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Analysis Of NACA 6412 Airfoil (Purpose: Propeller For Flying Bike)

Amit Singh Dhakad [1] Amit Sawarni [2] Gagan Sahu [3] Novel Sahu[4]
[1,2,3,4] Department Of Mechanical Engineering, Christian College of Engineering And Technology Chhattisgarh Swami Vivekanand Technical University Bhilia (Durg), C.G, INDIA.

Abstract:*The propeller for the aircraft is always an pull or pushed propeller. For the pull propeller it is always driven with the help of an engine being coupled with crank shaft and for the push propeller it has been always driven with the help of chain drive or by the pulley arrangement which means an propeller is connected to the wheels of the vehicle through a chain or belt drive. So, that when the wheels rotate it will rotate or spin the propeller in order to produce thrust for the forward movement. With reference to the paper " Analysis of Down-Wind propeller Vehicle" the selected Airfoil is NACA 6412 which does very well with the performance and a wind driven vehicle travels faster than the wind along its direction. The analysis i carried out in the Java Prop software to study the behaviour of NACA 6412 airfoil selected as push propeller to fly the bike in air to have the less induced drag and also with minimum drag for the same amount of lift and wing area. Even for the Wind Turbine it has been chosen best according to the paper" Design and Blade Optimisation of Contra rotation double Rotor Wind turbine" for its optimum results for the 3 blades with 600 mm diameter in the front and rear.*
Keywords: *NACA 6412, Propeller, Wind Turbine*

I. Introduction

To drive fly the vehicle in air one always needs a requirement of thrust. The thrust is based on the Newton's second law of motion. The main purpose of the propeller is to cut the air and to provide the movement (pull or push) of a vehicle in a road or in air. The best cutting angle provides the best performance of a propeller. While the wings helps in gliding much more than propeller. Also the performance of a propeller based on its diameter and the blade chosen for an angle of attack. The best propeller always results the minimum fuel consumption due to the minimum drag.

II. Research And Analysis

Objective:

With reference to the paper: Dhakad, Amit Singh, and Arun Singh. "Power Requirement for Flying Bike."International Journal of Innovative Research and Development 3.5 (2014), the required thrust is 88.75N for speed (axial vel.) = 16.6 m/s=60km/hr and 487.00 for speed (axial vel.) =38.88 m/s=140km/hr, the objective is to find the suitable propeller among 2 and 3 blades.

The input values for design and analysis in Java Prop are:

Propeller Chosen	NACA 6412
Blade	2 and 3 (for analysis)
Propeller diameter	580mm=0.58mm
Propeller spinner	19 mm
Max revolution per minute	8000 rpm
Max Thrust (T)	487.00 N
Max Velocity (V)	140 km/hr

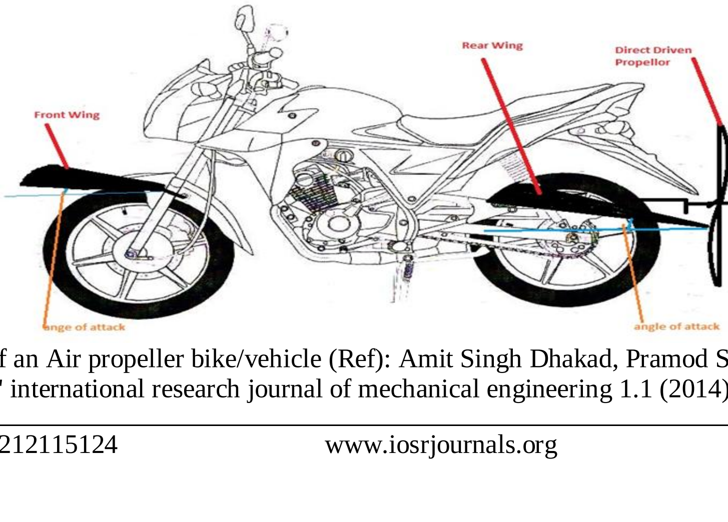


Fig 1 Side view of an Air propeller bike/vehicle (Ref): Amit Singh Dhakad, Pramod Singh. "Flying Bike Concept." international research journal of mechanical engineering 1.1 (2014): 001-011.

Design card:

For analysis on Java Prop we have the design output data (for two and three blade propeller) as:

