Numeric Simulation of Triangular Vortex Generator Straight on Swept-Back Wing Airfoil NACA 23018

Wahyu Putra(✉), Setyo Hariyadi, and Nyaris Pambudiyatno

Politeknik Penerbangan Surabaya, Jemur Andayani I/73 Wonocolo, Surabaya, Jawa Timur 60236, Indonesia
wpk2209@gmail.com

Abstract. Airfoil is a geometric shape that when placed in a fluid flow will produce a lift greater than the drag force (drag). With the slightly curved side of the airfoil, there is a point of separation in the airflow passing through the airfoil. In this research, aerodynamic testing is carried out, using numerical simulation with Ansys software. This study used NACA 23018 specimens which were given variations of the vortex generator and swept back wing. The type of vortex generator used is a triangular vortex generator with a length of 25 mm, and a height of 10 mm with a straight installation. The distance of the vortex generator to the leading edge is x/c = 10% and 15%, the swept angle is 15°, and the angle of attack varies. The freestream speed used is 20 m/s. Simulation results on the airfoil with the addition of a vortex generator can affect both performance and aerodynamic characteristics. The vortex generator on the airfoil can delay the airfoil separation, and can also delay the stall where the plain airfoil stalls at $\alpha = 15°$ with the addition of the vortex generator that has not stalled at this angle of attack. A vortex generator can affect the value of C_L/C_D. Overall, the most optimal variation of the vortex generator is the vortex generator with x/c = 15% where the C_L/C_D value is greatest at an angle of attack $\alpha = 12°$ which is 13.13.

Keywords: vortex generator · airfoil NACA 23018 · swept-back wing · angle of attack

1 Introduction

All aerodynamic phenomena that occur in airplanes are caused by the relative motion in the air along the wings of the aircraft. Aerodynamics relates to the distribution of lift and drag on all objects, the speed at which the surface of the object is heated during its passage through the air. When the angle of attack is greater, resistance will increase. One way to overcome these obstacles is to use a vortex generator on certain parts of the aircraft.

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A vortex generator is an aerodynamic device shaped like a fin that is usually mounted on the upper surface of objects, such as the wings of an airplane. A vortex generator is a type of turbulent generator that can accelerate the transition from the laminar boundary layer to turbulent boundary layer [1, 2]. Vortex generators are mainly used to delay flow separation (flow separation), which hurts the lift and drag on the moving body surface. The method used to support research in the field of aerodynamics is to use the Computational Fluid Dynamic method (CFD).

In this research, a study will be conducted on the effect of a swept-back wing airfoil NACA 23018 using Ansys (CFD) software with a fluid design and varying angle of attack from the airfoil so that the efficiency comparison between the velocity and pressure distribution along the NACA 23018 airfoil can be seen. Vortex generator with a triangular shape. Analysis of aerodynamic performance on a part of the wing surface is also needed to be able to find efficiency that can reduce the drag with velocity and vorticity magnitude phenomena to the angle of attack. Research on the addition of a vortex generator to the NACA 23018 wing airfoil has been carried out by Hariyadi [3].

2 Method

This study uses a three-dimensional numerical simulation method. Using software in the form of Ansys Fluent with a turbulent model used Realizable k-epsilon. The simulation process can be divided into three parts, namely: Pre-processing, processing, and post-processing. The test object uses a swept-back wing airfoil NACA 23018 and the addition of a vortex generator with a triangular shape (Figs. 1 and 2).

2.1 Domain Simulation and Boundary Condition

The domain is the shape of the test object. Boundary conditions are limitations that occur in the flow that passes through the object by determining the inlet, outlet, and walls (side) conditions. This boundary condition is a very significant influence on the simulations carried out. The boundary conditions must be adjusted to the actual state of the specimen model [4]. Figure 3 is the domain in the form of a wing in the text section in the form of a wind tunnel, the boundary condition is used with a freestream speed of 20 m/s. The determination of boundary conditions is based on Mulvany's research [5] which was adapted by Hariyadi.'s research [6]. The determination of the characteristics of the vortex generator variation is adjusted to the reference from Gudmundsson [7], Velte et al. [8], and Kundu [9].

