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Aerodynamic Analysis of Biplane Configuration Using NACA 001 Airfoil

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Abstract: -- The work reported here to show the effect of biplane configuration on aerodynamic performance of the NACA 0012 symmetric airfoil. The computational analysis was performed with the help of CFD program which were GAMBIT and FLUENT. The flow around the airfoils was incompressible, steady state, two dimensional Nevier-Stokes equations with different turbulence models were used to simulate the flow nature of aerofoils. This analysis have been carried out by varying the gap between the aerofoils such as 25%C, 50%C, 75%C and 100%C at various angle of attack and operating at Reynolds number 3×106. An interference effect occurs in gap between biplane configurations which can be varied with differ in angle of attack and chord length. The 50%C gap between the aerofoils shows the maximum increase in lift co-efficient. It is observed that biplane configuration provides greater maneuverability performance such as loops and rolls. The computational solutions gives information that increase in lift co- efficient at low speed conditions with little penalty in drag co-efficient. Computed results have been validated with existing experimental data.

Keywords: Angle of Attack, Chord length, Drag Force, Lift Force, stalling Angle.

I. INTRODUCTION

Monoplane aircraft having single pair of wing and the biplane aircraft with two wings on each side arranged one directly above the other. Biplanes aircraft are used for the low speed situation. The aerodynamic features of monoplane are different to those of the biplanes. The aerodynamic features of the biplanes vary with the distance between two aerofoils and the angle of attack. This work analyzes the aerodynamic characteristics of biplane computationally. The flow around the surfaces of an aircraft yields the lifting force. The lift force is produced because of pressure difference that exists among the lower and upper surfaces. Force opposing the motion of the wing through the air is called drag force. The angle bounded by chord line and relative wind is angle of attack. The aerodynamic characteristics of an aircraft are firmly influenced by the profile of wing section. Now NACA 0012 symmetric aerofoil shapes have been used in this research paper. The lift and drag forces are generated by an aircraft with the variation of angle of attack. The zero-lift angle is negative for cambered airfoil whereas the zero-lift angle is zero for symmetric airfoil sections. As such, the zero-lift angle is zero for NACA 0012 aerofoil. The lift force increases almost linearly with AOA until a extreme value is reach so the wing is said to be stall. The outline of the drag force vs. AOA is almost parabolic. It is appropriate for the wing to have the maximum lift and minimum drag force.

'Interference Effect' has been occurred in between the aerofoils of biplane configuration. It occurs due to the suction pressure established by the upper surface of the lower aerofoil and the positive pressure established by the lower surface of the upper aerofoil. The interference effect reduces the lift force and increases the drag force.

It will vary with the chord length and the distance between the aerofoils [1]. As such, it is necessary to keep the interference effect of a biplane as minimum as possible. Here aerodynamic characteristics of biplane have been computationally investigated with the help of CFD software like GAMBIT and FLUENT. The computational solutions gives information that increase in lift co- efficient at low speed conditions with little penalty in drag co-efficient. Computed results have been validated with existing experimental data.

II. PROPOSED WORK

This work represent computationally with CFD investigation by NACA 0012 symmetric aerofoil. For modeling and grid generation GAMBIT software and analysis purpose FLUENT software used in this research work. The flow of air through the aerofoils wing is incompressible and subsonic. The chord length of the aerofoil is 100mm used in this work. The free stream airflow is 45m/s and the outcome of temperature is ignored. The operating condition like density of air is 1.225 kg / m3, operating pressure is 0.101 MPa (1.01 bar or 14.7 psi) and absolute viscosity is 1.789 x 10-5 kg / m-s. The Reynold's Number is 3×106 based on chord length. The distance between the two aerofoils of the biplane (d) is 0.25, 0.5, 0.75 and 1.00 times of chord length (C). The data

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have been found at various angles of attack from 0° to 16° with 2° step angle. Here also we study the static pressure of biplane.