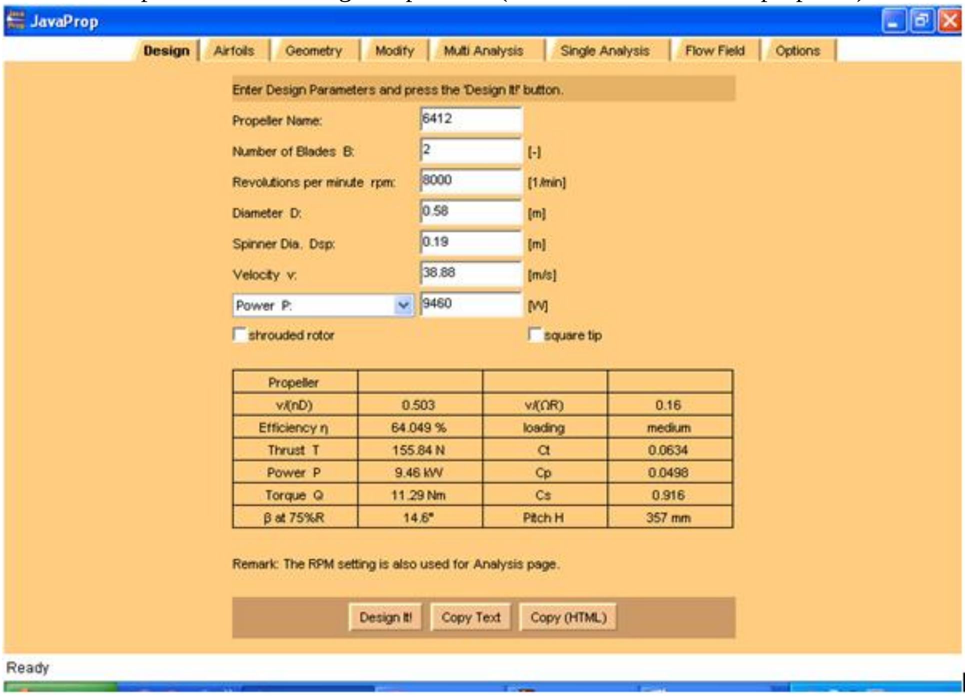


Fig 2 (Design parameter of 2 blade propeller)

So, by putting the input values we have output with certain properties of propeller where the propeller design is simple but without shrouded and squared tip condition.

Design card (shrouded)

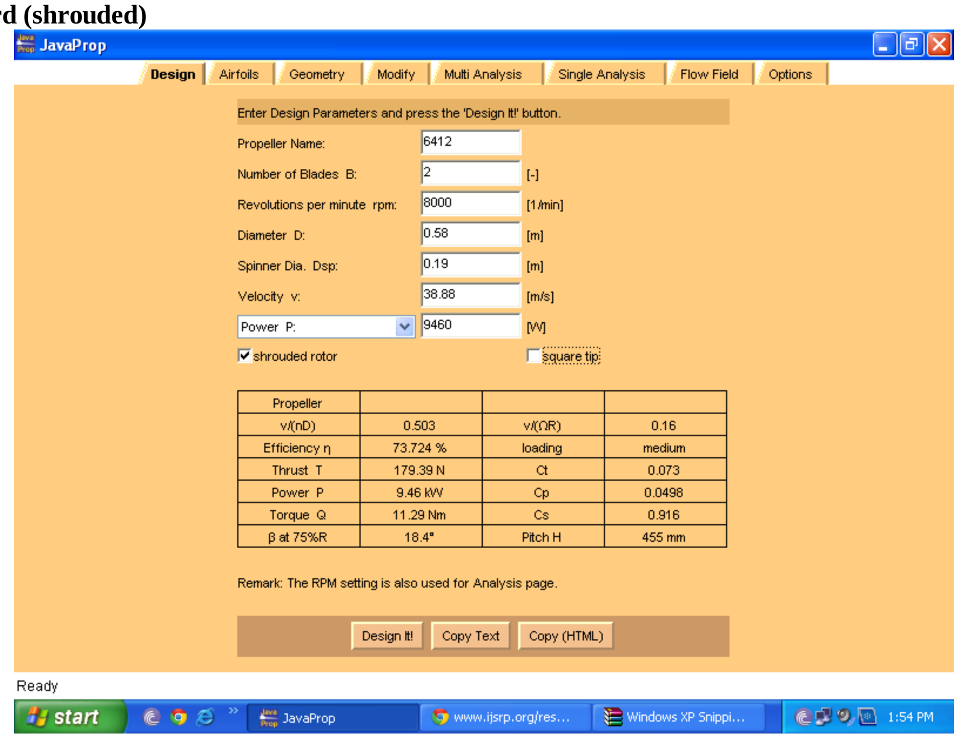
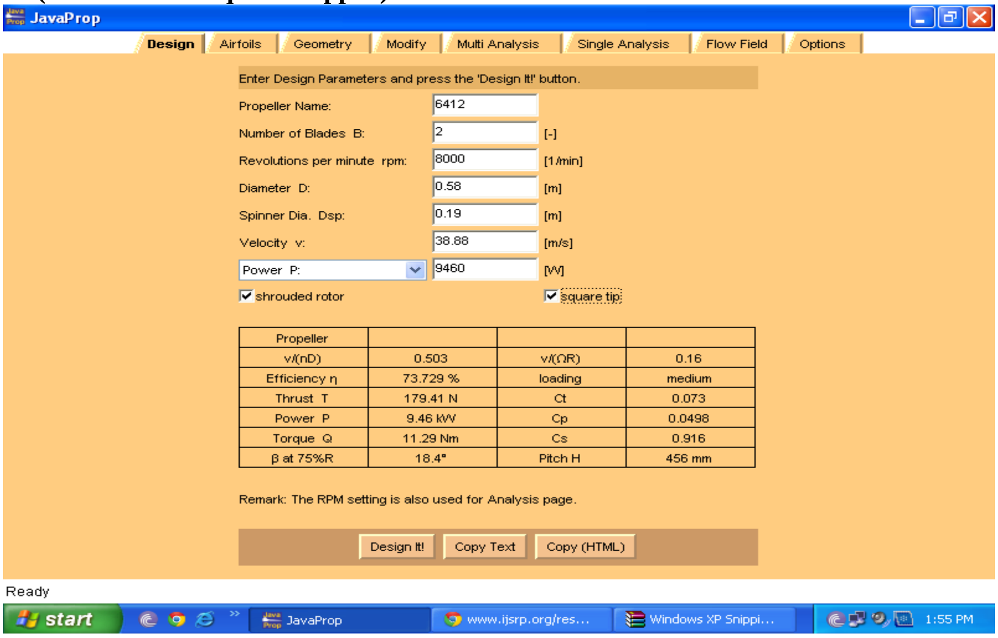


