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Detailed Study of Rotor Blade of a Helicopter

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ABSTRACT

In this paper the details of helicopter rotor blade design, materials and types has been studied by us. Special focus is given on the analysis of airfoil design and material used for manufacturing of rotor blade of helicopter.

Keywords

Helicopter rotor blade, helicopter, helicopter rotor, rotor blade, helicopter rotor blade material, helicopter rotor blade design, helicopter rotor blade airfoil, helicopter blade design

1. INTRODUCTION

Helicopters are made in different types and shapes depending upon their purposes and required payloads. But most of them share similar parts and components. One of the most important components among these is helicopter rotor or rotor system (fig.1). Its purpose is to generate the lift to carry the weight of helicopter and the payload as well as to provide thrust to act against the drag generated during forward flight. Main components of a rotor system are mast, hub and rotor blades. Mast is a cylindrical metal shaft which is hollow from inside and is attached to the gearbox. On the top of the mast a hub is present for the attachment of rotor blades. Rotor blades are very important part of rotor system and they attached to the hub by many different ways. Rotor system is divided into 3 different categories: rigid, semi-rigid and fully articulated. These classifications are done on the basis of attachment of rotor blades with hub and their motion with respect to the mast.

Fig. 1: Helicopter rotor system

2. TYPES OF ROTOR SYSTEMS

2.1 Rigid

In rigid rotor system there are no hinges present so it is also called hingeless rotor system and blades are flexibly attached to the hub (fig.2). Drag and flap motion of blade takes place at root about a flexible section. This type rotor system is much simpler than fully articulated rotor system.

Fig. 2: Rigid rotor system

2.2 Semi-rigid

In this rotor system there are two blades attached under one teetering or flapping hinge in opposite direction. This results in flapping motion of blades in opposite direction (fig.3). There is also a feathering hinge at the root for pitching of rotor blades.

Fig 3: Semi-rigid rotor system

2.3 Fully articulated

In this rotor system blades are attached to the hub through different hinges independently (fig.4). This helps in independent motion of blades with respect to each other. There is a vertical hinge or drag hinge for back and forth motion of blade and there is a horizontal hinge or flapping hinge for up and down motion of rotor blade. This type of system is used for three or more than three rotor blades and is much more complex in structure than other two rotor systems.

Fig 4: Fully articulated rotor system

3. ROTOR BLADE DESIGN

Rotor blades of a helicopter are designed in airfoil shapes to generate aerodynamic forces such as lift and thrust when they come in contact with air using Newton's 3rd law of motion. Rotational motion of blades throws down the air and the helicopter goes up.

3.1 Material Specifications

3.1.1 Wooden blades

Until early 1960's wooden rotor blades were used for manufacturing of helicopters. These blades were mostly of symmetrical airfoil shape (fig.5). The reason behind this was good lift-to-Drag ratio and easy manufacturability. These wooden blades had many problems like water absorption which increases vibration during rotation and they could be damaged beyond repair.

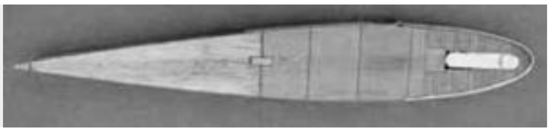

Fig 5: Wooden blade

3.1.2 Metallic blades

Metal blades took place of wooden blades because of the earlier problems. These blades were much more tuff and durable against harsh conditions and they also had fixed design life after which it was compulsory to replace them. But these metallic blades could show failure with little warning when damaged at critical areas.

3.1.3 Composite blades

These blades are made of different layers glass fiber and carbon fiber (fig.5.1). These glass and carbon fiber layers prevent propagation of crack. These composite materials are light in weight and have good strength-to-density ratio, even 6-8 times better than aluminium and its alloys. Introduction of honeycomb core inside composite blade made very easy for the designers to design various shapes and increased performance of blades. This honeycomb structure is mostly made of Nomex and provide high beam strength to the blade (fig.5.2).

