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A Review on Various Case Studies of Solar Powered Aircraft

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ABSTRACT: Finding alternative energy resources in a certain aspect to better sustaining our planet.With rapid Change in climate in the past century,it is become more prevalent that most of these rapid changes stem through anthropogenic means.Generally domain Aircraft uses conventional fuel. These fuel having limited life, high cost and pollutant.Also nowadays price of petrol and other fuels are going to be higher, because of scarcity of those fuels. So there is great demand of use of non-exhaustible unlimited source of energy like solar energy. Solar aircraft is one of the ways to utilize solar energy. Solar aircraft uses solar panel to collect the solar radiation for immediate use but it also store the remaining part for the night flight.

KEYWORDS: Solar powered aircraft,Solar cell,Aerofoil shape,Bernoulli's principle

I. INTRODUCTION

[1-3]Solar powered aircraft equipped with solar cells covering its wing, it retrieves energy from the sun in order to supply power to the propulsion system and the control electronics, and charge the battery with the surplus of energy.During the night, the only energy available comes from the battery, which discharges slowly until the next morning when a new cycle starts.A converter, called Maximum Power Point Tracker, ensures that the maximum amount of power is obtained from the solar panels. This power is used firstly to power the propulsion group and the onboard electronics, and secondly to charge the battery with surplus of energy.During the night, as no more power comes from the solar panels, only the battery supplies the various elements.

[2-3]Solar Panel: absorb sunlight as a source of energy to generate direct current electricity. A photovoltaics (PV) module is a packaged, connected assembly of photovoltaic solar cells available in different voltages and wattages. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity.

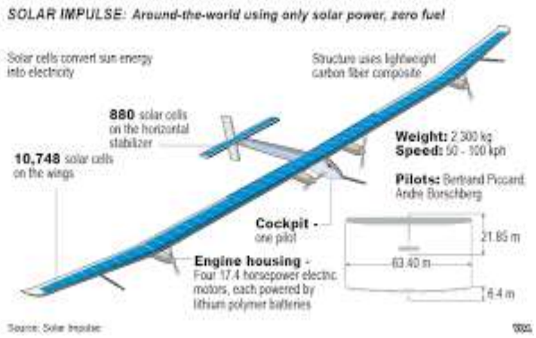

Fig.1 Solar Powered Aircraft

Fuel Cell: A battery and a fuel cell both store energy in the form of reactants and produce power through electrochemical reactions in cells. Unlike a battery, which is self-contained (all its components for storing energy and producing power are within a sealed volume), the fuel cell stores one or both of its reactants externally. The energy capacity of a system using a fuel cell can be made larger simply by storing more fuel.

The fuel cell brings hydrogen and oxygen gases together in a controlled reaction to produce electrical power and water during night time. During daylight hours, electrolytic cells recharge the system by decomposing the same water (by electrolysis) into hydrogen and oxygen gases that are then stored at high pressure in tanks in the wing. The reactants are recycled each day. This type of system is called a regenerative fuel cell.

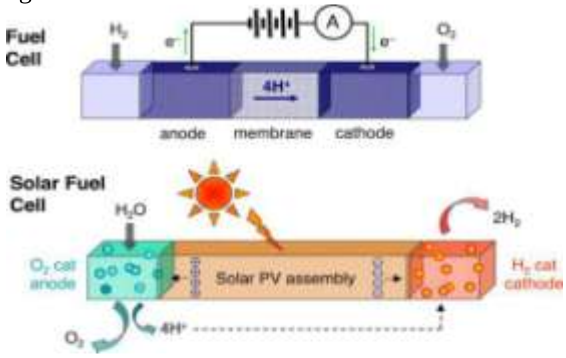

Fig.2 Working of Fuel cell

The system can be designed to use separate electrochemical cells to create electricity and to electrolyze water, or to use the same cells to perform both functions (at a very small sacrifice in efficiency). The second type is a reversible system called a unitized regenerative fuel cell.

