**Proceedings of the**
**International Conference on Mechanical Engineering 2011**
**(ICME2011) 18-20 December 2011, Dhaka, Bangladesh**

**ICME11-FL-010**

# INTERFERENCE EFFECT AND FLOW PATTERN OF FOUR BIPLANE CONFIGURATIONS USING NACA 0024 PROFILE

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## ABSTRACT

An interference effect occurs in between the aerofoils of biplane configurations. It varies with the change of angle of attack and chord length. This paper is written to determine the interference effect of different biplane configurations. NACA 0024 symmetric aerofoil with chord length of 100mm has been used here for four biplane configurations. The interference effect has been analyzed by varying the distance between the aerofoils and the angle of attack numerically with the help of CFD software. Finally some conclusions have been drawn on the basis of the computational result.

**Keywords:**  Angle of Attack, Lift Force, Drag Force, Interference Effect, Chord Length, Stalling Angle.

## 1. INTRODUCTION

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 biplanes vary with the change of angle of attack and chord length. In the biplane configuration, there occurs interference in between the two aerofoils. This paper mainly analyzes & compares the interference effect and flow pattern of four different biplane configurations from computational investigation.

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. The cross-sectional shape obtained by the intersection of the wing with the perpendicular plane is called an aerofoil. Here NACA 0024 symmetric aerofoil profiles have been used for the research work.

The pressure distribution around a two-dimensional aerofoil varies with the angle of attack. A positive pressure implies a pressure greater than the free stream value and a negative pressure implies a suction pressure less than the free stream value. With the increase of angle of attack, the height of the upper surface suction peak increases. Sudden flattening of the upper surface pressure distribution at high angle of attack occurs due to separation. With further increase of angle of attack, the lift decreases.

For a biplane, there will be an 'Interference Effect' in between the aerofoils. Mainly the interference effect is occurred 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 [2]. The interference effect reduces the lift force and increases the drag force. The interference effect will vary with the chord length and the distance between the aerofoils [3]. As such, it would be desirable to keep the interference effect of a biplane as minimum as possible.

## 2. COMPUTATIONAL RESULT

The research work has been 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 $1.225 \text{ kg} / \text{m}^3$, operating pressure 0.101 MPa (1.01 bar or 14.7 psi) and absolute viscosity $1.789 \times 10^{-5} \text{ kg} / \text{m-s}$. The Reynold's Number is $2.74 \times 10^4$. The distance between the aerofoils of the biplane (d) is 0.40, 0.50, 0.75 and 1.00 times of chord length (C). The data have been obtained at different angles of attack (α) from 0° to 21° with 3° step. Fifteen tapping points have been made computationally on each surface of the aerofoil to study the surface static pressure at each point.

## 2.1 Aerodynamic Characteristics of Biplane with Distance between the Aerofoils of 0.40 Times of Chord Length

The variation of static pressure with chord length for biplane at 0.40 of chord length at $18^o$ angle of attack is shown in Figure 1. The "upper surface pressure of aerofoil-1 and lower surface pressure of aerofoil-2" and "upper surface pressure of aerofoil-2 and lower surface pressure of aerofoil-1" of biplane at 40mm distance have coincided with each other at zero degree angle of attack as the aerofoil is of symmetrical type. The difference in pressure produced by the two lower surfaces of two aerofoils (pressure side-1 and 2) and two upper surfaces of two aerofoils (suction side-1 and 2) determines the amount of lift and drag force produced by the biplane aerofoils. Due to the interference effect between the aerofoils, there is increased drag force and reduced lift force. The interference effect has been occurred between 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. The interference effect affects the fluid flow and the effect is more if the distance between the aerofoils is less. The interference effect varies along the chord length. The suction pressure mainly determines the amount of lift force to be produced by the two aerofoils. The suction pressure develops by the two aerofoils have been increased with the increase of the angle of attack up to about $18^o$. Afterwards, separation starts and with further increase of angle of attack, the lift reduces.
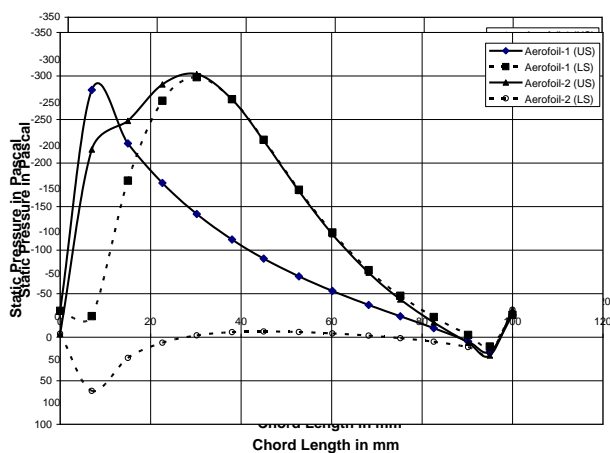