III. COMPUTATIONAL OUTCOMES

A. D= 0.25 times of Chord Length

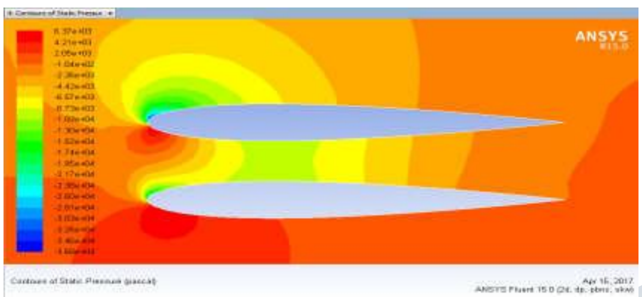

Figure 1: Contours of static pressure at 140 AOA for biplane d of 0.25 times of C

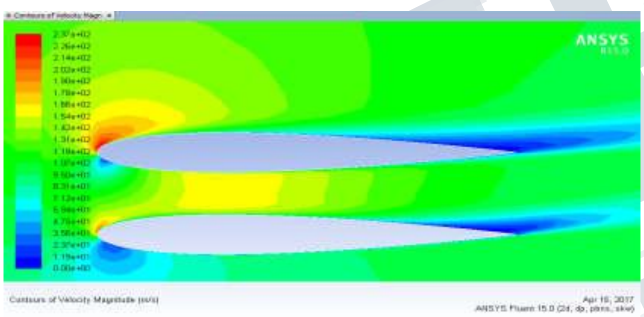

Figure 2: Contours of velocity magnitude at 140 AOA for biplane d of 0.25 times of C

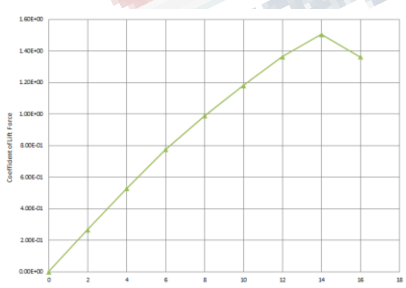

Fig 3: Variation of Coefficient of Lift Force with AOA for Biplane with d of 0.25 Times of C.

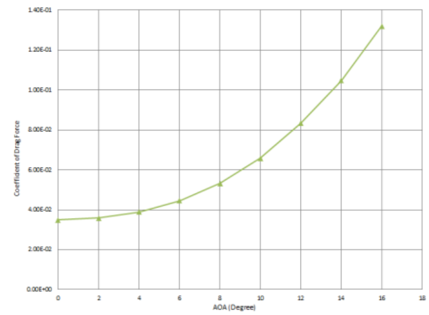

Fig 4: Variation of Coefficient of Drag Force with AOA for Biplane with d of 0.25 Times of C.

Figure 1 and 2 represents the contours of static pressure and velocity magnitude at 140 Angle of attack for biplane configuration with distance between the two aerofoil is 0.25 times of its chord length.

The coefficient of lift force vs. angle of attack for biplane with d of 0.25 times of Chord is shown in Figure 3. At zero degree AOA, the lift coefficient is zero and it increases linearly with the increase of AOA up to approximately 14o then, lift coefficient decreases with the further increase of AOA. As such, the stalling angle of biplane with d of 0.25 times of Chord is about 14˚. It is also observed that the maximum lift coefficient, CLmax is approximately 1.48 at 14o AOA. The variation of coefficient of drag force with angle of attack for biplane with d of 0.25 times of Chord is shown in Figure 2. The outline of the drag force coefficient vs. angle of attack curve is parabolic.

B. D=0.5 times of Chord Length

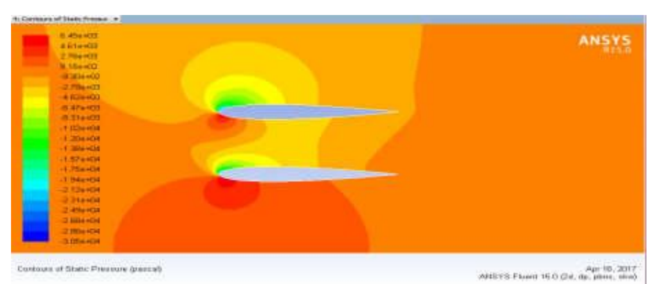

Figure 5: Contours of static pressure at 14o AOA for biplane d of 0.5 times of C

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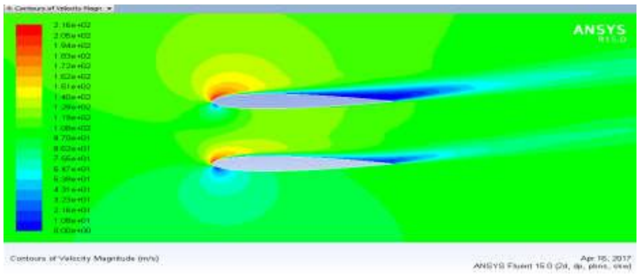

Figure 6: Contours of velocity magnitude at 140 AOA for biplane d of 0.5 times of C