2.2 Meshing

Meshing is a continuous process of discretizing fluid domains into discrete computational domains so that equations (in this case fluid flow) can be solved and produce solutions. The smaller the mesh to be made, the more accurate the results will be, but more computational power is required. This research requires validation so as to get optimal results by means of grid independence according to Anderson [4] and compared with the results of Hariyadi's research [3]. From the result of grid independency, research using Mesh A as a material for the next stage as shown in Table 1.

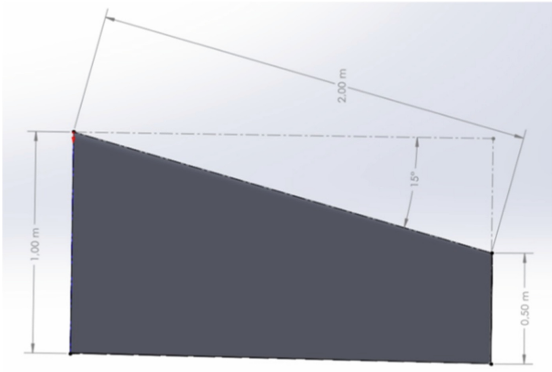

Fig. 1. Wing geometry in simulation

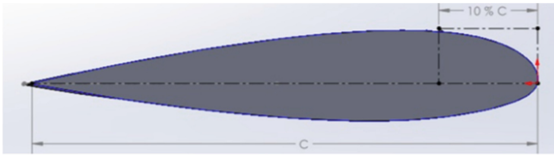

Fig. 2. Geometry placement of vortex generator x/c 10%

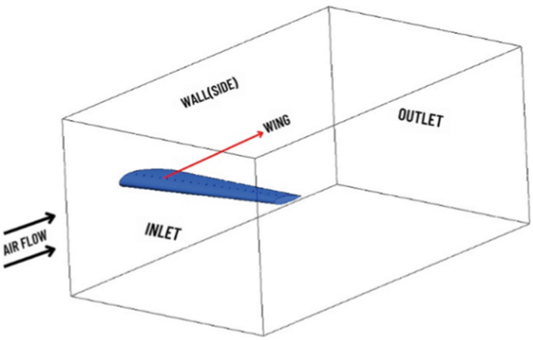

Fig. 3. Simulation domain and boundary condition

Table 1. Grid independency

Mesh	Node	Element	C_L	C_D	Error
A	529776	2924076	50,226	8,4428	0,00058
B	590761	3263309	48,234	8,4233	0,001404
C	668340	3692464	48,010	8,4434	0,001984
D	765794	4232605	48,787	8,4416	0,0018
E	887469	4915022	50,934	8,4609	0,000458
F	1021097	5647171	48,931	8,4702	0.000732
G	1104699	6106686	50,892	8,5134	0,000427
H	1195365	6611229	48,834	8,4827	0,000305
I	1296474	7183588	51,341	8,4789	0,000946

3 Result and Discussion

The type of airfoil used is the NACA 23018 type airfoil, designed using Solidworks. Ansys software is used to analyze the aerodynamic forces of lift and drag on the NACA 23018. The Ansys type used is Fluent and uses a wind speed of 20 m/s. The results of this research simulation are the pressure contours around the airfoil and the velocity distribution contours of the fluid flowing around the airfoil, as well as the drag coefficient and lift coefficient values.

3.1 Coefficient of Drag

Figure 4 shows a graph of the drag coefficient against the angle of attack. As the angle of attack increases, the value of the drag coefficient also increases. In the airfoil NACA 23018, the coefficient of drag produced is greater without a vortex generator compared to NACA 23018 with the addition of a vortex generator. At the angle of attack at $\alpha = 15°$ the C_D value on the plain is 0.121014, at x/c = 10% 0.111319 and at x/c = 15% the C_D value is 0.106164. It can be concluded that the coefficient of drag on the NACA 23018 airfoil is smaller by using the addition of a vortex generator at the x/c = 15% position than at x/c = 10% and without using a vortex generator, although the C_D value continues to increase with increasing angle of attack. The results of this simulation provide information that the addition of a vortex generator to the NACA 23018 airfoil causes the C_D value to decrease. This happens because the NACA 23018 airfoil without a vortex generator has separated earlier than the one using a vortex generator.

