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Experimental Study of Pressure Distribution of NACA4412 Airfoil with Square Dimbles

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Abstract

A wind tunnel is an excellent tool used in aerodynamics analysis to investigate the flow over the solid body. The ultimate objectives of the work are to investigate the pressure distributions of the airfoil profile blade under various operating conditions with and without Square dimples. Pressure distributions are investigated on the NACA4412 airfoil blade in the Low-speed suction type subsonic wind tunnel. The 26 pressure port is made at different x/c locations on the upper and lower surface of the blade and the 2D effect is considered in this study. Pressure measurement is done using a multi-tube manometer and pitot-static tube. Dimples are formed throughout the wing which is located at 25% of the Chord from the leading edge of the blade. The main aim of the investigation primarily focuses on the pressure distribution of NACA 4412 airfoil at a low Reynolds number. In this research, the effect of pressure distribution was investigated on the blade concerning two different velocity 10 m/s and 12 m/s, various angles of attack(AOA), and Square dimples further it is found that pressure distribution drastically varies over blade due to dimples and also spanwise flow distribution.

Keywords: NACA4412; Square Dimples; Co-efficient of Pressure; Reynolds number

1. Introduction

The wind is freely available in the environment has a high potential to fulfill the power demand of the entire world if it would be converted into electricity. The wind is one of the most alternative energy sources in the world. The wind turbine is the device that converts the available source of wind energy into mechanical energy which is used to produce electricity. Vertical axis wind is extracted the electrical energy from the wind supply the demand of the electricity in specific applications. The vertical axis wind turbine blade plays a vital role and has a long history from many researchers, Chaisiriroj et.al [1] experimentally investigated the performance optimization of Vertical axis wind turbines under low-speed conditions. Performance collected from the real experiment is compared with the numerical result has a good agreement. Hu et.al [2] have studied the aerodynamics characteristics of vertical axis wind turbine influence the structural parameter because baffle plate placed in front of the cup-rotor of the wind turbine increases the tip speed ratio and rotational velocity.

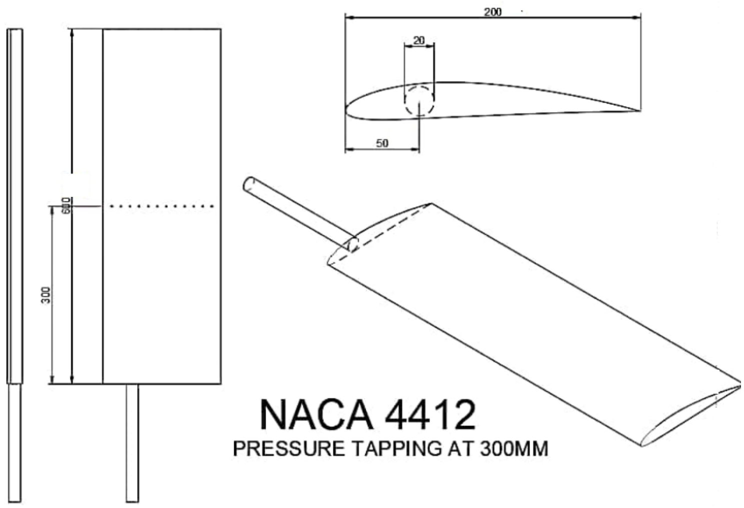


Fig. 1 Schematic Diagram of NACA4412 Blade with Pressure at x/s = 0.5

Navin et.al. [3] The aerodynamics braking system study found that even a little reduction in power production by using a simple method eliminates power loss. When the wind turbine is exposed to high wind velocity and the slot is held closed in the normal running state, it is also proposed to design a mechanism to open the slot. Balaji et.al [4] Experimental investigation of wake characteristics of a circular cylinder with different taper ratios is performed in the low-speed wind tunnel. Loganathan et.al [5] experimentally and numerically investigated the performance of the high aspect ratio of VAWT. Aerodynamics performance of VAWT Power coefficient and turning force to reverse ratio were calculated and compared for better capacity of harnessing the wind energy. Purwona et.al [6] numerical investigation of VAWT using wind turbine blade NACA4412 to power generation by varying the wind speed variations. It was revealed that increase the wind speed increases power generation. Rahman et.al [7] experimental and numerical investigation of aerodynamics performance VAWT models with different blade designs. It is observed that New Models CC and QM with 2 and 3 cutting significant self-starting characteristics in very low wind speeds. Balaji et al. [8-9] evaluated flow separation and reattachment across a round disc with an aerospike by varying the spike length and material properties of dual materials additive component characteristics.

