Challenge and Advantage of Materials in Design and Fabrication of Composite UAV

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Abstract. Unmanned Aerial Vehicles (UAVs) is constructed with composite materials, including its aerodynamic surfaces wings, horizontal stabilizer, and rudder. Three main constituents of our model is Kevlar 49, carbon fibre, glass fibre. KALPANA-1 is a pusher type, tail dragger, fixed wing radio controlled medium range remotely operated composite aircraft. This is designed for Aerial surveillance & reconnaissance. It is a kind of drone which has capability of carrying 2kg of operational payload as surveillance camera and its gimbal mount unit .It can be equipped with on-board sensors for weather monitoring as civilian use of UAV. It has a carbon frame body which makes it hassle to work in all-weather environment, protecting its electronics and payload from external entities. KEVLAR-49 is reinforced at the bottom part of the fuselage to overcome hard landing & impacts. The main disadvantage of using carbon fibre is that it partially shelled the RC signals so we fixed our receiver outside of the fuselage .For camera mounting purpose a duct made in front side of fuselage. It can use as other diplomatic mission as mounting camera and robotic arm for weight lifting mechanism. Some further upgrading two semi ducts at two side of the front face of the fuselage for steerable camera mounting. Aircraft using single electrical propulsive system and large wings which helps it for a long range, good endurance and smooth steady flight. Composite materials don't break easily, but that makes it hard to analyses if the interior structure has been damaged at all. In contrast, aluminum bends and dents easily, making it easy to detect structural damage; the same damage is much harder to detect with composite structures. Repairs can also be more difficult when a composite surface is damaged. Finally, composite materials can be expensive, but the high initial costs are typically offset by long-term cost savings and life cycle more compare to cost of material.
Keywords: Aero structure, wing design requirement, composite fabrication, kevlar49, carbon Fibre, Glass fibre, fabrication challenge of composite materials

1. Introduction

KALPANA-1 is a 5 Channel RC aircraft. Each Channel is used to control individual control surface like rudder, elevator, flaperon (using two channel for flap and aileron) .One remaining channel is used for throttle control. All individual Chanel received signal from receiver radio controller. Aircraft need ground runway to take-off and land. The propulsive system included one 650kv/1150w brushless out runner motor with 13 x 6 propellers. Polyhedral wing used to produce more aerodynamic lift and rolling stability with flaperon as trailing hinged surface. Yaw and pitch moment is controlled by servomotors connected to rudder and elevator. Flaperon can serve the purpose of both flaps as well as aileron .It is used to control rolling and banking moment. Due to high aspect ratio polyhedral wing this aircraft have better gliding and long endurance flight. With current available power source KALPANA-1 can fly continuously for 30 minutes in the sky, its flight time can be increase by using extra power shells .This aircraft is capable of carrying payload up to 2.5 kg. It also equipped with steerable wheels and camera mounting system.

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Nomenclature	
C.G	centre of gravity
UAV	unmanned aerial vehicle
R C	Radio controllable
ROA	Remotely operated aircraft
FPR	Fibre-reinforced plastic

2. Unmanned Aerial Vehicle

KALPANA-1 is a pusher type tail dragger fixed wing R C (radio controllable) medium range ROA (remotely operated aircraft) aircraft. Which is using a polyhedral shape wing (Clark-y shape aerofoil section) with gondola shape fuselage and main controlling hinged surface which producing the dynamic lift as well as good banking manoeuvre a flaperon (combination of flap+ aileron) mechanism is used . Conventional radar and elevator as hinged section at rare end of the horizontal and vertical stabilizer is used, which is responsible for flight stability (yaw and pitch). .All these controlled hinged surface are operate by servomotors. It is a working model and capable of takeoff and land on runway. The main power source or propulsive system included one brushless motor with13x6'' propeller for better airscrew, efficient endurance and long range flight. The whole fuselage, wings, horizontal and vertical stabilizer of aircraft is reinforced with carbon fibre cloth. Which is shaped with the thermo coal using hot wire cutter and it is fully handmade and shaped. Kevlar reinforcement is used at the base of our fuselage to strengthening the landing gear.

