IJE TRANSACTIONS B: Applications Vol. 31, No. 5, (May 2018) 820-825

International Journal of Engineering

Journal Homepage: www.ije.ir

Experimental Study on Flow Characteristics Around Twin Wind Blades

R. Kumar B.*, M. K. Saranprabhu

School of Mechanical Engineering, SASTRA Deemed to be University, Thanjavur, Tamilnadu, India

PAPER INFO

Paper history:
Received 07 May 2017
Received in revised form 30 January 2018
Accepted 08 March 2018

Keywords:
Rotor
Flow Characterization
Aerodynamic Performance
CFD Investigation

ABSTRACT

In the current study, twin wind blades are designed, fabricated and the effect of various gap ratio (g*) at various angle of attacks (α) on a next to each other twin wind blades are examined in an open-channel wind tunnel. Aerodynamic forces and moments are determined by using three-constraint force balancer. For gap ratio of zero, the aerodynamic attributes are like those of a solitary wind blade edge. As g* increases, these two wind blades actuate the vertical wake to stage vortex shedding modes. With further increment in g*, the wake stream pattern was like those behind a solitary wind blade. For a solitary wind blade, the maximum lift is found to be at α = 30. The pitching moment increases with α. The impact of upper aerofoil blade on the lower one diminished as g* increases.

doi*: 10.5829/ije.2018.31.05b.18*

NOMENCLATURE

g*	Gap ratio	C_P	Specific heat capacity
α	Angle of attack (AoA)	C_l	Coefficient of lift
c	Chord length	C_d	Co-efficient of drag
s	Blade Span	k	Thermal conductivity
A.R	Aspect Ratio	μ	Dynamic viscosity
V	Velocity	ρ	Density

1. INTRODUCTION[1]

In this work, flow study is carried out on twin wind blades in a low subsonic wind tunnel. The flow velocity is restricted to maximum 58 m/s. This study is a novel approach to evaluate the effects of various parameters on the design and performance of twin wind turbine blades. The blades of a rotor were headed to turn when fluid flows through the rotor. A bluff body creates a pressure difference around the rotor. The internal stream tube in gas turbines, blowers, and air compressors was used to create the pressure difference. In day to day applications, fans, wind turbines, and water turbines utilize the thrust incited from the pressure distribution. In these applications, the gap ratio between the next to each other significantly affects the machine performance. Gap ratio is defined as the ratio between the maximum thickness to the chord length of airfoil profile. The single blade demonstrated a critical association with the boundary layer on the suction side [1-3]. These aerodynamic phenomena include stream diversion, reattachment, and vortex arrangements. Also, surface flow behavior significantly affects wake vortex shedding coming about because of the shear unsteadiness wave in the boundary layer [4]. Studies on surface stream and streamlined execution have demonstrated a laminar boundary layer shaped close to the stagnation point on a wind blade leading edge. As the stream moves downward, the stream isolates at the minimum pressure point. Behind the detachment point, the shear layer enters into a turbulent stream.

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*Corresponding Author Email: ravikumar@mech.sastra.edu (R. Kumar B.)

Please cite this article as: R. Kumar B., M. K. Saranprabhu, Experimental Study on Flow Characteristics Around Twin Wind Blades, International Journal of Engineering (IJE), IJE TRANSACTIONS B: Applications Vol. 31, No. 5, (May 2018) 820-825

Consequently, the isolated stream re-attaches to the wind-blade edge surface. Between the reattached point and wind blade trailing edge, the surface stream framed a turbulent boundary layer.

