Design and Analysis of Propeller

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Abstract: The objective of this thesis is "Optimization of propeller for the existing UAV to produce maximum thrust of 1000N rotating at 8000rpm at higher speed". Diameter of propeller is restricted to 1000mm. Maximum power available is 40KW.The propeller will be made using carbon fiber composite to make it light weight .Propeller is one of the main component in a unmanned aerial vehicle which is responsible to produce thrust. The cross area of propeller edge is an airfoil segment which is ordinarily differing from tip to hub in terms of chord or twist distribution .There are many variables for designing the propeller such as pitch angle, flow angle, chord distribution at the blade span and twist distribution. Blade elements theory will be used for designing the propeller. The blade span is divided into number of cross sectional elements and for each element thrust generated and torque required will be calculated and summed to find total thrust and torque for the propeller. For optimization of blade, these variables will be varied iteratively and optimum solution will be selected.

1. Introduction

This thesis investigates aerodynamic design and analysis of UAV propeller in order to achieve improved thrust at higher speed over a wider operating range. The use of composite design will be employed to modify the stiffness properties of the propeller for a given geometry, providing blade deflections which result in improved aerodynamic characteristics. Optimization will be made with specific reference to the flight characteristics, with possible applications to similar aerospace-propellers. Preliminary calculations will be conducted to determine the optimal blade geometry using conventional blade element theories, along with a literature review of previous works and related topics. Initial analysis will involve analytical calculations based on the blade element theory with some initial inputs. Using those calculations a propeller is modeled and flow analysis is done for the validation and verification of analytical techniques.

The results of this analysis will then be used to conduct an extended finite element analysis of a propeller conforming to the ideal blade geometry in order to provide the propeller deflections under a certain applied load. To further assess the deflections of the propeller under aerodynamic loading, validate thrust and torque calculated using blade element theories, dynamic Fluid-Structure Interaction analysis techniques will be developed, with results and suggestions of further work made.

2. Description of Propeller

All through the improvement of the controlled flight as we probably am aware it, each airplane require some sort of gadget to change over motor energy to some type of push. About the greater part of the early handy flying machine outlines utilized propellers to make push.

A propeller is a pivoting airfoil which comprises of at least two sharp edges appended to a focal center point that is mounted on the motor crankshaft. The capacity of propeller is to change over motor energy to valuable push. Propeller cutting edges have a main edge, trailing edge, tip, shank, confront and a back. Propellers change over revolving movement from cylinder motors, turboprops or electric engines to give the propulsive power. They might be settled or a variable pitch. The propeller is normally appended to crankshaft of a cylinder motor, either specifically or through lessening unit. Light air ship motors frequently don't require many-sided quality of adapting, however on bigger motors and turboprop air ship it is basic.

2.1Blade Angle:

The edge between propeller's plane of pivot and the harmony line of propeller airfoil. The cutting edge point is the edge, harmony line of aerofoil makes with the propeller's rotational plane and is communicated in degrees. In view of the wind cutting edge will change all through its length, so typically standard sharp edge is measured at the edge station 75% of the separation from the center point focus to the edge tip. The point between aerofoil harmony line and the helical flight way at sharp edge station is, obviously, the approach and the edge between the helical flight way and the rotational plane is the edge of progress or helix edge.

The AOA and helix point change with the rotational-and-forward-speed.

