Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July, 2021:1570 – 1576

Experimental Investigations Of Pressure Distribution Of NACA0018 Airfoil With Triangular Vortex Generator

Balaji G[a], Naveen Kumar K[b], Sunil Kumar A[c], Sai Kumar [d]

[a] Faculty, School of Aeronautical Science, Hindustan Institute of Technology and Science, Padur, Chennai, India
[b,c,d] UG Student, School of Aeronautical Science, Hindustan Institute of Technology and Science, Padur, Chennai, India.

Abstract

An experimental investigation was made to study the influence of Vortex generators on the aerodynamic characteristics of the NACA 0018 is used in the design of aircraft wing and wind turbine blades. In this paper, the co-efficient of pressure performance of NACA0018 profile blade used experimentallyinvestigated for improve the aerodynamics performance of Wind turbine and Aircraft wing, in presence of with and without Triangular Vortex Generator(TVG). It is located at 30 % of the chord in the wing in a spanwise direction. Tests were made to find pressure distribution over the airfoils under various operating conditions and different angles of Attack from 0° to 25° with the step of 5°. The set of Triangular Vortex Generators (TVG) was arranged with uniform pitch and 15° tilted concerning freestream flow. Therefore, the Coefficient of pressure distribution is calculated for the different operating conditions, and results are plotted in the graph. It is observed that variation of pressure distribution is minimum at low angle of attache but huge variation in case of the higher angle of attack.

Keywords: Vortex Generator, NACA airfoil, Turbine blade, Aerodynamics, Trinagulat VG

1. Introduction

In wind turbines, Vortex Generators are a widely used device to control the flow over parts of theblades and lead to change pressure distribution. The application of Vortex Generators play a vital role and has a long history from many researchers, Antonio et.al [1] observed that aerodynamic characteristics of the NACA 63-215 and NACA 63-415, with Vortex Generators enhancing the maximum lift coefficient by delaying the boundary layer separation and in some cases reducing the drag coefficient, it avoids the sudden increase in pressure drag. Lin et.al [2] boundary layer separation control by low profile vortex generator, The Primary of the vortex generators (VG) flow control is based on generation of vortical structures, which transfer the high momentum fluid towards the surface.

The flow with higher momentum can resist greater unfavorable pressure gradients resulting in reduced or suppression of flow separation and related reduction of drag or noise, aerodynamics improvement, and heat transfer enhancement, etc. Bender et. al [3] it is described that a methodology for computing the effect of Vortex Generators on airfoil sections using CFD and grid generation method is developed that allows easy repositioning of the VG in chordwise direction on different airfoil sections, and where other VG parameters like inter spacing and the inclination angle can relatively easy be changed and stored in a library of VG units.Hansen et.al [4], Experimentally investigated the aerodynamically shaped VGs, and it is observed that such VGs, when applied on thicker aerofoils, provide a higher lift to drag ratio. The increase in efficiency of the wind turbine blade for extracting more power from the wind and better performance at low speeds. This helps to produce more energy from every functioning wind turbine.

Maximum lift and power generation are obtained by introducing vortex generators over the blades by Viswam [5]. **Experimentally studied by** Manolesos et.al [6] have used the Particle Image Velocimetry measurement to gain insight into (i) interaction between adjacent streamwise vortices, (ii) behavior of a pair of vortices shed from VGs, (iii) effect of VGs on flow near stall, etc. Navin et.al. [7-8] It is found that even a slight decrease in the power production by providing the simple mechanism the power loss can be eliminated and it's also proposed to create a mechanism to open the slot when the wind turbine exposed to high wind velocity and the slot is held closed in the usual running state and Cylinder wake is investigated with taper effects. Balaji et.al [9-10] investigated the flow separation and reattachment over the round disk with aerospike with changing the spike diameter and material properties of dual materials additive component characteristics studied.