In the experimental work, the Pressure distribution of the NACA4412 profile blade is experimentally studied in the low-speed suction types wind tunnel with and without square dimples. The main aim of the research work is to study the pressure distribution of NACA4412 airfoil profile blade at two different velocities as 10 m/s and 25 m/s at the various angle of attack 0° to 25° *and* 0° to -25°with the step of 5° *as shown in Fig.1.* Square Dimples are arranged over the blade spanwise as shown in fig.2.

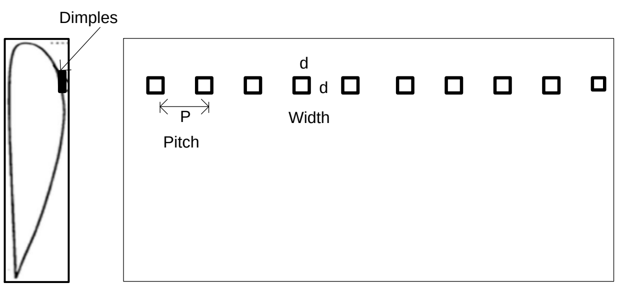


Fig. 2 Arrangement of Square Dimples on the blade

2. Experimental Set-Up

Pressure co-efficient is estimated over the NACA412 airfoil Blade which is important for aerodynamics performance improvement of Vertical Axis Wind Turbine (VAWT) carried out in the wind tunnel. Its performance is studied over the blade with and without square dimples effects. The NACA4412 airfoil profile blade is uniform throughout the span is fabricated using teak wood. The pressure distribution over the NACA4412 airfoil profile blade is measured at x/S = 0.5 and 26 pressure tap provided around the surface with equal distance. The leading edge and trailing edge of the blade have two pressure tap and the upper and lower surface has each 12 pressure tap as shown in Fig. 3

(a)

(b)

Fig.3 Experimental Model with Pressure tapping (a) and Square Dimples (b)

Pressure is measured at a different angle of attack of the blade 0° to 25° and 0° to -25°with the step of 5° and different velocity are 10 m/s and 25 m/s. The pressure measurement over the blade is carried at wind tunnel for specified operating conditions with and without square dimples. The dimples are arranged in uniform order over the surface of the blade at x/c = 0.25 and dimples geometry has equal width (b) on both sides and thickness (*t*).

Fig.4 Low-Speed Subsonic Wind tunnel Facility

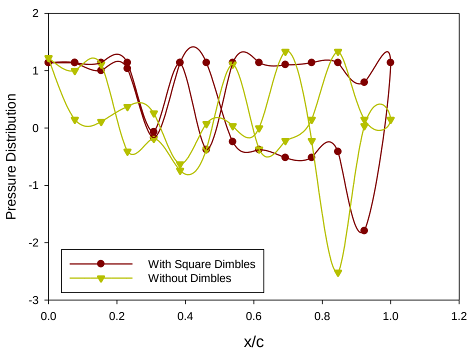
The experimental investigation was performed in the low-speed suction type subsonic wind tunnel with a test section size of 600mm wide, 600mm depth, and 1200mm length as shown in fig. 5. The wind tunnel can be operated at the maximum speed of 45 m/s in the present condition with a turbulence intensity range of less than 4%. The multitube manometer were used for pressure measurement over the NACA4412 blade at 26 point at x/s = 0.5 and x/c = 0.25. The pressure coefficient is the non-dimensional number that is used to describe the relative pressure over the object and is used for various aerodynamic applications. The pressure coefficient is given as

$$Cp = \frac{P_S - P_\infty}{P_O - P_\infty}$$

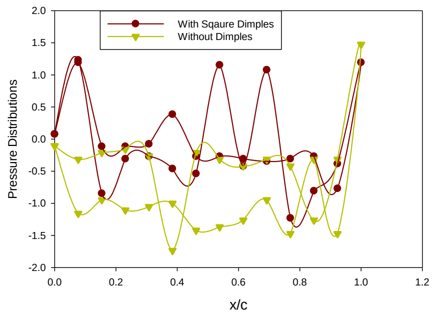
3. Results And Discussions

Pressure distribution over the NACA4412 with and without Square Dimples at 10 m/s

