Experimental Study of Airflow Characteristics in Airfoil Naca 43018 with the Addition of Gothic Vortex Generator Using Visualization of Smoke Generator

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Abstract. In this study, the topic studied was the characteristics of airflow passing through the gothic-type generator vortex by the smoke generator method. The purpose of this study was to visually observe the characteristics of the airflow on the upper surface passing through the NACA 43018 airfoil with varying angle of attack positions. The vortex profile of the generator x/c = 20% of the leading edge. Variations in this study are the angle of attack (α) and the placement of the generator vortex on the airfoil. The freestream speed used is a speed of 5 m/s, and at an angle of attack (α) of 0°, 3°, 6°, 9°, 12°, and 15°. From this study, it was found that the ratio of separation points between airfoils without VG compared to airfoils with VG and D = 10 mm at angles of attack (α) = 0°, 3°, 6°, 9°, 12°, and 15° had significant differences in separation points. Airfoil with VG and D = 20 mm at an angle of attack (α) = 0°, 3°, 6°, 9°, 12°, and 15° can delay separation better than D = 10 mm.

Keywords: Airfoil NACA 43018 · angle of attack · vortex generator · smoke generator · laminar · turbulent flow

1 Introduction

Aircraft aerodynamics determines the performance and stability of the aircraft. The aerodynamics of the aircraft also determines the movements and maneuvers that the aircraft can perform. The aerodynamics of the aircraft can be researched with a test tool in the form of a wind tunnel. In aircraft aerodynamics, flow separation in the boundary layer can cause stalls in the aircraft.

Flow separation occurs when the angle of attack begins to increase. At that time the value of flow separation was still small in scale because it only occurred near the trailing edge. As the angle of attack increases, the separated flow increases. With the increase in separated flow, the drag force has a greater impact.

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The results of research conducted by Hariyadi [1] proved that there was an increase in the performance of the NACA 43018 airfoil with the addition of a generator vortex compared to without a generator vortex because the generator vortex can slow down the separated flow. One way to reduce drag force and prevent stalls from occurring is to use a lifting surface on the upper surface of the aircraft wing. The addition of a vortex generator to the part serves to slow down the flow of separation and aerodynamic stalling.

Experiments were conducted in aerodynamic testing with the help of a subsonic wind tunnel tool. The way the wind tunnel works is to suck air into the room with the help of a motor equipped with a fan blade. The shape of the wind tunnel resembles a venturi tube in which there is a test section, namely the NACA 43018 airfoil. While research using smoke generators has previously been carried out by Trinder [2], Manovski [3], Raval [4], Gao [5] etc.

Next is the addition of a gothic-type generator vortex. The smoke generator medium is used as a fluid flow builder. The selection of airfoil and vortex generators is a development of research that has been carried out using NACA 43018 airfoils and different types of vortex generators.

2 Method

The test object will be forged in the wind tunnel at a predetermined speed constantly. Making the geometry of airfoils and wind tunnels with a length of 1 x 10.5 m is done so that the results obtained can be validated. The airfoil model used in this experiment is an airfoil with an Airfoil NACA 43018 with a visualization of a smoke generator derived from sewing machine oil heated by a smoke generator, then flowed through a small pipe in the leading edge airfoil. [6].

3 Result and Discussion

After research was conducted using the visualization of the smoke generator on the NACA 43018 airfoil with the addition of a vortex generator and not using a vortex generator. The shape of the vortex generator used is gothic, fed with smoke by a smoke generator at a speed of 5 m /s. The angle of Attack variations of 0°, 3°, 6°, 9°, 12°, and 15°. So some data was taken as evidence that the research had been carried out.

3.1 Research Results

From this research, it can be concluded that in airfoils that do not use a gothic vortex generator the separation point is longer and if using a gothic vortex generator the separation point is lower so that when using a gothic vortex generator the separation point on the airfoil is lower than without using a gothic vortex generator. And it can also be concluded that with every change in the angle of attack the lower the angle, the shorter the separation point obtained. If the higher the angle, the separation point obtained is greater than the end of the airfoil.