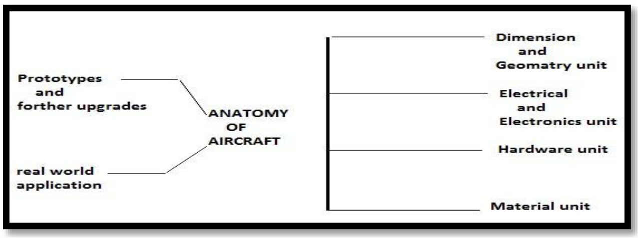
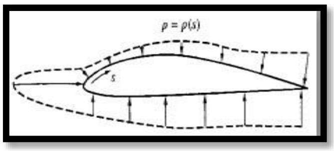


Fig1. Anatomy of aircraft

3. Flight Mechanics of UAV

UAV probably the most practical consequence of the flow of air over an object, experience a force which is known as aerodynamic force, in the case of airplane the take the advantage of this force. The net unbalancing of varying pressure distribution over the surface create the aerodynamic lift, the shear force creates the laminar flow over the wing.



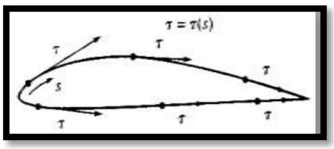


Fig 2.(a) Pressure distribution over Airfoil (b) Shear force over Airfoil

There are two main aspects which produce the aerodynamic lift

•The pressure difference between the lower and upper wing

•The shear distribution over the wing surface which causes the boundary layer formation over the aerofoil

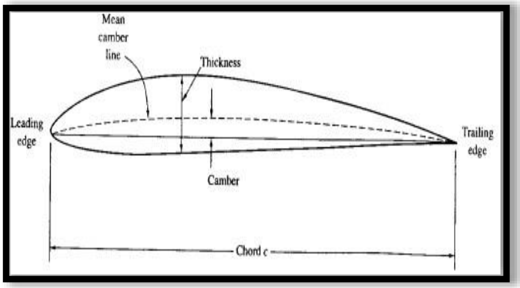


Figure.3 Example of an airfoil

3.1 Lifting Surfaces

The amount of lift generate by a wing depends on the shape of the airfoil. The wing area and aircraft velocity during take-off and landing the airplane's velocity relatively low .To keep the lift high. So that aircrafts designed to increase the wing area and change the airfoil shape ,which increase the effective camber of the wing as the curvature of the down surface increases so more air flow which causes to increase the reaction force relatively higher .

3.2 Stabilizers

Control and manoeuvre the aircraft, smaller wings are located at the tail of the plane .The tail usually have a fixed horizontal piece called horizontal stabilizer and a fixed vertical called the vertical stabilizer. The stabilizer provides stability for the aircraft to keep it flying straight and maintain its position of C.G.

3.3 Elevator

The elevator is the small moving section at the rear of the horizontal stabilizer that is attached to fixed section by hinges. As the elevator moves it varies the amount of lifting force at the rear end of the aircraft which causes the pitching motion of the aircraft .In kalpana-1 one single elevator configuration is pursued for control the pitching motion of the aircraft .Its actuation is done through Hitec HS-475HB with linkage rods connect to servo-horns.

Fig.4. Elevator

3.4 Rudder

The rudder is the hinged surface on the vertical stabilizer .it is used to control the position of the nose of the aircraft. Interestingly, it is not used to turn the aircraft in flight. Aircrafts turns are caused by banking the aircraft to one side using either aileron or spoilers. The banking creates an unbalanced side force component of the large wing lift force which causes the aircraft's flight to curve. The rudder inputs insure that aircraft is properly aligned to the curved flight path during the flight manoeuvre. Otherwise, the aircraft would encounter additional drag or even a possible adverse yaw condition in which due to increased drag of the control surfaces, the nose move farther off the flight path.