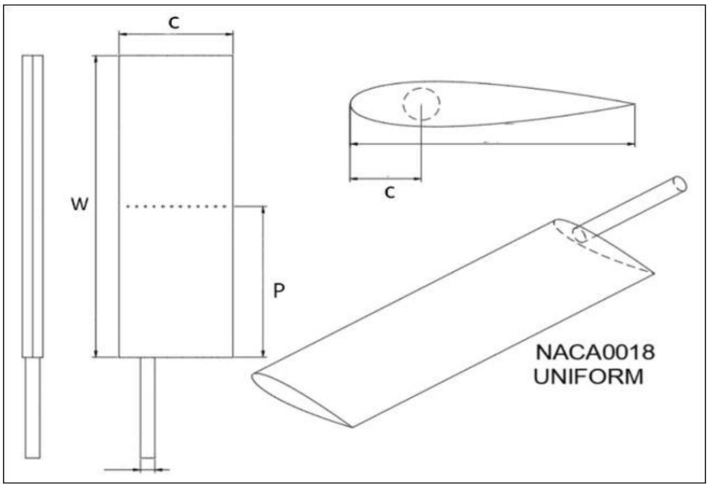


Fig 1 Schematic Diagram of NACA0018 Blade with Pressure at x/s = 0.5

In the present work, the Pressure distribution of the NACA0018 profile blade is experimentally studied with and without Trnaglular Vortex Generator (TVG). The main of the research work is to study the pressure distribution of the NACA0018 airfoil profile blade at two velocities as 12m/s and 20m/s at the various angle of attack 0° to 25° with the step of 5° as shown in Fig.1. Triangular Vortex Generators are arranged over the blade described as distance (d) and pitch (p) as shown in Fig.2.

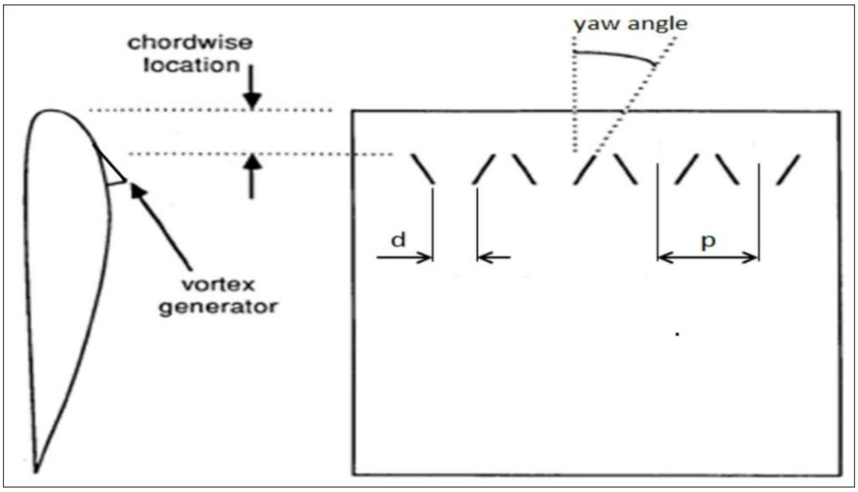


Fig.2 Arrangement of Vortex generator over the Blade

2. Experimental Procedure

To quantify the pressure distribution over the NACA0018 airfoil blade is measured at x/S = 0.5 location where 26 pressure were taken in the subsonic wind tunnel experiments. A different angle of attack of the blade 0° to 25° with the step of 5° and different velocities were measured in the experimental model as shown in the figure. In this section, the wind tunnel complete set is described. The experimental setup mainly consists of a suction-type low-speed subsonic wind tunnel, multitube manometer, pitot-static tube, and NACA0018 airfoil prole blade.

The experimental investigation was conducted in the low-speed suction type subsonic wind tunnel with the test is dimensions as 0.6m wide, 0.6m depth, and 1.2m length as shown in Fig.2. This facility is operated with a maximum speed of 45 m/sin current conditions with turbulence intensity level less than 5%. The multitube manometer was used for static pressure measurement over the NACA0018 at 26 points at x/s=0.5. The pressure co-efficient is the non-dimensional number that is used to describe the relative pressure over the object and it is used for aerodynamics and hydrodynamics applications.