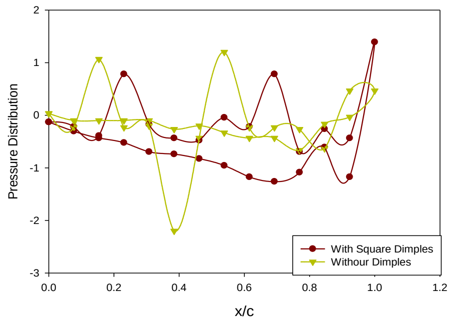
The experimental analysis of NACA4412 airfoil profiled blade with and without Square dimples is carried out in the subsonic wind tunnel to investigate the pressure distribution for freestream velocity of 10 m/s. The distribution of pressure coefficient (Cp) on the airfoil surface at different angle attacks range from 0° to 25° *and*0° to -25° with a 5° increment beside with and without dimples effect is considered as shown in Fig 5 (a-k). The pressure distribution over the airfoil is not uniform throughout the blade with and dimples. In fig.5(a) the pressure coefficient(Cp) is observed min of -2.5 at x/c =0.8 for without dimples. In Fig 5 (b-f), it is observed that the cp values vary drastically varies throughout the profile and reach the maximum of 1.5 at x/c-0.9 and a minimum of -2.4 at 0.85. further, it is observed that the pressure distribution varies maximum at a lower pressure surface than the high-pressure surface. In Fig 5 (g-k) the pressure co-efficient varies abruptly in throughout the airfoil and attain the maximum of 1.2 at x/c=0.2 for all the angle of attack and minimum of –2 at x/c =0.4 and further, it is observed that pressure distribution varies in the lower surface of the blade during negative angle of attack of the blade.



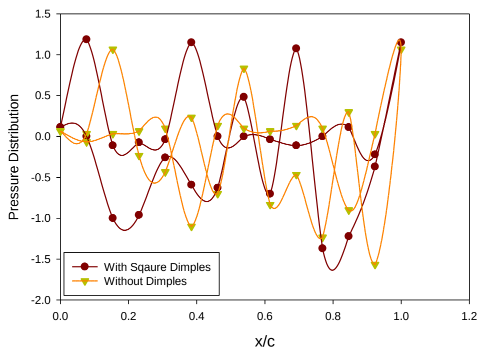
(a) Pressure distribution at 10m/s and AOA = 0 Deg



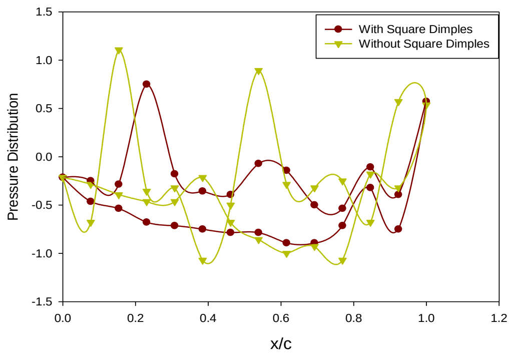
(b) Pressure distribution at 10m/s and AOA = 5 Deg



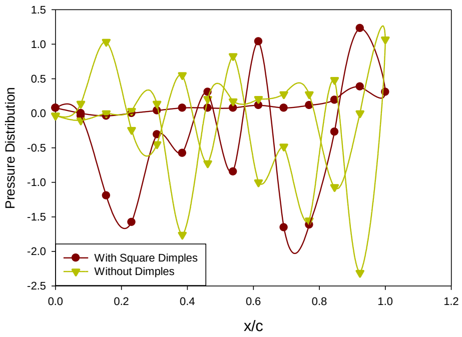
(g) Pressure distribution at 10m/s and AOA = -5 Deg



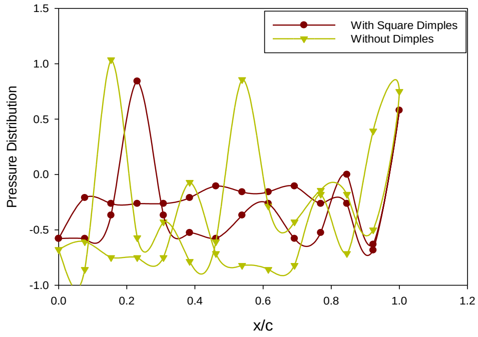
(c) Pressure distribution at 10m/s and AOA = 10 Deg



