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ECO-CARGO AIRCRAFT

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Abstract- **The evolution in aircraft industry has brought to us many new aircraft designs. Each and every new design is a step towards a greener tomorrow. Design plays a vital role in deciding the flight characteristics and determining its efficiency. The proposed design has been designed keeping 100000 lbs as the payload. Raked wingtips, canards and elliptical shaped fuselage are the highlighting features of the proposed design. Reduction of drag will also be observed due to delay in separation point. Expected outcome of proposed design is less amount of fuel burn because of reduction in drag.**

Index terms **–design, drag, fuselage, raked wing tips.**

Introduction- With the advent of globalization, air freighters are influencing the various global aspects like environment and economy. Due to the rapid pace of deterioration of the environment, the eye of aviation industry is now focused upon sustaining the balance of the environment. The proposed freighter closely addresses the need of greener tomorrow keeping in mind the today's constraints.

<u>Calculations of the individual parts are shown below:</u>

<u>Fuselage Geometry</u>

Fuselage is a long hollow tube which holds all the pieces of an airplane together. Fuselage contributes a significant portion of the weight of an aircraft. Fuselage of designed aircraft is flat and elliptical as per calculations.

<u>Calculations:</u>

Cargo container used: LD3 (IATA type 8)
Length of container: 200 cm
Height of container: 153 cm
Depth of container: 162 cm
Volume of one container: 4.3 m^3
Weight of 1LD3 container: 1588 kg (Ref. no. 1)
Given Payload: 45372.05 kg
Number of containers= Payload/weight of one container
= 45372.05/1588 = 28.571819
=› 28 containers + 0.571819 bulk cargo
Bulk cargo = 0.571819*1588 =908.05 kg
Now as per cargo arrangement, there are 2 columns of 14 container each, thus length of fuselage,
Length of fuselage = (Length of one LD3 container*14) + (bulk cargo) + clearance
= (1.53*14) + 10.72 + 3.98 = 36.13m
Height of fuselage = (Height of a container + clearance)
= (1.62 + 1.22) = 2.85m
Breadth of fuselage = (Breadth of a container *2) + (clearance)
= (2.0066*2) + 1.3868 = 5.4 m
Clearance kept in fuselage is calculated on basis of reference cargo aircrafts i.e. Galaxy C-5 and Beluga,
Length- 36.13 m
Width - 5.4 m
Height - 2.85 m

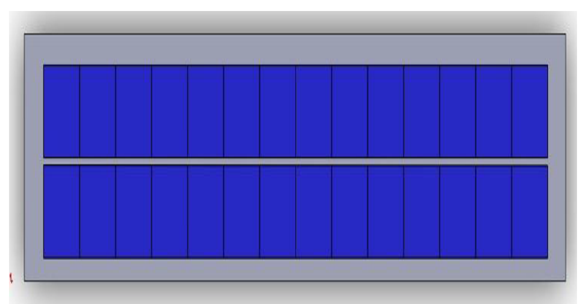

Fig 1: Cargo Arrangement in Fuselage

<u>AIRFOIL SELECTION :</u>

An airplane wing is a 3-D model of an airfoil. The main purpose of airfoil is generation of lift force. Using "Design-foil R6 demo", six series airfoil NACA 67-217 a= 0.6 is selected, where "a" is mean-line perimeter.