In studies on multi-blade designs, numerous analysts have numerically presented stream structures and streamlined execution. Dong and Lu [5] utilized three fish-like profiles to numerically study the impact of crevice proportion on streamlined execution. They found that the gap ratios affected the arrangement of in-stage and hostile to stage vortex regions. At low crevice proportions, the upper and lower vortex arrangements were close and after that pressed to frame an anti-phase vortex street. Conversely, the high crevice proportion brought on an in-phase vortex street. Moreover, the drag coefficient diminished with gap ratio. Hansen and Madsen [6] utilized the blade element momentum method to decide the blade profiles and process streamlined coefficients. Sieverding et al. [6] used a supersonic wind tunnel to concentrate the surface-pressure dispersion on one next to the other blades. They found the non-uniform pressure dissemination close to the blade trailing edge at subsonic rates. Moreover, the peak negative pressure was found to exist at the trailing edge. On the suction side, the vortex framed close to the trailing edge was impacted by the nearby blade. Uzol et al. [7] concentrated a transient stream field by utilizing particle picture velocimetry and a water tunnel. They found that the free-stream velocity changed by around 13% because of the transverse speed behind the blades. The gap ratio between the blades significantly affects blade efficiency. A three-force balancer was utilized to quantify the aerodynamic loadings. Saranprabhu et al. [8] studied the airflow interactions and aerodynamic heating on a supersonic aircraft and they found that airfoil shapes have significant effects on the aerodynamic efficiency of the wing as well as on the aircraft. Abbishek et.al [9] carried out a comprehensive structural and flow analyses using Ansys Fluent and structural workbenches and presented a detailed airfoil design and fabrication processes.

Ashory et al. [10] carried out a computational fluid dynamic study on turbine blades and have shown that blade angles and gap ratio have a significant effect on the power production capacity of a turbine.

Rajabi et al. [11] represented a comprehensive computational fluid dynamic design and analysis over an axial fan and have shown that the blade angles and gap ratio have significant effects on the pressure distribution around fans and also affects on the efficiency of the device. Numerous relevant studies on flow analysis using computational fluid dynamics approach and experimental methods are reported in the literature [12-15].

2.METHODOLOGY

NACA 0012 airfoil has been chosen for blade design. We selected four different gap ratios between the two wind blades and three different angles of attack for carrying out the wind tunnel experiment. Blades were designed as per the given specifications. Twin blade models for doing the experimental analysis in the open channel wind tunnel were fabricated and the analysis had been carried out. Finally, results are interpreted.

3. EXPERIMENTAL SETUP

Figure 1 shows the wind tunnel and experimental setup utilized as a part of this study.

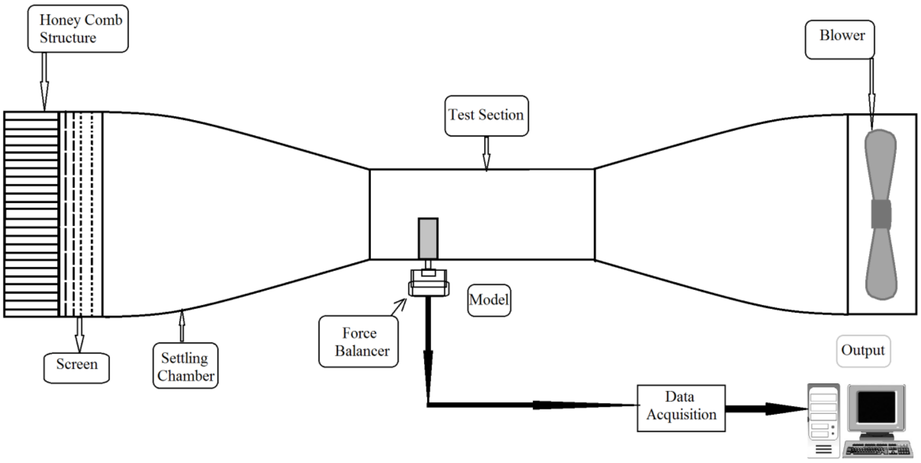

Figure 1. Subsonic wind tunnel

This is a low-speed subsonic wind tunnel of the maximum flow velocity of 60 m/s. Its test section size is 300×300×1500 mm (Figure 2). This open-circle wind tunnel was operated steadily in the flow speed in the range of 1.64 m/s –28.28 m/s. This wind tunnel included seven sections: noise separating area, steady segment (settling chamber), nozzle, test segment, vibration absorber, development segment (diffuser), and blower fan. The noise shifting segment included two sections: (1) an aluminum-made honeycomb for disposing of transverse stream fluctuations, and (2) a three-layer metal mesh for separating the longitudinal stream noise. A NACA 00122 [12] aerofoil was utilized to carry out flow analysis. The aerofoil blades were fabricated using eucalyptus tree wood. The chord length (C) and wind blade span (S) were 6 cm and 18 cm, respectively. Along these lines, the aspect ratio was 3. The wind blade surface was cleaned for reducing the surface roughness.