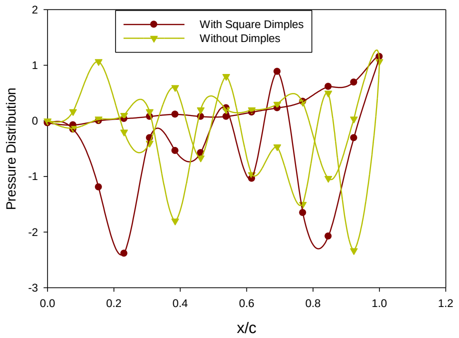
(h) Pressure distribution at 10m/s and AOA = -10 Deg



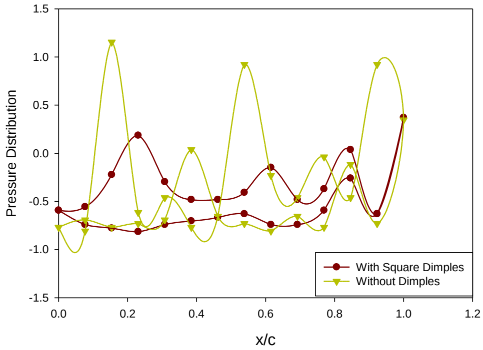
(d) Pressure distribution at 10m/s and AOA = 15 Deg



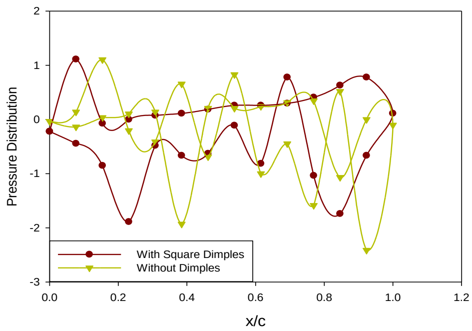
(i) Pressure distribution at 10m/s and AOA = -15 Deg



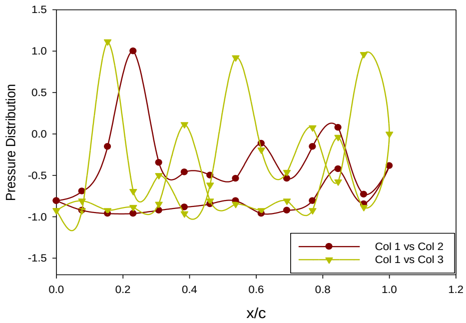
(e) Pressure distribution at 10m/s and AOA = 20 Deg



(j) Pressure distribution at 10m/s and AOA = -20 Deg



(f) Pressure distribution at 10m/s and AOA = 25 Deg

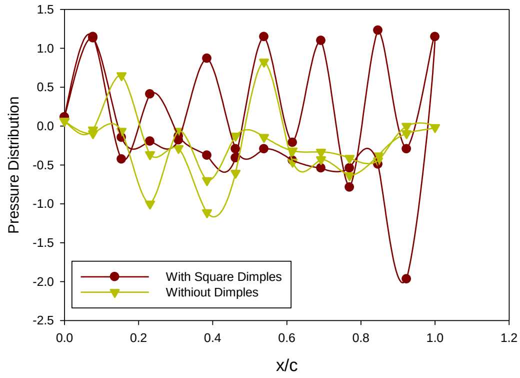


(k) Pressure distribution at 10m/s and AOA = -25 Deg

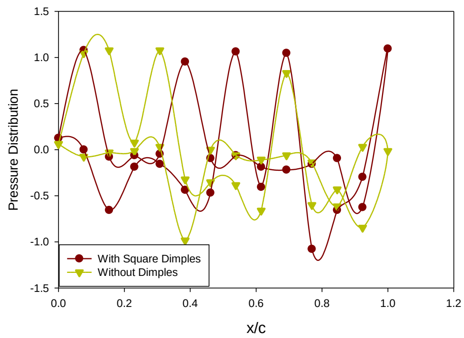
Fig. 5 Pressure Distribution over the NACA4412 Airfoil at 10 m/s for different AOA with and without dimples

Pressure distribution over the NACA4412 with and without Square Dimples at 25 m/s

