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Numerical Analysis of Flow Over Fixed Wing Mav with Bio Inspired Winglets

Ganesh. K
Dept. of Aeronautical engg
Sri Shakthi Institute of engineering and technology
Coimbatore, India

Aravindhkumar. SK
Dept. of aeronautical engg.
Sri Shakthi institute of engineering and technology
Coimbatore, India

Jamuna Kumari. J
Dept. of aeronautical engg.
Sri Shakthi institute of engineering and technology
Coimbatore, India

***Abstract*— A numerical study was undertaken to study the effect of feather like winglet configuration on the performance of fixed wing MAV at a velocity of 15 m/s and angle of attack of 15 and 20o. A baseline configuration along with four different feather configurations were studied where the size of the feather and the distance between the feather were varied.. The chord wise pressure distribution was seen to change with the span wise location from the center and this distribution is affected by the wing tip vortex. The wingtip was observed to change the pressure distribution near the tip. The velocity field, stream lines and the vorticity were seen to be affected by the presence of the wing tip. The wing tip configuration resulted in a minor loss of lift which may be due to the reduction in wing surface area due to the addition of the wing tip to the baseline wing. However, the drag and the corresponding lift to drag ratio were seen to be increased.**

Keywords ---Feather winglet; MAV; Wingtip; Velocity field; Drag; Lift by Drag ratio.

I. INTRODUCTION

Micro Air Vehicle (MAV)is a tiny flying vehicle which generally flies in low Reynolds number regime . The typical dimension, payload, endurance and the airspeed for the MAV is defined by The American Defense Advanced Research Projects Agency (DARPA) and they are 150mm, 20 to 60 minutes and 15 to 20 m/s respectively. The dimensional constraint forces the MAV to use a lower aspect ratio which will be usually in the range of 1. This low aspect ratio can be advantageous since it can offer higher stall angles compared to conventional large aspect ratio wings but also offers higher induced drag due to the wing tip vortex.

The major challenge for the designer of a MAV is to have a highest L/D ratio possible. This can be done by reducing the drag. Since the induced drag is a major portion of the drag, by reducing the induced drag, the L/D ratio can be increased.

The induced drag is reduced in wings by using winglets. Spiroid flat-plate and blended winglets are some of the winglets used for reducing induced drag. The size and position of the winglet plays important role in reducing the drag. Birds use tiny feathers at the tip of their wing to reduce the induced drag.

II. MODEL DESIGN

The objective of the current work is to study the effectiveness of the bio inspired winglet on the performance of the MAV. Thus as per the suggestions by The American Defense Advanced Research Projects Agency (DARPA), the size of the MAV is limited to 150 mm. This 150 mm is considered as the chord of the aerofoil section at the center plane of MAV. The MAV which has been already studied by Sujee was considered as a base line case.

The MAV consists of a wing profile that is tapered and swept with the Eppler 212 airfoil section across the span. The plot of the Eppler 212 aerofoil section generated and the coordinates of the Eppler 212 aerofoil section.

The MAV has as aspect ratio of 1 which lies within the range prescribed by DARPA. It has a maximum chord and span of 150 mm. It has a 17^{o} sweep at the leading edge and has a taper ratio of 0.8467. The isometric, top and side view of the 3D cad model of the MAV with winglets are shown in figs 3.7 to 3.9 respectively. The dimensions of the baseline MAV and MAV with winglets. In the winglet case, the distance between the winglets and the size of the winglet are marks as variables d and s respectively.

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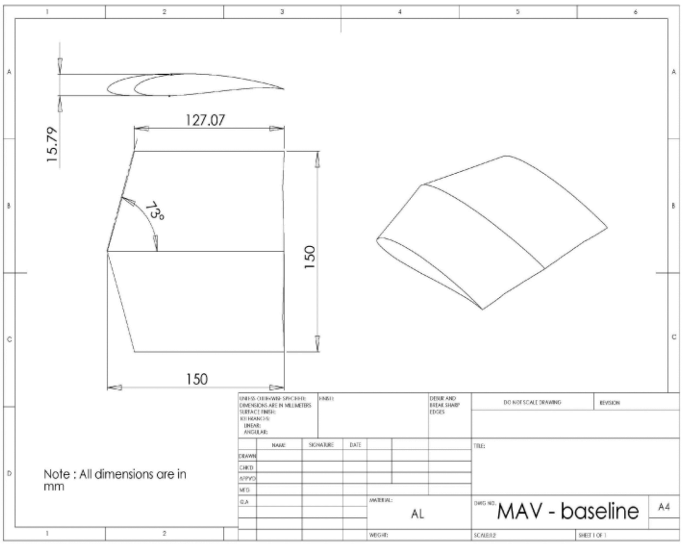

