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AERODYNAMIC CHARACTERISTICS OF BIPLANE CONFIGURATIONS USING NACA0024 PROFILE

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ABSTRACT

This paper presents the aerodynamic characteristics of the biplane configurations. NACA 0024 symmetric aerofoil with chord length of 100mm has been used for three biplane configurations. The aerodynamic characteristics have been analyzed numerically with the help of CFD software by varying the distance between the aerofoils and the angle of attack. Some experimental works have also been carried out and compared with those of the results obtained numerically. Stalling angle is found at 18^o to 19^o degree for all the biplane configurations. The lift and drag coefficients obtained from computational result are slightly higher than the experimental result. It is observed that the experimental aerodynamic characteristic agree reasonably with those obtained numerically.

Keywords: Biplane, Aerodynamic characteristics.

1. INTRODUCTION

Monoplane is the type of aircraft with a single pair of wings whereas biplane is an aircraft with two wings on each side mounted one above the other. Biplanes are used for the low speed condition. The aerodynamic characteristics of the biplanes are not similar to those of the monoplane configuration. The aerodynamic characteristics of the biplanes vary with the angle of attack. This paper compares the aerodynamic characteristics of biplane configurations both numerically and experimentally.

The flow of air through the surfaces of an aircraft produces the lifting force. The lift force is caused due to the pressure difference that exists between the lower and upper surfaces [1]. In addition to the lift, a force directly opposing the motion of the wing through the air is always present, which is called drag force. The angle between the relative wind and the chord line is the angle of attack of the airfoil. The aerodynamic characteristics of an aircraft are strongly affected by the shape of the wing section. Here NACA 0024 symmetric aerofoil profiles have been used for the research work.

The lift and drag forces developed by an aircraft vary with the change of angle of attack. For a cambered aerofoil, the zero-lift angle is negative. But for a symmetrical aerofoil, the zero-lift angle is zero. As such, the zero-lift angle for NACA 0024 aerofoil is zero degree [2]. The lift force increases almost linearly with angle of attack until a maximum value is reached whereupon the wing is said to stall [3]. The shape of the drag force vs angle of attack is approximately parabolic [4]. It is desirable for the wing to have the maximum lift force and smallest possible drag force.

For a biplane, there will be an 'Interference Effect' in between the aerofoils. Mainly the interference effect occurs due to the suction pressure developed by the upper surface of the lower aerofoil and the positive pressure developed by the lower surface of the upper aerofoil [5]. 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 [6]. As such, it would be desirable to keep the interference effect of a biplane as minimum as possible.

The aerodynamic characteristics of biplane have been experimentally investigated in the wind tunnels. Here an experimental set up of the biplane configuration has been made by using NACA 0024 profile and tests have been conducted in the wind tunnel. Finally, the results of the computational and experimental investigation have been compared and analyzed.

2. COMPUTATIONAL RESULT

The present research work is carried out numerically with CFD analysis by using NACA 0024 symmetric aerofoil profile. The flow of air through the aerofoils is incompressible and subsonic. The chord length of the aerofoil of biplane configurations is 100mm. The free stream airflow is 12.5m/s and the effect of temperature is neglected. The operating conditions like density of air 1.225 kg / m^3, operating pressure 0.101 MPa (1.01 bar or 14.7 psi) and absolute viscosity 1.789 x 10^{-5} kg / m-s. The Reynold's Number is 2.74 x 10^4 based on chord length. The distance between the aerofoils of the biplane (d) is 0.50, 0.75 and 1.00 times of chord length (C). The data have been obtained at different angles of attack from 0° to 21° with 1.5° step. Fifteen tapping points have been made computationally on each surface of the aerofoil to study the surface static pressure at each point.

