CFD ANALYSIS OF TANDEM WINGED AIRCRAFT

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Abstract: **Tandem wing configuration is similar to a biplane, however in these aircrafts the wings are offset horizontally far enough that the centre of gravity falls between the two lifting surfaces. Because the wings are further apart than with the biplane, it minimizes the downwash effect on the second wing. This design provides with a higher lifting capacity than with a single wing, while not increasing the overall dimensions of the aircraft. The lift generated by the wings of these aircrafts depends greatly on the angle of attack at which the airfoils are attached to the fuselage. Through this project we are carrying out Computational Fluid Dynamics analysis of the flow over a tandem winged aircraft, in order to determine the angle of attack at which maximum lift is obtained. The two-dimensional analysis, using CFD, of tandem or staggered arranged airfoils of the canard and wing of an Eagle 150 aircraft is carried out in this study. The tests is carried out with tandem and staggered placement of the airfoils in order to determine the optimum position of the wing with respect to the canard and also to determine the lift coefficient at various angles of attack. ANSYS software was used to study the aerodynamic performance of a two-dimensional model the airfoils which was created using PROFILI software.**

***Keywords: Biplane;* Computational Fluid Dynamics; Tandem wing; 2D Analysis.**

I. INTRODUCTION

History repeats itself. The first successful powered aircraft was the Wright brothers "KITTY HAWK FLIER", a canard or tail first plane that flew in 1903.Even after advanced developments in aircraft design tandem wing design aircrafts still remains in the limelight due to its unique advantages. What are the advantages of tandem wing or canard aircrafts? In the world of full scale general aviation, a high proportion of aircraft crashes result from stalls or spins at low speeds, too close to the grounds for recovery especially during take offs and landings. A well designed canards aft wing cannot be stalled. The fore plane will stall first, but this result in the plane nosing down, the fore plane unstalls and flight continues safely. In addition the front wing contributes to the overall lift, unlike the horizontal tail plane of a conventional aircraft which bears a down load. Tandem wings are those types where both wings are of equal area. Canards are those models whose fore-planes are smaller in area than aft planes, and may be only 20% of combined wing area. In nature, the closest thing to a tandem wing aircraft is a butterfly. Canards simply do not exist. Birds range from flying wings like the almost tailless albatross to the boat tailed grackle that sports a V tail.

II. DESIGN TOOL

Some of the structures are built from elements connected by pins at their joints. These two force elements can carry only axial tension or compression forces and stresses. Other structures built of long length slender members that are welded or bolted together may carry such small bending and torsion loads that they can be accurately analyzed by using a pin-jointed model. ANSYS software provides a comprehensive library of elements for use in the development of models of physical systems. While engineering problems always arise from consideration1-2 Trusses of some real-life 3D situation, 2D models are often times sufficient for describing the behaviour and therefore widely used. The ANSYS two-force element LISVK1 is used for planar (2D) truss models. The CARES/LIFE prediction code, developed by NASA Lewis Research Centre, was used to evaluate the fast fracture life of a ceramic turbine vane subjected to thermal loads.

PROBLEM DEFINITION:

The main objective of this study is to determine the optimum position of the Canard with respect to Wing so that flow over the canard does not interact with the flow over the main wing. Then at this most suitable position using CFD analysis the angle of attack at which maximum value of Coefficient of lift is obtained is easily found out.

For this purpose the entire work is divided into 3 different phases.

1. Selection of airfoils with respect to NACA series.

2. Determination of most suitable distance between Canard and main wing.

3. Determination of Coefficient of lift (CL) values at various angles of attack at the most suitable distance between canard and wing using CFD.

III. MODELLING AND ANALYSIS

SELECTION OF AIRFOIL:

This is the first stage of our study and it involves the selection and design of suitable airfoil using proper software .The EAGLE 150B aircraft uses a symmetrical airfoil .The NACA series of this airfoil is 0028. Here the first digit specifies the maximum camber in percentage of the chord (airfoil length).The second indicates the position of the maximum camber in tenths of chord. The last two numbers provide the maximum thickness of the airfoil in percentage of chord .NACA 0028 airfoil has a maximum thickness of 28% with a camber of 0% located 0% back from airfoil leading edge. The design of airfoil has been done using PROFILI software .A 2D view of the designed airfoil is as shown below.

