Numerical Simulation of Rectangular Vortex Generator in Sweptback Wing Airfoil NACA 0012 with Counter-Rotating Position

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NUMERICAL SIMULATION OF RECTANGULAR VORTEX GENERATOR IN SWEPTBACK WING AIRFOIL NACA 0012 WITH COUNTER-ROTATING POSITION

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ABSTRACT
Airplanes can fly because of the slightly curved shape of the plane's wings called the airfoil. Airfoil is still used by aircraft today but continues to be designed to get maximum results. The research method used is a simulation analysis method on the NACA 0012 test object with ANSYS-CFD software which is given a variation in the shape of a rectangle vortex generator with a length of 15 mm, a width of 10 mm, and a distance between vortex generators of 10 cm. The angles of attack reviewed are 0°, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 15°, 16°, 18°, and 20°. The result of this simulation is that the presence of a rectangular vortex generator on airfoil NACA 0012 can affect both performance and aerodynamic characteristics. The vortex generator on the airfoil can delay the occurrence of separation and can delay the occurrence of stall on the NACA 0012 airfoil, where the ordinary NACA 0012 airfoil stalls at $\alpha = 14°$ with the addition of the vortex generator has not stalled at this point. With this, the NACA 0012 airfoil which is given a vortex generator can affect the results of C_D. Overall, the most optimal variation is the NACA 0012 airfoil which is given a vortex generator with x/c = 15% where the value of C_D is greatest at an angle of attack $\alpha = 18°$.

Key Word: *vortex generator, airfoil, aerodynamic, NACA 0012.*

1. INTRODUCTION

A vortex generator (VG) is a fin-shaped component that is usually found on the surface of the wing and stabilizer to affect the boundary layer. With the addition of this vortex generator, it can delay the separation of the flow so that the performance of the wing increases. Research on vortex generators is a form of development in the world of aerodynamics.

There are many ways to analyze aerodynamic performance and one of them is using a wind tunnel. A wind tunnel is a tool used when conducting aerodynamic research to determine the effects that occur when air passes through a solid object. However, along with the development of the times and today's technology growing rapidly, analysis activities can be done at home only by utilizing Computational Fluid Dynamics (CFD). Computational Fluid Dynamics (CFD) is a method that can be used to research aerodynamics. CFD itself contains a set of methodologies using computers that can be used to simulate fluid flow, heat transfer, chemical reactions, and others. The working principle of CFD itself is that the object we are going to test will be divided into parts called cells and then processed which is called meshing. CFD itself can be accessed by installing software on a computer. Some of these software are ANSYS, Exceed, CATIA, and others. This study aims to determine the effect of adding a rectangular vortex generator to the upper wing surface of NACA 0012. Simulation using CFD on a vortex generator has been carried out by Oriol [1], Amnart [2], Velte et al [3], Shim [4], Syaiful [5] etc.

2. METHOD

2.1. Boundary Condition

A boundary condition is a condition where the control of calculation is defined as an early definition and becomes the boundary of flow that passes through the object by determining the walls, inlet, dan outlet. Boundary conditions should be by the shape of the object. The boundary conditions in this study were adapted to

Hariyadi's research [6] using the turbulent model K-ε Realizable which was initiated by Mulvany et al [7].

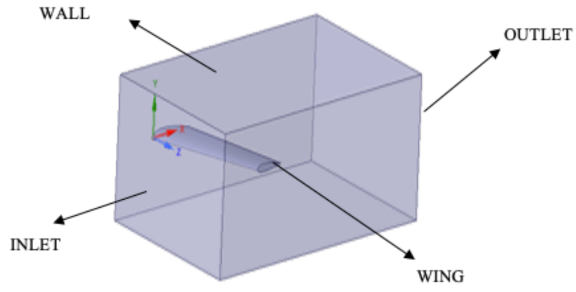


Figure 1 Domain and Boundary Condition

2.2. Meshing

The meshing process is a process to divide volume from the geometry object into small parts so the calculation results are more accurate. The results of the drag coefficient are compared with Abbot's research [8] so that the mesh used in the next study is Mesh A.