Fig 3 (Design parameter of 2 blade propeller under shrouded condition)

Shrouded:

The characteristic of propeller says that along the length of the propeller airfoil the thrust decreases and at tip it becomes zero. So, to avoid and to cover such thrust loss at the tip the propeller used to be shrouded and the thrust can be maximised.

Design card (shrouded and squared tipped)



Propeller			
v/(nD)	0.503	v/(ΩR)	0.16
Efficiency η	73.729 %	loading	medium
Thrust T	179.41 N	Ct	0.073
Power P	9.46 kW	Cp	0.0498
Torque Q	11.29 Nm	Cs	0.916
β at 75%R	18.4°	Pitch H	456 mm

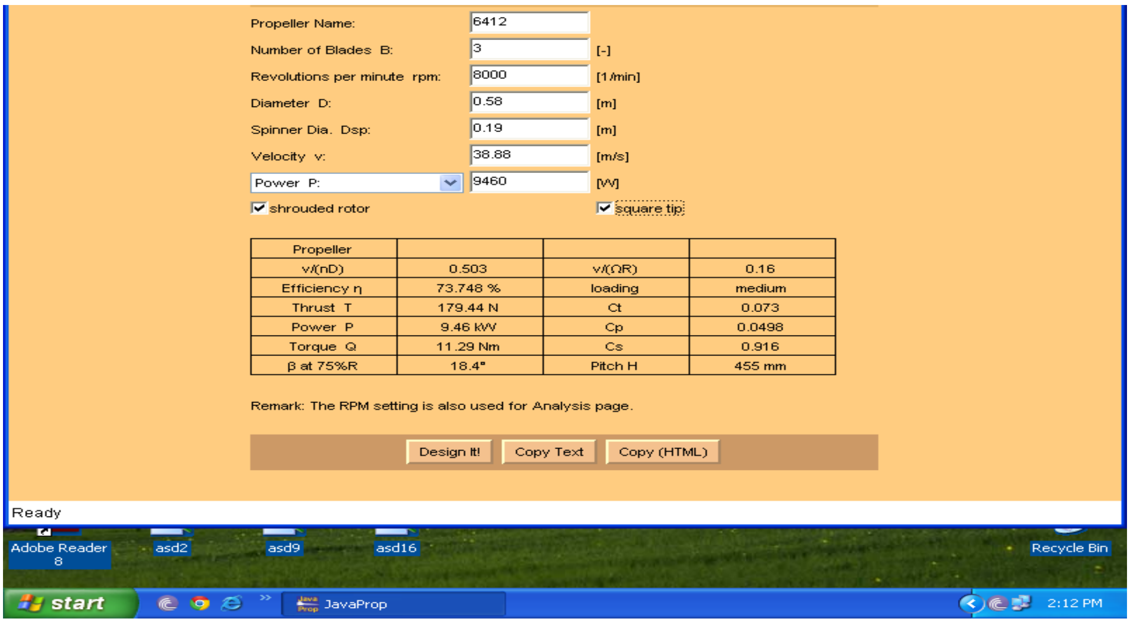
Fig 4 (Design parameter of 2 blade propeller with shrouded and square tip)

Square tip:

The square tip is the concept for creating the blades with rounded tips which produces a tip with final chord length by the simple extrapolation of the last section and the optimum design results good for the light and medium loaded propellers. And this is classified in terms of the coefficient of thrust. i.e.,

1. $T_C > 1$, (highly loaded)
2. $T_C > 0.25$, (medium loaded)
3. $T_C \leq 0.25$, (lightly loaded)

Note: So, under both shrouded and square tip condition the thrust can be maximise additionaly.



Propeller			
v/(nD)	0.503	v/(ΩR)	0.16
Efficiency η	73.748 %	loading	medium
Thrust T	179.44 N	Ct	0.073
Power P	9.46 kW	Cp	0.0498
Torque Q	11.29 Nm	Cs	0.916
β at 75%R	18.4°	Pitch H	455 mm

Fig 5 (Design parameter of 3 blade propeller)

Note: From fig 4 and fig 5, on design analysis we come to know that as we go for the increase of number of blades the propeller efficiency will increase with thrust for the same power and torque than two blade propellers with a different angle of attack along the length of the propeller but the weight consideration is the major issue for flight.

