DOI 10.15520/sslej.v5i07.2695 *http://sslej.in/index.php/sslej* Research Article

ISSN: 2456-2408 Social Science learning Education Journal

Dynamic Equations of Wind Turbine Blade

Xu run

Yantai University, Wen Jing College, Mechanical Electricity Department, Yantai 264005

Metallurgical Engineering Department, Gyeongsang National University, Gyeongnam Chinju 52828, Korea

Abstract: *- the wind generator is gradually increased recently according to new status, so the dynamic and kinematic equation is needed to use to them as well. This paper will express the all kinds of these respect to adopt curve to explain the relation of them. It is observed that the speed is 30r/m and 16m/s under the wind speed of 15.8 m/s at 0° that becomes cosine distribution. The decreasing α and β is the way from 0 to 83° to increase them. When α increases from 83° to 180° the power and force increase too. With the increasing time to 1.4s the angle of attack increases steeply to 145° then the line becomes sluggish until more than 4s. It expresses that the first several time is significant to turbine blades' turning rotation. There is a certain power changes in power with 200KW and force with 10KN with β changing from 0 to 20°. The acceleration at 15r/m is tow times larger than that at 7.5r/m. The power consumption and efficiency will be low. Only rotating speed reaching a certain value can the maximum effect be. The tip speed ratio Cp will be smaller below 10 when the v increases into 4m/s an then it shows a slow decreasing regardless of changing their radius.*

Keywords: *- wind generator; dynamics; kinematics; equation; turbine blades; α and β*

1 Introduction

Wind turbines are the latest to enter the market. To build wind turbines for environmental protection is an inevitable trend in the world. Although it is not as powerful or as efficient as other conventional thermal and hydro-electric generators, it is replacing them with Numbers and greenery. In places like Weihai in Shandong province, huge wind turbines are set up in groups on hillsides to bring freshness and wind energy utilization, and even appear in the game world of some large cities. These huge structures have an unexpected power generation effect by slowly rotating the same huge impeller. Therefore, this paper discusses its energy utilization status from its efficiency and quantity to evaluate its physical significance. Here processing is the most important link, and then transportation and erection costs, but its use is not low. [1,2]

In the 15 to 20 years since a wind turbine could be used, the calculations are low. These times it will spin 2.16 million times and calculate energy up to 100 million joules and 10 million watts of power. That's 50 times the size of a small city in the 70s and 80s.With 500 such generators, the total power would be 5 gigawatts and 50 gigajoules, about one-sixth of the 22,000 megawatts of installed capacity of the three gorges reservoir. And strong winds can quickly make up for their use, filling the countryside with the energy from wind turbines. At present, the number of wind turbines used by European and American countries is increasing year by year. China also needs to catch up and keep in line with the international developed level.

So 2,000 such turbines would be comparable to the Three Gorges Reservoir, China's biggest generator.

This means that an average medium-sized city can have nearly a quarter of the power generated by the Three Gorges Reservoir. Because these generators run 24 hours a day, there is a constant supply and quantity of electricity to these big cities without the interruption of power supply. Perfect storage function will really bring energy effect. Storing energy from strong winds for later use is an urgent problem for wind turbines. If you put it on a windy mountain, it will continue to generate electricity. At this time to set the number of more engines, in order to prepare for sporadic scattered wind brings the problem of insufficient wind power. Fengshui hybrid power generation needs to solve the problem of energy shortage and continuity. Seawater utilization should also be included in the plan such as the use of tide and high tide, etc.

In the case of typhoons and tsunamis, their strength, especially fatigue strength, needs to be guaranteed. Some typhoons can even pull up some trees. Therefore, the bending strength of the ground and straight head of the generator should be guaranteed to avoid economic losses. If the broken parts fly to buildings or roadside facilities, they can cause a second damaging effect, causing damage to public facilities and causing problems for the country such as repair.

2 Model establishment

Table 1 data of Nordex wind turbine.

N60	N60	S70	S77
P MW	1.3	1.5	1.5
V m/s	60	70	77
L m	29	34	37.5
Vrate m/s	15	13	13
mrate t	5	5.6	9.9
N r/m	12.8	19	17
Vin m/s	3	3	3
Vout m/s	25	25	25/20

The parameters of German Nordex N60, S70 and S77 models are shown in table 1. The wind generator has the overall layout of the wind turbine with blade length l and it rotates at the speed of ω. From Figure 1 the wind speed v and force F and the wind speed and direction. The pitch angle β which is angle of blade chord and rotational plain obtains x-y direction of velocity and force of component, is the inlet air speed v in generator blade vx、vy and force Fx、Fy. Angle of attack α which convergence speed being the angle of inlet air and rotational relative synthesis speed and blade chord obtains x'-y' direction of velocity and force of component is the main speed in turbine blade slope area. Flow angle ϕ which is the angle of convergence speed and rotational relative synthesis speed.

