HEFAT2012
9th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
16 – 18 July 2012
Malta

Effect of Second Wing on the Surface Pressure of an MAV Model

Soltani, M.R. *, Kamoushi, H., Abdi,M.A., and Masdari, M.

*Author for correspondence
Department of Aerospace Engineering,
Sharif University of Technology,
Tehran,
Islamic Republic of Iran,
E-mail: msoltani@sharif.edu

ABSTRACT
In this study surface pressure distribution over a Zimmerman type wing generally used for the MAV models in the presence of a second wing located on the top of the main wing was experimentally investigated. The model was tested in a low speed, low turbulence tunnel. Surface pressure data for various angles of attack and Reynolds numbers in the presence of the second wing is obtained. In addition, all data were repeated for the different locations, vertical and horizontal, positions of the second wing. The data are compared with those of the main wing alone. By comparing the surface pressure data for various cases one can clearly identify the best location, vertical and longitudinal, of the second wing. From the pressure data, it is seen that addition of the second wing affects the flow field over the main wing considerably. It increases the surface pressure distribution in front portion of the main wing, unfavourable effect, while it has a favourable effect in the rear portion of the wing.

NOMENCLATURE

V_∞	[m/sec]	Free stream velocity
C	[m]	Wing chord
C_{max}	[m]	Maximum wing chord
C_p	-	Pressure coefficient
A	Degree	Angle of attack

INTRODUCTION
Expensive flight costs of passenger aircrafts for doing a variety of operations including scientific, surveillance, and control operations as well as disability in doing missions in some ordous area make the expert design and produce new, smaller, cheaper UAVs with higher ability. UAVs are much smaller than the common aircraft, yet they are too big for rescue, search and spy operations in highly sensitive centralized places. Accordingly, some comprehensive researches have been done during the recent years, which have resulted in revising in UAVs and producing very small flying objects that fly at low altitude known as Micro Aerial Vehicles (MAVs).

Considering their features, MAVs have flight Reynolds number from 5×10^4 to 2.5×10^5 and they have also very low aspect ratio wings of about 1. Thus if the design of an MAV becomes optimal, it can be expected to do most of its expectations.

Researchers like Zimmerman, Bartlet, Vidal and Vadlin conducted extensive experiments on non-triangle wings with low aspect ratio, but with Reynolds number more than that encountered by the MAVs. From 1930 to 1950 and based on their researches, Bullay, Veining, Sarech, Rajan and Hamus presented theoretical and analytical theories of this field and then their activities have been continued by Hoerner[1].

The latest studies on the low aspect ratio wings at low Reynolds numbers are related to Toress and Muller's experimental works on aerodynamic features of four wings's having shapes of rectangular, elliptic, Zimmerman and inversed Zimmerman. The wings were flat plates with aspect ratios of 0.5, 1, 2 operating at Reynolds numbers of $7 \times 10^4$and 10^5 [1].

For their findings, for AR$\leq$ 1 and for the aforementioned Reynolds numbers, rectangular and inverse Zimmerman had the best results for lift and had greater $C_{L_{max}}$,but the drag of rectangular wing was more than other ones.

Since the most aerodynamic efficiency has been related to the Zimmerman shape with AR$\leq$ 1, this wing shape is used as the main wing of our model as shown in Fig. 1.

EXPERIMENTAL APPARATUS

All the experiments were performed in a subsonic open circuit wind tunnel of. The dimensions of its test section are 457x457x1200mm which has a maximum speed of 33m/s.

Several differential pressure transducers were used to measure the surface pressure difference over the wing surfaces.

The model used in this test consists of the three following main part:

1. The lower (main) wing (Fig. 2)
2. The upper wing
3. a pair of vertical fins

The tests were performed of two velocities of 10m/s and 15m/s and for angles of attack, ranging from -8 to 20 degree.
The vertical positions of the upper wing to the lower wing are, (see Fig.3):

a. h/C_{max} = 0.260 (a)
b. h/C_{max} = 0.312 (b)
c. h/C_{max} = 0.364 (c)

The longitudinal positions of the upper wing to the lower wing are, (see Fig. 4):

a. Front ,(a)
b. Middle ,(b)
c. Rear ,(c)

RESULTS AND DISCUSSION

To analyze the surface pressure over the wing, the upper surface is divided to 4 parts, 1-4, see Fig.5.

i) Area 1 extended along the leading edge and is parallel to it toward the wing tip that includes the nearest (or closest) pressure holes to the wing leading edge. It is used to examine the behavior of the sideslip flow along the leading edge from the center towards the wing tip.

ii) Area 2 located exactly at the middle of the wing, the section of the wing that has the maximum thickness to chord ratio. It is extended from the leading edge towards the trailing edge.

iii) Area 3 located at the center of the wing, and extends from the middle line to the wing tip, Fig.5.

iv) Area 4 is located near the wing tip and extends towards the trailing edge.

