EXPERIMENTAL STUDY ON STRENGTH COMPARISON OF LIGHT WEIGHT ALUMINIUM ALLOY PROPELLER BLADE WITH METAL PROPELLER BLADE

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Abstract:- Aluminum is the light weight metal used in various applications of Civil construction, Mechanical & Aeronautical machines etc. next to steels. The banana fibres are having various applications like natural absorbent remediation agent, in making paper cards, tea bags, fabric materials and rope. Also the ash of banana leaf sheath having pozzolanic property and used in green concrete. In aluminum matrix composite(AMC) aluminum is the matrix which forms network and other non-metallic material embedded into the matrix(Banana leaf sheath). Stir casting technique is the most promising and economical technique for processing MMC. In this aluminium alloy is made by using banana leaf sheath ash with aluminium 8011, it provides desirable material properties as the Particulate composite offer several advantages like strengthening the material and also provides specific material properties.

Key words: Aluminium 8011, Banana leaf sheath, composite material, light weight, propeller blade

1. INTRODUCTION
Due to the attractive properties of aluminium such as its lower weight, corrosion resistance, and easy maintenance of final product, have ensured that this metal and its alloys will be in use for a very long time.

In aerodynamic industry the aluminium is used to make an airfoil which play the vital part of a wing is to generate lift. It is very difficult to maintain the attached flow around the airfoil at high angle of attack, because which is leads considerable loss in the lift. Flow separation control is required for lift enhancement, improved pressure recovery, stall delay and attenuation of the form drag. The application of Stepped airfoils are developing an enhanced airfoil for the drag incurred and stability characteristics. Here the stepped airfoil is made using light weight aluminium alloy using aluminium 8011 and banana leaf sheath ash as are inforcement. Performance test on multi airfoil configuration aerofoil is carried out by testing it for various speed and blade angle in a propeller test rig[2].

1.1 Aircraft Propeller: Propellor is used to convert rotary motion to propulsive force to produce thrust. Early aircraft propellers were made from solid or laminated wood and then later propellers being made from metal. Now it is being replaced by high-technology composite materials.

2. METHODOLOGY
Materials used:
(a) Aluminium 8011
Aluminium / aluminum 8011 alloy is a manufactured alloy.

(b) Banana leaf sheath ash
Banana leaf sheath is selected due to its having more weight percentage of Silicon compared to fly ash which will use to decrease the wear rate.
Banana leaf sheath ash is prepared by the following procedure:
- Banana leaf sheath cut into small pieces.
- Banana leaf sheath is dried in oven for 300°C.
- Powered using dust making machine.

2.1 Propeller:
Propeller creates lift by creating pressure difference (Aerodynamic force) between front and back of the blade of propeller. In order to spin a propeller, a force is required which is called as torque. The resistance to the rotation of the propeller is called as propeller torque and engine/propeller rpm is become constant when these two forces are in balance. Thus power is absorbed by the engine.

2.2 Stir Casting Technique
The usage of Aluminium Matrix Composites (AMCs) as material in aerospace and automotive industries because of their excellent strength to weight ratio and high stiffness. From the research carried out for the production of composites various methods are used to fabricate the composites[6].

Among these techniques, stir casting method is the most promising way for production of aluminium matrix composites because of its simplicity and capability to produce composites on industrial scale.

Stir casting method is favoured for the production of large scale of complex shaped components in cost effective manner when compared to powder metallurgy process in which cost and size on the components is limited to a certain level.

Uniform distribution of reinforcement within the matrix directly affects on the properties and quality of composites[3]. Hence it is the challenge in this method.

2.3 Steps involved in stir casting
- Aluminium is heated and melted at 800°C
- The Banana Fly ash is also preheated to 300°C
- Aluminium and Banana Fly ash is mixed up by stirring mechanism
- The stirring was maintained between 10 to 15 min at an impeller speed of 650 rpm.

2.4 SEM Analysis
Scanning Electron Microscopy (SEM) or SEM microscopy, is used in micro analysis and failure analysis of solid inorganic material very effectively. It uses a focused beam of electrons to produce complex, high magnification images of a sample's surface topography by interacting with atoms in the sample and producing various signals which contains information about the surface topography and composition of the sample.

2.5 Experimental Approach
Test rig is used to obtain the performance of the fabricated stepped airfoil which replaces the conventional airfoil of the test rig[1]. The propeller is tested for various speeds and blade
angles. Thrust will be calculated from the values notes from the experiment and finally its efficiency[1]. Graphs are plotted to carry out the comparative study of the stepped airfoil and the conventional airfoil which is initially installed in the test rig.

\[ \eta_p = \frac{\text{Output power}}{\text{Thrust} \times \text{Velocity}} \]  \hspace{1cm} \text{Equ (1)}

Power required to produce a given thrust is:

\[ P = \frac{\pi D^2}{4} \left( v + \frac{\Delta V}{2} \right) \rho \Delta v \]

\[ T = \frac{3.14 \times (0.7)^2}{4} \left( 1.2 + \frac{2.8}{2} \right) 2.8 \times (1.1225) \]

\[ T = 2.216N \]