FIGURE 1: DIMENSIONS OF THE BASELINE MAV

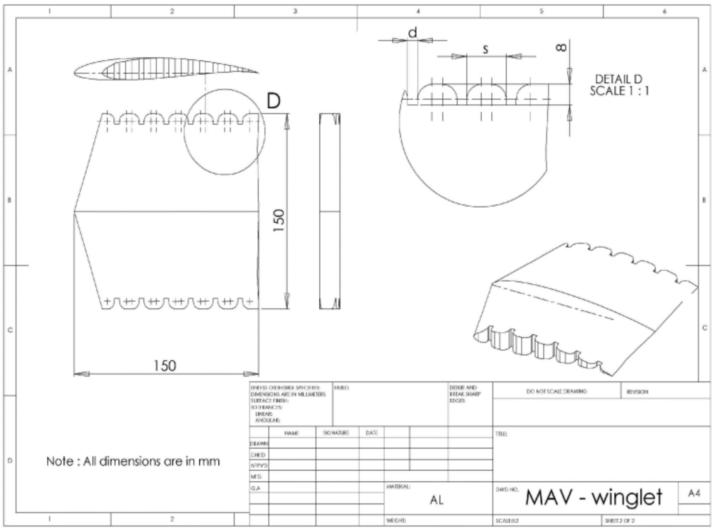

FIGURE 2: DIMENSIONS OF THE MAV WITH WINGLET

TABLE 1: DETAILS OF THE FEATHER CONFIGURATION USED

Config no	feather size, mm	distance, mm	α
0	NA	NA	15
1	16	4	15
2	16	8	15
3	8	4	15
4	8	8	15
5	NA	NA	20
6	16	4	20
7	16	8	20
8	8	4	20
9	8	8	20

III. GRID GENERATION

The domain size was maintained same for all the configurations tested. The mesh generated for the three dimensional domain with the baseline case The mesh distribution on the wing surface. A coarse mesh is used far away from the wing and a fine mesh is generated on the wing surface. This is done since the gradient in flow properties like velocity and pressure is high near the wing surface and far away from the wing surface, these gradients will usually be negligible and one can have a coarse mesh in these regions.
The surface of the MAV wing with the feather corresponding to the configuration 1.

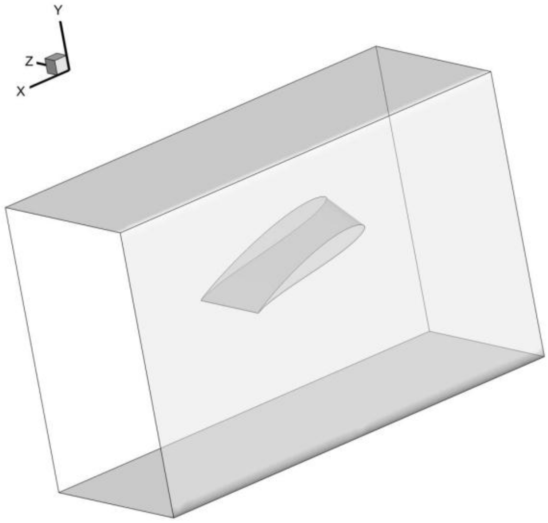

FIGURE 3: THREE DIMENSIONAL DOMAINS CONSIDERED FOR THE SIMULATION

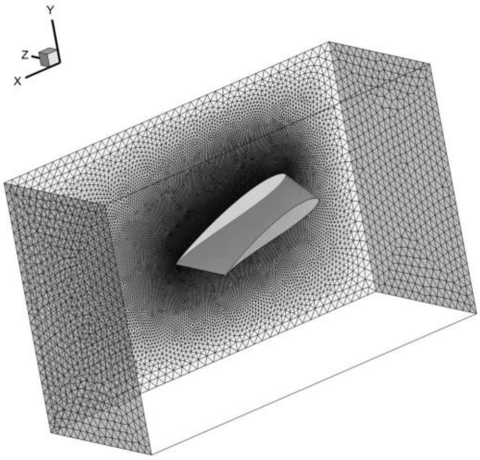

FIGURE 4: THREE DIMENSIONAL MESH ON THE BOUNDARIES OF THE DOMAIN

IV. ANALYSIS

A. Boundary conditions

A symmetry boundary condition is applied to one of the faces. This is given to reduce the computational requirement. This is justified sine the model have the physical symmetry about the vertical plane at the center for all the configurations considered.