Examining the effect of the upper wing on the lower wing pressure distribution

Due to the variety of test cases, this paper only presents the results, only for the V_∞=15m/s and for angle of attacks of -4, 0 and 8 degree. These are conditions of the cruise flight were the maximum time of flight happens.

1. The effect of longitudinal displacement of the upper wing on the pressure distribution of Area1, case i

a) h/C_{max} = 0.260,Fig. 3a case at V=15m/s

Cp variation is shown in term of 2y/b for different locations of the upper wing in Figs. 6 and 7. The pressure distribution for a single wing is also presented for comparison. Generally, comparing to the single wing one, the pressure coefficient has been increased for angles of attack of -4 and zero degree for the entire locations of area 1, note that area 1 is shown in Fig. 5. Thus it is concluded that the upper wing has an undesired effect on the pressure distribution over this area. This undesired effect is almost equal when the upper wing situated on the Rear, Middle and Front positions, see Fig.4 for these definitions. At angle of attack of 8 degree, the upper wing has an undesired effect on the pressure coefficient of this area but comparing with the two former angles of attacks, this undesired effect has been reduced. Furthermore, it seems that increasing the angle of attack, reduces the undesired effects of the upper wing on the pressure distribution of the lower one (Fig. 8).

b) h/C_{max} = 0.312, Fig. 3b case at V=15m/s

For this case, comparing with the single wing data, the pressure coefficient increases for the entire parts of the area 1, Fig.9. Note that the locations of the second wing with respect to the main wing are shown in Figs. 3 and 4. That is the upper wing has an undesired effect on the pressure distribution of the lower one. This undesired effect is less when the upper wing is in the Middle position (figure 4b), because the pressure coefficient of the entire area has been increased less than the other positions (Fig.9 and Fig.10). In addition, similar the former case, an increase in the angle of attack reduces the undesired effect of the upper wing on the pressure distribution of the lower one (Fig. 11).

c) h/C_{max} = 0.364, Fig. 3c case at V=15m/s

In this case comparing the pressure data with the single wing one, the pressure coefficient increases for the entire points of area 1. That is the upper wing has again an undesired effect on the pressure distribution of this area. This undesired effect is, however, less at all three angles of attack when the upper wing has been located at Rear, figure 4a, because the pressure coefficient of the entire area has been increased less than these for the other positions (Figs.12-14).
In general, it can be said that the upper wing has an undesirable effect on the pressure distribution of area 1. Therefore, If the upper wing is locate in any of the following places:

1) h/C_{max} = 0.260; Rear, Middle, Front
2) h/C_{max} = 0.312; Middle
3) h/C_{max} = 0.364; Rear

it has an undesired effect.
It further can be said that when the upper wing is on Rear and at h/C_{max} = 0.364 position, its undesirable effect on the pressure distribution of the area 1 is minimal.

2. The effect of longitudinal displacement of the upper wing on the pressure distribution of area 2, case ii

h/C_{max} = 0.260, V=15m/s
In general, comparing to the single wing case, Cp has increased throughout the entire position of area 2, Fig.15-17. It means that again the upper wing has an undesirable effect on the pressure distribution over this area. This undesirable effect is, however, minimum when the upper wing is situated on the Middle, because the Cp has been less increased over the entire area.
Upper wing has, however, relatively satisfactory effect on the Cp distribution near the trailing edge, Figs. 16,17. For the upper wing located at the Rear position and at 8 degree angle of attack, the deficiency is minimal, Fig.17.
For other h/C_{max} positions, h/C_{max} = 0.312 and h/C_{max} = 0.364, similar trends have been observed. The pressure distribution in the leading edge area has been inversed an undesirable effect, while near the trailing edge the reverse is true, desirable effect.