3.2 Separation Point Analysis

There is a difference between using a gothic vortex generator and not using a gothic vortex generator. The difference occurs in the airflow passing through the airfoil. If you use a gothic vortex generator, the airflow is still directed and follows the shape of the airfoil. Meanwhile, if you don't use a gothic vortex generator, the airflow is directed only when in front of the airfoil. After passing through the airfoil and at the time above, the airflow does not follow the shape of the airfoil but directly leads to the back.

3.3 Smoke Flow Characteristics on Airfoil Without Vortex Generator and Using Gothic Vortex Generator

At airfoil NACA 43018 exist line straight longitudinal from side right Wed left airfoil. The function is to know the letter Separation (Xs) with the letter Colored red, letter stagnation (Xp) with the letter Colored ears, letter Transition (Xl) with the letter Colored blue, letter vorticity (Xt) with the letter Colored green, so that get know effect from addition gothic Vg with Variations angle of attack. Division section at airfoil Obtained with face count 1 part full airfoil from the leading edge until the trailing edge. Obtained 10 parts with face divided 10% on every part. Laying gothic vortex generator exists at 20% from the leading edge, which exists at line 0.2. From the research that was Done with the use of airfoil NACA 43018 without the use of VG, use gothic VG with D = 10 mm dan D = 20 mm so the writer get data to result in the comparison (Table 1).

Figure 1 shows the smoke flow on the upper surfaces of the airfoil at an angle of attack $\alpha = 0°$, the freestream speed is 5 m/s so the transition point is shown to be at the point 0.2–0.7, and the separation point is shown to be at the point of 0.7. After separation, the smoke flow shows that the air heading towards the trailing edge becomes turbulent.

In Fig. 2, smoke flow is visible on the upper surfaces of the airfoil at an angle of attack $\alpha = 3°$, the freestream speed is 5 m/s. Transition points are indicated at points 0.2–0.6 and separation points are shown at points 0.6. After separation occurs, the smoke flow shows that the air heading towards the trailing edge becomes turbulent.

Table 1. Research Results of NACA 43018 airfoil without VG

Plain Airfoil			
A	**Xl**	**Xs**	**Xt**
0°	0.2–0.7	0.7	0.8
3°	0.2–0.6	0.6	0.8
6°	0.15–0.5	0.5	0.7
9°	0.1–0.5	0.5	0.6
12°	0.1–0.5	0.5	0.65
15°	0.1–0.3	0.3	0.4

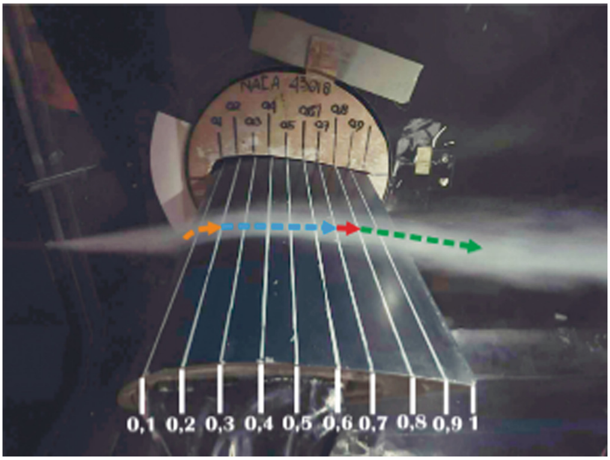

Fig. 1. Airfoil without Vortex Generator α = 0°

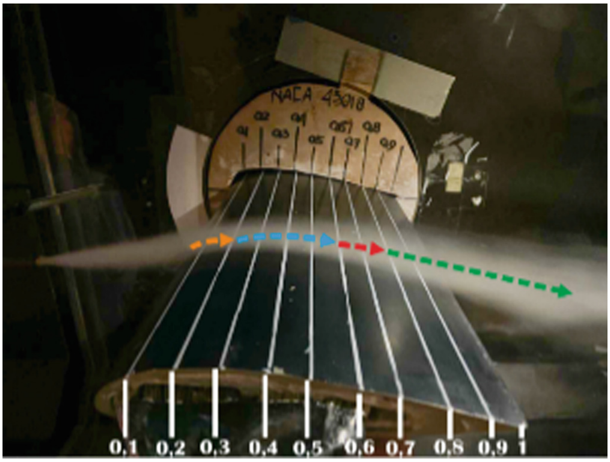

Fig. 2. Airfoil without Vortex Generator α = 3°

Figure 3 shows flow smoke at upper surfaces airfoil with α = 6°, velocity freestream 5 m/s. Lyrics Transition is shown by letter 0.15–0.5, letter Separation exists at letter 0.5. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent.

