Conceptual Design of Hybrid UAV

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***Abstract*: Hybrid aircrafts are unique type of aircrafts that combine the hover capability of helicopters with the speed and range of airplanes. In this work, we propose a novel hybrid aircraft based on the fixed-wing airplane and quad rotor structures. A complete mathematical model of the aircraft, in helicopter, transition and airplane flight modes is presented. Finally, simulation results are presented in order to illustrate performances of the proposed controller. The proposed UAV structure configuration is similar to V-22 osprey however it is designed based on the propeller thrust instead of jet-engines In any hybrid aircraft, the transition between hover flight and cruise flight is the most difficult regime to achieve and convertible rotor aircraft are no exception to this The design has been developed as UAV which is propelled by motors which has all the abilities of flight controls equipped in a single body. Which has a specification of weight up to 4kg's Future work will consist of creating a more detailed model for lift and drag.**

Keywords: VTOL, CTOL, HTOL, RPVs, payload, aerodynamic efficiency, wing geometry,

Nomenclature
Q=dynamic pressure
ρ =fluid density
v = true airspeed
A is the aspect ratio,
M = Mach number
CL = lift coefficient
Cd=coefficient of drag
G = climb gradient
ψ= turn rate.
M_{eff} = Effective Mach number
Re=Reynolds number
Cr=root chord
Ct=tip root
Cm=pitching moment

1. INTRODUCTION

The 21st century is marked as the beginning of aerial reconnaissance era which has paved the way in the development of high tech aerial vehicles with video and global positioning capabilities. Drones, aircrafts controlled from the ground, are an invaluable asset to soldiers in hostile environments. These aerial systems, which once upon a time weighed hundreds of pounds, have reduced significantly in size. Still, improvements on drones are in high demand. The success of drones has prompted governments to invest in making them more durable, lightweight, and autonomous.

Unmanned Aerial Vehicles (UAVs) have been referred to in many ways: RPVs (remotely piloted vehicle), drones, robot planes, and pilotless aircraft are a few such names. Most often called UAVs, they are defined by the Department of Defence (DOD) as powered, aerial vehicles that do not carry a human operator, us aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non lethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered UAVs by the DOD

There are a number of reasons why UAVs have only recently been given higher priority. Technology is now available that wasn't available just a few short years ago. Some say that the services' so-called "silk scarf syndrome" of preferring manned aviation over unmanned, has diminished as UAVs entered the mainstream.

The acronym HTOL refers to the aircrafts which are required to accelerate horizontally along a runway or strip in order to achieve flight speed. In this view, the acronym CTOL (conventional takeoff and landing) is outdated since VTOL is no longer unconventional. Indeed, many flying organizations and services employ more VTOL aircraft than HTOL aircraft. It also removes the problem in designating fixed-wing aircraft which have a VTOL capability.

The following sections will discuss:
a) HTOL or horizontal take-off and landing,
b) VTOL or vertical take-off and landing,
c) Hybrids which attempt to combine the attributes of both of these types

In the hovering mode the aircraft behaves like a helicopter and is able to vertically take off and land. The transition mode is the flight regime of converting from helicopter to airplane and vice versa. In the forward flight mode, the aircraft actually is a fixed-wing airplane that offers a wide range of speed and manoeuvrability. In this work, we aim to first investigate the dynamic characteristics of the hybrid aircraft in all flight modes.

Unmanned aerial vehicles (UAVs), also known as remotely piloted vehicles or drones, have always been part of aviation history. Therefore, UAVs are popular for missions that involve a high risk of mortality, which is why they are widely used in the military today.

1.1 OBJECTIVES

The primary objective of this project is to develop an UAV which is propelled by motors which has all the abilities of flight controls equipped in a single body. for this we are considering a rectangular wing and a cropped delta wing and estimating the best of both. Which has a specification of weight up to 4kg's of weight and it should be carried up to some range and perform the mechanism and work which has to be done by the aircraft with usage of motors which are placed inside the wing.

2. DESIGN REQUIREMENTS

For the proposed MAV these are the requirements that are needed to be satisfied.