3. The effect of longitudinal displacement of the upper wing on the pressure distribution of area 3, case iii

For this case, as can be seen from Figs. 18 and 19, addition of the second wing has an undesirable effect on the Cp distribution over the entire area 3 for all positions. However, for a few cases, a slight improvement in the Cp distribution in the vicinity of the trailing edge has been observed.

4. The effect of longitudinal displacement of the upper wing on the pressure distribution of area 4, case iv

Similar trends are observed when the second wing is added. The pressure distribution of area 4 has been increased in the forth position, but that of the Rear position has been improved slightly, Figs. 20-22. However, from the data it seems that in general addition of the second wing improves Cp distribution of area 4, thus its effect might be considered and be desirable.

CONCLUTSIONS

Extensive experiments were conducted to study the effect of the second wing location both laterally and longitudinally, on the pressure distribution of the main wing of an MAV. The experimental finding reveals that the upper wing has undesirable effect on the pressure distribution of the lower wing except at the trailing edge. Thus means that the upper wing may reduce lift force of the lower wing but it can increase the control surfaces efficiency significantly. If the upper wing is installed at with a positive angle of attack, it can increase total lift force of the MAV. In addition, the upper wing as a stabilizer can be effective in providing desired longitudinal stability of the MAV. In many cases observed in figures, at velocity of 15m/s, it can be said that the upper wing has undesirable effect on the surface pressure distribution on the wing in all areas when it (upper wing) is positioned at of $h/C_{max} = 0.364$, however, overall it might increase the lift when set at a positive angle of attack. Note, in all experimental conducted here, the upper wing was set at zero degree angle of attack.

REFERENCES

[1] Mueller, T. J., “Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Applications”, T. J. Mueller, Ed., 1th Ed., Vol. 195, 8 Jan 2002, pp. 115-134.

[2] Pope, A., Rae, W., and Barlow, J., “Low Speed Wind Tunnel Testing”, 3rd Ed., Wiley, New York, 1999.

[3] Thomas, G.B., Roy, D.M. and John, H.L.V., “Mechanical Measurements”, Fifth Edition, Addison-Wesley Publishing Company (1993).

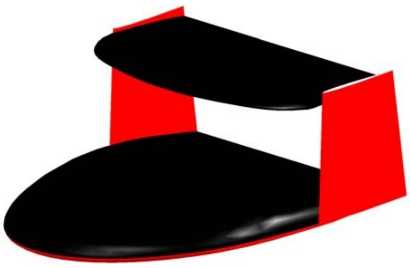

Fig. 1: Isometric view of MAV

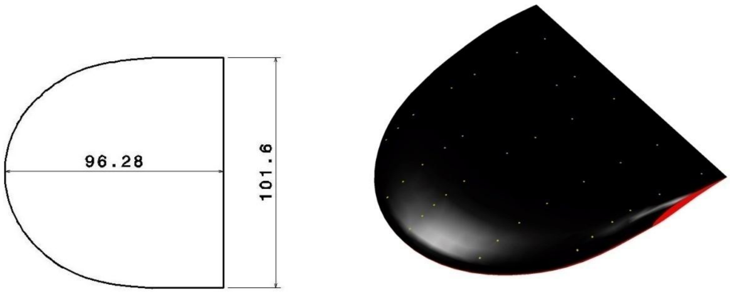

Fig. 2: Schematic view of low wing

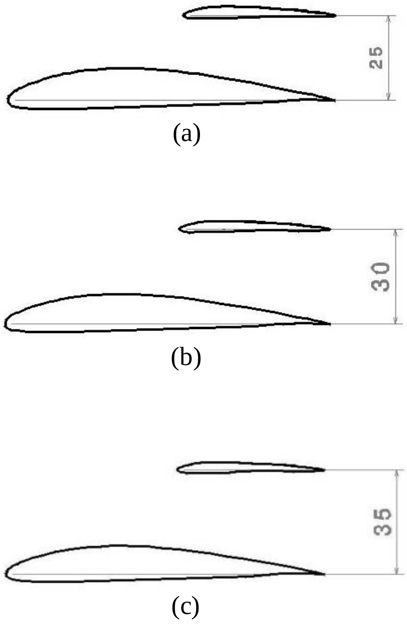

Fig. 3: Vertical position of upper wing

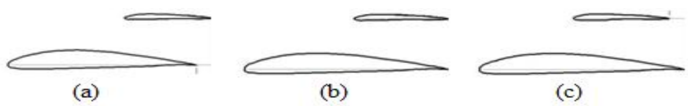

Fig. 4: Longitudinal position of upper wing, from left to right; Rear (a), Middle(b) ,Front(c)