Since the uniform wind speed acts on the blade, then

$$dv_L = d(\cos\phi) \quad \text{-------}（1）$$

Here. According to the law of conservation of energy

$$dQ_\tau = 3\times\frac{1}{2}Id\omega^2 = \frac{1}{2}mdv^2 \quad \text{-------}（2）$$

Here I is the inertia product, and m is the mass of the blade of the wind wheel.

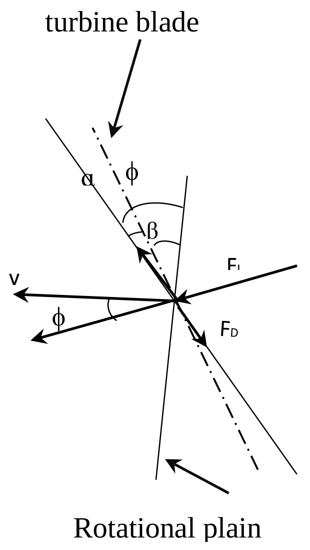


Figure 1 schematic of wind speed and force resolution

Ie. $d(3I\omega^2) = dmv^2$ -----（63）

Here I is the inertial product, omega is the angular velocity, m is the blade mass, and v is the blade velocity.

& $dP = \frac{Q}{dt} = \frac{mv^2}{d(2t)}$ -----（4）

$v = v\cos(\beta+\alpha)$

P is blade power, Q is kinetic energy, and it is time. Because

$d(\frac{F}{m}t) = dv$

Therefore, the calculation formula of acceleration is $da = dF/m = dv/t$ -----（5）

And the force calculation formula is $dF = d(\frac{vm}{t})$ ------（6）

And $v = \pi dn$ & $v_0 = \pi dn_0$ take place of above formula, it has

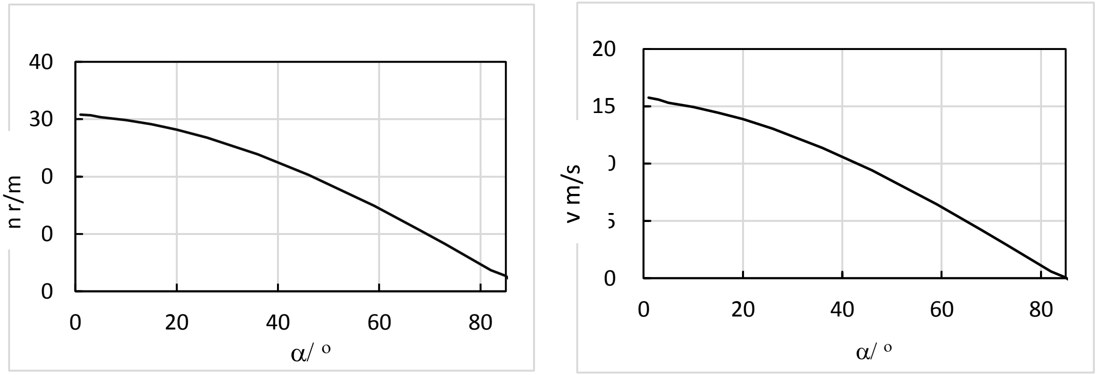
$dF = \frac{(n-n_0)\pi dm}{dt}$ -----（7）

& $da = \frac{(n-n_0)\pi dd}{t}$ -----（8）

The tip speed ratio Cp is in terms of

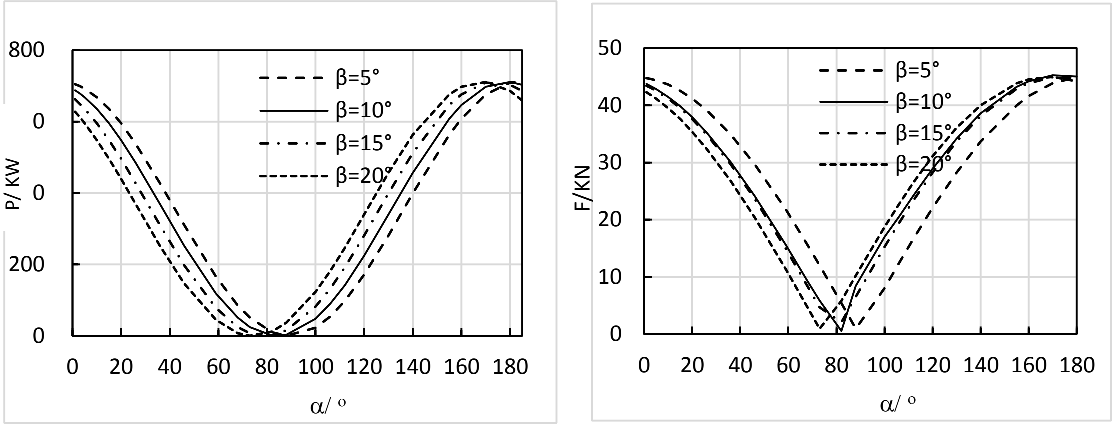
$C_p = 2P/(\rho v^3 A)$ ---- (9)

