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Comparative Study Aerodynamics Effects of Wingtip Fence Winglet on Fix Wing Airfoil Eppler E562

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ABSTRACT / ABSTRAK

Wings on airplanes and Unmanned Aerial Vehicles (UAVs) have a very important role in the formation of lift forces. This is because most of the lifting force arises on the wing. Therefore, aircraft designers pay great attention to wing modification. Today's aircraft designers tend to provide geometric modifications displayed in computational applications so that visualization of fluid flow can appear clearly. By increasing the lift as high as possible on the wing and lowering the drag as low as possible, it is expected that high aerodynamic efficiency will be achieved in air transportation. This research was done numerically by using the turbulence model k-ω SST. Reynolds number in this research was 2,34 x 10^4 with the angle of attacks are 0^o, 2^o, 4^o, 6^o, 8^o, 10^o, 12^o, 15^o, 17^o and 19^o. The model specimen is wing airfoil Eppler 562 with winglets. Two types of wingtips are used: forward and rearward wingtip fence. From this study, it was found that the wingtip fence reduced the strength of vorticity magnitude on the x-axis and z-axis compared to plain wings. With the addition of a wingtip fence, it has a significant effect on the shape of the vorticity magnitude behind the wing. This indicates a decrease in induced drag on the wing which has a wingtip fence.

Sayap pada pesawat terbang dan *Unmanned Aerial Vehicle* (UAV) memiliki peran yang sangat penting dalam pembentukan gaya angkat. Ini karena sebagian besar gaya angkat muncul di sayap. Oleh karena itu, perancang pesawat sangat memperhatikan modifikasi sayap. Perancang pesawat masa kini cenderung memberikan modifikasi geometrik yang ditampilkan dalam aplikasi komputasi sehingga visualisasi aliran fluida dapat tampil dengan jelas. Dengan meningkatkan daya angkat setinggi mungkin pada sayap dan menurunkan drag serendah mungkin, diharapkan akan tercapai efisiensi aerodinamis yang tinggi dalam transportasi udara. Penelitian ini dilakukan secara numerik dengan menggunakan model turbulensi k-ω SST. Bilangan Reynolds dalam penelitian ini adalah 2,34 x 104 dengan sudut serang 0o, 2o, 4o, 6o, 8o, 10o, 12o, 15o, 17o dan 19o. Spesimen model adalah wing airfoil Eppler 562 dengan *winglet.* Dua jenis ujung sayap digunakan: pagar ujung sayap depan dan belakang. Dari penelitian ini didapatkan bahwa *wingtip fence* mengurangi kekuatan besarnya vortisitas pada sumbu x dan sumbu z dibandingkan dengan sayap polos. Dengan penambahan wingtip fence berpengaruh signifikan terhadap bentuk besarnya vortisitas di belakang sayap. Hal ini menunjukkan adanya penurunan induced drag pada sayap yang memiliki *wingtip fence*.

INTRODUCTION

The winglet is one of the accessories on the wing of the aircraft that allows the addition of wing performance without having to widen the wingspan. Winglets can be additional fins that are mounted perpendicular to the wingtips or can be wing extensions that are bent vertically. The winglet serves to dampen the vortex at the wingtip caused by the meeting of the lower wing flow which has high pressure with the wing flow that has low pressure which causes turbulence. This flow rotation also causes the aircraft to need more energy to be stable in the air so that it will be wasteful of fuel. With the winglet, aircraft fuel can economize in large enough quantities for planes that travel long distances.

As is known, if there is an object placed in the viscous flow it will cause a drag caused by its shape or what is known as a drag profile, whether it raises or not. Whereas induced drag is another type of drag. That is caused by uneven pressure on certain wing tips between the top (pressure side) and the bottom surface (suction side). This imbalance is needed to produce elevators that are positive. However, near the tip with high pressure, the air from the lower side has tends to move to the top where the pressure is lower.