Analysis of two blade propeller in order to have minimum drag and weight:

Airfoils:

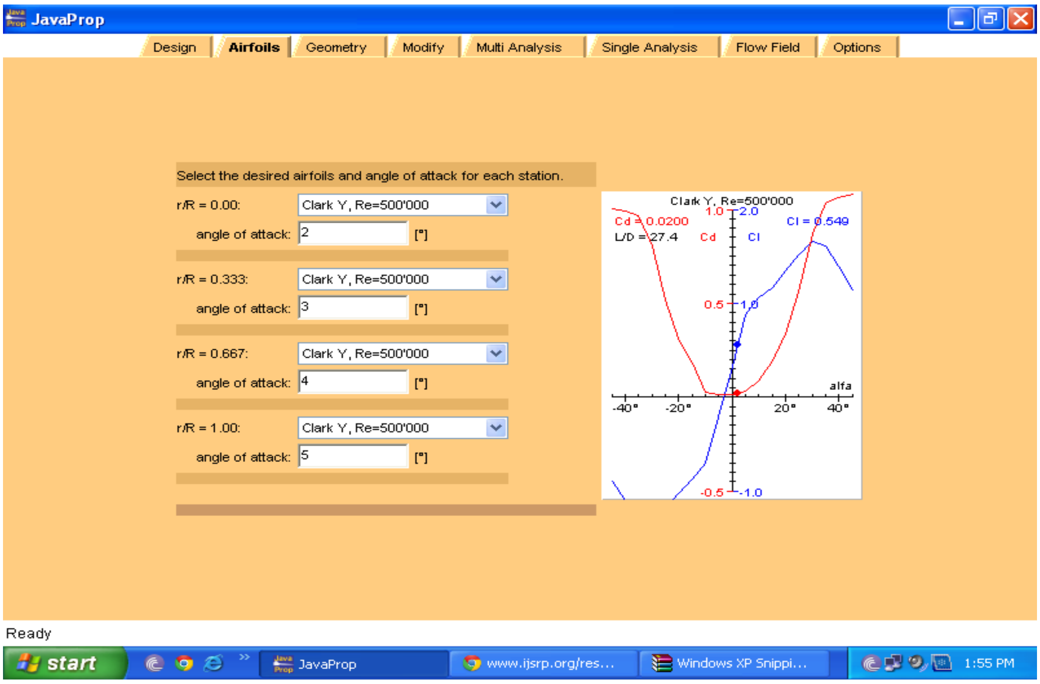


Fig 6 (Airfoil characteristics under Re=500000)

Note: The best performance of an airfoil depends on the blade angle. And by default the angle of attack is set as 3 degree always for best performance. And here we can see the red dot for coefficient of drag = 0.0200 and coefficient of lift = 0.549

Geometry card:

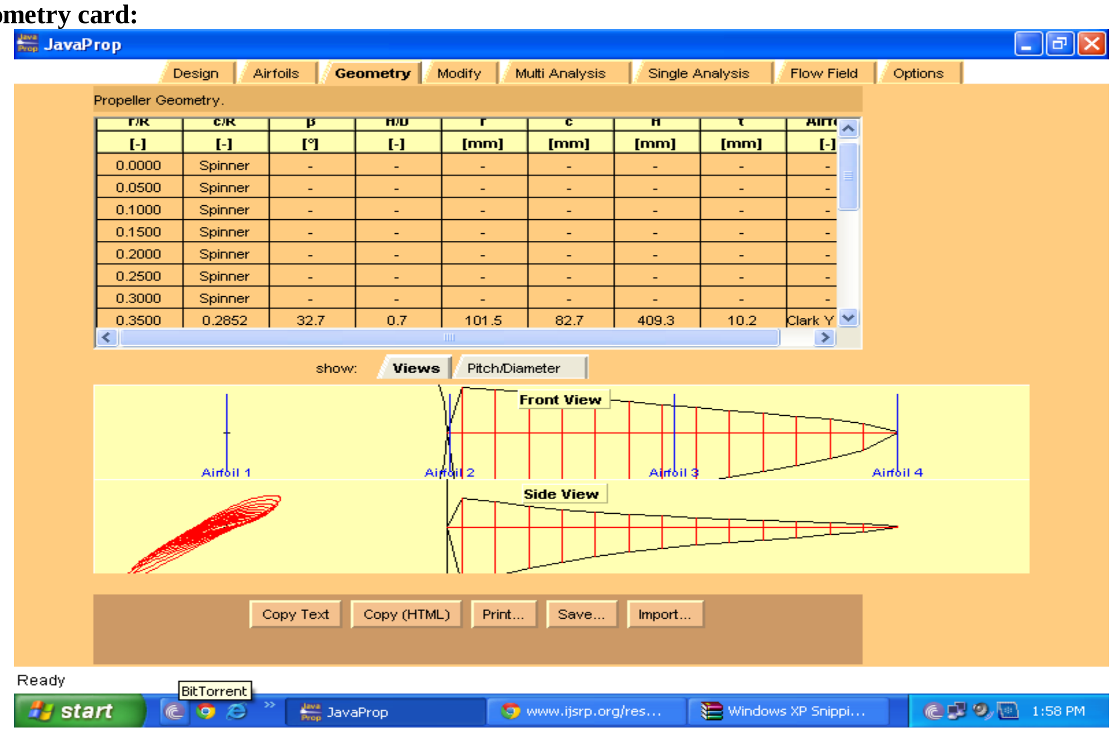


Fig 7 (Geometry of the Two blade propeller)