Fig 1. Variation of Static Pressure with Chord Length for Biplane at 0.40 of Chord Length at $18^o$ Angle of Attack

## 2.2 Aerodynamic Characteristics of Biplane with Distance between the Aerofoils of 0.50 Times of Chord Length

The surface static pressure vs chord length at $18^o$ angle of attack of biplane at 0.50 of chord length is shown in Figure 2. The "upper surface pressure of aerofoil-1 and lower surface pressure of aerofoil-2" and "upper surface pressure of aerofoil-2 and lower surface pressure of aerofoil-1" of biplane at 0.50 of chord length coincides with each other at zero degree angle of attack as the aerofoil is of symmetrical type. The difference in pressure produced by the two lower surfaces of two aerofoils (pressure side-1 and 2) and two upper surfaces

of two aerofoils (suction side-1 and 2) determines the amount of lift and drag force produced by the biplane aerofoil. An interference effect in the flow in between the aerofoils increases the drag force and reduces the lift force. The interference effect affects the fluid flow and the effect is more if the distance between the aerofoils is less. As such, the interference effect reduces in comparison with the biplane at 0.40 of chord length. The interference effect also varies along the chord length. The suction pressure mainly determines the amount of lift force to be produced by the two aerofoils. The suction pressures developed from the two aerofoils increases with the increase of the angle of attack up to about $18^o$. Afterwards, separation starts and with the further increase of angle of attack, the lift reduces.
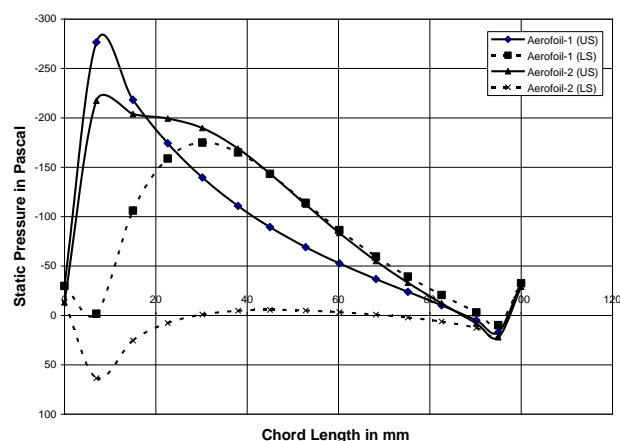


Fig 2. Variation of Static Pressure with Chord Length for Biplane at 0.50 of Chord Length at $18^o$ Angle of Attack