Table 1. Grid independency

Meshing	*Elements*	FY	*Drag* (N)	C_D	*Error* (%)
Meshing A	1715436	-0,761	0,761	0,012	-
Meshing B	1789181	-0,009	1,009	0,015	0,77
Meshing C	1817770	-1,682	1,682	0,013	2,64
Meshing D	1844006	-3,964	3,964	0,012	0,72
Meshing E	1867381	-4,533	4,533	0,014	1,78

3. RESULT AND DISCUSSION

Modeling geometry using Solidworks 2019 software and analyzing the aerodynamic forces of lift and drag on NACA 0012 using Ansys Fluent using wind speed of 20 m/s and default air density of 1,225 kg/m3. The results of the simulation in this study are in the form of visualization of the flow that occurs when passing through the airfoil and also the value of the drag coefficient and lift coefficient.

3.1. Drag Coefficient

The following is a graph of the drag coefficient against the angle of attack α = 0°, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 15°, 16°, 18°, and 20° From this graph, it can be seen the aerodynamic performance of NACA 0012 with the addition of a vortex generator and without the addition of a vortex generator. The drag coefficient value generated by NACA 0012 without the addition of a vortex generator is greater than that of NACA 0012 with the addition of a vortex generator. At NACA 0012 without the addition of a vortex generator, the value of the drag coefficient continues to increase to a maximum of α = 20°. At NACA 0012 with the addition of a vortex generator, the value of the drag coefficient continues to increase to a maximum at α = 20° of 0.51917 at 10% chord line direction and 0.491891 at 15% chord line direction.

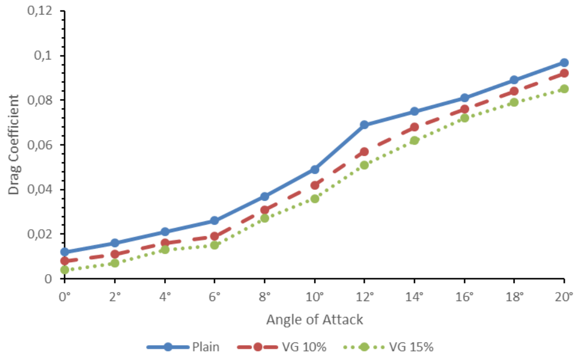


Figure 2 Drag Coefficient

3.2. Lift Coefficient

The following is a graph of the lift coefficient of the angle of attack α = 0°, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 15°, 16°, 18°, and 20°. From this graph, it can be seen the aerodynamic performance of NACA 0012 with the addition of a vortex generator and without the addition of a vortex generator. The lift coefficient value produced by NACA 0012 without the addition of a vortex generator is lower than that of NACA 0012 with the addition of a vortex generator. At NACA 0012 without the addition of a vortex generator, the lift coefficient value continues to increase to a maximum at α = 12° of 3.195271 and again decreases at an angle of attack α = 15°. At NACA 0012 with the addition of a vortex generator, the lift coefficient continues to increase to a maximum of α = 17° of 3.49720 at 10% chord line direction and 3.621980 at 15% chord line direction.

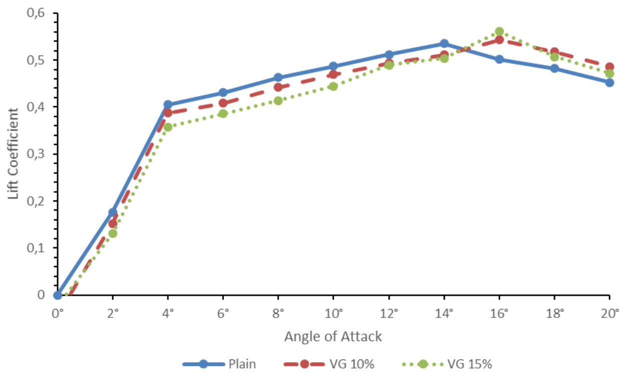


Figure 3 Lift Coefficient

3.3. Lift to Drag Ratio

From the lift coefficient and drag coefficient values, the lift-to-drag ratio (C_L/C_D) value can be determined. The following is a graph of lift to drag ratio against the angle of attack α = 0°, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 15°, 16°, 18°, and 20°. From this figure, it can be seen the aerodynamic performance of NACA 0012 with the addition of a vortex generator and without the addition of a vortex generator.