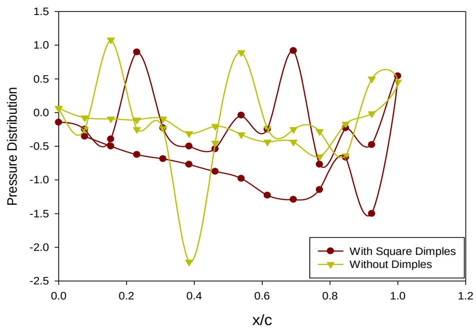
The experimental analysis of NACA4412 airfoil profiled blade with and without Square dimples is carried out in the subsonic wind tunnel to investigate the pressure distribution for freestream velocity of 25 m/s. The distribution of pressure coefficient (Cp) on the airfoil surface at different angle attack range from 0° to 25° *and* 0° to -25° with a 5° increment beside with and without dimples effect is considered as shown in Fig 6 (a-k). The pressure distribution over the airfoil is not uniform throughout the blade with and dimples. In fig.6(a) the pressure coefficient(Cp) is observed min of -2 at x/c =0.9 for without dimples. In Fig 6 (b-f), it is observed that the cp values vary drastically varies throughout the profile and reach the maximum of 1 at different x/c locations and a minimum of -2.2 at 0.9. further, it is observed that the pressure distribution varies maximum at a lower pressure surface than the high-pressure surface. In Fig 6 (g-k) the pressure co-efficient varies abruptly in throughout the airfoil and attain the maximum of 1.1 at x/c=0.1 & 0.5 for all the angle of attack and minimum of –2 at x/c =0.4 and further, it is observed that pressure distribution varies in the lower surface of the blade during negative angle of attack of the blade.



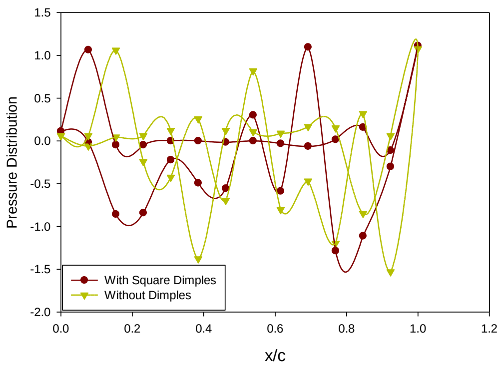
(a) Pressure distribution at 12m/s and AOA = 0 Deg



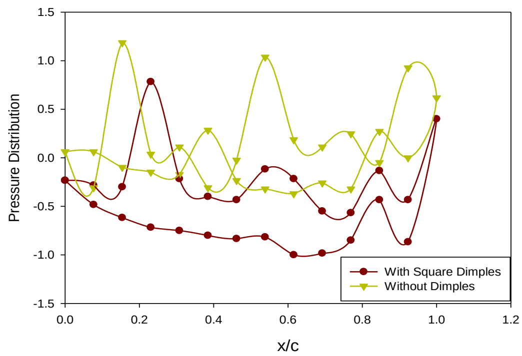
(b) Pressure distribution at 12m/s and AOA = 5 Deg



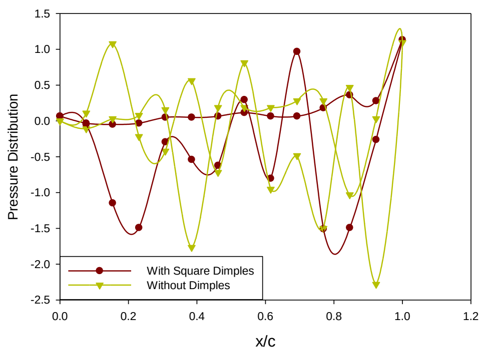
(g) Pressure distribution at 12m/s and AOA = -5 Deg



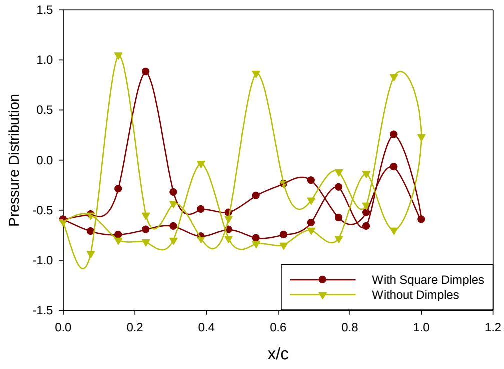
(c) Pressure distribution at 12m/s and AOA = 10 Deg