The winglet is one of the accessories on the wing of the plane that allows improving on-wing performance without lengthening wingspan. Winglets may be additional fins mounted on the wingtips or may be extensions of the wings bent vertically. Winglet blocked the vortex at the tip of the wing (tip vortex) caused by the airflow jump from the lower surface to the upper surface that results in the occurrence of trailing vortex. This condition will inhibit the movement of the plane and decrease the effective extent of the wing due to the increased drag force for the aircraft. The main function of the winglet to decrease the induced drag so that the aircraft can quickly fly through the sky. The use of wingtip plays an important role in aircraft design. Particularly in the field of aerodynamics, aircraft are very concerned about the aspects that are very influential on the lift coefficient and drag coefficient of the design so that ultimately will produce optimal aerodynamic performance.

Weierman, et al (Weierman 2003) use winglets on UAVs using the research geometry of Whitchomb (1976) applied to UAVs. The wing used is a straight chord wing making it easier to apply to UAVs. Winglets that are used as research by Whitchomb (1976) are then optimized to produce better performance. In that study, it was shown that wing performance after being equipped with winglets improved compared to the plain wing. It was also found that there was an increase in aerodynamic performance both from plain wing to Whitchomb winglet and from Whitchomb winglet to optimization in terms of C_L/C_D, root bending moment, range and durability.

Portillo (Amador Calvo Portillo 2011) compares several types of winglets on NACA 2415 airfoil with attack angles 0^o, 4^o, 8^o, 12^o and 16^o. Winglet types used are blended winglets, wingtip fence, and circular profile. This research shows that the minimum total vorticity magnitude is found in the wingtip fence and blended winglet. Wingtip fence has a minimum area but has a higher vorticity concentration than a blended winglet. Therefore it is clear that winglets can reduce wingtip vortex vorticity magnitude. If the vortex wingtip can be reduced, the induced drag associated with the formation of wingtip vortices can be reduced so that drag is decreased and aircraft performance can be improved.

Turanoğuz, et al (Turanoguz and Alemdaroglu 2015) compared the use of blended winglets, Hoerner wingtip and shifted downstream winglets against plain wing on wing with airfoil Eppler 562 on steady-state condition. The general result in the addition of the winglet will increase C_L/C_D. The resulting drag coefficient is lower than plain wing but is not visible increase in the stall point. C_L/C_D on wing increased with addition winglet than plain wing due to its drag coefficient decrease and not because of the increase of lift coefficient.

Kontogiannis, et al (Kontogiannis, Mazarakos, and Kostopoulos 2016) made designs for ATLAS IV UAV wings using Eppler 420 wing airfoil (E420). The speed used is 10 m/s or Re = 10^5 - 3 x 10^5. From the research, it was found that at a low angle of attack, the plain wing has a higher lift coefficient than the wing blended winglet. At the $\alpha = 7^o$, the wing blended winglet results in a higher lift coefficient up to the stall point. In that study, it was shown that the addition of winglets would reduce the drag coefficient at all angles of attack. Initial results show that induced drag is relatively constant but lift friction drag tends to decrease.

Hariyadi, et al (Setyo Hariyadi et al. 2018) compared the vorticity magnitude pattern of forward and rearward wingtip fence with cant angle variation δ = 90°. Vorticity magnitude area behind the wing increases with the increase of the angles of attack. Forward wingtip fence succeeds in reducing "jump" of the fluid flow from the lower surface to the upper surface although the vorticity magnitude increases wider area at a high angle of attack.

This research used airfoil type Eppler 562 for Unmanned Aerial Vehicle (UAV) application. Winglet with variations forward and rearward wingtip fence is studied to see the influence of the wingtip fence for increased performance wing and drag reduction that occurs with some angles of attack.