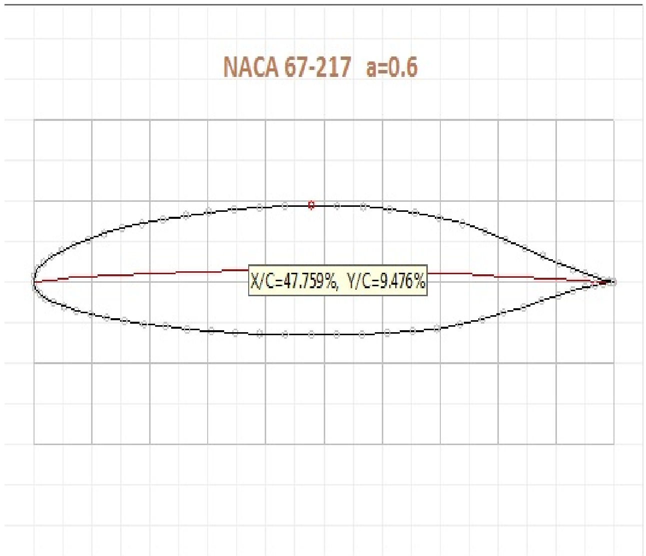

Fig2: NACA 67-217 a=0.6, Image obtained from Design Foil R6 DEMO

Design foil R6 demo is used for selection of an aerofoil. Various factors are considered such as:

-High lift coefficient.
-Low drag coefficient.
-High lift to drag ratio.
-Low pitching moment coefficient.
-High Stalling Angle.

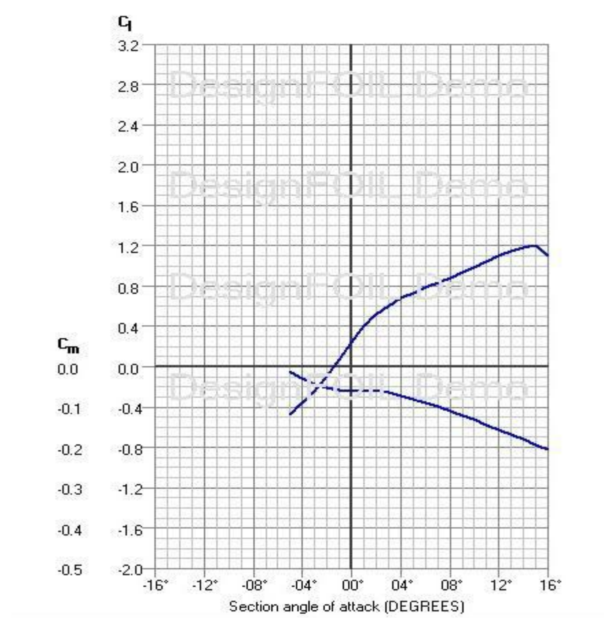

Fig3: C_l vs. α, C_m vs. α

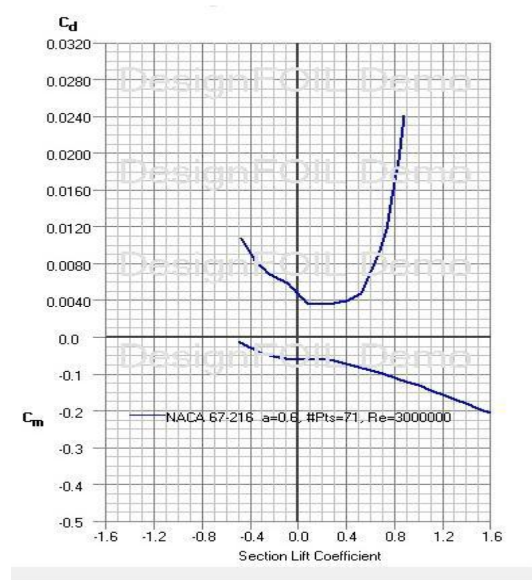

Fig4: C_l vs α, C_m vs α

Above images are obtained by substituting data in Design Foil R6 DEMO

Values from graph:
Stall angle = 15.24, C_{dmin} = 0.0032, C_m = -0.049, C_L = 1.332

Observations:
1. The airfoil with the highest maximum lift coefficient, max C_L
2. The airfoil with the lowest minimum drag coefficient, min C_D
3. The airfoil with the highest lift-to-drag ratio ((C_L/C_D) max).
4. The airfoil with the highest lift curve slope.
5. The airfoil with the lowest pitching moment coefficient (C*m*).
6. The proper stall quality in the stall region (the variation must be gentile, not sharp).