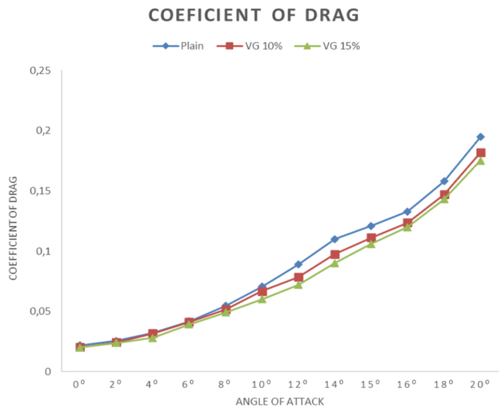

Fig. 4. Coefficient of drag against the angle of attack

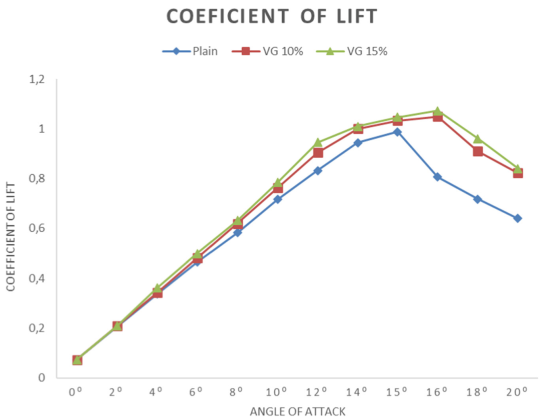

Fig. 5. Coefficient of lift against the angle of attack

3.2 Coefficient of Lift

Figure 5 is the result of the lift coefficient for the angle of attack. The plain airfoil NACA 23018 has a C_L max value at an angle of attack $\alpha = 15°$, which is 0.987408, at this point the plain airfoil stalls because the C_D value continues to increase and the C_L value begins to decrease. In addition, the NACA 23018 airfoil with the addition of a vortex generator at x/c = 10% and 15% continued to increase in the C_L value at an angle of attack $\alpha = 15°$. The C_L value in the airfoil with the addition of a vortex generator at x/c = 10% and 15% max at an angle of attack $\alpha = 16°$ with a C_L value of 1.049402 at x/c 10% and a C_L value of 1.072812 at x/c = 15% and starting to experience a decrease in the C_L value at an angle of attack $\alpha = 18°$. From the observation, the addition of a vortex generator to the NACA 23018 airfoil can increase the value of the coefficient of lift and can also delay stall at AOA maximum plain airfoil NACA 23018.

3.3 Lift to Drag Ratio

The next parameter is lift to drag ratio (C_L/C_D). This parameter can be used to find out how efficient an airfoil or airplane wing is to generate lift. It can be seen that the NACA 23018 airfoil without using a vortex generator produces a smaller C_L/C_D value. By adding a vortex generator to the NACA 23018 airfoil, it can increase the C_L/C_D value. It can be seen that the airfoil with the addition of a vortex generator x/c = 15% produces a C_L/C_D value of 13.13 at an angle of attack $\alpha = 12°$ and a plain 9.35 at an angle of attack $\alpha = 12°$. This is because the momentum of flow in an airfoil that uses a vortex generator is higher. Able to overcome the shear stress and adverse pressure gradient that occurs so that it can delay the separation and produce a larger C_L/C_D value (Fig. 6).