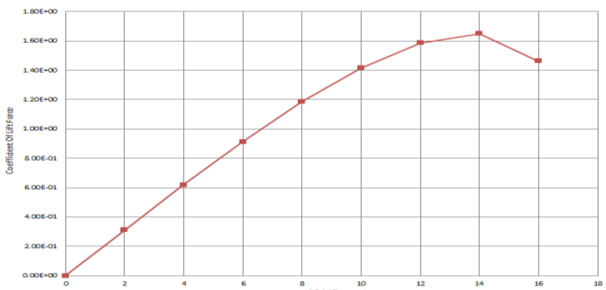

Fig 7: Variation of Coefficient of Lift Force with AOA for Biplane with d of 0.5 Times of C.

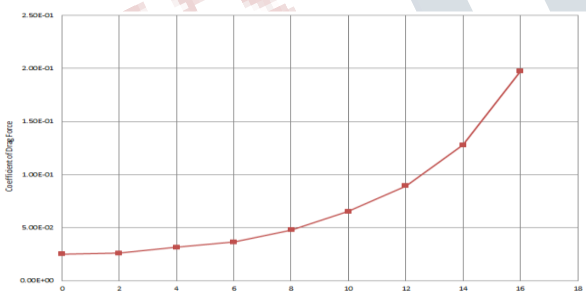

Fig 8: Variation of Coefficient of Drag Force with AOA for Biplane with d of 0.5 Times of C.

Figure 5 and 6 represents the contours of static pressure and velocity magnitude at 140 angle of attack for biplane configuration with distance between the two aerofoil is 0.5 times of its chord length. The coefficient of lift force vs. angle of attack for biplane with d of 0.5 times of Chord is shown in Figure 7. At zero degree AOA, the lift coefficient is zero and it increases linearly with the increase of AOA up to approximately 14o then, lift coefficient decreases with the further increase of AOA. No flow separation occurred up to 140 as such; the stalling angle of biplane with d of 0.5 times of Chord is about 14˚. It is also observed that the maximum lift coefficient, CLmax is approximately 1.65 at 140 AOA. The variation of coefficient of drag force with angle of attack for biplane with d of 0.5 times of Chord is shown in Figure 8. The outline of the drag force coefficient vs. angle of attack curve is parabolic.

C. D=0.75 times of Chord Length

Figure 9: Contours of static pressure at 140 AOA for biplane d of 0.75 times of C

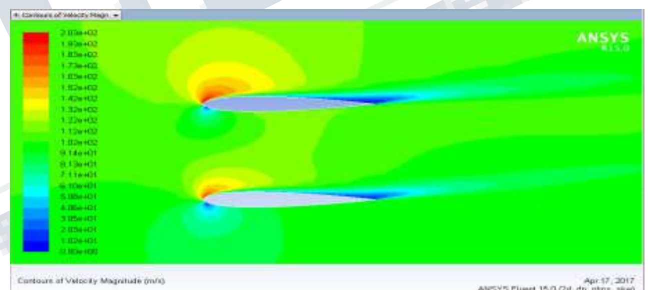

Figure 10: Contours of static pressure at 140 AOA for biplane d of 0.75 times of C

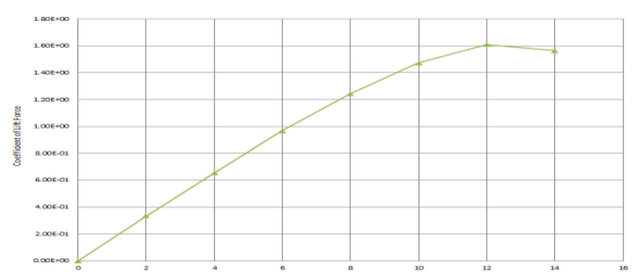

Fig 11: Variation of Coefficient of Lift Force with AOA for Biplane with d of 0.75 Times of C.

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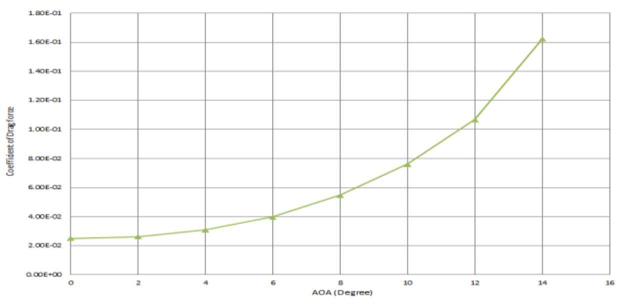

Fig 12: Variation of Coefficient of Drag Force with AOA for Biplane with d of 0.75 Times of C.