Co-efficient of Pressure $C_p = \frac{P_S - P_\infty}{P_o - p_\infty}$ (i)

Fig. 3 Low-Speed Subsonic Wind tunnel Facility

NACA0018 airfoil blade is fixed in the center of the wind tunnel test section using separate holding fixtures and all the pressure ports are numbered in the flexible rubber tube and connected in the multitube manometer and different AOA of the blade in the wind tunnel test is shown Fig.3. Pitot- static tube is positioned inside of the test section to measure the freestream pressure and total pressure which are calculated using Bernoulli's Equations. The wind tunnel facility is calibrated by varying the speed of the rotor by the various operating condition of RPM. The blockage ratio of the model in the wind tunnel test section is estimated at less than 5% and doesn't cause a significant effect in the study.

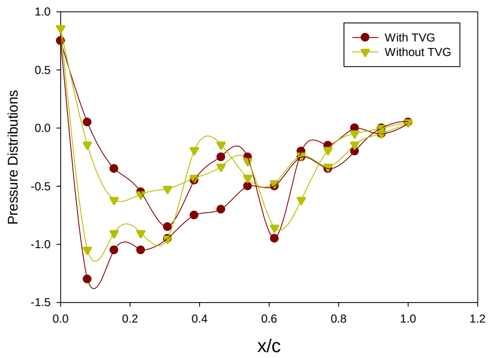
Fig.4 Experimental Model with Pressure tapping and Vortex Generator

The experiments were conducted at two different freestream velocities in the test section are 12 m/s and 20 m/s. the pressure distribution over the blade with and without Traingulr Vortex Generator (TVG) as shown in Fig.4. Studies are much important for designing the wind turbine blade and all other applications.

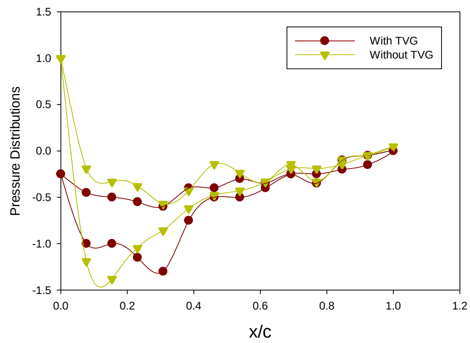
3. Result And Discussion

3.1 Pressure distribution over the NACA0018 with Triangular Vortex Generator at 12 m/s

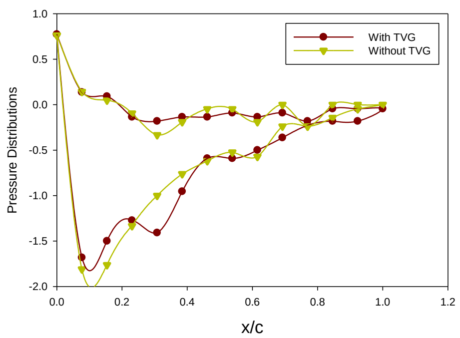
The experimental investigation is conducted in the subsonic wind tunnel facility to investigate the pressure distribution of NACA0012 airfoil profiled blade for different angles of attack with and without Triangular vortex generator (TVG) as shown in fig. 5 (a-f). The static pressure coefficient (Cp) distribution on the airfoil surface at various angles of attack range from 0° to 25° with a 5°increment as shown in Fig 5 (a-f). Because the pressure taps are at x/s =0.5 and on the pressure side of the TGVs, the Cp curve will be slanted downward at the TVGs' installation points. As demonstrated in Fig 5 (a &c), the Cp curves of the airfoil with and without TGVs are identical at 0° and 10° angles of attack, and there are no variations in VG heights. The separation position of the airfoil blade is closer to the installation location of the TGVs as the angle of attack increases.When the angle of attack is greater than 15°, this design helps the TVG's separate the control flow. When a result, as the angle of attack increases, the reverse pressure gradient for the airfoil grows higher. Figure 5 (b,c &d) shows that increasing the angle of attack from 5° to 15° causes negative pressure distributions to rise. As the angle of attack increases, the pressure co-efficient decreases, as seen in fig 5. (e & f).