METHODS

This research was marked numerically using Ansys 19 with turbulence model k-ω SST. Freestream velocity 10 m/s (Re = 2.3 x 10^4) with α = 0°, 2°, 4°, 6°, 8°, 10°, 12°, 15°, 16°, 17°, 19° and 20°. Test model specimens are airfoil Eppler 562. Winglet will be served with a variation of the forward and rearward wingtip fence. *Reynolds* number is chosen based on the wing chord length and freestream velocity. Model specimen form wing airfoil E562 with winglets like a wingtip fence dimension Figures 1 and 2. Figure 3 is the domain simulation and the boundary conditions used in the simulation. The properties of the environment conditions refer to Hariyadi research (Setyo Hariyadi et al. 2018)

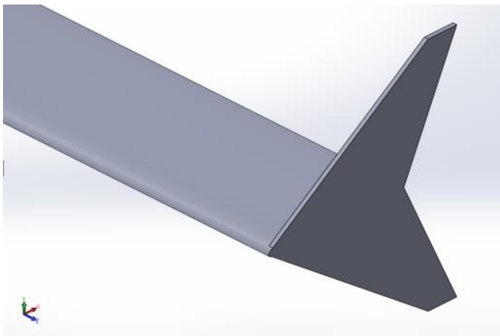


Figure 1. Forward Wingtip Fence. (Setyo Hariyadi et al. 2018)

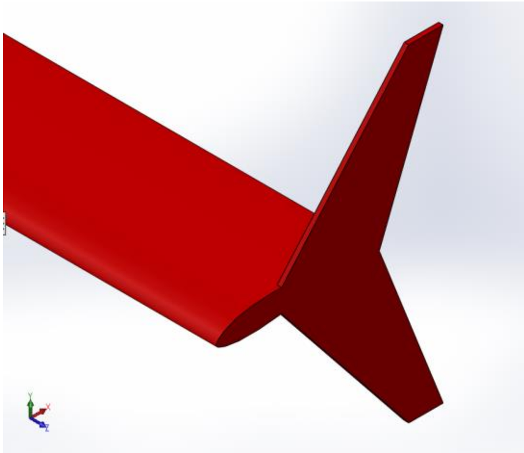


Figure 2. Rearward Wingtip Fence. (Setyo Hariyadi et al. 2018)

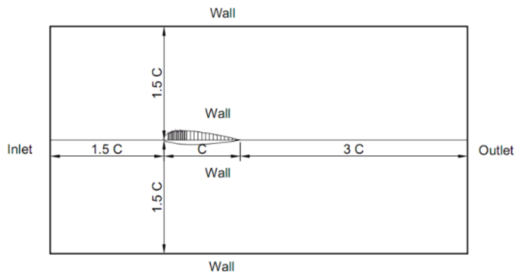
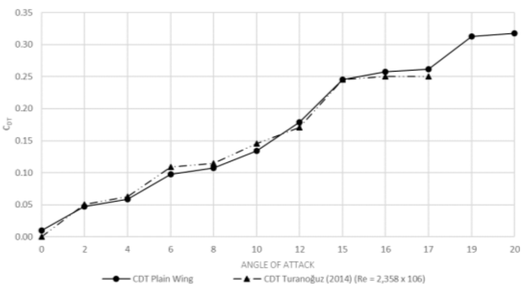
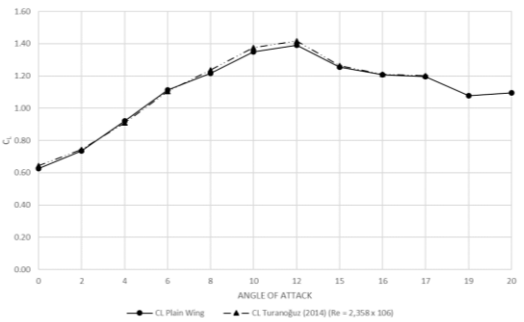


Figure 3. Modeling dimensions (Mulvany et al. 2004)