3.4 Velocity Contour

Figure 7 shows the schematic for taking the midspan section of the NACA 23018 airfoil. The freestream speed used in this velocity contour is 20 m/s. In general, the fluid flow velocity that passes through the upper surface airfoil is higher than the fluid flow velocity in the lower surface airfoil.

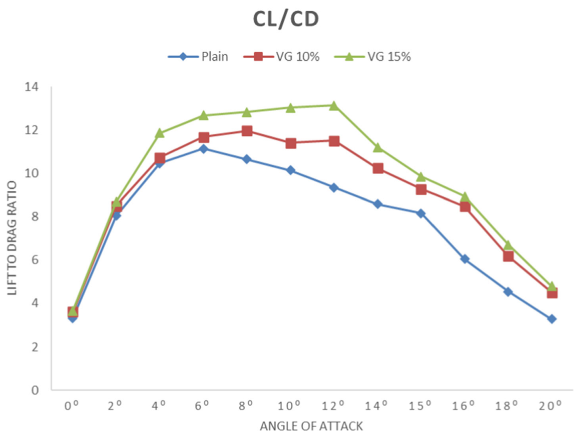

Fig. 6. C_L/C_D value against the angle of attack

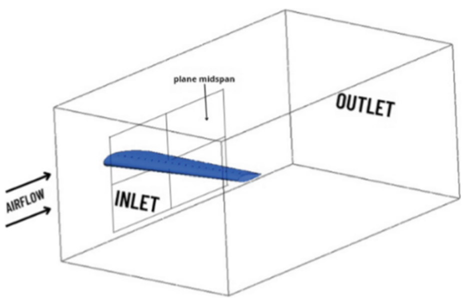

Fig. 7. Velocity Contour Data Collection Scheme

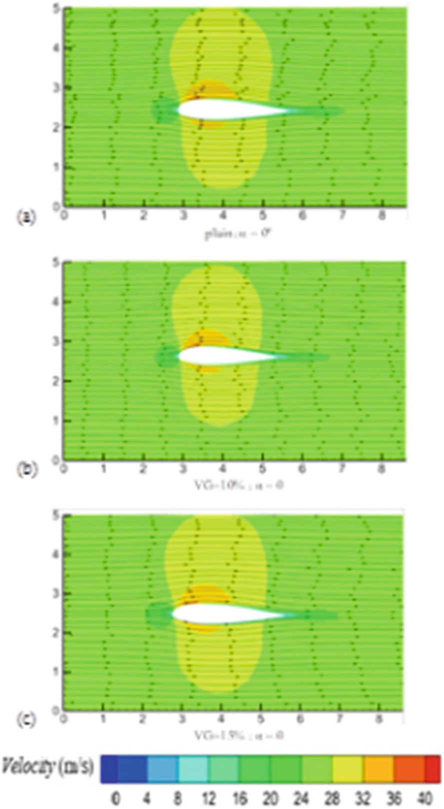

Fig. 8. Velocity contour angle of attack α = 0°.

In Fig. 8 the NACA 23018 airfoil without a vortex generator and using the addition of a vortex generator with an angle of attack α = 0º has a velocity contour that is not much different, so that at this angle of attack there is not a too significant change. In Fig. 9, when the angle of attack is α = 12º, there is a slight blue contour which shows that there is a point of separation in that section with a certain area, on the plain airfoil NACA with an angle of attack α = 12º, there is a dark blue color with a certain area which indicates that there is a point of separation in that section, while the airfoil with the addition of a vortex generator x/c = 10% and 15% makes the contour more backward and smaller.