Velocity	10	m/s
Range	1000	M
L/D	16	
Structural weight	4.3	Kg
Loiter Time	10	Min

Table 1. Design requirements

3. DESIGN METHODOLOGY

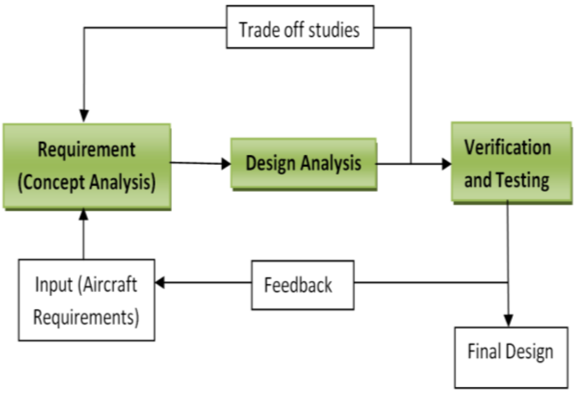


Fig.1 Block Diagram of Design Procedure

As specified in the above the design methodology starts with the aircraft requirements, then a brief conceptual design is done on the required requirements then the designing of aircraft is done with specific fixed values after the design gets completed, analysis works are being done on the aircraft such that it supports the required parameters as applied .if any changes are to be then a brief trade of study is done and again the model is refined. at last the design is verified and tested and it goes to the final design of the aircraft that is the manufacturing segment

Thus if any faults are observed in design then the feedback is given to the input system .

4. DESIGN PROCESS

The airplane must be easy to transport, hence fuselage length and half span should not exceed 15 feet, provided that the wings are removed or folded for transport.

Increasing the wingspan allows the airplane to cover a wider swath of field in a single pass, meaning fewer passes are required. This reduces the range that must be flown.

Purchase cost should be minimized. Because cost is closely tied to weight, weight should also be minimized. The payload and other internal components should fit without an excess of extra space. At the same time, provisions should be made for future upgrades including an increase in payload capacity, so some extra space should be available.

4.1.1 FIRST CONSIDERATION:

A Rectangle configuration, consisting of a monoplane, a canard and double vertical tails, a pusher, tractor configuration. Rectangle configuration also considered as a viable option but discarded because of requirements of robust control systems and as well as weight considerations, hence driving the initial cost up.

4.1.2 SECOND CONFIGURATION:

A trapezoidal wing configuration, single vertical tail, Tricycle gear, with 3 motors in which two of them are fixed to the both ends of wing section and another motor is fixed at the leading edge of fuselage.

4.2 AIRFOIL SELECTION

The airfoil, in many aspects, is the heart of the airplane. The airfoil affects the cruise speed, take-off and landing distances, stall speed, handling qualities and overall aerodynamics efficiency during all phases of flight

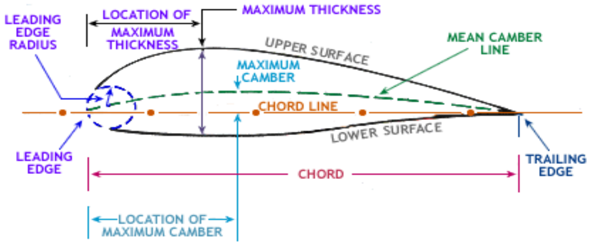


Fig.2 Airfoil nomenclature

The front of the airfoil is defined by a leading-edge radius which is tangent to the upper and lower surfaces. The "chord" of the airfoil is the straight line from leading edge to the trailing edge. "Camber" refers to the curvature of characteristic of most airfoils.

The "mean camber line" is the line equidistant from the upper and lower faces. "Total airfoil camber" is defined as the maximum distance of the mean camber line from the chord line, expressed as a percent of the chord.

The “thickness distribution” of the airfoil is the distance from the Upper surface to the lower one measured perpendicular to the line and is function of the distance from leading edge.
The airfoil “thickness ratio” (t/c) is the maximum thickness of the airfoil divided by its chord..

The camber line is scaled to produce the desired maximum camber, and then the original thickness distribution is added to obtain the new airfoil.

In airfoil selection the major criteria is (L/D) for an airfoil in this hybrid uav we selected 2 airfoils.

