Examination of optimum shape of S-shaped wind turbine with different number of blades using CFD technology

CFD: Computational Fluid Dynamics

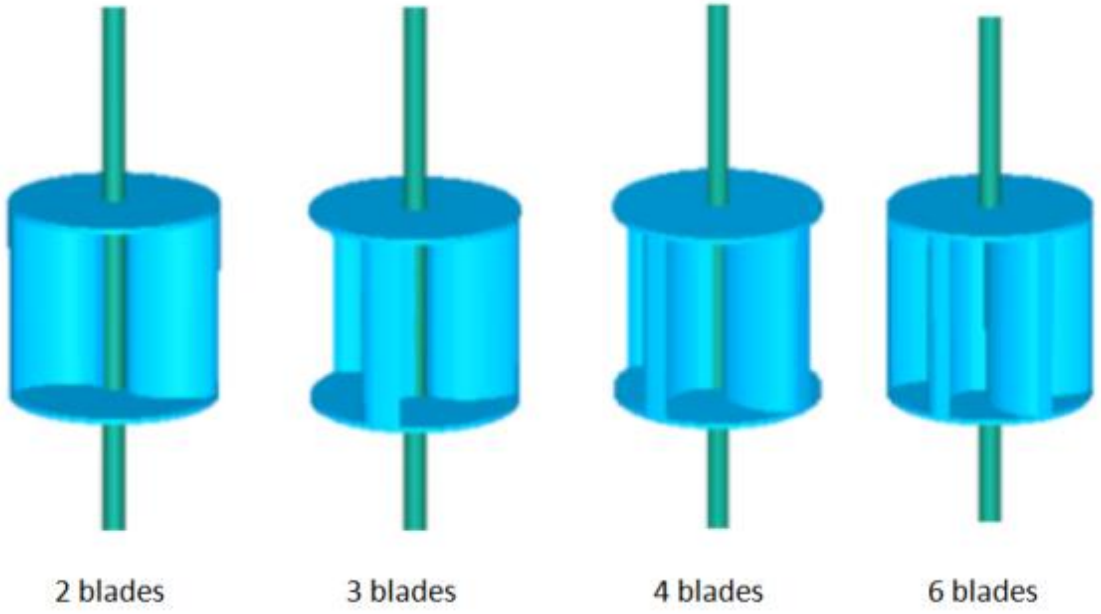
Xing Hao, Anna Kuwana, Bai Xueyan, Yao Dan, Haruo Kobayashi
Gunma University

Kobayashi Laboratory

群馬大学
GUNMA UNIVERSITY

Research Objective

Different Number of Blades
S-shaped Wind Turbine



Which is the optimal shape ?

Contents

- Research Background
- Definition of the shape of the wind turbine
- Numerical Method
- Results
- Conclusion

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Research Background

Global warming

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The use of
- Renewable energy
- Decentralized power generation

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Wind power generation

The research aim:
Small wind turbine simulator for complex wind conditions in Japan

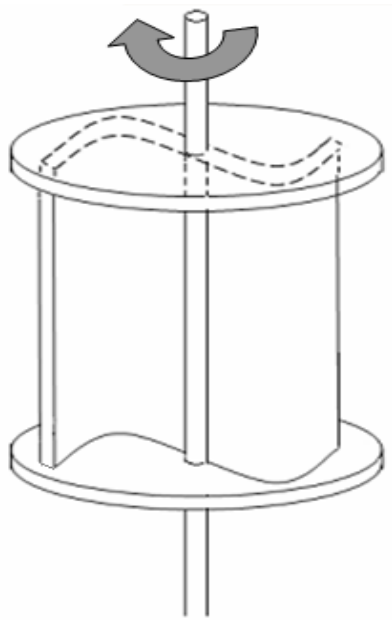
Contents

Target wind turbine of this research

S-shaped wind turbine (one of vertical axis type)

Advantage of S-shaped wind turbine

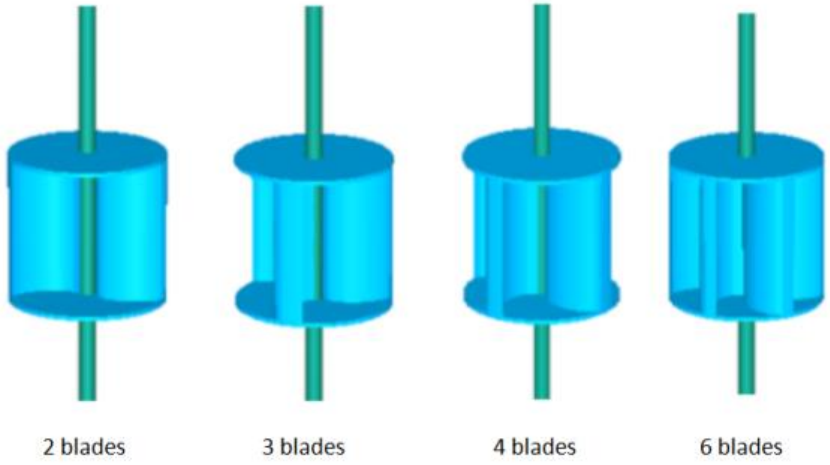
- simple construction with low cost;
- wind acceptance from most direction for the operation;
- low noise and angular velocity in operation;
- reduced wear on moving parts;
- various rotor configuration options;
- high static and dynamic moment

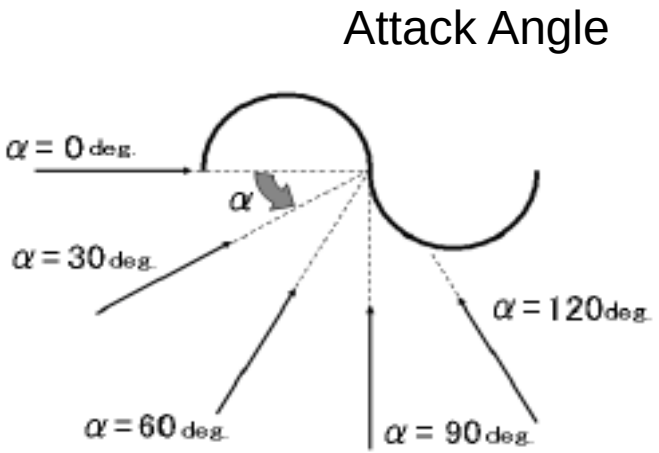


Blade definitions

To investigate the self-starting ability...