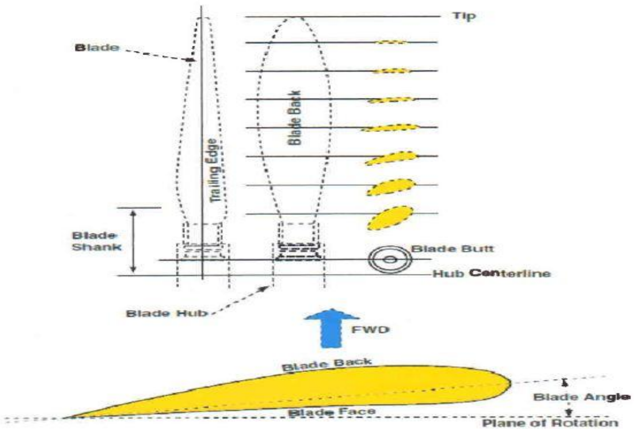

Figure 1: Airfoil forward speed

2.2 Blade Element Theory

A generally straightforward strategy for foreseeing the execution of a propeller is the utilization of Blade Element Theory. In this technique the propeller is isolated into various autonomous segments along the length. At each area a power adjust is connected including 2D segment lift and drag with the push and torque created by the segment. In the meantime an adjust of hub and rakish energy is connected. This delivers an arrangement of non-direct conditions that can be illuminated by emphasis for every edge segment. The subsequent estimations of area push and torque can be summed to foresee the general execution of the propeller. The hypothesis does exclude optional impacts, for example, 3-D stream speeds prompted on the propeller by the shed tip vortex or spiral segments of stream initiated by precise increasing speed because of the turn of the propeller.

Since the propeller sharp edge will be set at a given geometric pitch point, nearby speed vector will make a stream approach on the segment. Lift and drag of the segment can be computed utilizing standard 2-D aerofoil properties. The lift and drag segments typical to and parallel to the propeller circle can be computed so the commitment to push and torque of the contend propeller from this single component can be found. The two main methods used to determine the aerodynamic characteristics to be applied in this investigation are Momentum Blade Element Theory (MBET) and Vortex Blade Element Theory (VBET)[1].

2.3 Methodology

Primarily the analytical calculations are done based on Blade element hypothesis and equations. Since propeller blade is nothing but the stacking of the airfoil sections, we divide the blade into number of small airfoil sections. Choosing the appropriate angle of attack i.e., at L/D max say at 7 degrees for efficient operation. Each blade has its own value of L/D max .Therefore there exists a twist while stacking up of the airfoil sections to form a propeller blade creates a low flow incidence at various stations from root to tip .The AOA is, function of blade element pitch angle, effective pitch angle. Rotational speed of each section is different but the forward speed is the same as the pitch setting is to be varied from root to tip to keep up best angle of attack. Rotational speed varies with radius from root to tip as the forward sped let us say is same from , the pitch setting needs to be varied from hub to tip so as to maintain best AOA from each section as a result there exists TWIST.

There exist 2 velocity components

a) Axial velocity component: constant

b) Tangential velocity component: varies from root to tip.

3. Iterative Methods

The iterative strategies used to take care of issues of nonlinear programming vary as per whether they assess Hessian's, angles, or just capacity esteems. While assessing Hessian's (II) and slopes (G) enhances the rate of merging, for capacities for which these amounts exist and change adequately easily, such assessments increment the computational many-sided quality of every cycle. Now and again, the computational multifaceted nature might be too much high.

We have done some iteration based on single variable method. In this iteration process we have taken some aerofoil models and done some iteration. Out of it we consider best performance aerofoil and we do validate the outcome results of excels with the help of fluent analysis on same aerofoil. We compare both results of excel and computations and then write the error

4. CFD Introduction

Computational liquid elements, generally truncated as CFD, are a branch of liquid mechanics that utilization's numerical techniques and calculations to take care of and investigate issues that include liquid streams. PCs are utilized to play out the counts required to recreate the connection of fluids and gasses with surfaces characterized by limit conditions. With high- speed supercomputers, better arrangements can be accomplished. Progressing research yields programming that enhances the exactness and speed of complex reenactment situations such is turbulent streams.

Elle general process for playing out a CFD examination is laid out beneath to give a reference or understanding the different parts of a CFD recreation. The procedure incorporates:

• Depend on the particular reason and stream states of the issue, diverse CFD codes can be decided for various applications (aviation, marines, burning, multi-stage streams, and so forth.)