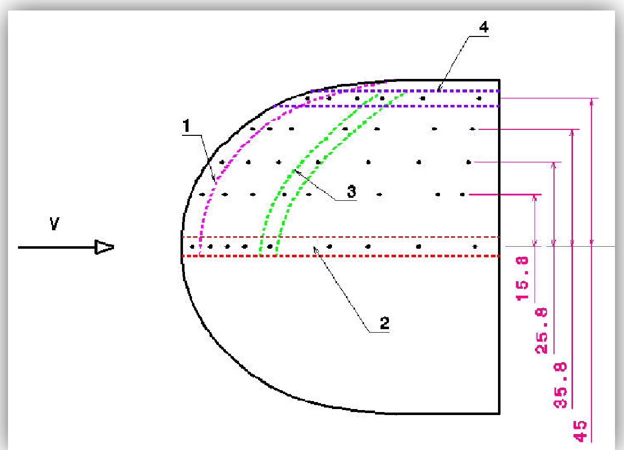

Fig. 5: Dividing surface of the lower wing, 1-4

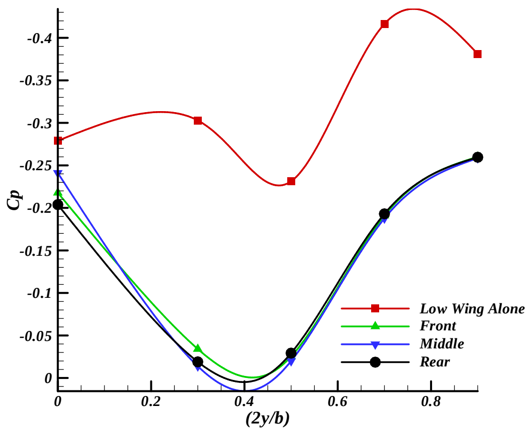

Fig. 6: Effect of upper wing on the pressure distribution of area 1 at **α** =-4, h/C_{max} = 0.260

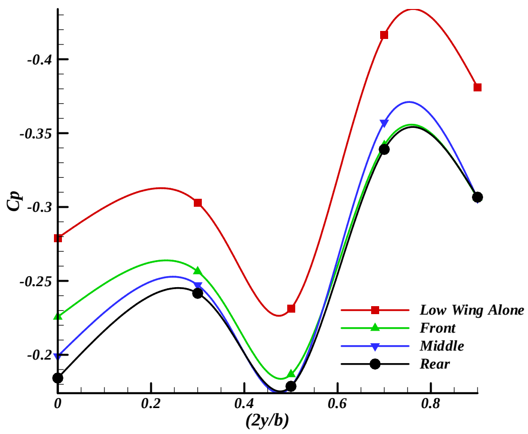

Fig. 7: Effect of upper wing on the pressure distribution of area 1 at **α** =0, h/C_{max} = 0.260

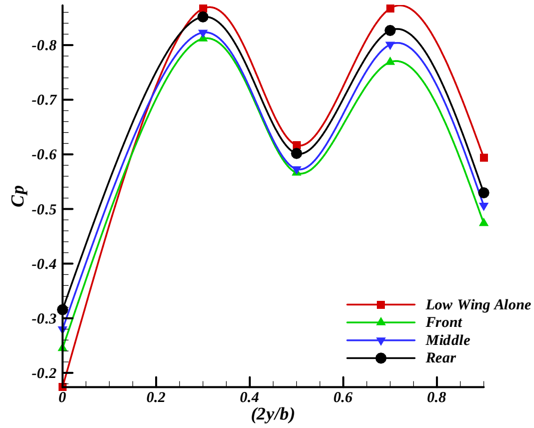

Fig. 8: Effect of upper wing on the pressure distribution of area 1 at **α** =8, h/C_{max} = 0.260