Figure 9 and 10 represents the contours of static pressure and velocity magnitude at 120 angle of attack for biplane configuration with distance between the two aerofoil is 0.75 times of its chord length. The coefficient of lift force vs. angle of attack for biplane with d of 0.75 times of Chord is shown in Figure 11. At zero degree AOA, the lift coefficient is zero and it increases linearly with the increase of AOA up to approximately 12o then, lift coefficient decreases with the further increase of AOA. No flow separation occurred up to 140 as such; the stalling angle of biplane with d of 0.75 times of Chord is about 12˚. It is also observed that the maximum lift coefficient, CLmax is approximately 1.60 at 12o AOA. The variation of coefficient of drag force with angle of attack for biplane with d of 0.75 times of Chord is shown in Figure 12. The outline of the drag force coefficient vs. angle of attack curve is parabolic.

D. D=1 times of Chord Length

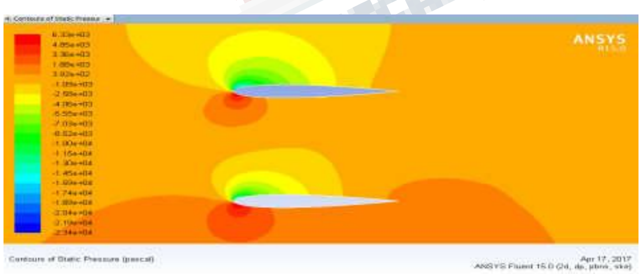

Figure 13: Contours of static pressure at 140 AOA for biplane d of 1.0 times of C

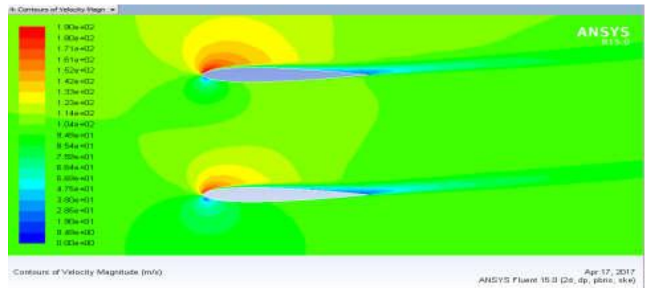

Figure 14: Contours of static pressure at 140 AOA for biplane d of 1.0 times of C

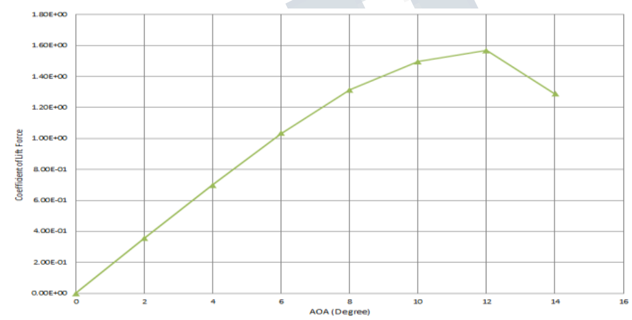

Fig 15: Variation of Coefficient of Lift Force with AOA for Biplane with d of 1.0 Times of C.

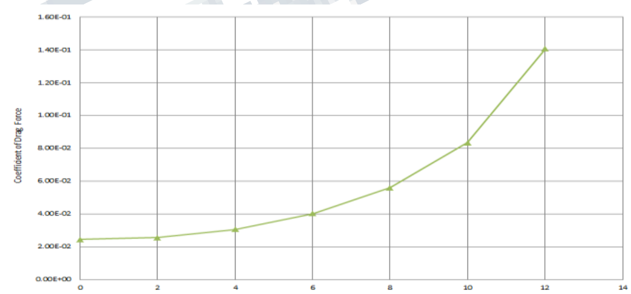

Fig 16: Variation of Coefficient of Drag Force with AOA for Biplane with d of 1.0 Times of C.