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Inlet velocity = 15 m/s
Inlet pressure (ambient pressure) = 101325 Pa
Outlet boundary condition was considered as an outflow.
Vertical plane at the side is considered as symmetric boundary condition as explained above.

B. Pressure distribution

The data on the star board side of the wing is mirrored about the symmetry plane to provide the pressure distribution over the entire wing surface.

The pressure distribution shows that the pressure decreases rapidly near the leading edge and then gaining the values in the downstream direction. This shows the acceleration of the flow around the leading edge and further deceleration as the flow travels downstream The flow near the tip of the wing is shown a lower pressure region that is extending its size in the downstream direction. With the distance downstream, the region is seen to penetrate inside the wing surface and this may be due to the action of the wing tip vortex
This is little different from the one for the baseline configuration. Near the symmetry plane, almost similar

Pressure distribution can be seen. But near the tip, the pressure distribution seems to be altered by the presence of the feather
Configuration. The variation of high to low pressure near the tip region shows the effect of the feather configuration on the pressure distribution near the tip surface. A minor difference could be seen on the pressure distribution on the bottom surface
The comparison of pressure a center line between the configuration 0 and. Minor difference could be seen on the front side. The comparison of pressure at z = 70 mm shows the effect of feather configuration on the pressure distribution near the tip.

C. Streamlines

The streamlines near the tip of configurations C0 and C1 is The difference in stream lines indicate that the tip device is altering the stream lines by introducing a gap for the stream lines to pass through
Vorticity

The vorticity levels are seen to reduce with the addition of the wing tip device. For the same wingtip configuration, the distribution of vorticity in the region between the feathers.

D. Effect on lift

The effect of the wing tip configuration on the C_L values of the MAV wing at =15º . As seen in the figure, the introduction of winglets results in a loss of lift, even though seems to be negligible. This could be due to the loss in lift generating area by making the tip into winglet configuration. Winglet configuration 1 is seen to have the lowest lift value at this .The percentage of the loss in lift shows the loss in lift is about to be 3%. The Variation of these values for the angle of attack of 20º

E. Effect on drag

The objective of the current study is to reduce the drag using these feather like winglets. The effect of the winglet configuration on the drag of MAV at =15º . Even though there is a loss of lift with the introduction of the winglet to the MAV, the drag is seen to reduce with the same which is appreciated. The maximum reduction in C_D is nearly 18 % and the corresponding configuration is 4

F. Effect on lift to drag ratio

The effect of the winglet configuration on the lift to drag ratio at the angle of attack of 15º . The lift to drag ratio is another important parameter as it discusses the efficiency of the lift generating part. The lift to drag ratio is seen to increase with the configuration number and the maximum value was achieved with the configuration 4. The maximum change in C_L=C_D is nearly 21%

At 20º, the configuration 8 is seen to give the maximum C_L=C_D and this could be due to the combination change in both lift and drag for the particular configuration. There is both positive and negative change in the C_L=C_D

G. Effect on pitching moment

The moment is seen to change with the change in configuration at the angle of attack 15º. There is a huge variation in the moment at this configuuration. The reason for this variation is unknown. At 20º, the moment is seen to reduce and the magnitude is also different from that of at 15º .