For the optimum in the use of Ansys 19.0, grid and meshing need to be optimum also. Grid independence is important to determine the extent and structure of the grid so that the best and most efficient model results closer to the real conditions. Based on Kontogianis (Kontogiannis, Mazarakos, and Kostopoulos 2016) research, the most optimal results obtained when the drag coefficient with meshing previously approximately y^+ less than 5. In this research, to get the best result used Kontogianis research (Kontogiannis, Mazarakos, and Kostopoulos 2016) criterion that $y+$ is less than 1. Based on Hariyadi (Setyo Hariyadi et al. 2018) research, the meshing used for the next simulation is Meshing C. To determine the most optimum grid by using grid independence, the chosen meshing is re-examined and compared with the Hariyadi research (Setyo Hariyadi et al. 2018). The velocity used in the Turanoguz research (Turanoguz and Alemdaroglu 2015) was 45 m/s. The results obtained from the test are shown in Figure 4. When viewed from graphs, the selected grid is close to Turanoguz research (Turanoguz and Alemdaroglu 2015).



a. C_{DT} grid independence



b. C_L grid independence

Figure 4. Comparison of C_{DT} and C_L grid independence and Turanoguz research (Turanoguz and Alemdaroglu 2015)

RESULT AND DISCUSSION

Vorticity Magnitude of the y-z Axis

The tendency of flow to "leak" around the wingtips has an important effect on the aerodynamics of the wings. This flow forms a rotating motion that leads downstream at the rear of the wing, that is, a trailing vortex that appears at each wingtip. This vortex wingtip induces a small component of the velocity of air around the wing downward. This bottom component is called downwash.

At the tip on the wing, the upper and lower surface pressures are the same. However, there is a tendency for airflow from the lower surface near the wingtip to "jump" to the upper surface. But the form of the stepping is not directed right at the top but rather backward, giving rise to a vortex.

The higher the angle of attack the wider the vortex formed. Vortex formation begins at the back end of the tip (Genç, Özden, et al. 2016) so that if the wingtip is absent it will produce a much larger vortex because the formation of the vortex starts from the front edge / leading edge as shown in Figure 5. Therefore the function of the winglet is to reduce vortex size will be more perfect if the formation of vortex is blocked from the front of the tip.

Figures 5 (a), (d), (g) show how the trailing vortex develops from the vorticity magnitude contours on Eppler 562 plain wing airfoil at $\alpha = 0^o$, $\alpha = 15^o$, and $\alpha = 17^o$. The area taken is at a distance x = 0.5C, x = 1C, x = 1.5C from the trailing edge airfoil. In Figure 5 it also appears that the vorticity magnitude of the vortex will increase with increasing angle of attack. The closer the trailing edge is, the stronger the concentration of vorticity. The further the strength of the vorticity decreases but the greater the area.

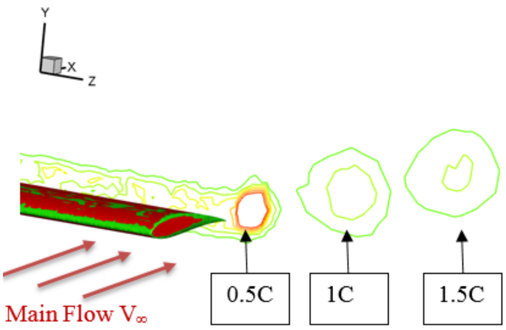
Formation of the vortex from the tip is blocked by the tip of the winglet as shown in Figure 5 (b), (e), (h) where the forward wing tip fence produces a vortex contour that is narrower than the plain wing. But if the wingtip is absent it will produce a much larger vortex, therefore the function of the winglet to reduce the size of the vortex will be more perfect if the formation of the vortex is blocked from leading the edge.

Tip vortices formed by winglets produce very different shapes from each other and appear to be a significant effect of the flow field on the wing's surface. These vortices will change shape when the angle of attack of the model is changed. The values of the vortices behind the winglets also differ which indicates the effect of induced drag.