The variation of coefficient of lift force with angle of attack for biplane with d of 0.50 times of C is shown in Figure 1. At zero degree angle of attack, the lift coefficient is zero and it increases linearly with the increase of angle of attack up to approximately 18^o. Then, lift coefficient decreases with the further increase of angle of attack. As such, the stalling angle of biplane with d of 0.50 times of C is about 18˚. It is also observed that the maximum lift coefficient, C_{Lmax} is approximately 1.45 at 18^o angle of attack.

The variation of coefficient of drag force with angle of attack for biplane with d of 0.50 times of C is shown in Figure 2. The shape of the drag force coefficient vs angle of attack curve is parabolic.

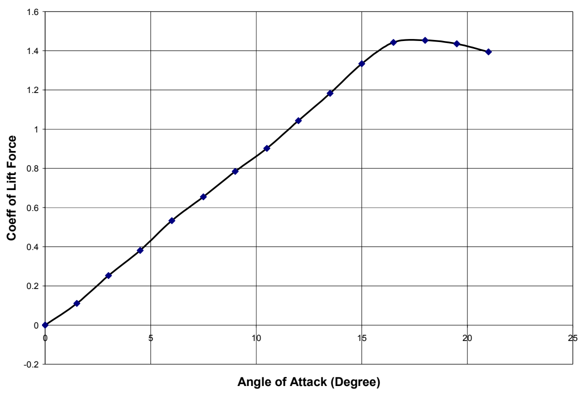

Fig 1: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.50 Times of C.

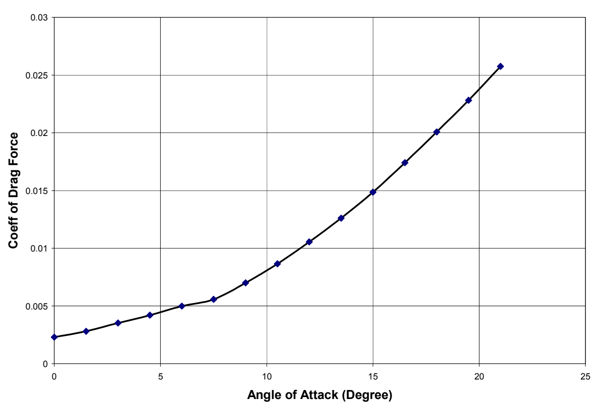

Fig 2: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.50 Times of C**.**

The variation of coefficient of lift force with angle of attack for biplane with d of 0.75 times of C is shown in Figure 3. At zero degree angle of attack, the lift coefficient is zero and it increases linearly with the increase of angle of attack up to approximately 18^o. After wards, lift coefficient decreases with the further increase of angle of attack. As such, the stalling angle of biplane with d of 0.75 times of C is about 18˚. It is also observed that the maximum lift coefficient, C_{Lmax} is approximately 1.5 at 18^o angle of attack.

The variation of coefficient of drag force with angle of attack for biplane with d of 0.75 times of C is shown in Figure 4. The shape of the drag force coefficient vs angle of attack curve is parabolic.

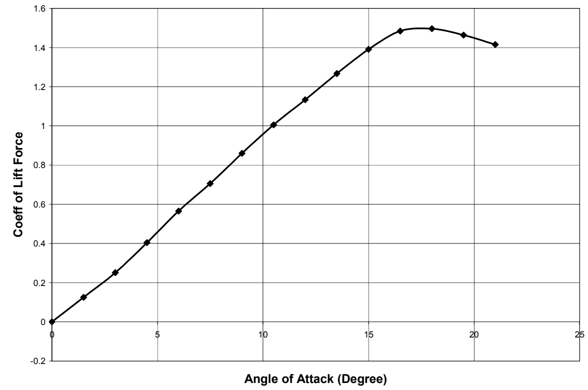

Fig 3: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.75 Times of C.