Fig.5. Rudder

3.5 Aileron

Aileron can be used to generate a rolling motion for an aircraft. It is small hinged section on the outer edge or outer board of a wing .Aileron usually work in opposition the right aileron is deflected upward and left is deflected downward and vice versa. The ailerons are used to bank the aircraft to cause one wing tip to move up and other wing tip to down. The airplanes are turn not because of a rudder it because of aileron, an unbalanced side force component of the large wing lift force which cause the aircraft’s flight path to curve.

4. Airframe Materials

The three main constituents used in KALPNA 1 are kevlar49, carbon fibre, glass fibre. The main advantage of these materials is used for composite materials, which are less weight with high strength. The carbon and glass fibres are commonly used for reinforcement.

4.1 Glass Fibres

Fiberglass is a lightweight, extremely strong, and robust material. These fibres have high strength to weight ratio and good dimensional stability, high resistance to temperature (high and low), low water absorption and high electrical insulation.

4.2 Carbon Fibres

Carbon fibres are long known for their electrical resistance and fragility. The strong covalent bond between two carbon atom would make carbon fibre very strong .These fibres were found to be developed high strength adhesive bond with epoxy resin results into FPR as strong as steel but lighter than aluminium. The main property of carbon fibre is low density, high strength and high modulus of elasticity.

4.3 Kevlar

Aramid fibres are basically aromatic polyamide fibres and commercially available in two forms kevlar29 and kevlar49 is known for high strength and low density. Kevlar49 has high modulus of elasticity .Distinct advantage of carbon fibres over E-glass can be seen in terms of strength, modulus of elasticity and density but carbon fibres are more brittle .Kevlar49 has higher strength, ductility and low density but its modulus of elasticity is lower than that of E-glass .Glass fibre have distinct advantage of low cost .Born fibres are so costlier. Both boron and carbon fibre are susceptible to oxidation .Glass fibres do not oxidize .Glass fibre have the disadvantage of losing strength with temperature but boron and carbon fibre do not.

The property of boron fibres, graphite fibres, Kevlar49, s-glass and E-glass fibre are prospectively compared .It can be noted that tensile strength varies between 1700 and 3400 MPa while the fracture strain varies between 0.4 and 4.0%.Best combination of strength, modulus of elasticity and density is available in carbon fibres.

5. Advantage of composite

We use Kevlar reinforcement at the base of our fuselage to strengthening the landing gear so that it able to protect and provide damage resistance to our aircraft at the time of rough landing and worst crass landings. One special quality of Kevlar is that it can resist and withstand sudden impacts as well as jerks. Kevlar is very resistant to impact and abrasion damage also less weight and high strength.
Kevlar carbon fibres also have same properties less weight, high strength, long durable. Fuselage and the body of the aircraft made of carbon fibre and wings are also reinforced with carbon fibre cloth. The tail boom, wing spars and linkage rods are made of aluminium.
Our intention of using Kevlar, carbon fibre and aluminium bars are to provide rigid, strong, light weight, durable and vibration resistive base structure. Which can withstand all type of worst condition faced at time of take-off, landing, complex flying manoeuvres, harassed weather condition(rain ,sudden wind blow) and able to protect sensitive electronics part from all type of hostile threatens (temperature variation) .

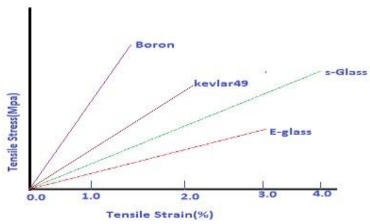


Fig.6. Comparison graph of composite material

6. Disadvantage of composite

The main disadvantage of using carbon fibre is that it partially shelled the RC signals so we fixed our receiver outside of the fuselage .For camera mountain purpose we made a duct in front side of fuselage Can use as other diplomatic as mounting for an camera, robotic adds, may be for weight lifting mechanism and some further upgrades .we made two semi duct at two side of the front face of the fuselage for steerable camera mounting.
Aircraft using single propulsive system and large wings which helps it for an long range, good endurance and smooth steady flight, For good air screw we are using a good quality rigid prop which is made up of fiberglass (fibre glass is an immensely versatile material, it combines with its light weight with an inherent strength to provide a weather resistant property) reinforced with nylon. Special property of glass fibre is Strength, Elasticity, heat resistance. We are using a steerable wheel mechanism at the tail of the plane (as a tail wheel) for batter taxi track and ground movement. Our flaperons are made of balsawood as the chance of damage is more, so in balsa wood it can easily built and replace. Advantage of balsa wood is its light weight.