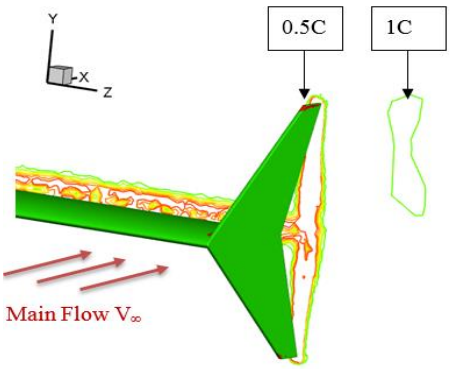
Figure 5 (c), (f), (i) show how the trailing vortex develops based on the contour vorticity magnitude on the Eppler 562 airfoil with the addition of a rearward wingtip fence at $\alpha = 0^o$, $\alpha = 15^o$, and $\alpha = 17^o$. The area taken is at a distance x / c = 0.5, 1, and 1.5 from the trailing edge airfoil. In figure 5 (c), (f), (i) it is shown that the addition of a rearward wingtip fence produces less effective effects than the forward wingtip fence. The contour of the vorticity magnitude produced is wider and the strength is higher than the forward wingtip fence even stronger than the plain wing. The amount of vorticity is possible because the flow of air that will jump from the lower side to the upper side accumulates leakage through the root of the lower winglet.

At the rearward wingtip fence, there is an indication of a fluid flow jump from the lower surface to the upper surface with the visible fluid leap in the form of an isosurface in three-dimensional images, especially at $\alpha = 0^o$ and $\alpha = 15^o$.

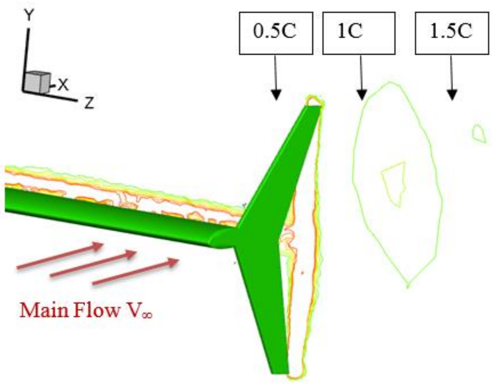
To get more information about the shape and extent of the wake, further discussion is needed. It is necessary to explore the 3-dimensional shape of the wake shape. This will add wake information to Figure 7 which requires a depiction of the y-z axis. This refers to the research of Narayan (Narayan and John 2016), Hariyadi (Setyo Hariyadi, Sutardi, and Widodo 2016), Demir (Demir et al. 2016), and Genc (Genç, Özden, et al. 2016) (Genç, Özkan, et al. 2016).