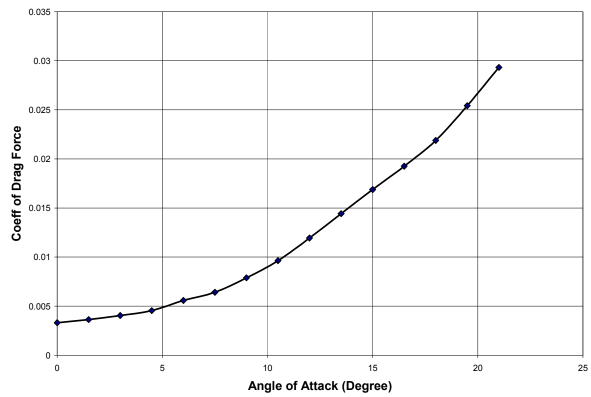

Fig 4: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.75 Times of C**.**

The variation of coefficient of lift force with angle of attack for biplane with d of 1.00 times of C is shown in Figure 5. At zero degree angle of attack, the lift coefficient is zero and it increases linearly with the increase of angle of attack upto 21^o. No separation of flow occurs upto 21^o angle of attack. As such, the stalling angle of this type biplane occurs after 21˚ angle of attack. It is also observed that the lift coefficient, C_L is approximately 1.39 at 21^o angle of attack. The value of lift force and coefficient of lift force are found to be less in comparison with the values of the other two types of biplanes as described earlier.

The variation of coefficient of drag force with angle of attack for biplane with d of 1.00 times of C is shown in Figure 6. The shape of the drag force coefficient vs angle of attack curve is parabolic. The value of coefficient of drag force is found to be higher in comparison with the values of the other two types of biplane configurations as described earlier.

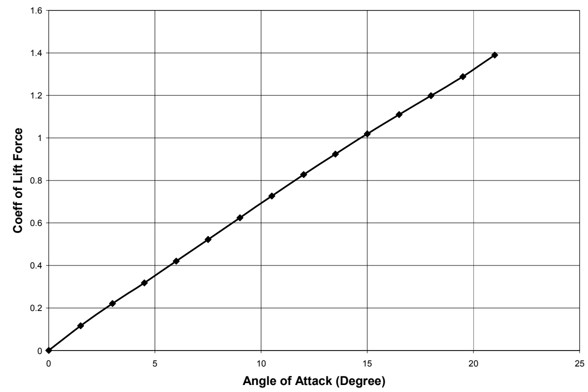

Fig 5: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 1.00 Times of C.

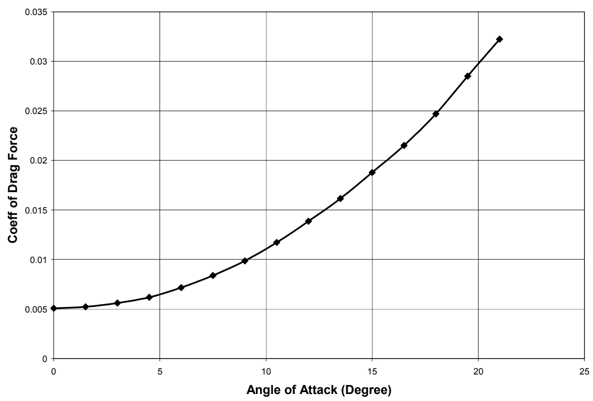

Fig 6: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 1.00 Times of C.

2. EXPERIMENTAL SET UP

Figures 7 and 8 show the photographs of the complete experimental set up before and after installing with the wind tunnel. Two aerofoils of biplane have been constructed by using NACA 0024 type aerofoil profile. The aerofoil is of symmetric type aerofoil and it's maximum thickness is 24mm at 30% chord length from the nose. The chord length of the aerofoil is 100mm, span 24mm, length 420mm and maximum thickness 24mm at 30% chord length from the nose. The upper aerofoil is identified as aerofoil-1 and lower aerofoil is identified as aerofoil-2. Six pressure tapping points have been constructed approximately 15%, 30%, 45%, 60%, 75% and 90% of chord length from the nose on each surface of the biplane wing. Inclined manometers are used for measuring the surface pressures. Provisions have been made to change the angle of attack of both the aerofoils from 0° to 21° with 1.5° step and to keep the distance between the upper and the lower aerofoil of the biplane at 0.50, 0.75 and 1.00 times of chord length. The wings of the biplane have been placed in a low speed subsonic wind tunnel to take experimental data at different angles of attack (α).