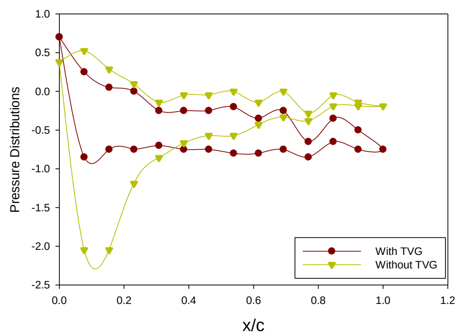
(a) Pressure Distribution at 12 m/s and AOA = 0 Degree



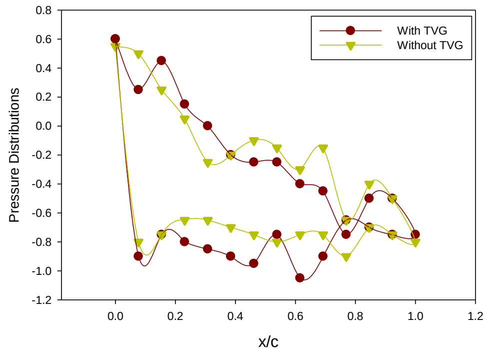
(b) Pressure Distribution at 12 m/s and AOA = 5 Degree



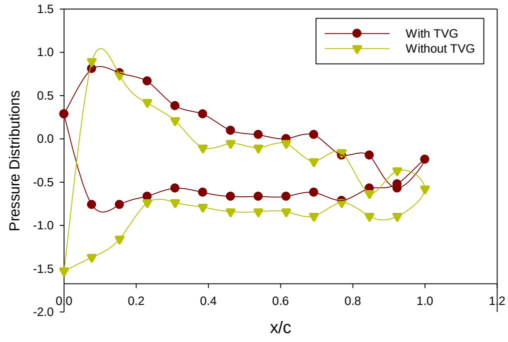
(c) Pressure Distribution at 12 m/s and AOA = 10 Degree



(d) Pressure Distribution at 12 m/s and AOA = 15 Degree



(e) Pressure Distribution at 12 m/s and AOA = 20 Degree

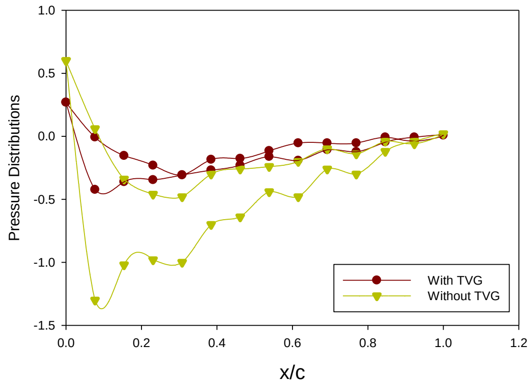


(f) Pressure Distribution at 12 m/s and AOA = 25 Degree

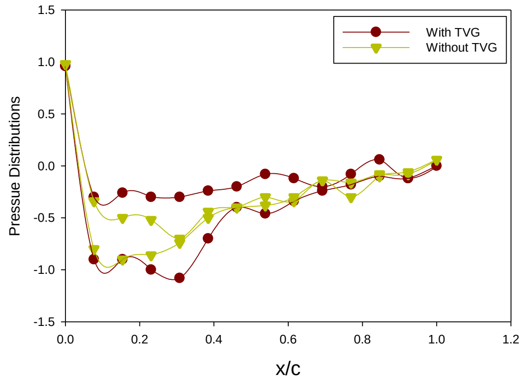
Fig.5 Pressure Distribution over the NACA0012 Airfoil at 12 m/s for different AOA with and without TVG