## 2.3 Aerodynamic Characteristics of Biplane with Distance between the Aerofoils of 0.75 Times of Chord Length

The surface static pressure vs chord length at $18^o$ angle of attack for biplane at 0.75 of chord length is shown in Figure 3. The "upper surface pressure of aerofoil-1 and lower surface pressure of aerofoil-2" and "upper surface pressure of aerofoil-2 and lower surface pressure of aerofoil-1" of biplane at 0.75 of chord length coincides with each other at zero degree angle of attack as the aerofoil is of symmetrical type. The difference in pressure produced by the two lower surfaces of two aerofoils (pressure side-1 and 2) and two upper surfaces of two aerofoils (suction side-1 and 2) determines the amount of lift and drag force produced by the biplane aerofoil. An interference effect in the flow in between the aerofoils increases the drag force and reduces the lift force. The interference effect affects the fluid flow and the effect is more if the distance between the aerofoils is less. As such, the interference effect reduces in comparison with the biplane at 0.40 and 0.50 of chord length. The interference effect also varies along the chord length. The suction pressure mainly determines the amount of lift force to be produced by the two aerofoils. The suction pressures developed from the two aerofoils have been increased with the increase of the angle of attack up to about $18^o$. Afterwards, separation starts and with further increase of angle of attack, the lift reduce
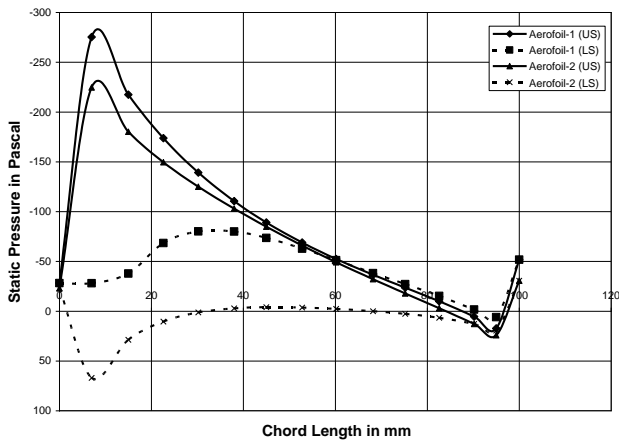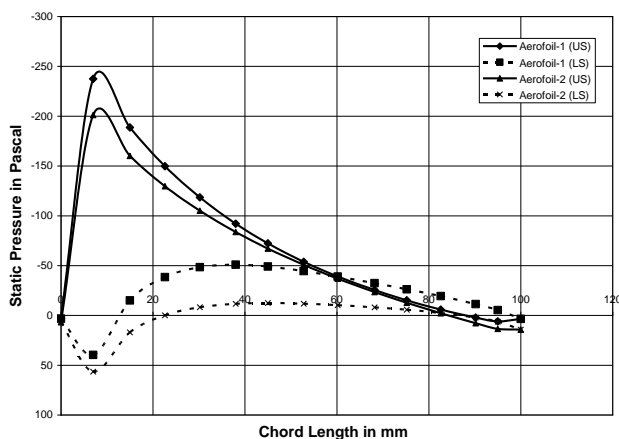
Fig 3. Variation of Static Pressure with Chord Length for Biplane at 0.75 of Chord Length at 18° Angle of Attack

## 2.4 Aerodynamic Characteristics of Biplane with Distance between the Aerofoils of 1.00 Times of Chord Length

The surface static pressure vs chord length at 21° angle of attack for biplane at 1.00 of chord length is shown in Figure 4. The "upper surface pressure of aerofoil-1 and lower surface pressure of aerofoil-2" and "upper surface pressure of aerofoil-2 and lower surface pressure of aerofoil-1" of biplane at 1.00 of chord length coincides with each other at zero degree angle of attack as the aerofoils is of symmetrical type. The difference in pressure produced by the two lower surfaces of two aerofoils (pressure side-1 and 2) and two upper surfaces of two aerofoils (suction side-1 and 2) determines the amount of lift and drag force produced by the biplane aerofoil. An interference effect in the flow between the aerofoils increases the drag force and reduces the lift force. The interference effect affects the fluid flow. The interference effect also varies along the chord length. The suction pressure mainly determines the amount of lift force to be produced by the two aerofoils. In this case, separation does not develop upto 21° angle of attack. It develops just after 21° angle of attack.



Fi 4 Variation of Static Pressure with Chord Length for Biplane at 1.00 of Chord Length at 21° Angle of Attack.