1. Wind blows from an angle to the stopped wind turbine.
2. Calculate torque coefficient.
3. Plot on the graph.
4. Wind blows from the other angle.
   This angle is defined as “Attack Angle”.

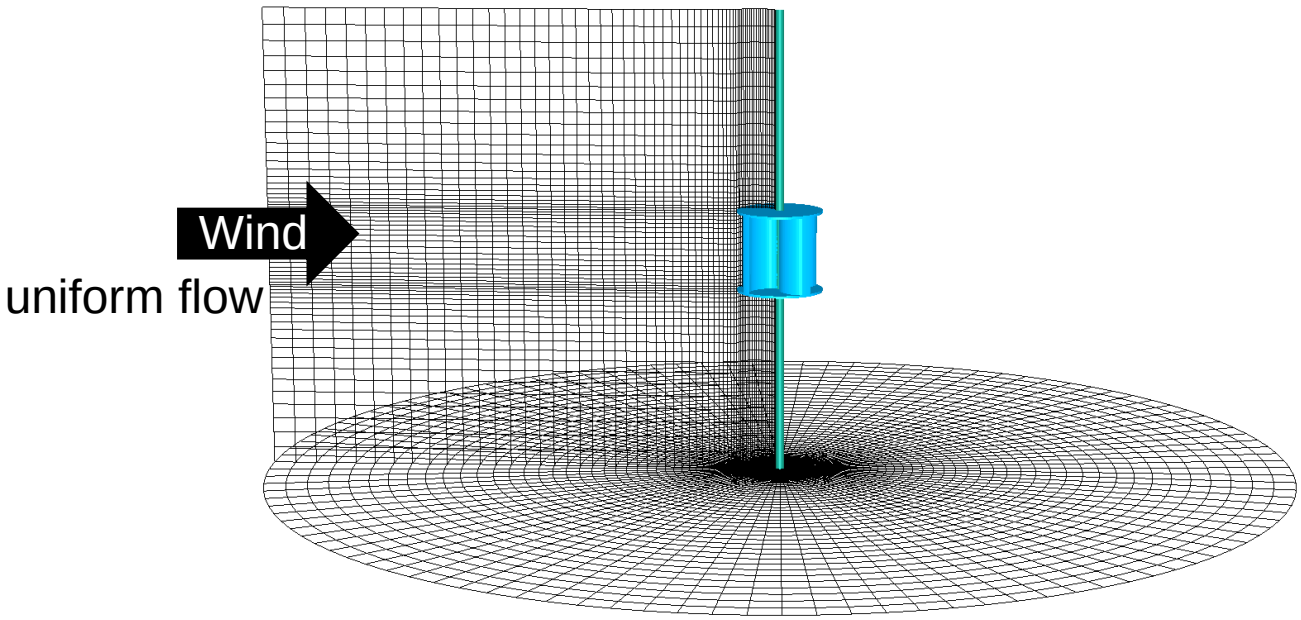




Which is the optimal shape ?

Contents

Calculation area / Boundary condition

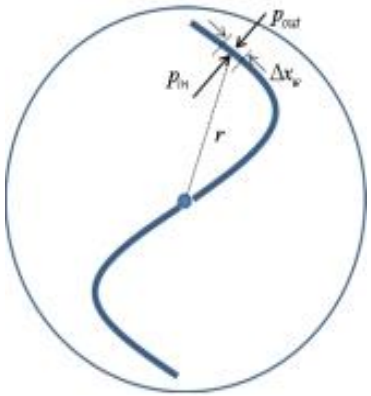


The number of grids:
circumferential 110 × radial 60 × height 60.

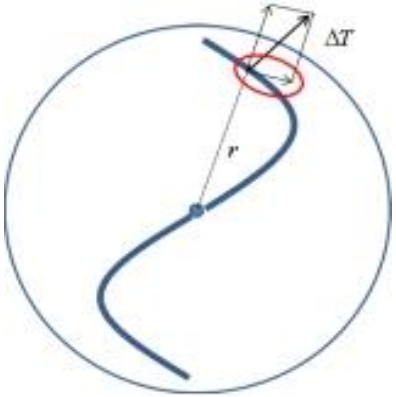
Boundary conditions:
Far boundary : a uniform flow
On the turbine blade: no-slip

Torque coefficient

Torque is the force to rotate the wind turbine.
Used as the index for investigate the optimal shape.



(a) Torque applied to the blade.



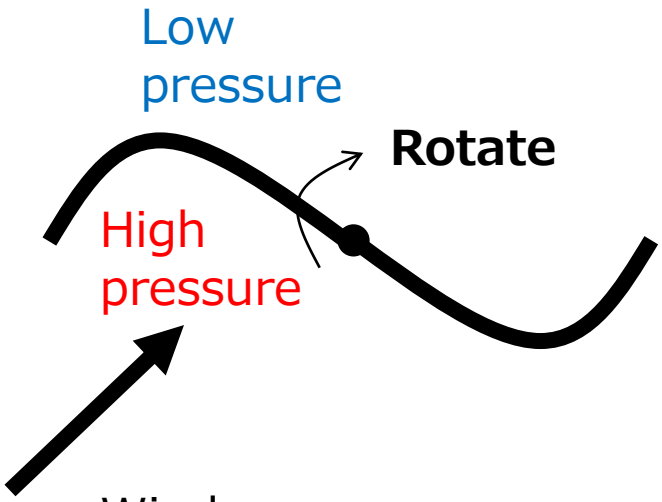
(b) Component of rotation direction of torque.