Fig 7**:** Photograph of Experimental Set Up before Installing with the Wind Tunnel

Fig 8: Photograph of Experimental Set Up after Installing with the Wind Tunnel

3. EXPERIMENTAL RESULT

For experimental investigation, the biplane models are placed in the open air at the exit end of a low speed subsonic wind tunnel. The flow is incompressible and subsonic. The free stream airflow is kept at 12.5 m/s and the effect of temperature is neglected. The experimental data have been obtained at different angles of attack from 0° to 21° with 1.5° step. The lift and drag coefficients have been calculated from the experimental data based on the consideration of 2-D aerofoil.

The variation of coefficient of lift force with angle of attack for biplane with d of 0.50 times of C is shown in Figure 9. At zero degree angle of attack, the lift coefficient is zero and it increases linearly with the increase of angle of attack up to approximately 18^o. Then, lift coefficient decreases with the further increase of angle of attack. As such, the stalling angle of biplane with d of 0.50 times of C is about 18˚. It is also observed that the maximum lift coefficient, C_{Lmax} is approximately 1.21 at 18^o angle of attack.

The variation of coefficient of drag force with angle of attack for biplane with d of 0.50 times of C is shown in Figure 10. The shape of the drag force coefficient vs angle of attack curve is parabolic.

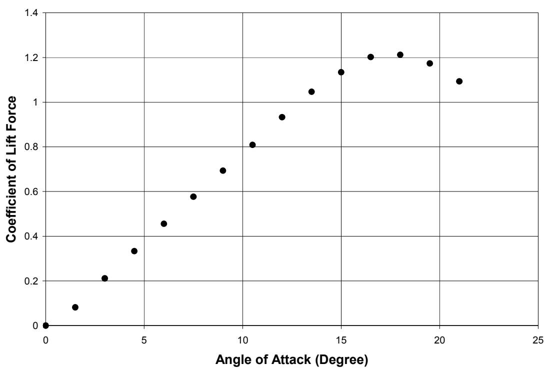

Fig 9: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.50 Times of C.

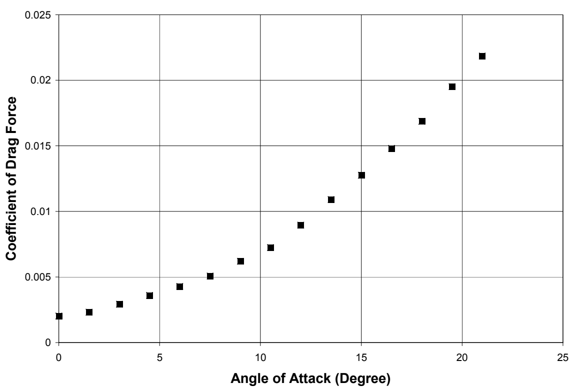

Fig 10: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.50 Times of C.

The variation of coefficient of lift force with angle of attack for biplane with d of 0.75 times of C is shown in Figure 11. The lift coefficient increases linearly with the increase of angle of attack up to approximately 18^{o}. After wards, lift coefficient decreases with the further increase of angle of attack. As such, the stalling angle of biplane with d of 0.75 times of C is about 18˚. It is also observed that the maximum lift coefficient is approximately 1.32.
The variation of coefficient of drag force with angle of attack for biplane with d of 0.75 times of C is shown in Figure 12. The shape of the drag force coefficient vs angle of attack curve is parabolic.

