------|-------|-------|
| 4 layers | 0.307 | 0.552 | 0.767 |
| 6 layers | 0.072 | 0.169 | 0.203 |
| 8 layers | 0.027 | 0.072 | 0.081 |

Figure 5. Displacement vs number of layer
3. Conclusions
The understanding of preliminary analysis on laminate composite has significant impact in decision making especially on laminate design. The ESAComp software can be used as a preliminary analysis to determine the suitability laminate design for further investigation. As the number of layers increase, the displacement is decrease. Meanwhile, the percentage displacement increase with increase the percentage of fibre weight ratio. This shows that the displacement decrease as the number of layer increase of the increase of stiffness.

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