7. Composite Design and Fabrication process

The composite technology manufacturing process consists

- 3D CAD shape design,
- CNC mould milling,
- Wet lay-up/ Pre-preg laminating,
- High temperature curing,
- Off mould fettling/dressing.

7.1 Fuselage and Tail parts

Fuselage design is gondola shape and first fabricate in thermo cool .The surface of fuselage is smoothed by sand paper. The mixture of epoxy -resin coated over carbon fibre cloth and fuselage body. The whole dome shape body is coated with carbon fibre cloth with proper alignment. The fabrication process took at least three hours to dry the fuselage and slot made at back portion down to fit to insert a tail boom and motor mount made upper back portion of fuselage . After the tail-boom is inserted the cloth is banded around the joint tightly and it glued up with hard epoxy binder, super glue adhesive to make it hard, tight and rigid. The fuselage is finished after the carbon fibre cloth reinforcement and extra thermo coals removed from fuselage.Tail boom is fixed and glued by araldite epoxy adhesive to get high strength. Rectangular canopy made over the fuselage upper part to remove the foam from the cavity to make a hollow cavity where electronic system is mounted.

At the left front of the fuselage there is a hole for mounting the camera system, and other clamping mechanism, or any robotics assessors can be mounted on these sensors, or any servo mechanisms according to need can be mounted. Camera systems inside two nuts are fixed to mount a wooden hold inside to clamp. We have a steerable wheel landing gear configuration, with the movement of the connecting rod controlling surface rudder is moving as well as the steerable wheel also changes its direction so taxiing on runway is done through this steerable while mechanism, It provides the aircraft to move in the ground freely at any direction.

Kevlar cloth reinforcement is done on the outer part at the bottom and inside of the fuselage where the landing gears are mounted. The landing gears tightened from inside with four screws and nuts. Kevlar is used at the bottom inside part of the fuselage to provide high resistance and strength and prevent sudden impacts.

We connect the all stabilizer (horizontal and vertical) to the main frame by epoxy we use syno for hinges which are made of fiberglass we stick it first half of the piece in to the stabilizers and then connect half to the hinged surface as rudder, elevator and aileron these all are glued by Cyanoacrylate super glue which is very powerful glue and it forms strong adhesive bond. Linkage rods are connected to the Heavy duty servo-horns by cleavages.

The main work is that to check the joints are strong or not otherwise structural failure may be occur, so the joints must be strong and it not lose after a long period ,to increase the strength and durability we bind the carbon fiber threads over the joint between the fuselage and the tail boom we first glued inside the tail boom and then bind the carbon fiber thread over this joint ,this carbon fiber threads are already draped with epoxy, and two extra layer of carbon-fiber cloth is given over the joins of the two stabilizer to give strength. All controlling surfaces are coated with carbon fiber cloth and kept inside the air pocket.

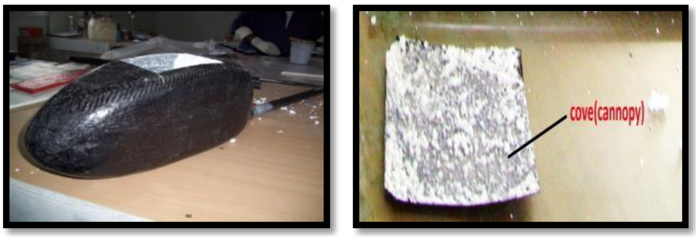


Fig.7. (a) fuselage of aircraft (b) canopy of fuselage

Fig .8 tail boom joined with fuselage

Fig.9. (a) Aircraft with tail (b) stabilizer of Aircraft

7.2 Wing Design and Fabrication

WING is the most important part of the aircraft, when construct a wing lot of attention is required, with as an accurate measurement and the proper dimension have to be consider and avoid as possible as mistakes. The main challenge in wing making how accurately you can cut the aerofoil section .Here we took clark-y aerofoil for our model which has upper part is cambered and the lower part is flat. First we made aerofoil in balsa wood and then we locate the notches on it for wing spars. The ribs are bulled by balsa wood and the notches are providing at the line of wing spar.