1. s7055-il
This is the airfoil we have selected and it is used in the main wing segment

The S series airfoil has high thickness as advantage
It produces high lift in low speeds and in hovering it gives high stability. The L/D ratio for s series airfoils are greater than other airfoils. Due to high camber we can generate high amount of lift and it has minimum amount of drag

2. NACA-0009
This is the airfoil which will be used in the elevator or empennage design

Increments of normal-force and hinge-moment coefficients for the airfoil, the flap,
It gives more hinging moment and also high stability

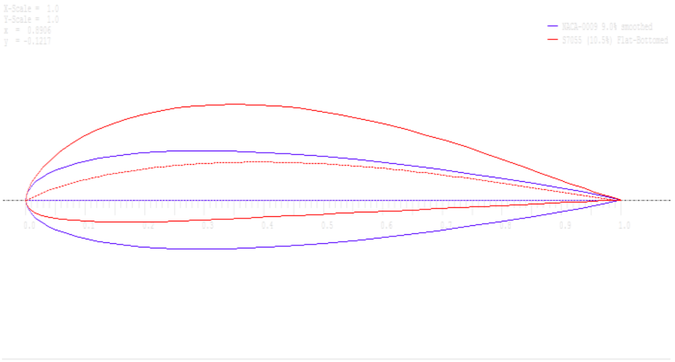


Fig.3 of naca0009 and s-7055sl

4.3 WING DESIGN

The wing design is the most important factor in lifting the aircraft the selection of airfoil will now play a crucial role in the outcome of stability and maneuvourability .
Now we select the wing positioning depending on the mission requirement and payload. For this hybrid uav high wing is considered because of Major benefit of the high wing is that it allows placing the fuselage closer to the ground. This allows easy loading and unloading the cargo without special equipment. With a high Wing, jet engines will have sufficient ground clearance without excessive landing-gear equipment.

This hybrid UAV has a capability of lifting more weight and carry a payload depending upon its wing platform.

First in this wing design we will create two platforms
I Rectangular wing
II Trapezoidal wing

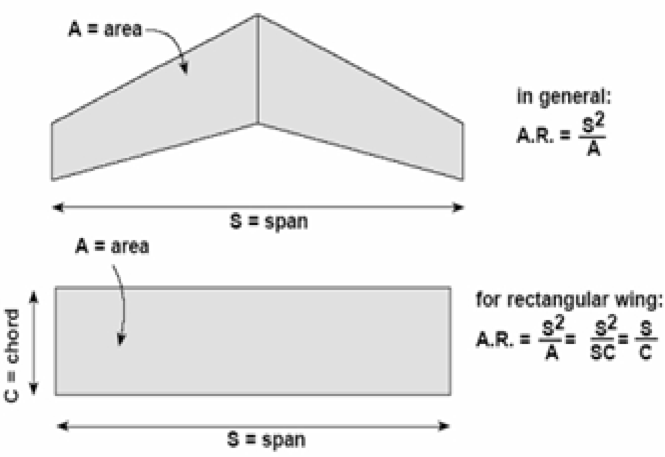


Fig.4 calibration of wing

4.3.1 CALCULATIONS

- For finding out the surface area of wing we take
  CL =1/2*þ*V^2*S
  S =CL*2/þ*V^2
- By this we know that we consider the lift to be 1.2times the weight of aircraft we know the fixed value of þ=1.225kg/m^3
- L=1.2*W , cl=1.5
  L=1.2*3.6
  =4.3kg
  =4.3*9.81
  L=42.183N

Substitute the value of L, þ,V,CL in the second equation to find out the “S” i.e. wing span area.
S=42*2/(1.225*(10)^2*1.5)
$\underline{S=0.45m^2}$

RECTANGULAR WING SPECIFICATIONS:

Aspect Ratio:

b2 /s = W/s = 6

W/s = w/ (b2/s) = b2/s

W/s = b2/s =4.3/0.45= 9.55

W/s : 9.55

Chord : 0.27m

Wing : Aspect ratio * Chord

: 6*0.27=1.62m

Length of aileron : 1/4 *Wing =0.405m

Width of aileron : 1/4 * Chord=1/4*0.27=0.0675m

Flaps : 1/8* Chord=0.3375 m

Wing Area : 0.45 m^2

TRAPEZOIDAL WING SPECIFICATIONS:

Root Chord : 0.37m

Tip Chord : 0.27m

Wingspan : 1.4m

Length of aileron : 1/4*1.4=0.35m

Width of aileron : 1/4*0.27=0.0675m

Wing area : 0.48 m^2

4.4 EMPENNAGE DESIGN

The empennage consists of the entire tail assembly, including the fin, the tail plane and the part of the fuselage to which these are attached. On an airliner this would be all the flying and control surfaces behind the rear pressure bulkhead. Aircraft empennage designs may be classified broadly according to the fin and tail plane configurations. The overall shapes of individual tail surfaces (tail plane plan forms, fin profiles) are similar to Wing plan forms. Some configurations are discussed below

Twin tails-A twin tail, also called an H-tail, consists of two small vertical stabilizers on either side of the horizontal stabilizer.

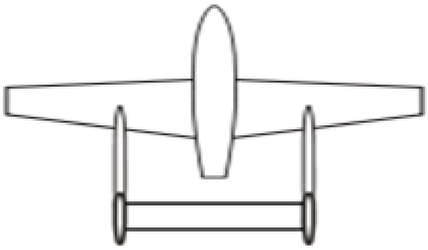


Fig.5 Twin tail-boom

4.4.1calculations

RECTANGULAR WING SPECIFICATIONS:

Stab area : 17.5/100 *wing area= 0.0675m2

Elevator area : 1/4*stab area = 0.02025m2

Tail place : 2.5 * 0.27=0.675m

Fin area : 33/100* stab area
=33*0.0675=0.022275m

Rudder : 5/12*stab area=0.0281

TRAPEZOIDAL WING SPECIFICATIONS:

Boom length from Wing : 0.221m

Distance between Booms : 300m

Rudder length : 0.13m from boom

Rudder area : 0.028125m

Tail length : 0.5m

4.5 FUSELAGE DESIGN

As our project is focused on the payload and endurance the fuselage design should be very critical thus the centre of gravity (Cg) and the length of fuselage must fixed .

RECTANGULAR WING SPECIFICATIONS:

Fuselage length : 3/4*6= 4.5feet

Fuselage (H) :1.21m

CG : 25.33%chord
(29/100)*0.27=0.0783m

TRAPEZOIDAL WING SPECIFICATIONS:

Fuselage length : 1.1m
Fuselage height : 0.08m

4.6 LANDING GEAR DESIGN

In this frames we will use “TRI CYCLE “landing gear because it has high shock absorption than compared to other landing gears.

4.7 POWER REQUIRED

The propulsion device which we are using to give thrust is by the electric motors . we will now find out the required (hp/w)i.e horse power to weight ratio

4.7.1CALCULATIONS

Home Built	Typical (hp/w)
	0.08

T/W : 1/ (L/D) Cruise

L/D : 0.866*L/D (max)

L/D (Cruise) :52.804

T/W : 0.019

T : 0.019*4.3
:0.8Kg

hp/w : 0.08

hp : 3.36
: 2.5Kv

5. WEIGHT ESTIMATION

The specifications that should be integrated in the hybrid mav are being estimated in terms of weights also. Weight is a crucial factor to that encounters during the test flight

PARTS	PARTS USED IN NUMBER	ESTIMATED WEIGHT
BRUSH MOTORS	3	3*100=300gms
SERVOS	8	8*9=72gms
Battery	1	250gms
Propellers	4	4*50=200gms
ESC	4	4*100=400gms
Landing gear	1	1*150=150gms
Frame	1	750gms
Flight controller	1	30gms
GPS module	1	50gms
Wire heat sink soldering	1	100gms
TOTAL		2302gms

Table.2 Weight estimation

6. DESIGN AND ANALYSIS OF HYBRID MAV

Depending upon the above calculations and dimensions we considered the values and designed the model in the software “PRO-E”. This is a user friendly tool to design the model .the analysis part and also the aerodynamic analysis were done in the “XFLR5v6”.both the Rectangular platform and Trapezoidal designs were developed for analysis