## 3. PRESSURE CONTOURS FOR DIFFERENT BIPLANE PROFILES

Figure 5 shows the pressure limits and associated colours use in CFD to visualize the pressure contours at different pressures. Figure 6 to 12 show the pressure contours for four different types of configurations from 3° to 21° angle of attack with 3° step. The positive pressure contours produced by the lower surfaces and negative pressure contours produced by the upper surfaces of all the four different types of biplane configurations can easily be visualized from these figures. The interference effect of biplane configurations at 0.40, 0.50, 0.75 and 1.00 of chord length can also be visualized from these figures. It is observed from the pressure contours that the interference effect affects the fluid flow and the effect is more if the distance between the aerofoils is less. From the pressure contours of different profiles, it is also observed that maximum negative pressure (suction pressure) is produced by the upper surfaces of biplane at 0.75 of chord length at 18° angle of attack ie maximum lift ($C_{Lmax}$) is produced by this biplane at 18° angle of attack. It is also seen that all types of aerofoils will stall beyond 18° angle of attack except the biplane at 1.00 of chord length.
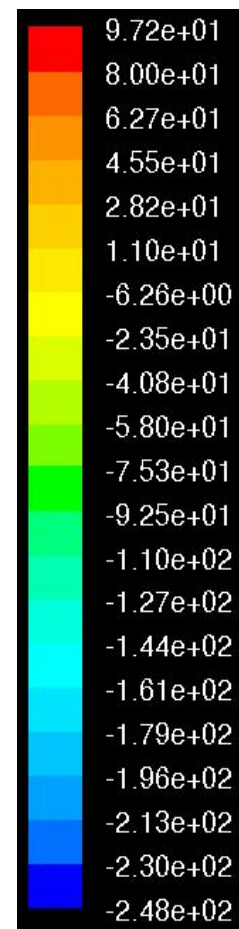


Fig 5. Pressure Limits and Associated Colours Use in CFD
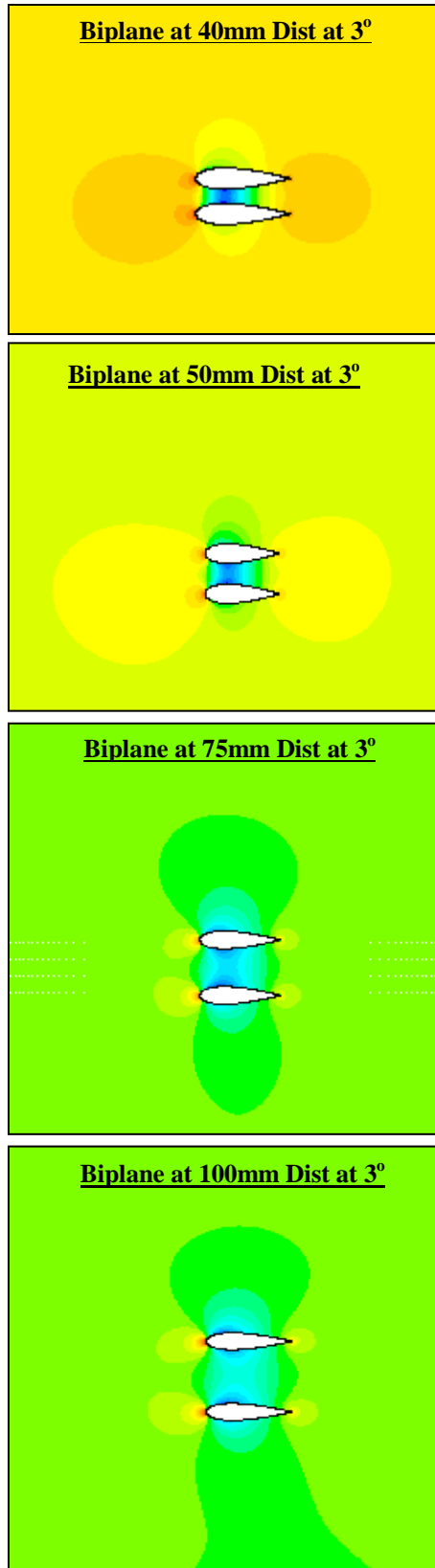
**3.1 Pressure Contour at 3$^o$ Angle of Attack**



Fig 6. Pressure Contour at 3$^o$ Angle of Attack for Different Configuration

**3.2 Pressure Contour at 6$^o$ Angle of Attack**



Fig 7.Pressure Contour at 6$^o$ Angle of Attack for Different Configuration.