Figure 4 shows the smoke flow on the upper surfaces of the airfoil at an angle of attack α = 9°, and the freestream speed of 5m/s. The transition point is indicated by the point 0.1–0.5. At this point the airflow indicates the laminar flow then the point of separation occurs indicated by point 0.5. After separation occurs, the smoke flow shows that the air heading towards the trailing edge becomes turbulent.

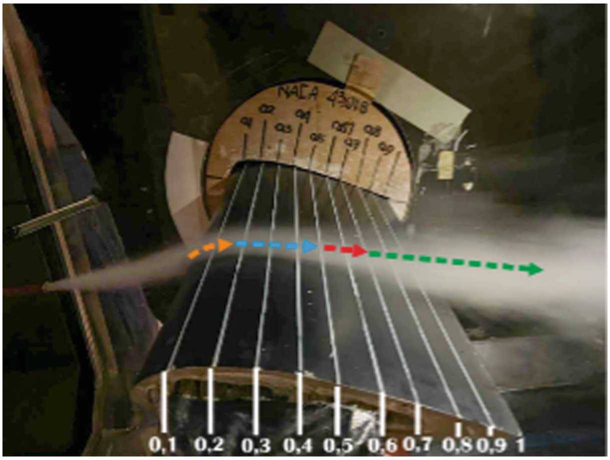

Fig. 3. Airfoil without Vortex Generator α = 6°

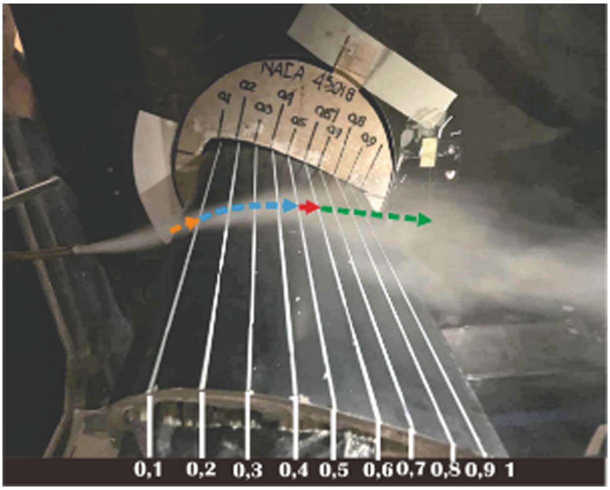

Fig. 4. Airfoils without Vortex Generator α = 9°

Figure 5 shows the smoke flow on the upper surfaces of the airfoil at an angle of attack α = 12°, the freestream speed is 5m/s. The transition point is at the point 0.1–0.5. At this point**,** there is a laminar flow on the upper surface. Then the separation point is located at point 0.5. After separation occurs, the smoke flow shows the air becoming turbulent.

Figure 6 shows the smoke flow on the upper surfaces of the airfoil at an angle of attack α = 12°, the freestream speed is 5 m/s., the transition point is indicated by the 0.1–0.3 point, and the separation point is shown by the 0.3 points. At the transition point, the smoke flow indicates if the airflow that occurs is a laminar flow. After separation