DISTANCE DETERMINATION BETWEEN CANARD & MAIN WING:

The objective behind carrying out this study is to determine the suitable distance of the canard from the wing; this is the position where there will be no trailing vortices of the canard affecting the flow conditions at leading edge of the wing. This can be determined using CFD analysis at various positions of canard and wing.

In order to determine the suitable distance between the canard and the wings the following factors have to be considered.

1. In the present analysis the position of the wing was changed with respect to a canard placed in either a tandem or a staggered arrangement.

2. The position of the canard is kept fixed because as per the design of the EAGLE 150B aircraft the canard cannot be moved vertically owing to limitations of space.

3. For carrying out analysis a test section of length 240 mm and breadth 152 mm was selected. The length of the airfoils was taken as 32 mm each.

4. keeping the position of the canard constant throughout three different positions of canard-wing combinations were tested.

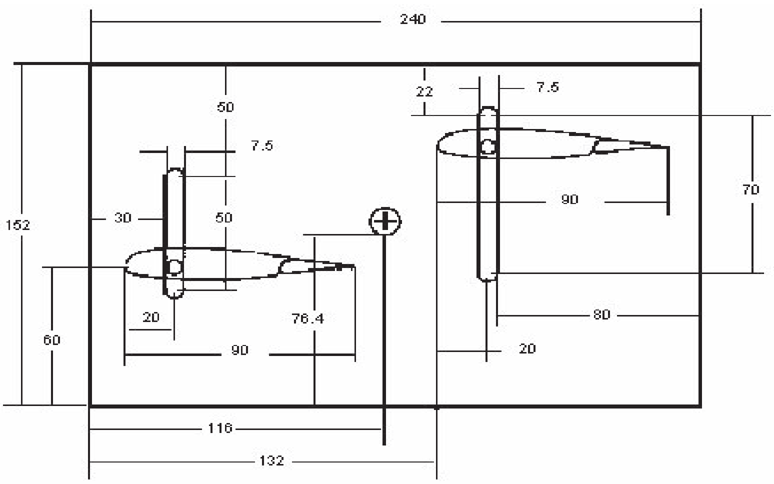

Fig.1. Dimensions of airfoils and test section

Three different positions of canard with respect to wings were tested. These positions were

1. Z/C = 0

2. Z/C = 20/90=.22

3. Z/C = 40/90=.44

Here Z is the vertical distance between the canard and the main wing, C is the horizontal distance between the canard and the main wing .The horizontal distance has been kept constant as 90mm during analysis.

PRELIMINARY CFD ANALYSIS:

As mentioned earlier this preliminary CFD analysis was carried out to determine the optimum position of the canard with respect to the main wing. For carrying out this analysis the following assumptions are used.

1. Two dimensional analysis is carried out based on the assumption that the length of the wings is infinite and their cross-sectional area is constant throughout the length of the airfoil. For two-dimensional analysis of airfoils, the investigations were carried out with chord lengths of 92 mm for the canard and 62 mm for the wing.

2. The turbulence intensity was taken as 2.5% while doing CFD analysis.

3. A factor for roughness was not included during CFD analysis, whereas, in the real situation there is certain amount of roughness on the airfoils.

4. In the CFD analysis model it was assumed that the flow over the aerofoil is fully turbulent, whereas initially the flow on the airfoils is laminar and later becomes turbulent and is fully turbulent at the trailing edge of the airfoils.

For carrying out CFD analysis the following boundary conditions were employed.