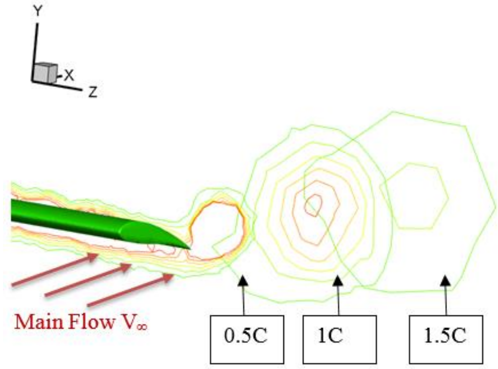
(a) Plain Wing α = 0°



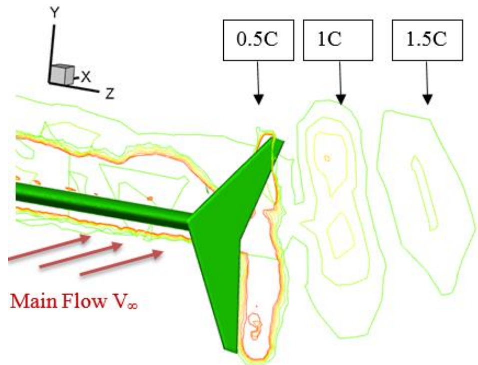
(b) Forward Wingtip Fence α =0°



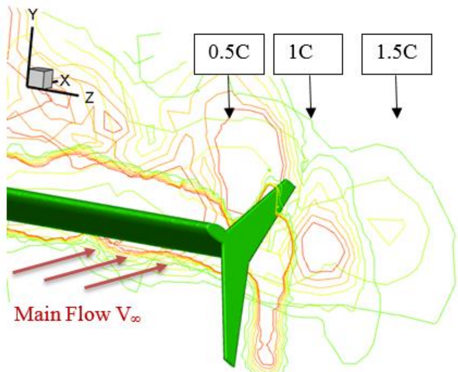
(c) Rearward Wingtip Fence α = 0°



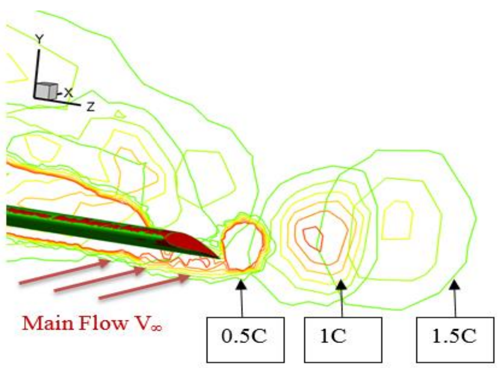
(d) Plain Wing α = 15°



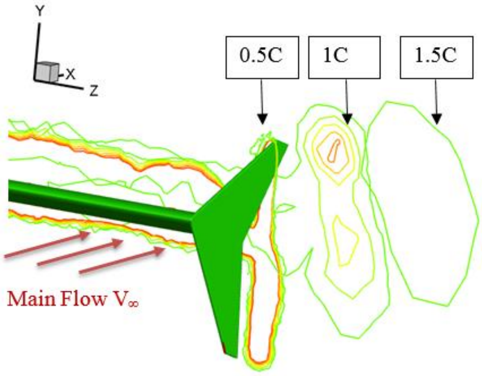
(e) Forward Wingtip Fence α =15°



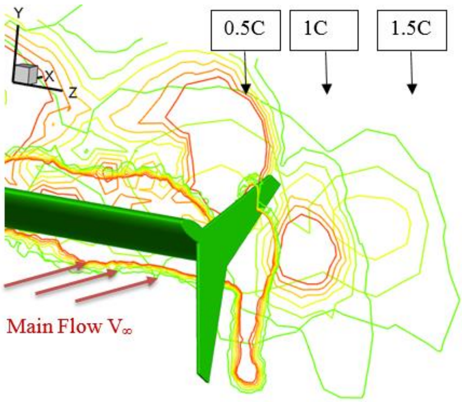
(f) Rearward Wingtip Fence α = 15°



(g) Plain Wing α = 17°



(h) Forward Wingtip Fence α =17°



(i) Rearward Wingtip Fence α = 17°

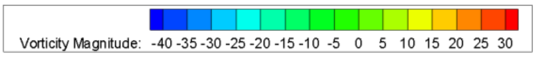
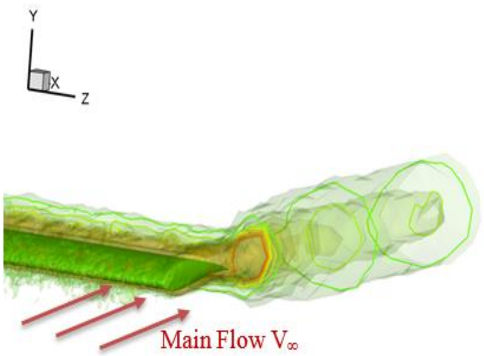
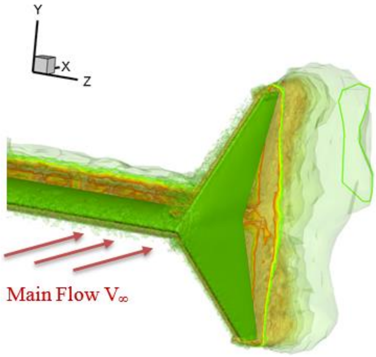


Figure 5. Comparison of Visualization Contour Vorticity Magnitude at x = 0.5C, x = 1C, x = 1.5C behind the wing

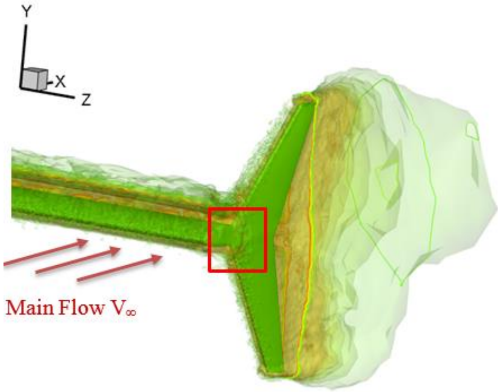
The visualization comparison of vorticity magnitude in three-dimensions can be seen in Figure 6.