II. WORKING PRINCIPLE

[3]Our basic principle is to use solar power by means of aircraft. And this thing can be done by solar panels which cover the whole surface of wing. This panels converts radiative energy into electric energy. This electric energy is used to charge battery which drives electric motor. Propeller which is mounted on motorshaft produces thrust continuously. Because of this, aircraft is moved and force is produced on wing by dynamic effect of air which opposes the downward force of weight. During the night, the only energy available comes from the battery.

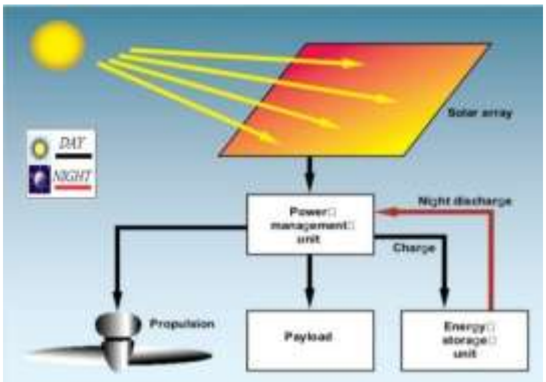

Fig.3 Working of solar powered aircraft

III.CASE STUDIES OF SOLAR POWERED AIRCRAFT

During manufacturing of aircraft various problems arises such as aerofoil shape of wings of aircraft for better lifting capacity,effect of altitude and latitude for maximum efficiency,storage of energy during day time and utilize it during night time,material used for manufacturing of aircraft.

III-1]Aerofoil shape used for wing:-

[3]One of the basic criteria to produce most effective lift force is a shape of wing aerofoil, this shape should have optimal surface area .Shape of aerofoil provides lift of aircraft. Also it should have better surface area for its smooth functioning. All airfoils are worked on same principle i.e., Bernoulli's principle. It shows the relationship between velocity and pressure in the air:

$$P+\frac{1}{2}\rho v^2+g\rho h=k$$

where,

P=Pressure(Pa)
ρ=Density(kg/m3)
v=Velocity(m/s)
g=Acceleration(m/s2)
h=Distance from reference, measured in opposite direction of the gravitational force(m)
k=constant(kg/m2)

This principle describes that if ρ,g,h will be constant then pressure will drop down when flow velocity increases. It means area under high velocity will have lower pressure and vice versa. Air which is moving over the wing moves faster than the air below as shown in fig.4

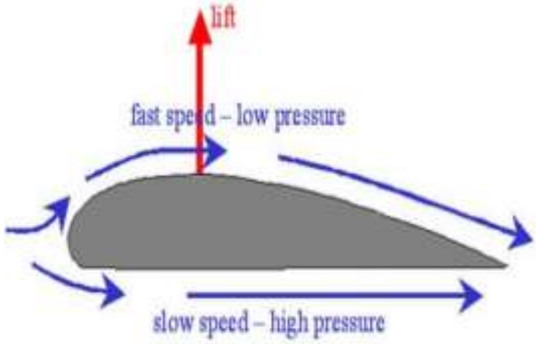

Fig.4 Bernoulli's principleFaster-moving air above exerts less pressure on the wing than the slower-moving air below. The result is an upward push on the wing. This is called lift.This is the reason why wings are shaped in such a way that air above the upper surface moves fast. And this can be done by moving air above the wing through longer distances than the air below the wing in same time. That's why upper surface of wing is more curved than its lower surface. Till now many airfoils have been developed for different purposes, like low or high speeds, or stability. We have used symmetrical aerofoil because the wings will be hand fabricated and developing a cambered airfoil will be difficult. That means there will be no camber. We have selected NACA aerofoil of 4 digit i.e., NACA 0015. [5]The 'NACA' aerofoils are shapes for aircraft wing developed by the National Advisory Committee for Aeronautics (NACA).