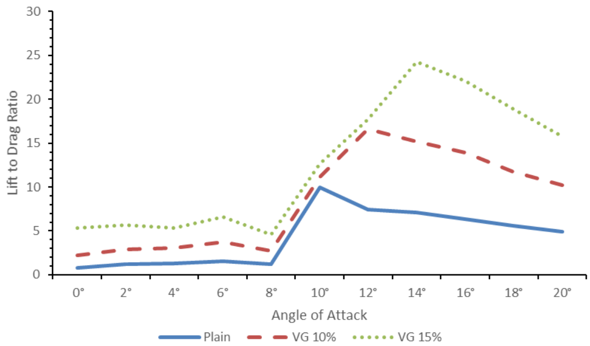


Figure 4 Lift to Drag Ratio

From the Figure 4, it can be seen that as the angle of attack increases, the value of the lift-to-drag ratio also increases. The lift-to-drag ratio value generated by NACA 0012 without the addition of a maximum vortex generator at an angle of attack α = 12° is 8.167 and again decreases at α = 15°. In NACA 0012 with the addition of a vortex generator, the maximum lift to drag ratio increases at α = 17° by 10,536 at 10% chord line direction and 11.252 at 15% installation position.

3.4. Velocity Magnitude Contour

This section will show how the visualization of the simulation results carried out on NACA 0012 without a vortex generator and NACA 0012 with the addition of a vortex generator to complete the explanation of the simulation carried out. Figure 5 is a velocity contour of NACA 0012 at an angle of attack α = 0°, from Figure 5 there is no significant difference because the three airfoils are still in normal condition so the flow separation is not visible.

Figure 6 is a velocity contour of NACA 0012 at an angle of attack of α = 16°, from Figure 6 it can be seen that there is a color difference between the wings without the addition of a vortex generator and the wings with the addition of a vortex generator. On the wing without the addition of a vortex generator, there is a dark blue section on the upper surface which is more dominant than the wing with the addition of a vortex generator which indicates the presence of a boundary layer, causing greater separation. So it can be concluded that the presence of a vortex generator can delay the flow separation so that the performance of the wing increases and the lifting force can be maintained which can be seen in Figures (b) and (c) in Figure 6.

Figure 7 is a velocity contour of NACA 0012 at an angle of attack α = 20°, from Figure 7 it can be seen that the three wings have a large flow separation which causes the three wings to lose their lift. So it can be concluded that the increasing the angle of attack, the greater the flow separation that can occur.

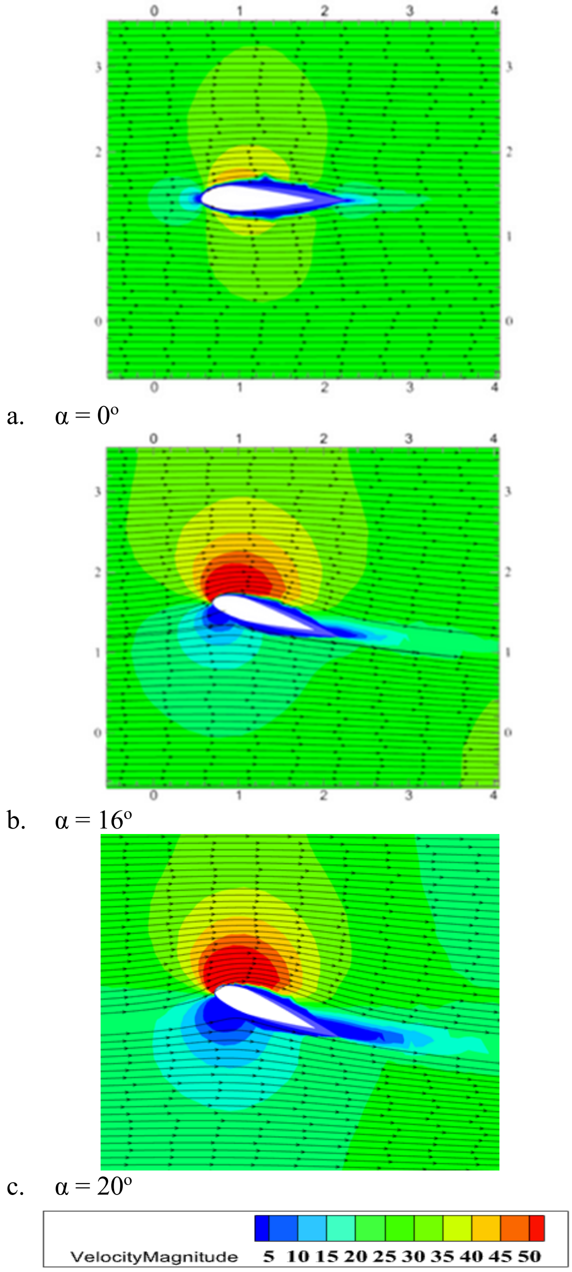
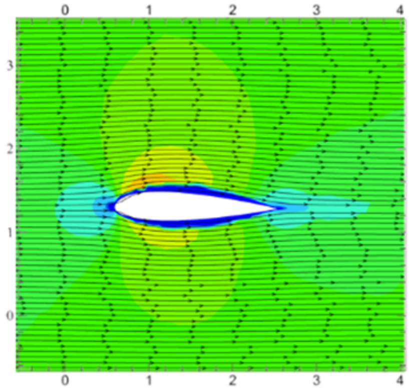