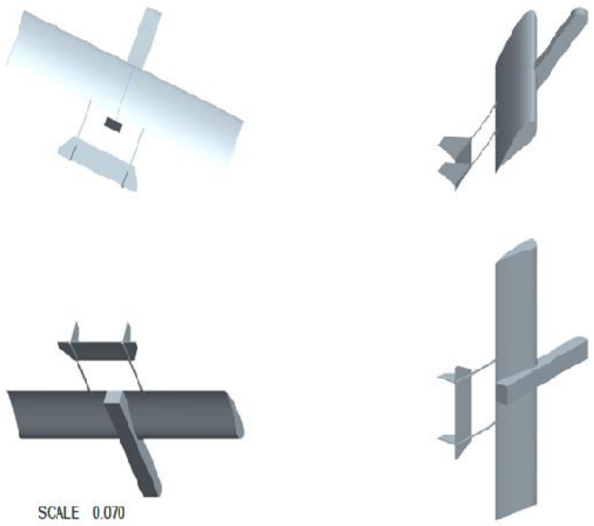


Fig.6 Design of Rectangular wing body

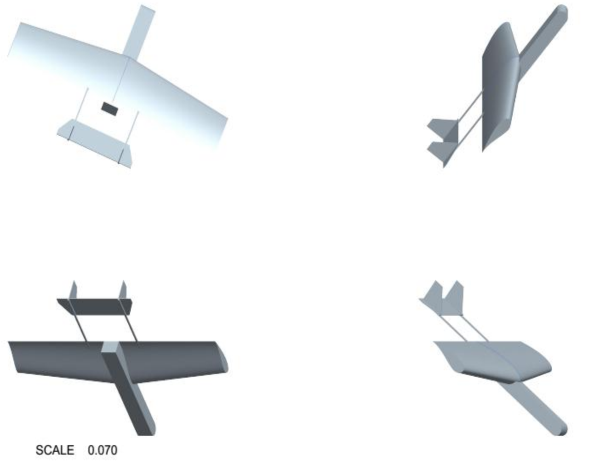
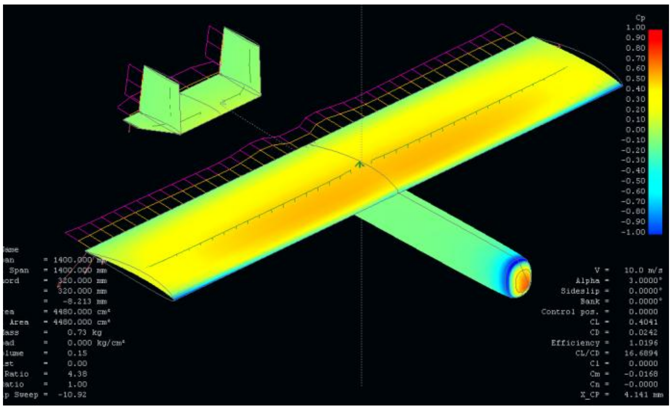


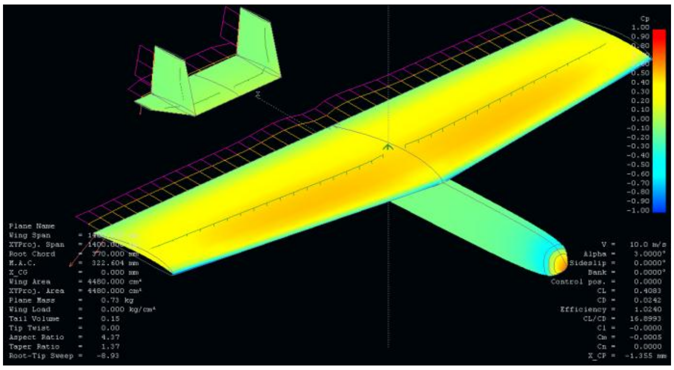
Fig.7 Design of trapezoidal wing body



```
ame
an       = 1400.000 mm
 Span    = 1400.000 mm
ord      =  320.000 mm
         =  320.000 mm
         =   -8.213 mm
ea       = 4480.000 cm²
 Area    = 4480.000 cm²
ass      =    0.73 kg
ad       =    0.000 kg/cm²
lume     =    0.15
st       =    0.00
 Ratio   =    4.38
atio     =    1.00
p Sweep  =  -10.92
```

```
             V =   10.0 m/s
         Alpha =   3.0000°
     Sideslip =   0.0000°
          Bank =   0.0000°
 Control pos. =   0.0000
            CL =   0.4041
            CD =   0.0242
    Efficiency =   1.0196
         CL/CD =  16.6894
            Cl =   0.0000
            Cm =  -0.0168
            Cn =  -0.0000
          X_CP =   4.141 mm
```