Figure 13 and 14 represents the contours of static pressure and velocity magnitude at 120 angle of attack for biplane configuration with distance between the two aerofoil is 0.5 times of its chord length. The coefficient of lift force vs. angle of attack for biplane with d of 1.0 times of Chord is shown in Figure 15. At zero degree AOA, the lift coefficient is zero and it increases linearly with the increase of AOA up to approximately 12o then, lift coefficient decreases with the further increase of AOA. No flow separation occurred up to 140 as such; the stalling

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angle of biplane with d of 1.0 times of Chord is about 12˚. It is also observed that the maximum lift coefficient, CLmax is approximately 1.65 at 12o AOA. The variation of coefficient of drag force with angle of attack for biplane with d of 1.0 times of Chord is shown in Figure 16. The outline of the drag force coefficient vs. angle of attack curve is parabolic.

IV. RESULTS AND COMPARISION

The comparison of coefficient of lift force with angle of attack between computational data of NACA 0012 biplane aerofoil and previously existed experimental data of NACA 0012 clean aerofoil configurations of profile is shown in Figures 17, 19, 21 and 23. It is seen that the lift coefficient obtained from computational result is higher than the previously existed experimental result for all the biplane configurations. Among the four types of biplane configuration, 'biplane with d of 0.5 times of C' provides maximum coefficient of lift force than those by the other three types of configurations.

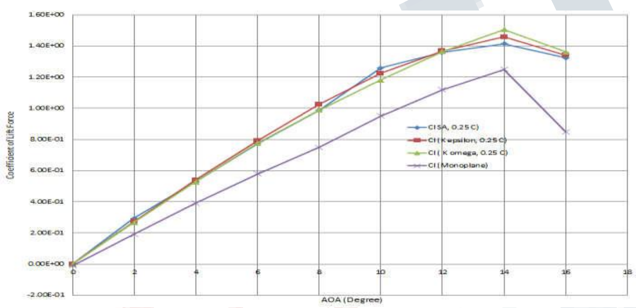

Fig 17: Comparison of Coefficient of Lift Force with AOA for Biplane with d of 0.25 Times of C

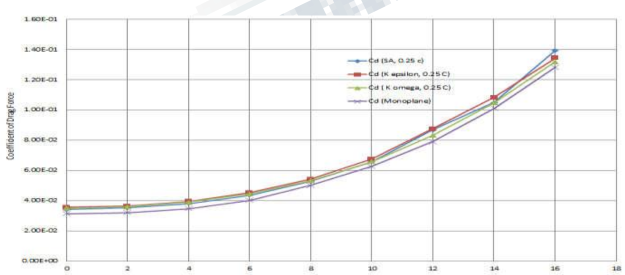

Fig 18: Comparison of Coefficient of Drag Force with AOA for Biplane with d of 0.25 Times of C

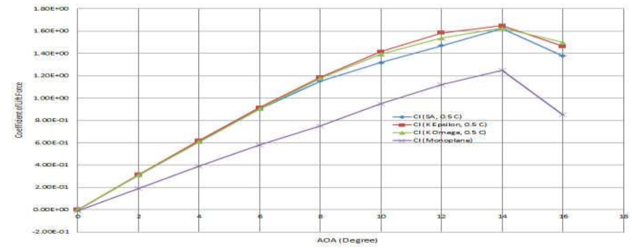

Fig 19: Comparison of Coefficient of Lift Force with AOA for Biplane with d of 0.50 Times of C

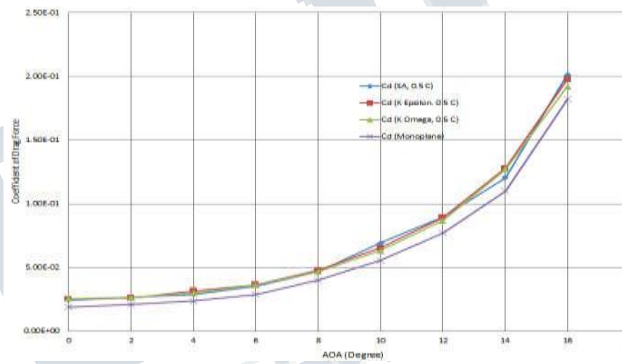

Fig 20: Comparison of Coefficient of Drag Force with AOA for Biplane with d of 0.50 Times of C

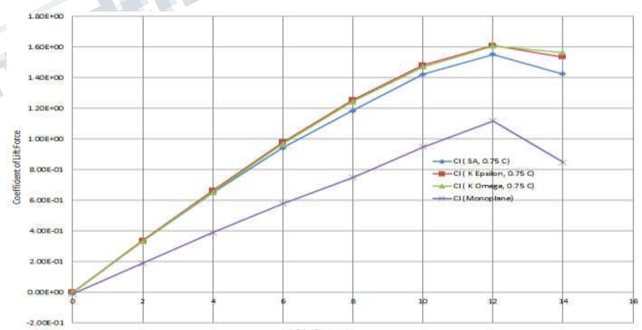

Fig 21: Comparison of Coefficient of Lift Force with AOA for Biplane with d of 0.75 Times of C