The torque involved in the micro area Δx_w : $\Delta \mathrm{T} = \Delta x_w (p_{in} - p_{out}) r$
The total torque T : $\mathrm{T} = \sum \Delta \mathrm{T}$ (Addition of all $\Delta \mathrm{T}$ on the blade)
The torque coefficient Ct: $\mathrm{Ct} = \frac{T}{qRA}$

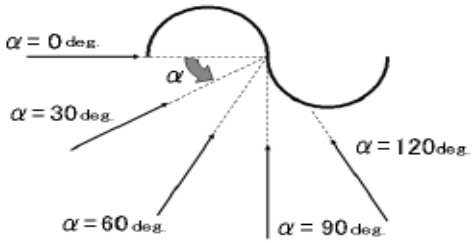
(non-dimensionalized torque by the size of wind turbine)

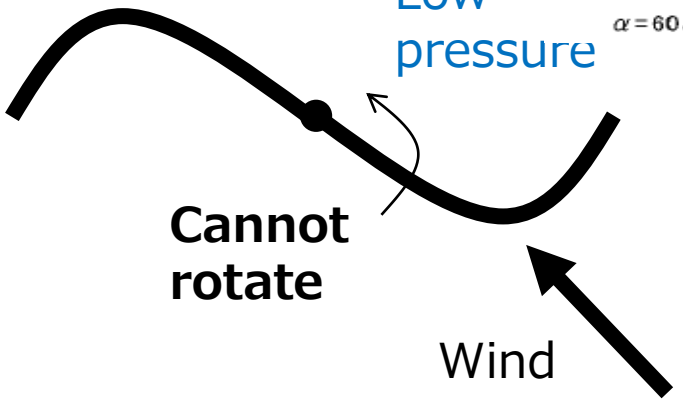
Contents

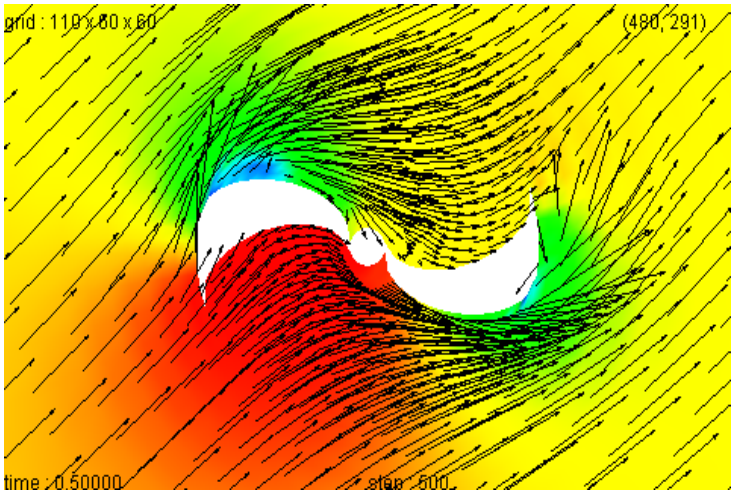
Mechanism of Rotation

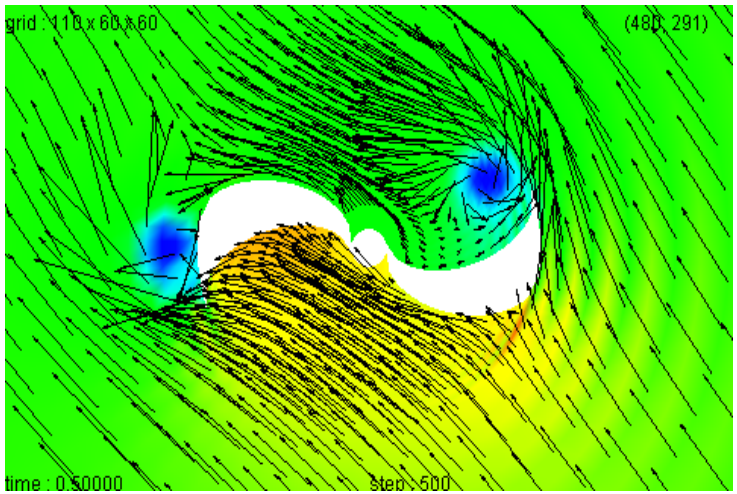


Attack Angle



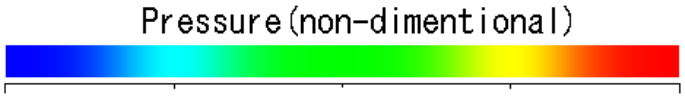




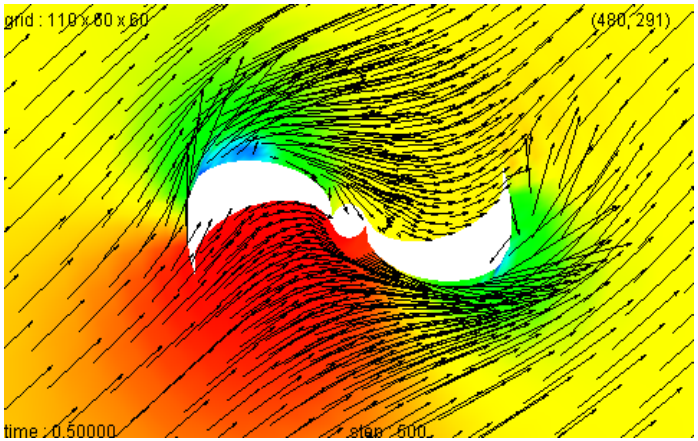


Pressure field and velocity vectors

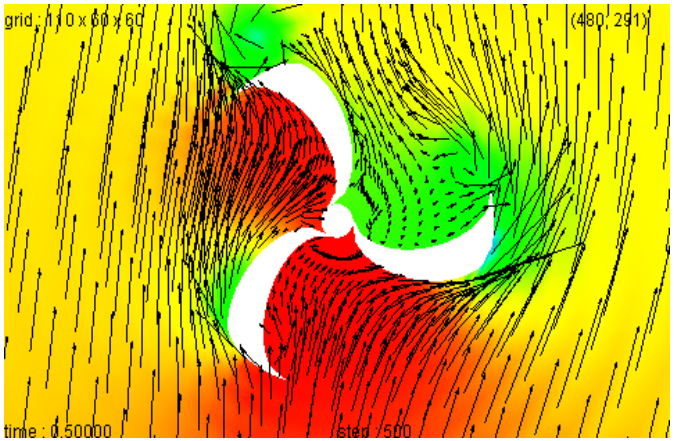
At the largest torque coefficient is generated.