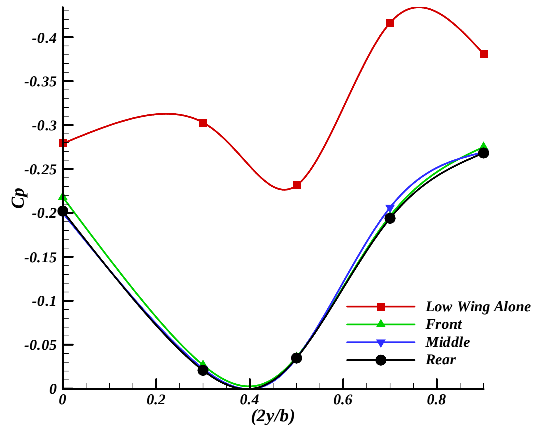

Fig. 9: Effect of upper wing on the pressure distribution of area 1 at **α** =-4, h/C_{max} = 0.312

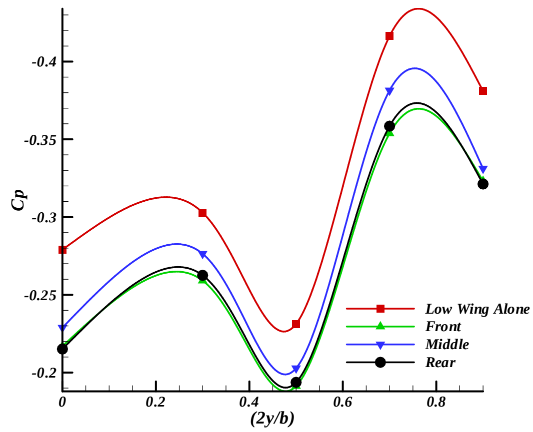

Fig. 10: Effect of upper wing on the pressure distribution of area 1 at **α** =0, h/C_{max} = 0.312

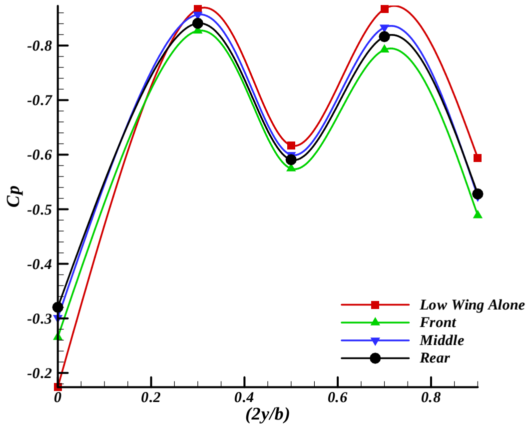

Fig. 11: Effect of upper wing on the pressure distribution of area 1 at α =8, h/C_{max} = 0.312

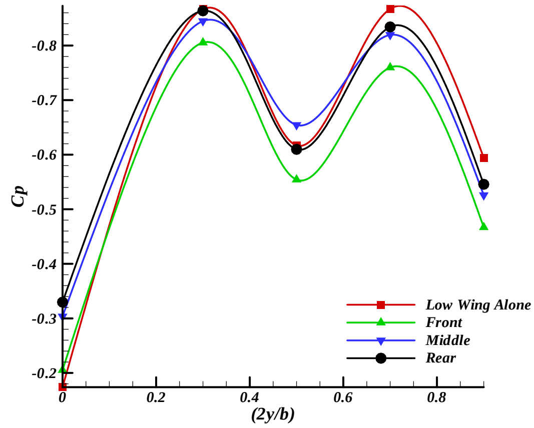

Fig. 14: Effect of upper wing on the pressure distribution of area 1 at E=8, h/C_{max} = 0.364

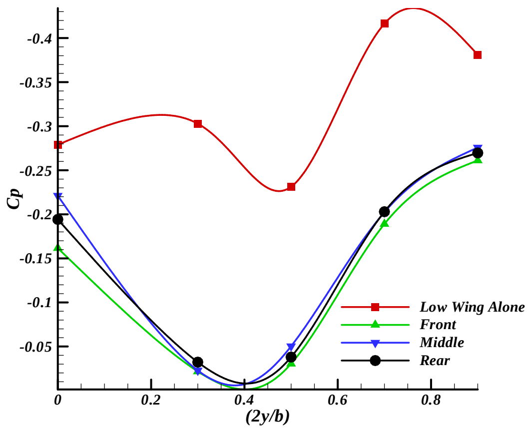

Fig. 12: Effect of upper wing on the pressure distribution of area 1 at α =-4, h/C_{max} = 0.364