In Fig. 10, it can be seen that at the angle of attack α = 20º, the blue contour is wider which represents a wider area of splash flow. During this angle of attack, there is also a turbulent flow which is indicated by an irregular streamlined direction. The plain airfoil NACA 23018 has a wider blue contour and starts to occur in the maximum chamber, while the NACA 23018 airfoil with the addition of a vortex generator x/c = 10% has a blue contour that occurs in the middle of the upper surface. It can be seen that the NACA 23018 airfoil with the addition of a vortex generator x/c = 15% at this angle of attack can delay the separation flow point by having a blue contour that is more backward and

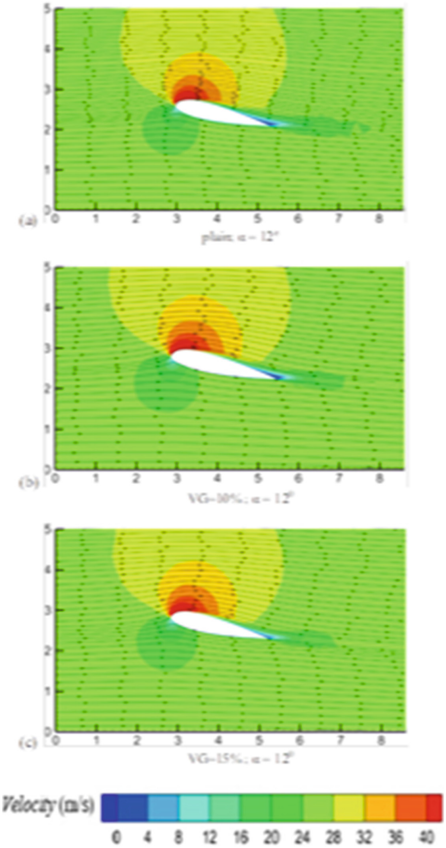

Fig. 9. Velocity contour angle of attack α = 12°.

with a smaller blue area. From the simulation results, it can be seen that the addition of a vortex generator to the airfoil greatly affects the aerodynamic characteristics of the high angle of attack. The greater the angle of attack, the greater the separation that will occur. However, the addition of a vortex generator on the NACA 23018 airfoil can delay the occurrence of separation points on the airfoil to be further backward.

3.5 Pressure Coefficient Contour

Figure 11 shows the pressure contour on the NACA 23018 airfoil with or without the addition of a vortex generator. The red pressure contour shows the maximum pressure value, while the blue pressure contour shows the minimum pressure value. On the NACA 23018 airfoil, there is a blue area on the top of the airfoil close to the leading edge, this indicates that this area has lower pressure compared to other parts of the wing. In addition, this area occurs due to the addition of a vortex generator on the NACA 23018 airfoil and also by increasing the angle of attack from the wing.

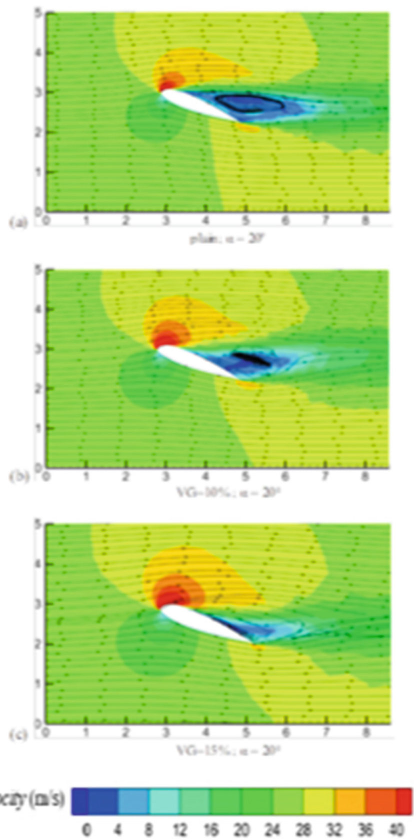

Fig. 10. Velocity contour angle of attack α = 20°.

At an angle of attack α = 20°, it can be seen that the upper part of the NACA 23018 airfoil with the addition of a vortex generator has a lower pressure distribution than the airfoil without using a vortex generator. In general, the upper surface pressure contour has a lower value than the lower surface pressure. It can be seen that the NACA 23018 airfoil with the addition of a vortex generator x/c = 15% at an angle of attack α = 20° is more effective than the NACA airfoil with the addition of a 10% vortex generator x/c. This happens because the NACA 23018 airfoil with the addition of a vortex generator x/c = 15% fluid flow that has reduced energy gains momentum by meeting the fluid flow and vortex generator, so that the fluid flow should start to separate from the surface of the NACA 23018 airfoil can withstand the friction and reverse pressure gradient. In the NACA 23018 airfoil with the addition of a vortex generator x/c = 15%, it can encourage fluid flow to be separated further backwards.