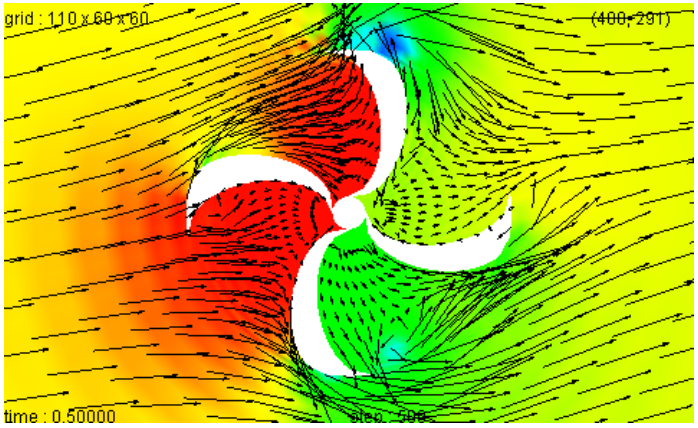
2 blades



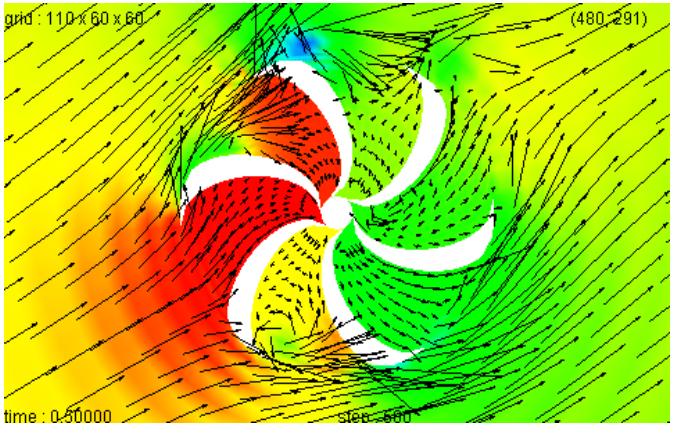
3 blades



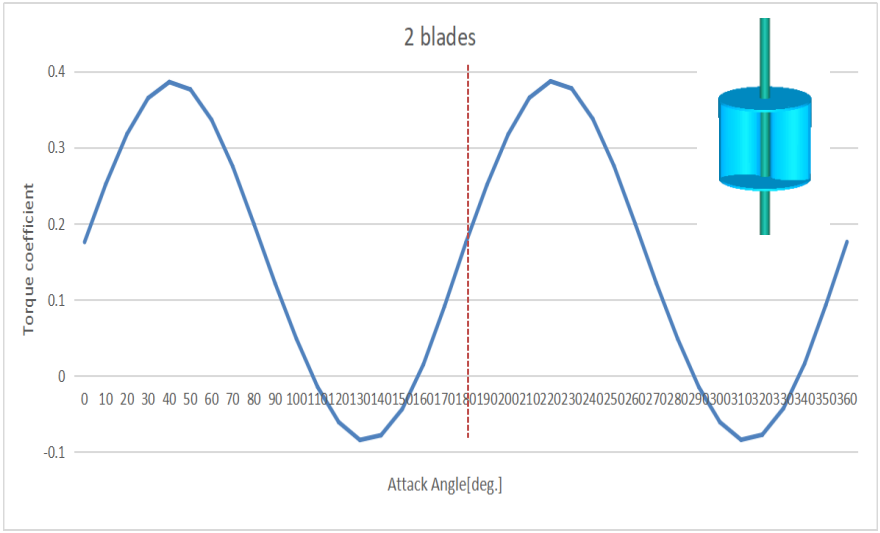
4 blades

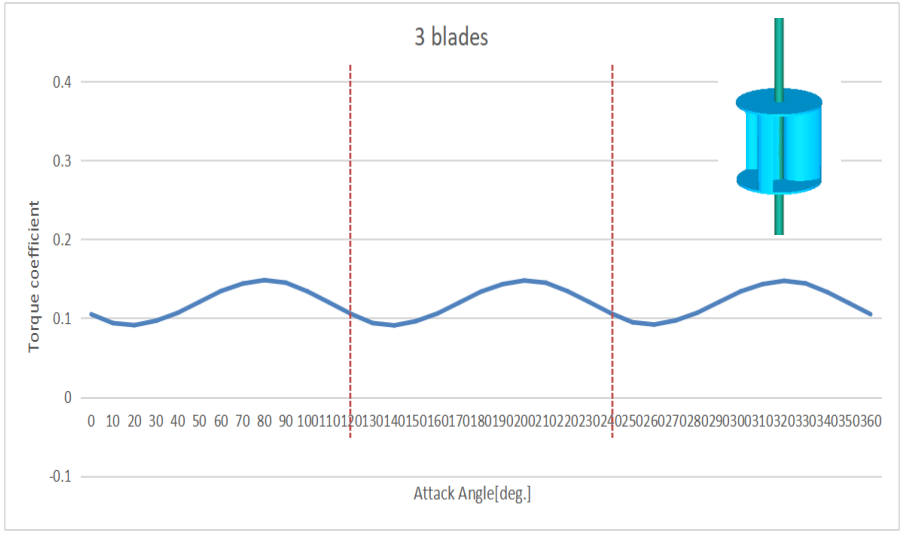


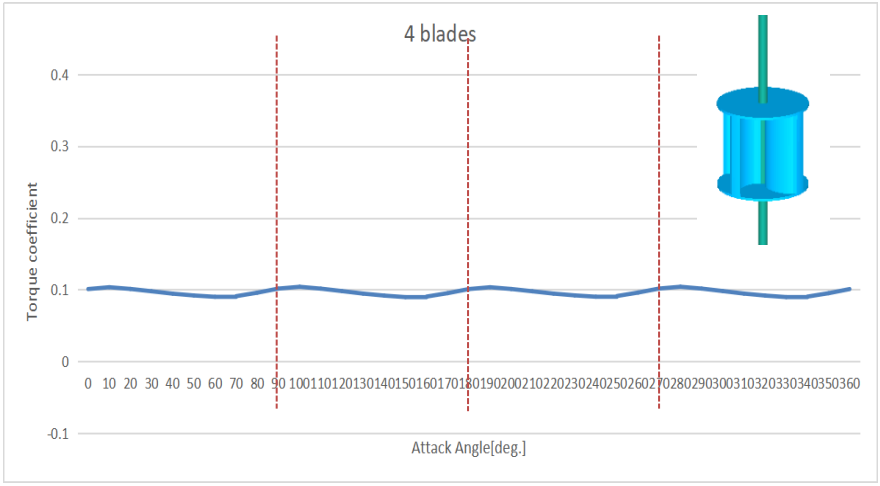
6 blades

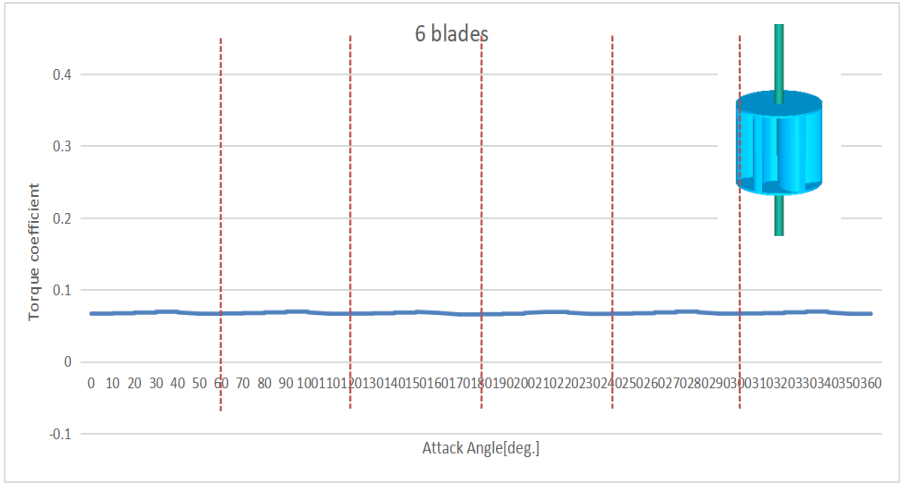


Starting characteristics

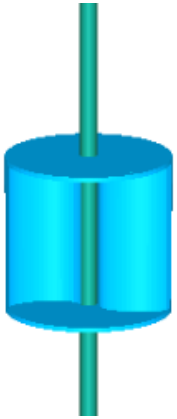