• Once purposes and CFD codes picked, "CFD process" is the means to set up the IBVP issue and run the code:

1. Geometry
2. Material science (Setup)
3. Work
4. Illuminate
5. Result

4.1 CFD Process

4.1.1. Geometry

• Selection of a proper facilitate
• Determine the space size and shape
• Any disentanglement required?
•What sorts of shapes should have been utilized to best purpose the geometry? (lines, roundabout, ovals, and so forth.)
• For business code, geometry is generally made utilizing business programming (either isolated from the business code itself, similar to Gambit)
• For look into code, business programming (e.g. Gridgen) is utilized.

4.1.2. Physics (setup)

• Flow conditions and liquid properties
1. Stream conditions: inviscid, thick, laminar, or turbulent, and so on.
2. Liquid properties: thickness, consistency, and warm conduction
3. Stream conditions and properties for the most part introduced in dimensional shape in mechanical business CFD programming, though in non-dimensional factors for inquire about codes. Choice of models: distinctive models normally settled by codes, choices for client to pick

Starting and Boundary Conditions: not settled by codes, client needs indicate them for various applications.

4.1.3.Mesh: Meshes ought to be very much intended to determine imperative stream highlights which are needy upon stream condition parameters (e.g., Re, for example, the lattice refinement inside the divider limit layer

• Mesh can be created by either business codes (Gridgen, Gambit, and so forth.) or research code (utilizing mathematical versus PDE based, conformal mapping, and so on.)
• The work, together with the limit conditions should be sent out from business programming in a

specific arrangement that can be perceived by the exploration CFD code or other business CFD programming.

4.1.4 .Solve
• Setup suitable numerical parameters
• Choose suitable Solvers
• Solution strategy (e.g. in-compressible streams)
Comprehend the energy, weight Poisson conditions and get stream field amounts, for example, speed, turbulence power, weight and essential amounts (lift, drag powers).

4.2 Use of CFD Results: The level of exactness required from a CFD examination relies upon the coveted utilization of the outcomes. A reasonable plan exertion might be content with general stun structure data, though a nitty gritty outline may require precise assurance of the weight recuperation. Every amount to be resolved by and large has its own precision prerequisite. Levels of believability may shift as per the data required.

4.3 Designs in Catia: Catia V5 is the chief CAD arrangement of Dassault Systems, and part of a detailed suite of-apparatuses, normally alluded to-as-PLM. We picked Catia V5 as our essential CAD framework, in light of the power and versatility-om, as well as because of the undeniably huge piece of the pie that is being picked up by Catia V5.I t is our objective to be pioneers in the range of offsite CAD configuration designing, and we know the course of our industry is plainly pointing toward Catia V5. Additionally, it is our conclusion that there are no better CAD framework applications, than Catia VS. The way that Catia V5 is setting the pattern for mechanical, industrial applications.