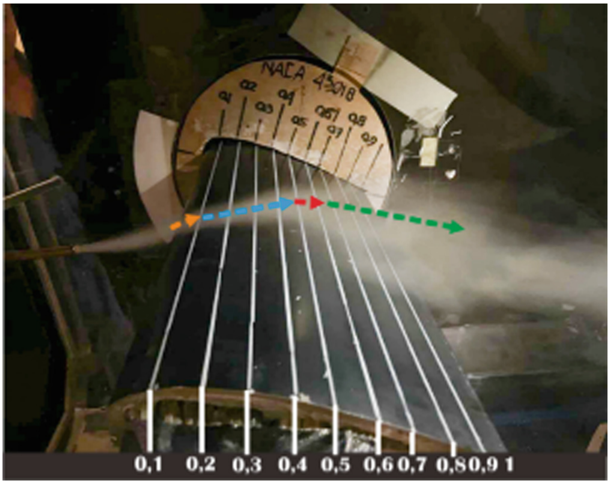

Fig. 5. Airfoils without Vortex Generator α = 12°

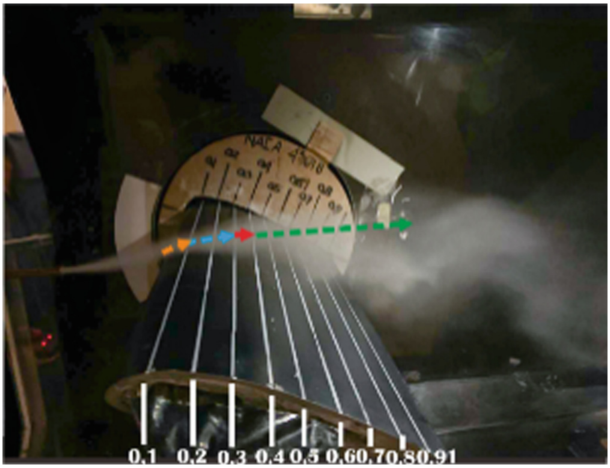

Fig. 6. Airfoils without Vortex Generator α = 15°

occurs, the smoke flow shows that the air heading towards the trailing edge becomes turbulent (Table 2).

Figure 7 shows that airfoil NACA 43018 α = 0° with added gothic vortex generator with D = 10 mm at airfoil so that letter separation is shown by letter 0.8, letter Transition shown by letter 0.2–0.8. At letter transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther if than without VG.

Table 2. Research Results of NACA 43018 Gothic VG airfoil with D = 10 mm

Gothic VG with D = 10 mm			
α	**Xl**	**Xs**	**Xt**
0°	0.2–0.8	0.8	0.9
3°	0.2–0.8	0.8	0.9
6°	0.2–0.6	0.6	0.8
9°	0.2–0.65	0.65	0.7
12°	0.2–0.55	0.55	0.7
15°	0.1–0.3	0.35	0.45

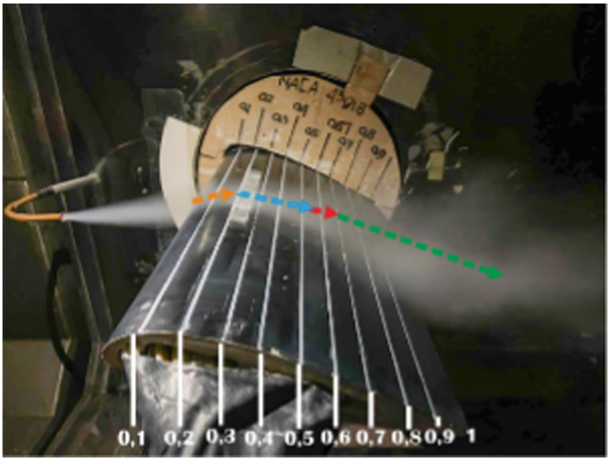

Fig. 7. Airfoils with gothic Vortex Generator, D = 10 mm, α = 0°

Figure 8 shows that airfoil NACA 43018 α = 3° with D = 10 mm that letter Separation shown by letter 0.8, letter Transition shown by letter 0.2-.0.8. At letter Transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther.

Figure 9 shows that airfoil NACA 43018 α = 6° with D = 10 mm so that letter Separation happens at letter 0.6, letter transition exists at letter 0.2–0.6. At letter Transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther if Than without VG.