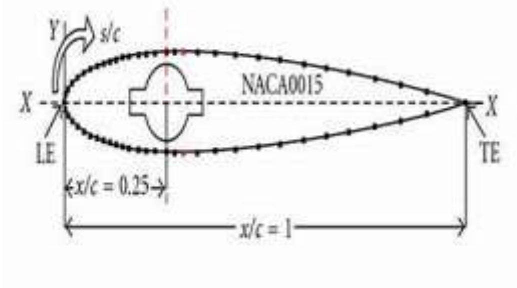

Fig.5 NACA 0015 Airfoil

The NACA four-digit wing sections define the profile by:
1.first digit describing maximum camber as percentage of the chord.
2.second digit describing the distance of maximum camber from the airfoil leading edge in tens of percent's of the chord.
3.two digits describing maximum thickness of the airfoil as percent of the chord.

Equation for a symmetrical 4-digit NACA airfoil:-

The formula for the shape of a NACA 00xx foil, with "xx" being replaced by the percentage of thickness to chord, is:

$$Yt = 5t[0.2969\sqrt{x} - 0.1260\,x - 0.3516\,x^2 + 0.2843\,x^3 - 0.1015\,x^4]$$

Where:-

- x is the position along the chord from 0 to 1.00 (0 to 100%),
- Yt is the half thickness at a given value of x (centerline to surface),
- t is the maximum thickness as a fraction of the chord (so t gives the last two digits in the NACA 4-digit denomination divided by 100).

III-2]The impact of altitude, latitude, and endurance duration on the power of a high altitude solar powered Aircraft :-

[7]Basically, the lift force generated by the aircraft at the appropriate flight level must be equal to its weight; likewise, the drag must be equal to the thrust. The required power for level flight (P_{lev}) can be calculated by:

$$P_{lev} = \frac{c_D}{c_L^{1.5}}\sqrt{\frac{2ARg^3}{\rho}}\,\frac{m^{1.5}}{b}$$

$$C_D = C_{DO} + \frac{C_L^{1.5}}{e\pi AR}$$

Where, ρ the air density, AR the aspect ratio, eis the span efficiency factor, b is the span, CL is the design reference lift coefficient of the aircraft, m is the total mass, and Cdo is the zero lift drag coefficient.

The total electric power consumption ($P_{electot}$) can be given by:

$$P_{electot} = \frac{1}{\eta_t}P_{lev} + \frac{1}{\eta_{bec}}(P_{av} + P_{pld})$$

Where η_t is the efficiency represented the powerlosses in the gearbox, propeller, motors, and the controller.

P_{pld} & P_{av} are the required power for given payload and avionics systems

respectively.(η_{bec}) is the voltage converter efficiency.The consumed power during the daytime (T_{day}) must be enough to operate the aircraft over a 24 hour period (T_{day}+ T_{night}). The solar energy can be saved using storage schemes such as a fuel cell or batteries.

The performance of the power storage capability during the charging and the discharging cycle is not ideal and hence this has to be taken into account by employing the charging and the discharging efficiencies (η_{chrg})and (η_{dchrg}). The total energy required

($E_{elec\ tot}$) over a 24-hour period for level flight can be evaluated by:

$$E_{electot} = P_{electot}(T_{day} + \frac{T_{night}}{\eta_{chrg}\eta_{dchrg}})$$

This total electric energy must beequal to the net solar energy consumed by the solar cell panels.The available solar energy (E_{sol}) inside the atmosphere depends on the flight altitude, latitude, the number of daylight hours and the time of the year.The effects of the curvature of the panels and the

efficiencies of both the solar cells and the power adapter can be incorporated in the energy equation by η_{cbr}, η_{sc} and η_{mppt} respectively:

$$E_{electot} = E_{sol}A_{sc}\eta_{cbr}\eta_{sc}\eta_{mppt}$$

where A_{sc} is the total solar cell area.