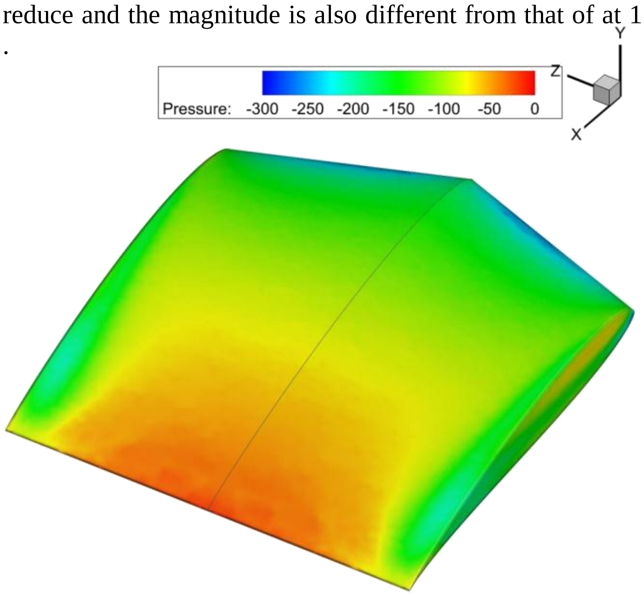

FIGURE 5: PRESSURE DISTRIBUTION ON TOP SURFACE OF CONFIGURATION 0 AT 15^{O}

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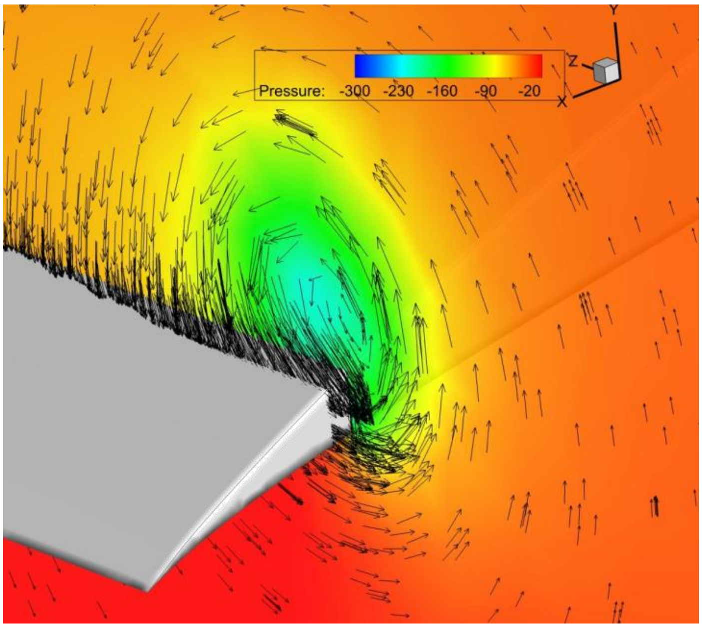