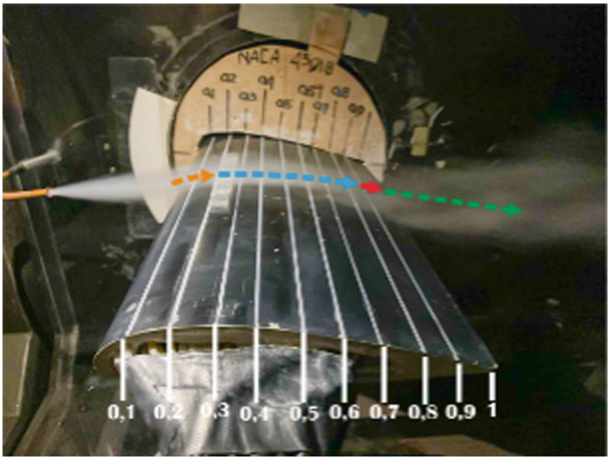

Fig. 8. Airfoils with gothic Vortex Generator, D = 10 mm, α = 3°

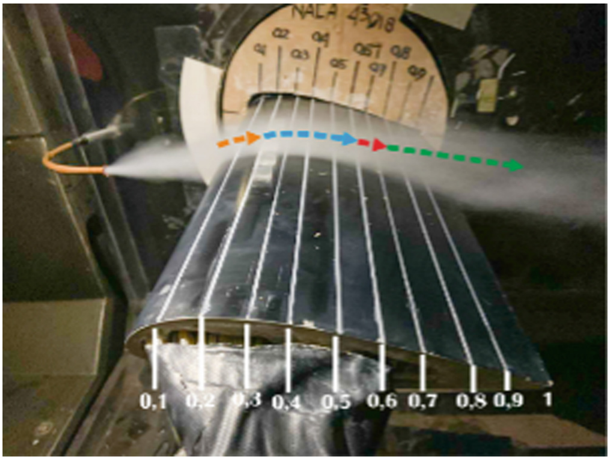

Fig. 9. Airfoils with gothic Vortex Generator, D = 10 mm, α = 6°

Figure 10 shows that airfoil NACA 43018 α = 9° at airfoil NACA 43018 with D = 10 mm so that letter Separation happens shown by letter 0.65, letter Transition exists at letter 0.2–0.65. At letter Transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther if than without VG.

Figure 11 shows that airfoil NACA 43018 α = 12° at airfoil NACA 43018 with D = 10 mm airfoils so that the separation point occurs at point 0.55, and the transition point is at point 0.2-.0.55. At the point of transition of the flow on the upper surface is a laminar flow. After separation, the smoke flow shows the air heading towards the trailing edge becomes turbulent but the transition point becomes farther when compared to without VG.