3.2 Pressure distribution over the NACA0018 with Triangular Vortex Generator at 20 m/s

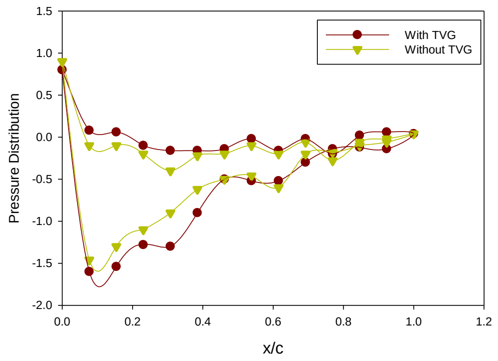
The experimental investigation is conducted in the subsonic wind tunnel facility to investigate the pressure distribution of NACA0012 airfoil profiled blade for different angles of attack with and without Triangular vortex generator as shown in fig. 6 (a-f).The static pressure coefficient (Cp) distribution on the airfoil surface at various angles of attack range from 0° to 25° with a 5° increment and freestream velocity of 20 m/s as shown in Fig 6 (a-f). Because the pressure taps are at x/s =0.5 and on the pressure side of the TGVs, the Cp curve will decrease downward at the TVG's installation points. As demonstrated in Fig 6 (a - f), the Cp curves of the airfoil with and without TGVs are identical at 0° and 25° angles of attack, and there are no variations in VG heights. The separation position of the airfoil blade is closer to the installation location of the TGVs as the angle of attack increases.When the angle of attack is greater than 15°, this design helps the TVG's separate the control flow. When a result, as the angle of attack increases, the reverse pressure gradient for the airfoil grows higher. Figure 6 (b,c & d) shows that increasing the angle of attack from 15° to 25° causes negative pressure distributions to rise. As the angle of attack increases, the pressure co-efficient decreases, as seen in fig 6. (e & f).



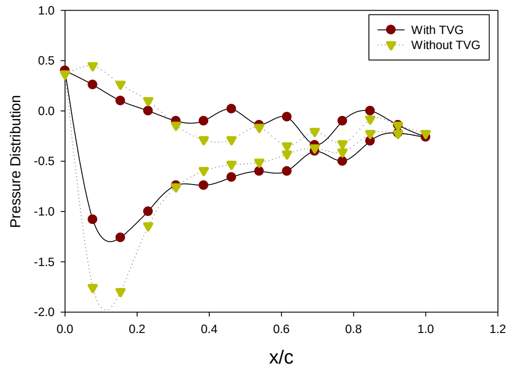
(a) Pressure Distribution at 20 m/s and AOA = 0 Degree



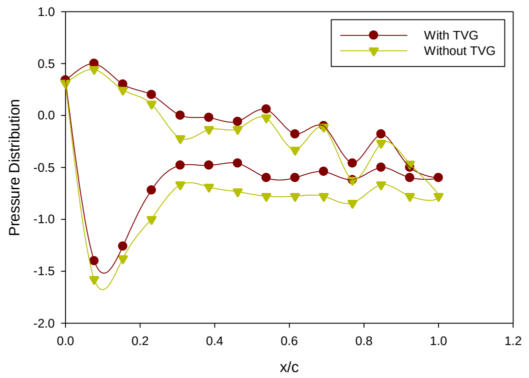
(b) Pressure Distribution at 20 m/s and AOA = 5 Degree



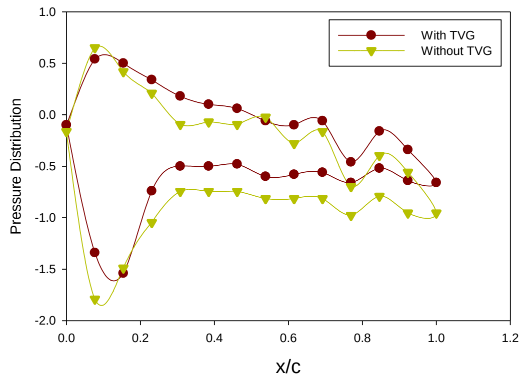
(c) Pressure Distribution at 20 m/s and AOA = 10 Degree