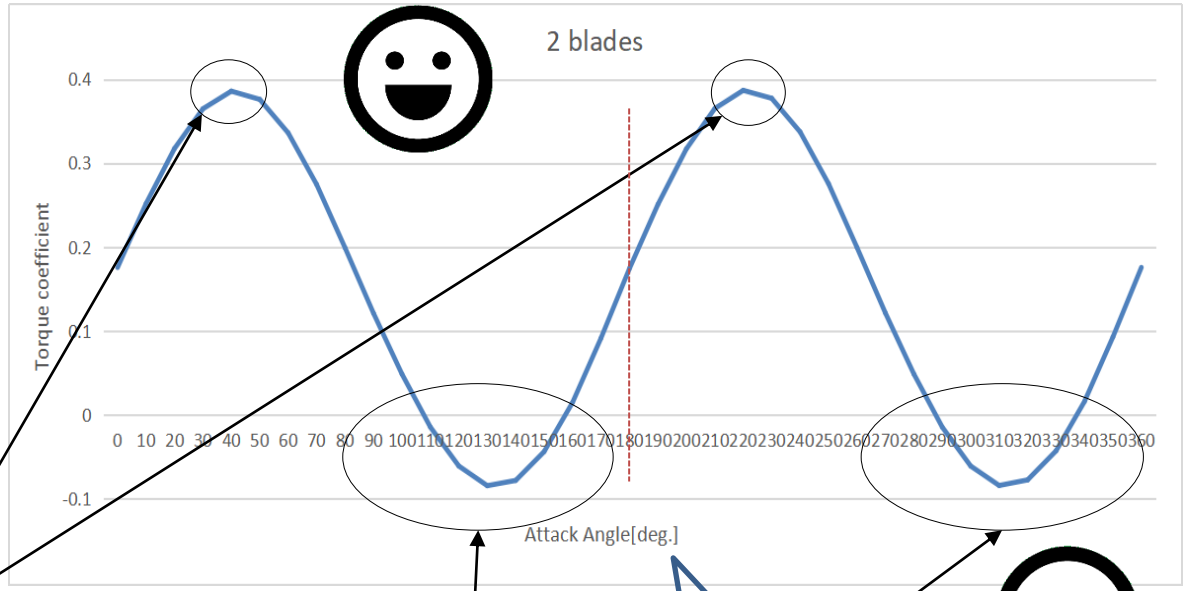




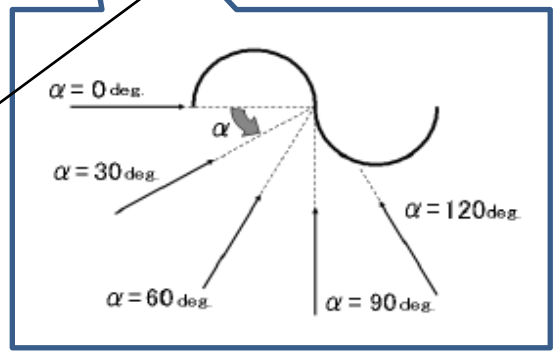
Starting characteristics of the 2 blades wind turbine



2 blades

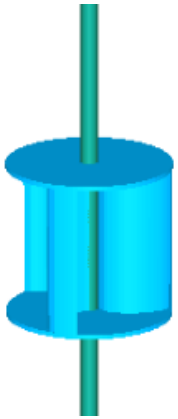


The change in torque coefficient is 180 degrees periodic.
Torque coefficient is large
@Attack Angle = near 40 and 220 degrees