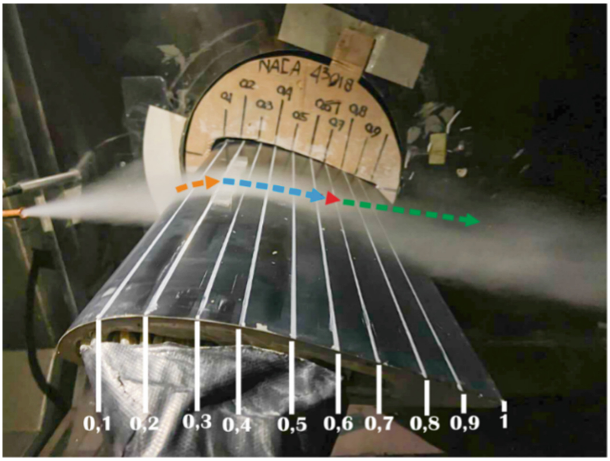

Fig. 10. Airfoil with gothic Vortex Generator, D = 10 mm, $\alpha = 9°$

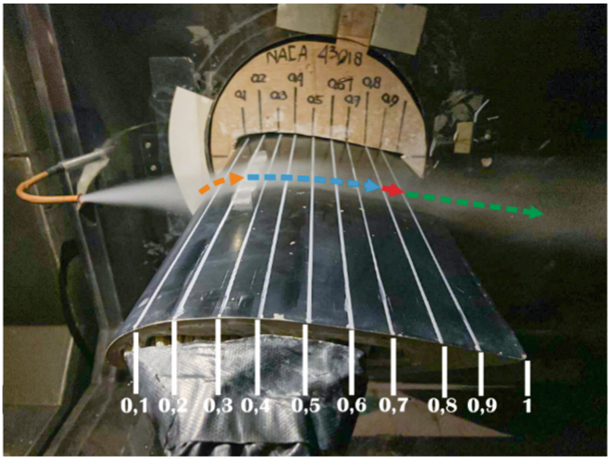

Fig. 11. Airfoil with gothic Vortex Generator, D = 10 mm, α = 12°

Figure 12 shows that airfoil NACA 43018 α = 15° at airfoil NACA 43018 with D = 10 mm so that the separation point is indicated by point 0.35, and the transition point is on line 0.1–0.3. At the point of transition of the flow on the upper surface is a laminar flow. After separation, the smoke flow shows the air heading towards the trailing edge becomes turbulent but the transition point becomes farther when compared to without VG (Table 3).

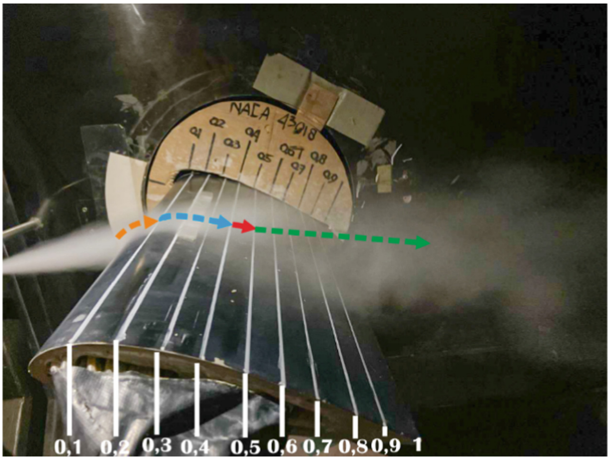

Fig. 12. Airfoils with gothic Vortex Generator, D = 10 mm, α = 15°

Table 3. Research Results of NACA 43018 Gothic VG airfoil with D = 20 mm

Gothic VG with D = 20 mm			
α	Xl	Xs	Xt
0°	0.2–0.8	0.8	0.9
3°	0.2–0.8	0.8	0.9
6°	0.2–0.75	0.75	0.8
9°	0.15–0.7	0.7	0.8
12°	0.15–0.6	0.6	0.75
15°	0.1–0.55	0.55	0.65

Figure 13 shows that airfoil NACA 43018 α = 0° at airfoil NACA 43018 with D = 20 mm so the letter separation is shown by letter 0.8, letter Transition shown by letter 0.2–0.8. At letter Transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther than the airfoil that Added VG with D = 10 mm.

Figure 14 shows that airfoil NACA 43018 α = 3° at airfoil NACA 43018 with D = 20 mm so the separation point is indicated by point 0. 8, and the transition point is indicated by point 0.2–0. 8. At the transition point of the flow on the upper surface is the laminar flow. After separation, the smoke flow shows that the air heading towards the trailing edge becomes turbulent but the transition point becomes farther when compared to the airfoil added by VG with D = 10 mm.