(d) Pressure Distribution at 20 m/s and AOA = 15 Degree



(e) Pressure Distribution at 20 m/s and AOA = 20 Degree



(f) Pressure Distribution at 20 m/s and AOA = 25 Degree

Fig.6 Pressure Distribution over the NACA0012 Airfoil at 20 m/s for different AOA with and without TVG

4. Conclusion

The experimental investigation of the pressure coefficient of the NACA0018 airfoil profile blade with and without the Triangular Vortex Generator (TVG) is tested in the wind tunnel for two different wind velocities. It is observed that the use of vortex generators can considerably improve the aerodynamic characteristics of the NACA 0018 airfoil enhancing the pressure coefficient by delaying the boundary layer separation. In NACA 0018 airfoil at low angle of attacks and speeds, there is no much variation with the help of the Triangular Vortex Generator. But at a high angle of attack, there is a noticeable variation in the pressure coefficient. When compared with the Triangular Vortex Generator the variation in the pressure coefficient vs x/c graph can be observed greater around 15° angle of attack.Hence, It can be concluded that by using Vortex Generator, experimental study of pressure distribution of over the symmetrical airfoil with and without TVG studied and also it enhances the performance characteristics of an airfoil.

References

[1] Antonio Carlos Daud Filho, Hernan Cerón -M, Fernando Catalano. "Experimental study of the influence of vortex generators on aerofoils for wind turbines." Conference Paper. (2013).

[2] Lin, John C. "Review of research on low-profile vortex generators to control boundary-layer separation." Progress in Aerospace Sciences 38, no. 4-5 (2002): 389-420.

[3] E. Bender, P. J. Yagle, and B. H. Anderson. “Prediction of the Effect of Vortex Generators on Airfoil Performance” this article: Niels N Sorensen et al 2014 J. Phys. (2019).

[4] Hansen, Martin Otto Laver, Clara Marika Velte, Stig Øye, R. Hansen, Niels N. Sørensen, J. Madsen, and R. Mikkelsen. "Aerodynamically shaped vortex generators." Wind Energy 19, no. 3 (2016): 563-567.

[5] Viswam, Rahul, and S. Sankar. "Efficiency Improvement of Wind Turbine Generator by Introducing Vortex Generator." (2015).

[6] Manolesos, Marinos, and Spyros G. Voutsinas. "Experimental investigation of the flow past passive vortex generators on an airfoil experiencing three-dimensional separation." Journal of Wind Engineering and Industrial Aerodynamics 142 (2015): 130-148.

[7] Balaji, G., S. Nadaraja Pillai, and C. Senthil Kumar. "``Wind tunnel investigation of downstream wake characteristics on circular cylinder with various taper ratios,"." Journal of Applied Fluid Mechanics 10, no. 3 (2017): 69-77.

[8] Rajendran, S., A. Vasudevan, and G. Balaji. "Aerodynamic braking system analysis of horizontal axis wind turbine using slotted airfoil." Materials Today: Proceedings 33 (2020): 3970-3979.

[9] Balaji, G., C. Senthil Kumar, S. Nadaraja Pillai, and R. Senthil Kumar. "Aerodynamic Performance Enhancement of Blunt Body using Aero Disk." International Journal of Applied Engineering Research 10, no. 33: 2015.

[10] Rangaraj, S., A. Muthuram, G. Balaji, and V. Umakarthika. "Experimental and theoretical investigation of mechanical properties of dual material additive manufactured component." In AIP Conference Proceedings, vol. 2207, no. 1, p. 020004. AIP Publishing LLC, 2020.