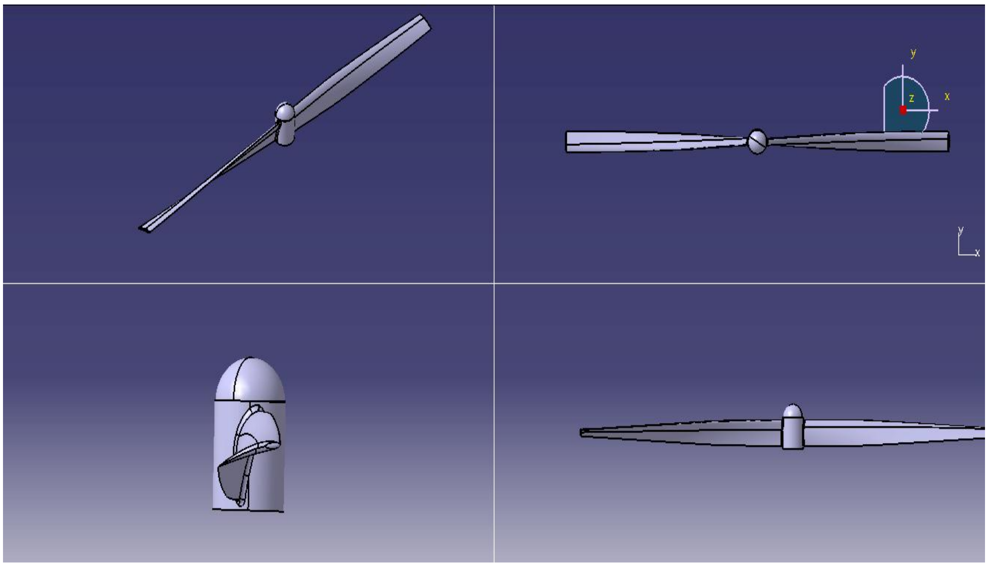

Figure 2: Catia model

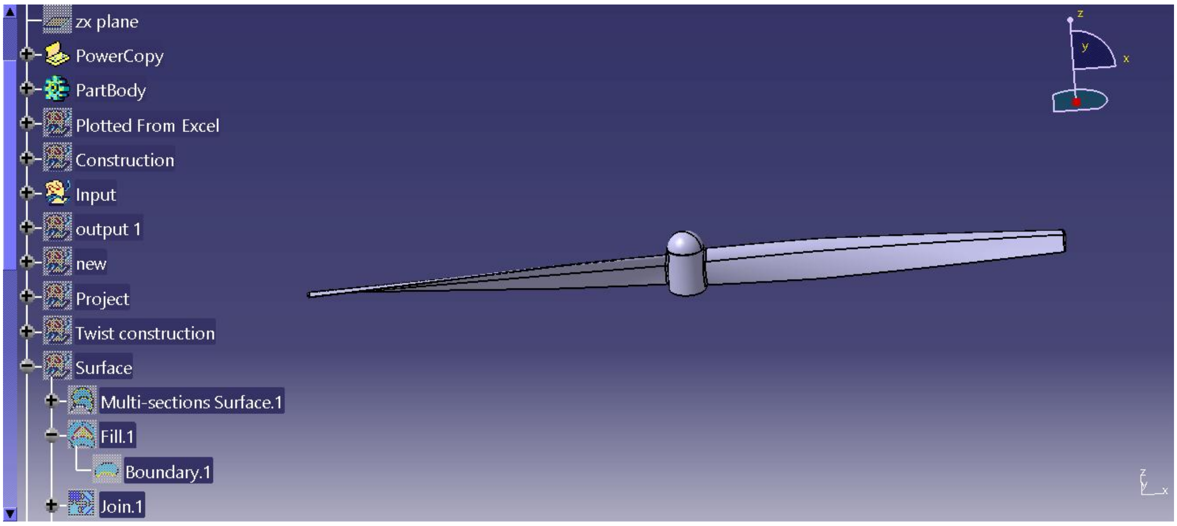

Figure 3: Blade profile

4.4 Validation and Verification:

Table 1: Specifications of blade

S.No	Parameters
1	2bladed propeller
2	Radius of hub = 50 mm
3	Radius of Propeller = 500mm
4	Power = 40kw
5	Rpm = 8000

- Modeling software : Catia V5
- Analysis Software used : ANSYS FLUENT
- Model : 3 —dimensional
- Flow conditions : laminar
- Flow properties : inviscid
- Mesh type : tetrahedral grids
- Total number of nodes : 36838
- Total number of elements : 1, 88,426
- Number of iterations : 30

5. Results

Results we obtained in the analysis of propeller using fluent are approximate to the analytical solutions and the error is 4.56 and obtained values are:

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Analytical results
Thrust = 946.32 N
Power = 38.96 watts

Computational results
Thrust = 976.3 N
Power = 46.512 watts

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