Figure 5 Velocity Contour without Vortex Generator

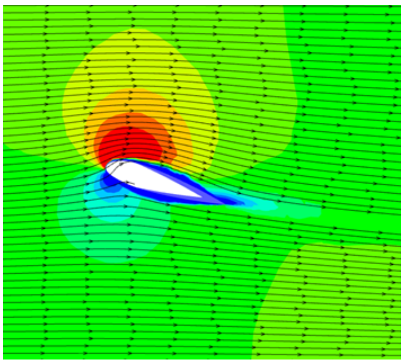
3.5. Pressure Coefficient

This pressure contour explains how the pressure distribution when air passes through the wing surface, with different angles, the pressure distribution will also be different. And on the wing without winglets, a tip vortex will be created on the wingtip as shown in Figure 8. Figure 6 is a pressure contour image of NACA 0012 at an angle of attack α = 0°, from Figure 13 it can be seen that there is a pressure drop in the maximum thickness area of the airfoil in Figure 6. (a), (b), and (c) caused by an increase in air velocity in the area. There is higher pressure in the leading edge area of the airfoil due to reduced speed as it passes through the leading edge of the airfoil.

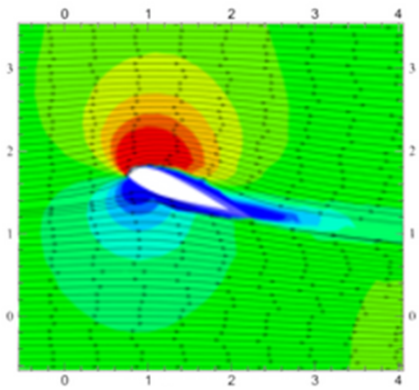
Figure 9 is a pressure contour of NACA 0012 at an angle of attack α = 16°, from Figure 9 there is a dark blue area on the leading edge area which indicates the lowest pressure occurs in that area, this is caused by the presence of fast airflow passing through the area. leading edge. And on the plain airfoil (figure 7 (a)) there is a yellow area on the upper surface of the back of the wing which indicates an increase in pressure in that area caused by airflow separation in that area which makes the airflow velocity in the area decrease so that the pressure increase. Figure 10 is a pressure contour of NACA 0012 at an angle of attack α = 20°, from Figure 10 it can be seen that there is an uneven pressure distribution which indicates that there is airflow separation when passing through the wing surface and the three wings are in a stall.