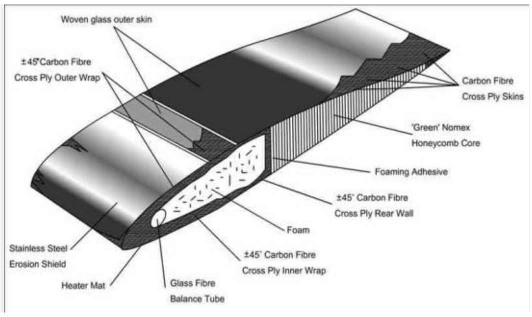

Fig 5.1: Composite blade

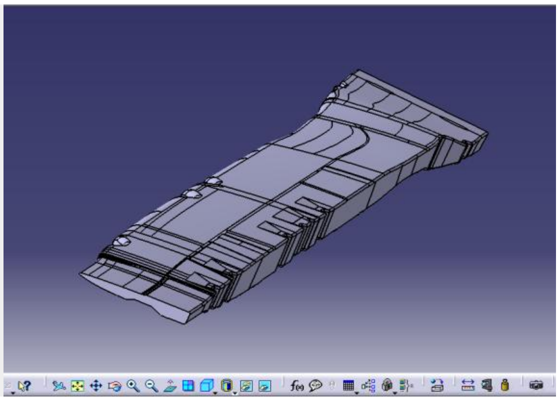

Fig 5.2: Honeycomb core of composite blade

3.2 Loads Specifications

3.2.1 Bending moment and cyclic loading

Three dimensional loads act on the rotor blade when in rotational motion. Due to varying span along the length of blade bending moment also occurs. This bending moment compresses the upper section of blade and creates tensile forces on lower section. It is also related to amount of lift generation and radial distance from the hub. Due to flapping motion of blade cyclic loading also takes place on the blade.

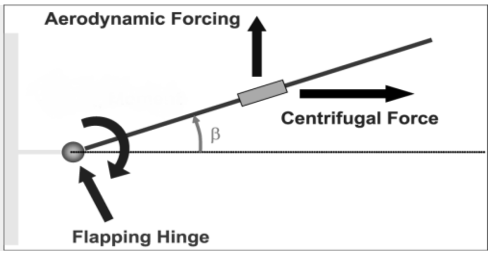

Fig 6: Forces acting on rotor blade

3.2.2 Twisting forces

During feathering motion of rotor blade the angle of attack of blade is change to generate lift. Due to this pitching inertia acts on the blade to restore its angle of attack to zero which results in twisting force which can damage the blade as it varies with changing speed of air from root of blade to the tip.

3.2.3 Balancing of forces

When a helicopter is hovering all the forces are balanced by each other. Thus load on each blade should be even to create symmetry. Unsymmetrical design can lead to unbalance of forces. All the blades should be adjusted to same angle which ensure same pitch is applied to each blade. This is done by a

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process called tracking. Tracking prevents unbalance and vibration in blades.

3.3 Design Criteria

Designing of rotor blade depends upon different designing criteria based upon material used, purpose of helicopter and different loads acting on blade.

3.3.1 Airfoil shape

Rotor blade of helicopter is responsible for the lift generation in helicopter. Airfoil shape of rotor blade is designed according to the flight purpose of helicopter. Airfoil design should have high lift-to-drag ratio which is very important parameter for rotor blade designing. An average lift-to-drag ratio is 30:1. There two types of airfoil designs used in lift generation: symmetrical and nonsymmetrical. Symmetrical has same upper and lower half and nonsymmetrical has different lower and upper half of the structure. Lift generation in unsymmetrical is more as compared to symmetrical.

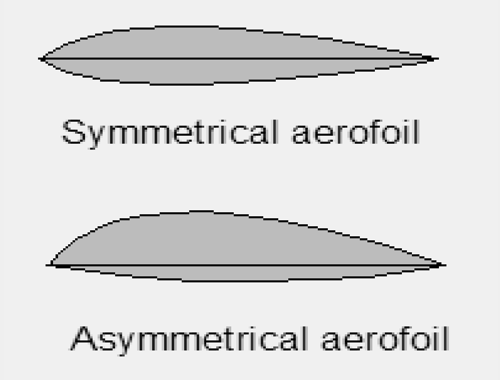

Fig. 7: Symmetrical and Asymmetrical airfoil

3.3.2 Material properties

While designing a helicopter rotor blade strength-to-density ratio is very important parameter. It should be very high. Composite materials have high strength-to-density ratio so different layers of composite material is used for designing blade. These materials also prevent crack propagation.

3.3.3 Environmental conditions

Lightning is very important environmental factor considered during designing of a rotor blade because it can damage the structure of rotor blade. Rotor blades should be equipped with electrical conductors throughout the span for discharging of high voltage electric current. For cold conditions de-icing system is very important equipment which is attached to the leading edge of rotor which increases its temperature for preventing the icing. Another factor considered while designing is moisture which leads to stress and crevice corrosion in stressed areas in metallic blades. This is very important factor when helicopter is working near sea as the salt in sea water enhances the corrosion in metals like aluminium. Metals like stainless steel and titanium are used to prevent this problem. Composite material is also resistant to corrosion.

4. CONCLUSION

We studied different design criteria for designing a rotor blade and different types of load acting on a rotor blade including study of materials used for construction of a working rotor blade by analyzing a general rotor blade design in CATIA V5 software.

5. FUTURE SCOPE

By analyzing the design of rotor blade in CATIA V5 software it is observed that some modifications needs to be done in the internal honeycomb core structure because of the stress variation along the leading edge of the blade and design changes in outer surface of blade.

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