The air properties are taken as follows,
Velocity: 2 m/s
Density: 1.225 Kg/m^3
C_P: 1006.43
Thermal Conductivity : 0.0242 $w/m-K$
Dynamic Viscosity :1.7894$e-05$ $Kg/m-s$

3. RESULTS AND DISCUSSION

The coefficient of lift C_l and coefficient of drag C_d are the most critical parameters that decide the performance of a rotor or any vehicle moving through the fluids. At whatever point fluid streams across the gas turbine, the crevice proportion between the blades and the angle of attack plays an important role.

Figure 3 shows the variation of the coefficient of lift with gap ratio at zero degree angles of attack. At an angle of attack 0 degrees and the gap ratio of 0, these twin blades can be seen as a solitary body blade and the flow around a twin wind blade is identical to that of flow around a solitary wind blade.

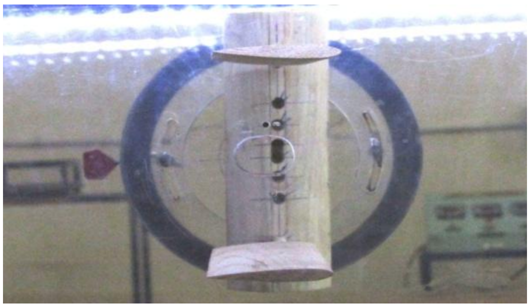

Figure 2. Subsonic wind tunnel test section

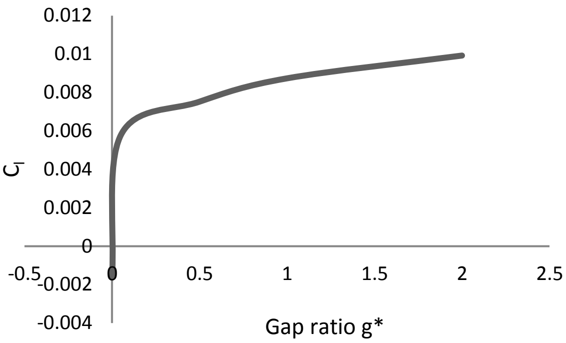

Figure 3. C_l variation with gap ratio at 0º angle of attack

The lift appears to get increase at higher gap ratio between the blades. It shows complete stalling of the flow at and above a gap ratio of 2.5 due to a larger area of the separated flow on the top surface of the airfoil blades.

Figure 4 shows the variation of the coefficient of lift with gap ratio at 15-degree angles of attack. At an angle of attack 15 degrees and that of increment in gap ratio, the C_l tends to increase with angles of attack up to 0.5 gap ratio and afterward, the Cl starts decreasing due stalling of the airfoils. The C_l attains its maximum value of 0.12 at a gap ratio of 0.5. The C_l starts decreasing because of the development of vortices at high gap ratio.

Figure 5 shows the variation of the coefficient of lift with gap ratio at 30-degree angles of attack. At an angle of attack of 30° and that of increment in gap ratio, the C_l increases up to a gap ratio of and afterward, the C_l shows decrement due to flow separation on the top surface of blades. The C_l achieves the maximum value of 0.13 at a gap ratio of 1. Based on the above observations it was identified that gap ratio of 1 is the optimum gap ratio which gives maximum lift and hence better aerodynamic efficiency.

Figure 6 shows the variation of the coefficient of drag with gap ratio at zero degree angles of attack.