P is shaft power. ρ is density of air, 1.3Kg/m^3; v is wind speed; A is area of blade leaf.



(a) n

(b) v



(c) P, β is pitch angle

(c) F, β is pitch angle

Figure 2 relations of P& F and angle of attack α in a cycle.

The calculated results are shown in Figure 1,2and 3. It has the structure of a wind turbine, whose blade length is denoted by l and angular velocity by ω. Figure 2 (a, b) is the kinematic simulation relationship of the rotating semi-cycle of the wind turbine blade. α angle as shown in Figure 2 (a) and the rate of n into cosine curve, under the wind speed of 15.8 m/s at 0° amplitude of 30r/m. Figure 2 (b) into cosine distribution, between speed and angle of the inclined line is a cosine amplitude is big. Figure 2 (c) is the power with the increase of angle α becomes cosine curve. The average force is 20KN. In order to improve the efficiency, the three blades are taken together so that they act continuously with a difference of 120° to produce energy and output energy like a three-phase star generator. The most effective way to increase power is to increase speed, so high speed is the main factor to improve efficiency. As shown in Figure 2, the corresponding power generation energy increases with the increase of rotating speed. So we think the basic requirement is to get to 25r/m. The second is mass. The more mass, the more energy. Therefore, mass greater than the specified value is the necessary condition to obtain high power.

In Figure 2(c&d) the power and force decreases with the increasing α changes 0-70°& β changes 5-20°. The power and force becomes periodical cosine curve. The maximum power is 0.7MW and force is 40KN at α is 0 and β is 5°. There is a certain power changes in power with 200KW and force with 10KN. It is known that the decreasing α and β is the way from 0 to 83° to increase them. When α increases from 83° to 180° the power and force increase too. Because of its high power above 80° of attack angle it is used to promote this one and another reason is its low force below 70 which can save its cost.

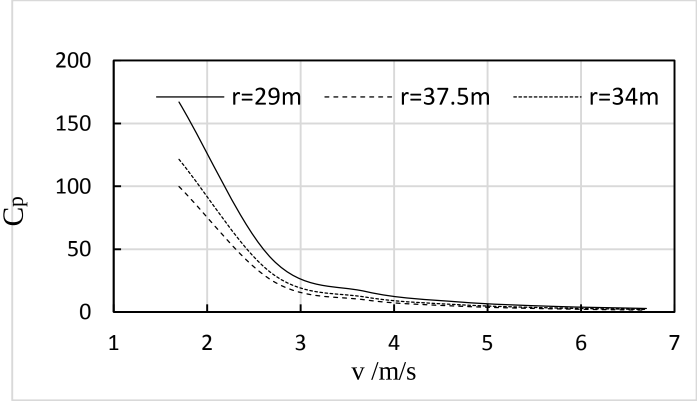


Figure 3 relations of tip speed ratio & speed v with changed radius at the power of N60.