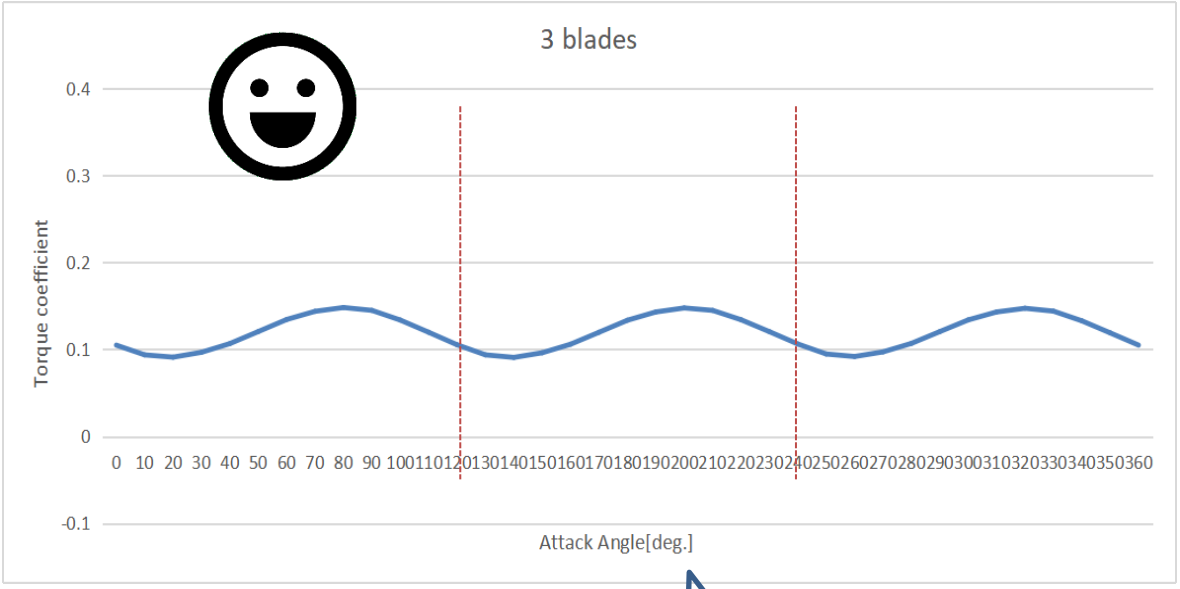


Static torque is negative.
→turbine cannot to start to rotate
@Attack Angle = 110～150, 290～330 degrees.

Starting characteristics of the 3 blades wind turbine

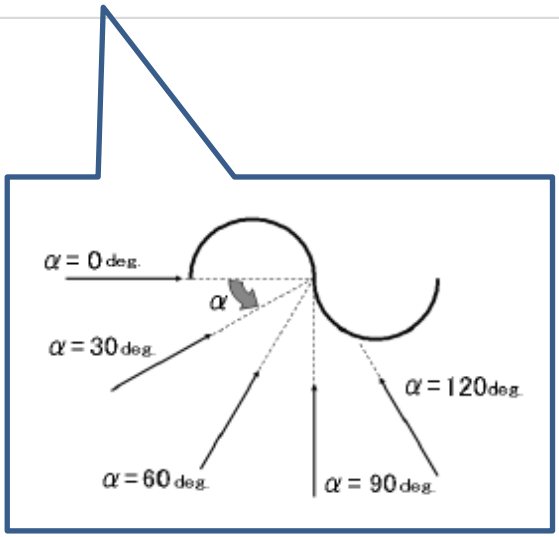


3 blades

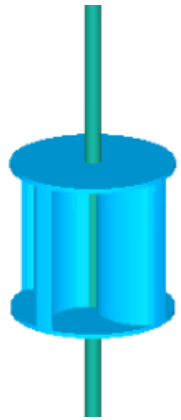


The change in torque coefficient is 120 degrees periodic.

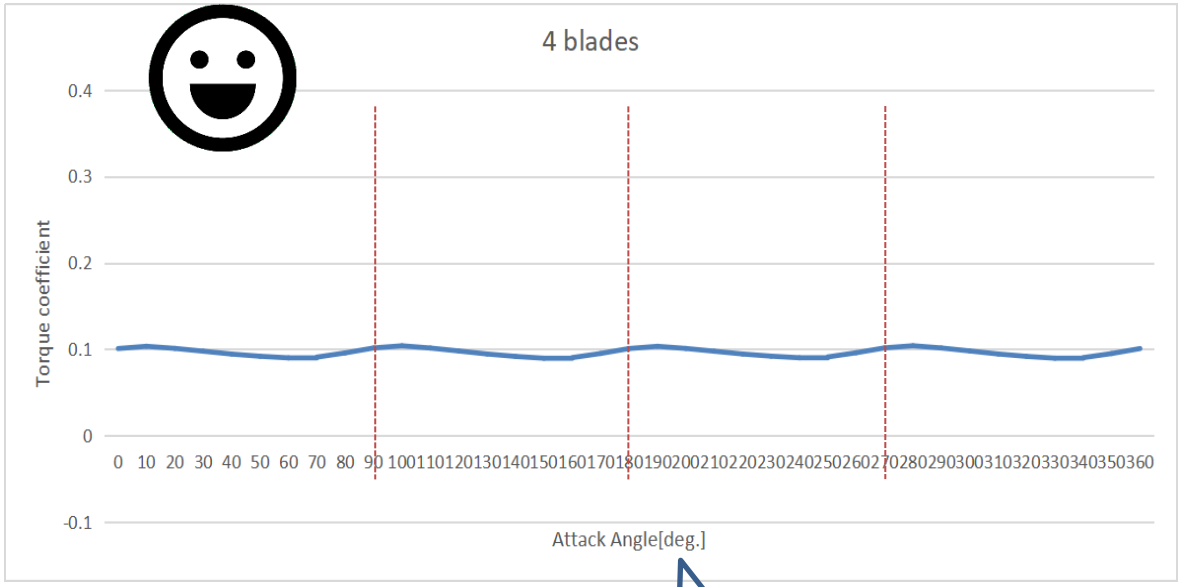
The torque coefficient is small, however the there is no negative torque.