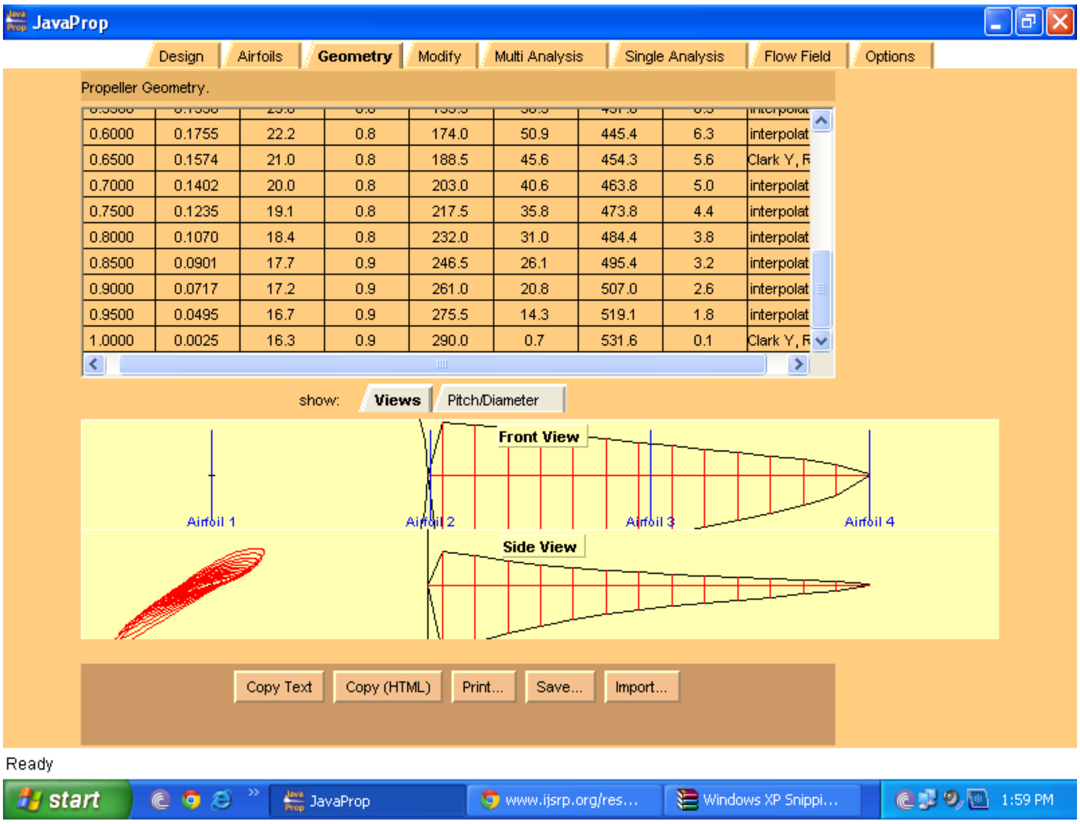


Fig 8 (Two blade propeller result along the length of propeller)