## 3.3 Pressure Contour at 9° Angle of Attack

**Biplane at 40mm Dist at 9°**

**Biplane at 50mm Dist at 9°**

**Biplane at 75mm Dist at 9°**

**Biplane at 100mm Dist at**
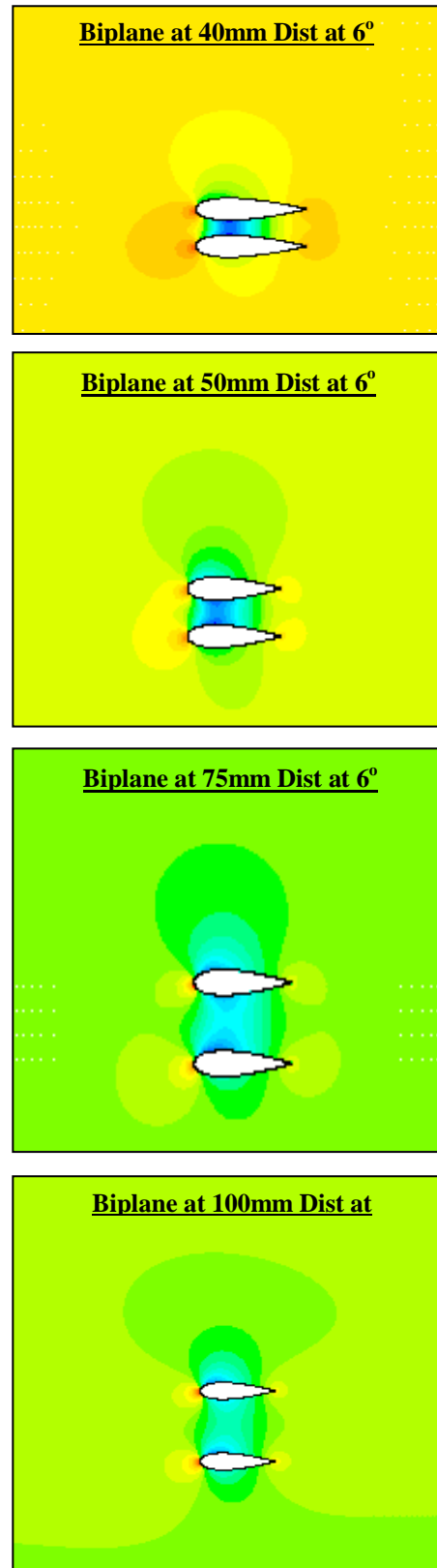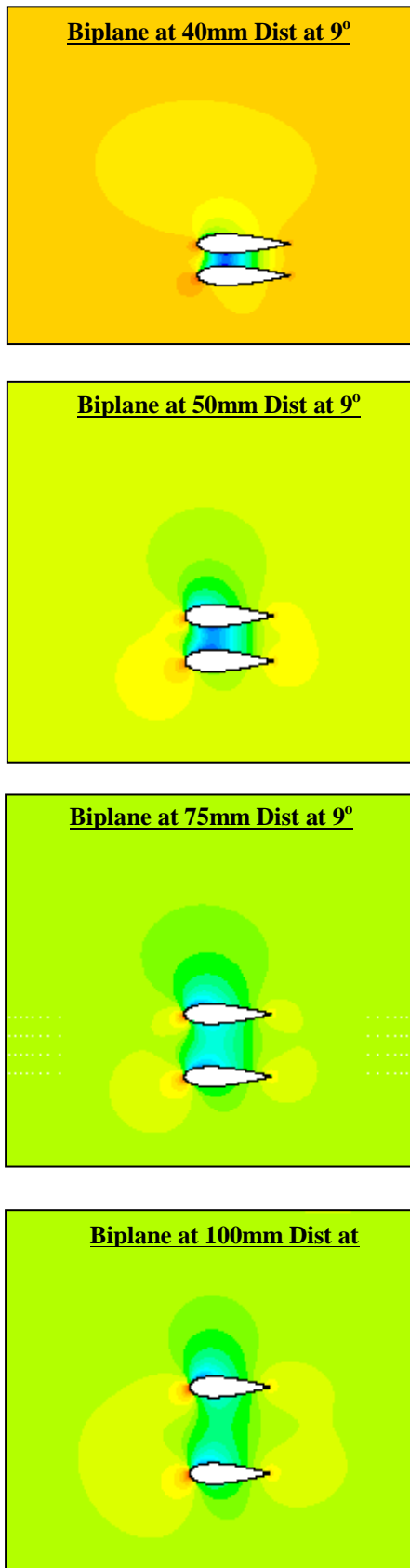
Fig 8. Pressure Contour at 9° Angle of Attack for Different Configuration.