Air speed	: 38 m/s
Turbulence intensity	: 2.5%
Ambient temperature	: 300 K
Density of air	: 1.22 kg/m^3

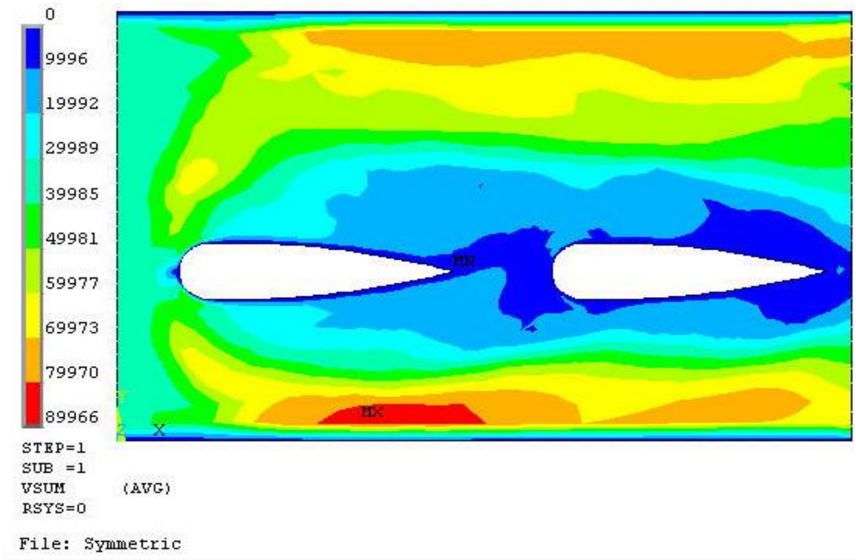

Fig.2. Velocity plot at Z/C=0

From the velocity plot at Z/C = 0,it can be noted that the boundary layer formed between the canard surface and the flow particles due to the flow over the canard directly interacts the flow over the main wing. The wake produced by the leading airfoil extending up to the leading edge of the trailing airfoil and disturbs the flow over the main wing. This results in reduction in lift produced by the main wing and increase in drag. The pressure is the maximum at leading edge of canard. Thus Z/C =0 is not a suitable position for fixing the wing and the canard.

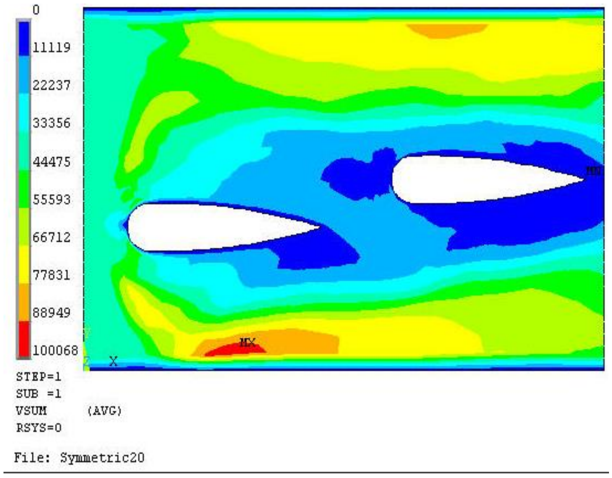

Fig.3. Velocity plot at Z/C=.22

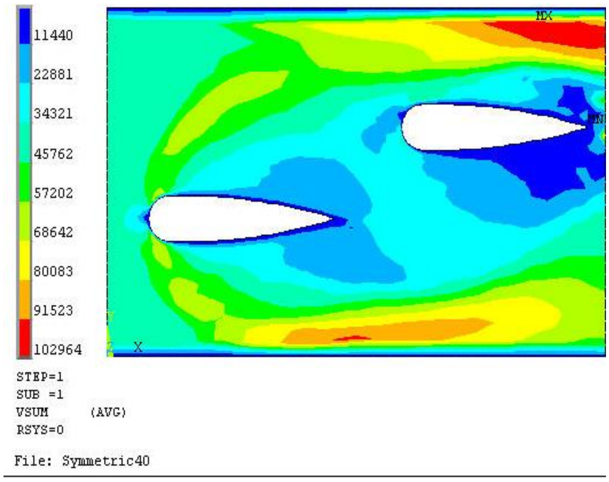

Fig.4. Velocity plot at Z/C=0.44

From the velocity plot at Z/C = 0,it can be noted that the boundary layer formed between the canard surface and the flow particles due to the flow over the canard directly interacts the flow over the main wing. The wake produced by the leading airfoil extending up to the leading edge of the trailing airfoil and disturbs the flow over the main wing. This results in reduction in lift produced by the main wing and increase in drag. The pressure is the maximum at leading edge of canard. Thus Z/C =0 is not a suitable position for fixing the wing and the canard.