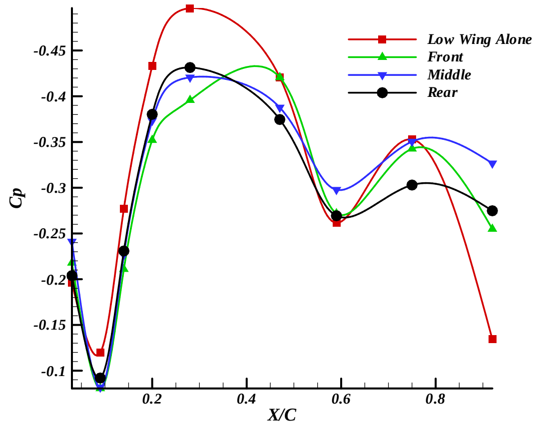

Fig. 15: Effect of upper wing on the pressure distribution of area 2 at α =-4, h/C_{max} = 0.260

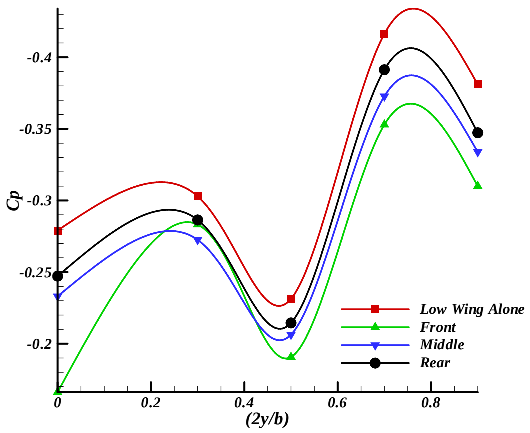

Fig. 13: Effect of upper wing on the pressure distribution of area 1 at α =0, h/C_{max} = 0.364

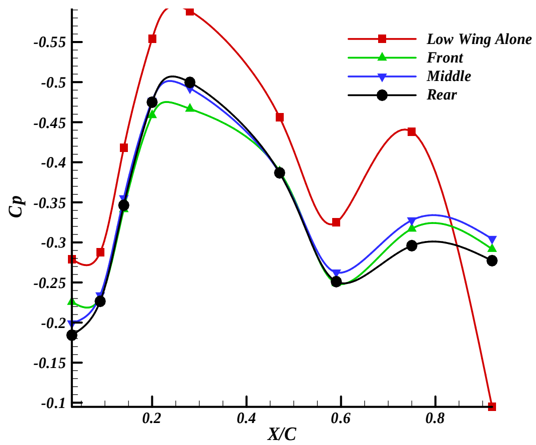

Fig. 16: Effect of upper wing on the pressure distribution of area 2 at α =0, h/C_{max} = 0.260

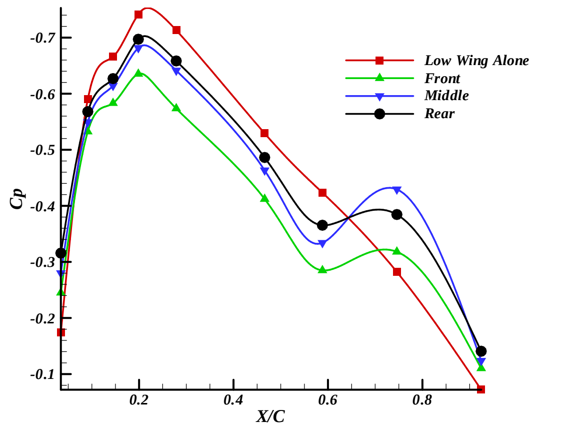

Fig. 17: Effect of upper wing on the pressure distribution of area 2 at **α** =8, h/C_{max} = 0.260

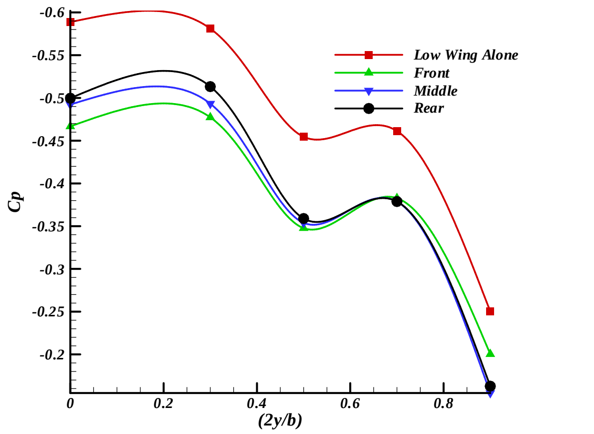

Fig. 18: Effect of upper wing on the pressure distribution of area 3 at **α** =0, h/C_{max} = 0.260