FIGURE 6: VELOCITY VECTOR IN THE VERTICAL PLANE OF CONFIGURAYION 0

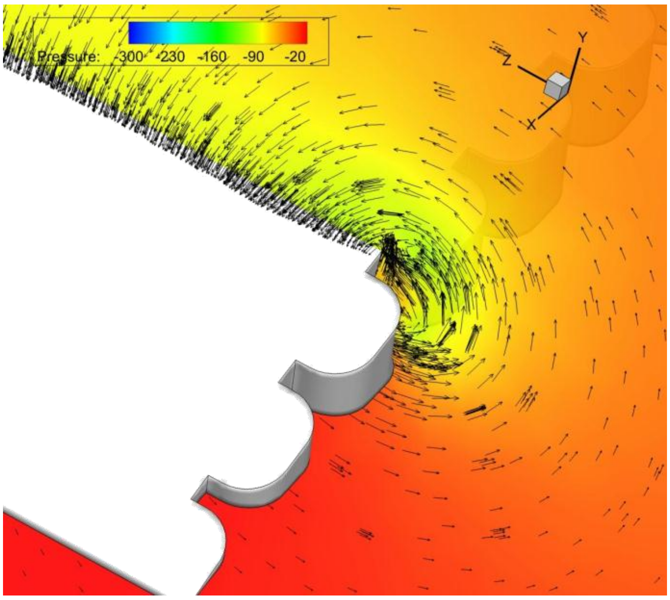

FIGURE 7: VELOCITY VECTOR IN THE VERTICAL PLANE OF CONFIGURATION 1

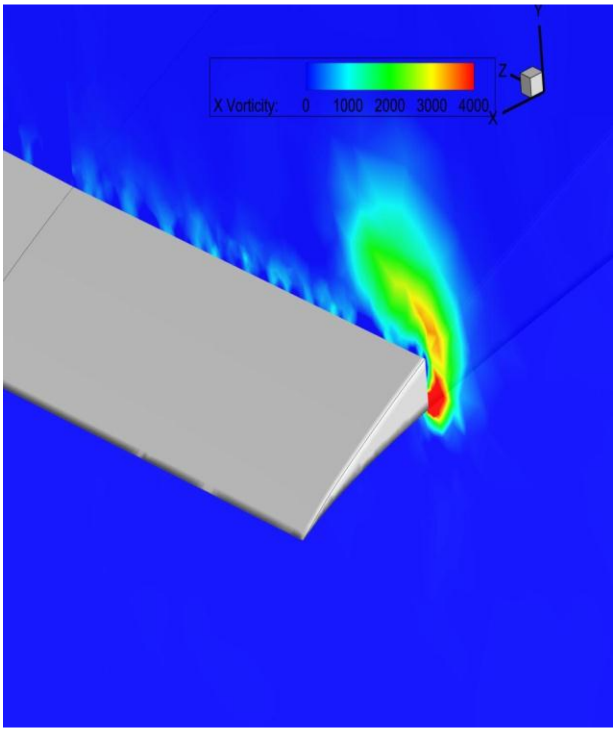

FIGURE 8: VORTICITY WITHOUT WINGLET

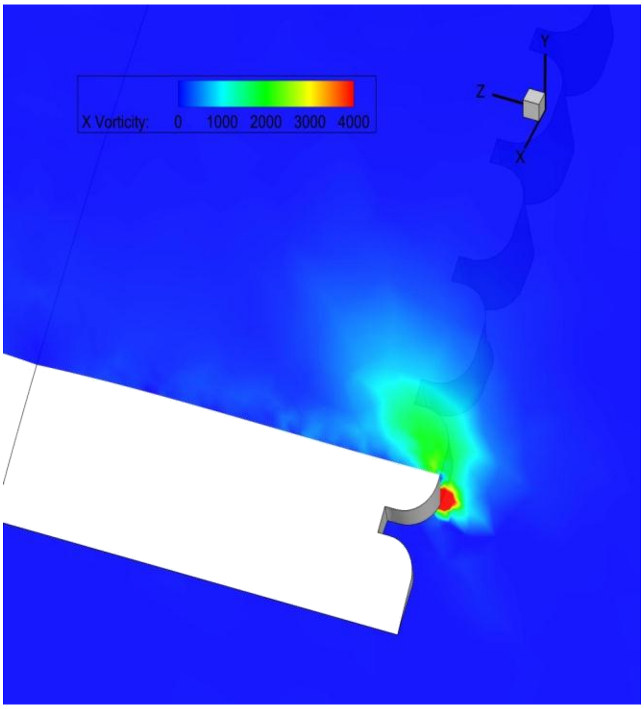

FIGURE 9: VORTICITY WITH WINGLETS

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V. RESULT

We have done flow analysis for different angle of attack [15 and 20 degree]. Here the coefficient of lift and drag values are changing according to configuration setup with their respective angle of attack. The tables are given below for both the angle of attack with their respective configuration setup.

TABLE 2: VALUES OF AERODYNAMIC COEFFICIENT AND RAW VALUES FOR 15 DEGREE ANGLE OF ATTACK.

CONFIGURATION	CL	CD	CL/CD	MOMENT
0	0.8355	0.2415	3.4601	0.0163
1	0.8101	0.2146	3.7752	0.0214
2	0.8192	0.2028	4.0391	0.0382
3	08180	0.1989	4.1118	0.0377
4	0.8163	0.1948	4.1914	0.0374

The above table reveals that the result of aerodynamic coefficient and raw values for 15 degree angle of attack.

TABLE 3: VALUES OF AERODYNAMIC COEFFICIENT AND RAW VALUES FOR 20 DEGREE ANGLE OF ATTACK.

CONFIGURATION	CL	CD	CL/CD	MOMENT
5	1.1613	0.3048	3.8106	0.0539
6	1.0668	0.2823	3.7788	0.0487
7	1.0328	0.2779	3.7165	0.0466
8	1.0629	0.2727	3.8971	0.0480
9	1.0514	0.2715	3.8731	0.0470

The above table reveals that the result of aerodynamic coefficient and raw values for 20 degree angle of attack.

VI. CONCLUSION

A numerical study was undertaken to study the effect of feather like winglet configuration on the performance of fixed wing MAV at a velocity of 15 m/s and angle of attack of 15 and 20^{o}. A baseline configuration along with four different feather configurations were studied where the size of the feather and the distance between the feather were varied.

The chord wise pressure distribution was seen to change with the span wise location from the center and this distribution is affected by the wing tip vortex

The wingtip was observed to change the pressure distribution near the tip The velocity field, stream lines and the vorticity were seen to be affected by the presence of the wing tip

The wing tip configuration resulted in a minor loss of lift which may be due to the reduction in wing surface area due to the addition of the wing tip to the baseline wing

However, the drag reduced and the corresponding lift to drag ratio were seen to increase which is appreciated that results in performance enhancement.

FUTURE PLAN

For the present study, only 15 m/s is considered as the freestream velocity. This study needs to be extended to other freestream velocities The effect of the wingtip configuration needs to be explored for the change in further feather curvature and feather length.

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