Fig,.8 Analysis on Rectangular wing



```
Plane Name
Wing Span        = 14[illegible]
XYProj. Span     = 1400.00[illegible]
Root Chord       =  370.000 mm
M.A.C.           =  322.604 mm
X_CG             =    0.000 mm
Wing Area        = 4480.000 cm²
XYProj. Area     = 4480.000 cm²
Plane Mass       =    0.73 kg
Wing Load        =    0.000 kg/cm²
Tail Volume      =    0.15
Tip Twist        =    0.00
Aspect Ratio     =    4.37
Taper Ratio      =    1.37
Root-Tip Sweep   =   -8.93
```

```
             V =   10.0 m/s
         Alpha =   3.0000°
     Sideslip =   0.0000°
          Bank =   0.0000°
 Control pos. =   0.0000
            CL =   0.4083
            CD =   0.0242
    Efficiency =   1.0240
         CL/CD =  16.8993
            Cl =  -0.0000
            Cm =  -0.0005
            Cn =   0.0000
          X_CP =  -1.355 mm
```

Fig.9 Analysis on Trapezoidal body

7. RESULTS AND DISCUSSION

The analysis reports of the xflr5 for both Rectangular and Trapezoidal wing platform are noted down in a tabular column.

S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
1	10	-2.0000	3.8784	-0.0288
		-1.0000	8.0058	-0.0239
		0	11.8193	-0.0193
		1.0000	14.8117	-0.0150
		2.0000	16.2839	-0.0110
		3.0000	16.6894	-0.0073
		4.0000	16.4980	-0.0040
		5.0000	15.9894	-0.0011
		6.0000	15.3161	0.0015
		7.0000	14.5809	0.0036
		8.0000	13.8366	0.0054
		9.0000	13.1138	0.0068
		10.0000	12.4262	0.0078
		11.0000	11.7703	0.0084
		12.0000	11.1492	0.0086
		13.0000	10.5491	0.0084
		14.0000	9.8951	0.0080
S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
2	15	-2.0000	4.6612	-0.0328
		-1.0000	9.6346	-0.0294
		0	14.6909	-0.0262
		1.0000	17.5854	-00230
		2.0000	18.6439	-0.0199
		3.0000	18.6851	-0.0169
		4.0000	18.1290	-0.0141
		5.0000	17.3119	-0.0113
		6.0000	16.3742	-0.0087
		7.0000	15.4318	-0.0062
		8.0000	14.5265	-0.0039
		9.0000	13.6720	-0.0017
		10.0000	12.8788	0.0004
		11.0000	12.1369	0.0023
		12.0000	11.4373	0.0041
		13.0000	10.7680	0.0057
		14.0000	9.9696	0.0073
S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
3	20	-2.0000	5.3746	-0.0329
		-1.0000	10.7170	-0.0295
		0	15.7469	-0.0262
		1.0000	18.6637	-0.0230
		2.0000	19.7641	-0.0199
		3.0000	19.7800	-0.0169
		4.0000	18.9868	-0.0141
		5.0000	17.9966	-0.0113
		6.0000	16.9251	-0.0087
		7.0000	15.8730	-0.0063
		8.0000	14.8803	-0.0039
		9.0000	13.9623	-0.0017
		10.0000	13.1102	0.0004
		11.0000	12.2985	0.0023
		12.0000	11.5641	0.0040
		13.0000	10.8335	0.0057
		14.0000	10.0885	0.0073