a. α = 0°



b. α = 16°



c. α = 20°

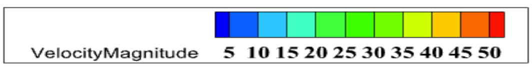
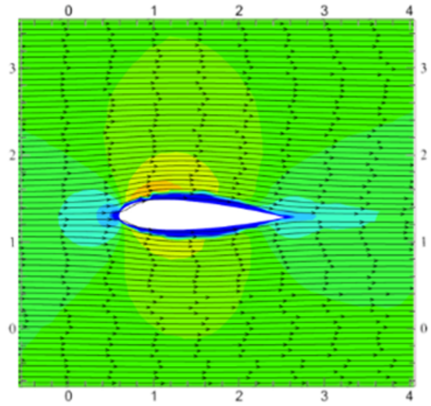
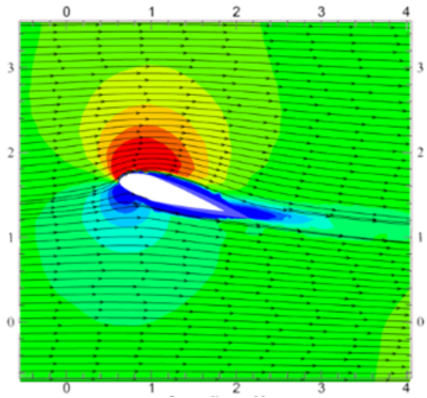


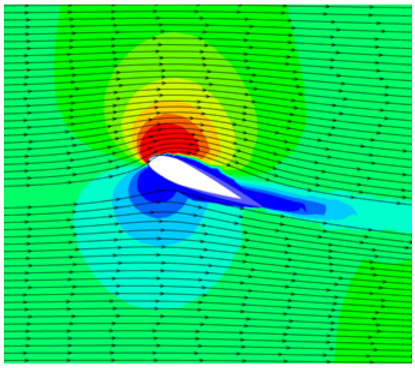
Figure 6 Velocity Contour with vortex generator 10%



a. α = 0°



b. α = 16°



c. α = 20°

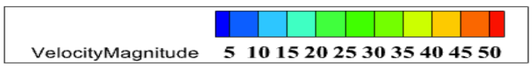
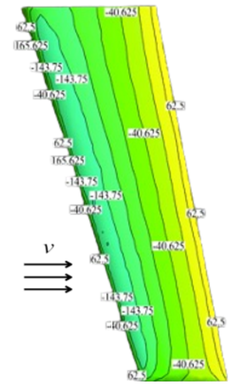
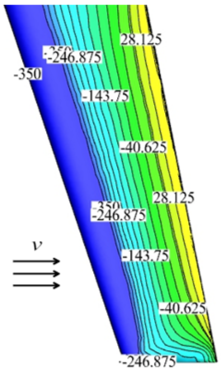


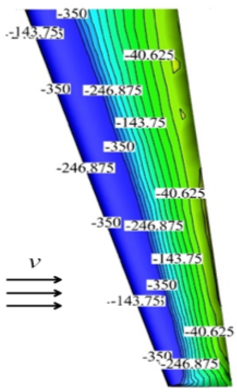
Figure 7 Velocity Contour with vortex generator 15%



a. α = 0°



b. α = 16°



c. α = 20°

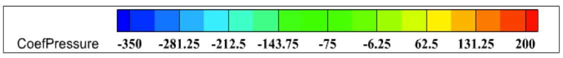
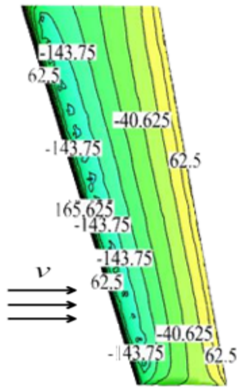
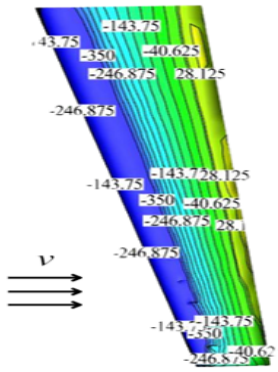


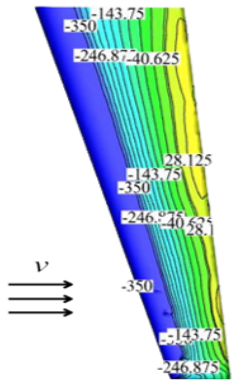
Figure 8 Pressure Coefficient without Vortex Generator