WING GEOMETRY:

Wings are considered to be lift producing devices. The designed aircraft has high wing. Basis of selection of high wings are:

- Eases and facilitate the loading and unloading of loads and cargo into and out of aircraft.
- High wing will increase the dihedral effect ($\dot{\Omega}$). It makes the aircraft laterally more stable. The reason lies in the higher contribution of the fuselage to the wing dihedral effect ($\dot{\Omega}$).
- The aerodynamic shape of the fuselage lower section can be smoother.
- There is more space inside fuselage for cargo, luggage or passenger.

The wing drag is producing a nose-down pitching moment, so it is longitudinally stabilizing. This is due to the higher location of wing drag line relative to the aircraft center of gravity ($M_{dcg} < 0$).

RAKED WINGTIPS

One of the new features introduced in the wings is the raked wingtip. Raked wingtips are the most recent winglet variants (they are probably better classified as special wings, though), where the tip of the wing has a higher degree of sweep than the rest of the wing. They are widely referred to as winglets, but they are better described as "integrated wingtip extensions" as they are (horizontal) additions to the existing wing, rather than the previously described (near) vertical solutions.

Key features of raked wingtip are:

-Improved fuel economy. An approximate 2% increase in fuel efficiency.

- Improved climb performance. Faster climb performance can mean quieter neighborhoods.
- Shortened take off field length.
- Reduction of drag by 5.5%

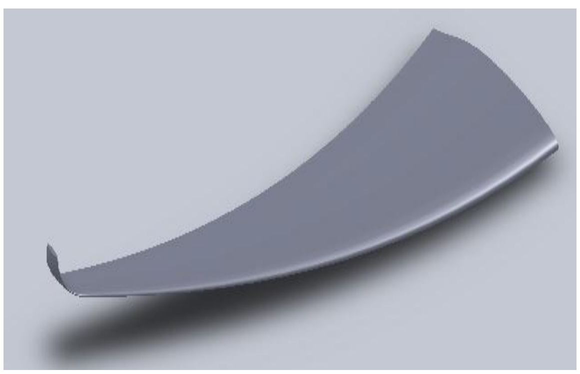

Fig 5: Raked Wing Tip

-Sweep Angle = Overall 21.2 degree (as there is sweep on complete wing span)

-Dihedral Angle = 7.86 degree

Calculations:

1) Wing loading: 750 kg/ m2 (assumed value from reference cargo aircrafts)

MTOW: 213918.6479 kg (as calculated in weight estimation)

Wing area= MTOW/Wing loading

=213918.6479/750 =326.67 m^2

2) Aspect Ratio: 9.89

AR=b2/S

B=√AR*S

=√9.89*326.67 =56.68 m

And also, AR = b/C, 9.89 = 56.86 C = 5.74 m

3) λ (taper ratio) = Ct/ Cr = 0.1906

$C = \frac{2(C_R(1+\lambda+\lambda^2))}{3(1+\lambda)} = 5.94$ m

C_R = 8.23 m and C_T = 1.57 m

All calculation formulae are from (Ref. no. 2)

Horizontal Stabilizer

The stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The horizontal stabilizer prevents up-and-down or pitching motion of the aircraft nose.

$V_{ht} = \frac{S_{ht} * l_{ht}}{S * C}$ (Assuming V_{HT} = 0.50)

$\frac{S_{ht}}{S} = 0.125$, S_{ht} = 40.81 m2

$\frac{L_{ht}}{C} = 4$, L_{ht} = 19.524 m

$\frac{C}{2} = \frac{C_T + C_R}{2}$ = 4.888 m

AR_{HT} = 0.6 * AR_{WING}, AR_{HT} = 5.934

$AR_{HT} = \frac{b_{ht2}}{S_{HT}}$

b_{ht} = √(40.81*5.934) = 14.23 m

Assuming, λ = 0.32

$C_R = \frac{2*S}{b_{ht}(1+\lambda)} = \frac{2*40.81}{14.23 (1.32)}$ = 4.34m

C_T = 0.32 * 4.34 = 1.28 m

Thus,

C_T = 1.28m , C_R= 4.34m

VERTICAL STABILIZER :

The vertical stabilizer keeps the nose of the plane from swinging from side to side, which is called yaw.