## 3.4 Pressure Contour at 12° Angle of Attack

**Biplane at 40mm Dist at 12°**

**Biplane at 50mm Dist at 12°**

**Biplane at 75mm Dist at 12°**

**Biplane at 100mm Dist at 12°**

Fig 9. Pressure Contour at 12° Angle of Attack for

Different Configuration

### 3.5 Pressure Contour at 15° Angle of Attack

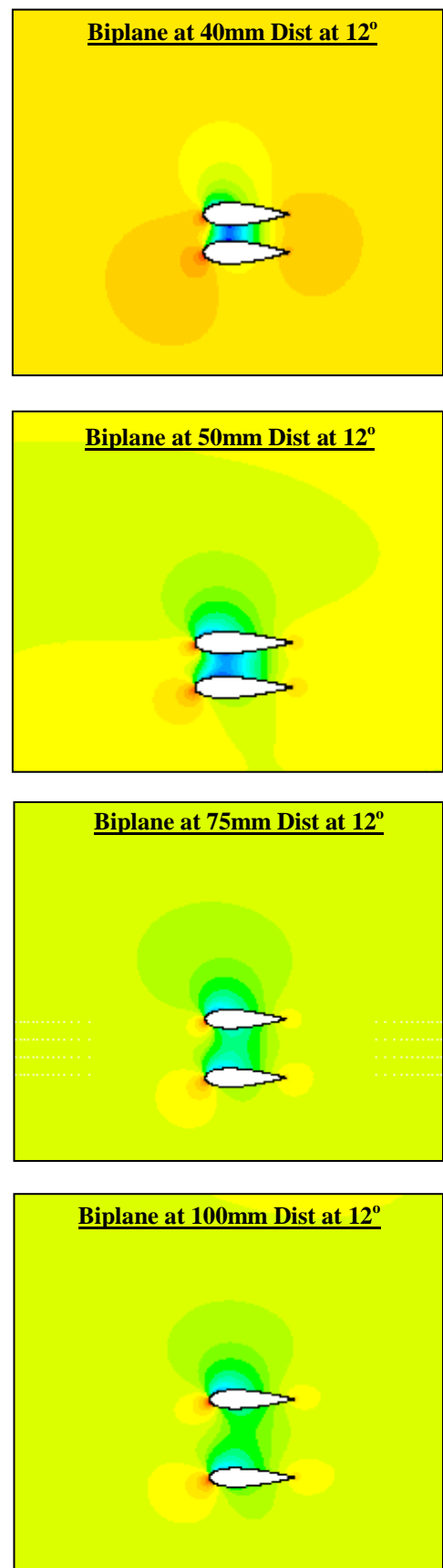**Biplane at 40mm Dist at 15°**

**Biplane at 50mm Dist at 15°**

**Biplane at 75mm Dist at 15°**