The mass and the power of each aircraft component can be estimated as a constant fraction of either the structural mass or the total mass, or of the total power. These fractions were evaluated statistically from existing solar powered UAV data, which are likely to improve with future technological developments.

III-3]Storage of energy:-

[4]Batteries are the most common energy carrier component of electric aircraft, due to their relatively high capacity. Batteries were the earliest

source of electricity, first powering airships in the nineteenth century. These early batteries were very heavy and it was not until the arrival of technologies such as nickel-cadmium (NiCd) rechargeable types in the second half of the twentieth century, that batteries became a practical power source for aircraft. Modern battery types include lithium-based and a number of other less widely used technologies. Such batteries remain a popular power source today, although they still have limited endurance between charges and hence limited range.A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity.Capacity is measured in units such as amp-hour (A·h).

The higher the discharge rate, the lower the capacity. The relationship between current, discharge time and capacity for a lead acid battery is approximated (over a typical range of current values) by Peukert's law:

$$t = \frac{Q_p}{I^K}$$

where

- Q_p is the capacity when discharged at a rate of 1 amp.
- I is the current drawn from battery (A).
- t is the amount of time (in hours) that a battery can sustain.
- k is a constant around 1.3.

III-4]Types of solar cell going to use:-

[2]Crystalline silicon cells: The most prevalent bulk material for solar cells is crystalline silicon (abbreviated as a group as c-Si), also known as "solar grade silicon". Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon, or wafer. E.g., monocrystalline-silicon(c-Si),Polycrystalline silicon, or multicrystalline (poly-Si or mc-Si). Crystalline solar cells are wired in series to produce solar panels.

Monocrystalline – made from a single large crystal,cut from ingots. Most efficient, but also the most expensive. Somewhat better in low light conditions.

Polycrystalline – basically cast blocks of silicon which may contain many small crystals. This is probably the most common type right now.

cells, Gallium arsenide multijunction, Lightabsorbing dyes (DSSC), Quantum Dot Solar Cells (QDSCs), Organic/polymer solar cells, Silicon thin films.

However in most of aircraft monocrystalline cells are used because of their lightness, flexibility and efficiency.

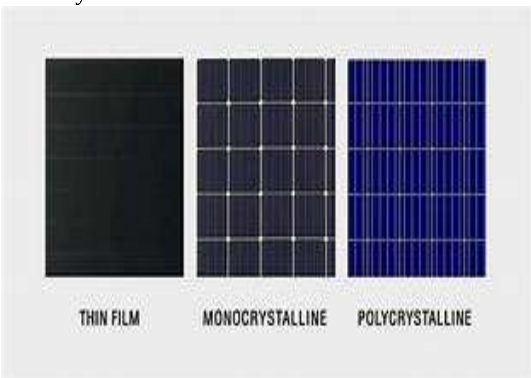

Fig.6 Types of solar cell

III-5]Material used for solar powered Aircraft :-

[6]There are many materials like aluminium, magnesium, titanium, steel, and their alloys; also some plastic is used in conventional aircraft.

Aluminum and alloy :- Aluminium is ideal for aircraft manufacture because it’s lightweight and strong. Aluminum is roughly a third the weight of steel, allowing an aircraft to carry more weight.Furthermore, aluminum’s high resistance to corrosion ensures the safety of the aircraft and its passengers.Aluminium Grades used in manufacturing of aircraft are:-

2024 – Typically used in aircraft skins, cowls, aircraft structures. Also used for repair and restoration.

7075 – Commonly used to strengthen aircraft structures. 7075 is a high-strength alloy and is one of the most common grades used in the aviation industry.

Magnesium and alloy :- Weight reduction is the reason for using magnesium alloys in aircraft. Magnesium is 34% less dense than aluminium (1.74 compared with 2.65 g/cm^3).

IV. CONCLUSION

Based on knowledge we get from paper we are going to design and develop a Solar Aircraft by using proper methods.Problem understanding and solving it using various approches that we are studied in this paper.

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