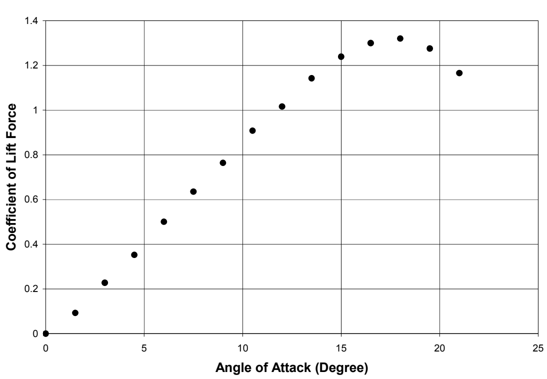

Fig 11: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.75 Times of C.

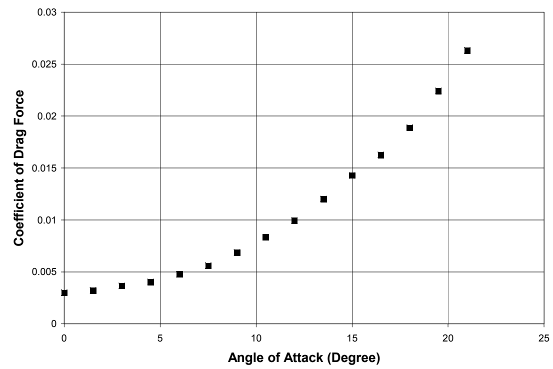

Fig 12: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.75 Times of C.

The variation of coefficient of lift force with angle of attack for biplane with d of 1.00 times of C is shown in Figure 13. The coefficient of lift force increases linearly with the increase of angle of attack up to approximately 19^{o}. As such, the stalling angle of this type biplane is about 19˚. It is also observed that the maximum lift coefficient, C_{Lmax} is approximately 0.913.
The variation of coefficient of drag force with angle of attack for biplane with d of 1.00 times of C is shown in Figure 14. The shape of the drag force coefficient vs angle of attack curve is parabolic.

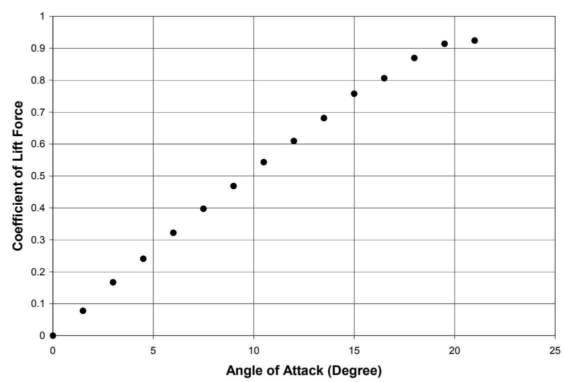

Fig 13: Variation of Coefficient of Lift Force with Angle of Attack for Biplane with d of 1.00 Times of C.

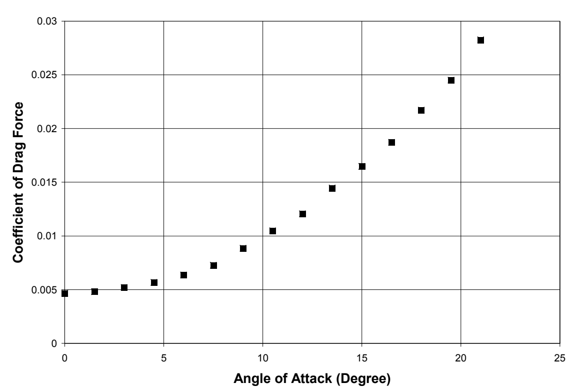

Fig 14: Variation of Coefficient of Drag Force with Angle of Attack for Biplane with d of 1.00 Times of C.

4. RESULTS AND DISCUSSION

The comparison of coefficient of lift force with angle of attack between computational and experimental data of biplane configurations of NACA 0024 profile is shown in Figures 15 to 18. It is seen that the lift coefficient obtained from computational result is higher than the experimental result for all the biplane configurations. Among the three types of biplane configuration, ‘biplane with d of 0.75 times of C’ provides maximum coefficient of lift force than those by the other two types of configurations.