**Biplane at 100mm Dist at 15°**
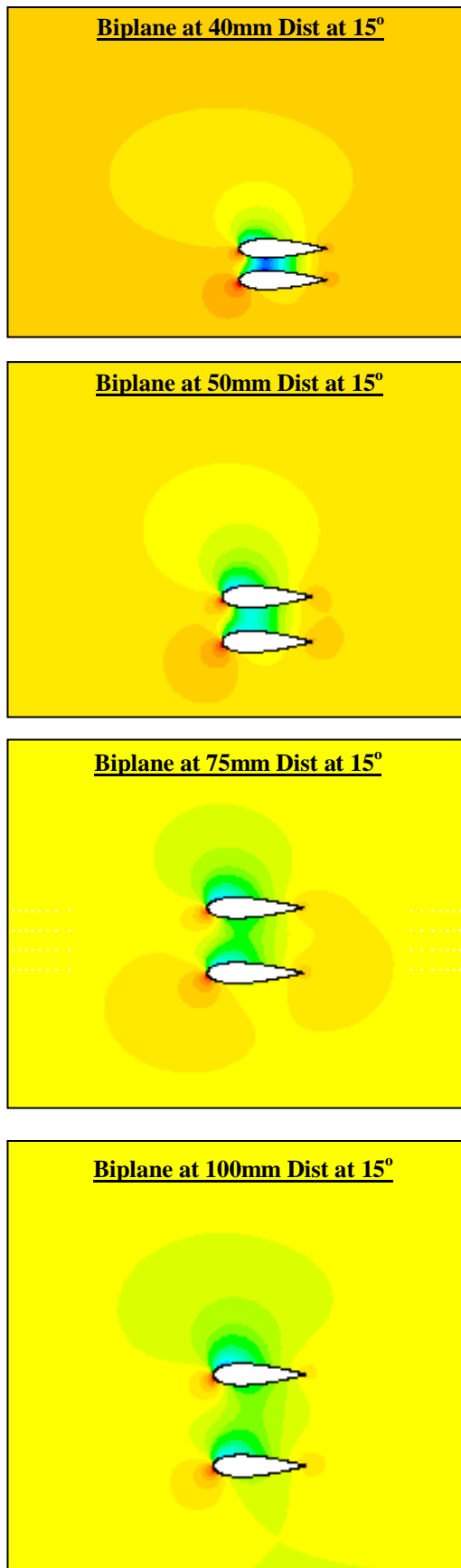
Fig 10. Pressure Contour at 15° Angle of Attack for

Different Configuration

### 3.6 Pressure Contour at 18° Angle of Attack

**Biplane at 40mm Dist at 18°**

**Biplane at 50mm Dist at 18°**

**Biplane at 75mm Dist at 18°**

**Biplane at 100mm Dist at 18°**
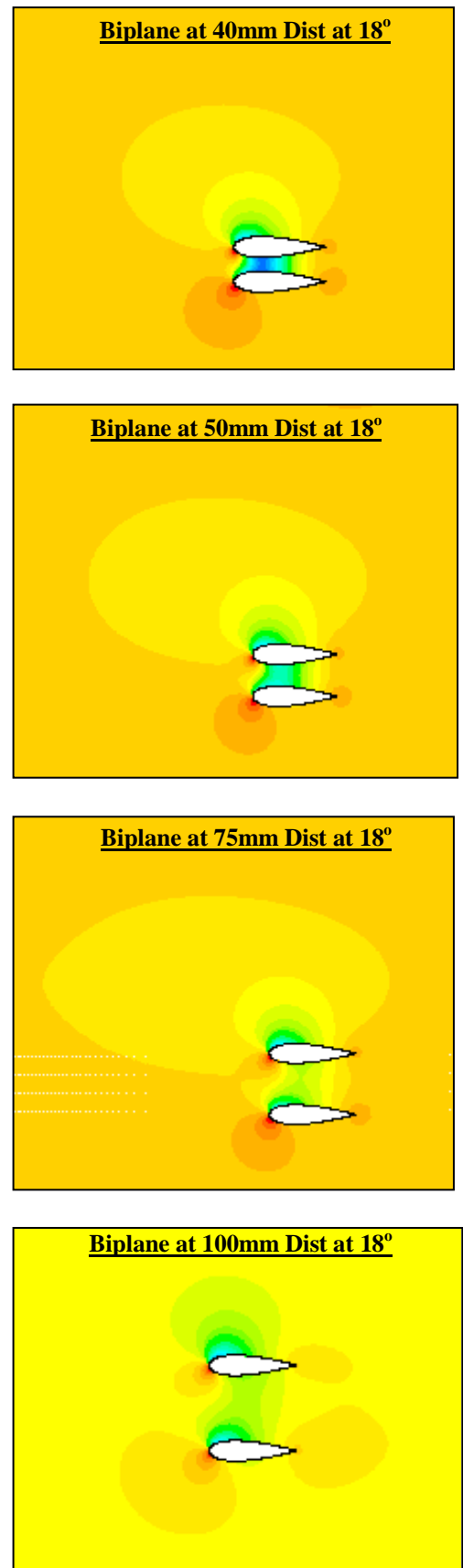
Fig 11. Pressure Contour at 18° Angle of Attack for Different Configuration