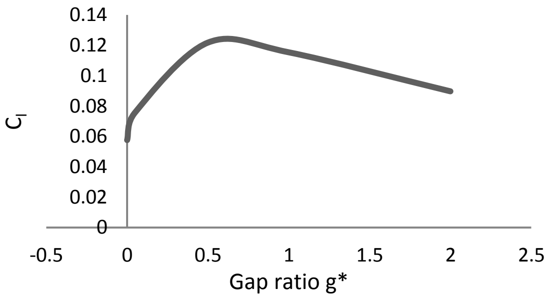

Figure 4. C_l variation with gap ratio at a 15º angle of attack

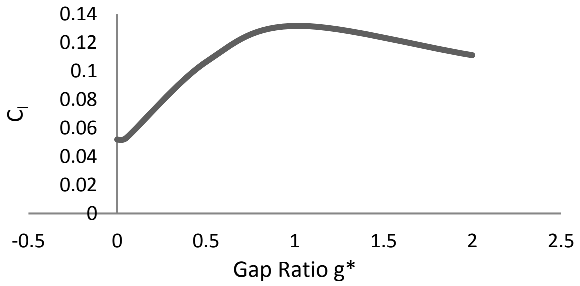

Figure 5. C_l variation with gap ratio at a 30º angle of attack

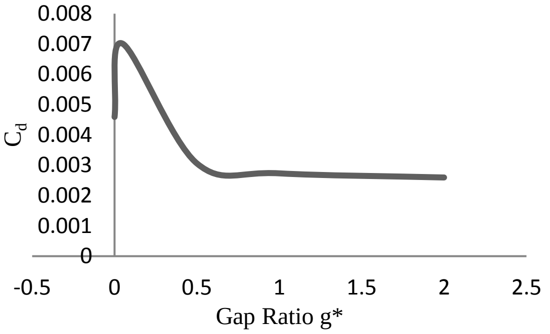

Figure 6. C_d variation with gap ratio at 0º angle of attack

At the point when stream attaches over twin-sided blades the C_d appears to show increasing trend and reaches its maximum value of 0.007 at 0 gap ratio, which is because of the development of vortices at the trailing edge of the blade surfaces. The vortices arrangements are the main reason for the production of the drag and it shows that the drag reduces as the crevice proportion increments.

Figure 7 shows the variation of the coefficient of drag with gap ratio at 15-degree angles of attack. The C_d achieves its maximum value of 0.08 near approximately a gap ratio of 0.7 and it decreases as the gap ratio increases.

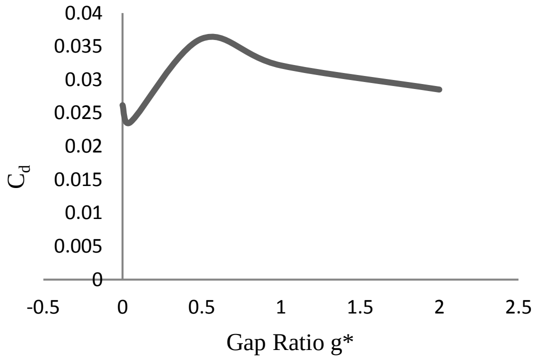

Figure 7. C_d variation with gap ratio at a 15º angle of attack

It is found that the C_d value was 0.025 at 0 gap ratio which is found to be the least value.

Figure 8 shows the variation of the coefficient of drag with gap ratio at 30-degree angles of attack. The C_d at an angle of attack 30 degree and at different gap ratios seems to increase first and then decreases further. It is found that the C_d has the least value at 0 gap ratio.

The experimental results for the variation of coefficient of lift at different angles of attack and gap ratios are shown in Table 1. It is clearly visible that the coefficient of lift C_l increases as the angle of attack and the gap ratio increases. The intake air velocity in the wind tunnel was maintained at 2 m/s.

The maximum lift seemed to be occurring at an a 30º angle of attack and at gap ratio =1.

Table 2 shows the experimental results for the variation of coefficient of drag at different angles of attack and gap ratios.