Table3.Determination of (Cl/Cd)max with different velocities and angle of attacks for RECTANGULAR WING

S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
1	10	-2.0000	4.2785	-0.0240
		-1.0000	8.4255	-0.0187
		0	12.2744	-0.0136
		1.0000	15.2131	-0.0090
		2.0000	16.5991	-0.0045
		3.0000	16.8993	-0.0005
		4.0000	16.6408	0.0033
		5.0000	16.0811	0.0066
		6.0000	15.3853	0.0096
		7.0000	14.6334	0.0122
		8.0000	13.8822	0.0143
		9.0000	13.1569	0.0161
		10.0000	12.4653	0.0175
		11.0000	11.8096	0.0185
		12.0000	11.1870	0.0191
		13.0000	10.6030	0.0193
		14.0000	10.0355	0.0191
		15.0000	9.3633	0.0189
S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
2	15	-2.0000	5.1435	-0.0244
		-1.0000	10.1400	-0.0191
		0	15.2546	-0.0141
		1.0000	17.9258	-0.0094
		2.0000	18.8741	-0.0049
		3.0000	18.8823	-0.0008
		4.0000	18.2252	0.0029
		5.0000	17.3647	0.0063
		6.0000	16.4127	0.0092
		7.0000	15.4599	0.0118
		8.0000	14.5544	0.0140
		9.0000	13.7024	0.0158
		10.0000	12.9081	0.0172
		11.0000	12.1647	0.0182
		12.0000	11.4710	0.0188
		13.0000	10.8206	0.0190
		14.0000	10.1824	0.0189
		15.0000	9.4154	0.0188
S.No	V(m/s)	Angle of attack	Cl/Cd	Cm
3	20	-2.0000	5.8556	-0.0247
		-1.0000	11.1719	-0.0192
		0	16.1928	-0.0142
		1.0000	19.0386	-0.0095
		2.0000	20.0381	-0.0050
		3.0000	19.9240	-0.0010
		4.0000	19.1217	0.0028
		5.0000	18.0682	0.0061
		6.0000	16.9725	0.0091
		7.0000	15.9076	0.0117
		8.0000	14.9084	0.0138

		9.0000	13.9893	0.0156
		10.0000	13.1484	0.0170
		11.0000	12.3381	0.0180
		12.0000	11.5987	0.0187
		13.0000	10.9192	0.0189
		14.0000	10.2105	0.0189
		15.0000	9.5151	0.0187

Table4.Determination of (Cl/Cd)max with different velocities and angle of attacks for TRAPEZOIDAL WING

8. CONCLUSION

The typical mission profile assumed for this design is Hybrid UAV has to travel to the maximum range which is of a 1000M distance from the base and has to come back to the base point in the time span of 10 minutes.

We can observe that at angle of attack 3.000 we will get max Cl/Cd for every velocity stream and also negative pitching moment .

According to the analysis results of both Rectangular and Trapezoidal body, we Preferred to go with Trapezoidal body because it having more Cl/Cd and also the Cm is negative so that we can counter the pitching moment when we have high wing flowing around the wing by which we can make the flight more controllable, the Trapezoidal wing supports better in hovering flight.

9. FUTURE SCOPE

Future work will consist of creating a more detailed model for lift and drag. A CFD code will be constructed in order to predict the pressure distribution, which can then be utilized to predict the lift and drag on the plane. The design of an airfoil more tailored for the mission profile will also be developed. More trade studies will also be conducted in order to maximize the lift while minimizing drag and weight.

To improve the ability to transport the plane on the ground, reduction in the dimensions of the wing will also be investigated.

The engine selected will need further evaluation to its performance at the given flight conditions. It has to been analysed at full throttle conditions, but it still need to be evaluated at 75% to properly determine the cruise characteristics. Most of this information will need to be obtained from the manufacturing as it was not readily available.

In further we will analyse the model in ansys work bench and compare the results with the xflr5 and optimize the values according to the data and manufacture the whole body

10. ACKNOWLEDGEMNT

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