Actual thrust power = \( P_{\text{actual}} = T_{\text{actual}} \times \Delta v \)

\( P_{\text{actual}} = 45.61 \times 2.8 \)

\( P_{\text{actual}} = 127.73 \text{watts} \)

2.6.2 Power supplied to the propeller

\( P_{\text{motor}} = 0.7 \times \text{motor wattage} \)

\( = 0.7 \times 9 \)

\( P_{\text{motor}} = 6.3 \text{watts} \)

2.6.3 Propeller Efficiency

\[ \eta = \frac{P_{\text{actual}}}{P_{\text{motor}}} \]

\[ \eta = \frac{127.73}{6.3} \times 100 \]

\[ \eta = 20.27 \% \]

2.7 Model calculations for stepped airfoil

2.7.1 Momentum theory thrust is given by.

\[ T = \frac{\pi D^2}{4} \left( v + \frac{\Delta V}{2} \right) \rho \Delta v \]

\[ T = \frac{3.14 \times (0.7)^2}{4} \left( 1.3 + \frac{2.9}{2} \right) 2.9 \times (1.1225) \]

\[ T = 3.7578N \]

Actual thrust power = \( P_{\text{actual}} = T_{\text{actual}} \times \Delta v \)

\( P_{\text{actual}} = 49.83 \times 2.9 \)

\( P_{\text{actual}} = 144.5 \text{ watts} \)
2.7.2 Power supplied to the propeller

\[ P_{\text{motor}} = 0.7 \times \text{motor wattage} \]

\[ = 0.7 \times 8 \]

\[ P_{\text{motor}} = 5.6 \text{ watts} \]

2.7.3 Propeller Efficiency

\[ \eta = \frac{P_{\text{actual}}}{P_{\text{motor}}} \]

\[ \eta = \frac{144.5}{5.6} \times 100 \]

\[ \eta = 25.8 \% \]

Figure 2.1: Stepped airfoil

3. RESULT

| Blade angle (degree) | Speed (rpm) | Power (watts) | Thrust Actual (N) | Velocity of incoming airflow \( v \) (m/s) | Velocity behind the propeller \( \Delta v \) m/s | Thrust Theoretical (N) | Power actual (\( \omega \)) | Power motor (\( \omega \)) | \( \eta \) in % |
|---------------------|-------------|---------------|-------------------|---------------------------------|---------------------------------|---------------------|-----------------|-----------------|-------------|
| +4                  | 1000        | 9             | 45.61             | 1.2                            | 2.8                             | 2.21                | 121.73          | 6.3             | 20.27       |
|                     | 1300        | 14            | 137.34            | 1.5                            | 3.2                             | 4.67                | 145.97          | 9.8             | 14.9        |
| -4                  | 1000        | 12            | 44.44             | 2.8                            | 1.2                             | 1.92                | 53.33           | 8.4             | 6.3         |
|                     | 1300        | 21            | 44.04             | 3.9                            | 1.5                             | 3.29                | 66.67           | 14.7            | 4.5         |
Table 3.2: Values for composite stepped airfoil propeller at various blade angles

| Blade angle (degree) | Speed (rpm) | Power (watts) | Thrust Actual (N) | Velocity of incoming airflow $v$ (m/s) | Velocity behind the propeller $(\Delta v)$ m/s | Thrust Theoretical (N) | Power actual ($\omega$) | Power motor ($\omega$) | $\eta$ in % |
|----------------------|-------------|---------------|-------------------|------------------------------------------|-----------------------------------------------|------------------------|-----------------------|------------------------|----------|
| +4                   | 1000        | 8             | 49.83             | 1.3                                      | 2.9                                           | 3.75                   | 144.5                 | 5.6                    | 25.8     |
|                      | 1300        | 14            | 49.93             | 1.7                                      | 3.3                                           | 5.21                   | 164.78                | 9.8                    | 16.8     |
| -4                   | 1000        | 19            | 49.05             | 3.3                                      | 2                                             | 4.05                   | 98.1                  | 13.3                   | 7.38     |
|                      | 1300        | 30            | 48.76             | 4.4                                      | 2.9                                           | 7.99                   | 141.39                | 21                     | 6.73     |

Based on the calculations, graphs are plotted between the conventional metal and stepped composite propeller.

Fig 3.1: Efficiency graph for blade angle +1°

From the figure 3.1 graph, it is understood that the stepped airfoils are found to give higher efficiency than the conventional airfoil.

4. CONCLUSION
The composite material is prepared by stir casting method and the composite stepped propeller is made using machining process. In this work, Aluminium 8011 alloy is selected as matrix phase while Banana leaf sheath ash is added to act as reinforcement. With the help of
stir casting process the AMC was successfully manufactured AMC with least cost. While manufacturing AMC we come to know that process parameters such as stirring speed and time plays a major role for uniform distribution of reinforcement. The performance of the composite propeller is tested in a test rig and thrust efficiency is calculated. The Composite propeller had 25.8% greater thrust efficiency compared to that of the normal propeller blade made of aluminium alloy. Thus Composite propeller can be installed in Reciprocating type of aircraft and even can be used in hybrid engine for producing higher thrust without any energy loss.

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