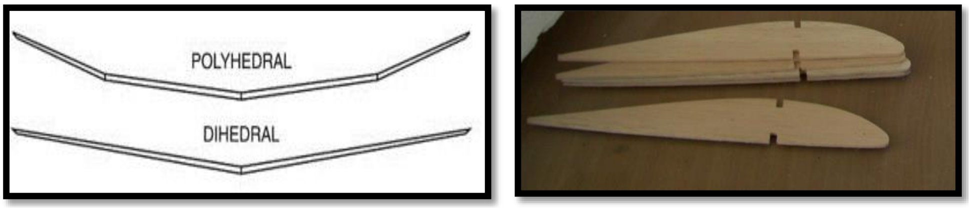


Fig.10. (a) Type of wing (b) Airfoil of wing ribs

The ribs are glued at the both side of the rectangular foam piece of 245×28cm. The both side the airfoil shape fix ribs at the both end of the foam. The wing is cut out of foam by the hot wire cutter, the hotwire cutter remove the extra foam from the wing surface and provides a nice air foil shape throughout the wing span. It gives an very good smooth and neat surface ,which is required we made four of piece of the saps and we clean the extra material from the surface and make two channel where the spars have to fit .The polyhedral part of the wing to the main wing .

Fig. 11 (a) Polishing the wing

(b) After polishing the wing

The hinged surface v-notch provide an 60°movement around the hinge , After completion of all four frames the two frames are cut off cross-section wise at an solid projection angle which is nothing but the, polyhedral angle which is 7° .

Fig. 12. Checking the angle of

Then the finolex pipes are inserted in to the wing ,they are rolled with carbon fibre cloth, which are already drop in to the epoxy and resin mixture, After the coating complicated, we make exact size of slots on the wing, and we put two piece of wooden piece at both side, to the of the pipes after that we totally glued at the both side by hot glue join by injecting hot glues in to the slots, Then we load weight on it to give pressure over it so that it properly insert in to the slut tightly .Next we just live for a 3hr further dry the glued part, The weight is loaded over the wing and the surface where finolex pipes are inserted. The carbon-fibre cloth coating over the finolex pipe and shaft is inserted inside the slot of the wing.

Fig.13 (a) Finolex pipe

(b) checking the angle wing

8. Application

Composite UAV have wider application and it can be deploy in multiple mission. kalpana 1 is very stable, durable and agile flying machine.

- Its integrated prototype versions with sensors and camera can be deploy for civilian purpose like inspection of terrain pipeline, buildings, road traffic, search and rescue, agriculture and forestry fire fight and security application.
- It can be deploy for scientific purpose like area mapping and meteorology, environmental monitoring and surveillance.

Fig.14. Composite UAV Kalpana 1

9. Conclusion

Composite UAV have several advantages except the cost of manufacturing compare to flight performance and clean aerodynamics. The fabrication process precision work during the fabrication may be chance to change wing angle of attack or tail-boom not fixed straight it may cause UAV can fly but not give aerodynamics performance or may it will damage the aircraft . It is inevitable that technological developments will permit UAVs to assume many military roles.

NDT Test result shown there is no defect on UAV near landing gear, wing joint and motor mount. Compare to the flight par cost composite UAV have significant cost effective advantage and physical inspection not able find any kind of external damage on body of UAV. UAV completed 30 flights including 20 crash and 10 normal landing .we expecting this vehicle have capable of more than 100 flight and every 25 flight we set of health monitoring for UAV NDT inspection to find out reliability of composite UAV.

Composite structures are the most popular technology employed in small UAV structures. This technology provides high accuracy, good quality of surface. The biggest advantage of composite technology is possibility of airframes manufacturing with very complicated shape. Disadvantage of this technology is high entry cost barrier related to mould preparation.

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