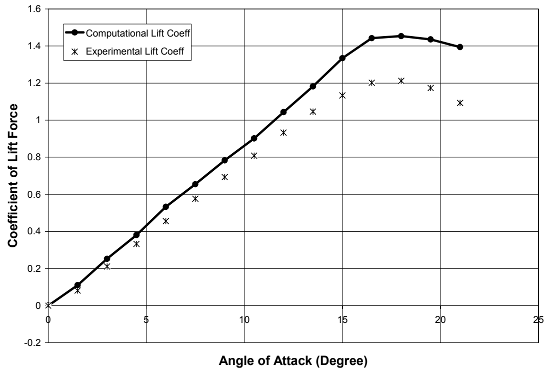

Fig 15: Comparison of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.50 Times of C

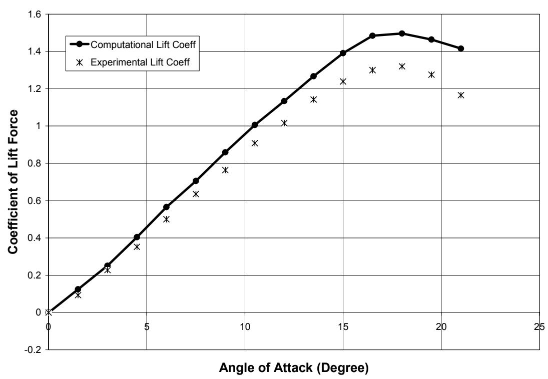

Fig 16: Comparison of Coefficient of Lift Force with Angle of Attack for Biplane with d of 0.75 Times of C

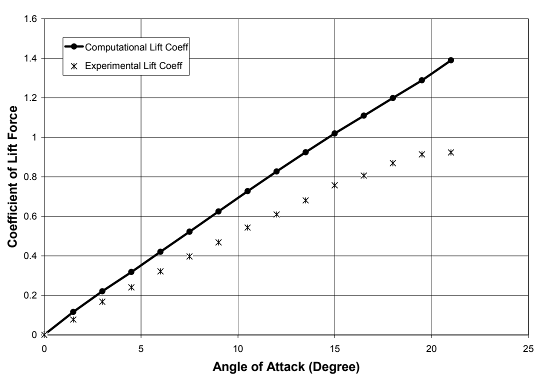

Fig 17: Comparison of Coefficient of Lift Force with Angle of Attack for Biplane with d of 1.00 Times of C

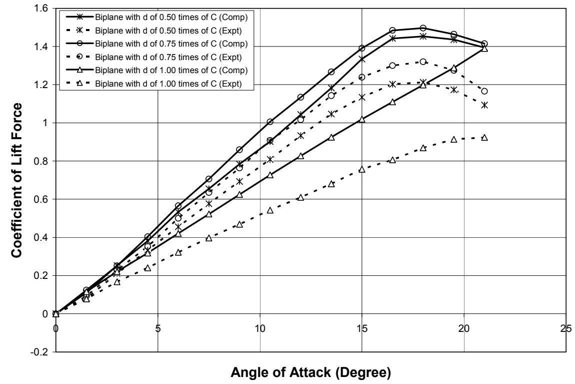

Fig 18: Comparison of Coefficient of Lift Force with Angle of Attack for Different Configurations of Biplane

The comparison of coefficient of drag force with angle of attack between computational and experimental data of biplane configurations of NACA 0024 profile is shown in Figures 19 to 22. It is seen that the drag coefficient obtained from computational result is higher than the experimental result for all the biplane configurations. During drag analysis, it is seen that among the three different types of biplane configurations, ‘biplane with d of 1.00 times of C’ provides maximum drag force than other two biplane configurations.