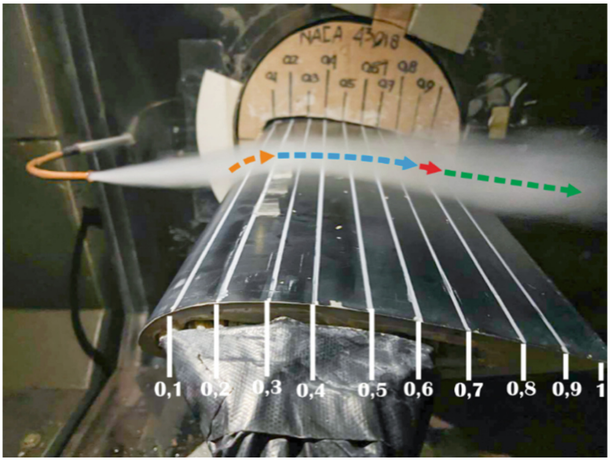

Fig. 13. Airfoils with gothic Vortex Generator, D = 20 mm, α = 0°

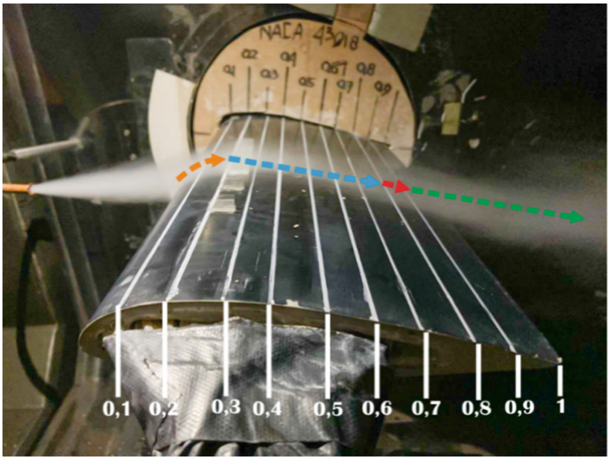

Fig. 14. Airfoils with gothic Vortex Generator, D = 20 mm, α = 3°

Figure 15 shows that airfoil NACA 43018 α = 6° at airfoil NACA 43018 with D = 20 mm so the separation point occurs at point 0.75, and the transition point is at point 0.2 –0.75. At the point of transition of the flow on the upper surface is a laminar flow. After separation, the smoke flow shows that the air heading towards the trailing edge becomes turbulent but the transition point becomes farther when compared to the airfoil added by VG with D = 10 mm.

Figure 16 shows that airfoil NACA 43018 α = 9° at airfoil NACA 43018 with D = 20 mm so the separation point occurs indicated by point 0.7, and the transition point is located at point 0. 15–0. 7. At the point of transition of the flow on the upper surface is a laminar flow. After separation, the smoke flow shows that the air heading towards the

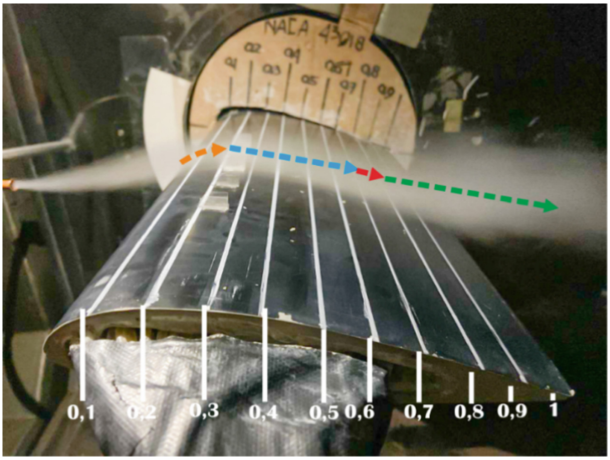

Fig. 15. Airfoils with gothic Vortex Generator, D = 20 mm, α = 6°

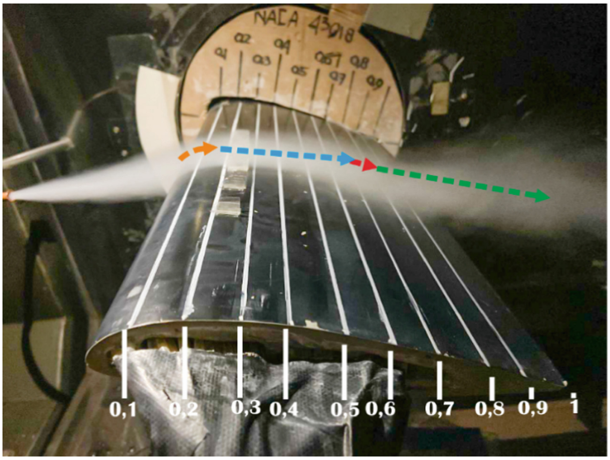

Fig. 16. Airfoils with gothic Vortex Generator, D = 20 mm, α = 9°

trailing edge becomes turbulent but the transition point becomes farther when compared to the airfoil added by VG with D = 10 mm.