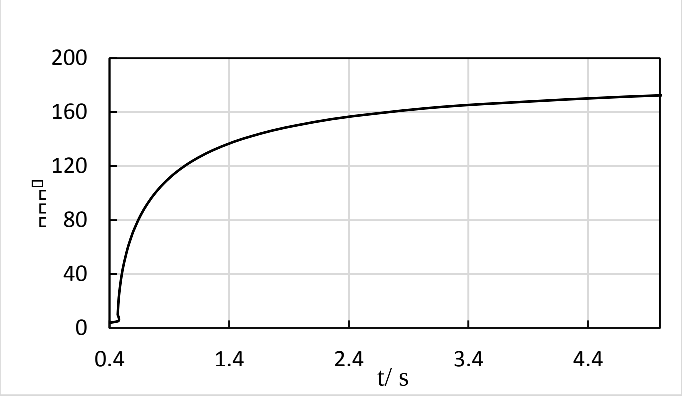
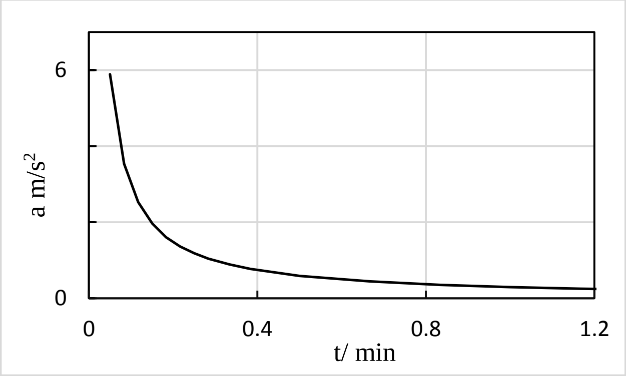
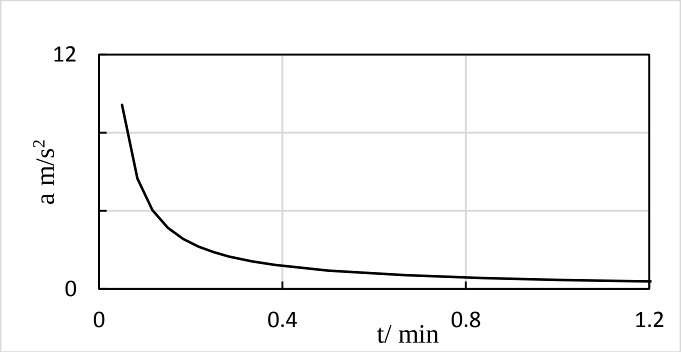


Figure 4 relations of t & angle of attack α in a certain time.

Figure 3 shows that the tip speed ratio decreases when speed increases while with the increasing radius the tip speed ratio decreases. For example at the 29m the Cp will be from 160 to below 5 with the speed from 1.7m/s to 6.7m/s. The Cp will be smaller below 10 when the v increases into 4m/s an then it maintains a stable one ie slow decreasing regardless of changing their radius. Figure 4 shows that with the increasing time to 1.4s the angle of attack increases steeply to 145° then the line becomes sluggish until more than 4s. It expresses that the first several time is significant to turbine blades' turning rotation due to it lasts near half circle. Because it has three blades to continue rotary in order to maintain the continuous turns.



(a) n=15r/m



(b) n=24r/m

Figure 5 relations of acceleration and time to different speed n for blade.

Figure 5 shows the data between acceleration a and time t at a speed of 15 and 24r/m. It can be seen that in the first 10 seconds the acceleration drops sharply to 1-2m/s^2, then gradually flattens out. This indicates that the moment of inertia Jc is at work, that is, the huge blades with a mass of 5.9ton are slowly driven by the large start-up energy. It can be seen from Figure 4 (a&b) that the acceleration increases near linearly with the increase of the speed of arrival. It indicates that a large amount of force is needed at the beginning of the drive, and the greater the mass, the greater the speed, the greater the force required. After 10 seconds the force becomes smaller, and the speed tends to stabilize so the kinetic energy becomes larger and larger. If the initial functional consumption cannot be reduced, we need to increase the speed and time to increase the kinetic energy. The rotation energy consumption is too large to meet the requirement of conversion to kinetic energy. In this way, power consumption and efficiency will be lower, which is not conducive to power generation. The acceleration at 24r/m in the Figure above is tow times larger than that at 15r/m. So the right amount of speed is the basic to ensure the maximum power. Too much speed requires more force, too little speed does not play its due role. From the above analysis, it can be seen that only when the rotating speed reaches a certain value can the maximum effect be guaranteed.

Conclusions

The speed is 30r/m and 16m/s under the wind speed of 15.8 m/s at 0° that becomes cosine distribution. The decreasing α and β is the way from 0 to 83° to increase them. When α increases from 83° to 180° the power and force increase too. With the increasing time to 1.4s the angle of attack increases steeply to 145° then the line becomes sluggish until more than 4s. There is a certain power changes in power with 0.2MW and force with 10KN with β changing from 0 to 20°. It expresses that the first several time is significant to turbine blades' turning rotation. The acceleration at 15r/m is tow times larger than that at 7.5r/m. The power consumption and efficiency will be low. Only rotating speed reaching a certain value can the maximum effect be. The tip speed ratio Cp will be smaller below 10 when the v increases into 4m/s an then it shows slow decreasing regardless of changing their radius.

References

1. Fei WL et al. Design of hydraulic variable propeller system for wind turbine [J]. Hydraulics pneumatics and seals.2019,10:58 (in Chinese)
2. Liu N et al, tang Juan et al. Power curve acquisition method of wind turbine [J}. Ship engineering.2019, supplement 1 (41) :291 (in Chinese).