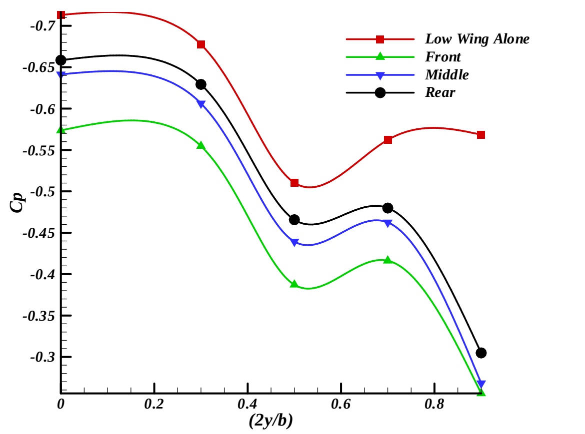

Fig. 19: Effect of upper wing on the pressure distribution of area 3 at **α** =8, h/C_{max} = 0.260

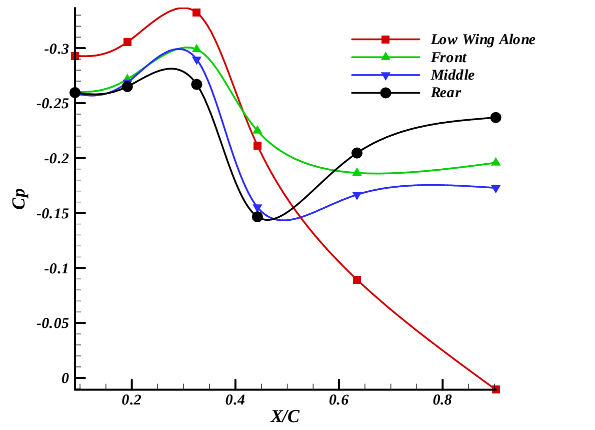

Fig. 20: Effect of upper wing on the pressure distribution of area 4 at **α** =-4, h/C_{max} = 0.260

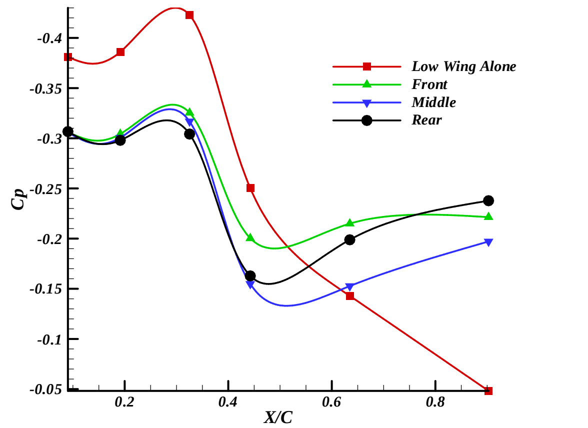

Fig. 21: Effect of upper wing on the pressure distribution of area 4 at **α** =0, h/C_{max} = 0.260

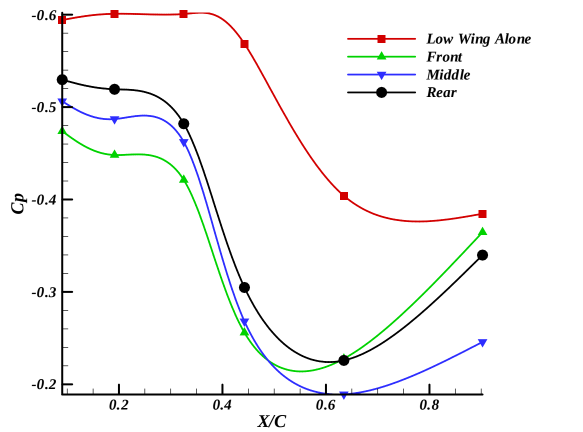

Fig. 22: Effect of upper wing on the pressure distribution of area 4 at **α** =8, h/C_{max} = 0.260