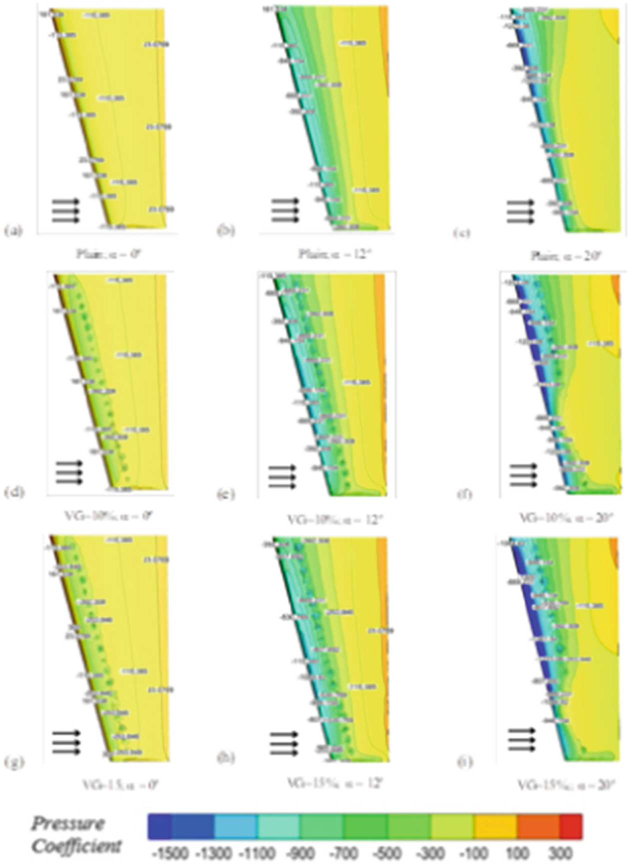

Fig. 11. Pressure coefficient contour on airfoil NACA 23018

4 Conclusion

Numerical simulation of triangular vortex generator straight arrangement on swept-back wing airfoil NACA 23018, on aerodynamic performance, resulted in the following conclusions.

1. The effect of adding a triangular vortex generator to the NACA 23018 airfoil can delay the stall, on the NACA 23018 plain airfoil with a variation of the angle of attack $\alpha = 0°–20°$ the C_L value increases to a max of $\alpha = 15°$, at this angle the C_L value begins to decrease and stall occurs. However, the airfoil with the addition of a triangular vortex generator, the C_L value increases to a max of $\alpha = 16°$, and stalls occur at this angle of attack.

2. The coefficient of drag on the NACA 23018 airfoil without using a vortex generator and with the addition of a vortex generator continues to increase as the angle of attack increases, from the angle of attack $\alpha = 0°$ to the angle of attack $\alpha = 20°$. However, the addition of a triangular vortex generator can reduce the value of the C_D.
3. The addition of a vortex generator to the NACA 23018 airfoil can increase the performance of the wing/airfoil, it has a higher C_L/C_D value of 13.13 on the NACA 23018 airfoil with the addition of a vortex generator x/c = 15% with an angle of attack $\alpha = 12°$. But plain The NACA 23018 airfoil has the largest C_L/C_D value at an angle of attack $\alpha = 8°$.
4. The pressure contour changes as the angle of attack increases. The most significant areas for pressure changes to occur are the leading edge and upper surface areas, especially the maximum chamber.
5. As the angle of attack increases, the flow of separation that will occur will be even greater. However, with the addition of a vortex generator on the NACA 23018 airfoil, the separation point that has occurred on the plain airfoil has not yet occurred in the airfoil with the addition of a vortex generator, and the vortex generator can make the separation point more delayed backward.

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