Starting characteristics of the 4 blades wind turbine

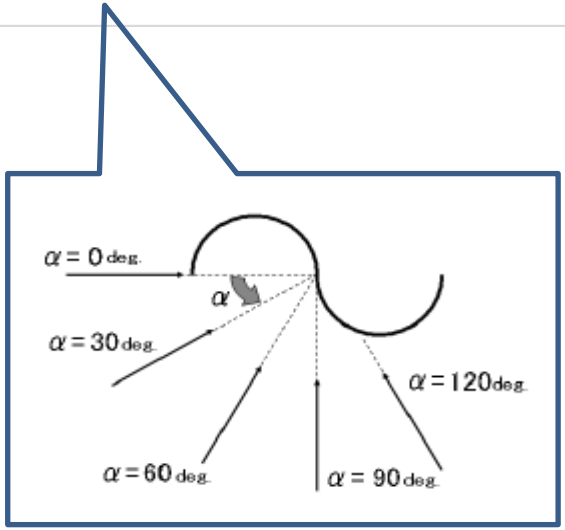


4 blades

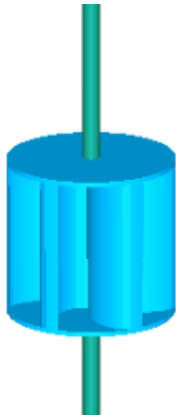


The change in torque coefficient is 90 degrees periodic.

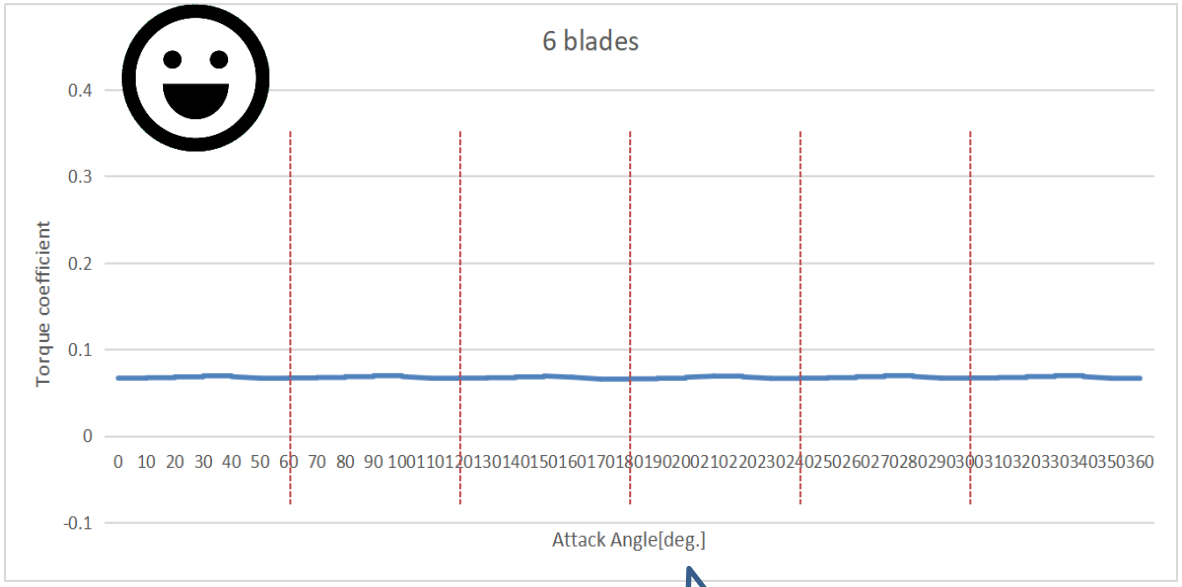
The torque coefficient is small, however the there is no negative torque.



Starting characteristics of the 6 blades wind turbine

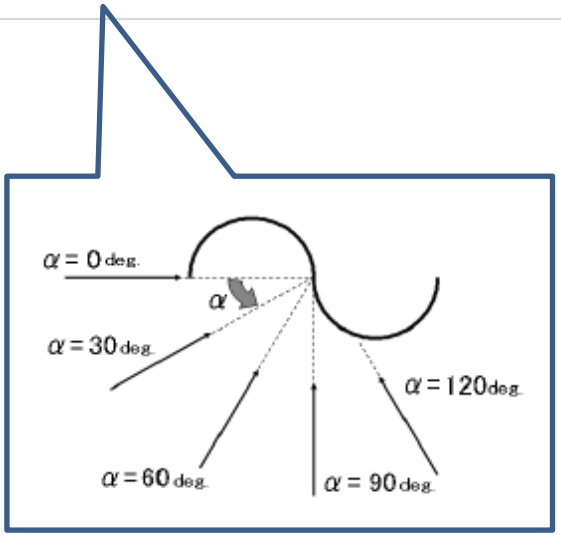


6 blades



The change in torque coefficient is 60 degrees periodic.

The torque coefficient is small, however the there is no negative torque.