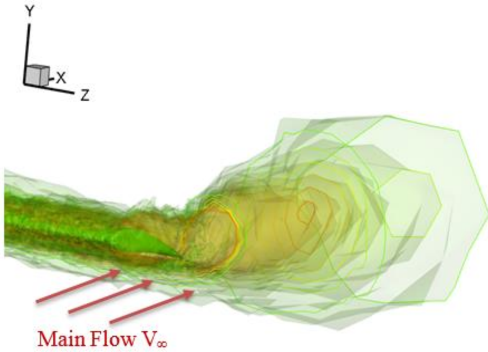
(a) Plain Wing α = 0°



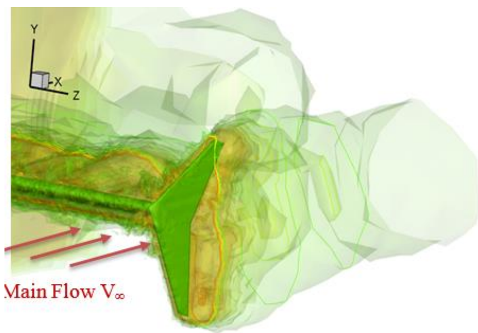
(b) Forward Wingtip Fence α =0°



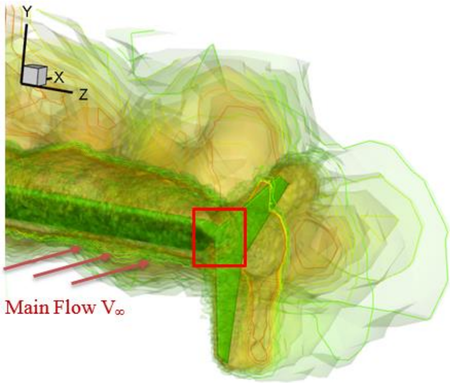
(c) Rearward Wingtip Fence α = 0°



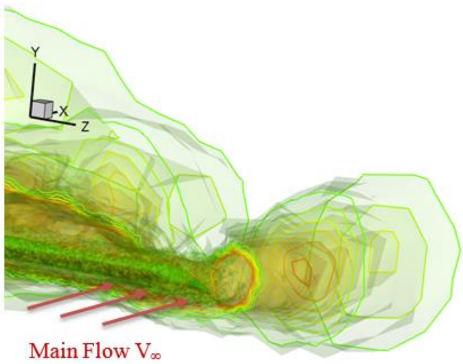
(d) Plain Wing α = 15°



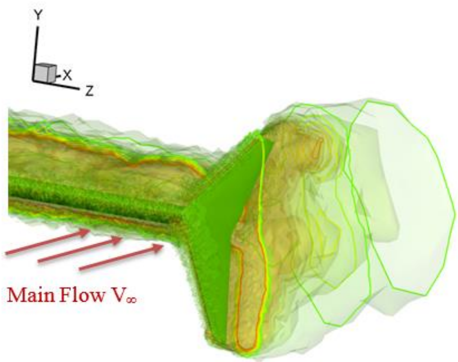
(e) Forward Wingtip Fence α =15°



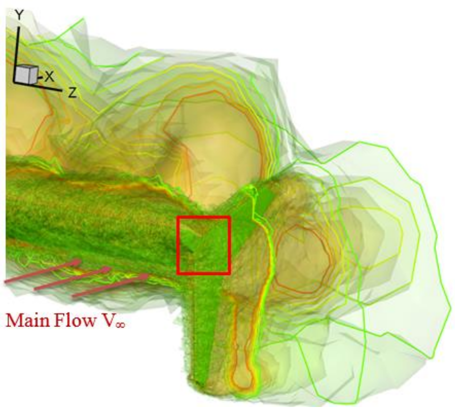
(f) Rearward Wingtip Fence α = 15°



(g) Plain Wing α = 17°



(h) Forward Wingtip Fence α =17°



(i) Rearward Wingtip Fence α = 17°

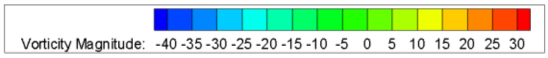
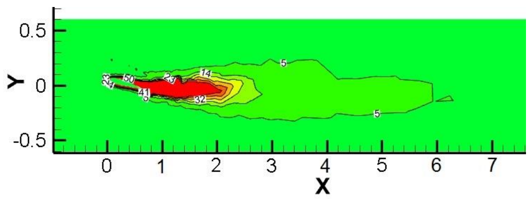


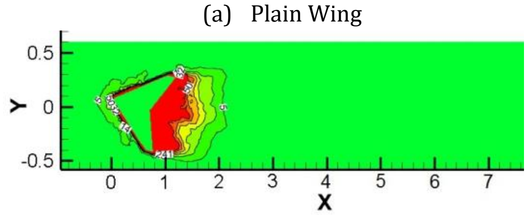
Figure 6. Comparison of Visualization of Contour Vorticity Magnitude behind the wing in three-dimensional form

Vorticity Magnitude of The X-Y Axis

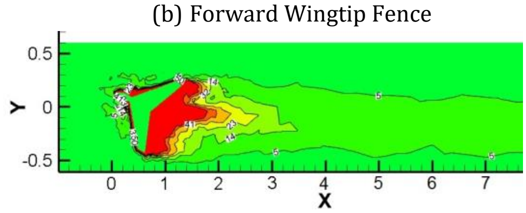
Figure 7 shows the contours of the x-y axis vorticity magnitude on the plain wing, the plain wing with forward wingtip fence and the plain wing with rearward wingtip fence at α = 17°. With the addition of a wingtip fence, it can be seen that the distribution of vortices is concentrated around the fence while the plain wing is seen extending behind the trailing edge. On the plain wing, vortices fade at ± x = 6C while on plain wings with forward wingtip fence vortices fade at ± x = 3C. On the plain wing with rearward wingtip fence vortices still affect more than x = 7C. The distance between the formation of vortices and waning vortices shows how much the vortex strength formed from the three models and the speed to change to other forms of energy.



(a) Plain Wing