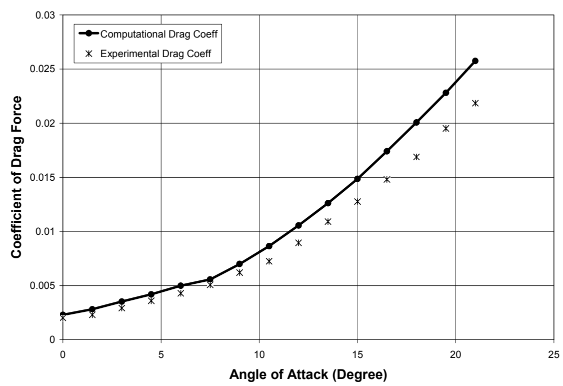

Fig 19: Comparison of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.50 Times of C

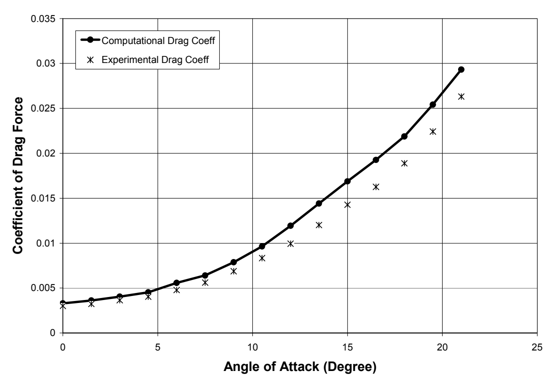

Fig 20: Comparison of Coefficient of Drag Force with Angle of Attack for Biplane with d of 0.75 Times of C

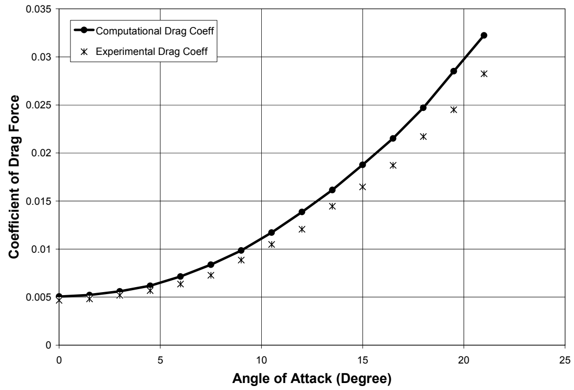

Fig 21: Comparison of Coefficient of Drag Force with Angle of Attack for Biplane with d of 1.00 Times of C

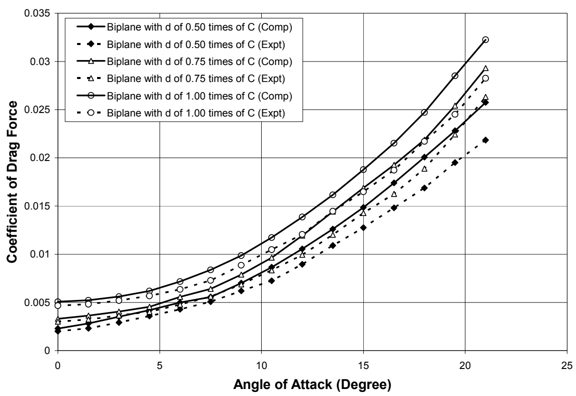

Fig 22: Comparison of Coefficient of Drag Force with Angle of Attack for Different Configurations of Biplane

5. CONCLUSIONS

The magnitude of the experimental 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 0.75 times of C' provides maximum lift coefficient than those by the other biplane configurations. The 'biplane with d of 0.50 times of C' provides lower lift and drag coefficient than the 'biplane with d of 0.75 times of C'. The 'biplane with d of 1.00 times of C' provides minimum lift coefficient and maximum drag coefficient among the three types of biplane configurations. Stalling angle is found approximately 18^o to 19^o degree for all the biplane configurations.

6. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning	Unit
C	Chord Length	mm
C_L	Lift Coefficient	-
C_{Lmax}	Maximum Lift Coefficient	-
d	Distance between the two Aerofoils of Biplane	mm
α	Angle of Attack	Degree