$V_{VT} = \frac{S_{VT} * l_{VT}}{S * C}$

We assume, V_{VT} = 0.075

$\frac{S_{VT}}{S} = 0.020$, S_{VT} = 6.53 m2

$\frac{L_{VT}}{C} = 3.75$

L_{VT} = 6.75 m

AR_{VT} = 1.2

$AR_{VT} = \frac{b^2_{VT}}{S_{VT}}$

b = 3.13 m

Assuming λ = 0.6

$C_R = \frac{2S_{VT}}{b(1+\lambda)}$ = 4.569 m

C_T = 2.2032 m

Back - Deflection = 18.78 degree from horizontal axis.

(All calculation formulae are from Ref. no. 3)

<u>3-Dimensional View of Cargo Aircraft :</u>

Three-dimensional models have been drawn using SOLIDWORKS 2010.

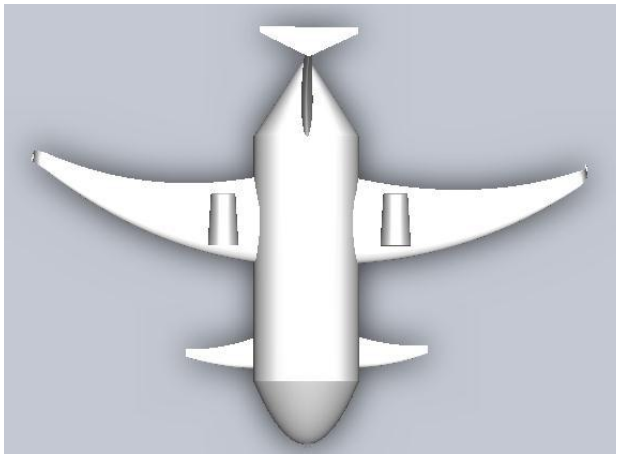

Figure6: Top View

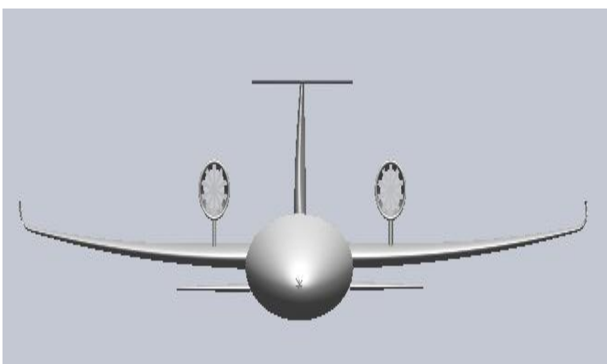

Figure7: Front View

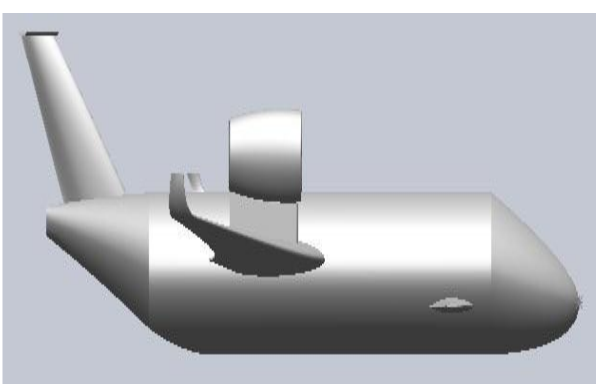

Figure8: Side View

<u>Analysis of Aircraft Model :</u>

1) Meshing of 2-D airfoil :