Starting characteristics of all wind turbines are compared

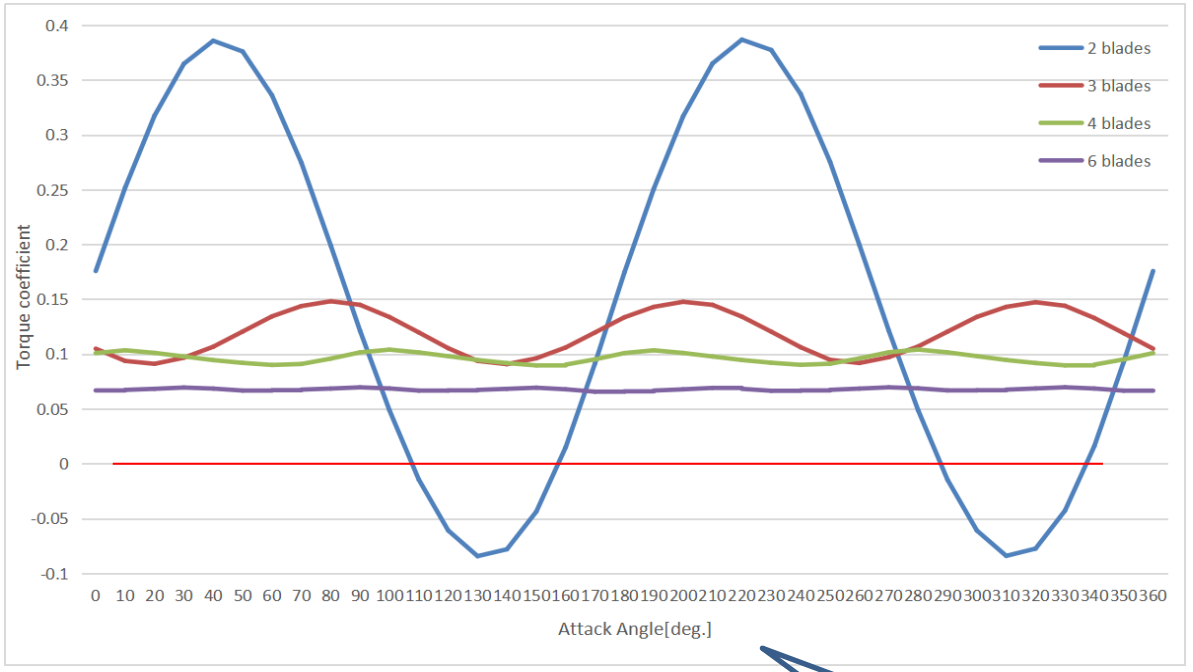
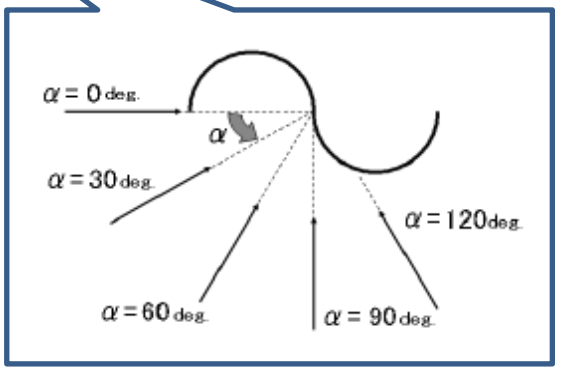


Table1. Average of torque coefficients at all Attack Angles.

2blades	3blades	4blades	6blades
0.149565459	0.119328435	0.096412234	0.067758829



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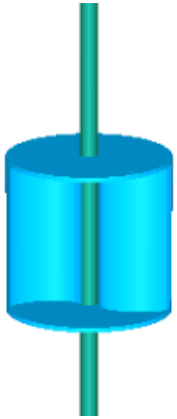
Conclusion

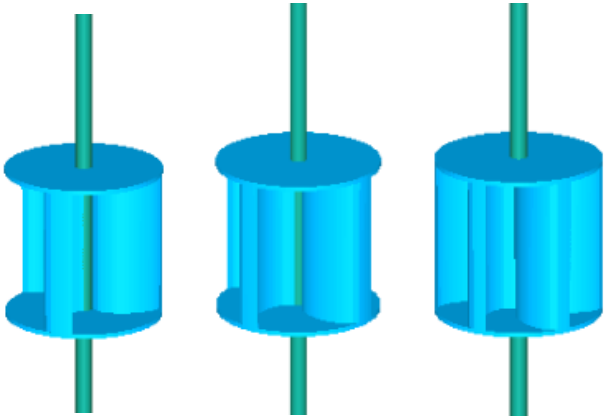
2 blades



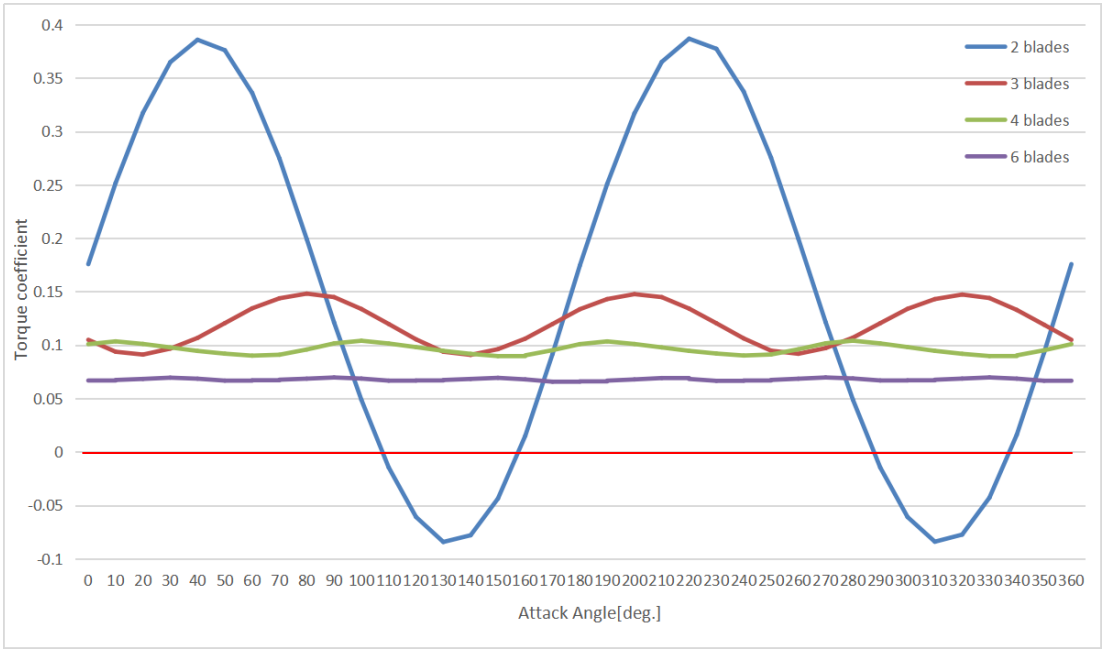
Generates a strong torque when the wind hits it from a specific angle.

It is necessary to adjust the wind direction.

3 blades 4 blades 6 blades



Start rotating regardless of the angle of the wind.



ご清聴ありがとうございました

Thank you for listening

謝謝

Q&A

- Q.調べるのは起動トルク（静止トルク）だけでよいのか？回転時のトルクを調べなくてよいのか？
- A：回転時のトルクはこれから調べます。

- Q.トルクの変動が大きいと音がうるさいですか？
- A：S字型風車は、他の風車に比べて回転速度が遅いですのでトルクの変動が大きくても、風切り音はうるさくありません。