DETERMINATION OF COEFFICIENT OF LIFT (CL)

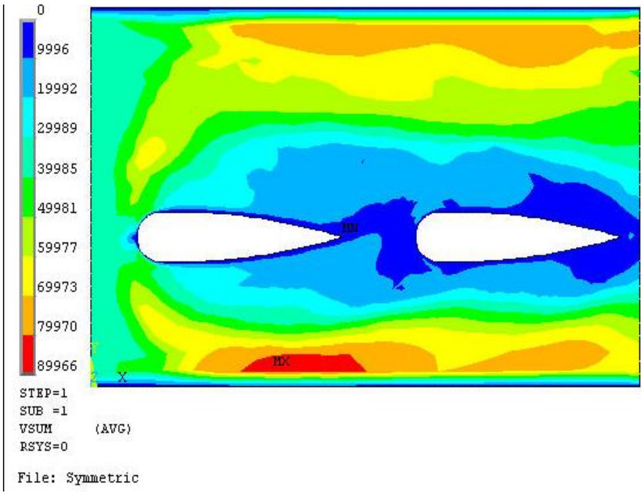

Fig.5. Velocity at α=0

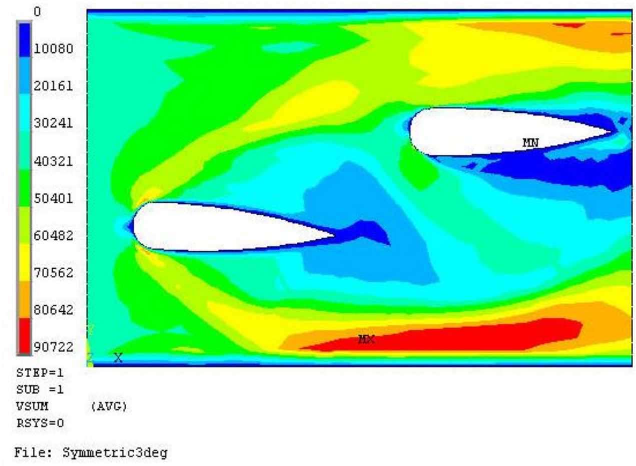

Fig.6. Velocity at α=3

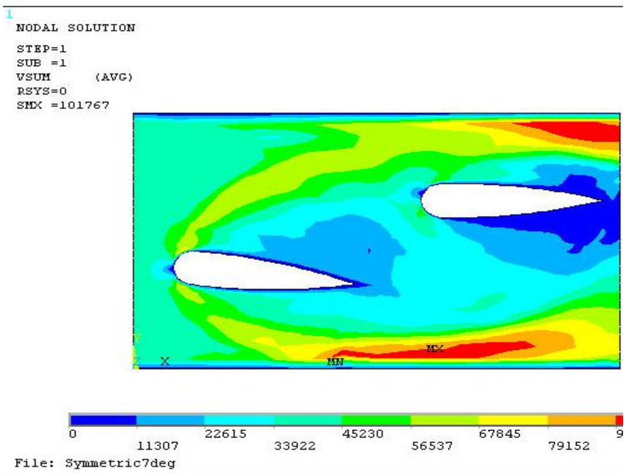

Fig.7. Velocity at α=7

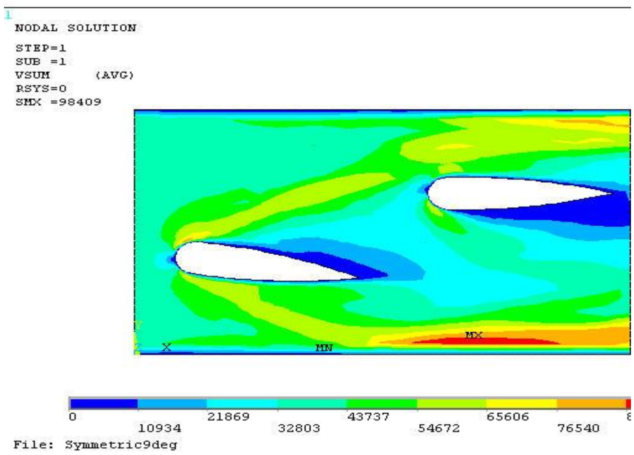

Fig.8. Velocity at α=9

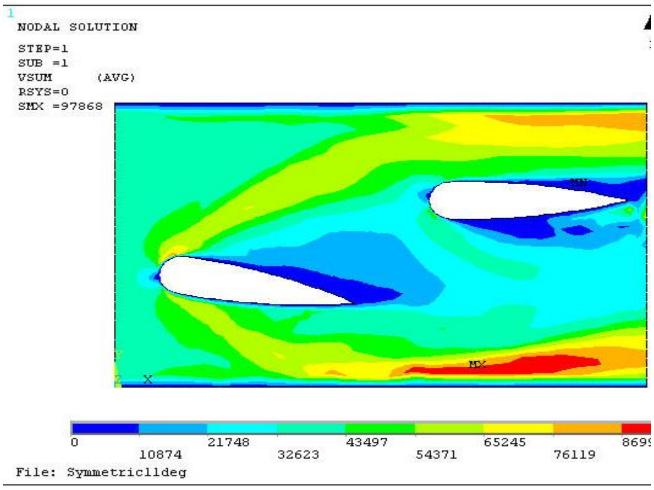

Fig.9. Velocity at α=11

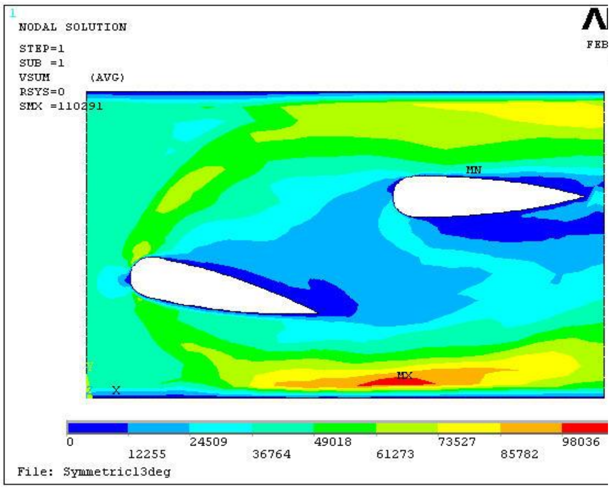

Fig.N. Velocity at α=13

IV. CALCULATION OF COEFFICIENT OF LIFT FROM CFD RESULTS

FORMULAE: CL =2((w/s))/(ρ*v*v)

For calculation, the following inputs were used

Weight of the aircraft =640kg

Density of air =1.225kg/m3

Area of wing =5.20m2

Area of canard =3.62m2

RESULTS:

TABLE I: CL for wing

Sl. no.	Angle of attack (deg)	Velocity of flow (m/s)	Coefficient of lift
1	1	30.22	0.22
2	3	19.84	0.51
3	5	16.59	0.73
4	7	14.77	0.92
5	9	12.88	1.22
6	11	12.43	1.30
7	13	13.39	1.12

TABLE II: CL for canard

Sl. no.	Angle of attack (deg)	Velocity of flow (m/s)	Coefficient of lift
1	1	47.12	0.13
2	3	29.13	0.34
3	5	22.70	0.56
4	7	19.23	0.78
5	9	17.71	0.92
6	11	17.16	0.98
7	13	17.56	0.94

V. CONCLUSION

The two-dimensional analysis of wing and canard using CFD has analysed. The best position for fixing the canard and the wing on the fuselage has been found at Z/C=0.44 by using CFD analysis. The CFD analysis performed with various angles of attack at Z/C=0.44 showed that for both the wings and canard the CL value increases with angle of attack. This continues until the stall angle for both the wing and canard is reached .The maximum value of CL was found to be 0.98 for canard and 1.30 for wings. If the value of angle of attack is increased beyond stalling angle the value of CL decreases.

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