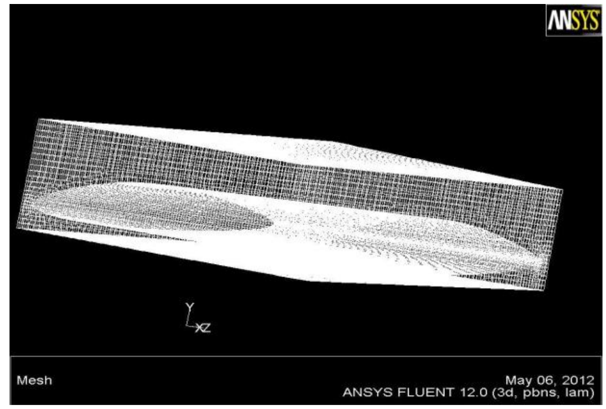

Figure9: 2-D mesh of airfoil

2) <u>Flow past airfoil :</u>

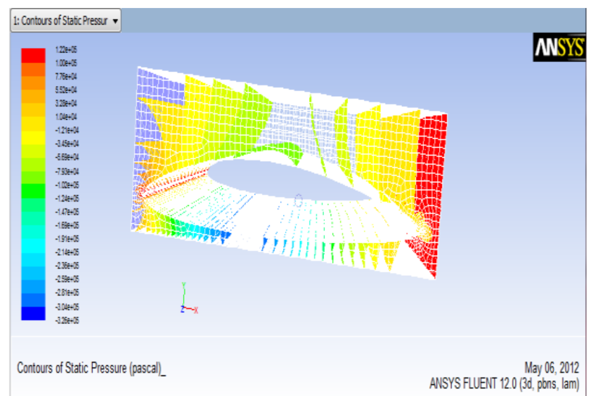

Figure10: 2-D flow past airfoil

<u>Airfoil :</u>

CFD analysis of NACA 67-217 a= 0.6 is done and results are obtained as follows after 2000 iterations. Low pressure on upper surface and high pressure on lower surface, thus airfoil selected is generating required lift force

3) <u>Elliptical fuselage :</u>

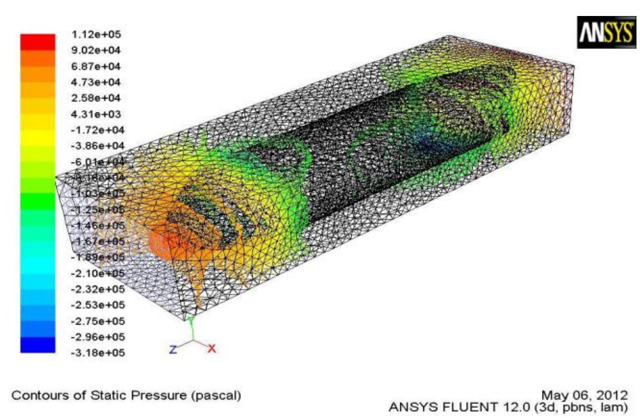

Fig 11: Pressure distribution along fuselage

Computational fluid analysis (CFD) has been done for elliptical fuselage with marine shaped nose. 5000 iterations has been done and pressure distribution obtained is as desired

CFD analysis of raked wings and complete design is the scope of future research.

Complete Vehicle Design:

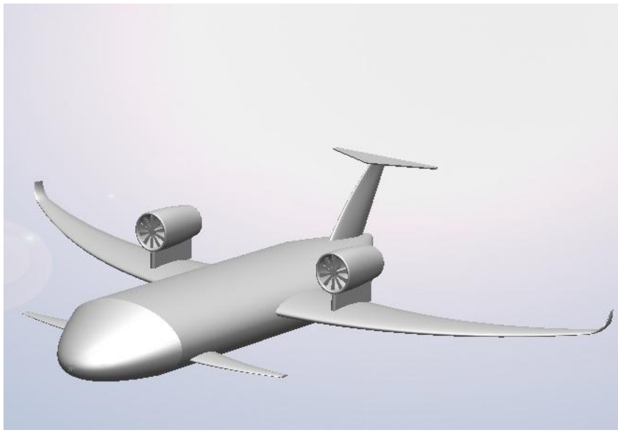

Figure 12

Conclusion:

To sum up, a greener and more efficient aircraft model has been designed using SOLIDWORKS and analyzed using ANSYS 12

Acknowledgement:

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