Figure 17 shows that airfoil NACA 43018 α = 12° at airfoil NACA 43018 with D = 20 mm so the letter separation happens at letter 0.6, and letter transition exists at letter 0.15–0.6. At letter Transition flow at upper surface flows laminar. After happening Separation, flow smoke show air that towards Towards trailing edge become turbulent but the letter Transition becomes farther than the airfoil that added VG with D = 10 mm.

Figure 18 shows that airfoil NACA 43018 α = 15° at airfoil NACA 43018 with D = 20 mm so the separation point is shown by point 0.55, and the transition point is on line 0.1–0.55. At the point of transition of the flow on the upper surface is a laminar flow. After separation, the smoke flow shows that the air heading towards the trailing edge

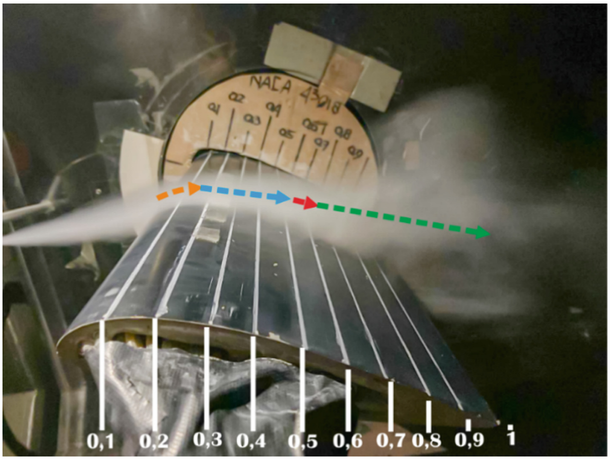

Fig. 17. Airfoils with gothic Vortex Generator, D = 20 mm, α = 12°

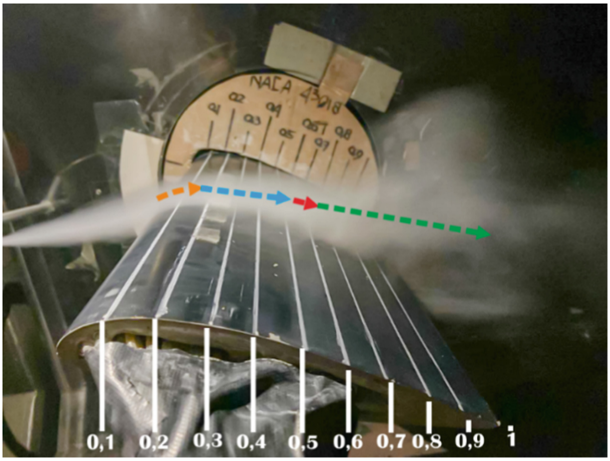

Fig. 18. Airfoils with gothic Vortex Generator, D = 20 mm, α = 15°

becomes turbulent but the transition point becomes farther when compared to the airfoil added by VG with D = 10mm. By adding a gothic vortex generator to the NACA 43018 airfoil, it can facilitate the transition from a laminar flow to a turbulent flow. It can be seen that the most significant addition of the gothic vortex generator occurs at an angle of attack α = 15° with the location of the separation point at point 0.3 of the leading edge.

From this angle of attack, it can be used as a comparison reference between airfoils that use a gothic vortex generator and airfoils that do not use a vortex generator.

4 Conclusion

From the results of simulation experiments and analysis carried out in the previous chapter, conclusions can be drawn.

1. The flow of air passing through the upper surface of the airfoil using a gothic vortex generator can delay the occurrence of separation when compared to airfoils that do not use a gothic vortex generator.
2. From the research experiments that have been carried out with an angle of attack of $\alpha = 0°–15^{o}$ against NACA 43018 type airfoils, it was obtained that the flow on the upper surface that passes through the airfoil with the generator vortex has a further laminate flow so that the separation point is also farther from the leading edge.

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