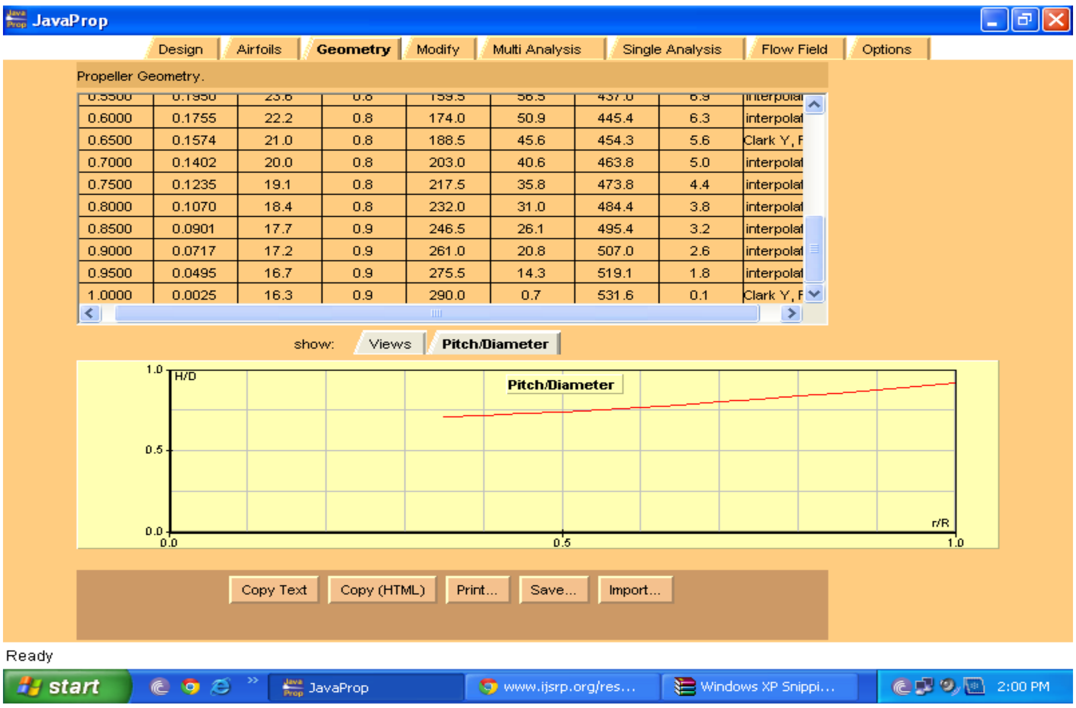


Fig 9 (Two blade propeller results with pitch along the diameter)

Therefore form the geometry card (Fig 6, 7 and 8) we have:

1. The 3D view of the propeller in red color and also the front and side view (fig 6)
2. The different properties like

(a) ‘r’ is the radius station or origin i absolute dimensions
(b) ‘c‘is the chord length in absolute dimensions
(c) ‘R’ is the radius of the propeller in m

(d) $\frac{r}{R}$ is the relative radius of propeller and can be read along the length of it.
(e) $\frac{c}{R}$ is the relative chord along the length of the propeller radius.
(f) 'H' is the pitch in mm
(g) 't' is the thickness of an propeller along the diameter of an propeller.

Note: Since the spinner is only to mount and spin the propeller their thickness, pitch and angle of radius is left blank as it nothing to do with it.

Modify card:

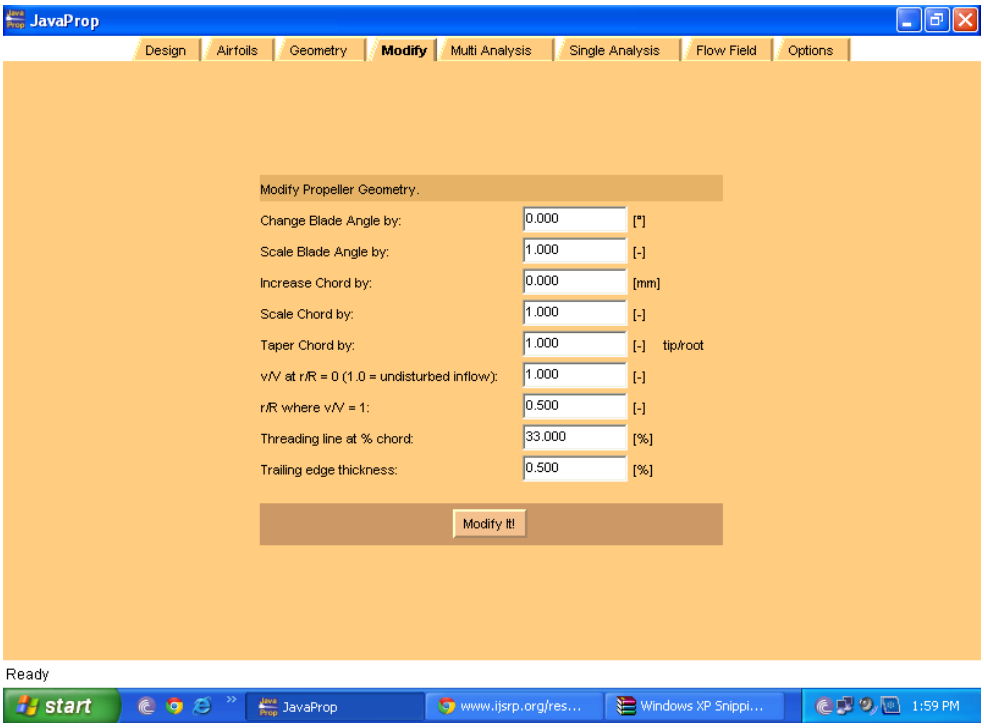


Fig 10 (The default desired data of an propeller)

The modify card is to modify in creation as per our requirement.

Multi Analysis card:

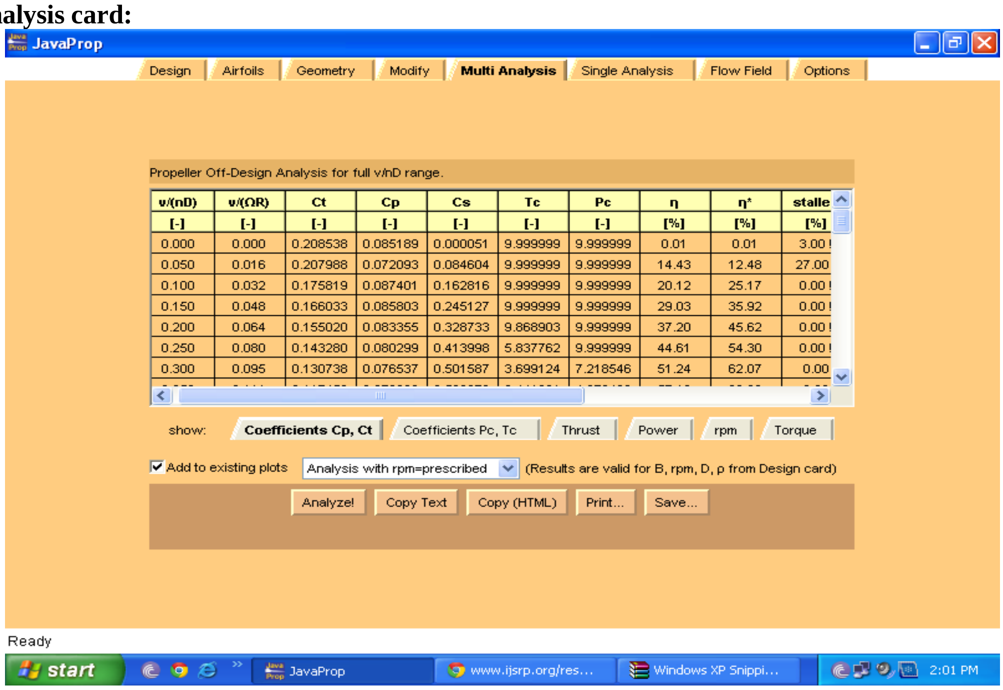


Fig 11 (The multi analysis result)

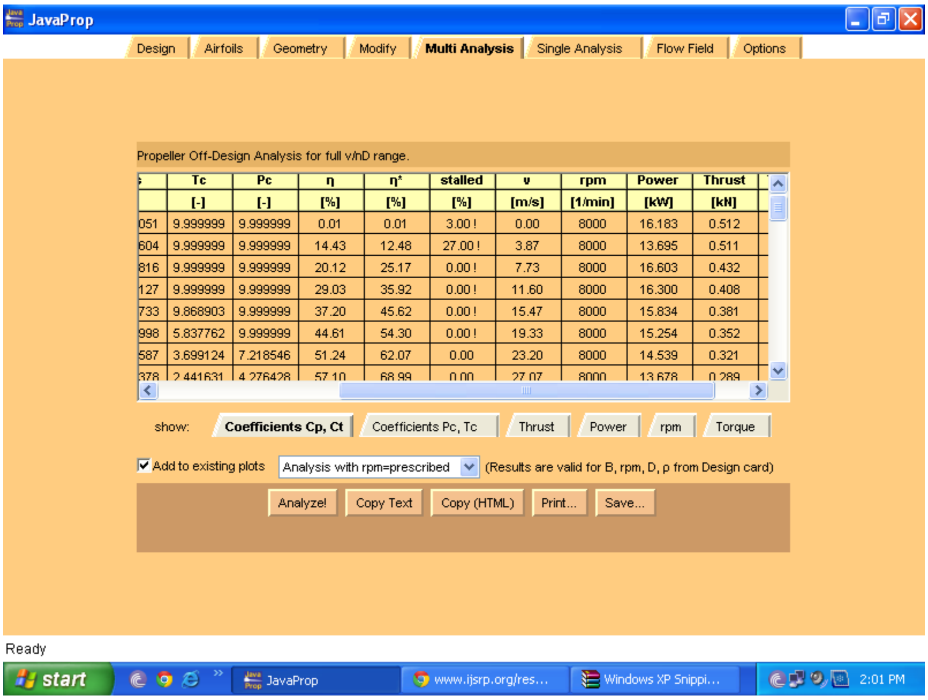


Fig 12 (The multi analysis result with various properties like power and thrust)

Therefore according to the multi analysis we have the different values based on the constant rpm=8000. i.e.,
(a) Different velocity (v) in m/s deliver by propeller rotating with constant speed.
(b) Power also varies from initial point to the final point with the thrust.

Flow Field:

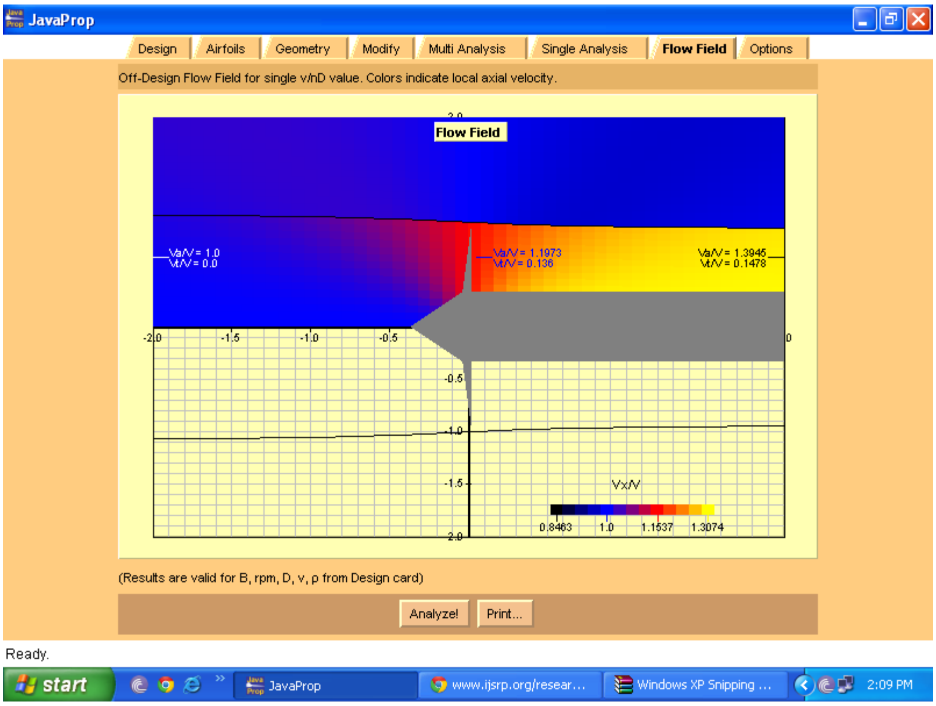


Fig 13 (The flow around propeller)

Here from the flow field we see that the (V_a): axial flow speed increment increases immediately after the propeller and also the (V_t): the tangential velocity increases immediately after the propeller.

Since, the ratio (V_x/V) for red colour start with 1.1537 and it is around 1.1973 and 0.136. And for the yellow colour the ratio (V_x/V) starts with 1.3074 and it is around 1.3945 and 0.1478 around the propeller with the delivering velocity.

Option card:

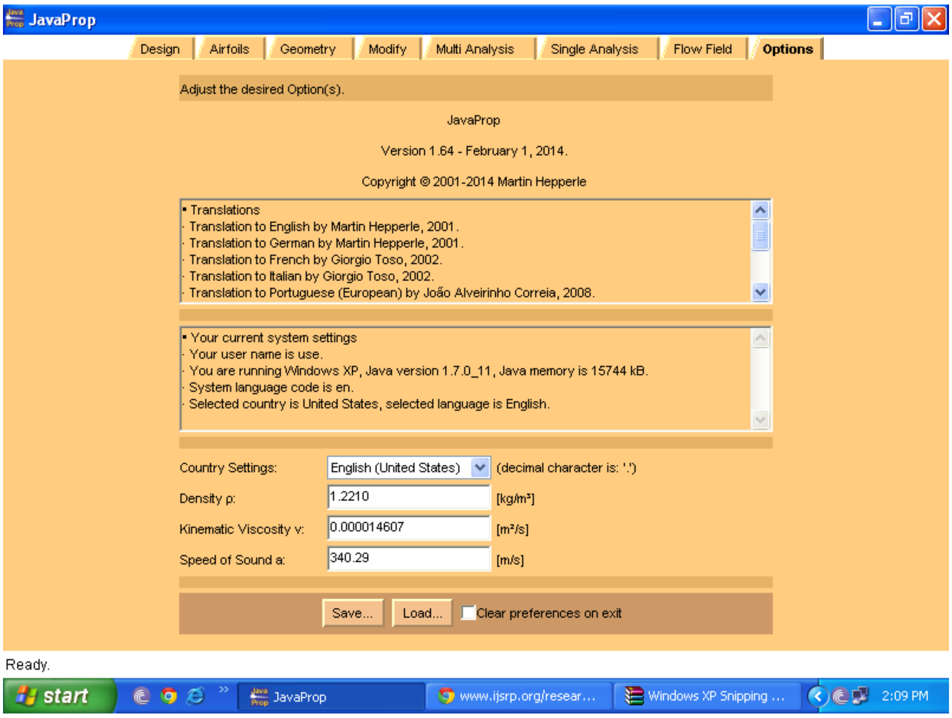


Fig 13 (Standard data for approximate result)

The option card is to set the data as per the standardization to get the appropriate result.

Validation:

According tom the reference paper:

1. Amit Singh Dhakad, Pramod Singh. "Flying Bike Concept." international research journal of mechanical engineering 1.1 (2014): 001-011 &
2. Dhakad, Amit Singh, and Arun Singh. "Power Requirement for Flying Bike." International Journal of Innovative Research and Development 3.5 (2014).

The force required for to overcome the drag (D) = F=ma, is 280kg*0.648m/s² = 181.44 N through mathematical modelling and the thrust obtained on analysis for three conditions are T= 155.84N in fig 2 (for unshrouded and unsquared tip propeller), T = 179.39 N in fig 3 (for shrouded propeller) and T = 179.41 N in (fig 4) for both shrouded and squared tip propeller). Hence the analysis validates the mathematical modelling meeting the nearby target with a difference 0.02%.

III. Conclusion

On analysis it is very clear that two blade propeller has (efficiency) η = 73.729 % and the three blade propeller has η = 73.748 producing the same thrust with constant power. Therefore keeping the weight into consideration it is better to have the two blade propeller for flying bike. And as the coefficient of thrust T_C = 0.073 the propeller is lightly loaded.

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