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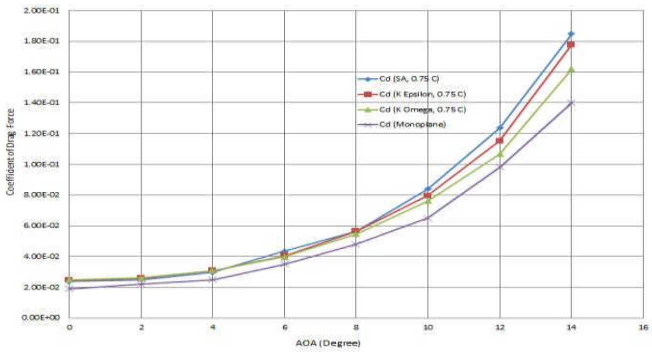

Fig 22: Comparison of Coefficient of Drag Force with AOA for Biplane with d of 0.75 Times of C

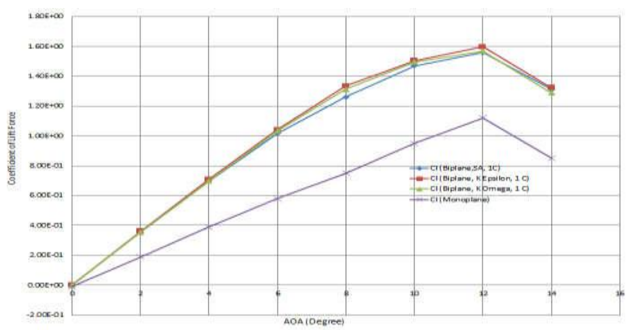

Fig 23: Comparison of Coefficient of Lift Force with AOA For Biplane with d of 1.0 Times of C

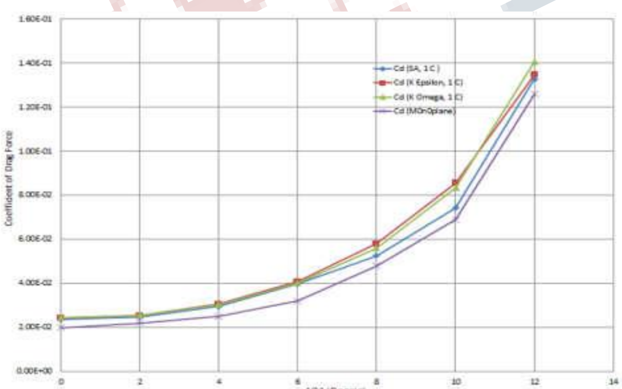

Fig 24: Comparison of Coefficient of Drag Force with AOA for Biplane with d of 1.0 Times of C

The comparison of coefficient of drag force with angle of attack between computational data of NACA 0012 biplane aerofoil and previously existed experimental data of NACA 0012 clean aerofoil configurations of profile is shown in Figures 18, 20, 22 and 24. It is seen that the drag coefficient obtained from computational result is higher than the previously existed experimental result for all the biplane configurations. During drag analysis, it is seen that among the four different types of biplane configurations, 'biplane with d of 0.5 times of C' provides maximum drag force than other two biplane configurations.

V. CONCLUSIONS

The magnitude of the previously experimental existed lift coefficient is lower than that of the computational value. The variation of drag coefficient with angle of attack follows the parabolic shape and the magnitude of the experimental value is less than that of the computational value. The 'biplane with d of 0.5 times of C' provides maximum lift coefficient than those by the other biplane configurations. The 'biplane with d of 0.75 times of C' provides lower lift and drag coefficient than the 'biplane with d of 0.5 times of C'. The 'biplane with d of 1.0 times of C' provides minimum lift coefficient and maximum drag coefficient among the four types of biplane configurations. Stalling angle is found approximately 14o to 15o degree for the biplane configurations.

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NOMENCLATURE

Symbol	Meaning	Unit
C	Chord Length	Mm
C_L	Lift Coefficient	-
C_D	Drag Coefficient	-
C_{Lmaax}	Maximum Lift Coefficient	-
D or d	Distance between two Aerofoils of Biplane	mm
AOA	Angle of Attack	Degree