### 3.7 Pressure Contour at 21° Angle of Attack

**Biplane at 40mm Dist at 21°**

**Biplane at 50mm Dist at 21°**

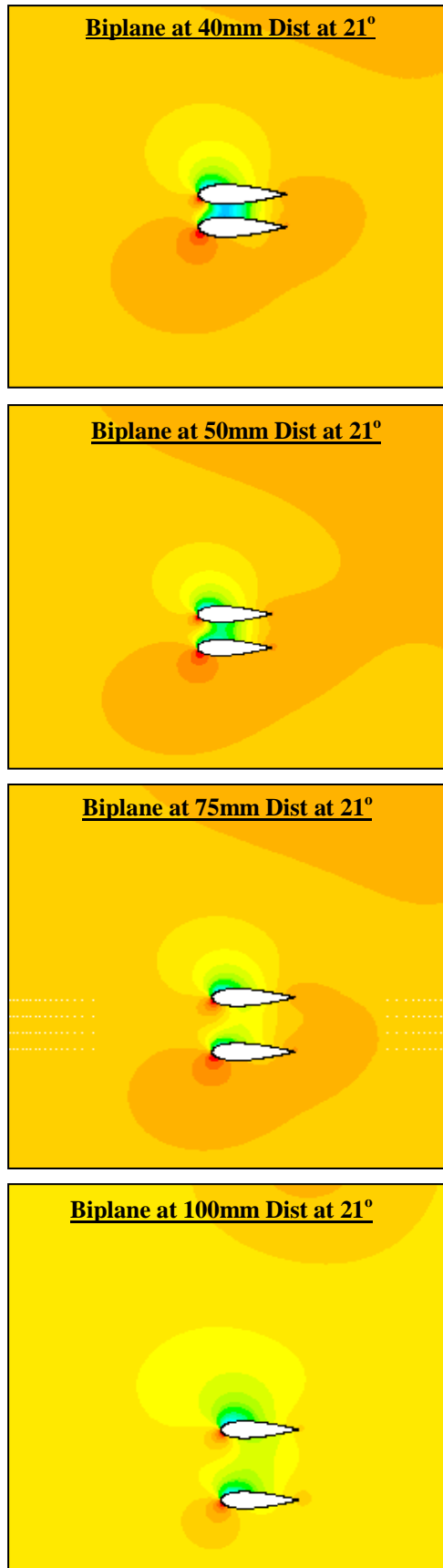**Biplane at 75mm Dist at 21°**

**Biplane at 100mm Dist at 21°**

Fig 12. Pressure Contour at 21° Angle of Attack for Different Configuration

## 4. CONCLUSIONS

The difference in pressure produced by the two lower surfaces of two aerofoils (pressure side-1 & 2) and two upper surfaces of two aerofoils (suction side-1 & 2) determines the amount of lift and drag force produced by the biplane aerofoils. An interference effect occurs in between the aerofoils for the biplane configurations. It varies with the change of angle of attack and chord length. The interference effect is more for biplane configuration at 0.40 of chord length and reduces when the distance between the aerofoils increases. The pressure contours of biplane at 0.40, 0.50 and 0.75 of chord length shows that the peak value of the upper surface suction pressure occurs at 18° angle of attack and then decreases with further increase of angle of attack indicating the appearance of separation while for biplane configuration at 1.00 of chord length, the peak value of the upper surface suction pressure occurs approximately at 21° angle of attack. For biplane configurations of NACA 0024 profile, the computational value of lift coefficient is maximum at 18° angle of attack for 0.40, 0.50 and 0.75 of chord length while for the biplane at 1.00 of chord length, the maximum value is observed approximately at 21° angle of attack.

## 5. REFERENCES

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## 6. NOMENCLATURE

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

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