(b) Forward Wingtip Fence



(c) Rearward Wingtip Fence

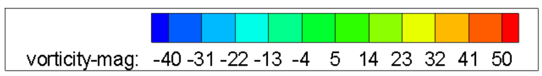


Figure 7. Contour distribution of Vorticity Magnitude x-y axis, z / l = 1 on the plain wing, forward wingtip fence, and rearward wingtip fence at α = 17°

CONCLUSION

From this numerical study, it is found that use winglet can produce the result:

The pattern of plain wing vorticity magnitude area 1C behind the trailing edge shows a single pattern that is concentrated in a circle shape with vorticity strength centered in the center. The size of the area increases with the increase in the angle of attack.

The existence of the wingtip fence gives a change in the pattern of vorticity magnitude. In vorticity magnitude forward wingtip fence produces a pattern divided into two, top and bottom. This area increases with increasing angle of attack. The concentration of vorticity strength is divided into two and the area is narrower than the plain wing.

In vorticity magnitude rearward wingtip fence produces a pattern divided into two, right and left. The resulting area is greater than the plain wing. With the open space at the leading edge causing some flow into the "inner section" of the wing both from the lower side and from the leading edge. The meeting of these two streams produces a three-dimensional flow which is represented as vorticity magnitude next to the main vorticity magnitude.

Wingtip fence gives a change in vorticity magnitude pattern. The vorticity magnitude of the forward wingtip fence results in a smaller vortex strength compared to other geometries.

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