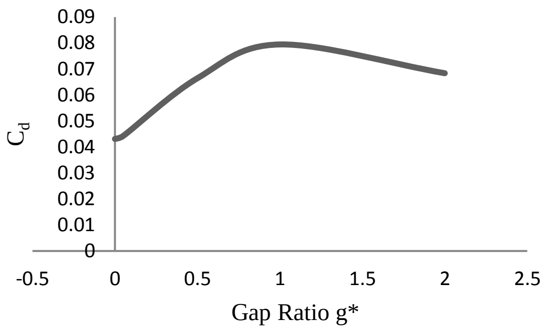

Figure 8. C_d variation with gap ratio at a 30º angle of attack

TABLE 1. C_l at different AoA & gap ratio

Gap Ratio	**C_l**		
	α= 0º	**α= 15º**	**α= 30º**
0	-0.0025678	0.04835	0.04274
0.05	0.00649784	0.08309	0.06021
0.5	0.00838782	0.13043	0.1151
1	0.00946381	0.12263	0.13908
2	0.01044883	0.09494	0.1165

TABLE 2. C_d at different AoA & gap ratio

Gap Ratio	**C_d**		
	α= 0º	**α= 15º**	**α= 30º**
0	0.00367	0.01694	0.03388
0.05	0.00773	0.03087	0.05149
0.5	0.00392	0.04479	0.07511
1	0.00346	0.03938	0.08672
2	0.00312	0.03376	0.07363

From Table 2, it is clearly visible that coefficient of drag has its least value at a gap ratio of 0 at various angles of attack.

4. CONCLUSION

The present work reported an experimental investigation on flow characteristics on twin wind blades. The flow attributes of one blade next to the other twin wind blade demonstrate the comparative flow properties of single wind blade. As gap ratio g* increases, the association amongst upper and lower wind blades instigates vertical wake, crevice stream and hostile to stage vortex shedding modes. Moreover, the wake stream behind one next to the other twin wind blade is like those behind single twist blade as g* increments to the particular value. For one next to the other twin wind blades, the streamline pattern of the flow on the upper wind blade was like those on single wind blade. The lift, drag on the lower wind blade diminished altogether because of the pressure distribution of upper wind blade. The impact of upper twist blade on the lower wind blade perished as gap ratio g* increases. For crevice proportion of zero, the stream qualities were like those of a solitary wind blade. As gap ratio increases, these two wind blades actuate wake structures, i.e., vortices behind the blades. The maximum lift coefficient occurs at α= 30^{o} and the least value of drag coefficient is found to be 0.025.

The current experimental study could be used to design more streamlines airfoil shaped wind blades for effective utilization of energy. Future study would focus on the experimental and theoretical analysis of wind turbine under variable air loading and with side wind effects.

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چکیده

در مطالعه حاضر، تیغه های دوقلو بادی طراحی و ساخته شده اند و اثر نسبت فاصله گشتاور (g^*) در زاویه های مختلف حملات (α) در کنار یکدیگر تیغه های دوقلوی باد در یک تونل باد باز کانونی بررسی می شود. نیروها و ممانت آیرودینامیکی با استفاده از سه برابر کننده تعادل نیروی محدود تعیین می شود. برای نسبت شکاف صفر، مشخصه های آیرودینامیک مانند لبه ی تیغه ی انفرادی است. همانطور که g^* افزایش می یابد، این دو تیغه باله به سمت عمودی حرکت می کنند تا حالت های انفجار گردابه را کنترل کنند. با افزایش بیشتر در g^*، الگوی جریان پی در پی همانند کسانی بود که پشت یک تیغه ی هوای انفرادی بودند. برای یک تیغه ی هوای انفرادی، حداکثر لیفت در $\alpha = 30$ دیده می شود. لحظه ی پچینگ با α افزایش می یابد. تاثیر تیپ بالایی هواپیما بر روی پایین تر به عنوان g^* افزایش می یابد.

***doi**: 10.5829/ije.2018.31.05b.18*