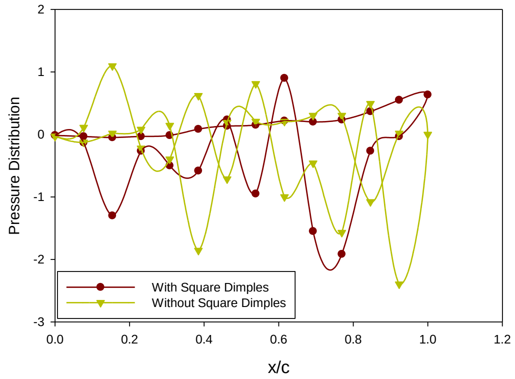
(h) Pressure distribution at 12m/s and AOA = -10 Deg



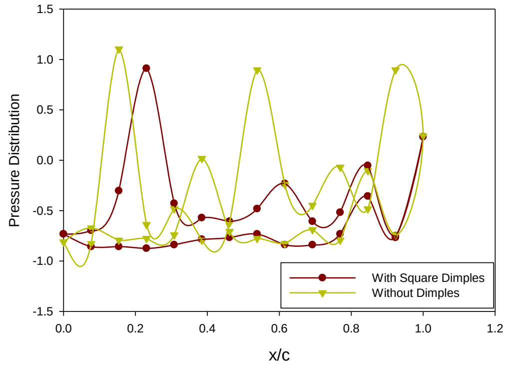
(d) Pressure distribution at 12m/s and AOA = 15 Deg



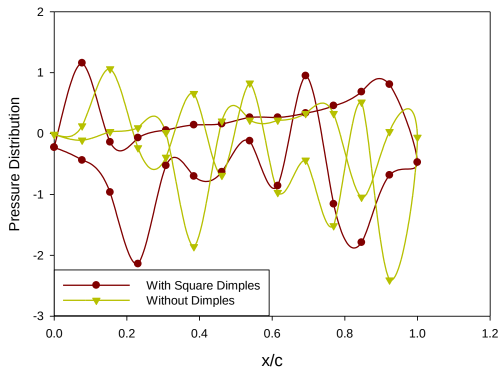
(i) Pressure distribution at 12m/s and AOA = -15 Deg



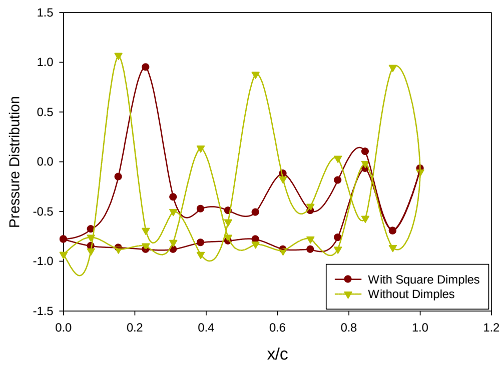
(e) Pressure distribution at 12m/s and AOA = 20 Deg



(j) Pressure distribution at 12m/s and AOA = -20 Deg



(f) Pressure distribution at 12m/s and AOA = 25 Deg



(k) Pressure distribution at 12m/s and AOA = -25 Deg

Fig. 6 Pressure Distribution over the NACA4412 Airfoil at 25 m/s for different AOA with and without dimples

4. Conclusion

The experimental study of pressure co-efficient of NACA4412 airfoil profile blade with and without square dimples is investigated in the subsonic wind tunnel for two different freestream velocities 10m/s and 25 m/s and different angle of attack range from 0° to 25° *and*0° to -25° with a 5° increment. It is observed that considerably improves the aerodynamics performance of NACA4412 airfoil using dimples over the surface of the blade. It is observed that increasing the freestream velocity leads to drastic variation in pressure coefficient and also observed that pressure measurement in the positive angle of attack causes huge variation of pressure distribution in the upper surface of the blade. Similarly, the negative angle of attack cause huge pressure distribution in the lower surface of the blade. In this research, it is concluded that the variation of pressure distribution is throughly studied for two different velocity and different angle of attack and also dimples improve the aerodynamics performance of an airfoil.

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