a. α = 0°



b. α = 16°



c. α = 20°

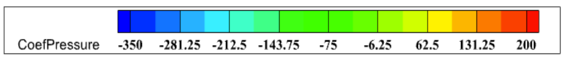


Figure 9 Pressure Coefficient with vortex generator 10%

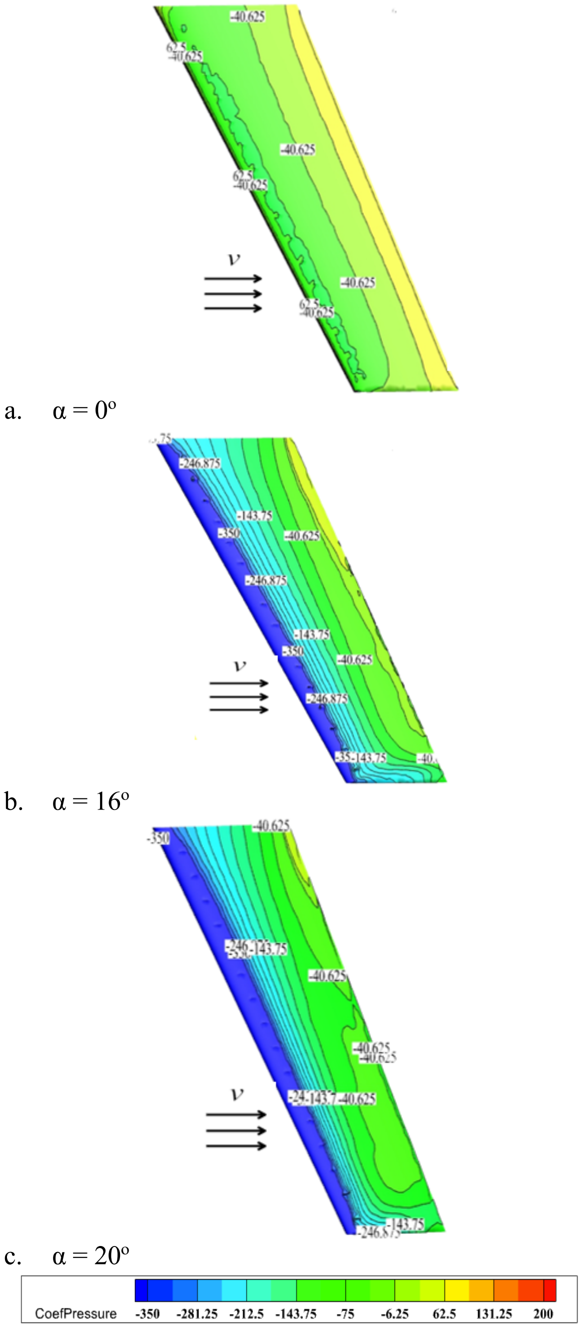


Figure 10 Pressure Coefficient with vortex generator 15%

4. CONCLUSION

From the results of research and discussion, the following conclusions can be drawn:

1. From the simulation results, it can be seen that the NACA 0012 airfoil with a 10% vortex generator with variations in the angle of attack α = 0º, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 16°, 18°, and 20° get points the optimal value of C_L is at an angle of attack α = 16°, and the NACA 0012 airfoil with a 15% vortex generator with the same variation of the angle of attack produces an optimal point of C_L value at an angle of attack α = 18°, with these results showing that the NACA 0012 airfoil given a vortex generator can get a more optimal C_L α = 2°- 4° compared to airfoils that are not given a vortex generator.
2. From the simulation results, it can also be seen that the addition of a vortex generator will delay the stall. It can be seen that for the NACA 0012 airfoil which is given a 10% vortex generator, a stall occurs at an angle of attack α = 16º, and for the NACA 0012 airfoil which is given a 15% vortex generator, a stall occurs at an angle of attack of 16º. stall occurs at an angle of attack around α = 12º while the presence of a Vortex generator occurs at a higher angle of attack. So, the benefit of adding a vortex generator is the delay in stalling.
3. Drag coefficient on plain airfoil and airfoil with vortex generator continues to increase with increasing angle of attack from the angle of attack 0º to angle of attack α = 20º
4. The addition of a 10% and 15% vortex generator can improve the performance of the NACA 0012 airfoil, it can be seen from the C_L/C_D distribution which is increasing by α = 2º - 4º from the NACA plain airfoil and the presence of a vortex generator on the NACA 0012 airfoil can delay the separation up to the leading edge.

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